1st NOAA User Workshop on the GPM Mission
Global Precipitation Measurement Mission

Hosted by the National Oceanic and Atmospheric Administration
August 18-19, 2010
College Park, Maryland

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Executive Summary

Precipitation is both vital to, and a significant hazard to, human life. Satellite estimates are critical to precipitation monitoring over much of the Earth. The upcoming Global Precipitation Measurement (GPM) mission, a joint mission between the United States and Japan, directly relates to NOAA mission goals (i.e., climate, weather and warnings, etc.) and presents an opportunity to prepare NOAA for routine ingest and processing of multiple data streams from satellites containing passive microwave sensors and a core satellite with a spaceborne precipitation radar. The GPM Core Satellite is scheduled for launch in July 2013 while another, low inclination satellite, will be launched in November 2014. GPM represents an expansion to and follow-on of the successful Tropical Rainfall Measurement Mission (TRMM) science mission, which has provided operationally useful data far past its anticipated lifetime. As detailed in a recent National Research Council Study, NOAA's advance preparation for GPM (core-satellite launch in July 2013) must begin immediately if NOAA is to leverage the huge investment being provided by NASA and JAXA and avoid a large gap between mission launch and data utilization at NOAA (NRC 2007). We hope that GPM will point the way toward use and maintenance of an operational satellite constellation for global precipitation.

The ***1st NOAA User Workshop on the GPM Mission*** was organized by NOAA's Steering Group on Precipitation Measurement from Space to update interested NOAA stakeholders about GPM; identify their needs for such information and their current observational gaps; determine ways to accelerate GPM data use at NOAA; and identify other applications of the GPM-era microwave radiances. Over 50 attendees were briefed on the current status of the mission by NASA GPM managers and scientists, and learned that GPM is a "constellation" mission, consisting of a "core" satellite that will anchor a fleet of low-inclination orbiting satellites from domestic and international partners, achieving 3-hourly or less global precipitation measurements. They also learned of accomplishments to date in preparing NASA's Precipitation Processing System (PPS) for GPM Core satellite launch in July 2013. The PPS will ingest GPM core and constellation data in near real-time and generate a host of orbital and gridded products. NASA and NOAA are in the process of formalizing data arrangements for GPM through an interagency agreement. ***Details can be found in Section 3 of this report.***

We also heard from various parts of NOAA, including NESDIS, NWS and OAR, about their current uses and future needs for precipitation and related information. These include precipitation rates, type and intensity; microwave radiances; vertical distribution of liquid and ice; total precipitable water; ocean surface wind vectors. Collectively, the group voiced concern over the current state of the passive microwave satellites, with several missions such as TRMM, the EOS Advanced Microwave Scanning Radiometer (AMSR-E), Polar Orbiting Environmental Satellites (POES) and the Defense Meteorological Satellite Program (DMSP) containing sensors that are well beyond their life expectancy, and the huge observational gap that will be created if future missions such as GPM are not leveraged by NOAA. Additionally, the precessing orbit of the GPM-core will be crucial for maintaining the calibration of the entire constellation, much like the role TRMM has been performing over the past decade. ***Details of these presentations can be found in Section 4 of this report.***

Three working groups were formed: Observational Requirements and Gaps; Accelerating GPM Use at NOAA; and GPM Applications. Each was populated with members from the different NOAA line offices to gather a broad NOAA perspective. The working groups were tasked to assess the current state and needs under each topic, and to develop a specific path forward if the identified needs are not presently being addressed at NOAA. There were several common themes identified by the working groups, which can be captured by the following ***five major recommendations from the working groups, all of equal importance (listed below; details are provided in Section 5 of the workshop report).*** Because of the strong interest in GPM at NOAA, a follow-on workshop will likely be planned for late 2011 or early 2012. The format will be more user-focused and opened to a broader audience, with specific topical areas being addressed and specific issues being identified. Finally, ***the next steps and plan forward are presented in Section 6 of the report.***

Five Major Recommendations from the Working Groups

1. **Accelerate the use of GPM data at NOAA through the development of a NOAA GPM Proving Ground and use of existing testbeds.** GPM era precipitation products, including winter season precipitation, are vital to NOAA to fill in observational gaps and in ground-based radar and gauge networks, specifically in Alaska, intermountain, and coastal regions, and over the open ocean. These data are also critical for continuity of operations with existing data being used at NOAA, especially at the Tropical Prediction Center, Climate Prediction Center, and the Joint Center for Satellite Data Assimilation (JSCDA) and NESDIS Satellite Analysis Branch (SAB). To accelerate use of GPM-era data at NOAA, a NOAA GPM Proving Ground and corresponding proxy data should be developed to support existing testbeds (e.g., Hydrometeorology, Joint Hurricane, Climate, etc.) and the JCSDA. A series of format conversion tools should be developed. Training is also vital to maximize the greatest benefits of GPM data at NOAA. ***(see pages 25-29 – Accelerating WG; pages 30-32 – New Applications WG)***

2. **Enhance research and development, and encourage scientific and technological innovation to maximize use of GPM-era data at NOAA.** NOAA is urged to support activities to integrate GPM-era satellite data into "merged" products (e.g., Q2, CMORPH, etc.), to move toward a "One NOAA" suite of precipitation products. Additionally, data assimilation in cloudy and precipitating atmospheres is urgently needed for both passive and active microwave measurements. There are other attributes of the GPM-era sensors (e.g., oxygen and water vapor bands) that are presently being under-utilized by the R&D community. To facilitate such advances, NOAA should continue its partnership

with NASA on the Precipitation Measurements Mission Science Team and other GPM-related activities, and infuse its own resources to develop GPM-related products for its own needs. ***(see pages 19-24 – Observations WG; pages 25-29 – Accelerating WG; pages 30-32 – New Applications WG)***

3. **Develop synergy with other existing and developing programs.** NOAA should encourage synergy between GPM and GOES-R to greatly improve flash flood and hydrological forecasting such as those activities already underway at the NWS. Also, synergy between NOAA's Climate Data Record (CDR) program and GPM is encouraged. Additionally, other linkages to operational satellite missions like the Joint Polar Satellite System (JPSS) and research missions like the Soil Moisture Active-Passive (SMAP) are strongly encouraged. ***(see pages 25-29 – Accelerating WG; pages 30-32 – New Applications WG)***

4. **Provide GPM-era data operationally at NOAA with minimal data latency and in a variety of formats.** NOAA should transition NASA's Precipitation Processing System (PPS) to NESDIS operations and develop enhancements (e.g., monitoring tools, data format converters, etc.) to provide 24 hour/day, 7 day/week operational support to NOAA users. The data will need to be freely available, with minimal data latency, and in a wide array of formats to suit NOAA user needs. ***(see pages 19-24 – Observations WG; pages 25-29 – Accelerating WG; pages 30-32 – New Applications WG)***

5. **Develop a dedicated NOAA budget for GPM and for mission continuity.** NOAA needs to ensure a coordinated budget planning and execution across line offices and its Cooperative Institutes to ensure the proper and timely utilization of GPM-era data to support all its mission goals. Linkages to existing NOAA related programs like the U.S. Weather Research Program (USWRP), the National Climate Service (NCS), NOAA CDR, Global Space-based Intercalibration Center (GSICS), Hurricane Forecast Improvement Program (HFIP), Integrated Water Services (IWSS), GOES-R and JPSS are encouraged. NOAA is urged to develop a continuity mission for the GPM Core Satellite to serve as the calibration anchor for the passive microwave constellation, as well to maintain global 3-hourly, or less, passive microwave radiances/precipitation products in the 2020 timeframe. ***(see page 19-24 – Observations WG)***

1. Introduction

NOAA relies on space-borne passive microwave (MW) sensors flown aboard a variety of operational and research missions to support its mission goals. In particular, the microwave radiances and derived products such as precipitation rate, total precipitable water and ocean surface wind speed are critical in a number of applications. Presently, this set of sensors includes NOAA's Advanced Microwave Sounding Unit (AMSU), EUMETSAT's Microwave Humidity Sounder (MHS), DMSP's Special Sensor Microwave Imager/Sounder (SSM/IS), NASA and JAXA's Advanced Microwave Scanning Radiometer (AMSR-E) and TRMM Microwave Imager (TMI), and the Department of Defense's WindSat. It is through the strength of this "virtual constellation" of low earth orbiting (LEO) satellites that the following has been achieved at NOAA over the past decade:

- Advances in numerical weather prediction (NWP) model forecast accuracy through assimilation and forward modeling of the microwave radiances

- Improved prediction of tropical cyclone track and intensity by utilization of the MW radiances for storm center fixing and monitoring of rapid intensification

- Climate quality data sets of hydrological parameters that help monitor seasonal to interannual climate variability

- Improved precipitation monitoring from space in data sparse regions over land and over oceans

- Improved hydrological monitoring and prediction through integration of satellite precipitation estimates with ground based radar and gauges

NOAA must rely on partner agency satellite assets to sustain and enhance its precipitation monitoring capability from space. Without such a partnership, NOAA's ability to improve its use of such data will degrade and compromise our ability to monitor and predict hydrological events such as floods that endanger the public. NASA's Global Precipitation Measurement (GPM) science mission, a concept that utilizes a core satellite that contains advanced instruments – The GPM Microwave Imager (GMI) and the Dual Frequency Precipitation Radar (DPR) – and a constellation of current and planned MW radiometers, will provide global precipitation estimates every 3 hours or less using state-of-the-art algorithms and a flexible ground processing segment that is ripe for transition to NOAA operations. GPM builds from the successful TRMM mission, presently in its 13th year of operation, but will expand its coverage to near global. NOAA has engaged with NASA for several years in preparation for GPM, however, a consolidated and updated set of requirements from NOAA stakeholders has not been assembled since a workshop was held in 2001 (Arkin et al. 2002).

2. Workshop Background and Objectives

The purpose of the ***1st NOAA User Workshop on the GPM Mission***, co-sponsored by NESDIS/STAR, NWS/OHD and OAR, is to determine the NOAA stakeholders, their interests and their use of GPM data, and to develop an updated, unified set of requirements for GPM data and related products at NOAA. This information will provide a much needed update from similar information compiled from the Workshop on NOAA Precipitation Requirements held in November 2002 in Silver Spring, MD (Arkin et al. 2002). This information can be used to develop the proper connectivity across NOAA Line Office plans for GPM data use and the potential transition of the GPM ground processing segment from NASA to NOAA to support 24 hour, 7 day per week operations.

The measurements for the GPM core satellite and constellation members will provide more than just precipitation information for NOAA. Thus, the workshop aimed to explore uses of the passive MW radiances and Precipitation Radar (PR) reflectivities, other potential products like TPW and OSWV, in addition to the level 2 and level 3 products that NASA is planning to produce through its Precipitation Processing System (PPS).

The two-day workshop, hosted by the University of Maryland's Earth System Science and Interdisciplinary Center (ESSIC) in College Park, Maryland, was attended by nearly 50 people (See Appendix A) and was organized as follows (see Appendix B for complete agenda). On the first day, a set of plenary talks were presented which included overarching goals and needs by NOAA Line Office leads and major programs at NOAA. The plenary talks also included a series of briefings from NASA on GPM and its status. Next, short briefings from specific NOAA stakeholders, who were provided a template of information to compile (e.g., products, required temporal and spatial resolution, accuracy, etc.), were presented (some remotely), setting the stage for working group discussions on the second day. A summary of these talks is provided in Section 4 of this report. All of the talks can be found at
http://www.star.nesdis.noaa.gov/star/meeting_GPM2010_agenda.php

Three working groups were convened and chaired as follows:

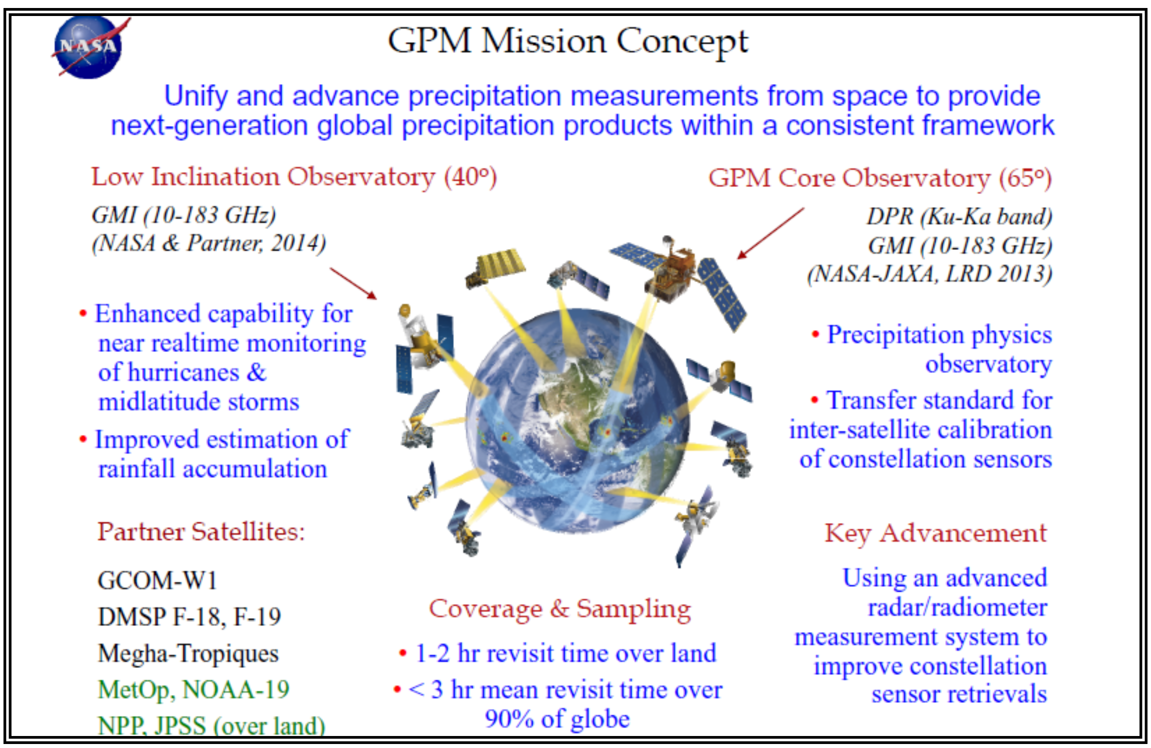
- Observational Requirements and Gaps (Chandra Kondragunta, NESDIS)
- Accelerating GPM Data Use at NOAA (Timothy Schneider, OAR)
- New Applications (Fuzhong Weng, NESDIS)
-

Each working group met for a half a day, with findings presented at a final plenary during the afternoon of the second day. These are summarized in Section 5 of this report and can also be found at the workshop web site.

