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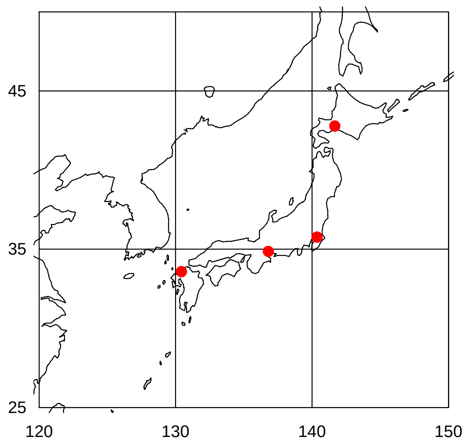
AN ASSESSMENT OF CLEAR-AIR ECHO OCCURRENCES TO DEVELOP AN ADVANCED WIND SHEAR DETECTION SYSTEM FOR PRECIPITATION- FREE CONDITIONS

Kenichi Kusunoki[1)], Chagihira Tetsuya[2)], Motodate Yutaka[2)], Tadayoshi Aoshima[3)], Hiroyuki Kobayashi[3)], Fujio Taka[4)], Fujio Mawashi[4)], Yoshimi Hirakawa[5)], Hiroshi Kiyota[5)]
1) Meteorological Research Institute, 2) New Chitose Aviation Weather Station, 3) Narita Aviation Weather Service Center, 4) Chubu Aviation Weather Service Center, 5) Fukuoka Aviation Weather Station

1. INTRODUCTION

The Doppler Radar for Airport Weather (DRAW) system, which started its operation in 1995 as a wind shear detection and warning platform (Ishihara and Hata 1995), has been installed at eight major airports in Japan. During the warm season, the DRAW system's sensitivity and high resolution allow detection of clear-air echoes that were not generally detectable with conventional weather radars. Whereas the DRAW system has been sensitive enough to observe clear-air echoes, the premise of using this system has been considered phenomena with precipitation. For example, the wind shear detection algorithms have been tuned to recognize the velocity and reflectivity signatures associated with microbursts and gust fronts, which are considered to occur with precipitation in Japan.

In order to assess the utility of these clear-air echoes for use in operational systems, clear-air echo data from the four DRAW sites (Shin-Chitose, Narita, Chubu, Fukuoka) have been analyzed. These sites were selected to represent a range of latitudes (from north to south). In this presentation, we focuses on obtaining quantitative information regarding clear-air echo frequency, area coverage, diurnal structure, and the environmental conditions.



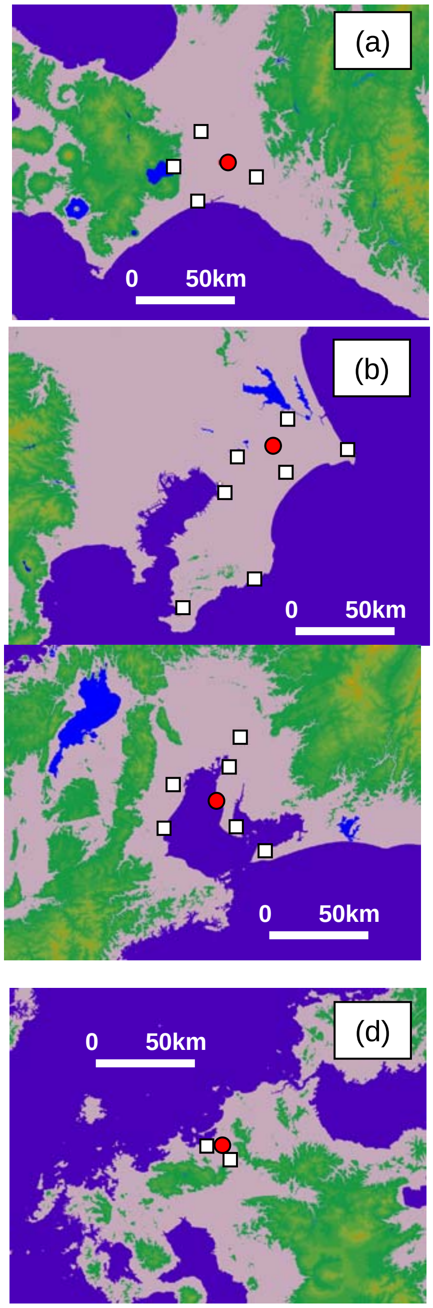


FIG. 1. Map showing the study area. The circles indicate the positions of each DRAW site. Squares indicate the positions of AMeDAS stations. (a) Shin-Chitose DRAW, (b) Narita DRAW, (c) Chubu DRAW, and (d) Fukuoka DRAW.

