

## Abstract

On removing to Tsukuba Science City, the Meteorological Research Institute installed 5 cm wavelength and 3 cm wavelength Doppler radars in 1980 and 1981, respectively. These radars are in the charge of the Meteorological Satellite Research Division and the Typhoon Research Division for their maintenance and improvement. The capability of the Doppler radars in measuring the motion of scatterers has provided an effective means to solve many problems in six out of the nine research divisions of the M.R.I. For example, observations of typhoons, extratropical cyclones, thunderstorms and heavy snowfalls use raindrops and snow particles as scatterers. In the observation of clear air, "chaff" and refractive index irregularities are used as scatterers. Water waves are scatterers in the sea surface observation. Many facts have been revealed by these observations. The research divisions participating in the Doppler radar observation are the Forecast Research Division, Physical Meteorology Research Division, Applied Meteorology Research Division and Oceanography Research Division as well as the above-mentioned two.

Doppler radar observations have been carried out for about five years at our institute. Some of their results have been published and others are now in preparation. Doppler radar has been considered as one of the very important tools in the very-short-range forecast of heavy rainfall, snowfall and strong wind not only in the Meteorological Agency but also outside. This paper reports on the present situation of the development of Doppler radar and the research activities in its use. It is desired that this report is helpful in showing clearly the capability of Doppler radar and our research activities.

This volume consists of ten chapters which are summarized as follows.

### Chapter 1 Processing of Doppler signals and radar equipment

The method of processing Doppler signals is described. In particular, the pulse pair processors which are incorporated in the two Doppler radars used at our institute are described in detail. Then the main functions and characteristics of the radars are stated. And the function of the three-dimensional sector scan which is developed and added after the installation of the radars is described in detail.

## Chapter 2 Observation mode of Doppler radars

The upper wind measurement by a single-Doppler mode, that is, the V.A.D. method is described, and its accuracy is discussed. Then the methods of observation and data processing for the dual-Doppler mode are described to obtain three-dimensional wind fields.

## Chapter 3 Structure of typhoon rainbands

The analysed typhoon rainbands were associated with Typhoon 8124, Typhoon 8305, and Typhoon 8514. These were observed around Tsukuba. The rainband associated with Typhoon 8124 was observed by a single-Doppler mode, since the dual-Doppler observation system had not been established yet in 1981. This rainband included a mesoscale slant updraft with a gentle slope from the low levels on the typhoon center side to the higher levels on the outer side. A heavy rainfall occurred below this updraft. The two rainbands in Typhoons 8305 and 8514 were observed by the dual-Doppler mode. The most prominent feature in these rainbands is the relatively steep slant updrafts from the typhoon center side to the typhoon outer side.

## Chapter 4 Structure of rain areas associated with extratropical cyclones

Rain areas in this case were observed by single-Doppler mode. A warm-frontal heavy rain area associated with a small low pressure was observed by the 5 cm wavelength Doppler radar at Tsukuba. A heavy rain occurred in front of the area where the low-level strong southerly wind intruded into the warm-frontal zone. Cold-frontal rainbands on the Kanto Plain observed by the same radar usually show indistinct structure because of the effects of the mountainous region to the west of the Plain. Therefore, we observed a rainband around western Hokuriku by the 3 cm wavelength Doppler radar during an observation period of heavy snowfalls. Thus a typical cold-frontal rainband in winter was observed, which showed its decay process due to the mountains.

## Chapter 5 Structure of multicell thunderstorms

Two cases of multicell thunderstorm over the Kanto Plain were observed by the dual-Doppler mode. One case was associated with a strong vertical wind shear. Lines of thunderstorms were formed along the wind shear. The internal airflow was three-dimensional in spite of the two-dimensional external appearance. The other case occurred in a weak shear condition. In this case the thunderstorm propagated in sequences of formations and dissipations of cores.

### Chapter 6 Structure of convective snow clouds

The structure of convective snow clouds which appeared over the Sea of Japan in the cold air outbreak in winter is described. These clouds were observed by the 3 cm wavelength Doppler radar located at Kanazawa in western Hokuriku. Three cases of characteristic snow clouds were analysed. In the first case snow clouds were formed above the convergence zone over the sea affected by the land breeze, causing snowfalls near the coast. In the second case, snow clouds had already been organized like squall lines over the sea and they caused snowfall mainly in the inland area. In the last case, snow clouds were organized in a very wide cloud band by mesoscale horizontal flows. They also caused snowfall mainly in the inland area.

### Chapter 7 Airflow observation by dispersing "chaff"

Airflow observation by dispersing "chaff" as scatterers is described in non-precipitation conditions. In particular the characteristics of the chaff and the features different from those observed by using precipitation particles as scatterers are described in detail.

### Chapter 8 Observation of "angel" echoes

The "angel" echoes observed were probably associated with the irregularities of refractive index. Winds estimated by the angel echoes during the passage of a sea-breeze front agree well with the winds measured by the anemometer at the top of the tower of the M.R.I. (213 m above the ground). The mechanism of the backscattering by the irregularities of refractive index is described. In addition, examples of the observation of non-precipitation echoes which were due to insects and birds are shown.

### Chapter 9 Observation of sea waves

The sea surface echoes observed by the 3 cm wavelength Doppler radar at Choshi were compared with the sea surface wind measured at Hazaki and the wave height data at Kashima. The radial component of the motion of scatterers was of the order of several meters per second. The reflectivities and Doppler velocities in sea surface echoes indicate better correlation with the sea surface wind than with the height of swells. It was found that the backscattering by waves can be distinguished from that by precipitation particles because of the difference in the Doppler spectra.

## Chapter 10 Closing remarks —Tasks for the future —

The tasks for the future are shown in two fields, that is, (1) improvement of observation equipment and data processing method and (2) further Doppler radar study of meteorological and sea surface phenomena.