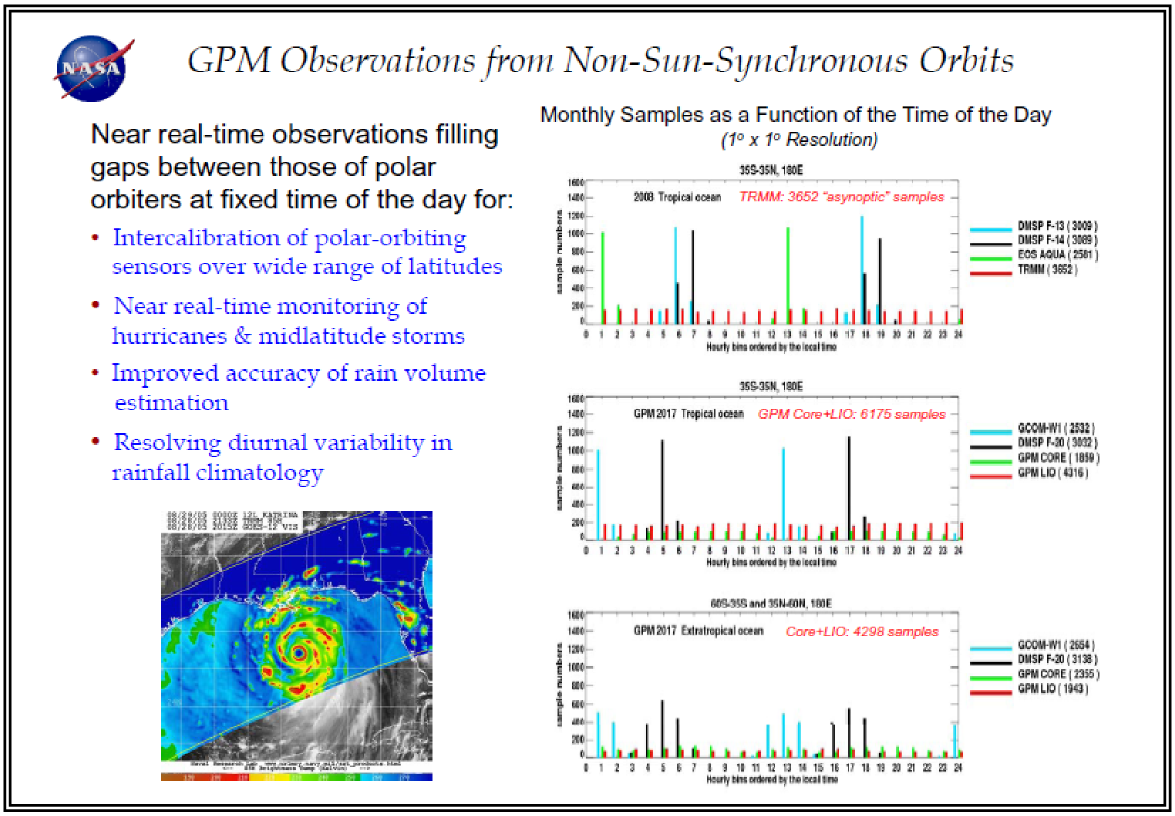
3. Background Information about GPM

Most users of satellite precipitation products and monitoring of tropical systems are familiar with TRMM. GPM will extend TRMM's observations of precipitation to higher latitudes, including cold season precipitation, with more frequent sampling. GPM will provide a 3-hour or less revisit time over 90% of the globe, with 1 to 2 hour revisit time over land, with a data latency of 3 hours or less. This will fill in many observational gaps that presently exist with current satellites.

NASA and the Japanese Aerospace Exploration Agency (JAXA) are working together to build and launch the GPM Core Satellite. The Core is the central precipitation-measuring observatory of GPM and will fly both a Dual-frequency Precipitation Radar (DPR) and a high-resolution, multi-channel passive microwave (PMW) rain radiometer known as the GPM Microwave Imager (GMI). The Core will also serve as the calibration reference system for a constellation of support satellites. As was the case with TRMM, JAXA will provide the precipitation radar and the launch vehicle while NASA will provide the passive microwave radiometer, the satellite superstructure, and the ground control segment. **The GPM core will be launched in July 2013**. It is estimated that the total budget for GPM between NASA and JAXA up until GPM core launch will exceed 1 billion U.S. dollars. The figure below illustrates the GPM concept.



In addition to the core satellite, a constellation, containing up to 10 satellites, will comprise the GPM mission as a whole. NASA will provide a second GMI to fly on a stand-alone satellite and is seeking an international partner to fly it, most likely Brazil (an MOU between NASA and Brazil is in progress). **This satellite will be launched in November 2014 and will likely be in a low inclination orbit somewhat similar to TRMM.** Other vehicles in the constellation are contributed by domestic agency partners such as NOAA (e.g., POES and JPSS) and the Department of Defense (DMSP and DWSS), and GPM international partners (e.g., GCOM/Japan; Megha-Tropiques/France-India; MetOp/Europe). Each of these constellation satellites has its own unique scientific mission but will also contribute precipitation measurements to GPM through its passive microwave sensors. The figure below provides some information on the impact of adding various satellites to the constellation.

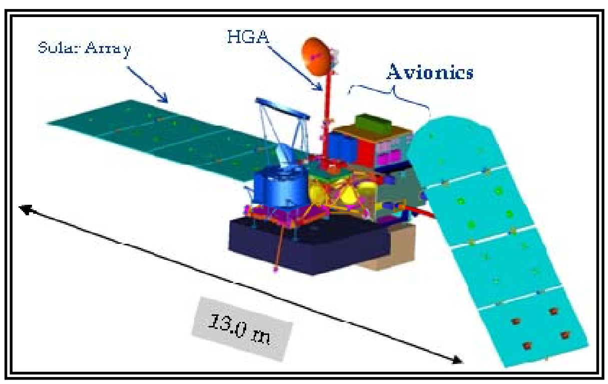


In summary, the GPM concept is a synergistic use of the DPR and GMI on the core satellite to serve as the anchor for the constellation (e.g., algorithm development and validation; radiance calibrator), the latter of which will provide the global set of precipitation retrievals. Key to the success of GPM is the algorithms and ground segment being developed by NASA. Known as the Precipitation Processing System (PPS), it will serve to obtain the level 1 radiances from all of the satellites in the constellation, intercalibrate them to a level 1c format, then generate a series of level 2 (orbital), level 3 (multi-sensor integrated; time-space averaged) and level 4 (integrated with NWP model fields). The PPS is being designed to be flexible enough to handle the various data streams from the constellation. The algorithms that are run by the PPS are developed and provided by NASA's Precipitation Measurement Missions (PMM) science team. The nearly 60 scientists on the team, including six from NOAA, are responsible for algorithm development, data and product calibration/validation, code delivery to PPS, etc. The science team is recompeted every three years through a full, open competitive proposal process and consists of a broad cross section of scientists from government and academia.

4. Summary of Plenary Talks

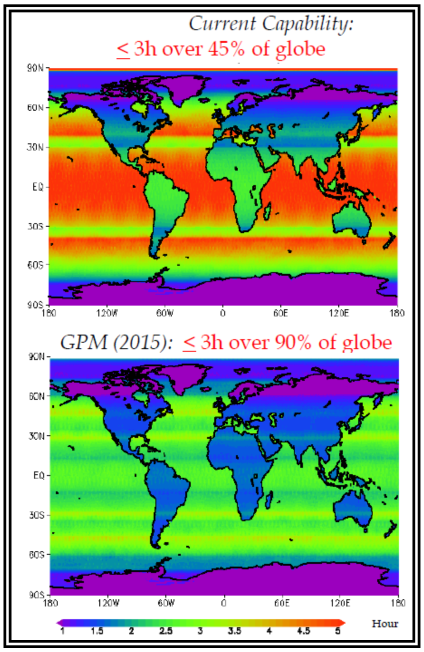
Session 1 – Overview (Session Chair, Ralph Ferraro, NESDIS)

Mary Kicza, Assistant Administrator for Satellites and Information, provided a charge to the workshop participants to lead off the meeting. She discussed the importance of satellites to meet NOAA mission goals, and stressed that NESDIS's top priority is the continuity of its GOES and POES missions, including taking the lead role in the recently reconfigured polar program, JPSS. NESDIS is also actively involved with continuity of research missions and has established budgets for TSIS, COSMIC-2, and OSWV. Beyond these missions, emerging 'research to operations' (or R2O) activities are the next priority, and this includes NASA programs such as GPM and SMAP. She urged the participants to formulate well thought-out recommendations from this workshop that can be carried forward at NOAA.



The next five speakers were from NASA and gave excellent overviews of the various aspects of GPM. First, we heard from Ramesh Kakar, GPM Program Scientist. He reported that GPM follows upon the highly successful TRMM mission, which is approaching 13 years in length. TRMM is likely to extend into the GPM era (depending upon fuel consumption and solar activity). GPM is well funded and on track for a July 2013 launch date of the core satellite, which will have the GMI and DPR. GPM also features an extensive ground validation (GV) program and has a number of national and international partners who will provide passive microwave sensors that will make up the GPM constellation.

Next, Art Azarbarzin, GPM Project Manager, talked in more detail on the GPM spacecraft and payloads. The GPM core satellite will operate in a 407 km orbit with an inclination of 65 degrees. It is designed for a 3-year life but will have enough fuel to extend it to over 5 years. The GMI, being built by Ball Aerospace, contains dual polarization channels at 10.6, 18.7, 23.8 (V only), 36.5, 89, 166 and 183 GHz. The DPR, being built by JAXA, will operate at 13.6 (Ku) and 35.5 (Ka) GHz. A second GMI is being built and will fly on a partner satellite, most likely in a low inclination orbit. It is scheduled for launch in November 2014.



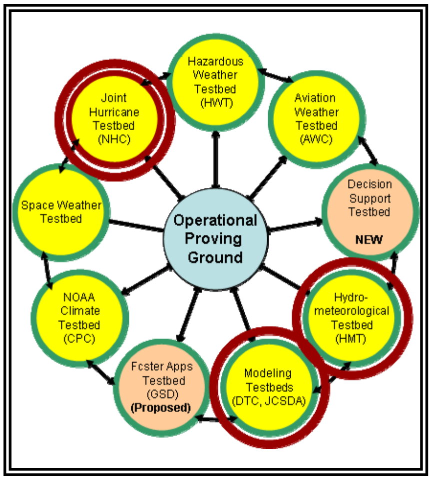
Arthur Hou, GPM Project Scientist, talked about algorithms and partnerships. The GPM products will be derived from an intersatellite calibrated radiance data set, denoted as Level 1C. The Level 1C will ensure unbiased precipitation products across the GPM constellation; this is a unique concept never employed before. GPM will utilize state of the art algorithms being developed by the PMM Science Team, and will be flexible in nature to accommodate the GPM constellation members, including both MW imagers and sounders. GPM will provide global precipitation products every 3 hours or less. He also described the various components of the GPM GV program, including direct statistical validation, physical validation and integrated hydrological validation.

The final NASA speaker, Erich Stocker, manager of the GPM's PPS, reviewed the GPM data products and PPS status. GPM will provide Level 1 through Level 4 products (with level 4 including NWP model data in addition to the satellite products). The PPS conducts annual reviews, with the PPS Build 2 review recently completed in August 2010. The PMM algorithm teams will begin algorithm delivery in November 2010, with final versions due no later than January 2013.

Session 2 – NOAA Perspective – (Session Chair, David Kitzmiller, NWS)

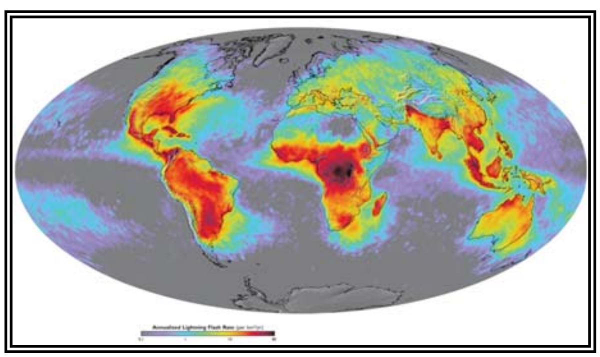
NOAA is a prime user and interpreter of precipitation information on many time and space scales, and already devotes considerable resources to precipitation estimation and prediction. Satellites have been an integral part of this effort for several decades. This session heard from various NOAA programs and perspectives to understand their current uses and needs for precipitation information, and where satellite-based estimates from missions such as GPM can augment their current capabilities and envisioned future requirements.

