2nd NOAA User Workshop on the Global Precipitation Measurement Mission

Hosted by the National Oceanic and Atmospheric Administration
November 29 - December 1, 2011
College Park, MD

Executive Summary

Satellite measurements are a critical component of a global observing precipitation network since most surface measurements of precipitation are generally limited to the populated areas of the world. The upcoming Global Precipitation Measurement (GPM) Mission, a joint mission between the United States and Japan, will generate global precipitation data sets at 3-hour intervals with unprecedented accuracy. When merged with geostationary data, GPM will produce 30-minute global data. This data coverage directly relates to NOAA mission goals and objectives and presents an opportunity to prepare NOAA for routine ingest and processing of multiple data streams from the GPM core satellite (passive microwave and space-borne radar) and from the GPM constellation satellites that carry passive microwave sensors.

> **Critical to NOAA's mission success will be the ability to expand river, surface, and remote observations, and leverage the observations of partners… Climate observing systems are sustained and the state of the climate system is routinely monitored**. *- NOAA Goals*

The GPM Core Satellite is scheduled for launch in February 2014. GPM represents an expansion and follow-up to the successful Tropical Rainfall Measurement Mission (TRMM), which has provided operationally useful data far past its anticipated lifetime. NOAA's advance preparation for GPM, as detailed in a National Research Council Study, is critical if NOAA is to leverage the huge investment being made by the National Aeronautic and Space Administration (NASA) and the Japan Aerospace Exploration Agency (JAXA) and avoid a large gap between mission launch and data utilization at NOAA (NRC 2007). We hope that GPM will lead to use and maintenance of an operational satellite constellation for global precipitation that will serve NOAA and the overarching goals of the Global Earth Observation System of Systems.

The ***1st NOAA User Workshop on the GPM Mission in August 2010*** (see Ferraro et al. 2011) identified a strong need for GPM data across several NOAA line offices and programs. Building on this success, the ***2nd NOAA User Workshop on the GPM Mission*** (organized by NOAA's Steering Group on Precipitation Measurement from Space) focused on engaging users of precipitation products to define specific tasks that need to be accomplished over the next three years to enhance NOAA's ability to use GPM data. Over 60 participants attended the three-day workshop that included plenary talks from NESDIS, the National Centers for Environmental Prediction (NCEP) headquarters and the NASA GPM Program Office. In addition, panel discussions were led by topical area experts and four working groups (WGs). The working groups addressed the following primary topics from the first workshop:

- Enhancing Research and Development (R&D) and innovation of GPM-era data at NOAA
- Accelerating GPM data use at NOAA
- Data fusion
- Data delivery and formats

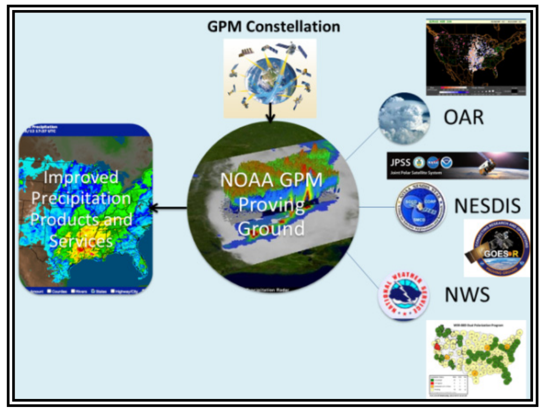
Each WG provided a set of recommendations in the form of tasks (with specific focal points, budget requirements, and funding sources/targets) to be completed over the next three years, leading up to the GPM-core satellite launch (February 2014) and its checkout. Further details will be presented in later sections of this report.

Major Recommendations from the Working Group

1. NOAA needs to prepare immediately to exploit GPM-era data and products through the establishment of a GPM Proving Ground. The Proving Ground will also serve as a coordinating group for GPM products at NOAA.

   Specifically, the Proving Ground will focus on data delivery and distribution, research and development, data fusion, and integration with other observations of precipitation, and accelerating GPM-era data use through existing testbeds, including:

   - Hydrometeorological Testbed
   - Climate Testbed
   - Joint Hurricane Testbed
   - Developmental Testbed and the Joint Center for Satellite Data Assimilation
   - Hazardous Weather Testbed
   - Aviation Weather Testbed

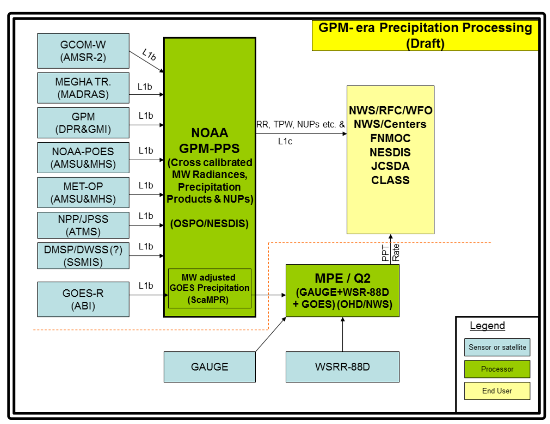


2. Complimentary to the activities within the GPM Proving Ground, NOAA should focus on the following areas of research and development to better exploit GPM-era data:

   - Continuity of operations from current passive microwave sensors into GPM-era sensors
   - Climate applications and model verification
   - Numerical Weather Prediction (NWP) assimilation (especially in precipitating atmospheres with both passive and active GPM-era sensors) and model verification
   - Data fusion with information from other sources and uncertainty estimation
   - Development of NOAA Unique Products (NUP) from GPM sensors such as total precipitable water and ocean surface winds.

3. Move toward a "One-NOAA" suite of precipitation products that can serve all aspects of NOAA mission goals related to water monitoring and prediction on the time and space scales required across NOAA.

4. Obtain specific NOAA requirements for GPM-era data through the development of the Level 1 Requirements Document and subsequent Transition Plan for a NOAA-specific, operational version of NASA's GPM Precipitation Processing System (PPS), including the necessary IT infrastructure to meet latency requirements.



At the time of this report writing, a new NOAA Fiscal Year (FY) 2014 budget initiative is being considered as part of a broad-based NOAA satellite enterprise approach to obtain the proper infrastructure to support such missions outside of NOAA's baseline GOES-R and JPSS programs; GPM is contained within this initiative. If such an initiative were to move forward and become successful, these resources would be able to accomplish the majority of the tasks identified within the workshop.

Finally, it is envisioned that a follow-on workshop will be held in late 2012/early 2013 that will focus on the GPM Proving Ground and its priorities, as well as research priorities related to data fusion and NOAA Unique Products.

Acknowledgements

Report prepared by:

NOAA's Steering Group on Precipitation Measurement from Space and Workshop Working Group Leads and Scribes:

Alan Basist	WeatherPredict Consulting, Inc.
Ralf Bennartz	UW-Madison
Rob Cifel	NOAA/OAR, (Steering Group Co-Chair)
Ralph Ferraro	NOAA/NESDIS, (Steering Group Co-Chair)
David Kitzmiller	NOAA/NWS, (Steering Group Co-Chair)
Chandra Kondragunta	NOAA/NESDIS
Tilden Meyers	NOAA/OAR
Christopher Miller	NOAA/OAR
Marty Ralph	NOAA/OAR
Timothy Schneider	NOAA/OAR
Tom Schott	NOAA/NESDIS
Bill Sjoberg	NOAA/NWS
James Yoe	NOAA/NWS
Fuzhong Weng	NOAA/NESDIS
Allen White	NOAA/OAR
Pingping Xie	NOAA/NWS
Limin Zhao	NOAA/NESDIS

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Ken Carey	Noblis, Inc.
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Introduction

NOAA relies on space-borne passive microwave (MW) sensors flown aboard a variety of operational and research satellites to support its mission goals. Satellites supplement ground precipitation observations, where limitations exist with ground data such as over sparsely populated areas, mountainous regions, and over coastal and open water regions. 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 NOAA weather and climate applications. The data for these products are derived from a number of satellite sensors deployed by various partner agencies. Presently, this set of satellite sensors includes the NOAA Advanced Microwave Sounding Unit (AMSU), the European Meteorological Satellite (EUMETSAT) Microwave Humidity Sounder (MHS), the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager/Sounder (SSM/IS), the NASA Tropical Rainfall Measurement Mission (TRMM) Microwave Imager (TMI), and the Department of Defense WindSat. Recently, new sensors such as the Advanced Technology Microwave Sounder (ATMS) on the Suomi National Polar-orbiting Partnership (NPP) satellite and the Microwave Analysis and Detection of Rain and Atmospheric Systems (MADRAS) and Sounder Atmospheric Profiling Humidity Radiometer (SAPHIR) on the Megha-Tropiques (M-T) satellite will be used to fill in observational voids in this “virtual constellation” of Low Earth-orbiting (LEO) satellites.

