meeting/workshop summaries

2010 Precipitation Measurement Missions (PMM) Science Team Meeting

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Introduction

The Precipitation Measurement Missions (PMM) Science Team held its annual meeting in Seattle, WA, from November 1–4, 2010. The PMM Program supports scientific research, algorithm development, and ground validation activities for the Tropical Rainfall Measuring Mission (TRMM) and the upcoming Global Precipitation Measurement (GPM) Mission. Additional information about PMM can be found at: *pmm.nasa.gov*.

TRMM, a partnership between NASA and Japan Aerospace Exploration Agency (JAXA), was launched in 1997 and is in its thirteenth year of mission operation. GPM, a constellation satellite mission initiated by NASA and JAXA in partnership with other international space agencies, will extend current precipitation sensing capabilities from space with more accurate and frequent measurements over all latitudes. In July 2013, NASA and JAXA will launch the GPM "Core Observatory" carrying an advanced radar/radiometer instrument package in a non-Sun-synchronous orbit at a 65° inclination to unify and refine precipitation estimates from all constellation sensors. NASA will also provide a second radiometer to fly on a partner-provided Low-Inclination Observatory (LIO) at a 40° inclination to improve GPM constellation sampling for near real-time monitoring of hurricanes and more accurate estimates of rain accumulation. The LIO has a target launch date in late 2014.

The 2010 PMM meeting agenda comprised:

- updates on mission status, programmatic news, and other team business;
- scientific and activity reports from Principal Investigators (PIs) and international partners; and
- coordination of pre-launch algorithm development and ground validation activities for GPM.

The meeting had more than 170 participants from 12 countries that included representatives from NASA, JAXA, National Oceanic and Atmospheric Administration (NOAA), as well as universities, industry, and international partner agencies. The first three days of the meeting focused on TRMM/GPM programmatic summaries, international activities, ground validation plans, and science reports from new science team members in 12 oral sessions. In addition to the oral presentations, two afternoon poster sessions were held to facilitate discussion of research results in an interactive forum. The fourth day was devoted to GPM algorithm team meetings. Working groups focusing on hydrology, algorithm development, latent heating, and land surface characterization met throughout the week. On November 5, the NASA–JAXA Joint PMM Science Team held an invitation-only panel review of GPM sensor algorithms, confirmed the schedule for the next TRMM data reprocessing, and identified a list of candidates for GPM standard products.

Photo of the NASA Precipitation Measurement Missions Science Team Meeting participants

Programmatic Updates

Ramesh Kakar [NASA Headquarters—*GPM Program Scientist*] provided a NASA PMM Program status update, outlining seven NASA Earth science missions currently in formulation and implementation, including GPM. Kakar reported that TRMM instruments and spacecraft remain in excellent condition, and fuel use indicates that TRMM operations will likely overlap with GPM. He also described international participation in Ground Validation (GV) activities and gave an overview of several field experiments that have taken place to support GV.

Arthur Hou [NASA Goddard Space Flight Center (GSFC)—*GPM Project Scientist*] opened the first day's session and honored Joanne Simpson, the "heart and soul of TRMM," who passed away in March 2010. Hou introduced the new 2010-2013 PMM Science Team, which includes 59 domestic PIs and 19 international PIs from 11 countries. He presented an overview of PMM science activities, a series of GPM field campaigns in support of pre-launch algorithm development, and the integrated schedule and milestones for GPM science deliverables.

Scott Braun [GSFC—*TRMM Project Scientist*] provided an overview of TRMM-related activities and presented a status update for TRMM *Version 7 (V7)* algorithms. He discussed key differences between TRMM Precipitation Radar (PR) and TRMM Microwave Imager (TMI) algorithms, outlining several steps forward for resolving these discrepancies, including reprocessing of TRMM data—scheduled to begin in May 2011.

Art Azarbazin [GSFC—*GPM Project Manager*] provided an update on the GPM Core Observatory development, reporting that the High Gain Antenna has been assembled and meets all radio frequency requirements and the Core Observatory Lower Bus Structure is ready for Integration and Test. The integration timeline includes delivery targets of July 2011 for the Dual-frequency Precipitation Radar (DPR) and August 2011 for the GPM Microwave Imager (GMI).