The first speaker was David Goodrich, OAR/Climate Program Office. He noted that precipitation is the climate component with the single greatest societal impact. Currently-supported programs were briefly described. GCOS target requirements for satellite input were listed as accuracy (0.1 mm/hr, with total precipitation amount at an accuracy of <10% of actual values on monthly time scales); resolution (100 km horizontal resolution and 3-hourly observing cycles; 1 km and 10 min observing cycle for extreme events); stability (0.6%/decade for large-scale trends). GPM is viewed as an important contributor to help meet the GCOS accuracy goals.



The following speaker, Donald Berchoff, the Director of the NWS Office of Science and Technology (OST), indicated that a prime goal is effective utilization of new satellite products covering high latitudes and radar coverage gaps – including Alaska, Canada, eastern Pacific Ocean, Mexico, and the Intermountain region. Both precipitation estimates and satellite radiance observations are needed. Prime concerns at this time are ensuring testing of GPM products in operational environments, and leveraging existing GOES-R and NOAA testbeds (see graphic on left) toward this purpose.

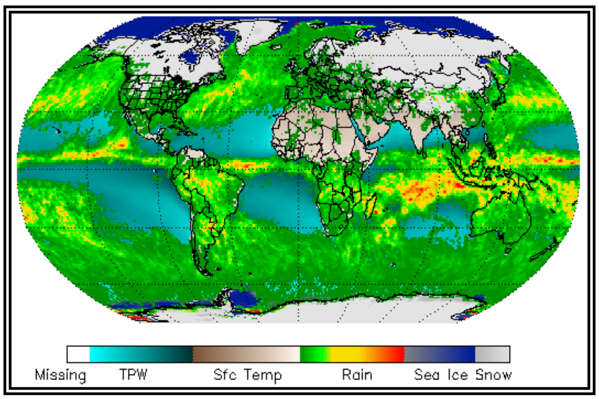
John Pereira, NESDIS/OSD, described the overarching background on the NESDIS transition authorities and goals for GPM and similar science programs. In general, planning for an operational follow-on satellite capability after a successful research mission may require planning 10+ years in advance. Hence, the acquisition process must begin 5-10 years prior to the end of the research satellite mission to ensure observation continuity. QuikSCAT is a good example of the need for this process, as there is a continuity gap between the original mission and now the operational capability. NESDIS and its line offices will coordinate the satellite transition planning and will coordinate with other NOAA organizations, who are the ultimate "customer" for the data. In terms of GPM, a draft Transition Plan for GPM is now in preparation. Coordination is aided by a NASA-NOAA joint working group on research to operations and NOAA's early involvement with GPM joint activities with NASA.



Another speaker from NESDIS, Steve Goodman, GOES-R Program Senior Scientist, described the complementary relationship between GOES and LEO satellites like GPM. GOES-R, with advanced sensors, will be launched in 2015. In particular, the visible and Infrared sensor (ABI; Advanced Baseline Imager) and the lightning mapper (GLM;

Geostationary Lightning Mapper) offer excellent synergies with the GPM constellation and GPM core satellite. The GOES-R program office is already funding some activities along these lines as part of its "Risk Reduction" program and is also interested in contributing to GPM's GV efforts.

Al Powell, Director of NESDIS's Center for Satellite Applications and Research (STAR), spoke about the new vision of NOAA products in the GPM era. In particular, the GMI will serve as an excellent anchor to routinely inter-calibrate microwave satellite instruments. Additionally, Powell pointed out the importance of accurate soil moisture information to hydrological and NWP forecasts and the need for the GPM constellation to aid in the monitoring of tropical cyclones.

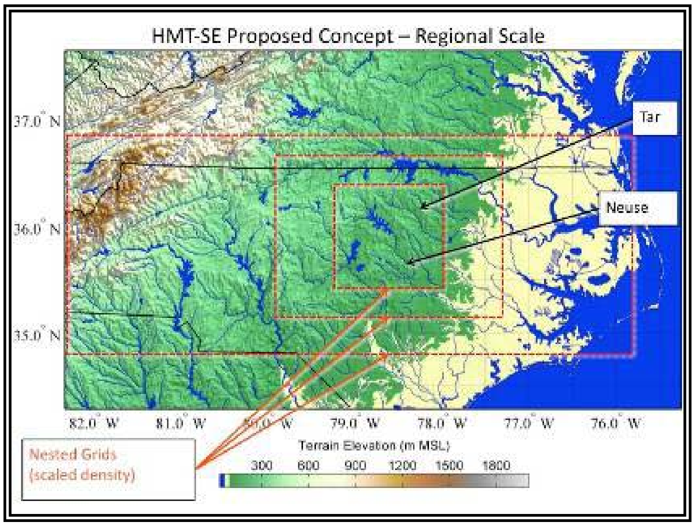


Jim Silva, NDE Project Manager from NESDIS, explained how the NPOESS Data Exploitation (NDE) system would provide mutual benefits to NOAA and GPM through the availability of a processing system and enhancement of existing algorithm packages that use GPM input. In particular, blended products can be generated using NPP data, specifically, the ATMS sensor, which can retrieve snowfall rates that can be used as part of the GPM constellation. The ATMS will be critical to help GPM meet its goal of global 3-hourly (or less) precipitation data.

The workshop organizers were pleased to have Shanna Pitter, from NOAA's PPI Office, who reviewed important information on the new budgeting/tracking process (Strategy Execution and Evaluation - SEE), which includes simplification of the existing 45-program structure and different reporting requirements. Future activity by the NOAA Steering Group on Precipitation Measurement from Space will be directed toward the new planning and documentation standards.

Fuzhong Weng, Chief of NESDIS/STAR's Sensor Physics Branch, presented information on the Global Space-based Inter-Calibration System (GSICS), an initiative of CGMS and the WMO. It is an effort to produce consistent, well-calibrated data from operational meteorological satellites. The GPM X-cal working group is presently involved with GSICS, and leading the Level 1C development. The GMI instrument will be a critical sensor because of its climate quality on-board calibration and it being flown in low-inclination, precessing orbits, thus offering many opportunities for co-incident match ups with the constellation members.

The next speaker, Brian Nelson from NESDIS/NCDC (speaking on behalf of Jeff Privette, Manager of NESDIS/NCDC's Climate Data Record Program), described the development of a Climate Data Records (CDR) at NOAA under the leadership of NCDC. GPM could contribute as a spatial and temporal gap filler in precipitation records, as well as anchor the stability of the precipitation CDR. NCDC is willing to work with developers of observing systems to insure eventual fulfillment of climate record needs.



The final speaker of the session was Tim Schneider of NOAA/OAR, who is the manager of the Hydrometeorology Testbed (HMT). HMT will offer special observations for ground validation and opportunities to test multi-satellite and multi-system algorithms. Observing campaigns are and will be executed over California, North Carolina, and later, the Pacific Northwest. The HMT program has been actively engaged with the GPM GV program, with the HMT-SE (North Carolina) being a focal point for joint validation activities beginning in 2013. More information about HMT's field measurements can be found at http://hmt.noaa.gov/field_programs/hmt-west/2011/.

Session 3– Interest & Needs from NOAA Stakeholders (Session Chair, Tim Schneider, OAR/ESRL)

A series of short (10-minute) presentations from current and potential users of satellite data provided a survey NOAA's data/information gaps and needs, to collect and document requirements, and set the stage for the breakout sessions on the second day. The stakeholders were invited from a cross-section of NOAA and included representatives from three Line Offices: NESDIS, NWS, and OAR. These talks are summarized in the table on the next page.

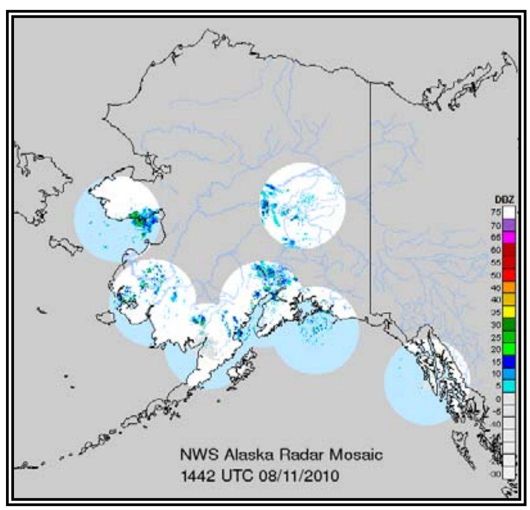
Each stakeholder was asked to compile information on their respective office's gaps and needs for GPM data and information via a template supplied by the workshop organizers (e.g., products, required temporal and spatial resolution, accuracy, etc.). Specifically, the template requested information that addressed three specific issues:

i.) Individual program requirements (Observation Requirement; Threshold/Objective (T/O); Geographic Coverage; Vertical Resolution; Horizontal Resolution; Measurement Accuracy; Measurement Precision; Sampling Interval; Data Latency) ii.) Gaps in current satellite product suite

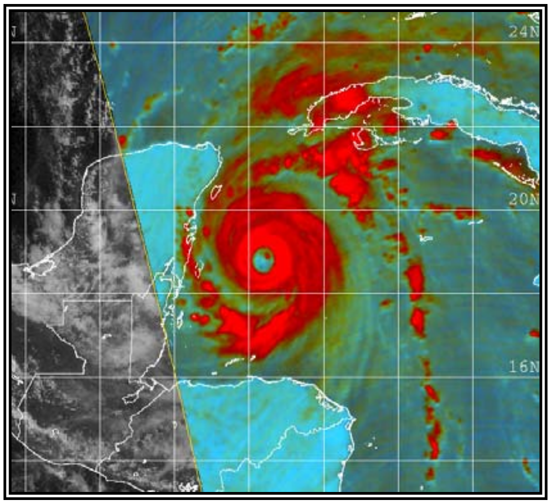
iii.) Next steps for GPM-era data and products

Focus	Presenter	Affiliation (LO)
NWS/NCEP/TPC *(phone)*	J. Beven	NWS
NWS/NCEP/CPC	P. Xie	NWS
NWS/NCEP/EMC	J. Meng	NWS
NWS/NCEP/EMC	G. White	NWS
NWS/NCEP/HPC	M. Bodner	NWS
NWS/OHD	D. Cline	NWS
JCSDA	L. Riishojgaard/M. Kim	JCSDA
NESDIS/SAB	S. Kusselson	NESDIS
NESDIS/NCDC	D. Kim	NESDIS
NOAA/Aviation Program	C. Miner	NWS
OAR/ESRL/GSD – Assimilation *(phone)*	S. Albers	OAR
OAR/NSSL *(phone)*	J. Gourley	OAR
OAR/ESRL – NIDIS *(phone)*	J. Verdin	OAR
OAR/ESRL/GSD – Moisture Observ. *(phone)*	S. Gutman	OAR
NOAA/RFCs & Regional Offices	D. Kitzmiller	NWS
Alaska Pacific River Forecast Center		
Colorado Basin River Forecast Center		
West Gulf River Forecast Center		

From their perspective, all users emphasized needs for fairly high spatial/temporal resolution to drive advanced hydrologic models and to pinpoint local high-impact events such as tropical cyclones, extreme rainfall events associated with atmospheric rivers, etc. Additionally, GPM data latency, its availability at NOAA and bandwidth and storage requirements were also concerns.

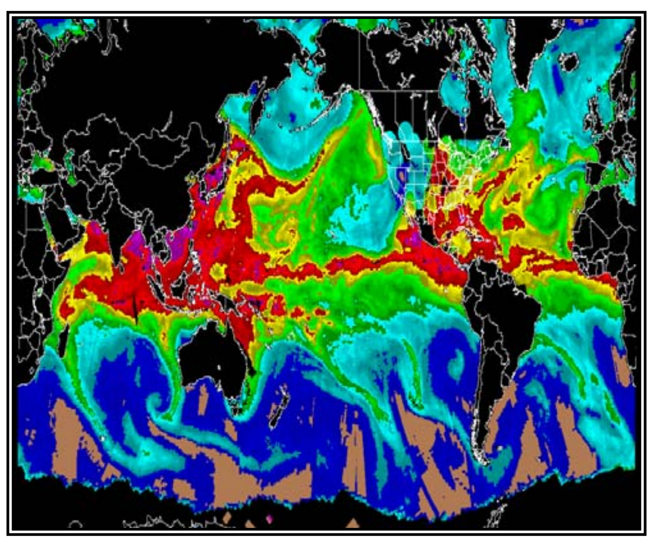


Presentations from the Alaska-Pacific, Colorado Basin, and West Gulf River forecast centers, and a presentation from Donald Cline, director of Hydrology Laboratory, NWS Office of Hydrologic Development, all noted requirements for precipitation products with resolution roughly commensurate with ground radar (4-km grid mesh, 1-h update interval). Similar information was also echoed by Mike Bodner of the NCEP/Hydrometeorological Prediction Center (HPC) and the Hydrometeorology Testbed. However, coarser spatial temporal resolution, such as 10-km grid mesh and 6-h update interval, will serve to drive currently operational lumped models that rely on basin average input. Particularly in some areas with no geostationary observations, such as high latitudes, the currently-available microwave rain-rates might be an adequate supplement to the limited, available precipitation gauge observations that are available, and operational numerical prediction model output.

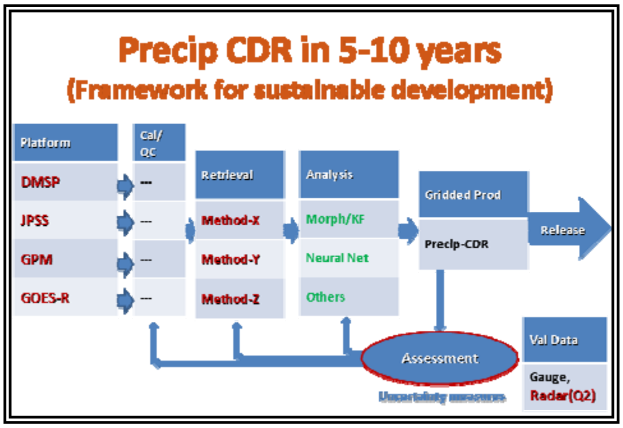


In addition to the value of the GPM products to aid in hydrological prediction, a number of other uses of the data were identified. For example, Jack Bevin, a forecaster from NOAA's Tropical Prediction Center, showed compelling examples of how the microwave radiances are crucial to improved storm center fixing and subsequent track forecasts. In particular, the MW measurements are vital in developing storms and those undergoing rapid intensification; situations where a well-defined eye is not apparent in the visible and IR imagery, but is clearly indicated in the microwave radiances.

