# Launch of a Raincloud Scanning Radar Satellite

## *—The Global Precipitation Measurement (GPM) mission gets under way—*

**Hiroshi Hanado**
Research Manager
Applied Electromagnetic Research Institute
Radiowave Remote Sensing Laboratory
National Institute of Information and Communications Technology

**Katsuhiro Nakagawa**
Senior Researcher
Applied Electromagnetic Research Institute
Radiowave Remote Sensing Laboratory
National Institute of Information and Communications Technology

### 1. Introduction

Although seas and oceans cover about 70% of the earth's surface, the water that supports human life does not come from the sea but from the air in the form of precipitation (like rain and snow). Too much precipitation causes cloudbursts and flooding, while too little precipitation causes droughts. In both cases, the consequences can be disastrous. Thus, although precipitation provides us with life-giving water, it can also be a life-threatening hazard. Since precipitation has such a major influence on our lives, the Global Precipitation Measurement (GPM) mission aims to use satellites to make measurements of precipitation on a global scale.

### 2. Combining the precipitation radar and microwave radiometer

GPM works by combining observation data from a core observatory satellite equipped with precipitation radar and microwave imaging instruments and from a constellation of subsidiary satellites equipped with a microwave radiometer, resulting in frequent and accurate measurements of rainfall distributions worldwide. A precipitation radar is able to analyze the distribution of precipitation in the vertical as well as horizontal directions, which means it can produce detailed and highly accurate three-dimensional measurements. Microwave imaging is a two-dimensional imaging method that works by measuring the faint microwaves radiated from the earth's surface and atmosphere, but allows measurements of water vapor, clouds, precipitation and seawater surface temperatures to be made more frequently because it can cover a wider area with each measurement. The GPM core observatory satellite was developed jointly by Japan and the United States, and was launched by H-IIA rocket flight No. 23 on 28th February 2014. The GPM core observatory satellite is equipped with a dual-frequency precipitation radar (DPR) developed jointly by the Japan Aerospace Exploration Agency (JAXA) and National Institute of Information and Communications Technology (NICT), and a GPM microwave imager (GMI) developed by NASA. The primary role of the core observatory satellite is to measure the precipitation distributions simultaneously with two sensors (radar and microwave radiometer), allowing us to make more accurate measurements by improving the precipitation strength estimation algorithm of the microwave radiometers carried by the subsidiary satellites. The orbit of the GPM core observatory satellite is inclined at an angle of 65°, allowing it to make observations from the tropics to high latitudes. Since it is not synchronized with the sun, it can also measure daily changes in precipitation patterns. The satellite orbits the earth at an average altitude of 407 km and travels at approximately 7 km/sec, or about 90 minutes per orbit. It makes 15 or 16 orbits each day, and measures the precipitation distributions along each orbit.

### 3. Dual-frequency precipitation radar (GPM/DPR)

The dual-frequency precipitation radar (GPM/DPR) mounted on the GPM core observatory satellite is the successor of the world's first satellite-mounted precipitation radar (TRMM/PR) on board the Tropical Rainfall Measuring Mission (TRMM) satellite launched in 1997. The TRMM/DPR is still in orbit, where it is still making homogenous precision observations of rainfall distributions in the tropics without distinguishing between land and oceans, and measuring three-dimensional rainfall distributions inside typhoons during their early stages of development over the ocean,

