Characteristics and Sources of Gravity Waves in the Summer Stratosphere Based on Long-Term and High-Resolution Radiosonde Observations

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Abstract

- Using high-resolution radiosonde observation data over 23 years, GW characteristics were examined by hodograph analysis.
- One of the most important GW sources in summer mid-latitudes is shear instability above the jet near the tropopause.
- The favorable condition of shear instability in mid-latitudes is likely maintained by two following reasons: 1) the vertical shear of the zonal wind is stronger at higher latitudes, and 2) the static stability is lower at lower latitudes.

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1. Introduction and Method

Motivation: What are possible sources of summer GWs?

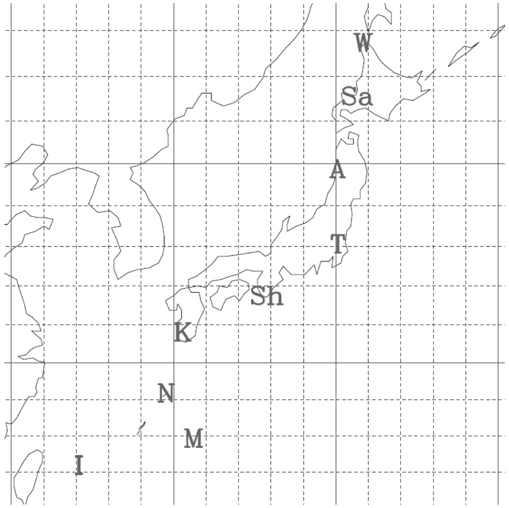
- GWs are mainly generated in the troposphere and propagate into the middle atmosphere.
- Possible sources of summer stratospheric GWs must be nonorographic because of the existence of zonal wind reversal layer.

- Cumulous convection [e.g., Fritts and Alexander., 2003]
- Shear instability above the upper-tropospheric jet

→ Theoretically suggested by Bühler et al. [1999] and Bühler & McIntyre [1999]

→ Since the jet is weak in summer, observational studies are necessary to examine the possibility of GW excitation from shear instability.

	Station	Latitude (°N)	Longitude (°E)
W	Wakkanai	45.42	141.68
Sa	Sapporo	43.07	141.33
A	Akita	39.72	140.10
T	Tateno	36.06	140.13
Sh	Shionomisaki	33.45	135.76
K	Kagoshima	31.56	130.55
N	Naze	28.30	129.55
M	Minamidaitojima	25.83	131.23
I	Ishigakijima	24.33	124.17



Method: hodograph analysis of the long-term and high-resolution radiosonde data

- Twice-daily (0000 and 1200 UTC) u, v and T data from operational radiosonde observations for 23 years (1995-2017) from nine stations in Japan
- The vertical resolution: ~200m for T / ~300m for u and v [Sato & Dunkerton, 2002]
- u, v and T components with $\lambda_z < 4$ km were designated as GWs
- Wave parameters were estimated by hodograph analysis [Sato, 1994]

2. Results

Characteristics of background fields

- The upper tropospheric jet is located at ~40°N and z~12km in summer. There is a wind-reversal layer of zonal winds at ~17km (Fig. 1a).
- The static stability N^2 slightly below the tropopause is lower than $1 \times 10^{-4}\ s^{-2}$ to the south of 38°N. In the lowermost stratosphere, N^2 is high ($N^2 > 6 \times 10^{-4} s^{-2}$) to the south of 36°N (Fig. 1b).

Characteristics of GW Kinetic energy (KE)

- The KE divided by density is significantly large in a height range of 6 km around the tropopause (Fig. 1c).