Erich Stocker [GSFC] gave an update on the role of GSFC's Precipitation Processing System (PPS) in TRMM *V7* algorithm development, highlighting several issues that need to be addressed with *V7*. Stocker also reported that the Component Build 2 review is complete and all *V1* GPM algorithms are due to PPS for processing by November 30, 2011.

Thomas Wilheit [Texas A&M University] spoke about *consensus calibration* and how it will improve the performance of the TMI. Wilheit also announced that the Intersatellite Calibration (X-CAL) Working Group has completed a preliminary analysis of the JAXA Advanced Microwave Scanning Radiometer Earth Observing System dataset, and that the group is in the process of organizing a methods comparison for sounders.

Partner Activities

Programmatic status presentations from JAXA included **Riko Oki** [JAXA Earth Observation Research Center], who reported on improvements to the TRMM PR *V7* algorithm and GPM algorithm development, as well as Japanese participation in GV activities. **Toshio Iguchi** [National Institute of Information and Communications Technology] provided the status of DPR development for GPM. The DPR development test is complete and manufacturing of flight hardware is ongoing. The DPR will provide greater precipitation measurement sensitivity, increased sampling intervals, and guaranteed maximum measurement height compared to the TRMM PR.

Ralph Ferraro [NOAA] outlined NOAA's contributions to GPM, including an update on NOAA Polar Operational Environmental Satellites and the Joint Polar Satellite System, that will be included in the GPM constellation. He also presented on NOAA's participation on the PMM Science Team, Hydrometeorology Testbed (HMT) activities, satellite calibration activities, and GOES-R contributions to GPM.

Remy Roca [National Center for Scientific Research (CNRS) of France], **Marielle Gosset** [CNRS], and **Nicholas Viltard** [Pierre Simon Laplace Institute (IPSL) for Research and Environment] gave overviews of the French–Indian Megha-Tropiques (MT) mission, a satellite dedicated to increasing understanding of the water and energy cycle in the tropics, which will operate as a member of the GPM constellation. The team also reported on MT calibration/validation activities. MT is scheduled to launch in 2011.

Chris Kidd [University of Birmingham] and **Paul Joe** [Environment Canada (EC)] presented a proposal to the European Space Agency (ESA) for a Polar Precipitation Measurement (PPM) mission, to address current gaps in observational capabilities over polar regions and answer questions about high latitude precipitation. This information is vital to understanding the global water cycle, and will provide synergies with GPM.

The remaining international reports focused on ground validation, including project descriptions and status reports from **Dmitri Moisseev** [University of Helsinki], **Paul Joe** and **David Hudak** [EC], **Mi-Lim Ou** [Korea Meteorological Administration], **Luca Baldini** [Institute for the Science of the Atmosphere and Climate (ISAC) of Italy], and **Paola Salio** [University of Buenos Aires]. **Luis Machado** [Instituto Nacional de Pesquisas

Espaciais (INPE) of Brazil] described the pre-CHUVA[a] field campaign, which measured soil moisture in Alcântara, Brazil. Machado also outlined seven upcoming CHUVA field campaigns planned for 2011 and 2012 in Brazil. **Alessandro Battaglia** [University of Leicester, U.K.] reported on the Advanced Microwave Radiometer for Rain Identification (ADMIRARI) used in the Pre-CHUVA campaign. This campaign provides the unique opportunity to understand ground-based polarimetric observations of rainfall structure in three dimensions.

Applications Research and Land Surface Characterization

Several presentations from new team PIs described how PMM science applications are being used for flood and drought prediction, hydrological modeling, data assimilation, climate studies, land characterization, and emissivity. **Dennis Lettenmaier** [University of Washington] explained the economic impacts of floods and droughts worldwide, stressing the importance of focusing hydrological research on large river basins in the developing world. **Mekonnen Gebremichael** [University of Connecticut] discussed several satellite rainfall products that are being tested for hydrological modeling, and the need for sustainable satellite rainfall estimation in hydrologic applications.

