The Japan Coast Guard continuously operates two types of real-time ocean current observation systems with High-Frequency (HF) radar. These have been operational in the area of Izu Islands since August 2001 and Sagami Bay since August 2002. They were installed to monitor the Kuroshio Current that flows generally from south-west to north-east along the south coast of Japan, and to monitor the coastal current normally flowing anti-clockwise in the Bay, and sometimes clockwise due to inflow from the Kuroshio. The total vector maps produced by each HF-radar are released on the internet (www1.kaiho.mlit.go.jp).

By Tomotaka Ito and Hideki Kinoshita, Director, Environmental and Oceanographic Research Division, Hydrographic and Oceanographic Department, Japan Coast Guard, Japan

Ocean Current Observations

Application of HF-radar in Japan

The main purpose of this article is to introduce ocean current observation with HF-radar operated by the Hydrographic and Oceanographic Department of the Japan Coastguard and to point out its accuracy and benefits.

Observation Systems

Japan Coast Guard is operating HF-radar in two observation areas, located at the south of Tokyo Bay (hereinafter called the Outer Ocean HF-radar) and at Sagami Bay (hereinafter called Sagami Bay HF-radar). Figures 1 to 3 show the location of the radar sites, the coverage of the Outer Ocean HF-radar and the Sagami Bay HF-radar, respectively. The Outer Ocean HF-radar system is operated on the 5MHz frequency (using two different frequencies) located at Nojima-saki and Hachijo Island, separated by a distance of about 200km. Radial velocity components from each site are computed at three-hourly intervals, with horizontal resolution of about 10km. The other system, Sagami Bay HF-radar is operated on the 24MHz frequency (using single frequency) and installed at Arasaki and Izu-Ohshima to cover a field of about 60km in distance. Radial velocity components are taken every hour at each site, with horizontal resolution of about 1.5km. As soon as the radial velocity components are calculated at each site these are transmitted to headquarters of the Department in

Figure 1: Location of HF-Radar.

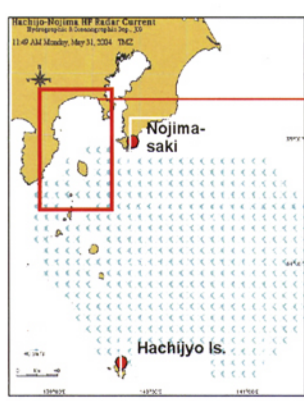

Figure 2: Outer-ocean HF-Radar.

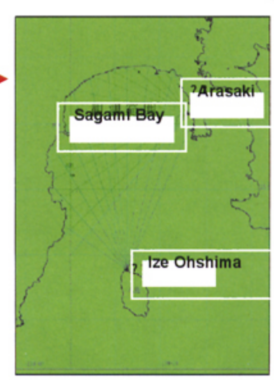

Figure 3: Sagami Bay HF-Radar.

Tokyo by telecommunication. The specifications of both radar systems are shown in Table 1.

Ocean Current Image

In Figure 4 may be seen the total vector map of Outer Ocean HF-radar, which clearly images the Kuroshio Current flowing from south-west to north-east. In general there is a sector along the baseline where only one velocity component is resolved, since the two antennas oppose each other over much of the region of interest. The current vectors in the sector are replaced with the interpolated values. The spatial coverage typically reaches nearly 200km in daytime; however, it is found to be highly sensitive to radio interference and noise, especially at night. One of typical characters of HF-radar is its ability to make observations without any influence of weather. As an example, Figure 5 shows the vector map as a typhoon passed through the region on 16th July 2002. Normally, the speed of the Kuroshio is around 2 to 3 knots in its main current but strong currents of over 4 knots were observed under these weather conditions. The central pressure and maximum wind speed of the typhoon were 975hPa and 39m/s respectively. In this connection, it was shown that the structures of both radar systems could stand up to maximum 70m/s wind-speed. The points A and B indicate the positions of centre of the typhoon at 9 and 12 o'clock on 16th July.

