Millimeter-Wave Cloud Radar Upgrades: Review, Status, and Plans

K.B. Widener
Pacific Northwest National Laboratory
Richland, Washington

K.P. Moran
National Oceanic and Atmospheric Administration-
Earth System Research Laboratory-Physical Sciences Division
Boulder, Colorado

Introduction

The Atmospheric Radiation Measurement (ARM) Program currently operates five millimeter-wave cloud radars (MMCRs) at the ARM Climate Research Facility (ACRF) Southern Great Plains (SGP) site, North Slope of Alaska (NSA) locale's Barrow site, and Tropical Western Pacific (TWP) locale's Manus, Nauru, and Darwin sites. Currently, three different signal processors are deployed, and we are in process of upgrading the remaining two radars to provide higher reliability and efficiency along with the capability of recording Doppler spectra.

Figure 1. Southern Great Plains MMCR

Figure 2. Barrow MMCR

Figure 3. Darwin MMCR

MMCR History and Status

Table 1 summarizes MMCR configuration at the five installations. All MMCRs began with digital signal processors (DSPs) and software common to radar wind profilers – Profiler Online Program (POP). These processors provided reliable moments data (reflectivity, Doppler velocity, and spectral width) but at a low collection efficiency and without the ability to collect Doppler spectra at a sufficient resolution. An upgrade effort was undertaken to alleviate these problems.

Radian (now Vaisala) with National Oceanic and Atmospheric Administration-Earth System Research Laboratory (NOAA-ETL) oversight developed a new DSP board based on the Texas Instruments C40 DSP along with their new LAP/XM software. Originally, this was planned to be a supported Radian product but this never came to pass and the C40 became obsolete. The National Center for Atmospheric Research licensed its PC-Integrated Radar AcQuisition System (PIRAQ-III) technology to Vaisala. This was chosen for the TWP MMCRs.

Table 1. MMCR Summary Modes: 1 – boundary layer, 2 – cirrus, 3 – general, 4 – precip, 5 – co-pol, 6 – cross-pol

Site	Installed	Processor	Upgrade	Modes	Polarization	Spectra GB/day
SGP	11/8/96	C40	9/03	1-6	Yes	6.4
Barrow	3/25/98	C40	4/04	1-4	2006	8.7
Manus	6/14/99	POP	4/06	1-4	No	-
Nauru	10/22/98	POP	6/06	1-4	No	-
Darwin	3/6/02	PIRAQ-III	11/05	1-4	No	14.8

The first PIRAQ-III upgrade was completed at Darwin in November 2005. The upgrades for Manus and Nauru are scheduled for April and June 2006, respectively.

2005 Data Availability Summary

Figure 3 shows a histogram of the availability of data from the three TWP sites (Darwin, Manus, and Nauru). The Nauru and Darwin MMCRs generally have very good records of uptime. However, we are experiencing an intermittent thermal problem on the Manus MMCR that causes a loss of sensitivity by approximately 25 dB. The figure also points out the difficulties of maintaining instruments in remote locations. When there is a failure, i.e. the Traveling Wave Tube Amplifier in August, the time to troubleshoot, get the parts to the site, and a technician to install them can be quite lengthy. To help remedy this situation, we have procured two major components, a Traveling Wave Tube Amplifier and coherent up/down converter, and have located them in Darwin to support the TWP sites.

