MEASUREMENT OF GLOBAL PRECIPITATION

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***Abstract*- The Global Precipitation Measurement (GPM) Program is an international cooperative effort whose objectives are to (a) obtain increased understanding of clouds and rainfall processes, and (b) make frequent rainfall measurements on a global basis. The National Aeronautics and Space Administration and the Japanese Aviation Exploration Agency have entered into a cooperative agreement for the formulation and development of GPM. This agreement is a continuation of the partnership that developed the highly successful Tropical Rainfall Measuring Mission (TRMM). NASA has taken lead responsibility for the planning and formulation of GPM. Key elements of the Program are discussed in this paper.**

I. Introduction

The measurement of precipitation frequently and on a global basis has many applications. In the scientific community it provides the climate modelers with information on latent heat transfers, and hydrologists with rainfall measurements over large water collection basins; for the weather community it provides weather modelers and weather forecasters information concerning on-going rainfall events. Knowledge of cloud dynamics facilitates advancements in the understanding of rainfall processes and aids in the further refinement of models. The Tropical Rainfall Measuring Mission (TRMM), launched in November 1997, demonstrated both the capability of making rainfall measurements from space, and the value of those measurements to the scientific and meteorological communities. The National Aeronautics and Space Administration (NASA) of the United States and the Japanese Aerospace Exploration Agency (JAXA) have agreed to develop a successor mission to TRMM, called Global Precipitation Measurement (GPM), that will expand the spatial extent over which measurements are made, and provide improved measurement capabilities. This paper will discusses the major elements of the GPM Program.

II. Global Precipitation Measurement Program

The Tropical Rainfall Measuring Mission is a joint mission between the United States and Japan that was launched in November 1997 from Tanegashima, Japan. It was initially placed into a 35° inclination, 350 kilometer (km), low-earth orbit. In order to extend operations following the conclusion of its three year design life, the spacecraft was boosted to 400 km, where it continues to provide exceptionally valuable data. The instruments onboard the TRMM spacecraft include the Precipitation Radar (PR), the TRMM Microwave Imager (TMI), the Lightening Imaging Sensor (LIS), the Visible Infrared Scanner (VIRS), and the Clouds and the Earth's Radiant Energy System (CERES). The PR and the TMI are the primary instruments used for rainfall measurement. The PR is a single-frequency, phased array, nadir-pointing radar, operating at 13.8 Gigahertz (GHz) that takes range-gated measurements in 250 meter layers, has measurement cells 4.5 km in diameter, and measurement swaths 215 km wide. The TMI is a passive, conical-scan, microwave radiometer that takes measurements at 10.65, 18.7, 23.8, 36.5 and 85.5 GHz. Noteworthy characteristics of the TMI include both its broad measurement swath of 760 km, and the constant-size measurement footprint at each frequency regardless of scan position. TRMM rainfall retrieval algorithms show good (and improving) correlation between measurements obtained independently by the PR and the TMI. The Global Precipitation Measurement Program will build upon the strengths of these two instruments by providing improvements to the measurement capabilities of each. This capability will facilitate continued research and advancements in climate and weather modeling, weather forecasting, and the understanding of precipitation, cloud dynamics and the associated processes.

III. Global Precipitation Measurement Program

GPM has been formulated to satisfy two primary goals: (a) make frequent, accurate, rainfall measurements on a global basis, and (b) develop an increased understanding of cloud dynamics and rainfall processes. Although NASA currently classifies GPM as a Project in "Formulation", it is at a mature level of formulation, and authorization is anticipated shortly to proceed with "Development". (At the time of preparation of the is article, NASA Headquarters has authorized the Project to release the procurement solicitation for the GPM Microwave Imager.) The major elements of the GPM program are:

- Core Spacecraft with the GPM Microwave Imager (GMI) and the Dual-frequency Precipitation Radar (DPR),
- Multiple Constellation spacecraft to provide frequent, global measurements of precipitation,
- Ground Validation (GV) system,
- Precipitation Processing System (PPS) to provide ground data processing.

These areas will be discussed in the following paragraphs.