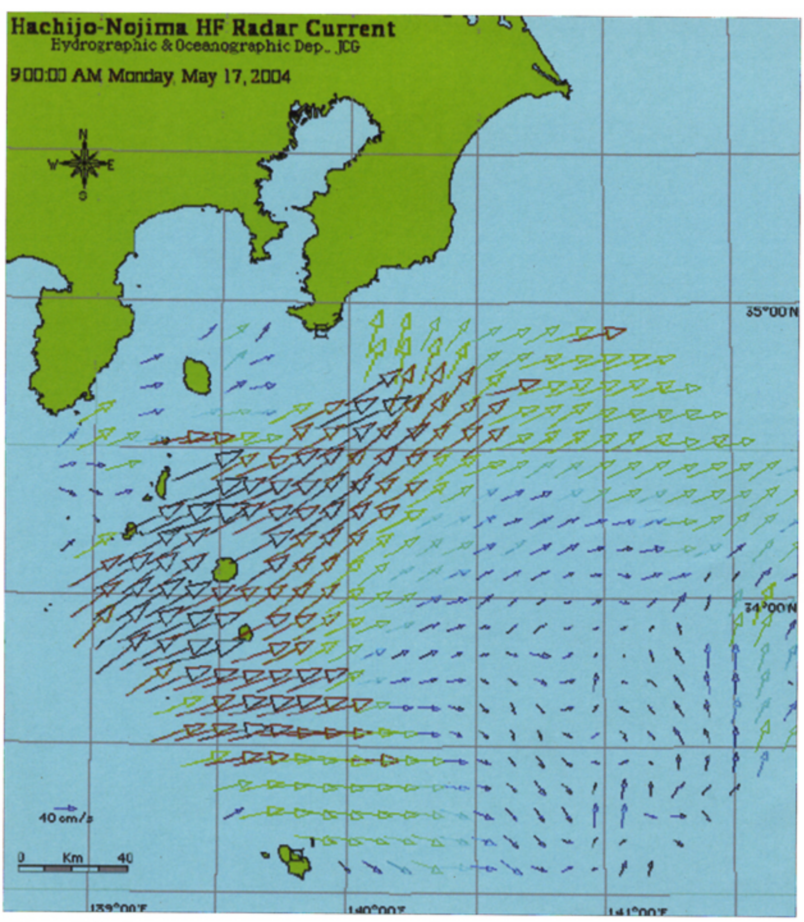

Figure 4: Total vector map at outer-ocean HF-Radar.

Verifying Observation Data

To understand the characteristics and the quality of HF-radar data, three types of comparison were carried out. Radial current speeds measured at each radar site were compared with 1) the current observed by shipboard ADCP (Acoustic Doppler Current Profiler), 2) with the moored ADCP and 3) the geostrophic current from sea-level difference between Miyake Island and Kozu Island.

1) Results of comparison between radial velocity by HF-radar and radial component of velocity at 10m depth by shipboard ADCP are shown in Figure 6. The rms difference of radial velocity measured by HF-radar is 37.6cm/s at the Hachijo Island site and 35.6cm/s at the Nojima-saki site. Direct comparison is not suitable in this case because the current observed by HF-radar and ADCP differs with observation time, point and layer.
2) Comparison between radial velocity by HF-radar and the moored ADCP was conducted. The moored ADCP was set up at 350m

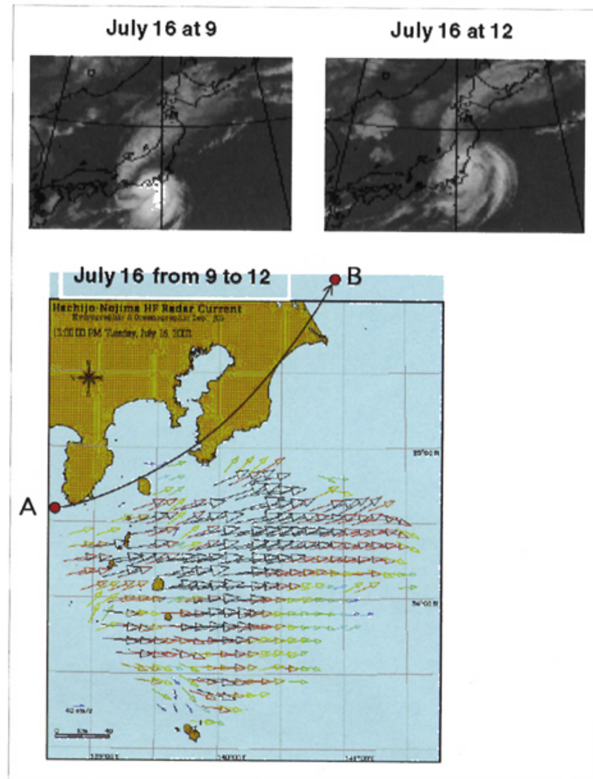

Figure 5: Vector map at typhoon pass.

	Outer-Ocean Radar	Sagami Bay Radar
Manufacturer	CODAR (US)	Mistubishi Ltd
Frequency	_MHz	24 MHz
Sweep Band	15 kHz	100 kHz
Range	200 km	60 km
Resolution	10 km	1.5 km
Sampling Interval	_hours	_hour
Transmitter Power	<50 watts	<100 watts
Receiver Antenna	a monopole 2 crossed loop	4 monopoles
Transmit Antenna	a monopole	2 monopoles

Table 1: Specification of radar.