Pingping Xie [NOAA Climate Prediction Center (CPC)] spoke about bias correction for the CPC MORPHing technique (CMORPH) to develop more accurate passive microwave rainfall propagation vectors. **Wade Crow** [U.S. Department of Agriculture] explained that soil moisture retrievals have a viable role in multi-sensor satellite precipitation products, citing that surface soil moisture products obtained from current (and planned) satellite missions contain useful information for global rainfall accumulation estimation over land. **Milija Zupanski** [Colorado State University (CSU)] spoke about using data assimilation to combine information from satellite observations and cloud-resolving models to improve short-term precipitation forecasts.

The remaining presentations focused on improving land surface characterization, which is essential for advancing over-land rainfall retrieval algorithms and satellite-based precipitation applications. **Joe Turk** [NASA/Jet Propulsion Laboratory] provided an overview of the Land Surface Working Group activities to compare independently-produced emissivity datasets over 12 unique areas. He concluded that surface emissivity is highly variable in space and time and its response to precipitation is an indirect means to compare and validate surface emissivity estimates. **Karen Mohr** [GSFC] presented findings from testbed activity in Tillabery, Niger to characterize changes in vegetation state in semi-arid surfaces as a result of seasonal rainfall, concluding that vegetation dynamics are strongly tied to interannual and intraseasonal rainfall variability. **Sid Boukabara** [NOAA National Environmental Satellite, Data, and Information Service (NESDIS)] reported on the Microwave Integrated Retrieval System (MIRS) and the algorithm's contribution to surface emissivity characterization for the GMI. **Fuzhong Weng** [NOAA NESDIS] summarized the Microwave Integrated Land Emissivity System (MILES), which compares emissivity and snow depth.

Ground Validation

Walter Petersen [NASA Marshall Space Flight Center] and **Mathew Schwaller** [GSFC] gave an overview of GPM GV activities, from pre-launch algorithm development to post-launch product evaluation. They outlined pre-launch GV activities, including the Brazilian Pre-CHUVA campaign (March 2010), the Light Precipitation Validation Experiment (LPVEx) in Finland (September–October 2010), and upcoming campaigns, including the Mid-Latitude Continental Clouds and Convection Experiment (MC3E) planned for Spring 2011, the GPM Cold-Season Precipitation Experiment (GCPEx) in early 2012, and NOAA's Hydrometeorological Testbed in the southeastern U.S. (HMT-SE) in 2013. Field campaigns will utilize NASA's Dual-Polarimetric Radar (NPOL), a NASA Ka-Ku Dual-Frequency Dual-Polarimetric Doppler Radar (D3R), and GPM Disdrometer and Radar Observations of Precipitation (GPM-DROP) instrumentation, and other aircraft and ground measurements.

Walter Petersen, Tim Schneider [NOAA Earth System Research Laboratory], and **Dmitri Moisseev** detailed the MC3E, HMT-SE, and LPVEx field campaigns, respectively. MC3E seeks to improve rainfall retrievals over mid-latitude land surfaces, while the HMT-SE experiment will focus on warm season precipitation over terrain and the resultant implications for hydrologic applications of satellite-precipitation estimates. The just-completed LPVEx campaign represents collaboration between NASA's CloudSat and GPM missions, the Finnish Meteorological Institute, and the University of Helskinki. LPVEx employed an array of ground-based polarimetric and vertically-pointing radar, disdrometer observations, and *in situ* aircraft data collections motivated by the disparity among satellite products to estimate the frequency and accumulation of light rainfall at higher latitudes characterized by shallow freezing levels.

Initiating a ramp-up in planning for GPM integrated hydrologic validation, a sequence of discussions was held to evaluate plans for potential integrated Hydrology GV activities. **Wade Crow** described the Walnut Gulch and San Pedro watersheds in southeastern Ari-

[a] CHUVA is not an acronym; it is the Brazilian word for rain.

zona as potential locations for a field campaign during the monsoon season. Crow noted that the extensive observational network in this region as well as coordination with Soil Moisture Active-Passive (SMAP) validation activities will provide an excellent opportunity to evaluate and characterize background land-surface emissivity and measure evaporation effects in a semi-arid environment. **Robert Houze** [University of Washington] discussed the possibility of using the Olympic Mountains in Washington as a "natural laboratory" for precipitation studies in orographic settings, while **Witold Krajewski** [University of Iowa] described the heavy rainfall and high flood rate in Iowa as ideal for studying the role of rainfall verses non-rainfall factors in flood genesis. Concurrent to and in association with these discussions, the PMM Hydrology Working Group is refining the set of objectives to be pursued within the aforementioned activities and integrating the objectives toward creating an updated plan for conducting GPM Integrated GV.