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 uses 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 three 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 14th year of operation, but will expand its coverage to near-global. More details on the GPM mission can be found in the first workshop report (Ferraro et al. 2011), as well as at NASA’s GPM web site (http://pmm.nasa.gov/GPM).

The GPM core satellite and constellation members will provide passive microwave radiances, DPR radar reflectivities, precipitation rates, and other related products (e.g., total precipitable water, ocean surface wind speed, etc.) with spatial resolution of 5 – 25 km and near-global coverage every three hours or less, that can be used to support the NOAA Weather and Water and Climate strategic goals.

Examples include:

1. Weather Forecasting and Analysis (NWS, NESDIS, OAR): GMI’s unique orbit allows it to temporally sample hurricanes when no polar orbiters can and allows real-time support for:
    - Tropical cyclone monitoring

- Quantitative Precipitation Estimates (QPE) and Forecasts (QPF)
- Hazards tracking and analysis (e.g., flooding and flash flooding)
- Hydrological forecasts
- Monitoring of atmospheric rivers
- Ocean surface wind vectors

2. Numerical Weather Prediction (NWS, JCSDA, OAR):

- Assimilation of microwave radiances and space-borne precipitation radar reflectivities into both global and regional forecast models
- Derived products provided for model diagnosis and verification

3. Climate Monitoring, Analyses, and Assessments (NWS, NESDIS):

- Calibration of microwave radiances from the core satellite (which is in a precessing orbit that allows for ample overlap with the constellation radiometers) for continuity of hydrological product time series dating back to the 1980s
- Improved real-time monitoring, analysis, and diagnosis of short-term climate variability enabled by high-resolution global precipitation analyses constructed through integration of the GPM passive microwave (PMW) observations with other NOAA observations for an extended period (from 1998)

Background and Objectives

Purpose: The purpose of the *2nd NOAA User Workshop on the GPM Mission*, co-sponsored by NESDIS, NWS and OAR, is to further build from the topical areas identified in the *1st NOAA User Workshop on the GPM Mission* (Ferraro et al. 2011) and to develop specific, traceable actions to be carried out over the next one to three years, leading up to GPM-core launch (February 2014) and through its post-launch check out. Specifically, the meeting was organized around four primary topical areas:

- Enhancing R&D and innovation of GPM-era data at NOAA
- Accelerating GPM data use at NOAA
- Data Fusion
- Data delivery and formats

The three-day workshop, hosted by the University of Maryland's Earth System Science and Interdisciplinary Center (ESSIC) in College Park, Maryland, was attended by nearly 60 people (see Appendix A) and was organized as follows (see Appendix B for complete agenda):

Day 1 (November 29):

- Plenary talks by NOAA and NASA providing insight to importance of GPM and mission status
- Panel discussions centered on the overarching themes of the workshop. The panelists were chosen prior to the workshop by the organizers and were provided a set of questions to consider for their briefings (see Appendix C)

Day 2 (November 30):

- NASA GPM Precipitation Processing System (PPS) briefing by NASA
- Working group organization, expectations, and initial sessions, followed by a group plenary session

Day 3 (December 1)

- Group plenary session, final working group meetings, final group plenary

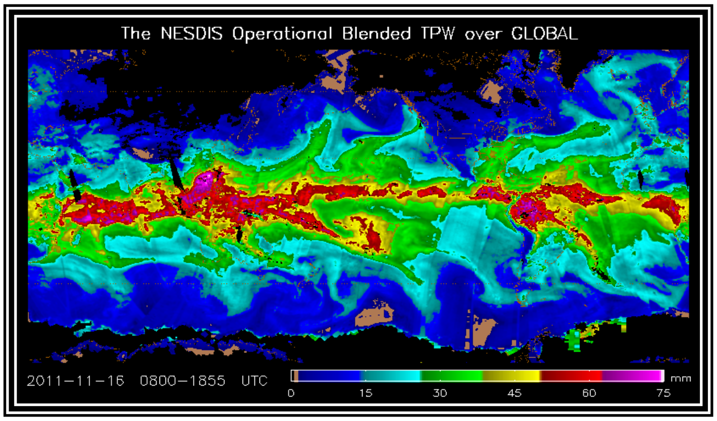
A summary of these talks is provided in Section 4 of this report. All of the talks can be found at http://www.star.nesdis.noaa.gov/star/meeting_GPM2011_agenda.php.

Summary of Presentations

Session 1: Overview

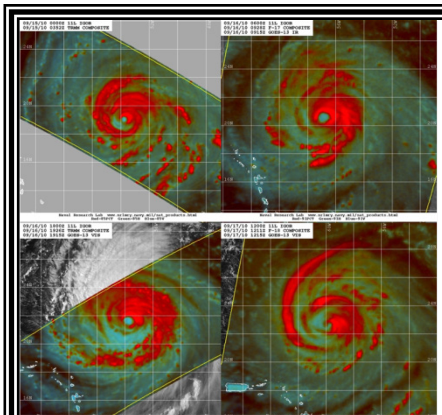
Session Chair: Ken Carey, Noblis, Inc.

Charles Baker, Deputy Assistant Administrator for NOAA's Satellite and Information Services, led off by providing a charge to the workshop participants. He summarized the innovativeness of GPM from NOAA's perspective and how it is closely aligned to NOAA's mission strategies.



He also described how GPM fulfills NESDIS's investment priorities and the leveraging opportunities it offers. Finally, he presented several examples of where GPM-era data will improve current operational NOAA satellite products derived from multi-satellite data sets. Despite potential budget challenges, Dr. Baker was excited about NOAA's future use of GPM data and charged the workshop audience to develop the high-impact, innovative tasks that NOAA needs to carry out over the next few years leading up to the GPM-core satellite launch.

William Lapenta, Acting Director, NOAA/NCEP/ Environmental Modeling Center (EMC), presented a thorough overview on the potential applications of GPM data at NCEP. Contributions were provided by several of the NCEP centers, including the Storm Prediction Center (SPC), Aviation Weather Center (AWC), Hydrometeorological Prediction Center (HPC), National Hurricane Center (NHC), Climate Prediction Center (CPC), and EMC. Satellite-derived precipitation products and associated microwave radiances and imagery are currently used across these centers. Improved data and products from GPM-era sensors would provide continuity from the present forward and offer enhancements to present capabilities. Such data would be used in existing testbeds at the various NCEP centers. In addition, NCEP could provide valuable feedback to the satellite scientists in terms of data quality, etc.