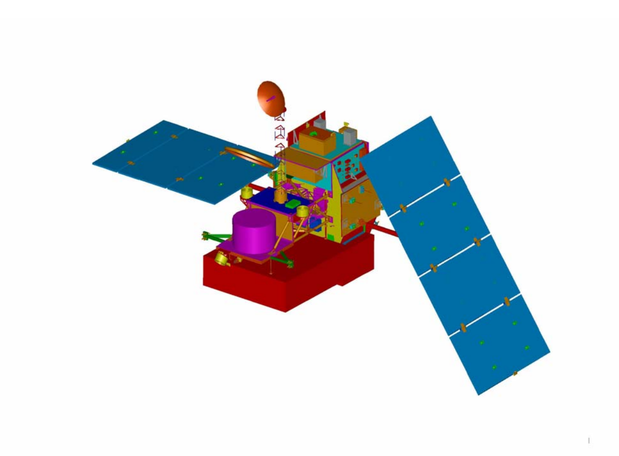

Figure 1. Core Spacecraft

IV. CORE SPACECRAFT

The Core spacecraft will have two instruments, the GPM Microwave Imager, and the Dual-frequency Precipitation Radar (DPR). This compliment of instrument will provide high precision measurements of rainfall, rainfall processes, and cloud dynamics. The Core spacecraft will be launched into a 65° high inclination orbit at a 407-kilometer altitude. This orbit provides coverage over most of the regions of the globe where liquid precipitation occurs. Its slightly higher altitude than where TRMM was initially placed will require less fuel for drag make-up, thus increasing the possibility that the mission may continue to operate beyond its three-year design life. The GMI will have a 1.2 meter diameter main reflector, double the size of the TMI. This will reduce the size of its ground measurement footprint to half the size of TMI's (and it will also be smaller than other radiometers in the GPM Constellation). GMI's improved ground spatial resolution will provide improved beam-filling, and thus contribute to a significant reduction in measurement error.

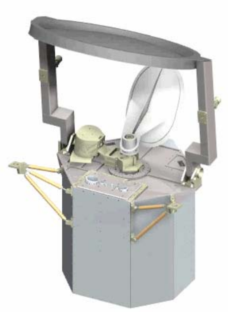

Figure 2. Conical-scan Microwave Radiometer

The co-located DPR makes measurements at two broadly separated frequencies (13.6 and 35.55 GHz). The second radar (called the PR-A) is an addition to the Precipitation Radar flown on TRMM. The two phased array antennas will be sized to provide identical, co-incident measurement footprints. The frequency separation provides differential signal reflectivities from rain and cloud structures which provides inferences on drop size distributions and rain-rates. Co-location of the DPR with the GMI provides the opportunity to use the DPR to make high-precision measurements of the clouds, cloud structure, rainfall and rainfall processes, and to compare those high-precision measurements with the radiometric measurements made by GMI. This comparison will improve understanding of the physical basis for the measurements, and help in the development of more accurate retrieval algorithms. This process can be extended to members of the GPM Constellation as orbital overpasses occur. These overpasses provide an opportunity for comparing various microwave scene measurement obtained by the GMI with measurements of the same scenes from the microwave radiometers on the Constellation spacecraft; over time a data base can be developed comparing the sets of measurements for each constellation radiometer, and an "inter-comparison algorithm" can be developed. It is anticipated that his process will result in substantial improvements in the accuracy of measurements obtained by the individual instruments, and collectively, by the GPM Constellation. For this inter-comparison process the Core spacecraft and the GMI will be considered the "Reference Standard" for the GPM Constellation.