Corresponding author address:
* Kenichi Kusunoki, Meteorological Research Institute, 1-1,Nagamine, Tsukuba, Japan
E-mail: kkusunok@mri-jma.go.jp

2. METHODOLOGY

The data used in the present study includes the following: (i) the Doppler radar data from the four DRAW sites and (ii) surface weather data from sites of the Automated Meteorological Data Acquisition System (AMeDAS). The locations where the data were taken are shown in Fig. 1.

PPI scan data from each DRAW at the lowest elevation angle (0.8deg) taken in 1-h intervals on September 2005 were used. The reason for the elevation angle is that the depth of the clear-air echoes was usually below 2 km, and this elevation was the best to them. Because clear-air echoes in boundary would be affected by surface environmental conditions, the relationships of clear-air echo appearances to weather data were examined. Hourly surface wind, temperature, and sunshine duration from the DRAW site and AMeDAS sites surrounding each DRAW site were used for this research.

According to the clear-air echo observations over the Kanto plain, radar reflectivity values of clear-air echoes were usually more than 0 dBZ and typically 10-20dBZ (Kusunoki and Matsumura 1999). Furthermore, on the DRAW system, Doppler velocities and rainfall rates with corresponding reflectivity values below 4 dBZ are not considered. Therefore, as the working definition of a clear-air echo, a continuous region of echo with reflectivities from 4 dBZ was targeted. In order to distinguish clear-air echoes and precipitation echoes, a careful check of synoptic conditions, surface precipitation data, and echo patterns was performed.

3. RESULTS

a. Spatial distribution

Clear-air echo areas observed throughout September 2005 are superimposed in Fig. 2. These figures indicate distinct contrasts between clear-air echoes observed over land and their absence over the ocean. Clear-air echo over the ocean has been observed except for short distances offshore.

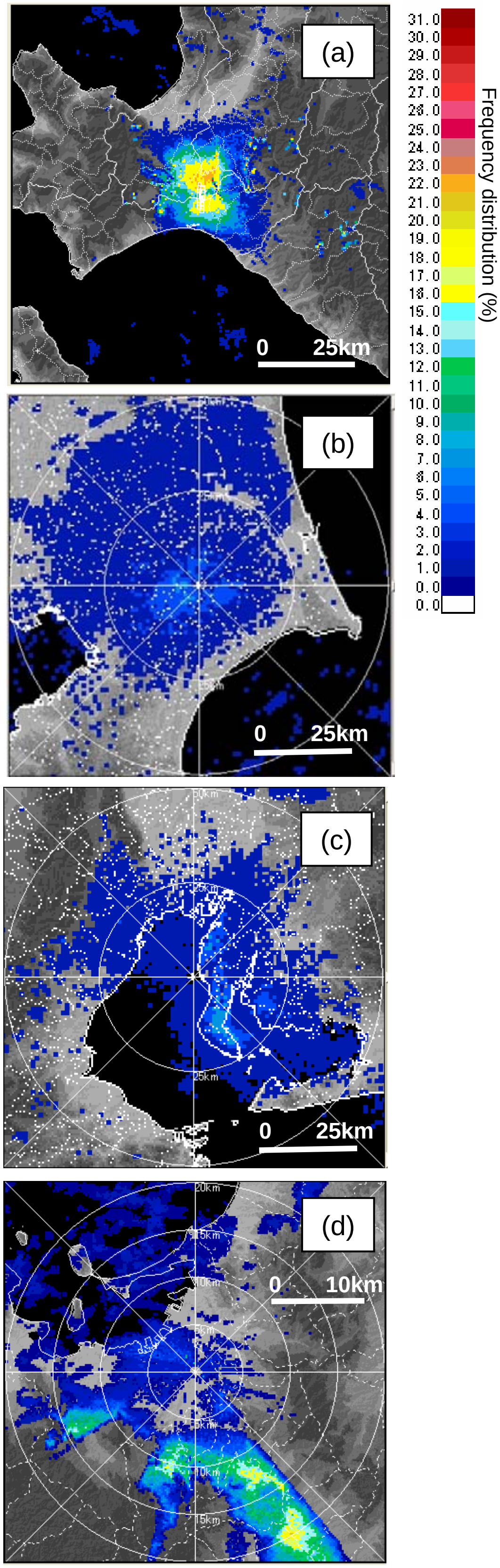


FIG. 2. The spatial distributions of clear-air echo appearances (shaded) observed with each DRAW. All clear-air echo areas during September 2005 are superimposed. The locations of each DRAW are indicated by the crosses. Range marks are at 25-km intervals centered at each DRAW. (a) Shin-Chitose DRAW, (b) Narita DRAW, (c) Chubu DRAW, and (d) Fukuoka DRAW.