Eyewall replacement cycles in Hurricane Igor from multiple satellites 13-18 Sep 2010

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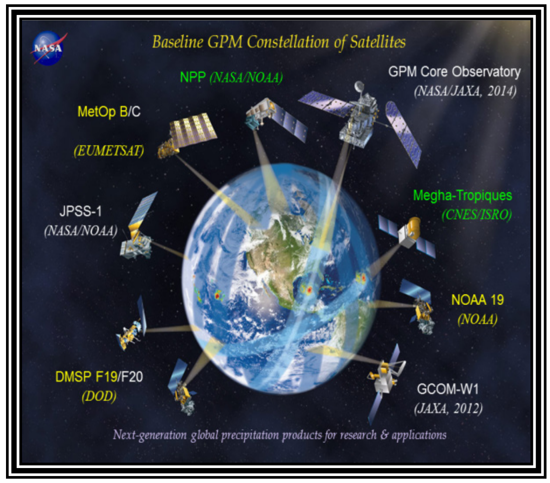
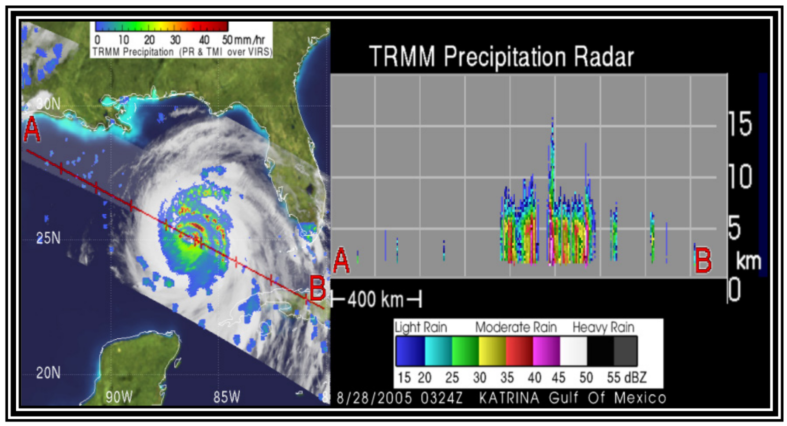


Gail Skofronick-Jackson, Deputy GPM Project Scientist at NASA / Goddard Space Flight Center (GSFC), provided an overview of the current status of the GPM Mission and related science. The GPM core satellite launch has been postponed approximately six months (now February 2014) primarily due to the impact of the recent earthquake in Japan. Recent launches of GPM constellation satellites, M-T and NPP, are exciting developments in this GPM era and NASA anxiously awaits other constellation launches of METOP-B and Global Change Observation Mission, Water (GCOM-W), in 2012. International collaborations are a key component of GPM, including several ongoing and upcoming ground validation projects that focus on various aspects of precipitation microphysics, hydrology and product validation.



Dailia Kirschbaum, GPM Applications Scientist, provided an excellent background on some of the primary applications that GPM can support, including tropical cyclone tracking and three-dimensional precipitation structure, extratropical storm tracking, NWP data assimilation and validation, hydrological applications, land hazard forecasting (e.g., floods and landslides), and disease outbreaks. She also expanded upon recent education and outreach activities, including an improved web site and outreach team.

Erich Stocker, Manager of the GPM PPS, spoke on November 30, but his presentation is summarized in this opening plenary session. Detailed information regarding the PPS algorithms and data products was presented. Additionally, product latency for the GPM-core satellite (which will be vastly improved over TRMM latency) and constellation members were provided.

Toolkit ID	Size in MB	Description
1AGMI	58.16	GMI unpacked packet data
1BGMI	90.72	GMI Brightness Temperatures
1CGMI	52.51	GPM Common Calibrated Brightness Temperature
GMIBASE	107.96	GMI Antenna Temperatures
1BKa	272.03	Ka Power
1BKu	344.47	Ku Power
2AGPROFGMI	75.23	Radiometer Precipitation/profiling
2BCMB	2970.48	L-2 Combined DPR and GMI
2ADP	1928.56	DPR precipitation
2AKa	970.85	Ka precipitation
2AKu	1254.16	Ku precipitation
3IMERGH	181.44	I-MERG 30-minute (.1 x .1 grid)
3IMERGM	58.32	I-MERGE monthly (.1 x .1 grid)

The PPS will use a "Level 1C" inter-satellite calibrated radiance data set to drive the passive microwave-derived products. This is a feature unique to GPM and should be of tremendous value to NOAA. Finally, data formats (nominally in HDF5) and sub-setting options were described.

Session 2 – 5: Panel Discussions

The next part of the workshop focused on panel discussions for the four overarching themes. Each of the panelists, representing a cross-section of expertise from NOAA, NASA, and academia, was presented a set of questions by the thematic leads to capture their perspective on different issues (see Appendix C). The following sections of the report summarize the presentations given by the panelists.

Session 2: Enhancing R&D and Innovation of GPM-Era Data at NOAA

Session Chair: Allen White, NOAA/OAR

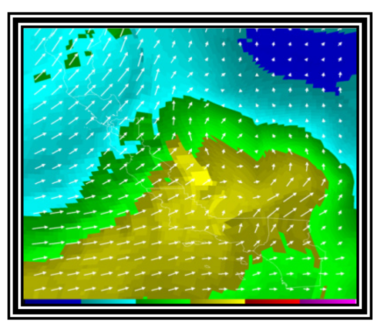
For NOAA to take full advantage of GPM-era data and products, a well-coordinated and funded effort dedicated to state-of-the-art research and development (R&D) is urgently needed. This was the main objective of this panel session. The first panelist, Brad Ferrier from NOAA/NWS/NCEP, spoke about the need for GPM data to help enhance NCEP models in both data assimilation and verification. Most of these enhancements would be accomplished through the Community Radiative Transfer Model (CRTM), the Global Forecast System (GFS), and the North American Mesoscale (NAM) model. Having data in the proper Binary Universal Form for the Representation of Meteorological Data (BUFR) and the Gridded Binary (GRIB) formats is crucial for the use of GPM-era data.

GPM-era data and products will enhance NCEP models and the JCSDA Community Radiative Transfer Model through the assimilation of passive microwave radiances and radar reflectivities under all weather conditions.

Min-Jeong Kim, representing the Joint Center for Satellite Data Assimilation (JCSDA), spoke about the desire to expand NWP data assimilation to cloudy and precipitating conditions. This is perhaps one of the most challenging problems that this community faces today. Progress is being made with AMSU and SSMIS and the hope is to extend this progress into the GPM era, especially with the core satellite (e.g., GMI). DPR data can be useful: (1) for validating the cloud and precipitation analyses after assimilating cloudy radiance observations, and (2) for validating performance of the NWP models' cloud microphysics schemes.

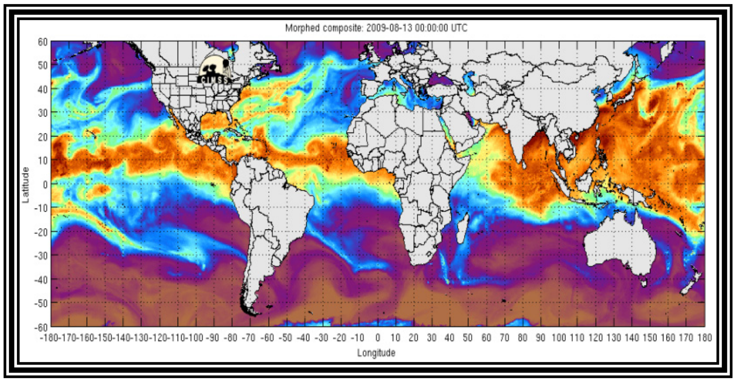
David Kitzmiller of NOAA/NWS/OHD, spoke about GPM's potential contribution to the emerging Integrated Water Resources Science and Services (IWRSS) program, a joint center among NOAA, the United States Geological Survey (USGS) and the United States Army Corp of Engineers. In particular, GPM-era products would serve as gap fillers for current satellite and surface observing systems that NOAA relies on. Areas of particular concern are northern Mexico, the intermountain western states, and Alaska.

Chris Kummerow of Colorado State University, and the lead for NASA's GPM radiometer algorithm development, stated that an area needing considerable research and development is the merging of precipitation products at a regional scale. He felt that NOAA needs to become the leader in this effort. Additionally, uncertainties in each input data source need to be quantified before useful merged products can be developed.



GPM-era precipitation products will serve as gap fillers for the present satellite and surface-based observing systems presently used in NOAA.

Pingping Xie, NOAA/NWS/NCEP, focused his discussion on the need for GPM Level-3 products to enhance NOAA applications of the data. Similar to what was presented by the previous panelist, he stressed the continued need for NOAA to lead data merging R&D and to also better coordinate activities at NOAA with the NASA GPM program. Additionally, he urged that NOAA consider a "One-NOAA" program to better consolidate its wide array of precipitation products to better support the wide user base for these data.



