Lower-stratospheric and upper-tropospheric disturbances over Thailand during January 2000

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Abstract

Wave characteristics in the lower-stratosphere over Thailand were studied by GAME-T enhanced rawinsonde observations. Three types of disturbances were found, and they were interpreted as 1) a diurnal tide 2) an internal inertial gravity wave, and 3) a disturbance due to inertial instability.

Keyword: gravity wave, tide, inertial instability, radiosonde.

1. Introduction

The radiosonde observations conducted by GAME project provided valuable information not only in the troposphere but also in the lower stratosphere. Although phenomena in the lower stratosphere are not directly related to the GAME objectives, we consider that it is also important to understand the stratosphere-troposphere coupling and exchange in relation to the monsoon circulation. As the first step to approach this issue, disturbances in the lower-stratosphere and the upper-troposphere over Thailand during January 2000 were studied by GAME-T enhanced rawinsonde observations.

2. Frequency spectra

The temporal sampling interval of the observations was 3 hours. Such high temporal resolution data were used to analyze the wind fluctuations due to lower-stratospheric and upper-tropospheric disturbances with a period shorter than about 10 days. Frequency spectra showed three distinct peaks: a 1-day period above 20 km in height, a near-inertial period at heights around 19 km and 27 km, and a period of 2.5-9 days (or longer) in the height range of 12-17 km (Fig. 1).

3. Interpretation

3.1 1-day waves: migrating tide and non-migrating tide

The wave with a 1-day period (Fig. 2) was interpreted as a diurnal tide. A comparison with the migrating tide in the global scale wave model showed that the observational results had larger amplitude and shorter vertical wavelength than the model (Fig. 3). The difference between the observation and the model may be caused by the superimposition of the non-migrating tide.

3.2 Near-inertial period waves: inertial gravity waves propagating toward the equator

The wave with the near-inertial period (Fig. 4) was interpreted as an internal inertial gravity wave. A hodograph analysis was performed in order to investigate the wave properties (Fig. 5). It was found that the wave which appeared at a height around 19 km (just above the tropopause height) propagated southwestward with a ground-based group velocity of about 1.4 m/s.

3.3 Disturbances due to inertial instability

The longer period disturbances which appeared at 12-17 km had layered structures with the vertical scales of 2-4 km (Fig. 4). They were considered to be due to inertial instability, based on the facts that the potential vorticity of the background atmosphere was nearly zero (Fig. 7) and that their phase structures were consistent with theory (Fig. 8). It was shown by a backward trajectory analysis that the air parcel with negative potential vorticity had its origin in equatorial Indonesia (Fig. 9). It was also shown by a forward trajectory analysis that the air parcel was transported to the Pacific to the south of Japan (Fig. 9). This is consistent with the existence of similar layered disturbances that are shown using rawinsonde data at a station there (Fig. 10; Fig. 11; Fig. 12).

References

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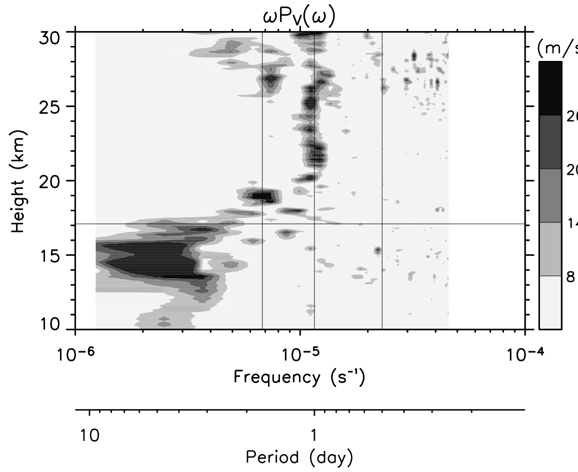

Figure1 Height variation of the frequency spectra for meridional wind. The vertical lines indicate, from left to right, the inertial period at NongKhai (about 41 hours), 1 day and a half day. The horizontal line indicates a mean tropopause height during the observation period.