**Figure 1: Concept of radar precipitation measurements**

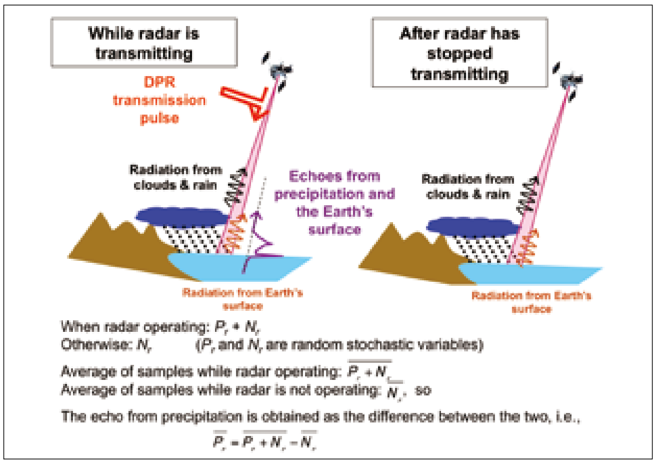
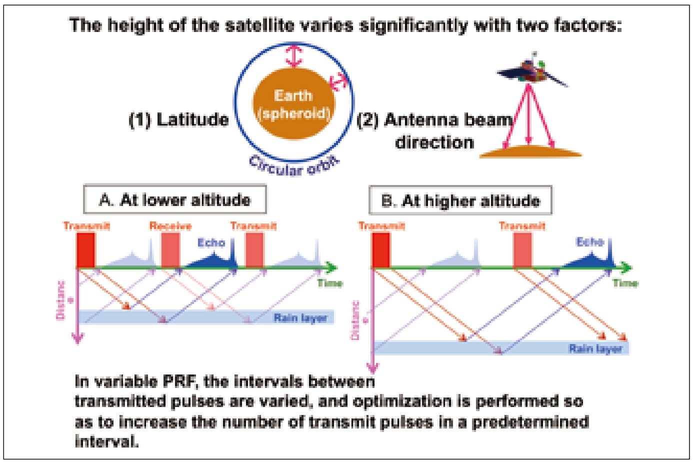
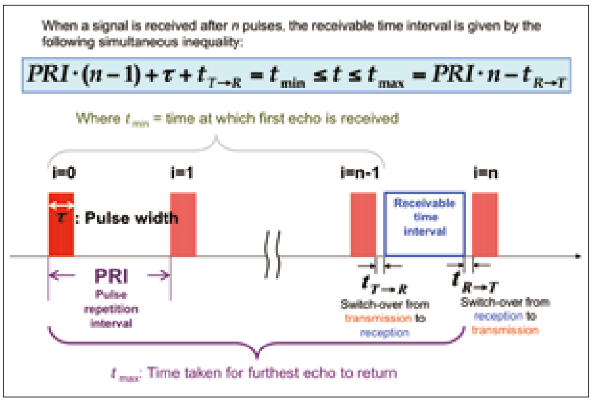


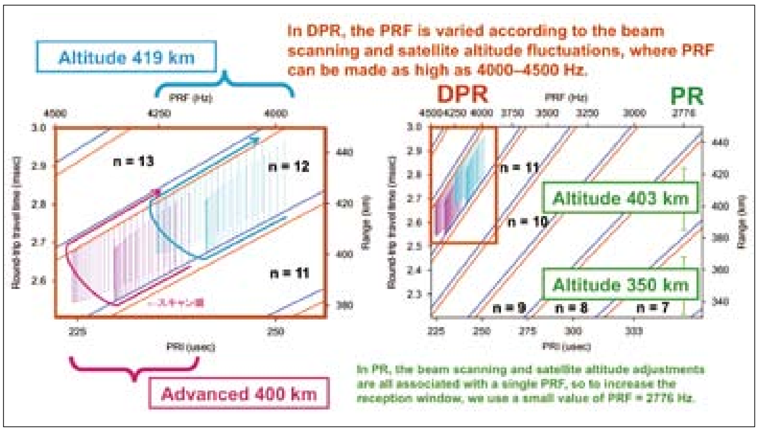

**Figure 2: Schematic illustration of variable PRF (VPRF)**



■ Figure 3: Conditional formula for determining the pulse repetition frequency (PRF)