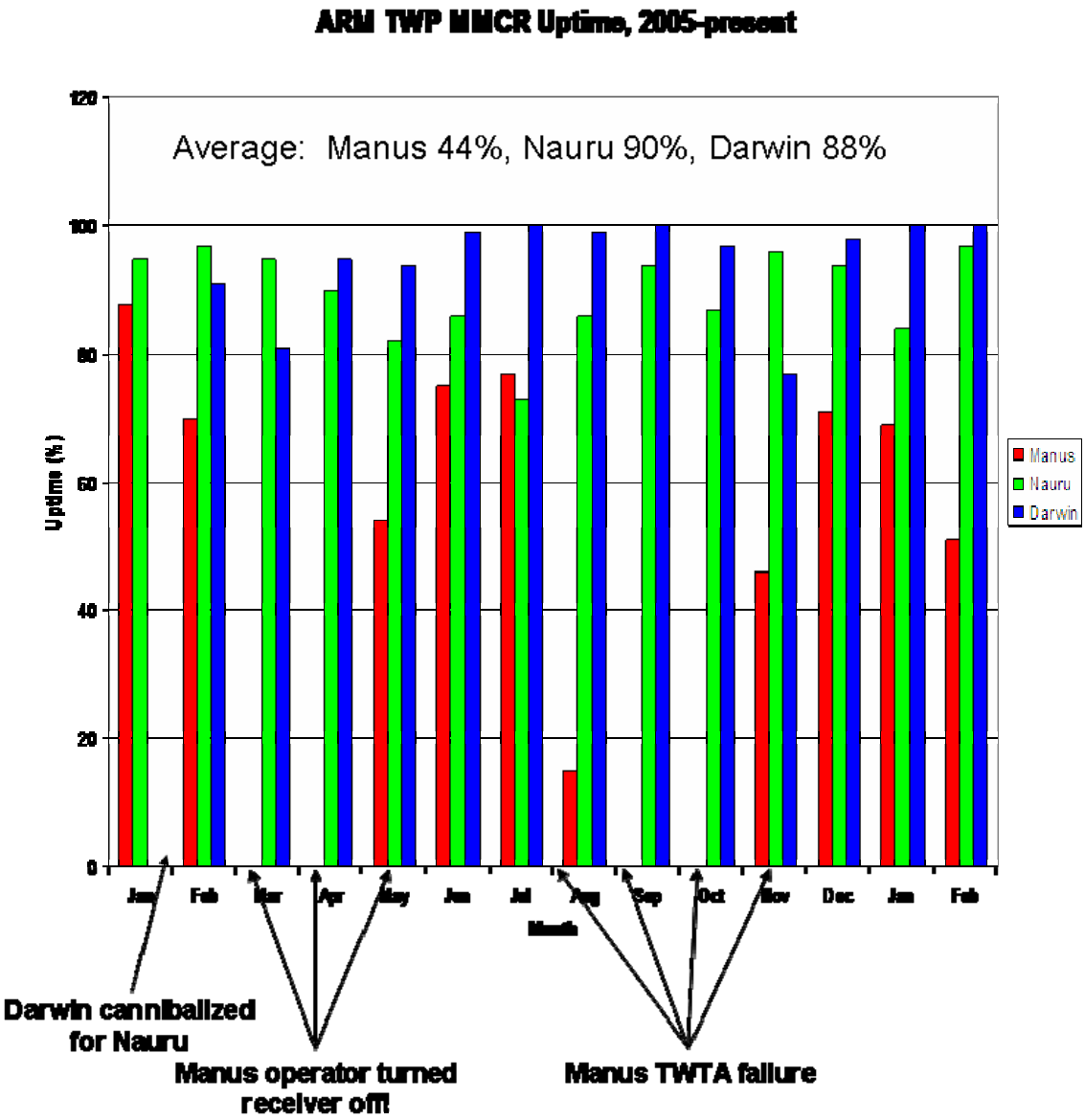

Figure 4. TWP 2005/2006 Uptime

Figure 4 shows exceptional uptime at SGP and Barrow. Some failures occurred early in the year, but the time to repair is relatively quick.

