Characteristics of Low Level Jets Over Okinawa in Warm Season Revealed by 400-MHz WPR Observations

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Abstract

Monitoring observation of the wind with 400 MHz Wind Profiler (WPR) over Okinawa, Japan subtropical island has been continuously done. We analyze the data during warm season (May, June, and July) focusing on the low level jet (LLJ). Results show that the stronger LLJs occur more frequently during the Baiu subperiod with heavier precipitation than the post-Baiu subperiod. Post-Baiu subperiod is the subperiod when Baiu front has moved further north of the site. The distribution of the jet height and the mean wind structure are compared between the rain and no-rain cases to clarify the features of the LLJs in association with the precipitation. Statistically, the frequency of LLJ occurrences exhibits a diurnal cycle with the maximum occurring in the nighttime and early morning. Additional investigations of LLJs using data from the Japan Meteorological Agency WPR network for three other stations surrounding Okinawa provide supposting evidences for the role of the atmospheric boundary layer in diurnal variation of the LLJ over Okinawa.

Data and methods

•The 400-MHz WPR installed at the Ogimi site (26°40'N, 128°09'E, 225 m above MSL), belonging to the Okinawa Subtropical Environment Remote-Sensing Center of the NICT of Japan, has been in continuous operation for several years. It has two operating height modes with vertical extension to 7.5 km and 24 km, corresponding to vertical resolutions of 100 m and 150 m starting from the heights of 300 m and 450 m above ground level (AGL). Every mode completes an observational cycle made up of 5 beam sequences in about 2 minutes. In this study, we use the low height mode data.

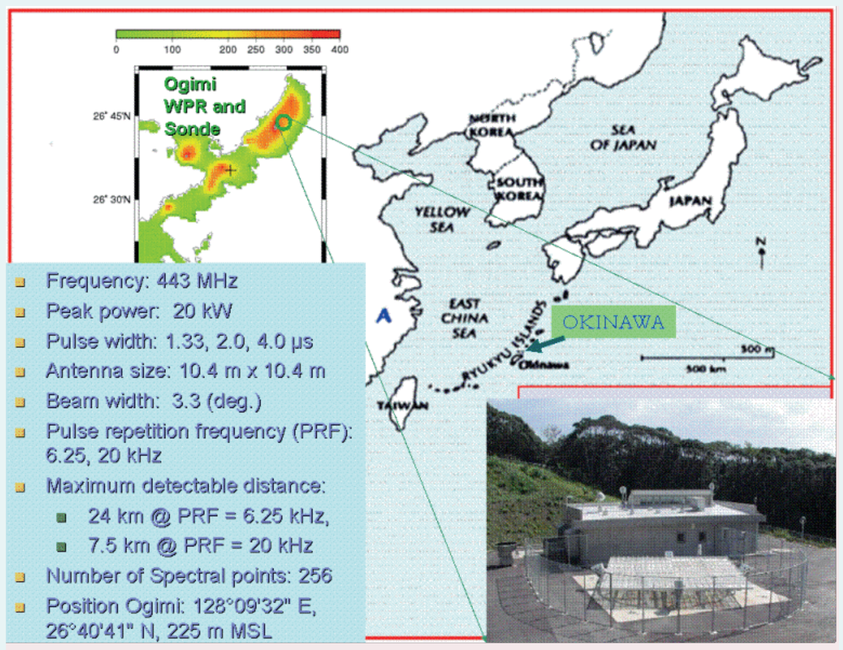

Fig. 1 Okinawa map and Ogimi observation site with WPR picture and specification

• Data from twelve continuous months from May 2005 to April 2006 and three summer months (May-July) of three years (2004-2006) are used for this study with the focus on southwesterly monsoons.

Results

Frequency of the LLJ

• The monthly distribution of total (T-LLJ), southerly (S-LLJ), and northerly LLJ (N-LLJ) occurrences (Fig. 4) indicates that the LLJ occurs around the year, but the southerly LLJ is typically confined to the summer season (from April to August) of prevailing southerly winds, while northerly LLJs are dominant mostly from September to February.

