Vol. 24(3):263-266 | Ocean and Polar Research | September 2002

Article

Search for Gravity Waves with a New All-sky Camera System

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Abstract : Gravity waves have been searched for with a new all-sky camera system over Korean Peninsular. The all-sky camera consists of a 37 mm/F4.5 Mamiya fisheye lens with a 180 deg field of view, interference filters and a 1024 by 1024 CCD camera. The all-sky camera has been tested near Daejeon city, and moved to Mt. Bohyun where the largest astronomical telescope is operated in Korea. A clear wave pattern was successfully detected in OH filter images over Mt. Bohyun on July 18, 2001, indicating that small scale coherent gravity waves perturbed OH airglow near the mesopause. Other wave features are since then observed with Na 589.8 nm and OI 630.0 nm filters. Since a Japanese all-sky camera network has already detected traveling ionospheric disturbances (TID) over the northeast-southwest range of Japanese islands, we hope our all-sky camera extends the coverage of the TID's observations to the west direction. We plan to operate our all-sky camera all year around to study seasonal variation of wave activities over the mid-latitude upper atmosphere.

Key words : airglow, gravity waves, all-sky camera.

1. Introduction

Gravity waves are disturbances of air due to buoyant forces in the atmosphere. Hines (1960) has successfully theorized internal acoustic-gravity waves and predicted that small disturbances in the lower atmosphere are amplified as they propagate to the mesosphere and thermosphere. According to his dispersion relation of gravity waves, gravity waves are preferentially propagated horizontally with periods of several minutes to a few hours. Since the amplitude of a gravity wave increases with height up to altitudes of mesopause or lower thermosphere (~90 km), airglows from these altitudes must show wave structure as the gravity wave disturbs densities and temperature of airglow sources. However, it was not until Krassvovsky (1972) reported that the oscillations seen in the intensity and rotational temperature of the hydroxyl (OH) (4,1) emission band had periods and phase speeds similar to those expected from internal acoustic-gravity wave theory.

Gravity waves play a dominant role in influencing the global circulation in the 80- to 110 km altitude region, where the atmospheric temperature is minimum (Fritts and Van Zant 1993). Current global circulation models (GCM) do not adequately include gravity wave forcing in their sources of energy and momentum (Swenson *et al.* 1999). Gardner (1996) summarized most of the current theories of wave dissipation that affects winds and temperatures in the upper mesosphere and lower thermosphere (MLT). In order to include the gravity wave forcing in the GCM, characteristics of the waves should be obtained from a large set of observations over various times and places.

Taylor and Hill (1991) have shown that images of gravity waves perturbing nightglow emissions can be obtained from camera observations utilizing broadband filters. Since then, wide field of view or all-sky optical systems with sensitive CCD cameras were developed to observe gravity waves in the upper atmosphere (Hecht *et al.* 1994; Garcia 1999; Swenson *et al.* 1999). All-sky camera

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systems were also used to observe auroral activity in the polar regions (Amm *et al.* 2001).

Currently we are setting up an all-sky airglow camera system to observe gravity wave activities in the mid-latitude upper atmosphere. In this paper we describe characteristics of the KORDI all-sky camera system and present preliminary results of observations at Mt. Bohyun.

2. KORDI all sky camera system

The KORDI all-sky camera system consists of three parts: an optical system, a detector, and an operating computer. A schematic diagram for the optical lay-out of the all-sky camera system is presented in Fig. 1. The optical system collects lights from 180 deg field of view with a Mamiya RB fish eye lens that has focal length of 37 mm and focal ratio of 4.5. The collected light beam is collimated by a telecentric optical lens combination to pass through a narrow-band filter with nearly perpendicular incidence angles. Four filters are so far installed among five filter positions of a filter wheel. The collimated beam after the filter is fed to a Cannon 85 mm/F1.2 lens to make an image onto a CCD chip. The detector is a liquid-cooled CCD camera from Photometrics. The CCD chip has 1024 by 1024 square pixels of 24 micron. A field curvature corrector is mounted inside the camera to match with the fore optics. The filter wheel and camera shutter are controlled and image data are acquired and stored by a Pentium III computer with an operating system of Redhat 6.2.

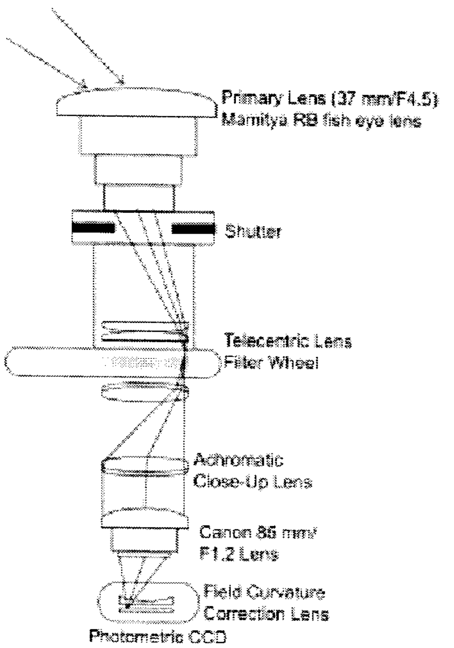

Fig. 1. Schematic diagram for optical paths of KORDI all-sky camera.