Algorithm Activities

Robert Meneghini [GSFC], **Chris Kummerow** [CSU], and **Bill Olson** [University of Maryland, Baltimore County Joint Center for Earth Systems Technology] provided status updates for the radar, radiometer, and combined radar–radiometer algorithms, respectively. These presentations discussed the theoretical frameworks, algorithm research, and validation activities for each algorithm. **Courtney Shumacher** [Texas A&M University] reported on the evolution of the PR algorithm and its dependence on attenuation correction and Z-R[b] choices in relation to ground sites and physical results, especially over land. **Toshihisa Matsui** [GSFC] provided a status update on the Synthetic GPM Simulator while **Simone Tanelli** [JPL] outlined recent upgrades to the Airborne Precipitation Radar-2 dataset and algorithm suite. **Steve Durden** [JPL] explained why the Surface Reference Technique (SRT) is better suited for applications over ocean rather than land and proposed using SRT for surface properties and Path Integrated Attenuation (PIA) characteristics for rain properties to determine the best algorithms for land and ocean. **Darren McKague** [University of Michigan] reported on X-CAL activities at the University of Michigan, where the team is working to develop accurate, stable brightness temperatures that are consistent from sensor to sensor.

An important advancement of GPM will be the ability to measure light rain and falling snow in middle and high latitudes. **Ralf Bennartz** [University of Wisconsin] spoke about assessing ice scattering models against available active and passive satellite observations to create a GPM proxy dataset. **Andrew Heymsfield** [National Center for Atmospheric Research] explained the difficulty in determining radar reflectivity and calculating snowfall rates. **Pavel Groisman** [University Corporation for Atmospheric Research/National Climatic Data Center] described the importance of bias-adjusting precipitation time series in high latitudes to distinguish between true changes in precipitation and indirect impact of global warming on the measured fraction of precipitation. **Gerald Heymsfield** [GSFC] explained the importance of the time evolution of convection and the use of strongly attenuated radar in combination with weakly attenuated radar to better understand convective structure in ice regions.

Algorithm development and instrument validation are essential components of PMM Science Team activities for improving TRMM products and preparing for the launch of the GPM Core Observatory. Progress has been made on the TRMM *V7* algorithms, with ongoing improvements and processing continuing into the spring of 2011. GPM algorithm teams met on November 4 to discuss radar, radiometer, and combined algorithm development for the GPM Core Observatory as well as multi-satellite algorithm strategies. GPM algorithm teams for Level 2 and Level 3 data products will submit to the Precipitation Processing System (PPS) the following items: 1) Algorithm Theoretical Basis Documents by November 30, 2010; 2) Baseline Algorithm Codes by November 2011; and 3) At-Launch Codes by November 2012 to support the launch of the GPM Core Observatory in July 2013.

Summary

The 2010 PMM Science Team Meeting provided a forum to review the current status of TRMM and GPM Mission activities as well as report on a range of scientific advancements, partner activities, and algorithm developments. Specific topics included outlining TRMM's development and testing of TRMM *V7* algorithms for data reprocessing, to begin in May 2011, and several discussions detailing advanced satellite-based applications that will markedly improve precipitation measurements with the launch of the GPM Core Observatory. Ground Validation activities were also discussed in detail, including summaries of three PMM Program field campaigns in 2010—one in Brazil jointly with INPE studying warm rain processes (March), one over the tropical Atlantic and Caribbean studying hurricane Genesis and Rapid Intensification Processes (GRIP) in August–September, and one jointly with CloudSat and FMI focusing on low-altitude melting layers over the Gulf of Finland in September–October. Upcoming field campaigns include the MC3E, jointly with the Department of Energy in central Oklahoma in April-May, 2011 and the NASA-EC GCPEx in Ontario, Canada in early 2012. ■

[b] Z-R is an empirical relationship between radar reflectivity and rainfall rate.