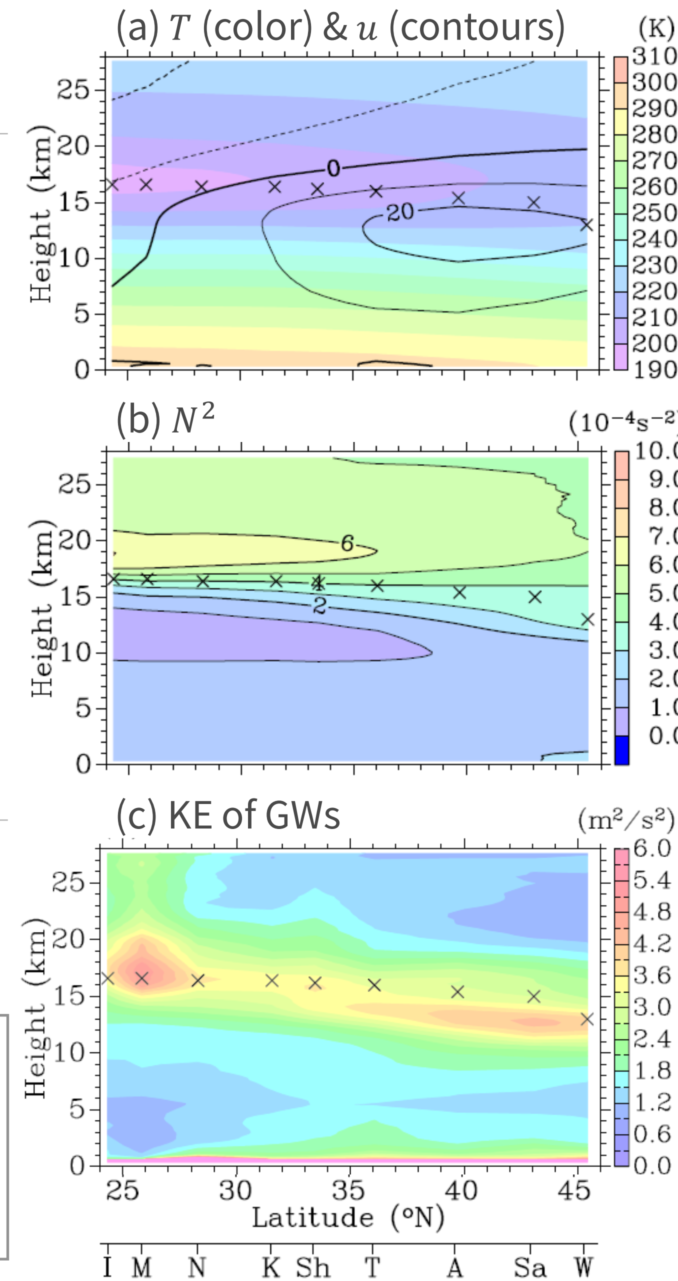


Figure 1 Latitude-height sections of (a) T (color) and u (contours, interval = 10m/s), (b) N^2, and (c) kinetic energy of GWs climatology in summer (JJA).
The height of the tropopause is denoted by “X”. The characters at the bottom of figures stand for each station.

2. Results

The occurrence frequency of $\hat{c}$ and c of GWs (Fig. 2)

- The frequency of eastward c is relatively high in summer, while westward c is dominant in winter.

The occurrence frequency of Ri<0.25 and the ratio of GWs propagating energy upward

- The frequency of Ri<0.25 is high in the upper troposphere especially at 30°N-37°N (Fig. 3a).
- The ratio of upward GWs is high (low) above (below) that region (Fig. 3a).
- The correspondence between shear instability and GW propagation is remarkable especially in summer at Shionomisaki (Fig. 3c).

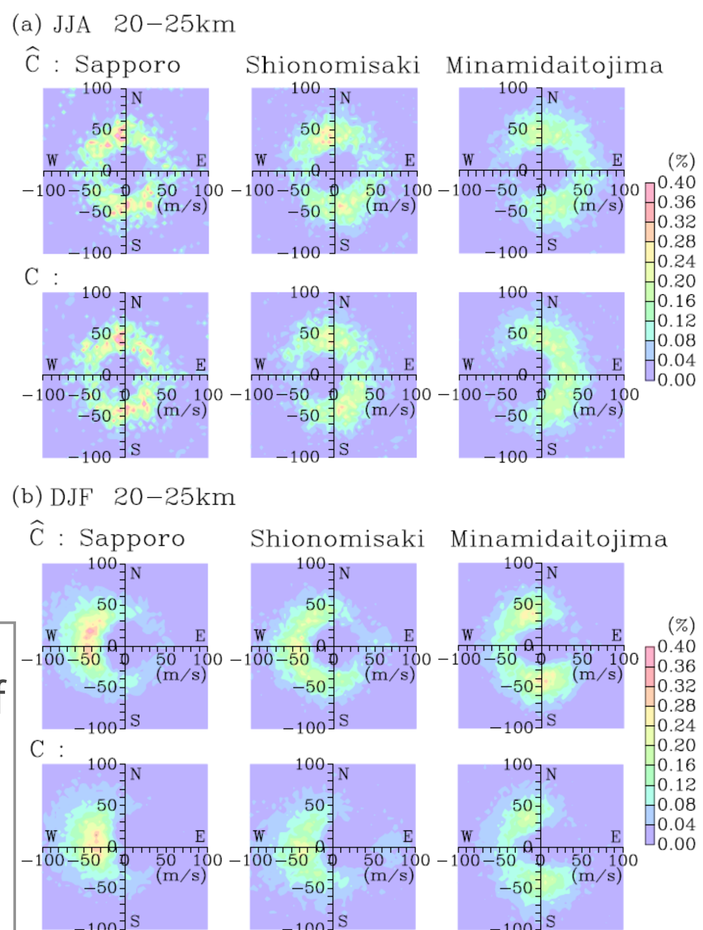


Figure 2(→) The frequency distributions of (top) intrinsic $\hat{c}$ and (bottom) ground-based phase velocities c of GWs in (a) JJA and (b) DJF for each station.