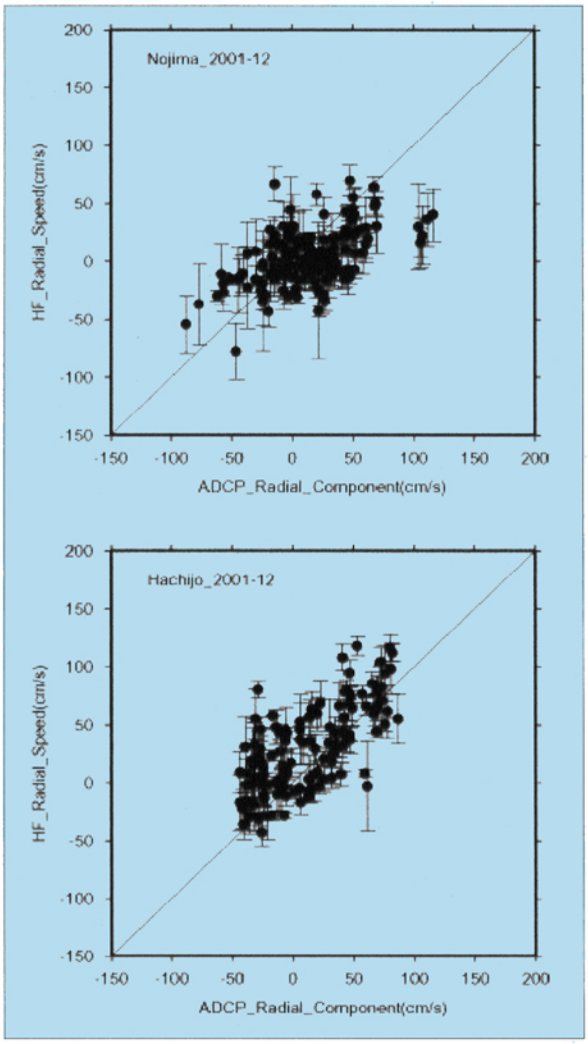

Figure 6: Comparison between radial vector of HF-Radar and ADCP.

depth near Hachijo Island, with 20 min. sampling interval, observed layer every 5m from surface to 100m depth, for 45 days from 19th June 2003 to 5th August 2003. The radial velocity at 10m depth by ADCP is averaged every three hours.

3) The third verification is the comparison of the radial vector by HF-radar at the Nojima-saki site and geostrophic velocity calculated from sea-level difference between the Miyake and Kozu tide stations. The radial velocity of HF-radar is derived from the average of four HF-radar cells between the two stations.

Tidal Current Component

The periodical component in the current is not remarkable in the area between Hachijo Island and Nojima-saki, because the Kuroshio is dominant. However, a trial to extract periodical components was conducted to estimate the ratio of its contribution of tidal current in the area. Every three hours, observation data from 6th August 2001 to 27th August 2003, including missing data due to noise or mechanical troubles, was analysed by the least-square method to extract harmonic constituents from tidal current at eight points in the area (see Figure 7). Substitute V and D for the maximum current speed and the direction. The summation of amplitude of four dominant tidal components (K1, O1, M2, S2) for east-west and north-south components are Ve and Vn. Then the maximum speed and the direction can be expressed as follows:

$V=\sqrt{(Ve*Ve+Vn*Vn)}$

$D=\arctan(Ve/Vn)$

A	0.68	E	0.78
B	0.61	F	0.64
C	0.56	G	0.41
D	0.49	H	0.95

Table 2: Maximum speed at each point (knots).

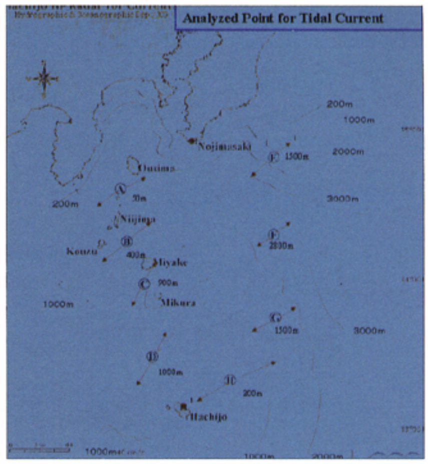

Figure 7: Dominant speed and direction of tidal current at each point.

Table 2 shows maximum current speed in knots. The strongest tidal current of about 1kn appears at point H, to the north east of Hachijo Island. The maximum speeds of tidal current for the rest of the points are about 0.5 knots to 0.7 knots.

Conclusion

Although the technology of surface current observation with HF-radar is not yet established, hopefully in the near future we be able to make widespread and timely observations under all weather conditions. In addition, since it is possible to extract the tidal current components from HF-radar data, HF-radar is expected to become a desirable observation method in especially strong tidal current areas such as those featuring more than 10 knots, in which it is quite difficult to install traditional current meters.

Biographies

Tomotaka Ito is deputy director in the Hydrographic and Oceanographic Department of Japan. He received his BS in Mathematics from Tokyo Science University.

Hideki Kinashita is senior researcher in the Hydrographic and Oceanographic Department of Japan. He received his MS in Physical Oceanography from Tohoku University. ■

E-mail: tomotaka-itou@kaiho.mlit.go.jp