The NWP community (Jesse Meng and Glenn White, NCEP/Environmental Modeling Center; Steve Albers, OAR/ESRL; Lars Peter Riishojgaard/Ming-Jeong Kim, JSDCA) mentioned that GPM-era data and products would be most useful for global model validation, data assimilation in cloudy and raining atmospheres, land surface data assimilation and advancing local forecast models (i.e., WRF) cloud microphysics. For the latter, the GPM DPR would be the most promising.



The short-term weather forecasting community (Mike Bodner, NCEP/EMC; Seth Guttman, OAR/ESRL; Sheldon Kusselson, NESDIS/OSDPD) all stressed the importance for NOAA to be able to monitor "atmospheric rivers" which are a strong contributor to prolonged flooding events in the CONUS. GPM era data, would be vital to the continuity of our current monitoring capability, which includes the NESDIS blended TPW product. Inclusion of ground-based measurements from GPS-Met stations is also vital to expand coverage over land, as well as providing an important monitoring tool for the satellite observations. Additionally, we heard from J.J. Gourey and Ken Howard, OAR/NSSL, who talked about the importance of the GPM-era data to help fill in data gaps over the CONUS for an emerging blended high time/space resolution precipitation product known as NMQ-Q2.

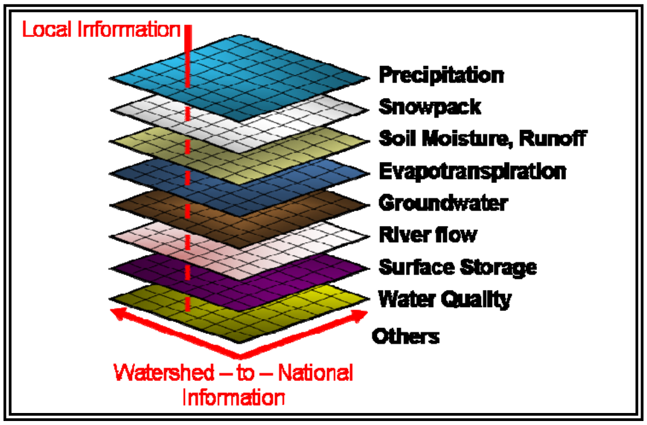


The climate community (Pingping Xie, NCEP/CPC, James Verdin, USGS, and Dongsoo Kim, NESDIS/NCDC) all stressed the need for long-term, global precipitation information to supplement ground observations (e.g., rain gauge and radar), which are typically restricted to populated land areas. Such data are important for monitoring, prediction, and assessments. GPM data are viewed as critical for continuing the satellite precipitation record and for serving as the calibration anchor, much like TRMM is serving today, but with expanded capability in terms of geographical coverage and sensitivity to winter season precipitation. GPM data will be a key contributor to the precipitation CDR that NCDC will be developing over the next 5 to 10 years.

Cecilia Miner of NOAA's Aviation Weather Center, presented compelling information on the impact of heavy rainfall and its impact on aviation, such as contributing factors to airline accidents (e.g., hydroplaning on runways, poor visibility, etc.) and flight delays. GPM-era products may provide important information to the emerging Next Generation Air Transportation System (NextGen), a joint NOAA – FAA effort in development.

Satellite observations provide critical information in the monitoring, assessments and diagnostics of global precipitation, especially over the oceans. GPM is expected to ensure continued production of high-quality, high-resolution global precipitation products for improved climate applications both inside and outside NOAA. Development of future GPM precipitation products should take into account the data continuity and homogeneity for long-term applications and should be integrated as part of a unified NOAA precipitation products suite.

Of particular concern is being able to anticipate when/where/how the products will be obtained from NASA, and approximate bandwidth and storage requirements. We have made initial contacts with NASA staff, which are planning upgrades to the existing server farm that disseminates the TRMM-era precipitation product suite.



Another concern is obtaining documentation on the statistical distribution of errors associated with GPM products; such information is necessary for data assimilation and to optimally blend the products with other data sources such as radar and rain gauges. The error statistics will likely have to be derived relative to point rain gauge, or possibly gauge-radar multi-sensor, estimates.

A final immediate concern is gathering documentation on potential impacts to hydrologic prediction and monitoring, given that we will attempt to apply new information from the GPM constellation over areas where only very limited data are currently available. This information will be needed to get future NOAA support. In particular:

- Given the anticipated level of error in the estimates, will the precipitation estimates still increase the net amount of useful information? A number of studies on satellite estimates as applied to soil moisture monitoring and streamflow prediction have been published; these might provide some guidance.

- Can these new satellite estimates positively affect NOAA operational performance goals over the United States and non-CONUS areas of responsibility?

5. Working Group Reports

5.1. Working Group 1 - Observational Requirements and Gaps

Chair: Chandra Kondragunta

Members: Ralph Ferraro, David Kitzmiller, Martin Yapur, Christopher Williams, Nai-Yu Wang and Seth Gutman (via phone).

Overview: The group met to identify precipitation related observation requirements and gaps in NOAA. The group was first presented with a listing of precipitation related requirements (Table 1) that are documented in the Consolidated Observation Requirements List (CORL). This listing was based on the old Goal- Program structure under Planning, Programming, Budgeting and Execution System (PPBES) that was in effect at the time of this workshop. The requirements that are listed are: Precipitation Amount, Precipitation Rate, Precipitation Type, Microwave Radiances and Total Precipitable Water.

The group then focused their discussion on the following five points and the outcomes are listed as findings and recommendations:

1. List observing requirements; review requirements listed in the CORL and identify additional requirements that are not currently listed in the CORL
2. List current capabilities and their limitations and gaps
3. List future capabilities
4. Are there any multi-sensor techniques that are in development to meet the current and future needs?
5. How do you think GPM can fill the current and or future needs of your program or function?

Requirement	NOAA Program	Priority
Precipitation Amount	CL – Climate Observation & Monitoring	1
	EC – Coastal and Marine Resources	1
	WW – Integrated Water Forecasting	1
	WW – Local Forecasts & Warning	1
	WW - Coasts, Estuaries & Oceans	2
	WW - Weather, Water Sci & Tech Infusion	R
Precipitation Rate	CL – Climate Observation & Monitoring	1
	CT – Aviation Weather	1
	CT – Surface Weather	1
	WW – Integrated Water Forecasting	1
	WW – Local Forecasts & Warning	1
	WW - Coasts, Estuaries & Oceans	2
	WW – Weather, water Sci& Tech Infusion	R
Precipitation Type	CL – Climate Observation & Monitoring	1
	CT – Aviation Weather	1
	CT – Surface Weather	1
	WW – Integrated Water Forecasting	1
	WW – Local Forecasts & Warning	1
	WW – Coasts, Estuaries & Oceans	2
	WW – Weather, Water Sci & Tech Infusion	R
Radiance: Microwave	MS – Environmental Modeling	1
	CL - Climate Observations & Monitoring	1
Precipitable Water: Total	WW - Local Forecasts and Warning	1

Table 1: Precipitation related requirements as listed in the CORL. The requirements are listed in the first column, the NOAA Goal Programs that needs these requirements are listed in the second column and the priority of each of these requirements to the Program is listed in the third column.

Findings: The group endorsed the requirements that are listed in the CORL database by the NOAA Goal – Programs as the precipitation needs of NOAA. This list is presented in Table 1. In addition to these requirements, the group identified several other operational and research observing requirements, and data products requirement to meet the precipitation needs in NOAA. The group identified the following additional requirements that are not listed in the current CORL database.

- Precipitation radar reflectivity
- Precipitation occurrences
- Regional requirements (e.g., Integrated Water Forecast Program (IWF)

The detailed attribute values of the **NOAA Stakeholder Observing Requirements from workshop are listed in Appendix C-1**.

The group identified the following derived products that are capable of being produced by the GM sensors as the operational derived product requirements.

- Ocean Surface Wind Speed (NOAA unique product from GMI)
- Latent heat profiles
- Hydrometeor profiles
- Freezing level

In addition to the aforementioned operational requirements, the group identified the following research requirements that will be useful for improving the accuracy of precipitation retrievals and estimating retrieval uncertainties.

- Total column water vapor
- Winds at 1km level
- Minimum number of rain gauges for bias adjustment

The working group also discussed observing capabilities and Information Management Systems (IMS) in terms of current capabilities, their limitations and gaps.

<u>Current Capabilities:</u>

The group identified satellites, radars and rain gauges as major current observing capabilities. The detailed list of the current observing systems that are found in the NOAA Observing System Architecture (NOSA) database are listed in the Appendix C-2.

The group identified the following IMS as the current capabilities:

- Multi-Sensor Precipitation Estimator (MPE): The MPE algorithm combines precipitation information from NEXRAD system, operational rain gauge network timates. This is currently operational in the NWS hydrologic operations.

- Hydroestimator: Hydroestimator produces high resolution precipitation estimates based on GOES-IR brightness temperature and modifies them using numerical weather model data. This is operational is at STAR, NESDIS.

- CPC MORPHing Technique (CMORPH): This algorithm produces global precipitation analysis at very high spatial and temporal resolution. This technique uses microwave estimates whose features are transported via spatial propagation information that is obtained from the geostationary satellite IR data. This data has a data latency of 18 hours.

- Blended Total Precipitable Water: NESDIS produces smooth operational blended total precipitable water product by combining information from several data sources such as SSM/I from DMSP, AMSU from POES, information from Global Positioning Satellite (GPS) meteorological data, GOES-West and GOES-E sounder data.

The detailed list of the current IMS capabilities that are listed in the NOSA database are listed in the Appendix C-3

Limitations:

- *Radar limitations:*
  - Radar technology is limited to land and near shore waters in developed countries. Even in the United States, the radar coverage is poor in the western mountainous region because of the beam blockage issue - the current effective radar coverage in the western United States is less than half in the winter season.
  - Lack of uniformity of Z-R relationship from one climatic region to another.
  - Radar beam overshooting at far ranges causes underestimation of precipitation.
  - Mixed phase and frozen precipitation are difficult to estimate with radar technology.
- *Rain gauge limitations:*

- Coverage: The major issue with rain gauges is non uniformity in the gauge coverage. Non-uniformity of rain gauge coverage causes sampling biases. Rain gauge coverage is also poor in the western United States and in several parts of the world. Reports of gauge observations for precipitation of sub-daily time resolution are rarely available.

- Quality: While rain gauges provide the best accuracy for the rainfall measurements, the quality of rain gauge data is of major concern because most of the gauges are remotely operated. Some examples are malfunctioning of the gauges, data transmission errors, poor gauge citing etc . In addition, undercatch caused by wind effects, especially in measuring snowfall, is poorly corrected.

- Network issues: Rain gauge data comes from several different gauge networks and each network operates on its own temporal sampling intervals and data latencies.

- *Satellite Technology Limitations:*

  - Infrared: While the infrared data based precipitation estimates provide the best spatial and temporal sampling, the weak relationship between rain rate and brightness temperature causes their estimates to be of poor accuracy. Parallax error causes another problem with the IR based estimates.

  - Microwave - Passive: The limitations of passive microwave estimates are poor temporal sampling, beam filling error, poor estimation over land and complex surfaces (eg. Frozen ground), and warm rain detection

  - Microwave – Active: The limitations of active microwave sensors are narrow swath width. They are also expensive to build.

The group identified the following observing system capabilities and information management systems as future capability needs of NOAA.

Future observing Capabilities:

- Dual-polarimetric Radar: With both vertically and horizontally polarized pulses, the dual-polarimetric radars will be able to discriminate type, shape and size of hydrometeors better than the current NWS operational NEXRAD system. This enhanced characterization of the hydrometeors will allow more accurate estimation of precipitation, and better discrimination of precipitation type. NWS is in the process of upgrading the current NEXRAD system to dual-polarimentric radar capability.

- Geo-Microwave Sensor: There is a need for a microwave sensor in a geostationary orbit to study the diurnal variation of precipitation, which in turn will improve the daily and monthly mean precipitation estimates. This is right now in a concept phase.

- Space-based Precipitation Radar: There is a need for a space-based precipitation radar in a precessing orbit for climate quality precipitation measurements. The precipitation estimates from this type of space-based radar serve as a reference standard for inter calibration of microwave precipitation estimates from the other polar orbiting microwave sensors. This is essential for continuation of climate quality precipitation records beyond GPM era.

Future IMS capabilities:

- Next Generation QPE (Q2): This is a scientific and community-wide convergence towards high resolution, accurate QPE and very short term quantitative forecasts. This will glean best practices of the multi-sensor precipitation estimator of OHD, NWS and National Mosaics Multi-sensor QPE (NMQ) of National Severe Storms Laboratory (NSSL) of OAR.

- Self Calibrating Multivariate Precipitation Retrieval (SCaMPR): This algorithm combines the relative strengths of infrared (IR) based and microwave (MW) based estimates of precipitation. This combination produces better quality precipitation estimates in higher spatial and temporal resolution. This algorithm has far reaching consequences in the GPM and GOES-R era to produce high resolution precipitation estimates for flash-flood forecasting.