The final panelist of the session, **Ralf Bennartz** of the University of Wisconsin, identified forecasting and nowcasting, NWP data assimilation, and climate as the three primary areas where NOAA should enhance R&D with GPM-era data and products. Examples such as blended Total Precipitable Water (TPW), lake-effect snowfall, cloudy/precipitating assimilation, CRTM enhancements (e.g., improved absorption models and radar simulator), and the use of the GPM core satellite to anchor passive microwave sensor calibration were all discussed.

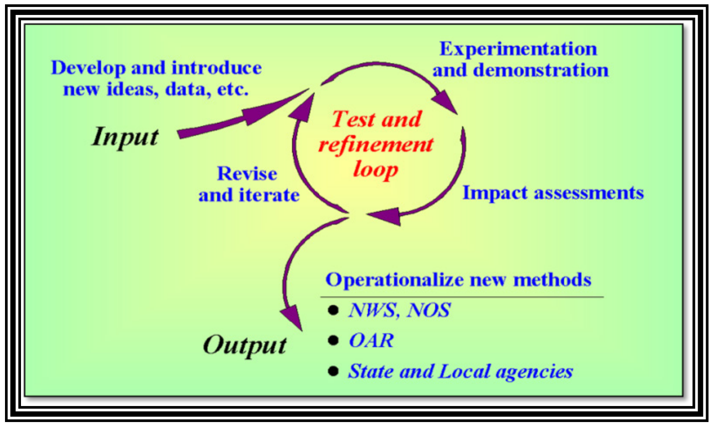
NOAA and its Cooperative Institute partners should continue to develop new and improved techniques to merge multi-satellite products to enhance their usefulness in weather analysis and forecasting, as well as climate applications. In addition, NOAA-derived, GPM-era, valued-added products such as TPW are needed and would contribute to these blended products.

Session 3: Accelerating GPM Data Use at NOAA

Session Chairs: Tim Schneider, NOAA/NWS & Pingping Xie, NOAA/NWS

The objective of this session was to examine how new information and capacity brought in by the future GPM Mission can be capitalized on to improve NOAA research, operations, and service activities in a timely manner. Tim Schneider of NOAA/NWS/OHD introduced the topic and emphasized the critical importance of developing an optimal strategy for the transition. Discussion was stimulated by presentations from a balanced mix of product developers, training experts, end users, and program managers, covering various aspects of a Research-to-Operations (R2O) transition.

Rob Cifelli, from the NOAA/OAR/Earth System Research Laboratory (ESRL), the first speaker of the panel session, focused his discussion on the use of testbeds at NOAA as a way to accelerate GPM data use. In particular, the Hydrometeorology Testbed (HMT) is a logical place to serve as a proving ground for Quantitative Precipitation Estimates (QPE). Additionally, he presented some ideas on a new QPE Proving Ground concept for NOAA.



Jin Huang, NOAA/NWS/NCEP and the Director for NOAA's Climate Testbed (CTB), gave an overview of CTB and its linkages to NCEP's Climate Prediction Center (CPC). She provided examples of how CTB can be used to transfer GPM products to NOAA operations, including testing of climate monitoring tools and use in climate model diagnosis.

The use of existing NOAA testbeds and other research-to-operations facilities, like the NASA Short-term Prediction Research and Transition (SPoRT) Center, is crucial to accelerate the use of GPM-era products at NOAA. There are many current opportunities that can be used through prototype GPM products.

Tom Schott, from the NESDIS/OSD/Systems Engineering and Integration Division (SEID), described some of the current hydrological satellite products provided by the NESDIS Environmental Satellite Processing Center (ESPC). He recognized the outstanding NOAA requirements review that was accomplished as a result of the 1st NOAA User Workshop on the GPM Mission. Tom is the Chair for NOAA's Low Earth Orbiting Requirements Working Group (LORWG). He emphasized that NOAA needs to develop a GPM Level 1 Requirements Document (L1RD) and seek approval through the NOAA Observing System Council (NOSC). Validating the GPM Level 1 requirements will enable NOAA to focus GPM acquisition efforts to address the NOAA mission needs. The LORWG can assist the NOAA project manager in the development of the GPM L1RD.

Brian Motta, NOAA/NWS/Office of Climate, Water and Weather Services (OCWWS), stressed the importance of training for the National Weather Service Forecast Office (NWSFO) forecasters; for GPM, this could be accomplished through the NWS/Satellite Proving Ground.

Glenn White, NOAA/NWS/NCEP, spoke about GPM data use by NCEP NWP data assimilation systems. Keys for immediate use of these data by NCEP are for data providers to be in sync with the NCEP data requirements (i.e., formats, timeliness, etc.) and identifying how such data can benefit the NWP community. In addition to the assimilation of the data, the data will be useful for model validation.

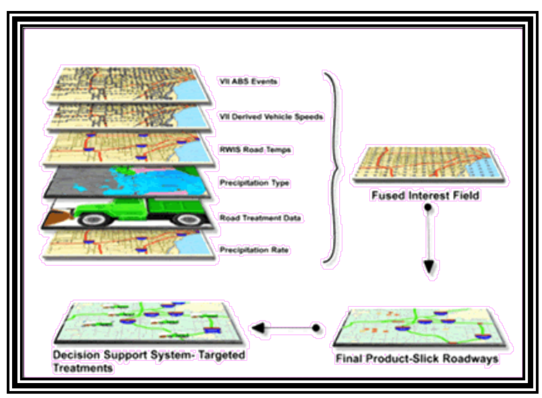
Providing timely data and in the proper formats are critical for using GPM data across NOAA. Additionally, proper training is needed for NWS forecasters.

Brad Zavodsky of NASA/Marshall Space Flight Center (MSFC) and the Short-term Prediction Research and Transition (SPoRT) Center, provided a detailed description of their experiences with transitioning new satellite products to operational users at NOAA. He outlined the steps necessary to ensure an efficient transition and identified several GPM-era products that are "ripe" for SPoRT Center-like activities, including Total Precipitable Water (TPW), QPE, and basic imagery.

Session 4: Data Fusion

Session Chair: Rob Cifelli, NOAA/OAR

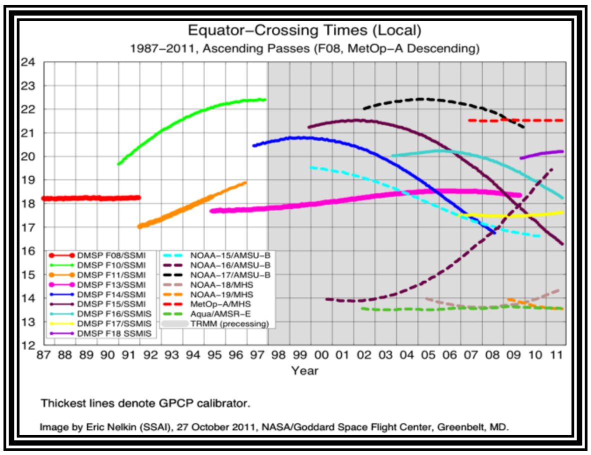
This session was built around a challenge that arose from the first workshop: "How can NOAA integrate GPM-era satellite data into merged products (e.g., Q2, MPE, CMORPH) and move toward a "One-NOAA" suite of precipitation products?" The panelists presented a range of views on this topic, from details of how robust data fusion is accomplished in a general framework to the importance of defining uncertainty in the observations and the need for a modular framework to advance QPE data fusion techniques. The main points from each panelist are summarized below.



V. Chandrasekar, Colorado State University, indicated that data fusion and image fusion are both needed to bring all data together into a coherent time and space framework. He explained that fusion can occur at four different processing stages: signal, pixel, feature, and decision-level, and that these different fusion stages are used for different applications. The most effective fusion methods include intensity/hue saturation, high-pass filtering, principal component analysis, analysis methods (e.g., wavelet transform), and neural networks.