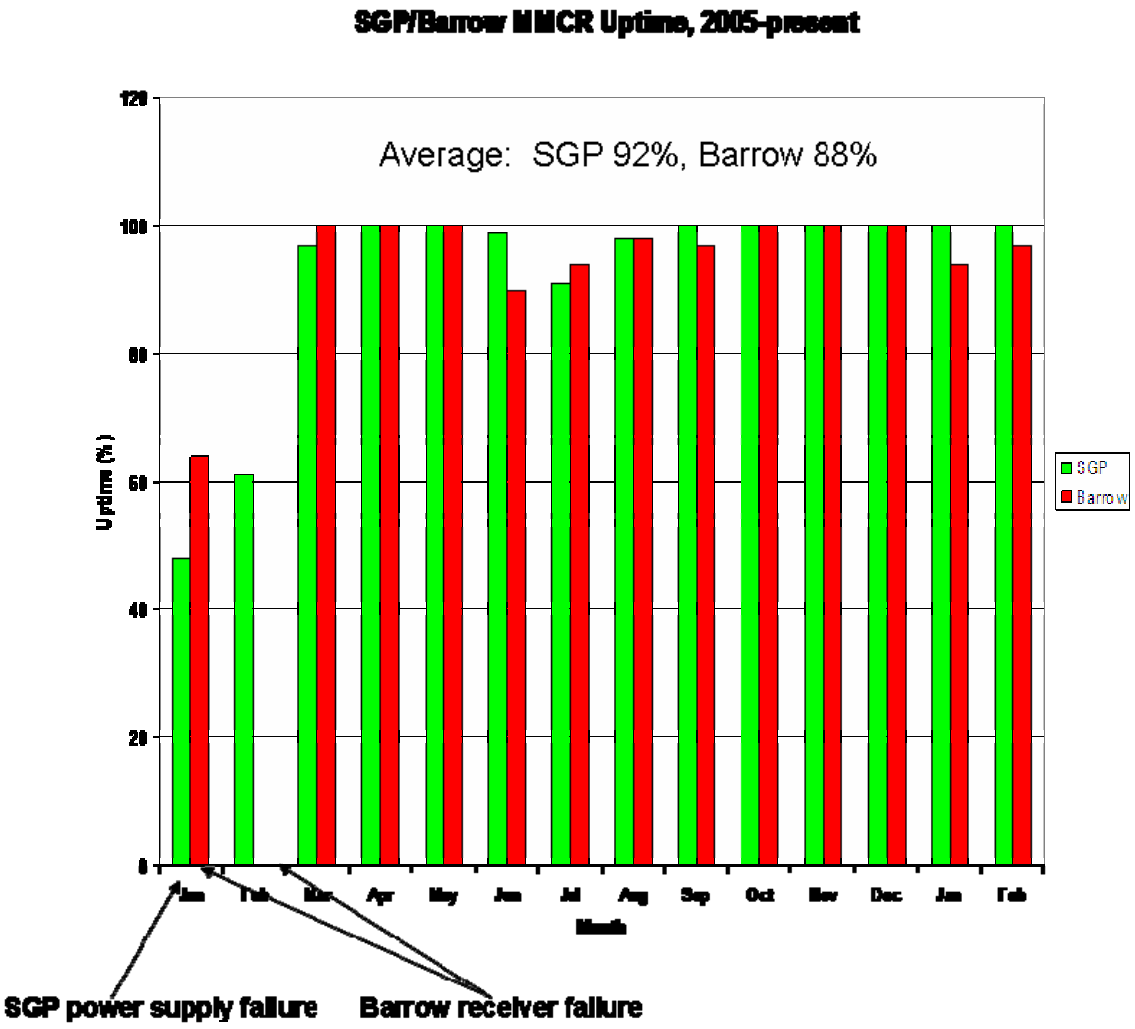

Figure 5. SGP/Barrow 2005/2006 Uptime

Current Challenges

Spectra Images are seen in the spectra data when there are relatively large returns. This is happening in both the C40 and PIRAQ-III processors. We have just learned that the problem may be due to internal circuit timing, and a solution may not be readily available.

SGP Antenna Polarization Isolation is only 18-20 dB where it should be a minimum of 30 dB. This has an impact on researchers wishing to use circular depolarization ratio. Planned antenna refurbishment will correct this.

Manus Receiver Sensitivity intermittently but routinely shifts making measurements useless during this time. The problem appears to be thermally generated. We hope that the PIRAQ-III upgrade will conquer this problem once and for all.

Spectra data file size is very large and we are unable to transmit them electronically from the sites to the ACRF Archive. We are currently shipping disks from the sites to the Archive. Investigations are underway to see if the spectra data can be compressed to allow for Internet delivery.

Future Plans

- Web-based real-time plots developed for the Tropical Warm Pool-International Cloud Experiment will be installed at all upgraded MMCRs.
- Calibration comparison with the W-band ARM cloud radar (WACR) at the SGP site tying it to the WACR's corner reflector.
- Manus PIRAQ-III Upgrade will occur in April 2006.
- Nauru PIRAQ-III Upgrade is planned for June 2006.
- Barrow polarization capability is planned for September 2006.
- Antenna refurbishment will begin in Fiscal Year 2007. This will result in replacing an antenna with a spare and having it refurbished and recalibrated on an antenna test range.
- Advanced Radar Processor investigations and specifications are beginning.

MMCR Primer

The MMCR transmits narrow pulses of radio frequency energy which reflect off vertically distributed targets such as clouds as well as point targets such as birds, insects, etc. These "echoes" are digitized, resolved in time, and several Fast Fourier Transforms are averaged to estimate the velocity spectral signal for each range gate. The first three calibrated moments of the spectra (reflectivity, radial velocity, and spectra width) are stored. Figure 6 shows a time height plot of reflectivity data.