Four filters installed in the filter wheel are to transmit OI 630.0, Na 589.8 lines, OH Meinel bands in 720.0-910.0, and background light at 572.9 nm. The OI and Na filters have 1.5 and 2.1 nm bandwidths, while the OH filter has blocking between 850.0 and 870.0 nm to avoid $O_2(0,1)$ Atmospheric bands at 865.0 nm. The maximum altitudes of OI 630.0, Na 589.8 nm and OH Meinel band airglow emissions are 250, 90, and 87 km, respectively (Garcia 1999).

The all-sky camera system is installed in a container box with a plexiglass dome on its roof. Both temperature and humidity inside the container box are controlled by an automatic heater and air-conditioner system.

3. Operation plan and preliminary results

Test observations of the all sky camera have been made in Chongwon near Daejeon city. Street lights from a highway about a few km away seem to overwhelm airglow from the upper atmosphere. Various exposure times have been attempted with all four filters, but the effect of street lights could not be reduced to the level that any airglow feature form the upper atmosphere be visible.

After the test observations, the all-sky camera system has moved to Mt. Bohyun, where astronomical telescopes are operated by Korea Astronomical Observatory (KAO).

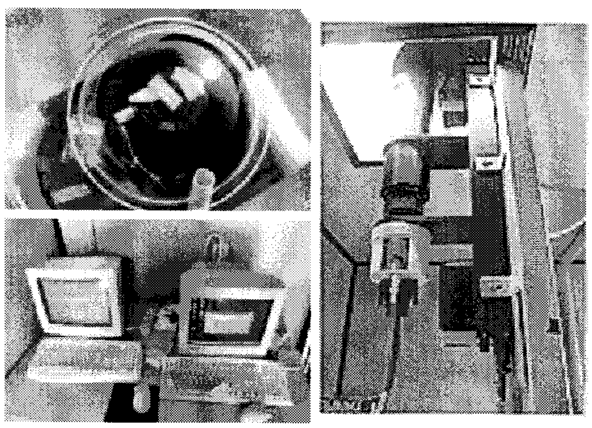

Fig. 2. KORDI all-sky camera system. Upper left : a plexiglass dome on the roof of a container. Right : All-sky camera installed inside the container. Lower left: two operating computers for the all-sky camera and a Michelson spectrometer.