Yu Zhang, NOAA/NWS/Office of Hydrologic Development (OHD), described how OHD has been trying to fuse satellite, radar, and gauges to improve QPE. Using the GOES-based SCaMPR method over Texas, they found that the satellite estimates added more value to QPE than gauges at short time scales (one-hour), but the opposite was true at longer time scales (24-hour). OHD will continue to test a number of satellite algorithms for QPE, as well as MPE, to do objective 3-way merging of satellite, gauges and radar.

NOAA needs to continue to improve the science related to data fusion and uncertainty estimation to better use precipitation products developed from satellite, radars and rain gauges.



The next panelist, **George Huffman,** of NASA/GSFC and algorithm lead for GPM's Level-3 products, described NOAA's involvement in GPM through the merging of satellite precipitation products into a new product called the Integrated Multi-satellitE Retrievals for GPM (IMERG). Critical to the success of IMERG and other data fusion techniques is determining the errors of the individual input sources. Ensemble approaches could be useful as a way to characterize uncertainty. Also, NWP model data should be part of the fusion process since short-term QPF does better than observations for winter precipitation in complex terrain. As a side note, Huffman mentioned that NOAA is running the risk of a microwave sensor data gap, in particular, with imager sensors.

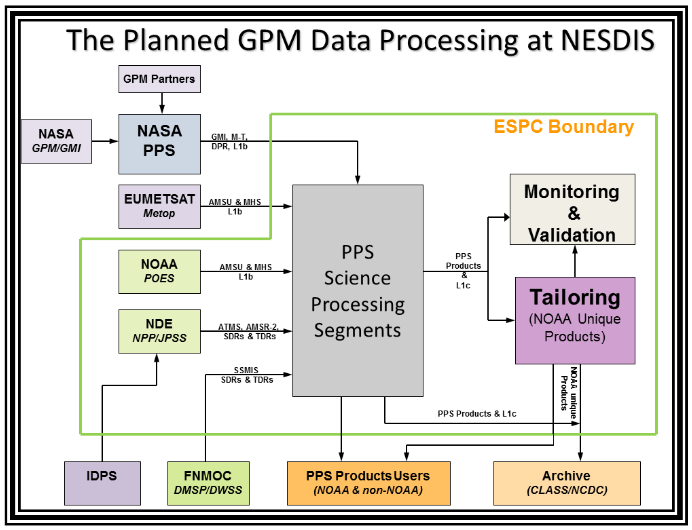
Robert Kuligowski, NOAA/NESDIS/Center for Satellite Applications and Research (STAR), stated that satellite IR data are critical for short-term satellite QPE due to the greater latency of microwave data. Blending MW and IR can either be Eulerian (fit IR data to MW rain rates) or Lagrangian (use IR data to interpolate MW data in time and/or space); Eulerian better captures rainfall between MW overpasses than Lagrangian; however, Eulerian fits of IR-to-MW rain rates result in loss of information. The SCaMPR product is Eulerian. IR data can be used to downscale GPM products to flood forecast resolutions and IR would also be useful to fill in gaps between radar networks, provided IR could be calibrated to radar. For data fusion advancement, a new concept of a Weather Research and Forecasting (WRF)-like framework would be useful: a modular rainfall retrieval algorithm with multiple components for each part of the rainfall solution problem.

Session 5: Data Delivery and Formats

Session Chair: Chandra Kondragunta, NOAA/NESDIS

NOAA requires GPM-era data with minimal data latency and in formats suitable for immediate use across NOAA. Additionally, NOAA Unique Products can be generated from the GPM radiometer constellation data. The panel members' discussion was centered on six questions (Appendix C) to identify needed actions to prepare for a potential transition of relevant portions of the NASA ground processing segment for the GPM and to determine specific NOAA-needs from the PPS and its related components (e.g. communication lines, computing power etc.).

Limin Zhao, of NOAA/NESDIS/Office of Satellite and Product Operations (OSPO), discussed the NOAA/NESDIS operational requirements and support for the GPM-era data products. She reviewed TRMM products and the real-time users currently supported by ESPC and discussed the requirements for supporting the continuity of operation with TRMM-like capability, in terms of product accuracy, time latency, etc. for the GPM era. She emphasized the need for developing and tailoring the capability to generate NOAA Unique Products to fulfill NOAA users' unique requirements for product quality, type, format, and distribution from the GPM core and constellation members. The discussion also covered the required transition of the PPS core capability from NASA to NOAA to ensure the 24/7 support for operational users. As NESDIS moves toward its IT enterprise approach, a consolidated processing and distribution solution will be adopted for future GPM data products.

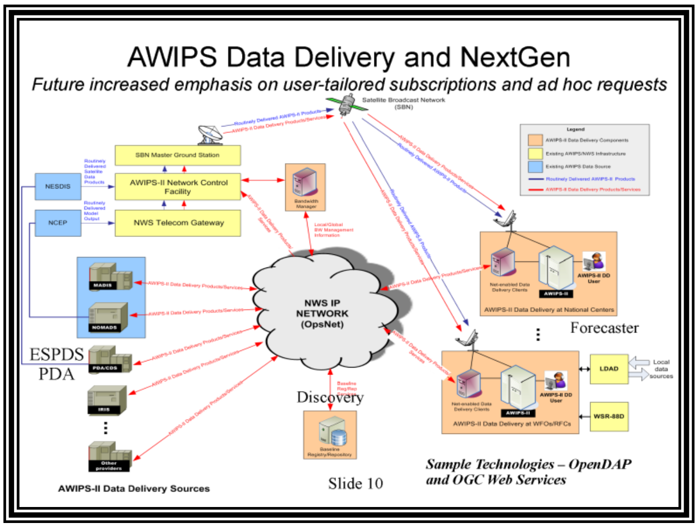


NOAA needs to transition relevant portions of NASA's Precipitation Processing System (PPS) and transform it to a 24 hour by 7 day per week system to meet NOAA operational requirements. In addition, the PPS needs to be modified to deliver NOAA Unique Products from GPM-era sensors, such as total precipitable water, ocean surface wind speed, and sea surface temperature.

Joseph Mani, of NOAA/NESDIS/OSPO, provided the National Satellite Operations Facility (NSOF) data center's perspective. The NSOF data center, which provides the ESPC systems with power, cooling and floor space, is a finite resource. To understand this concept and accept that doing business-as-usual is unsustainable in the long run will be the key to the ability of the ESPC to continue providing our customers with satellite products. To better use the data center resources, ESPC is moving from the business-as-usual approach to an Enterprise or Tier 1 approach. No longer will the center host science algorithms on a one algorithm per server configuration. Testing has shown that the current servers are being used at a peak rate of 10%.

The data center is looking to virtualization technologies to consolidate as many physical servers as possible and to increase the underlying system utilization to maximize the IT investments.

This is a short-term solution as the server sprawl would be shifted from the current physical state to a virtual state. The administrative burden would remain. The mid-term goal would be to better provision the virtual servers to handle more than one algorithm per server and fine-tune the control systems to allow this stacking to occur. The long-term goal would be to use the virtual environment for transactional systems as virtual machines such as database servers, management nodes, monitoring nodes, and logging nodes. The computational power would be leveraged in HPC (High Performance Computing) clusters with resources available to all the science algorithms. The change from business-as-usual to a long-term solution will require changes in corporate culture, the way products are developed, and core technologies. These changes are not to move the ESPC to the cutting edge of technology, but only to bring the ESPC on par with other government and private sector Tier 1 service providers.



Brian Gockel, NOAA/NWS, provided the NWS perspective. For NWS applications, the expected data latency is seconds for Short-Fuse Warnings such as Flash Flood Warnings, minutes for Watches/General Forecasts, and hours for Reanalysis/Survey/Climate applications. NWS is planning on enhancing communication lines between NESDIS nodes (e.g., NSOF) and NWS (e.g., Advanced Weather Interactive Processing System (AWIPS)) but, so far, bandwidth enhancements do not explicitly account for GPM products and data. Alternative data delivery methods are under development. GPM-era data products could use the existing NWS architecture, which includes the NWS Ground Readiness Project, AWIPS, NextGen and NWSTG architecture (WMO gateway). The current major/baseline data formats supported are GINI/imagery, GRIB1/2, BUFR, netCDF3, and text. Planned major/baseline data formats to be supported are netCDF4, HDF5, GRIB2, BUFR and text.