- Quick CMORPH (QMORPH): In order to meet the needs of users who require more timely precipitation estimates, QMORPH is being developed. This product is same as CMORPH, except that the passive microwave features are propagated via IR data forward in time only with no morphing. Unlike CMORPH, QMORH has a data latency of 3 hours.

- Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN): This neural network based precipitation estimation algorithm primarily uses IR information from the geostationary satellites and adjusts the model parameters when microwave data from the Low Earth Orbiting (LEO) satellites are available.

Challenges:

The group identified the following challenges the precipitation community is facing in improving precipitation estimates.

- Precipitation estimates in the orographic regions
- Light precipitation estimation in the mid- and high latitude regions
- Reducing uncertainty in the oceanic rainfall estimation

How GPM can fill the gap:

The group identified that GPM can fill the gaps in the current and future capabilities in the following way.

- It can improve light and frozen precipitation estimations in mid-latitudes

- It can account for diurnal variation by providing observations at a sampling intervals of 3 hours or less

- It can give high quality precipitation estimates all over the globe. This improvement is significant in high latitudes and over ocean upon the current capability

- Provides continuity of current climate quality precipitation record

- Provides anchor calibration for climate quality data record

- Improves spatial and temporal sampling for hurricane track forecasting.

5.2. Working Group 2: Accelerating the use of GPM Data

Chair: Tim Schneider

Members: Mike Bodner, Rob Cifelli, Steve Goodman, Dongsoo Kim, Sheldon Kusselson, Chris Miller, Glenn White, Pingping Xie

Overview:
In order to enhance and accelerate the use of GPM data in NOAA, the group met to identify NOAA's GPM data requirements, gaps, needs, and barriers to use; to discuss mechanisms and processes to enhance usage, conduct testing and evaluation of GPM data; and means to increase and/or improve engagement with users through training and other mechanisms. Our desired outcomes are to:

- Enable NOAA (broadly) to use GPM data
- Conduct research and to provide improved climate, weather and water products and services
- Develop a plan that identifies a NOAA process to enhance and accelerate the use of GPM data

The discussion was organized around eight questions:

1. What cal/val (sensors/algorithms) is needed?
2. What do we need to do to prepare NOAA's infrastructure?
3. What R&D is needed?
4. What is role of testbeds/proving grounds?
5. How do we transition and deliver science products and services?
6. How do we integrate GPM data with other "QPE" systems?
7. What are NOAA's funding resource gaps?
8. What training is needed?

It should be remarked that one common thread (finding) cropped up a number of times in the discussion: the general principle that users should be engaged in every aspect of planning and development (data flow, requirements, product identification and assessment, data archival, etc.).

Findings:

- NOAA's derivative products will require additional *calibration/validation* (cal/va/) above and beyond NASA's, to best benefit NOAA operations: a robust and uniquely NOAA cal/val and quality control (QC) effort is needed to build confidence in GPM data and information.
- *NOAA liaisons* to NASA are needed to facilitate communication between NASA Ground and Integrated Validation and NOAA users (this is a role of the NOAA steering group – but working groups will be necessary for different themes)
- *Data access/data management* – GPM should be integrated into existing data framework/system for long-term analysis (R&D); we also need to consider integrating into NOAA operations. A clear understanding of data pathway and archive from NASA to NOAA, and then internally within NOAA is needed
    - *Accelerate & integrate:* NOAA needs to make sure that a process is in place to receive and work with GPM data – unique issues for NESDIS, NCEP and research (testbeds) – resources need to be in place to accommodate GPM data flow early in the process (ahead of the core satellite launch)
    - In general, NESDIS is probably the logical "owner" of NOAA-GPM data – however it was acknowledged that different users may have

different requirements for GPM data sets. It is proposed that NESDIS STAR will be able to bring in GPM data – a NOAA MOA will cover access to data. Further investigation is required to explore issues internally to NESDIS, with NCEP, and with other LOs
    - *Metadata* needs to be developed and included: i.e. algorithms, data and products need to state uncertainty, limitations, references, etc.
    - Note that frequent product updates can be detrimental to operations (what is the appropriate update cycle?). Also, NOAA requirements for updates are not necessarily same as NASA's – NOAA needs more stability of product suite
- *Model physics* (NWP) may have to be adjusted to *assimilate* GPM data. NOAA needs to start testing data assimilation process/parameterizations ahead of GPM data flow. Development of physics may be out of sync with development of computer resources, etc.
- NOAA's GPM-related *R&D* efforts should consider: GPM-now (NASA update cycle), next (1st generation of products and services that are evaluated), and future (needs of researchers). R&D gaps include (but are not limited to):
    - Assimilation (JCSDA) and model physics (NWP);
    - The impact of GPM data on reanalysis efforts:
        - Seasonal forecasts and climate applications
        - Regional variability over different spatial and temporal scales
        - Error characteristics as product resolution changes
    - Producing precipitation records: we don't want to disrupt the continuous, long term record – make compatible; we need to identify the best way to integrate GPM data into the long-term precipitation record (consistency and scaling issues)
        - Use for developing sparse network records (from gages)
    - Development of multi-sensor/multiplatform products (QPE, now-casting, QPF), and algorithms beyond precipitation, such as clouds, moisture
    - Other applications such as aviation and high impact weather
- *Testbeds and proving grounds* can and should play a significant role. They are means to infuse GPM data into NOAA (in the context of climate, weather and water), and can provide operationally relevant feedback to GPM community
    - Establish product development activities within testbeds to "train" users – researchers and ops people together test data (annual testbed workshops good way to compare results among different testbeds)
    - Feedback can be done daily (don't need to wait for workshops)– tools are available to put data on the web: forecasters can provide feedback via blogs
    - Identify priority testbeds: potentially including Hydrometeorology, Joint Hurricane, Hazardous Weather, Climate, Aviation, JCSDA, SPoRT,

GOES-R proving ground working with other test beds. Is there a need for a GPM testbed?

- NOAA needs to identify a long term strategy to integrate GPM data into suite of NOAA products (e.g. CMORPH; MPE; NMQ/Q2; etc.). How does GPM complement (fill gaps) other satellite data used by NOAA to produce precipitation products (what is optimal use of GPM data)?
- NOAA's *funding gaps/needs* are massive. Funding needs include:
    - Engage users and developers in an end-to-end process (sensor, development, assimilation, QC, applications, cal/val, etc.)
    - Base funding is currently spotty and inadequate (sat algorithm testbed, satellite proving ground, OST forecasting office of the future); funding should be considered more from an integrated product standpoint (i.e., satellite, radar, in-situ)
    - Bridge funding (e.g., modeled after the GOES-R Risk Reduction program) is needed for user participation in workshops, test beds – currently almost non-existent
    - External support for people to engage in process
- In terms of transitioning and delivering new science products and services, efficient implementations and feedback between users and developers (is value being added?), and open and transparent data availability on a variety of dissemination platforms (AWIPS, NAWIPS, ALPS - need to consider data formats) are needed
- Training is a critical element to accelerate the use of GPM data, and to enhance and ensure better products and services.
    - GOES-R has couple of good examples (JPSS is adopting this model), for example, training opportunities through the COMET program
    - There are some chicken-and-egg problems: (i) We cannot train forecasters until products become available, so early training should be developed using TRMM or other proxies to demonstrate utility; (ii) However, testing and evaluation of products/services is important before being trained on them (to build credibility and consistency)
    - Educate users (forecasters) to realize that existing products may disappear and they may have to advocate for new (GPM) products
    - Training should be considered as a two-way street: R2O ⇔ O2R. I.e. the product developer develops training for user – feedback from user included to train developer

- Some outstanding questions:
    - Can the NASA product suite be influenced by NOAA user needs?
    - What is the current understanding of NOAA's access to the GPM data?
    - Are data formats same as TRMM?

Recommendations:

- Best practices require algorithm theoretical basis documents (ATBD) to be developed for calibration/validation (for sensors/algorithms) and for QC. Request metadata from NASA to describe QC/validation procedures, uncertainties, etc. Be aware of NASA's validation efforts so as not to reinvent the wheel – collaborate with NASA where appropriate
- Organize joint NASA-NOAA workshops on various topics, but especially focused on NOAA user needs
- Conduct an analysis of *NOAA's current capacity* to handle GPM data (both externally and internally) and identify gaps
- Conduct an analysis of *cost, risk, and benefit* of different products, and establish requirements for QC/accuracy, etc
- Consider a uniform way to provide access to integrated data to users (different satellite data streams are used to pull data from different sources). Make case for multiple access of GPM data via AWIPS, etc (a plan for dissemination to multiple points is needed)
- Explore ways to *reduce latency over CONUS:* e.g. is it possible to retrieve data over North America and deliver it more quickly than a full global orbit (is the existing infrastructure capable of doing this)?
- An early start effort is recommended to address gaps in GPM data assimilation… leverage/utilize NOAA-NASA joint center (JCSDA), DTC for model studies, and testbeds to address this problem
  - Is model physics optimal for assimilation of GPM data and will this degrade other users? What physics (NWP) do we need? E.g. cloud microphysics
  - Implementation of model formulation needs to be consistent
- NOAA should actively tap academic institutions and Cooperative Institutes (e.g via a grants program), to augment and/or complement internal R&D efforts
- Engage USWRP to develop a strategy to engage with various testbeds and proving grounds, and to facilitate the process. Each relevant testbed should identify a liaison to the NOAA Steering Group on Precipitation Measurement from Space
- To address funding gaps, we need to identify how GPM can address grand challenges in climate, weather and water (e.g. a process patterned after the HFIP model). NOAA also needs to ensure a coordinated budget planning process and execution across LOs (e.g. get heads of line offices together and sign MOU to this effect; JCSDA could play a role here)
- Recommendations on training:
  - Hold workshops to engage users and to define uses/pathways of the data

- GPM training modules should be developed for the NOAA Learning Center

5.3. Working Group 3: New Applications

Chair: Fuzhong Weng

Members: Limin Zhao, Kevin Garrett, Bill Sjoberg, Brian Nelson, Allen White, Ninghai Sun, Ding Liang, Min-Jeong Kim

Findings: The working group has identified these following unique areas that need to be brought to the user community for specific attention:

- GMI has no oxygen sounding channels and this limits some advanced applications that rely on atmospheric temperature

- A few channels (e.g. 10-22 GHz) will be affected by RFI, which will degrade the quality of surface products

- NASA's GPM program has a strong emphasis on precipitation (solid precipitation) over land but there are several challenges. For example, it lacks of surface products in general, such as, land surface emissivity and soil moisture and it has limitations in terms of synergy/collocation with other satellites, such as SMAP and JPSS.

- In addition, GPM era sensors contain water vapor sounding information (i.e., observations near the 183 GHz band) and offers some new science studies (e.g. high frequency/dual polarization may separate surface snow and falling snow)

Recommendations:

1. To utilize GPM data and products in NOAA operational systems effectively, understanding benefits and limitations of GPM data products and making strategies to take advantage of the benefits and to make up for the limitations by combining with other observations and/or models available in NOAA operational centers are urgent. The highlighted issues discussed by the GPM application working group during the workshop are listed in the above.

2. Utilizing additional information from numerical models through data assimilation will be a possible approach to overcome the limitations. For these applications that are not supported by the primary mission objective by NASA, the funding and human resources need to be identified for data assimilation task.

3. To compensate the limitations and extend the benefits, combining GPM observations with other instruments is expected to generate synergy effects. For example, combining with SMAP will help for better soil moisture retrieval and combining with JPSS sensors will help for ocean surface wind speed, surface temperature under heavy precipitation condition. For atmospheric products, combining with NPP/JPSS and POES, Metop will improve total precipitable water (TPW) retrievals over land and combining with GOES-R GLM will help for identifying precipitation type, and electrification. It will be worthwhile to explore the capability to retrieve liquid water path (LWP) and ice water path (IWP) over land along the way.

4. The proxy data need to be developed for future implementation of the GPM data and products in the NOAA operational centers, one of requirements made by the user community is developing GPM proxy data to test the readiness of their systems. However, challenges of developing GPM proxy data using TRMM TMI observations were found because of difference in frequency range, scan swath width.

5. Another overarching user requirement is real-time monitoring of (1) GPM data bias through analyzing of differences between observations and background fields and (2) GMI noise (NeDT) trend, calibration targets, and house-keeping information. In addition, independent assessments of GPM level-1c cross calibration by Polar over-passing technique, Double difference technique (DDT), GSICS MWRG and GPM Xcal combined capability, or Non-linearity calibration science are requested.

6. We might need to tailor the product capability for specific NOAA users in sense of formats, regions, and etc. Specifically:

    a. Level-1 data will be needed to be prepared for CRTM readiness for GPM and to convert data format to BUFR, etc. The GMI sensor level of information should be sent to us for generating fast radiative transfer coefficients. This is necessary for users to generate GMI proxy data and perform the data assimilation experiments once the radiance data become available.

    b. Format conversion tools are also required to be developed for GPM data utilization in NOAA. Radiances should be in BUFR for data assimilation and in NetCDF4 for NWS/AWIPS. BUFR toolkit developed at NDE can be a potential leverage

    c. Enhancing GPM imagery with polarization correction is expected to be beneficial for tropical and mid-latitude storm monitoring in terms of positioning, intensity monitoring and eye-wall replacements. In addition, Level-1 data can be useful for constructing multi-sensor co-registered radiance data. Level-2 products will be useful for multi-sensor blended products, such as, Ensemble Tropical Rainfall Potential, blended precipitable water and rainfall, etc.

d. Finally, Level-3 products are expected to be useful for Quantitative Precipitation Estimation (QPE). It is possible to produce GPM data merged or through a unified NOAA precipitation product.