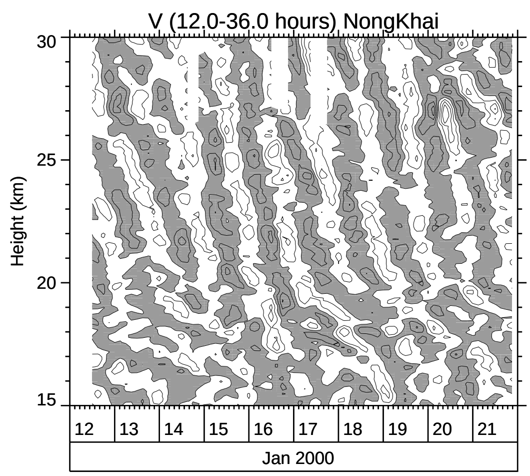

Figure2 Time-height section of the 1-day components of meridional wind. The 1-day components were extracted by a bandpass filter in time with cut off lengths of 12 and 36 hours. The contour interval is 2.5 m/s. The regions with positive values are shaded.

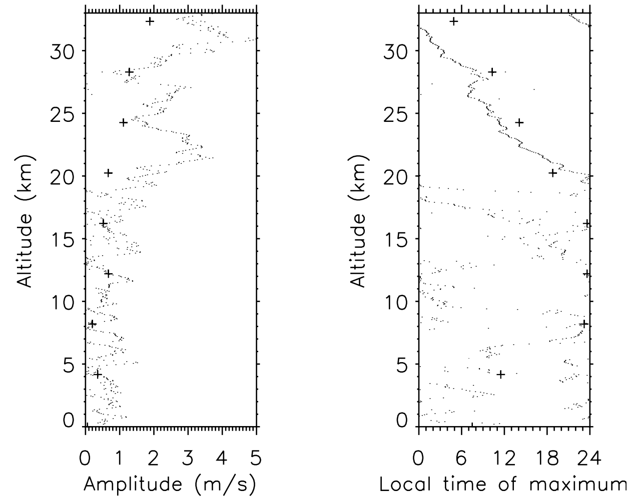

Figure3 Vertical profiles of (left) amplitude and (right) phase for 1-day wave. Thin dotted lines indicate the results obtained from observation. The + marks indicate the results in the GSWM by Hagan *et al.* (1999).

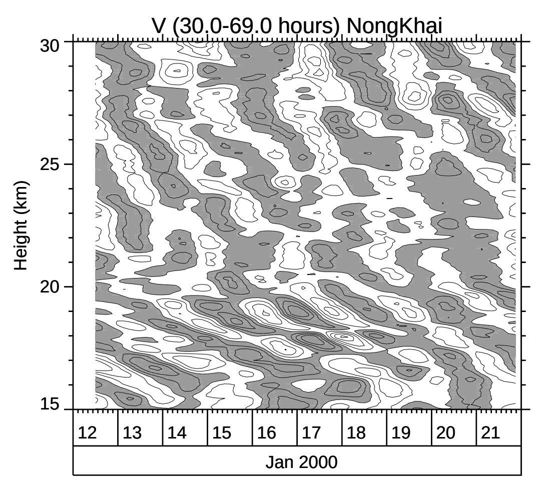

Figure4 Time-height section of the near-inertial period components of meridional wind. The components were extracted by a band-pass filter in time with cut-off lengths of 30 and 69 hours. The contour interval is 1.5 m/s. The regions with positive values are shaded.

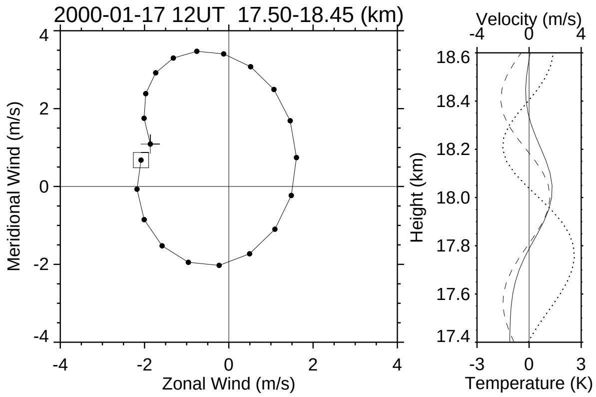

Figure5 The left panel shows a hodograph drawn with the horizontal winds in the height range of 17.50–18.45 km at 12UT on 17 January 2000. Plus and square marks indicate the bottom and top points of the height range. The right panel shows corresponding vertical profiles of temperature (solid line), meridional wind (dotted line) and zonal wind (dashed line). Band-pass filters in time with cut-off lengths of 30 and 69 hours and in height with cut-off lengths of 0.5 and 3 km were applied to the data plotted in the panels in order to extract a monochromatic wave.