Non-baseline data formats supported include all the formats mentioned previously plus McIDAS (e.g. N-AWIPS). Introduction of GPM data and products into NOAA Unique Products (NUP) could establish the initial leg of a longer pathway to disseminate GPM data/products to NWS field forecasters. ESPC could develop data fusion techniques to generate NUPs. AWIPS could provide decision-assistance tools at the end-user location. Short-term actions include developing product-oriented requirements and validating these requirements. Direct participation of NWS, OCWWS, Office of Science and Technology (OS&T), and NCEP is recommended in developing and validating these product requirements.

Having the proper IT infrastructure is critical to NOAA's successful use of GPM-era data and products. Continual changes to this infrastructure across NOAA, in addition to a variety of new software requirements, must be properly accounted for to deliver timely data to NOAA users.

Brian Nelson, of NOAA/NESDIS/NCDC, talked about the best practices for data archive, format and delivery. Best practices can be followed similar to the process used by the Climate Data Record (CDR) Program to transition a CDR from research to Initial Operating Capability (IOC). This process is commonly called the R2O Transition Process. Some of the highlights of the process include checking the readiness of the software, verifying metadata, having complete documentation, and following a submission agreement. Each of these steps helps to ensure that the IOC is met and that this capability can be transitioned to a Full Operating Capability (FOC). As GPM has not become operational yet, the key is to have the IOC in place beforehand. Data format, archive and access will be a much smoother process with an IOC in place.

Session 6: Working Group Formation and Charge to the Working Group

Session Chair: Chandra Kondragunta, NOAA/NESDIS

The WGs were tasked to define concrete, achievable goals for both near term (next one to three years) and long term (beyond three years) and identify resources that are needed. In addition, specific focal points for each task were to be identified since these actions will be tracked on a regular basis by NOAA's Steering Group on Precipitation Measurement from Space. Due to anticipated budget constraints, the WG's were asked to consider work that can be done with in-house NOAA resources, e.g., FTEs. A standard template to capture these tasks was to be used in the WG summary reports. Each WG was assigned a chair and a scribe; their findings are presented below.

Working Group Reports

Group 1: Enhancing R&D and Innovation of GPM-era data at NOAA

Chair: Ralf Bennartz, University of Wisconsin, Atmospheric and Oceanic Sciences Department
Scribe: Allen White, NOAA/OAR/ESRL
Members: Ralf Bennartz, Brad Ferrier, Jin Huang, Min-Jeong Kim, Allen White, Ingrid Guch

Overview: Passive microwave imagers and sounders have been at the heart of numerous weather forecasting and climate research applications for decades. Currently, passive microwave sounders (e.g., AMSU) are possibly the most important data source for global NWP data assimilation. Conically scanning instruments, such as SSM/I and SSMIS, provide one of the very few data sets suitable for climate monitoring (sea ice coverage, cloud liquid water, water vapor path, precipitation) with continuous coverage starting in 1979. The GPM Core satellite and its diverse set of constellation satellites will not only ensure continuity of these observations into the future but will also provide opportunities for new and enhanced products because of improved spectral coverage and, first and foremost, better temporal sampling.

The group focused on R&D efforts needed to:

- **Prepare/enhance existing tools and support software for new/upcoming GPM-era instruments.** These preparations include data dissemination/formatting (discussed in separate WGs) but also enhancements to key scientific software, such as CRTM, to ensure newly available data can be ingested and processed in a timely manner.
- **Ensure continuity of existing products/applications when transitioning into the GPM era.** Research is needed, e.g., to blend precipitation estimates from Megha-Tropiques, AMSR-2, and the GPM-Core satellite into existing climatologies such as CMORPH.
- **Develop new application and enhance existing applications** to optimally leverage the enhanced capabilities of the GPM constellation. New capabilities include the GPM-era's unprecedented temporal sampling.
- **Prepare for the GPM mission by establishing one or more GPM proving ground** activities through engagement with other satellite proving grounds (GOES-R, JPSS) and/or collaboration with NOAA testbeds (Joint Hurricane, Hazardous Weather, Hydrometeorology, Climate, JCSDA).

Specific Actions: Specific actions revolved around the use of GPM-era active and passive microwave data, with emphasis on data assimilation and climate research. Particular recommendations for the one to three-year time frame are listed in the following table.

Group 1: Short-Term Goals				
Task	Cost Estimate	Champions	Steps Needed to Accomplish	Funding Source or Targets
Prepare for use of GPM data in enhanced climate monitoring (drought, floods, monsoons, MJO)	TBD	J. Huang P. Xie	- Evaluate current use of TRMM data and future use of GPM data/algorithms for climate monitoring, including strengths, limitations, and uncertainty. - Ensure continuity of TRMM to GPM era.	Potential funding from CTB (CPO/ COMP), NASA, NIDIS
Climate model verification	TBD	J. Huang	- CFS-v2 evaluation workshop on 4/30 – 5/1/12 - Establish a vehicle to engage satellite community to provide utility of TRMM/GPM products including rainfall and other products (e.g., water paths, latent heating profile, precipitation regime), and ongoing scientific support services.	Potential funding from CTB (CPO/MAPP), DOE, NASA, NSF, TBD
GPM Proving Ground	TBD	R. Ferraro I. Guch	- Engage internal NOAA users by establishing one or more GPM proving grounds similar and possibly linked to existing JPSS and GOES-R proving grounds with emphasis on high impact weather. Possible candidates: - NHC/HPC and HMT-SE (hurricanes, land-falling tropical storms, predecessor rain events, warm season QPF) - AWC/SPC and HWT (severe weather, aviation weather, convection) - HPC and HMT winter weather (atmospheric rivers, snow and ice accumulation, precipitation type)	Potential funding from JPSS and GOES-R Program Offices Use in-house resources
Prepare for GPM-era cloud and precipitation data assimilation	TBD	JCSDA M-J. Kim EMC	- Support activities to enhance use of passive (and potentially active) MW sensors in data assimilation: - Ensure CRTM is capable of working with GMI frequencies under cloudy and precipitating conditions - Conduct assessment for a space-borne radar within framework of CRTM - Continuing studies to improve characterization of observation error covariances - Continuing studies to improve characterization of background error covariances and moisture control variables	Potential funding from JSCDA
Product development	TBD	R. Ferraro P. Xie B. Ferrier	NOAA Unique Products need to be developed for: - Blended products (e.g., CMORPH) - Reduced data volume radar products such as column maximum composite radar reflectivity and 1km AGL radar reflectivity (i.e., SPC requirement) - GMI suite of products - Water vapor - Soil moisture	Potential funding from NOAA satellite programs, OAR

Group 2: Accelerating GPM Data Use at NOAA

Chair: Christopher Miller, NOAA/OAR
Scribe: Pingping Xie, NOAA/NWS; Bill Sjoberg, NOAA/NWS
Members: Chris Miller (CPO), Rob Cifelli (HMT), Jin Huang (CTB), Sheldon Kusselson (NESDIS), Mike Bodner (HPC/HMT), Mamoudou Ba (NWS/MDL), Pingping Xie (CPC), Shyam Bajpai (NESDIS/OSD), Jesse Meng (NWS/EMC), Richard Fulton (NESDIS/OSD), Bill Sjoberg (NOAA/NWS)

Overview: The purpose of this group was to explore and examine ways to accelerate the use of GPM data in NOAA. We believe that the fundamental challenge in this regard is to prepare NOAA to be able to develop and use new precipitation information from GPM and other satellite-based systems before they come online. To achieve this we need to understand where we are with regard to both the requirements and the usage of the current and future GPM products, quickly establish one or more "test teams," which comprise both product developers as well as end-users, and implement and test products and services end-to-end. We also envision ample use being made of testbeds, such as NOAA's Hydrometeorology Testbed (HMT) and Climate Testbed (CTB), to facilitate and evaluate this process.