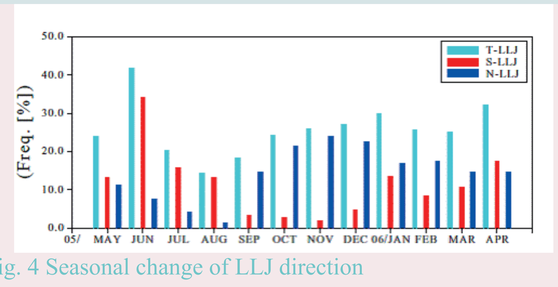

Fig. 4 Seasonal change of LLJ direction

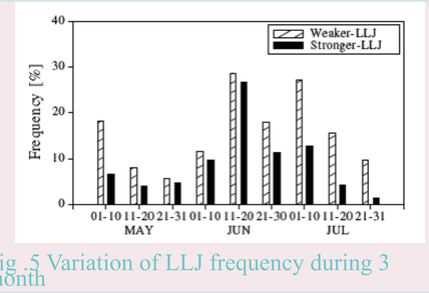

Fig .5 Variation of LLJ frequency during 3 month

Results (cont.)

• The variation of the 10-day frequency of the southwesterly LLJ in every 10 days during the three month period of three years, is displayed in Fig. 5. It shows a higher frequency of LLJ occurrences starting from June 01 and reaching a maximum of nearly 30% in 10-day period of June 11-20. The stronger jets occur more frequently during 1-20 of June, the later half of the Baiu period, when the Baiu activity is usually the most intense over Okinawa and heavy precipitation is frequently observed.

• The hourly distribution shows a diurnal variation of LLJ (Fig. 6). A higher frequency was observed at night and early morning than during daytime, and the early morning preference is more pronounced in the post-Baiu period.

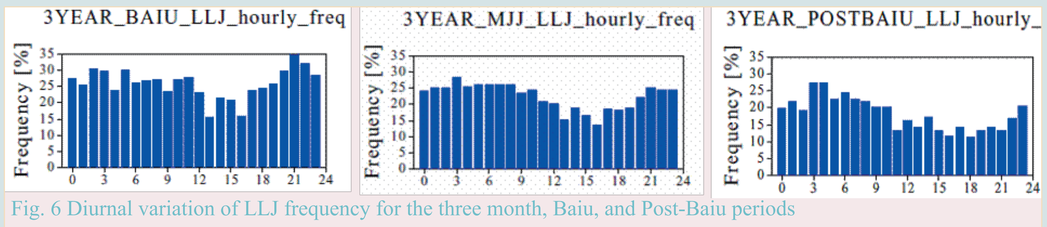

Fig. 6 Diurnal variation of LLJ frequency for the three month, Baiu, and Post-Baiu periods

Vertical structure

• The height distributions of wind speed maxima of LLJs for three month periods of three years, separated into rain and non-rain cases, are shown in Fig. 7. The height of the jet maximum has a double peak structure. The first peak occurs the 500-700 m (AGL) height range, and the second at 1100-1300 m height range