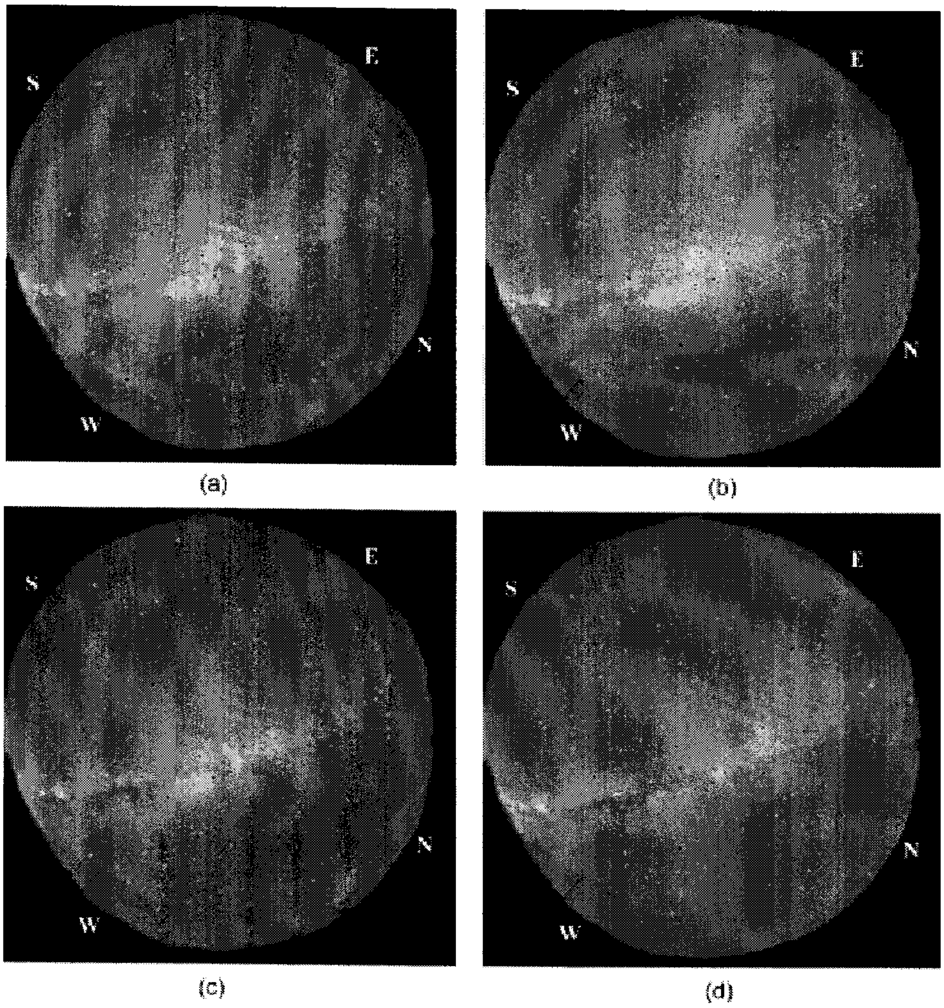

Fig. 3. All-sky images taken at a) 02:14 LT, b) 02:17 LT, c) 02:22 LT, d) 02:25 LT, at Mt. Bohyun with OH filter on July 18, 2001. The exposure time was 20 sec. Note that the a wave structure is present east to the middle of the milky way.

The site at Mt. Bohyun is considered to be the best suit for astronomical observation in the nation, and thus the night sky is expected to be dark enough to show faint airglow from the upper atmosphere. The all-sky camera at Mt. Bohyun is operated remotely from our laboratory in Daejeon city via internet. Every evening a batch program that determines a sequence of exposure times and filter selection is sent to the all-sky camera computer, which controls the camera during the night. Every morning image data taken during the night are fetched to a computer in our laboratory for analysis and storing. Observations have been carried out every moonless night. Image data taken during cloudy periods are removed after inspection from storage in our laboratory computer.

About two weeks after the all-sky camera system was set up at Mt. Bohyun, the camera successfully captured signatures of gravity wave as shown in Fig. 3. The images taken with the OH filter clearly show a small wave pattern near the zenith that is aligned with about southwest-northeast direction. The wave pattern sustained over the next 40 minutes, until it moved toward the north-east direction and faded away. The wave pattern is believed to be due to OH airglow perturbed by gravity wave in the mesosphere because neither images taken contiguously with other filters nor bare sky images show any wave pattern or cloud at all during this period. This type of gravity wave has been known as 'ripple' (Taylor *et al.* 1987). Detailed analysis of the wave pattern seen in this night is being underway.

Images taken with the 630.0 nm filter can reflect ionospheric F region disturbances since OI 630.0 nm emission originates from recombination of O^+ in the F region. One of large scale F-region disturbances, known as traveling ionospheric disturbances (TID), has been observed by a Japanese all-sky camera network over the Japanese islands (Kubota *et al.* 2000). We anticipate the KORDI all-sky camera system at Mt. Bohyun to observe similar TID's sometime soon, so that we can collaborate with the Japanese network to cover more extended area than previously done.

The observation at Mt. Bohyun is planned to continue only until the camera system should move to another site for polar research during the year 2002. However, at least a few more years of observation at Mt. Bohyun are needed to study seasonal and statistical characteristics of gravity waves in the mid-latitude region.

4. Conclusion

Gravity waves have been searched for with a new all-sky camera system over Korean Peninsular. The all-sky camera consists of a 37 mm/F4.5 Mamiya fisheye lens with a 180 field of view, interference filters and a 1024 by 1024 CCD camera. The all-sky camera has been tested near Daejeon city, and moved to Mt. Bohyun where the largest astronomical telescope is operated in Korea. A clear wave pattern was successfully detected in OH filter images over Mt. Bohyun on July 18, 2001, indicating that small scale coherent gravity waves perturbed OH airglow near the mesopause. Other wave features are since then observed with Na 589.8 and OI 630.0 nm filters. Since a Japanese all-sky camera network has already detected traveling ionospheric disturbances (TID) over the northeast-southwest range of Japanese islands, we hope our all-sky camera extends the coverage of the TID's observations to the west direction. We plan to operate our all-sky camera all year around to study seasonal variation of wave activities over the mid-latitude upper atmosphere.

Acknowledgments

Two of authors (Kim, Y.H. and J.-K. Chung) thank KORDI for providing financial support. Authors appreciate kind cooperation of staff at Korea Astronomical Observatory during observation at Mt. Bohyun.

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Received Mar. 20, 2002
Accepted Sep. 30, 2002