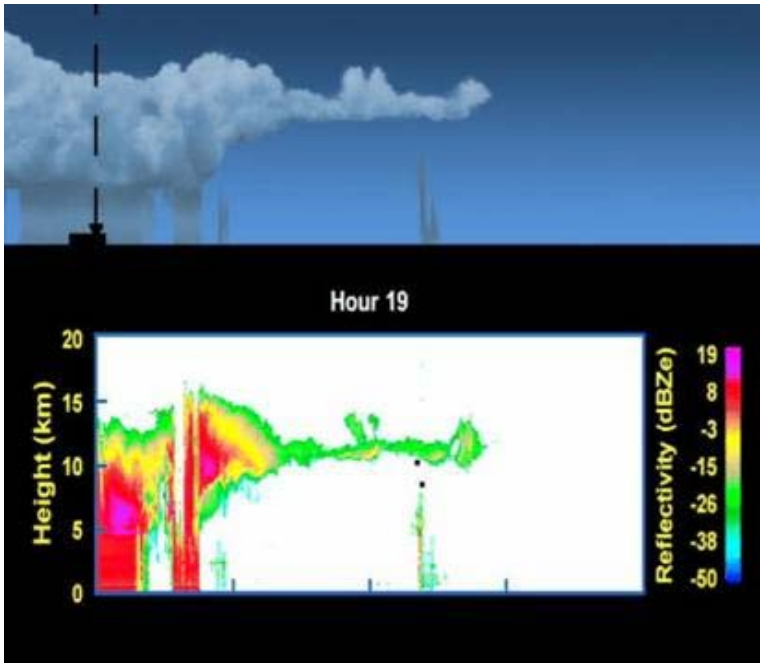

Figure 6. Time height plot of reflectivity.

Figure 7 shows a simulation of a spectra plot for ten range gates. You will notice that there are returns on the bottom three range gates at approximately + 5 m/s. By convention, positive velocities are towards the radar, negative velocities are away from the radar.

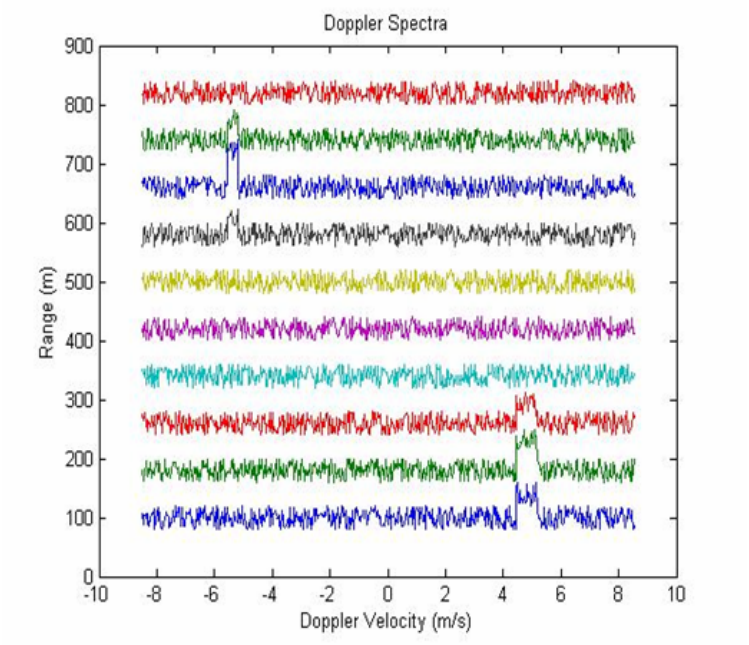

Figure 7. Simulation of a spectral plot for ten range gates.

The MMCR operates in different modes to focus on different types of clouds:

- Boundary Layer Mode – looks at the first 10 km at increased range resolution of 45 m.
- Cirrus Mode – is the most sensitive (-55 dBz @ 5km) mode and uses pulse compression.
- General Mode – 90-m range gates with coherent averaging.
- Precip Mode – general mode with the addition of an attenuator to prevent saturation during precipitation.
- Co-Pol Mode – 45-m range gates, no averaging
- Cross-Pol Mode – 45-m range gates, no averaging.

The data from these modes are merged with data from ceilometers, microwave radiometers, and micropulse lidars in a value-added product called Active Remote Sensing of Clouds. More information on Active Remote Sensing of Clouds can be found at http://science.arm.gov/vaps/arscl.stm

Acknowledgments

We would like to thank and acknowledge the Operations staff at the SGP, NSA, and TWP sites. Their help and vigilance is essential in keeping these radars running.

Thanks also to the ARM Data Quality Office for providing quicklook plots of the data. These are invaluable tools.

We appreciate the continued support of staff at NOAA-ESRL-PSD.