■ Figure 4: Trying out VPRF to improve PRF




where they cannot be observed by land-based radar. As a result, it has provided a wealth of new knowledge to help explain climate mechanisms on a global basis. One role of the dual-frequency precipitation radar is to expand the success of TRMM/PR from the tropics into middle and high latitudes. For this reason, the GPM/DPR consists of two radars operating at different frequencies — a Ku-band radar (KuPR, 13.6 GHz) and a Ka-band radar (KaPR, 35.55 GHz). By using two frequencies, we can obtain detailed measurements of precipitation at a variety of high latitudes by exploiting frequency-based differences in the scattering and attenuation of electromagnetic waves by precipitation in order to estimate the precipitation intensity with greater accuracy and figure out the phase of the precipitation (i.e., to distinguish between liquid phases like rain and solid phases like snow). Table 1 shows the performance of the GPM/DPR and TRMM/PR radars. The KuPR radar is an improved version of the TRMM/PR with a higher transmitter output power and better sensitivity. The KaPR radar is a new addition that uses the shorter Ka band wavelengths to achieve higher sensitivity. It also has a dual observation mode where observations of the same volume are made simultaneously with the KuPR radar and a dual-frequency method is used to compensate for precipitation attenuation so that the precipitation intensity can be estimated more accurately.

■ Table 1: Main specifications of the GPM/DPR dual-frequency radar and TRMM on-board precipitation radar (TRMM/DPR) on the GPM core observatory satellite

| | GPM/DPR | | TRMM/PR |
|---|---|---|---|
| | KaPR | KuPR | |
| System | Active phased array (128 elements) | | |
| Frequency | 35.55 GHz | 13.6 GHz | 13.8 GHz |
| Scanning width | 125 km | 245 km | 215 km |
| Horizontal resolution | 5 km | | 4.3 km |
| Distance resolution | 500 m | 250 m | 250 m |
| Observation altitude range | From ground level to 19 km | | From ground level to 15 km |
| Minimum observable precipitation strength | 0.2 mm/h | 0.5 mm/h | 0.7 mm/h |
| Dimensions (m) | 1.4 ×1.2×0.8 | 2.5×2.4×0.6 | 2.2×2.2×0.6 |
| Mass | 324.0 kg | 429.9 kg | 464.87 kg |
| Power consumption | 314.8 W | 423.1 W | 217.1 W |

## 4. Improving the sensitivity of GPM/DPR (using variable PRF)

In addition to the scattered waves from precipitation, the signals received by the radars also contain additional noise — some from external sources and some generated inside the receiver equipment. To quantitatively measure the scattered waves from precipitation, we measure the precipitation echo (including noise signals) while the radar is transmitting, then measure the noise signal after the radar has stopped transmitting. The difference between the two is used to measure the intensity of the waves scattered from the precipitation (Figure 1). The waves that are scattered back to the radar from precipitation are the sum of scattered waves from many precipitation particles, so their intensity will vary with an exponential distribution in the same way as noise signals. A meaningful measurement value can be obtained by performing measurements multiple times and averaging the results together. The GPM core observatory satellite is in low earth orbit traveling at a speed of approximately 7 km/sec. Since the GPM/DPR radar has a horizontal resolution of 5 km and performs observations by scanning continuously without interruption, it is necessary to align the measurement direction 49 times in 0.7 seconds while performing a single scan. The GPM core observatory satellite has a large orbital inclination angle of 65° in order to perform observations at high latitudes, and due to the ellipsoidal shape of the earth, its distance from the ground varies more than the TRMM satellite. And so, whereas the TRMM/PR satellite used a fixed pulse repetition frequency (PRF), we used a variable PRF (VPRF) to enable efficient observations. A schematic illustration of VPRF is shown in Figure 2, and Figure 3 shows the formulation of this technique. Figure 4 shows the improvement in PRF compared with TRMM/PR.

## 5. Conclusion

GPM/DPR has passed its initial functional validation, and has now begun routine operations. At the NICT, in cooperation with JAXA, we are performing external calibration tests to check the radar performance and monitor any changes over time, and we are performing ground-based validation of the measurement data from the dual-frequency precipitation radar and the algorithm for extracting this data. We are planning to perform direct validation of the measurement data by conducting synchronized observations with the C-band precipitation radar (nicknamed COBRA) installed at the NICT's Okinawa Electromagnetic Technology Center and the PANDA (Phased Array Weather Radar and Doppler Lidar Network Fusion Data System) system that combines an X-band phased array weather radar and Doppler radar. We are also planning to verify our algorithms by performing balloon observations with the aim of making detailed measurements of the size of precipitation particles inside the melting layer of the sky where snow or ice melt to form rain.