6. Summary and Next Steps

It was apparent from the workshop that there is considerable interest in GPM data in NOAA, as it will be critical for continuity of our current capabilities in the hydrologic and land surface monitoring and prediction. Additionally, it will offer tremendous opportunities to advance our use of such data at NOAA. In particular, uses of the GPM intercalibrated data will serve needs beyond precipitation, including NWP model assimilation, monitoring of atmospheric rivers, and tropical cyclone center fixing.

This workshop was a first attempt to determine broad-based NOAA stakeholder interests and needs for GPM era data and products and to consolidate the information in a way to advance NOAA's planning for the GPM mission; presently, this information has been somewhat disjointed across the organization, primarily due to the wide array of needs and responsibilities of individual line offices for hydrological information. In some sense, it was an update to the workshop that was held in 2001 when NESDIS was pursuing an initial interest in GPM.

The path forward can be developed in both a general sense, with specific details being available in some areas, and lacking in others. These are summarized below:

1. Continue to publicize the proposed GPM product suite to potential NOAA users: geographic coverage, latency, and input sources. Associated with this action is emphasizing the gaps the GPM suite might fill: high-latitude coverage, more frequent radiance information for NWP, tropical cyclone monitoring, etc. Update the CORL requirements as needed. Hold a follow-on GPM Users Workshop (late 2011 timeframe) with more user application focus. This activity will be lead by NOAA's Steering Group on Precipitation Measurement from Space.

2. Identify plan to obtain near-real time GPM data/products by GPM-core launch in 2013. In parallel to this, NESDIS is to continue to pursue the transition of NASA's Precipitation Processing System (PPS) to NOAA to ensure real-time data delivery. NASA will continue to operate a parallel developmental system for algorithm upgrades and new products. Secure resources for the transition. Coordinate data format and delivery requirements within NOAA for PPS.

3. Develop GPM Proving ground/proxy data, in particular using existing products such as QMORPH to demonstrate the possibilities from an enhanced suite of passive microwave sensors

4. Continue and enhance GPM R&D by coordinating funding availability between NASA and NESDIS, and tracking and publicizing progress on funded R&D activities.

5. Develop synergies with ongoing and future activities. These include Hydrometeorological Testbeds, GOES-R proving ground and risk reduction, the JPSS program, and development of a center to support Integrated Water Resources Science and Services (IWRSS). GPM elements could be integrated with operational and operational-track product suites including NCEP Stage II multisensor and NMQ-Q2 precipitation

6. Prepare Initial basic training material, based on NASA science team documents; in particular emphasizing advances that are possible beyond the current capabilities of infrared precipitation estimates, high-latitude satellite precipitation, and enhancements to numerical weather prediction .

7. As feasible, identify strategies for demonstrating the potential impact of GPM-era products on NOAA operations, and on related efforts of interest to multiple agencies, particularly global drought and flood monitoring. This requires development of estimates of error distributions for the GPM product suite, as well as documentation on error distributions of existing products.

8. Develop a strategy for a GPM follow-on capability, especially budgetary documentation and planning. As noted before, an operational GPM follow-on would fill some anticipated gaps in the existing satellite and sensor constellation, as well as serve as a calibration anchor, both important points of emphasis.

9. Hold a User Focus/Application Focus workshop in autumn 2011 (FY 2012), perhaps organized around the five top priority themes in this report. The workshop will be held in the Washington, DC or Boulder, CO area.

7. References

Arkin, P.A. and co-authors, 2002: NOAA Workshop on Requirements for Global Precipitation Data. November 29-30, 2001, Silver Spring, Maryland.

National Research Council, 2007: NOAA's Role in Space-based Global Precipitation Estimation and Application, National Research Council, Washington, DC.

List of Acronyms

ABI: [GOES-R] Advanced Baseline Imager
AMSR: Advanced Microwave Scanning Radiometer
AMSU: Advanced Microwave Sounding Unit
ATMS: Advanced Technology Microwave Sounder
CDR: Climate Data Record
CGMS: WMO Coordination Group for Meteorological Satellites
CMORPH: [NOAA] CPC Morphing Technique
CORL: [NOAA] Consolidated Observational Requirements List
CPC: [NOAA] Climate Prediction Center
COSMIC: Constellation Observing System for Meteorology Ionosphere & Climate
DPR: Dual-frequency Precipitation Radar
EMC: [NOAA] Environmental Modeling Center
ESSIC: Earth System Science and Interdisciplinary Center, University of Maryland
GCOS: Global Climate Observing System
GLM: Geostationary Lightning Mapper
GOES: Geostationary Operational Environmental Satellite
GMI: GPM Microwave Imager
GPM: [NASA] Global Precipitation Measurement
GSICS: Global Space-based Inter-Calibration System
GV: Ground Validation
HMT: [NOAA] Hydrometeorology Testbed
JAXA: Japanese Aerospace Exploration Agency
JPSS: Joint Polar Satellite System
LEO: Low Earth Orbiting
MHS: Microwave Humidity Sounder
NASA: National Aeronautics and Space Administration
NCDC: [NOAA] National Climatic Data Center
NDE: NPOESS Data Exploitation
NESDIS: [NOAA] National Environmental Satellite, Data and Information Service
NOAA: National Oceanic and Atmospheric Administration
NOSA: [NOAA] NOAA Observing System Architecture
NWP: Numerical Weather Prediction
NWS: [NOAA] National Weather Service
NPOESS: National Polar Orbiting Environmental Satellite System
NPP: NPOESS Preparatory Project
OAR: [NOAA] Office of Atmospheric Research
OHD: [NOAA] Office of Hydrological Development
OSWV: Ocean Surface Wind Vectors
PMM: [NASA] Precipitation Measurement Missions
POES: Polar Orbiting Environmental Satellite
PPS: [NASA] Precipitation Processing System
PR: Precipitation Radar
SEE: [NOAA] Strategy Execution and Evaluation
SMAP: [NASA] Soil Moisture Active-Passive mission
SSMIS: Special Sensor Microwave Imager Sounder
STAR: [NOAA] Center for Satellite Applications and Research
TMI: TRMM Microwave Imager
T/O: Threshold/Objective
TRMM: [NASA] Tropical Rainfall Measurement Mission
TSIS: Total Solar Irradiance Sensor
WMO: World Meteorological Organization

Appendix A: Workshop Participants and Meeting Agenda

Name		Agency/Organization
Steve	Albers	OAR/ESRL
Ardeshir	Azarbarzin	NASA
Shyam	Bajpai	NESDIS/OSD
Don	Berchoff	NWS/OST
Jack	Bevin	NWS/NCEP/TPC
Mike	Bodner	NWS/NCEP/HPC
Yong	Chen	NESDIS/STAR
Rob	Cifelli	OAR/ESRL
Don	Cline	NWS/OHD
Ralph	Ferraro	NESDIS/STAR
Kevin	Garrett	NESDIS/STAR
Steve	Goodman	NESDIS/GOES-R
David	Goodrich	OAR/CPO
J.J.	Gourley	OAR/NSSL
Seth	Gutman	OAR/ESRL
Arthur	Hou	NASA
Ken	Howard	OAR/NSSL
Paul	Hwang	NASA
Mike	Johnson	NWS/OST/SPB
Ramesh	Kakar	NASA
Mike	Kalb	NESDIS/STAR
David	Kitzmiller	NWS/OHD
Mary	Kicza	NESDIS
Dongsoo	Kim	NESDIS/NCDC
Min-Jeong	Kim	JCSDA
Chandra	Kondragunta	NESDIS/OSD
Sheldon	Kusselson	NESDIS/OSDPD
Ellen	Liang	NESDIS/STAR

Name		Agency/Organization
Dan	Mamula	NESDIS/OSD
Stephen	Mango	NESDIS/OSD
Jesse	Meng	NWS/NCEP/EMC
Christopher	Miller	OAR/CPO
Cecilia	Miner	NWS/OCWWS
Steve	Neeck	NASA
Brian	Nelson	NESDIS/NCDC
John	Pereira	NESDIS/OSD
Walt	Peterson	NASA
Shanna	Pitter	PPI
Al	Powell	NESDIS/STAR
Lasr Peter	Riishojgaard	JCSDA
Tim	Schneider	OAR/ESRL
Jim	Silva	NESDIS/OSD
Bill	Sjoberg	NWS/OST
Erich	Stocker	NASA/GSFC
Ninghai	Sun	NESDIS/STAR
Nai-Yu	Wang	Univ. Maryland/ESSIC
Fuzhong	Weng	NESDIS/STAR
Allen	White	OAR/ESRL
Glenn	White	NWS/NCEP/EMC
Christopher	Williams	OAR/ESRL
Youlong	Xia	NWS/NCEP/EMC
Pingping	Xie	NWS/NCEP/CPC
James	Verdin	OAR/ESRL and USGS
Martin	Yapur	NESDIS/OSD
Jim	Yoe	NWS/NCEP
Limin	Zhao	NESDIS/OSDPD

Appendix B: Workshop Agenda

Day One

Wednesday, August 18, 2010

Time	Presentations / Topics	Speaker	Affiliation
800 - 830 am	*Registration/Sign In*		
830 - 1000 am	*Session 1 - Overview*	Chair - Ferraro	NESDIS
830 - 840 am	*Introductions, Welcome, Logistics, Goals, Format, etc.*	R. Ferraro; A. Busalacchi; D. Kitzmiller	NESDIS & NWS
840 - 900 am	*Charge to the Workshop - Importance of GPM to NOAA Users*	M. Kicza	NESDIS
900 - 915 am	*GPM Program Overview*	R. Kakar (Phone)	NASA
915 - 930 am	*GPM Project Status - Instruments*	A. Azarbarzin	NASA
930 - 945 am	*GPM Project Status - Algorithms and Partnerships*	A. Hou	NASA
945 - 1000 am	*GPM Project Status - Precipitation Processing Systems*	E. Stocker	NASA
1000 - 1030 am	*Coffee Break & Group Photo*		
1030 - 1200 pm	*Session 2a - NOAA Perspective*	Chair - Kitzmiller	NWS
1030 - 1045 am	*GPM's Importance to CPO*	D. Goodrich	OAR
1045 - 1100 am	*GPM Mission - National Weather Service Perspective*	D. Berchoff	NWS
1100 - 1110 am	*GPM as a Research to Operations Transition Candidate*	J. Pereira	NESDIS
1110 - 1120 am	*GPM's Importance to GOES-R Program*	S. Goodman	NESDIS
1120 - 1130 am	*Vision of New NOAA Products in GPM Era*	A. Powell	NESDIS
1130 - 1140 am	*NDE's contribution to GPM*	J. Silva	NESDIS
1140 - 1150 am	*Changes to NOAA's Program Planning - SEE*	S. Pitter	PPI
1200 - 100 pm	*LUNCH*		
100 - 130 pm	*Session 2b - NOAA Perspective*	Chair - Kitzmiller	NWS
100 - 110 pm	*GSICS and GPM Coordination*	F. Weng	NESDIS
110 - 120 pm	*NOAA's CDR Program and Linkage to GPM*	B. Nelson	NESDIS
120 - 130 pm	*Synergy between GPM and HMT*	T. Schneider	OAR
130 - 500 pm	*Session 3 - Interest / Needs from NOAA Stakeholders*	Chair - Schneider	
130 - 140 pm	*NWS/NCEP/TPC*	J. Beven (Phone)	NWS
140 - 150 pm	*NWS/NCEP/CPC*	P. Xie	NWS
150 - 200 pm	*NWS/NCEP/EMC*	J. Meng	NWS
200 - 210 pm	*NWS/NCEP/EMC*	G. White	NWS
210 - 220 pm	*NWS/NCEP/HPC*	M. Bodner	NWS
220 - 230 pm	*NWS/OHD*	D. Cline	NWS
230 - 240 pm	*JCSDA*	L. Riishojgaard/M. Kim	JCSDA
240 - 300 pm	*COFFEE BREAK*		
300 - 310 pm	*NESDIS/SAB*	S. Kusselson	NESDIS
310 - 320 pm	*NESDIS/NCDC*	D. Kim	NESDIS
320 - 330 pm	*NOAA/Aviation Program*	C. Miner	NWS
330 - 340 pm	*OAR/ESRL/GSD - Assimilation*	B. Albers (Phone)	OAR
340 - 350 pm	*OAR/NSSL*	J. Gourley (Phone)	OAR
350 - 400 pm	*OAR/ESRL - NIDIS*	J. Verdin (Phone)	OAR
400 - 410 pm	*OAR/ESRL/GSD - Moisture Observations*	S. Gutman (Phone)	OAR
410 - 440 pm	*NOAA/RFCs and Regional Offices*	D. Kitzmiller	NWS
	Alaska-Pacific River Forecast Center	D. Kitzmiller	NWS
	Colorado Basin River Forecast Center	D. Kitzmiller	NWS
	West Gulf River Forecast Center	D. Kitzmiller	NWS
440 - 500 pm	*Day 1 Wrap up and Plans for Day 2, including formation of working groups*		
500 pm	*ADJOURN FOR THE DAY*		
600 pm	*Group Dinner at Hard Times Café, College Park, MD*		

Day Two

Thursday, August 19, 2010

Time	Presentations / Topics	Speaker	Affiliation
830 - 900 am	*Working Groups - Planning*	Ferraro/Kitzmiller	NESDIS & NWS
900 - 1030 am	*Working Groups Meet*		
1030 - 1045 am	*COFFEE BREAK*		
1045 - 1200 pm	*Working Groups Meet*		
	Working Group: Observational Needs & Gaps	Chandra Kondragunta	NESDIS
	Working Group: Accelerating Use at NOAA	Tim Schneider	OAR
	Working Group: Applications & Other Needs (e.g., radiances, climate, NOAA-unique products)	Fuzhong Weng	NESDIS
1200 - 100 pm	*WORKING LUNCH - WG Chairs Prepare Reports*		
100 - 300 pm	*Session 5 - Plenary - Working Group Reports*		
100 - 200 pm	*Working Group Reports (15 min each)*		
200 - 300 pm	*Final Plenary and Assigned Actions*		
300 pm	*Workshop Ends*		