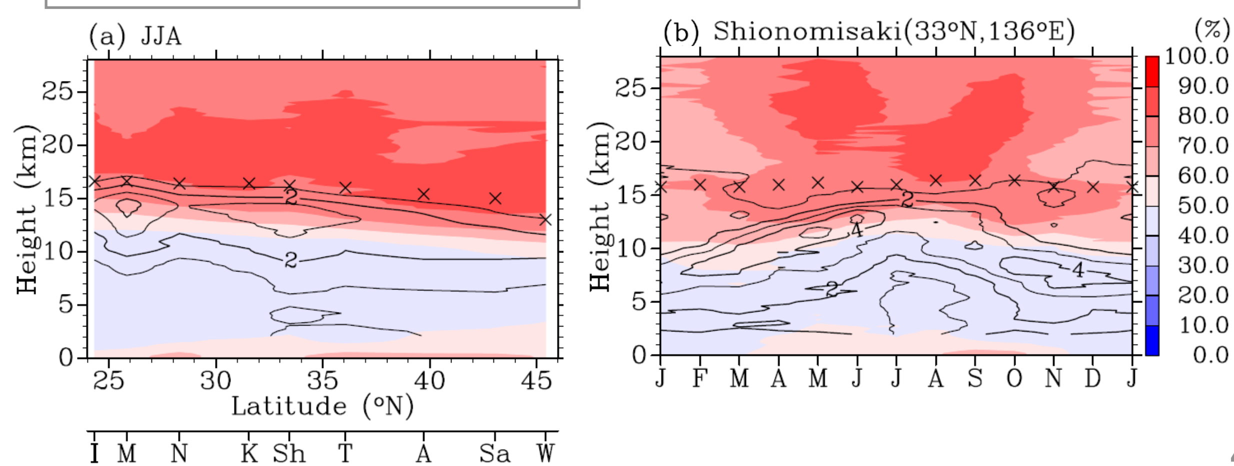


Figure 3 (→) (a) The latitude-height section of the occurrence frequency of Ri < 0.25 (contours, interval=1%) and the ratio of GWs with c_{gz} > 0 (colors) in JJA. (b) The same as (a) but for the time-height section for Shionomisaki.

3. Discussions and Conclusions

- The results strongly suggest that shear instability (SI) above the upper-tropospheric jet is one of the most important GW sources in summer:
  1. The GW KE has its peak slightly below the tropopause.
  2. Eastward propagation is dominant.

     Eastward GWs can propagate upward without suffering critical-level filtering in the westward wind shear above the upper-tropospheric jet.

  3. The percentage of GWs propagating energy upward (downward) is high above (below) the height region with high SI occurrence frequency.
  4. At 30°N-37°N, the GW KE for a height region of 20-25km is highly correlated with the SI occurrence frequency at z=6-17km (not shown).
- The possible reason for the high SI frequency at 30°N-37°N/12-15km:
  - The vertical shear of u is large at higher latitudes
  - N^2 below the tropopause is low at lower latitudes

The region of 30°N-37°N is exactly the location with background conditions conducive to shear instability.

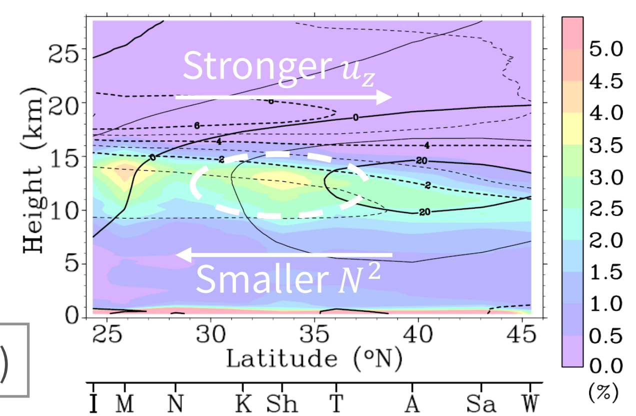


Figure 5 SI frequency (color), u (solid lines) and N^2(dashed lines)