P1.7 **The NOAA *Ron Brown's* Shipboard Doppler Precipitation Radar**

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1. INTRODUCTION

Oceans cover two-thirds of the planet's surface but remain data-sparse regions for weather and climate observations for obvious logistical reasons. On land, networks of research-grade, operational Doppler weather radars became commonplace in the 1990s in several nations, but similar precipitation data at sea are still rare. Consequently, relatively little is known about marine precipitation mechanisms, although their impact on civilization through climate energetics and land-falling coastal storms may be very large.

Temporary deployments of non-coherent weather research radars on scientific ships dates back to the 1970s, but the use of onboard Doppler radars is more recent (*e.g.* Short *et al.* 1997). Even more recently, spaceborne radar and radiometer observations from the Tropical Rainfall Measurement Mission are helping fill the ocean precipitation data void in the lower latitudes (Kummerow *et al.* 2000).

Another new tool for oceanic precipitation observations is the 5.6-GHz (C-band) Doppler radar on board the NOAA research vessel, *Ronald H. Brown* (*RHB*), shown in Fig. 1. Commissioned in 1997, the *RHB* is among the world's most technologically advanced seagoing research platforms and is the only ship in the U.S. civilian fleet to carry Doppler radar. Initially, a smaller C-band Doppler radar was used on the RHB in 1997, while the permanent system was being designed. The new radar was installed in 1998 to further enhance the vessel's impressive environmental observing attributes.

2. BASIC CAPABILITIES

The new C-band radar was built and installed on the *RHB* by Radtec Engineering, Inc.

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Figure 1. The C-band radar atop the central mast of the Ronald H. Brown research vessel.

NOAA/ETL currently serves as instrument mentor for the system, which is available to principle investigators on the ship's numerous annual cruises for a wide variety of marine studies sponsored by NOAA and other agencies. A typical cruise lasts about six weeks.

C-band represents a compromise between more heavily attenuated higher radar frequencies, such as X-band, and the larger size and weight requirements of lower frequency S-band weather radars, such those used for the land-based WSR-88D (NEXRAD) systems. The *RHB* radar's 4.3-m antenna is mounted atop the ship's main mast within a protective radome and is designed for operations in heavy weather up to sea state 8.

Scanning, data processing and recording are controlled by a data system located in the chart room just aft of the bridge. The radar's beam is motion-stabilized by the use of an inertial navigation system which monitors the ship's attitude at 50 Hz and, through coordination with the antenna control system, compensates for ship motion to maintain the beam at the desired earth-relative elevation and azimuth angles. This motion-stabilization feature provides accurate Doppler velocity data even in rough seas. The system transmits and receives horizontal polarization, and has been designed for future implementation of dual-polarization capability. The radar has very good sensitivity (-22 dBZ at 10 km range) and resolution (75-m), which endow it with the ability to observe some non-precipitating clouds within a few kilometers of the ship, in addition to nearby and distant rain. Basic operating characteristics and capabilities are summarized in Table 1.

Table 1. Characteristics of the *RHB* radar.

Major Capabilities: ship-based,
scanning,
Doppler,
platform-motion-stabilized.
Primary Uses: measurements of precipitation at sea,
3D storm structure and airflow,
satellite and model validations.
Frequency: 5.595 GHz (λ = 5.4 cm, C-band).
Peak Transmit Power: 250 kW, magnetron.
Antenna: 4.3-m-diameter parabolic center-feed dish
within a 5.5-m radome.
Antenna Gain: 44 dB, with -22 dB sidelobes.
Beam Width: 1.0 deg.
Pulse Length: selectable, typical defaults are
0.5, 0.8, 1.4 and 2.0 μs
(resolution = 75, 120, 210, 300 m).
PRF: selectable, 250-2100 Hz
Scans: PPI, RHI, sector, fixed beam; elevations
from below horizon to near zenith.
Scan Rates: up to 36 deg/s (12 deg/s typical).
Polarization: linear horizontal
Number of range gates: 1024
Maximum unambiguous range: 300 km at PRF=500.
Sensitivity: approx. -22 dBZ at 10 km using
0.5 μs pulse length.
Data System: Sigmet RCP-02 and RVP-07
on HP Unix workstation.
Platform: 83-m oceanographic research ship.

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3. DATA SYSTEM

Radar operation and data processing are conducted with the RCP-02 antenna control and RVP-07 data systems from Sigmet, Inc. Computer controlled scans include PPI, RHI, fixed beam, and sector sweeps with elevations from below the horizon to near zenith (~87 deg.). Scan rates, scan sequences, and many other parameters, including pulse lengths, can be pre-programmed or adjusted in realtime. Recorded parameters at each range gate include reflectivity factor (with and without clutter rejection), mean Doppler velocity, and Doppler spectrum width. A color display presents realtime PPI (constant elevation angle) images of these parameters. Data are recorded on 4-mm DAT tapes which typically last at least 24 h. An onboard post-processing data system allows numerous derived products to be generated with Sigmet software, including Z-R-based rainfall rate maps, RHI (constant azimuth) displays (*e.g.* Fig. 2), and vertical and horizontal cross-sections from volume scans. Identical data systems for more extensive post-cruise analysis exist at NOAA/ETL and various other institutions.