Appendix C-1: NOAA Stakeholder Observing Requirements

(T=Threshold, O=Objective, V=Value, U=Unit)

NWS/National Hurricane Center (Jack Beven):

- GPM core and constellation passive microwave radiances/imagery
- GPM core radar reflectivity and profile
- Primary uses: storm center fixing and assimilation into NWP models

NWS/Climate Prediction Center (Pingping Xie):

Observation Requirement	T/O	Geographic Coverage	Vertical Resolution		Horizontal Resolution		Measurement Accuracy		Measurement Precision		Sampling Interval		Data Latency	
Global Precip. Rate from PMW	T	Global		Km	4	km	.5	mm/h	.5	mm/h	3	hr	1	hr
	O	Global		km	4	km	0.5	mm/h	0.5	mm/h	3	hr	01	hr
Global precip L3 Product	T	Global			4	km	0.5	Mm/h	0.5	Mm/h	.5	hr	1	hr
	O	Global			4	km	0.5	Mm/h	0.5	Mm/h	.5	hr	1	hr
	T													
	O													
Comments:	T													
	O													

NESDIS/Satellite Services Division (Sheldon Kussleson):

Observation Requirement	T/O	Geographic Coverage	Vertical Resolution		Horizontal Resolution		Measurement Accuracy		Measurement Precision		Sampling Interval		Data Latency	
Precip. Rate Type: Rain/Snow	T	Global	-----	-----	5	km	0.6	mm/h	0.5	mm/h	3	hr	2	hr
	O	Global	-----	-----	> 3	km	0.3	mm/h	0.25	mm/h	> 1	hr	>0.5	hr
Total Precip Water (TPW)	T	Global	-----	-----	22	km	1	mm	1	mm	3	hr	2	hr
	O	Global	-----	-----	>11	km	0.5	mm	0.5	mm	> 1	hr	>0.5	hr
MW channel brit values 85-91GHz/ 36-37GHz	T	Global	-----	-----	4 X 6 8 X14	km	------	Deg K	------	Deg K	3	hr	2	hr
	O	Global	-----	-----	1 X 2 2 X 4	km	------	Deg K	------	Deg K	> 1	hr	>0.5	hr
MW reflectivities (precip radar)	T	W Hemis	250	m	4	km	1	mm/hr	0.4	mm/h	3	hr	2	hr
	O	Global	100	m	>2	km	0.5	mm/hr	0.25	mm/h	>0.5	hr	>0.5	hr

Comments/Other Desires:

- Range of Rain Rates – minimum (T) 0 to 55 mm/hr; objective (O) 0 to 100 mm/hr
- Range of Total Precipitable Water – minimum (T) 1 to 75 mm; objective (O) 0.5 to 85 mm
- Swath width – min (T) 250 km Precip Radar (PR) / 1700 km MW; objective (O) 700km PR / 2200km MW
- Rain mask for TPW – min (T) only for moderate to heavy rain; objective (O) only for heavy rain

1st NOAA User Workshop on the GPM Mission
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NWS/Aviation Weather Services & Climate and Transportation Goal (Cecilia Miner):

Observation Requirement	Program Acronym	Prty	T / O	Geographic Coverage	Vertical Resolution		Horizontal Resolution		Measurement Accuracy		Sampling Interval		Data Latency	
					V	U	V	U	V	U	V	U	V	U
Precipitation Rate														
Precipitation Rate CONUS + AK & HI	CT-AWX (CONUS + AK & HI)	1	T	CONUS+AK+HI	na	na	10	km	1	mm/hr	15	min	3	min
			O	CONUS+AK+HI	na	na	5	km	1	mm/hr	15	min	3	min
Precipitation Rate Global	CT-AWX (Global)	1	T	Global	na	na	15	km	1	mm/hr	3	hr	3	min
			O	Global	na	na	5	km	1	mm/hr	1	hr	3	min
Precipitation Type														
Precipitation Type	CT-AWX	1	T	Global	na	na	10	km	20	%	15	min	3	min
			O	Global	na	na	5	km	10	%	15	min	3	min

NWS/Office of Hydrologic Development (Donald Cline):

Observation Requirement	T/O	Geographic Coverage	Vertical Resolution		Horizontal Resolution		Measurement Accuracy		Measurement Precision		Sampling Interval		Data Latency	
Precipitation accumulations	T	North America, PR, HI, Guam	NA		4	km	1	mm/h	1	mm/h	1	hr	15	m
	O	""			1	km	0.5	mm/h	0.5	mm/h	0.5	hr	15	m
Precipitation rates	T	""	NA		4	km	1	mm/h	1	mm/h	1	hr	15	m
	O	""			1	km	0.5	mm/h	0.5	mm/h	0.5	hr	15	m

Comments:
Accumulations needed for hydrologic modeling;
Rates needed for rapid update and nowcasting

Regional requirements provided by NOAA River Forecast Centers (RFC) (David Kitzmiller)
APRFC (Alaska-Pacific); CBRFC (Colorado Basin); West Gulf (WGRFC):

APRFC Precipitation Requirements

Requirement	T/O	Geo Coverage	Vertical Res.	Horizontal Resolution	Measurement Accuracy	Measurement Precision	Sampling Interval	Data Latency
AK-Yukon Precip. Accum.	T	Regional	NA	4 km	1 mm/hr	1 mm/hr	1 hr	1 hr
	O	Regional	NA	1 km	0.25 mm/hr	0.25 mm/hr	1 hr	0.5 hr
AK-Yukon Precip. Rates	T	Regional	NA	4 km	1 mm/hr	1 mm/hr	1 hr	1 hr
	O	Regional	NA	1 km	0.25 mm/hr	0.25 mm/hr	1 hr	0.5 hr

CBRFC Precipitation Requirements

Requirement	T/O	Geo Coverage	Vertical Res.	Horizontal Resolution	Measurement Accuracy	Measurement Precision	Sampling Interval	Data Latency
Precip. Accum.	T	Regional	NA	4 km	1 mm/hr	1 mm/hr	1 hr	0.5 hr
	O	Regional	NA	1 km	0.5 mm/hr	0.25 mm/hr	5 min	0.25 hr
Precip. Occur .GE.0.25mm	T	Regional	NA	4 km	10%	5%	3 hr	1 hr
	O	Regional	NA	1 km	5%	1%	1 hr	0.25 hr
Snow Accum.	T	Regional	NA	4 km	2.5 mm SWE	2.5 mm SWE	24 hr	1 hr
	O	Regional	NA	1 km	2.5 mm SWE	2.5 mm SWE	1 hr	1 hr

WGRFC Precipitation Requirements								
Requirement	T/O	Geo Coverage	Vertical Res.	Horizontal Resolution	Measurement Accuracy	Measurement Precision	Sampling Interval	Data Latency
1 HR Precip. Accum.	T	CONUS+MX	NA	4 km	1 mm/hr	1 mm/hr	1 hr	10 min
	O	CONUS+MX	NA	1 km	0.25 mm/hr	0.25 mm/hr	1 hr	5 min
24 HR Precip. Accum.	T	CONUS+MX	NA	4 km	1 mm/hr	1 mm/hr	24 hr	30 min
	O	CONUS+MX	NA	1 km	0.25 mm/hr	0.25 mm/hr	24 hr	30 min
Precip. Rates	T	CONUS+MX	NA	4 km	1 mm/hr	1 mm/hr	15 min	10 min
	O	CONUS+MX	NA	1 km	0.25 mm/hr	0.25 mm/hr	15 min	5 min

NESDIS/NCDC and Climate Goal Requirements (Dongsoo Kim):

Observation Requirement	Program Acronym	Prty	T / O	Geo. Coverage	Vertical Res.		Hor. Res.		Meas. Accuracy		Sampling Interval		Data Latency		Long-Term Stability	
					V	U	V	U	V	U	V	U	V	U	V	U
Precipitation Amount																
Precipitation Amount: Surface (measured 1.5m above surface)	CL-COM_Atmos	1	T	CONUS+AK+HI	na	na	100	km	0.5	mm	1	min	1	hr	0.5	mm
			O	CONUS+AK+HI	na	na	100	km	tbs	tbs	tbs	tbs	tbs	tbs	tbs	tbs
Precipitation Rate																
Precipitation: Rate	CL-COM_Atmos	1	T	Global	na	na	285	km	0.25	mm/hr	15	min	6	hr	0.5	mm/hr/decade
			O	tbs	tbs	tbs	tbs	km	tbs	tbs	tbs	tbs	tbs	tbs	0.003	mm/hr/decade
Precipitation Type																
Precipitation: Type	CL-COM_Atmos	1	T	Global	na	na	1000	km	4	types	1	hr	tbs	tbs	tbs	tbs
			O	tbs	tbs	tbs	tbs	km	tbs	tbs	tbs	tbs	tbs	tbs	tbs	tbs
Radiances: Microwave																
Radiances: Microwave	CL-COM_Atmos	1	T	Global	na	na	10	km	0.15	%	1	hr	6	hr	0.03	%/decade
			O	tbs	tbs	tbs	tbs	tbs	tbs	tbs	tbs	tbs	tbs	tbs	tbs	tbs

NWS/Environmental Modeling Center (Jesse Meng and Glenn White):

- Verification for NWP model forecasts
- As input into Land Data Assimilation System (LDAS) (both global and North America)
- GPM radiances as input into NWP model assimilation

NWS/Hyrometeorological Prediction Center (Mike Bodner):

- Derive TPW products from GPM radiances for monitoring of atmospheric rivers
- GPM precipitation rates for real time use for short term hydrological events

JCSDA Requirements (Min-Jeong Kim and Lars-Peter Riishojgaard):

Observation Requirement	T/O	Geographic Coverage	Vertical Resolution	Horizontal Resolution	Measurement Accuracy	Measurement Precision	Sampling Interval	Data Latency	
Microwave Radiances	T	Global		raw	A few tenth degree	A few tenth degree		120	min
	O	Global		raw	A few tenth degree	A few tenth degree	Once per hour	28	min
Radar Reflectivity	T	Global	raw		TBD	TBD		120	min
	O	Global	raw		TBD	TBD	Once per hour	28	min

OAR/Earth System Research Laboratory (Seth Guttman)

Observation Requirement	T/O	Geographic Coverage	Vertical Resolution		Horizontal Resolution		Measurement Accuracy		Measurement Precision		Sampling Interval		Data Latency	
Microwave radiances	T	Global			40	km					3	hr	1	hr
	O	Global			10	km					1	hr	0.5	hr
Radar reflectivity	T	Global	500	m	10	km					3	hr	1	hr
	O	Global	250	m	5	km					1	hr	0.5	hr
TPW Retrieval	T	Global	n/a		n/a		1	mm	2	mm	3	hr	1	hr
	O	Global	n/a		n/a		0.5	mm	1	mm	1	hr	0.5	hr
	T													
	O													

OAR/Earth System Research Laboratory (Steve Albers)

- GPM DPR – validation of WRF model cloud physics
- GPM radiances for direct assimilation into WRF model

OAR/Earth System Research Laboratory (Jim Verdin)

- Daily accumulations at 10 km scale for drought monitoring
- Fill in data voids in surface radar and gauge networks

OAR/National Severe Storms Laboratory (J.J. Gourley and Ken Howard)

- GPM precipitation products would be integrated into the Q2 rainfall product

Appendix C-2: Observing Systems listed in the NOSA database

GCMD Variable	Title	User/Obs Sys	Life Cycle Phase	Sensing Element
Precipitable Water: Profiles				
	nesdis-poes layer precipitable water (amsub; MHS)	NESDIS - POES	Operations	nesdis-poes-amsu-b; MHS
	nesdis-poes layer precipitable water (amsub)	NESDIS - POES	Operations	nesdis-poes-amsu-b
	nesdis-goes k/n-precipitable water	GOES I/P	Operations	nesdis-goes i/m-sounder
	nesdis-goes i/j-precipitable water	GOES I/P	Operations	nesdis-goes i/m-sounder
	nesdis-poes layer precipitable water	JPSS	Planned	
Precipitable Water: Total				
	dscovr - precipitable water	DSCVR	Concept	dscovr-epic
	nesdis-goes m/p-dpi tpw	GOES I/P	Operations	nesdis-goes i/m-sounder
	nesdis-goes op-precipitable water	GOES I/P	Operations	nesdis-goes nop-sounder
	nesdis-jpss-mis (cat.ii) precipitable water, total	JPSS	Planned	nesdis-jpss-mis (cat.ii)
	fy3-mwri total precipitable water	FY3 Series	Operations	cast-fy3 microwave radiation imager (mwri)
	nesdis-goes i/l-dpi tpw	GOES I/P	Operations	nesdis-goes i/m-sounder
	oar-gps-met ipw precip water	OAR - GPS Met	Operations	oar-gps water vapor sensor-cors gps receiver
	oar-gps-met ipw precip water (mm)	OAR - GPS Met	Operations	oar-gps water vapor sensor-cors gps receiver
Precipitation Amount				
	oar/gsd-cwop precipitation amount	OAR - CWOP	Operations	oar-cwop rain gauge
	faa-tdwr precipitation	FAA - TDWR	Operations	faa-tdwr radar reflectivity
	nws-ushcn-m precipitation amount	NWS - HCN-M	Planned	nws-ushcn-m geonor precipitation gauge
	nws-asos-precipitation (awpag)	NWS - ASOS	Operations	nws-asos-awpag precipitation gauge
	nws-asos-precipitation (htb)	NWS - ASOS	Operations	nws-asos-htb-heated tipping bucket
	nws-asos-precipitation amount (sensor-misc)	NWS - ASOS	Operations	nws-asos-sensor-misc
	nws-coop-precipitation amount	NWS - COOP	Operations	nws-fnp-precipitation
	nws-nexrad-precipitation	NWS - NEXRAD	Operations	nws-nexrad-radar reflectivity
	nws-phased array radar par precipitation	NWS - PAR	Development	nws-phased array radar
	nasa-trmm-precipitation amount	NASA - TRMM	Operations	nasa-trmm-precipitation radar
	gpm constellation- precipitation amount	GPM Constellation	Development	gpm constellation dual frequency precipitation radar
	nws-nexrad dual polarization precipitation	NWS - NEXRAD Dual Polarization	Development	nws-nexrad dual polarization radar
	nws-coop-precipitation	NWS - COOP	Development	nws-sensing- recording gauges
	nasa - gpm precipitation amount	NASA - GPM	Operations	nasa-gpm- dual frequency precipitation radar
	nesdis-uscrn-precipitation amount	NESDIS - USCRN	Operations	nesdis-uscrn-precipitation amount
	oar-recon rainfall	OAR - ReCON	Development	oar-recon csi rain gage
	wmo-www-rbsn-precipitation amount	WMO - RBSN	Operations	wmo-www- rbsn various surface instruments
	nos-swmp-rainfall	NOS - SWMP	Operations	nos-swmp-rain gauge
	oar-sebn precipitation amount	OAR - SEBN	Planned	oar-sebn precipitation
	oar-raman-precipitation	OAR - RAMAN	Operations	oar-raman-precipitation sensor
	oar-oco reference stations-precipitation (imet)	OAR - OCO Reference Stations	Operations	oar - stratus - imet