The group discussions were extended around the following eleven questions prepared by Chris Miller of the NOAA Climate Program Office (CPO):

- Issues on transition from NASA to NOAA (MOU…)
- Training issues (end-to-end plan)
- Calibration/Validation
- Synergy with other programs (integrating information from various platforms)
- Proving usefulness of potential GPM products
- Need to consider/establish infrastructure to co-ordinate the activities across Line Offices (inventory of products, with priorities)
- GPM products (current applications, current applications in different contexts, new applications)
- Testing of GPM data in operational environments (current Proving Ground efforts)
- Climate considerations for GPM (adherence to GCOS Climate Monitoring Principles for satellites; maintaining continuity of measurements critical to climate; reprocessing capability)
- Resources
- Communications

Active discussion and interactions with other WGs led to the recommendation of a set of four actions to be taken by the NOAA satellite precipitation community to ensure smooth and timely transition of the GPM to NOAA.

Specific Actions: Particular recommendations for the one to three-year time frame are listed in the Group 2: Short Term Goals table.

Group 2: Short-Term Goals			
Task/Milestone	Champion(s)	Steps Needed to Accomplish	Funding Source or Targets
Surveying current use / non-use of GPM constellation (TRMM, AMSR, MT, SSMIS, AMSU, NPP, etc.) capabilities in NOAA	Someone appointed by the Steering Group (SG)	- Check meeting attendees for potential contacts - Survey NOAA offices / centers for related info - How / why they are using or not using - Create a survey table summarizing the results - Post the results to NOAA GPM web page - Consider possible extension of the survey beyond NOAA	Use in-house NOAA resources Funding - None
Stimulating the use of current and future GPM constellation capabilities	TBD	- Provide information on the current GPM capabilities - Provide access to the data sets - Provide training to end users - Create on-going two-way communication between developers and current and potential users	Use in-house NOAA resources Funding - None
Establishing an initiative to fuse GPM data with existing and future NOAA non-satellite data sources for improved hydrometeorological and climate applications	TBD	This is an important issue: other working group(s) will work on the technical details to ensure future NOAA GPM products satisfy requirements of both operations and climate research applications	Use in-house NOAA resources Funding - TBD
Advocating funding from NOAA and NASA for increased support	Ralph Ferraro Pingping Xie Rob Cifelli (SG co-chairs)	Strengthen the roles of the SG in communications and advocacy	Use in-house NOAA resources Funding - None

Group 3: Data Fusion

Chair: David Kitzmiller, NOAA/NWS/OHD
Scribe: Alan Basist, Weather Prediction, Corp.
Members: Chris Kummerow, Jeff McCollum, Tom Smith, Eyal Amitai, Pingping Xie, Rob Cifelli, George Huffman, Bob Kuligowski, Yu Zhang, Chandra Kondragunta, V. Chandrasekar.

Overview: This group attempted to identify the elements that would define the most useful global and regional-scale precipitation analyses. This is already a goal shared by NOAA programs such as the HMT, the IWRSS consortium, and the mission of the NCEP/CPC. There was general consensus that the user community will be best served by two general forms of precipitation data sets. One form is developed solely from platforms with global coverage, particularly satellite and numerical prediction models ingesting satellite information. Another form would augment this global-coverage data set with regionally-available sources such as ground radar and rain gauge networks. A goal is to insure that the two forms of data sets are unbiased with respect to each other, at some conservative time and space scale.

It should be noted that there are real-time global precipitation analysis operations within CPC, and regional-scale analysis operations for North America conducted by CPC, River Forecast Centers (RFC), and other offices of the NWS. We envision one or more these to be operational centers for production of multi-sensor precipitation products, thus the enhancement of their current plans are likely to be the only major funding requirement.

We identified several key questions, some of which might already have partial answers. The discussions centered on:

- Assurance that user requirements are being met, in terms of data density and temporal update rate.
- Development of a community-accepted blend of data sources, including satellite, radar, rain-gauge, and numerical prediction models.
- A compact and useful definition of errors for these observing and modeling systems. These error definitions are vital to most methods of data blending.
- Gaining acceptance of a multivariate analysis method for blending the data.
- Identification of production platforms.
- A shared vision of "what defines success," in terms of reliability of the blended multisensor products relative to reference surface data such as rain gauges, and as a forcing driver for hydrologic modeling.

As noted in the Group 3: Short-Term Goals table, information on some of these questions is being or has been collected but must be retrieved from project investigators.

Specific Actions:

Group 3: Short-Term Goals			
Task/Milestone	Champion(s)	Steps Needed to Accomplish	Funding Source or Targets
ORGANIZATIONAL			
Define user requirements	Already achieved?	Get the document GEO is putting together in a survey performed by Battelle. Ensure NOAA CORL is considered	Use in-house NOAA resources, including L1RD team Cost – 0
Define success of the data blending task	HMT	Identify a procedure to quantify added value and impact, in terms of precipitation accuracy, downstream impacts such as soil moisture or stream flow	HMT, IWRSS Cost – TBD
Define NOAA processing center	NOAA Precipitation SG can help define	- Investigate existing and proposed resources, direct and support scientific team to achieve this goal, possibly NCEP, National Water Center, NESDIS/OSPO. - Technical requirements to be considered	Use in-house NOAA resources Cost - 0
Clarify funding sources, priorities of products from the core instrument (GPM)	NOAA and NASA teams to generate precipitation products	Get commitment from upper level managements as to the resources and priorities to product development, data generation and distribution	Use in-house NOAA resources Cost - 0
SCIENTIFIC QUESTIONS			
Locate a gridded climatology and daily precipitation PDF, regional and global	David Kitzmiller George Huffman	This would be limited to gauge-only based data sets. However, there is value in adding layers of information to complement the global, where there are additional information (i.e., satellite, radar), such as modular, that allow for easy comparisons	Use in-house NOAA, NASA resources, particularly NWS/NCEP/CPC and NWS/OHD Cost - 0
Can we arrive at a statement of error characteristics, compact representation of the errors?	Jeff McCollum George Huffman	- Go to the individuals who have that information and compile it. These errors will change when layers are added. - A meeting at NCDC could assist in advancing this goal. - Identify the random errors and biases to determine how best to fuse the inputs into a final produce	NASA Science Team Cost - TBD
Identify additional data source layers to provide enhanced near real time products (spatially and temporally)	Dave Kitzmiller IWRSS, NCEP	The methodology underlying the climatology data reprocessing and the near real time products should be consistent across the product suite. Goal is the best available product subject to latency constraints.	Use in-house IWRSS resources Cost – TBD
Provide time and space co-registered input grids that contain additional information of precipitation	TBD (depends on source information)	- Engage with source scientists and organizations, generating center (such as NCEP and/or NWC). - Integrate various inputs, sources and scales into a common grid that combines data sources into a fused produce (minimize seams through an engineering procedure; this is less of a science questions, e.g., optimal interpolation analysis).	Generating center would start with level two and provide the justification for the support to make this happen. Costs - TBD

Group 3: Short-Term Goals (cont.)			
SCIENTIFIC QUESTIONS (cont)			
Integrate GPM radar information with existing ground radar operations and products	Eyal Amatai, HMT	Submit grant applications and/or get support by the NOAA precipitation development community to achieve goal	NESDIS satellite programs, OAR, IWRSS Cost - TBD
FINAL PRODUCT TARGETS			
Global and regional analyses that are spatially homogeneous Develop a methodology for globally and regionally homogeneous input	David Kitzmiller (global) Chandrasekar V. (regional)	Inputs need reprocessing, data custodians should be responsible for maintaining currency with the best algorithms and data quality over the period of record for the various data sources; all seams should be minimized	IWRSS resources, possibly others Cost - TBD

Group 4: Data Delivery and Formats

Chair: Tom Schott, NOAA/NESDIS/OSD
Scribe: Limin Zhao, NOAA/NESDIS/OSPO
Members: Chandra Kondragunta, Ralph Ferraro, Tom Schott, Erich Stocker, Limin Zhao, Brian Nelson, Brian Gockel, Joe Mani

Overview: The group met to discuss the path forward to provide GPM-era data operationally at NOAA with minimal data latency and identify the required GPM data products, data formats, and dissemination strategies. The discussion was centered on the questions that included:

- What products are available from NASA?
- What products are needed for NOAA users?
- Do the products provided from the NASA PPS meet NOAA user needs on time latency, accuracy, format, 24/7 operational support nature, etc.