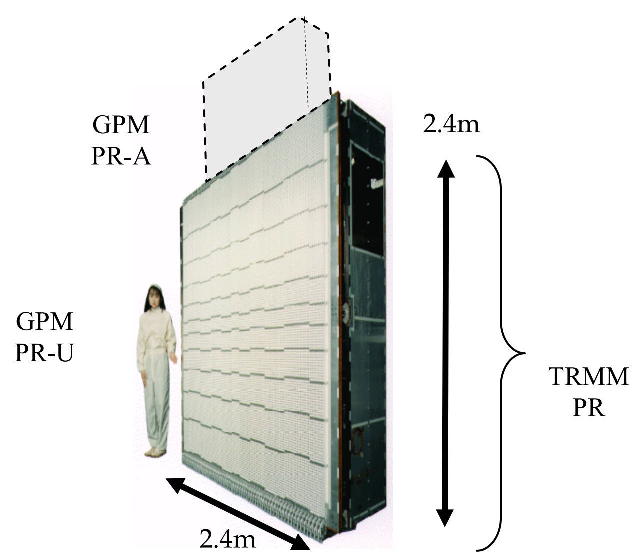

Figure 3. Dual-frequency Precipitation Radar

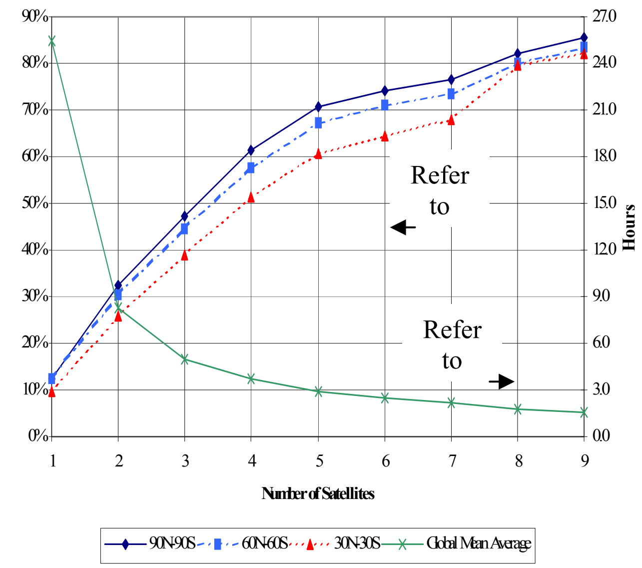

Figure 4. Percent Sampled Bins and Global Mean Revisit Time vs. Number of Satellites

V. Constellation Spacecraft

In order to make frequent measurements of rainfall on a global basis, multi-channel microwave radiometers capable of broad measurement swaths will be utilized. Simulations undertaken by NASA suggest that a three-hour revisit time can be achieved with the use of eight spacecraft equipped with this instrument. A Constellation spacecraft is a broadly encompassing term that include any spacecraft that contributes rainfall measurements to the GPM Program. The GPM Constellation includes the Core spacecraft, other spacecraft specifically developed to be a part of the GPM Constellation (e.g. Euro-GPM) and spacecraft that are developed primarily for other purposes, but have a rainfall measurement capability (e.g. weather satellites). In addition to the Core spacecraft, the following are anticipated to be members of the GPM Constellation:

- Constellation spacecraft provided by NASA,
- EGPM provided by the European Space Agency (ESA), and equipped with a nadir-viewing, pencil-beam cloud radar and a microwave radiometer,
- Megha Tropiques, a joint French and Indian low-inclination, tropical rainfall measurement satellite,
- Three National Polar-orbiting Operational Environmental Satellite System (NPOESS) weather satellites, each equipped with the Conical-scan Microwave Imager-Sounder (CMIS)
- Possible additional international GPM contributions
- Other satellites currently in planning or whose operational life may extend into the GPM-era, including GCOM-B1 (JAXA), DMSP F19/20 (USA), FY-3 (China).

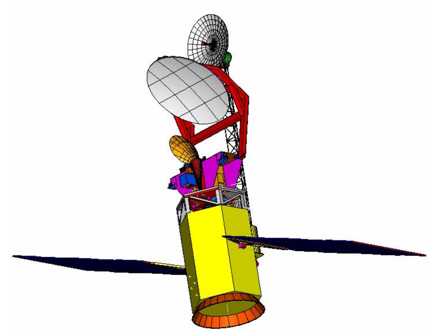

Figure 5. NASA-provided Constellation Spacecraft

VI. Ground Validation System

The GPM Program is in the process of developing an extensive, worldwide Ground Validation (GV) System. This system will help characterize errors, quantify measurement uncertainty, and provide a measurement standard against which to assess performance and aid in the improvement of the science retrieval algorithms. The development of a worldwide GV network is necessary because of the variability in the types of rainfall, and the effects that latitude and regional geographical features have upon the types of rainfall and their frequency. At least 7 heavily instrumented GV "super-sites", and a large number of standard GV sites and regional rain gauge networks are expected to be placed into operation by the United States and its partners. (See "Preparations for Global Precipitation Measurement (GPM) Ground Validation" by S.W. Bidwell, et al, these Proceedings).

VII. Precipitation Processing System (PPS)

The GPM Precipitation Processing System (PPS) will be a science data processing system dedicated to the needs of GPM. The PPS will collect and process rainfall data from the Core spacecraft and the GPM partners. The data from the DPR will initially be processed by JAXA and then provided to the PPS. The PPS will be the central data processing and distribution facility to all members of the GPM Program. The PPS will also receive inputs from the Ground Validation Program, and provide calibration and error corrections to the GPM data products.

VIII. Summary

In summary, the Global Precipitation Measurement Program is a major collaborative between NASA, JAXA, the European Space Agency and other national and international partners. The objectives of this program are to build upon and continue the research initiated by TRMM in the areas of global climate modeling, weather predictions, global and regional weather modeling, and to advance the understanding of hydrology and the water cycle. GPM has several major elements, including a multi-national space segment, a ground validation system and a precipitation processing system.