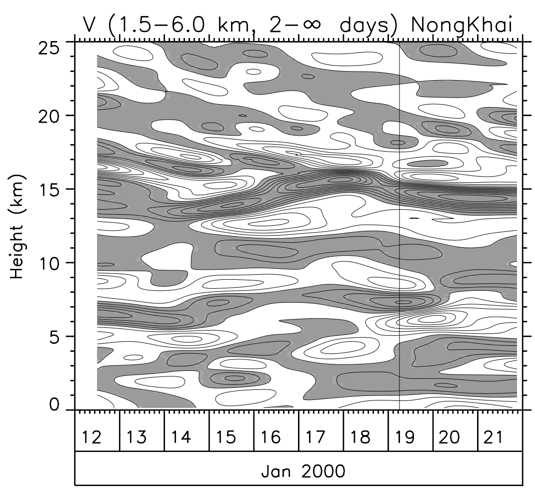

Figure6 Time-height section of meridional wind at NongKhai. A low-pass filter in time with a cut-off length of 2 days and a band-pass filter in height with cut-off lengths of 1.5 and 6 km were applied to the original data. Dark shaded regions denote positive values and light shaded negative. Contour intervals are 1 m/s. A vertical line indicates 06UT on 19 January 2000.

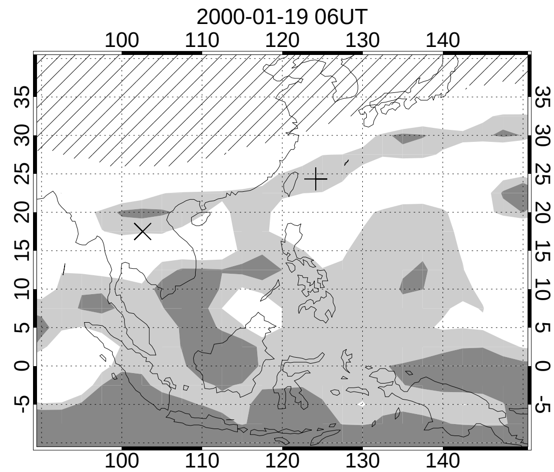

Figure7 Horizontal distribution of PV on the isentropic surface of 350 K at 06UT on 19 January 2000. The regions in which PV < 0 (0.1) PVU is dark (light) shaded. The stratospheric regions (PV > 1.6 PVU) are hatched. Cross and plus marks denote the locations of NongKhai and Ishigakijima, respectively.

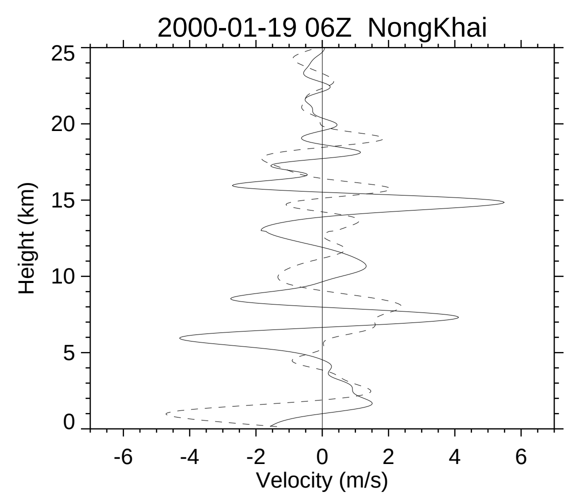

Figure8 Vertical profiles of meridional (solid line) and zonal (dashed line) winds at NongKhai at 06UT on 19 January 2000. It is seen that the meridional and zonal winds have opposite phase relation in the height region around 15 km and that the meridional wind has larger amplitude than the zonal wind, which are consistent with the linear theory of inertial instability (Sato and Dunkerton, 2002).