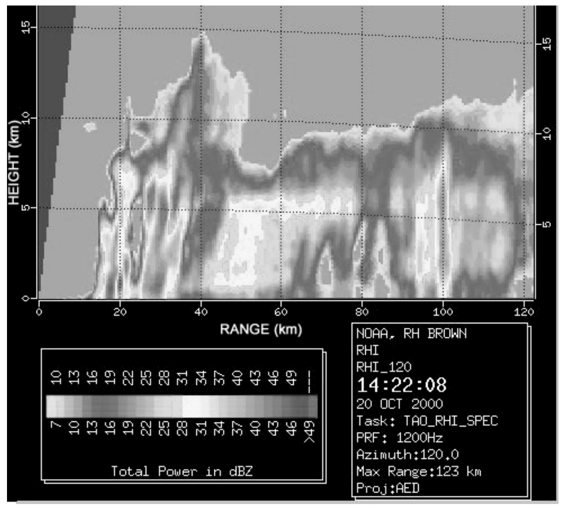

Figure 2. Example of a reflectivity image from an RHI scan through a widespread storm during a PACS cruise in the eastern Pacific Ocean. This storm included convective and stratiform regions and a melting layer bright band near 5 km MSL.

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4. APPLICATIONS

The *RHB's* Doppler C-band radar enables studies of precipitation to be conducted at sea beyond the reach of conventional, land-based weather surveillance radars. Three-dimensional storm structure and airflow patterns can be examined with very good resolution and area coverage. In many respects, this radar is the equivalent of an oceangoing NEXRAD that can provide research-quality observations, in addition to routine storm surveillance. Rain statistics at sea derived from its data are well suited for evaluating assumptions used in satellite precipitation algorithms. Initial uses of the RHB radars include studies of tropical rainfall (*e.g.* Yuter and Houze 2000), drizzle-producing stratocumulus (Yuter *et al. 2000),* monsoons (Webster *et al.* 2001), and physical validation of satellite-based rainfall algorithms.

The *RHB* radar can provide the temporal continuity needed to document evolving conditions, diurnal trends, and statistical averages over ocean regions that cannot be directly obtained with “snapshots” of data from occasional satellite overpasses. In Figure 3, for example, the distributions of echo reflectivities changed greatly over the course of a single active weather day in the eastern Pacific.

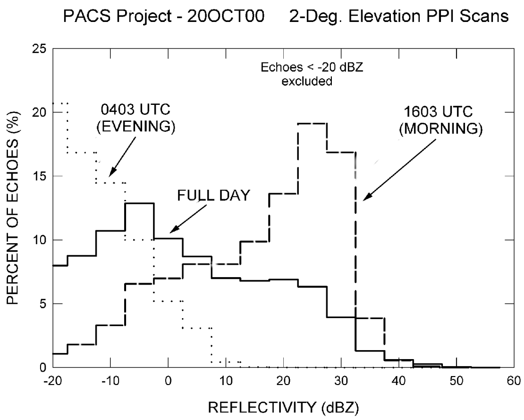

Figure 3. Histograms of reflectivity from the RHB’s radar during one PACS cruise day.

Table 2 lists the primary experiments that have used RHB radars to date. Much of this work has occurred within or near the inter-tropical convergence zone, which is the Earth’s global climate-driving engine.

The RHB carries numerous other meteorological and oceanographic instruments which combine synergistically to enhance various studies by providing more thorough documentation of the conditions at sea. Radiosondes, standard meteorological sensors, rain gages, and a new motion-stabilized wind profiling radar are available. Oceanographic tools on board include bathymetric acoustic sounders, ocean current profilers, salinometers, and expendable bathy-thermographs (XBTs).

The ship also commonly hosts several investigator-provided instruments for individual cruises. Examples from NOAA/ETL have included a millimeter-wave radar and microwave radiometer system for cloud research, and fast-response flux sensors for studying air/sea interactions near the water’s surface. The new radar provides the wide-area precipitation context for interpreting data from the other shipboard instruments, and they, in turn, enhance the usefulness of the radar’s observations for precipitation research beyond the confines of land.

Table 2. *RHB* cruises using C-band radar.

Project	Year	Ocean	Primary Sponsors
PACS/TEPPS	1997	E. Pacific	NOAA
INDOEX	1999	Indian	NOAA/NSF
JASMINE	1999	Indian	NOAA/NSF
Nauru99	1999	W. Pacific	NOAA/DOE
KWAJEX	1999	W. Pacific	NOAA/NASA
PACS	2000	E. Pacific	NOAA
EPIC/PACS	2001	E. Pacific	NOAA/NSF

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