b. Diurnal variation

Figure 3 shows the hourly totals of clear-air echo and no echo for each month. The sunrise and sunset times are also indicated by black arrows. The diurnal variation of clear-air echo appearances had some peaks at the periods of the daytime and the twilight. The first peak was in the daytime, starting after sunrise and fading before sunset (all four sites). The second one appeared during twilight after sunset for a short time (Narita, Chubu, and Fukuoka). The third one also appeared during twilight but before sunrise (Narita and Fukuoka).

c. Relationships of clear-air echo appearances to surface weather conditions

Figures 4, 5, 6, and 7 show the relative frequencies of clear-air echo appearances categorized by temperature, sunshine duration, wind speed, and wind direction. As mentioned in sections 3b, clear-air echoes were likely to appear after sunrise and fade before sunset. In order to examine the dependence of the echo appearances upon surface weather conditions, data were used in the period of 0900-1600 JST, when such variations would not have an effect. The correlation of clear-air echo appearances with temperature (Fig. 4) was quite high; the frequency increase with increasing surface temperature. There also appeared to be a strong correlation between clear-air echo appearances and wind speed (Fig. 6); the frequency decreased considerably under relatively strong surface wind conditions. On the other hand, the correlations of clear-air echo appearances with sunshine duration (Fig. 5) and wind direction (Fig. 7) were significantly low.

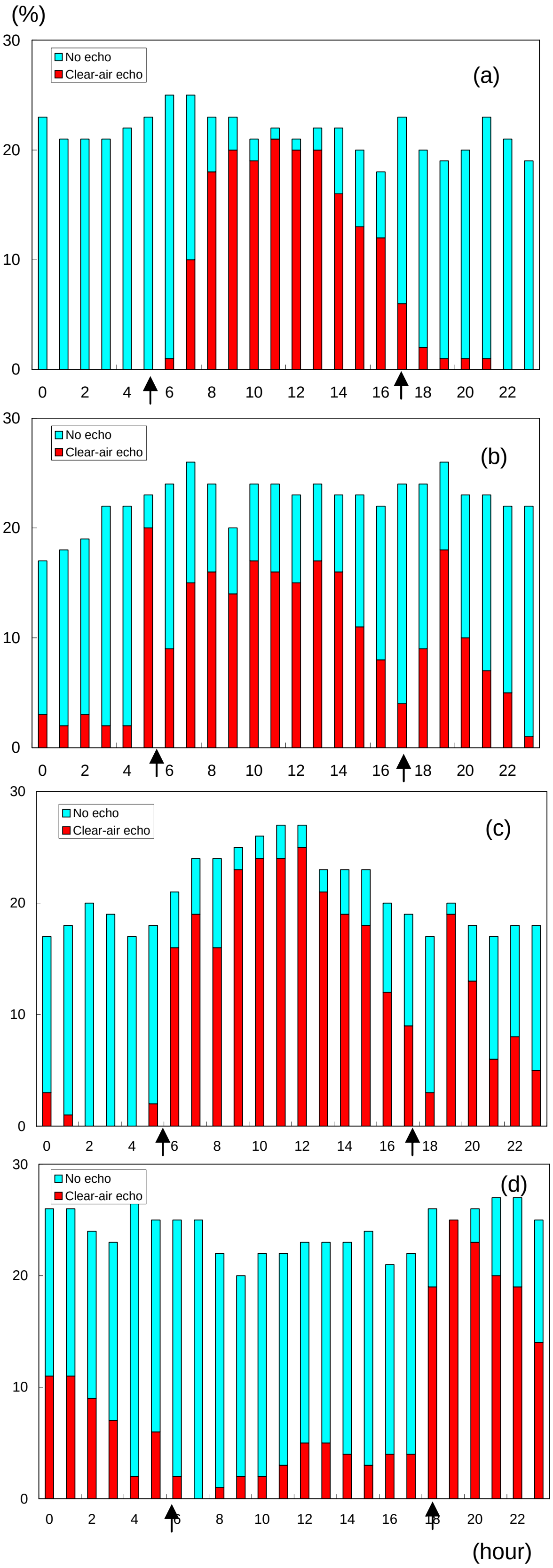


FIG. 3. Diurnal variations of clear-air echo appearances. (a) Shin-Chitose DRAW, (b) Narita DRAW, (c) Chubu DRAW, and (d) Fukuoka DRAW. The red bar shows the hourly totals of “clear-air echo” and the blue bar those of “no echo” for each month. The black arrows show sunrise and sunset times, respectively.