GCMD Variable	Title	User/Obs Sys	Life Cycle Phase	Sensing Element
Precipitation Amount: Snow Water Equivalent				
	faa-tdwr snow fall water equivalent	FAA - TDWR	Operations	faa-tdwr spectrum width
	nesdis-poes snow water equivalent orbital	NESDIS - POES	Operations	nesdis-poes-amsu-a
	nws-asos-freezing rain	NWS - ASOS	Operations	nws-asos-zr
	nws-gamma-snow water equivalent (pha)	NWS - GAMMA	Operations	nws-gamma-pha
	nws-gamma-snow water equivalent (scintillation detector)	NWS - GAMMA	Operations	nws-gamma-scintillation detector
	nws-gamma-snow water equivalent (upward-looking detector)	NWS - GAMMA	Operations	nws-gamma-upward-looking detector
	nws-nexrad dual polarization snow water equivalent	NWS - NEXRAD Dual Polarization	Development	nws-nexrad dual polarization radar
	nws-nexrad-snow fall water equivalent	NWS - NEXRAD	Operations	nws-nexrad-spectrum width
	nws-phased array radar par snow water equivalent	NWS - PAR	Development	nws-phased array radar
Precipitation Rate				
	nasa - gpm - precipitation rate	NASA - GPM	Development	nasa-gpm- dual frequency precipitation radar
	nasa-trmm-precipitation rate	NASA - TRMM	Operations	nasa-trmm-precipitation radar
	nasa/conae aquarius precipitation	NASA/CONAE Aquarius	Planned	conae aquarius mwr
	gpm constellation- precipitation rate	GPM Constellation	Development	gpm constellation dual frequency precipitation radar
	nesdis-goes r/s - rainfall rate/qpe (t)	GOES R/S	Planned	nesdis-goes r/s- abi
	jaxa-gcom-w1 precipitation rate: oceans	JAXA-GCOM-W1	Planned	jaxa-gcom-w1 amsr2
	nasa - aqua - precipitation type/rate	NASA - Aqua	Operations	nasa-aqua-amsr-e
	nesdis-poes-precip (amsu-b)	NESDIS - POES	Operations	nesdis-poes-amsu-b
	nesdis-poes-precip (mhs)	NESDIS - POES	Operations	nesdis-poes-mhs
	oar-glerl-recon/icon alternative - csi rain gauge - rainfall rate	OAR - RECON/ICON Alternative	Concept	oar-glerl-recon/icon alternative - csi rain gauge
	nesdis-jpss-mis (cat.ii) precipitation rate	JPSS	Planned	nesdis-jpss-mis (cat.ii)
	nesdis-poes-precip (amsu-a)	NESDIS - POES	Operations	nesdis-poes-amsu-a
	nesdis-uscrn-precipitation presence	NESDIS - USCRN	Operations	nesdis-uscrn-wetness
	nesdis-uscrn-precipitation rate	NESDIS - USCRN	Operations	nesdis-uscrn-precipitation rate (secondary gauge)
	nesdis-dmsp-precipitation	NESDIS - DMSP	Operations	nesdis-dmsp-ssmis
	jaxa-gcom-w1 precipitation type/rate: land	JAXA-GCOM-W1	Planned	jaxa-gcom-w1 amsr2
	faa-tdwr precipitation rate	FAA - TDWR	Operations	faa-tdwr radar reflectivity
	nws-nexrad- precipitation rate	NWS - NEXRAD	Operations	nws-nexrad-radar reflectivity
	nws-tao-rain rate	NWS - TAO	Operations	nws-tao-sensing element
	oar-pirata-rain rate	OAR-PIRATA	Operations	oar-pirata-sensing element
	oar-rama-rain rate	OAR-RAMA	Operations	oar-rama-sensing element
	nesdis-goes i/p-precipitation (conus)	GOES I/P	Operations	nesdis-goes i/m-imager
	nesdis-goes i/p-precipitation (conus) (nop)	GOES I/P	Operations	nesdis-goes nop-imager
	nesdis-goes i/p-precipitation (hemi)	GOES I/P	Operations	nesdis-goes nop-imager
	cnes-megha-tropiques-madras-precipitation rate	CNES-Megha-Tropiques	Development	cnes-megha-tropiques-madras
	fy3-mwri rain rate	FY3 Series	Operations	cast-fy3 microwave radiation imager (mwri)
	nos-creios-icon-atlantic-vaisala rain rate	CREIOS-ICON-Atlantic	Operations	nos-creios-icon-atlantic - vaisala weather station (meteorological)
	eumetsat - meteosat-precipitation type/rate	EUMETSAT-Meteosat	Operations	eumetsat-meteosat-vissr
	eumetsat - msg-precipitation type/rate	EUMETSAT-Meteosat MSG	Operations	msg spinning enhanced visible and infrared imager
	isro - insat-3a - precipitation type/rate	ISRO - INSAT-3A	Operations	isro - insat-3a - vhrr
	nasa - path - precipitation rate	NASA - PATH	Concept	nasa-path instrument
	nasa-trmm-microwave imager-precipitation rate	NASA - TRMM	Operations	nasa-trmm-microwave imager
	oar-etl-bao-precipitation	OAR - BAO	Operations	oar-cmdl bao observatory measurement package

GCMD Variable	Title	User/Obs Sys	Life Cycle Phase	Sensing Element
Precipitation Type				
	nesdis-jpss-mis (cat.ii) precipitation type	JPSS	Planned	nesdis-jpss-mis (cat.ii)
	gpm constellation- precipitation type	GPM Constellation	Development	gpm constellation dual frequency precipitation radar
	jaxa-gcom-w1 precipitation type: land	JAXA-GCOM-W1	Planned	jaxa-gcom-w1 amsr2
	jaxa-gcom-w1 precipitation type: oceans	JAXA-GCOM-W1	Planned	jaxa-gcom-w1 amsr2
	nasa - gpm - precipitation type	NASA - GPM	Operations	nasa-gpm- dual frequency precipitation radar
	nasa-trmm-precipitation type	NASA - TRMM	Operations	nasa-trmm-precipitation radar
	nws-asos precipitation type (enhancement)	NWS - ASOS	Development	nws-asos precipitation type enhanced
	nws-asos-precipitation type prewx	NWS - ASOS	Operations	nws-asos-ledwi
	wmo-www-rbsn-precipitation type	WMO - RBSN	Operations	wmo-www- rbsn various surface instruments
	nasa - path - precipitation type	NASA - PATH	Concept	nasa-path instrument
	NEXRAD dual-polarization hydrometeor classifier	NWS - NEXRAD	Operations	NEXRAD dual-polarization radar
Radiance: Microwave				
	nesdis-poes mhs 1b*	NESDIS - POES	Operations	nesdis-poes-mhs
	nesdis-poes amsu-b 1b	NESDIS - POES	Operations	nesdis-poes-amsu-b
	nesdis-poes brightness temperatures amsu-b	NESDIS - POES	Operations	nesdis-poes-amsu-b
	nesdis-poes amsu-a 1b	NESDIS - POES	Operations	nesdis-poes-amsu-a
	nesdis-poes brightness temperatures amsu-a	NESDIS - POES	Operations	nesdis-poes-amsu-a
	DMSP SSMIS brightness temperature	DMSP-SSMIS	Operations	DMSP-SSMIS
	nasa-GMI brightness temperature	NASA-GMI	Development	NASA-GMI
	JPSS ATMS brightness temperature	JPSS-ATMS	Development	JPSS-ATMS
	cnes-megha-tropiques-madras-brightness temperature	CNES-Megha-Tropiques	Development	cnes-megha-tropiques-madras
	GCOM-AMSR2 brightness temperature	GCOM-AMSR2	Development	GCOM-AMSR2
	cnes-megha-tropiques-saphir-brightness temperature	CNES-Megha-Tropiques	Development	cnes-megha-tropiques-saphir

Appendix C-3: Information Management Systems listed in the NOSA database

GCMD Variable	Title	User/Obs Sys	Life Cycle Phase
Precipitable Water: Profiles			
	nesdis-espc layer precipitable water (msps)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc composited precipitable water conus (sounder/ ssm/i)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc composited precipitable water hemisheric (sounder/ ssm/i)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc layer precipitable water (sounder)	IMS-Environmental Satellite Processing Center	Operations
Precipitable Water: Total			
	nesdis-espc total precipitable water (imager)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc total precipitable water (atovs)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc dpi total precipitable water (imager)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc dpi total precipitable water (sounder)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc gsip precipitable water	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc precipitable water index (gvi3)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc total precipitable water (blended)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc total precipitable water (msps)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc total precipitable water (sounder)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc total precipitable water mapped (mspps)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc total precipitable water mapped (ssm/i)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc total precipitable water orbital (mspps)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc total precipitable water orbital (ssm/i)	IMS-Environmental Satellite Processing Center	Operations
Precipitation Amount			
	nesdis-espc-nde-nup rainfall prediction (atms)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc interactive flash flood analysis (iffa) text	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc rainfall auto estimator (goes)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc interactive flash flood analysis (iffa) graphical	IMS-Environmental Satellite Processing Center	Operations
	nws-awips-mean areal precipitation	IMS-Advanced Weather Interactive Processing System	Operations
	Multisensor Precipitation Estimator (MPE)	IMS _ Advanced Weather Interactive Processing System	Operations
	High-Resolution Precipitation Estimator (HPE)	IMS _ Advanced Weather Interactive Processing System	Operations
	National Mosaic and Multisensor QPE (NMQ)	IMS - National Severe Storms Laboratory	Development
	Hydroestimator	IMS - NESDIS Center for Satellite Applications and Research	Operations
	CPC MORPHing Technique (CMORPH)	IMS - NWS Climate Prediction Center	Operations

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GCMD Variable	Title	User/Obs Sys	Life Cycle Phase
Precipitation Amount: Snow Water Equivalent			
	nesdis-espc snow water equivalent (ssm/i)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc snow water equivalent mapped (mspps)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc snow water equivalent orbital (mspps)	IMS-Environmental Satellite Processing Center	Operations
	Snow Data Assimilation System (SNODAS)	IMS - NWS-OHD_National Operational Hydrologic Remote Sensing Center	Operations
Precipitation Rate			
	nesdis-espc rain rate orbital (ssm/i)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc rain rate orbital (mspps)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc rain rate mapped (mspps)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc rain rate mapped (ssm/i)	IMS-Environmental Satellite Processing Center	Operations
	nws-awips-flash flood guidance	IMS-Advanced Weather Interactive Processing System	Operations
	nws-awips-flash flood statement	IMS-Advanced Weather Interactive Processing System	Operations
	nws-awips-flash flood warning	IMS-Advanced Weather Interactive Processing System	Operations
	nws-awips-flash flood watch	IMS-Advanced Weather Interactive Processing System	Operations
	nws-awips-flood potential outlook	IMS-Advanced Weather Interactive Processing System	Operations
	nws-awips-flood statement	IMS-Advanced Weather Interactive Processing System	Operations
	nws-awips-flood warning	IMS-Advanced Weather Interactive Processing System	Operations
	High-Resolution Precipitation Estimator (HPE)	IMS _ Advanced Weather Interactive Processing System	Operations
	National Mosaic and Multisensor QPE (NMQ)	IMS - National Severe Storms Laboratory	Development
	Hydroestimator	IMS - Center for Satellite Applications and Research	Operations
Precipitation Type			
	nesdis-espc maximum potential hail size (goes)	IMS-Environmental Satellite Processing Center	Operations
	nesdis-espc maximum theta-e difference	IMS-Environmental Satellite Processing Center	Operations
	nws-awips-hail index 59/hi	IMS-Advanced Weather Interactive Processing System	Operations
	NEXRAD dual-polarization hydrometeor classifier	IMS - NEXRAD-RPG; NWS-AWIPS	Operations
	Snow Data Assimilation System (SNODAS)	IMS - NWS-OHD_National Operational Hydrologic Remote Sensing Center	Operations
Radiance: Microwave			
	No Information Management Systems		