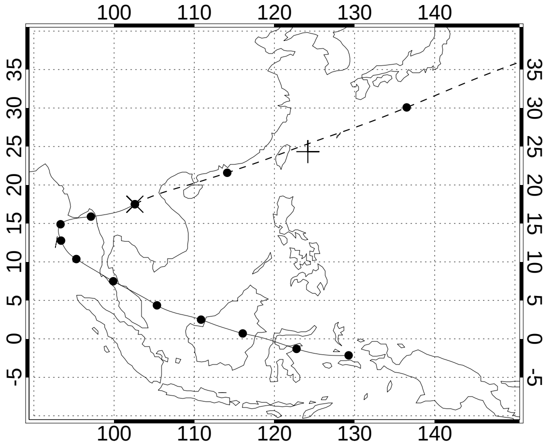

Figure9 Backward (solid line) and forward (dashed line) trajectories starting at NongKhai at 06 UT on 19 January 2000. The distance between closed circles corresponds to 12 hours.

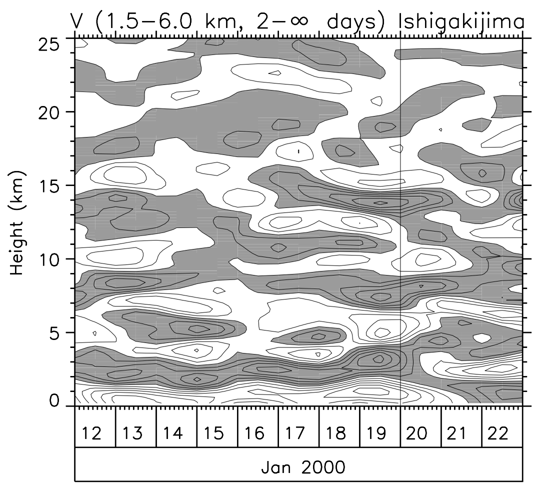

Figure10 Same as Fig. 6 but for Ishigakijima. A vertical line indicates 00UT on 20 January 2000.

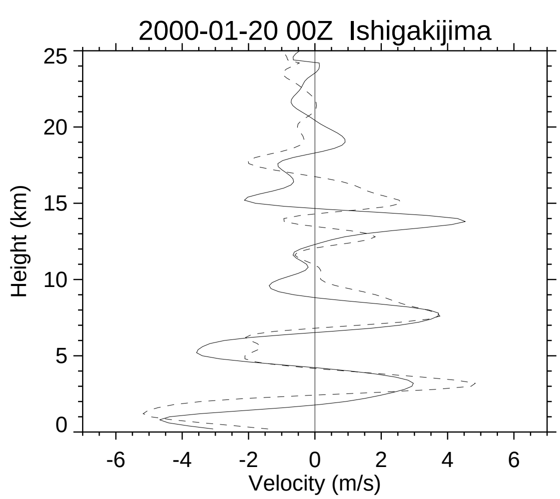

Figure11 Same as Fig. 8 but for Ishigakijima at 00UT on 20 January 2000.

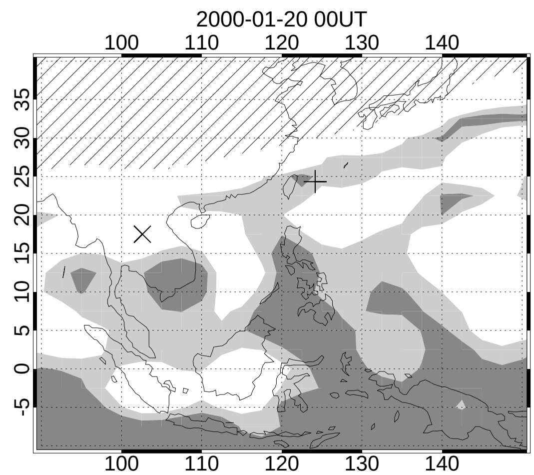

Figure12 Same as Fig. 7 but for 00UT on 20 Jan, 2000.