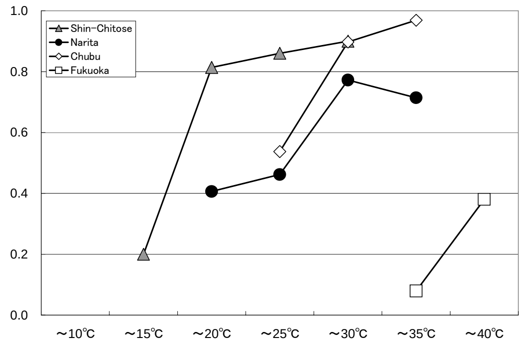


FIG. 4. The relative frequencies of clear-air echo appearances around each DRAW categorized by temperature. (a) Shin-Chitose DRAW, (b) Narita DRAW, (c) Chubu DRAW, and (d) Fukuoka DRAW.

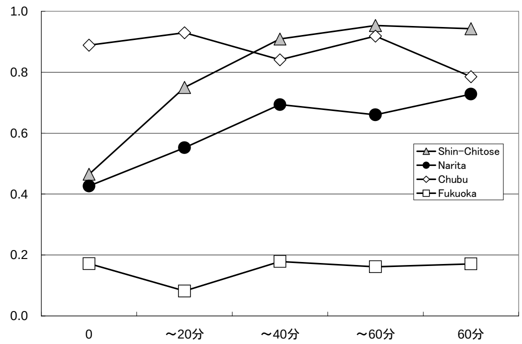


FIG. 5. Same as FIG. 4 but for sunshine duration.

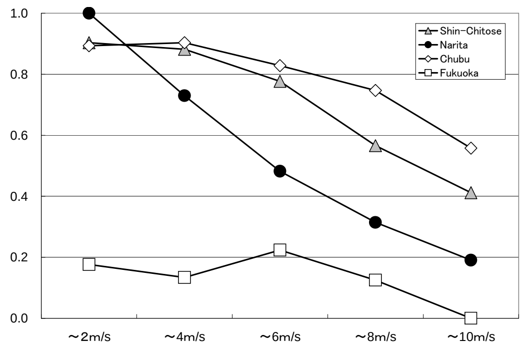


FIG. 6. Same as FIG. 4 but for wind speed.

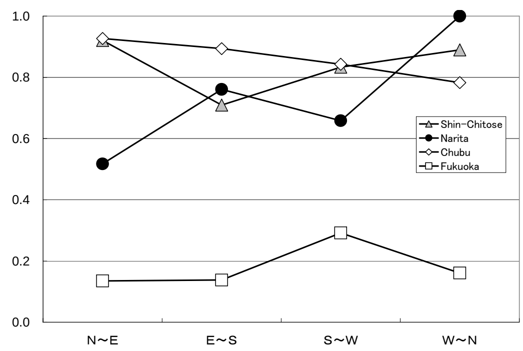


FIG. 7. Same as FIG. 4 but for wind direction.

4. SUMMARY AND DISCUSSIONS

This study exhibits the unique characteristics of space distribution, diurnal variations, and sensitive dependence on surface weather conditions. These results will be reflected in the limitations and time schedules concerning routine operational use of clear-air echoes. 1) Concerning the spatial distribution, a disadvantage is that clear-air information is not available in the oceanic sector of the radar coverage area because clear-air echoes only appear over land. 2) The daily timetable for the use of clear-air echoes should be limited to almost daytime. 3) Clear-air wind shear detection algorithms may not work accurately due to lack of scatterers under strong wind conditions, because the clear-air echo frequency decreased considerably under relatively strong wind conditions. To obtain reliable information from clear-air echoes, it is necessary to monitor boundary layer conditions such as surface wind speeds and temperatures, simultaneously with radar observations.

Our results are consistent with the previous study of Kusunoki (2002). We are beginning to extend the study period to six months in order to investigate seasonal variations of clear-air echo appearances and their latitude distributions. The comparisons between Doppler velocity from the echoes between actual wind will be also discussed in future work.

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