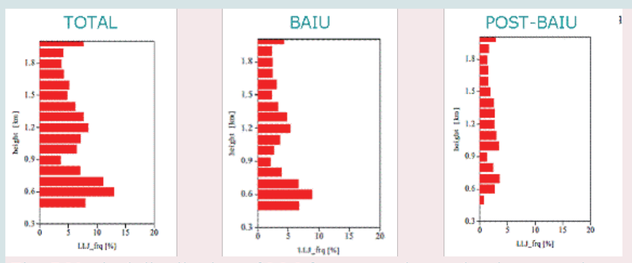

Fig. 7 Vertical distribution of LLJ frequency the total, rain, non-rain periods

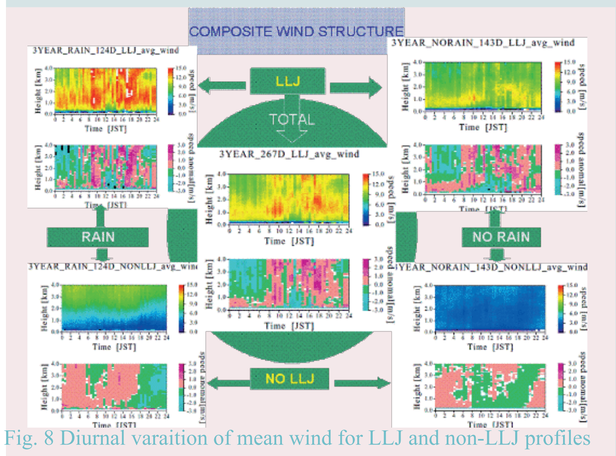

Fig. 8 Diurnal varaition of mean wind for LLJ and non-LLJ profiles

• Figure 8 presents the mean diurnal variation of horizontal wind made up from (a) jet profile and (b) non-jet profile for three months of three years data. The jet profiles are separated for rain and non-rain cases. The mean jet wind of LLJ profiles shows a significant enhancement of wind speed up to greater 12 ms^{-1} in the lowest 2 km until 08 JST, and this enhancement tends to extend upward between 10-14 JST. The stronger shear above the level of the maximum wind speed occurs at night.

Discussion

• The clear upward extension of the LLJ in non-rain cases suggests that the minor second peak around 1.2 km in Fig. 8 occurs as a result of boundary layer processes. The diurnal variations of frequency separately for jets above and below 1 km for the rain and non-rain cases are displayed in Fig. 9. The difference between the rain cases and no-rain cases is that in the non-rain cases the higher jets (above 1 km) occurring in the daytime, are likely a result of an upward extension of the LLJ, while in rain cases LLJs above 1 km could also occur during nighttime.

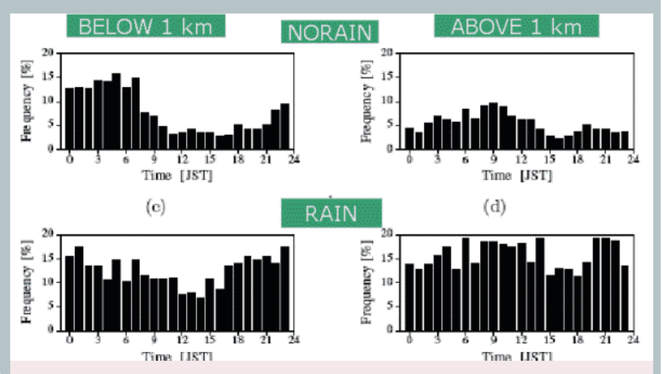

Fig. 9 Diurnal varaition of mean wind for LLJ and non-LLJ profiles

• To examine the phenomena in similar conditions, we expand our analysis to three islands surrounding Okinawa by using data from the JMA WPR network (Fig. 10). A clear diurnal variation with higher occurrences at night and early morning is found in the LLJ frequency distribution only at Naze station, whose land scale is comparable to Okinawa.

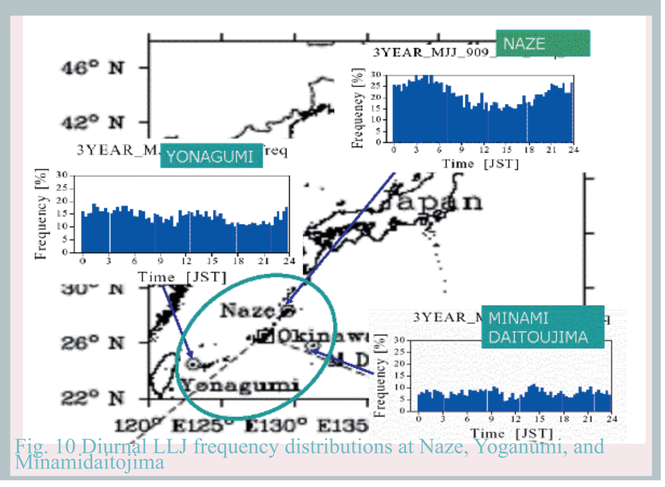

Fig. 10 Diurnal LLJ frequency distributions at Naze, Yoganumi, and Minamidaitojima

Main conclusions

- The result of WPR observations of 3 years in Okinawa shows a clear diurnal variation of the LLJ during SW monsoon: More enhancement of LLJ occurrence in the nighttime during the Baiu subperiod while more in the early morning for the post-Baiu subperiod.
- Frequency distribution of wind direction is more concentrated in south-westerly direction in the Baiu subperiod.
- Double structure in frequency distribution of height of maximum wind, which is more enhanced at the rain cases, suggests different mechanisms for LLJ occurred in the rain and non-rain cases.
- Results from surrounding stations with the similar variation only at Naze support the role of the ABL in regulating the diurnal variation of observed LLJ.

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