To properly answer these questions, the group recommends that a GPM L1RD be developed to provide a clear definition of the full spectrum of user needs in terms of products, time latency, accuracy, type, format, etc. Once a L1RD is developed, then the GPM group can develop acquisition strategies and options for execution consideration. The requirements should include both the continuity of current data products and potential products from the GPM-era sensors. The group recommended that a Preliminary L1RD be developed. A Final L1RD would be approved once funding for the project has been identified. NOAA plans on submitting a Fiscal Year 2014 initiative that includes GPM.

Another important issue discussed is the operational support of the GPM data at NOAA, including product generation and dissemination. Different strategies were discussed, such as getting the data directly from NASA to support the NOAA's operational mission and/or transferring the PPS or PPS-lite from NASA to NOAA. At some point NOAA will need to understand the "pros and cons" for each acquisition option and decide on a baseline acquisition strategy. The group recommends a scalable acquisition and dissemination strategy be developed, including key elements such as a "PPS-lite" approach (i.e., GPM-core satellite only) and/or rely on NASA for high data latency products, etc. The cost estimate and "pros and cons" will be presented for each possible strategy and included in the future version of the NOAA GPM transition plan. The group also discussed issues that place more weight on operations than on research, such as: (1) how to coordinate the changes among the partners, (2) how to get users informed in a timely manner, and (3) how to get the PPS updated to meet the NESDIS operational documentation and software standards. It was suggested that the NOAA GPM transition plan be updated to finalize the roles of NASA and NESDIS (i.e., OSD, STAR, OSPO, and NCDC) using the current NESDIS research to operations process. In addition, the group also discussed establishing a GPM Proving Ground concept, and how it would help to get the GPM products to users and provide GPM feedback on their operational utility. The GPM Proving Ground concept should exploit existing NWS testbeds. For example, the National Hurricane Center testbed is considered to have good capability for testing tropical storm applications of GPM data, and the initial proving ground/test- bed activities might start with M-T data products.

Specific Actions:

Group 4: Short-Term Goals			
Task/Milestone	Champion(s)	Steps Needed to Accomplish	Funding Source or Targets
Define NOAA GPM Level 1 Requirements Document (L1RD)	C. Kondragunta T. Schott R. Fulton	- Form a Tiger team cross NOAA line offices to develop a NOAA GPM Level 1 Requirements Document. - Team to include: Chandra Kondragunta, Tom Schott, Richard Fulton, Ralph Ferraro, Michael Mineiro, Kevin Schrab, David Kitzmiller, Limin Zhao, Rob Cifelli, Jim Yoe, Michael Brennan, Pingping Xie, Mike Bodner, Sheldon Kusselson, Dave Hermreck. - Begin in January 2012.	Use in-house NOAA resources Cost – 0
Define a scalable NOAA acquisition concept or strategies for GPM	C. Kondragunta R. Ferraro L. Zhao	- Once an initial GPM L1RD has been develop, then define acquisition concept/strategies for meeting the NOAA GPM L1RD requirements. This will include GPM product generation and delivery options - Finalize the GPM Transition Plan roles and responsibility of OSD, STAR, OSPO and NCDC from executions perspective - Update the transition plan to include the outcomes from the previous two steps - This activity should include the champions, plus Tom Schott, Richard Fulton, Joe Mani, Erich Stocker, - Begin in March 2012	Use in-house NOAA resources Cost – 0
Recommend to the JCSDA that NASA PPS (Erich Stocker) be included in the JCSDA BUFR WG.	T. Schott	Action through email.	Use in-house NOAA resources Cost – 0

Summary and Next Steps

Building on the success of the ***1st NOAA User Workshop on the GPM Mission*** (August 2010, see Ferraro et al. 2011), which identified a strong need for GPM data across several NOAA line offices and programs, the ***2nd NOAA User Workshop on the GPM Mission*** (organized by NOAA's Steering Group on Precipitation Measurement from Space) focused on engaging users of precipitation products to define specific tasks that need to be accomplished over the next three years to enhance NOAA's ability to utilize GPM data. Over 60 participants attended the three-day workshop that included plenary talks from NESDIS and NCEP headquarters and the NASA GPM Program Office; panel discussions from topical area experts, and four working groups, the latter of which were organized around primary topics that resulted from the first workshop: Enhancing R&D and innovation of GPM-era data at NOAA; Accelerating GPM data use at NOAA; Data fusion; Data delivery and formats.

The ***2nd NOAA Workshop on the GPM Mission*** brought together scientists from NOAA, NASA, academia, and private sector who are currently involved with the use of satellite derived precipitation products and radiances as to perform their day-to-day jobs: weather forecasting, climate monitoring and prediction, and research and development. The need for GPM-era data and vastly improved products for continuity of operations, as well as an opportunity for enhanced capabilities beyond those currently available was made quite clear by the workshop participants. Specific uses cited included: hydrologic and land surface monitoring and prediction, NWP model assimilation, the monitoring of atmospheric rivers, tropical cyclone center fixing, and climate monitoring and prediction.

Each WG provided a set of recommendations in the form of tasks (with specific focal points, budget requirements, and funding sources/targets) to be completed over the next three years, leading up to the GPM-core satellite launch (February 2014) and during its checkout. Four major recommendations resulted from these working groups:

1. NOAA needs to prepare immediately to exploit GPM-era data and products through the establishment of a GPM Proving Ground. The Proving Ground will also serve as a coordinating group for GPM products at NOAA.

   Specifically, the Proving Ground will focus on data delivery and distribution, research and development, data fusion and integration with other observations of precipitation, and accelerating GPM-era data use through existing testbeds, including:

   - Hydrometeorological Testbed
   - Climate Testbed
   - Joint Hurricane Testbed
   - Developmental Testbed and the Joint Center for Satellite Data Assimilation
   - Hazardous Weather Testbed
   - Aviation Weather Testbed

2. Complimentary to the activities within the GPM Proving Ground, NOAA should focus on the following areas of research and development to better exploit GPM-era data:

   - Continuity of operations from current passive microwave sensors into GPM-era sensors

- Climate applications and model verification
- Numerical weather prediction (NWP) assimilation (especially in precipitating atmospheres with both passive and active GPM-era sensors) and model verification
- Data fusion with information from other sources and uncertainty estimation
- Development of NOAA Unique Products (NUP) from GPM sensors such as total precipitable water and ocean surface winds.

3. Move toward a "One-NOAA" suite of precipitation products that can serve all aspects of NOAA mission goals related to water monitoring and prediction on the time and space scales required across NOAA.
4. Obtain specific NOAA requirements for GPM-era data through the development of the Level 1 Requirements Document and subsequent Transition Plan for a NOAA-specific, operational version of NASA's GPM Precipitation Processing System (PPS), including the necessary IT infrastructure to meet latency requirements.

The next steps will be to execute the specific tasks defined by each WG and seek funding where needed through the potential sources noted; it can be reported that some of the actions are already in progress, such as the submission of several proposals to the NOAA JPSS Proving Ground program (page 19), the development of the L1RD Tiger Team (page 25) and the organization of a one-day workshop to better define a path forward for satellite, radar and rain-gauge data fusion at NOAA (page 21). Where applicable, the "champions" for the specific tasks will be asked to provide bi-annual updates to the NOAA Steering Group on Precipitation Measurement from Space.

At the time of this report writing, a new NOAA Fiscal Year (FY) 2014 budget initiative is being considered as part of a broad-based NOAA satellite enterprise approach to obtain the proper infrastructure to support such missions outside of NOAA's baseline GOES-R and JPSS programs; GPM is contained within this initiative. If such an initiative were to move forward and become successful, these resources would be able to accomplish the majority of the tasks identified within the workshop.

Finally, it is envisioned that a follow-on workshop will be held in late 2012/early 2013 that will focus on the GPM Proving Ground and its priorities, as well as research priorities related to data fusion and NOAA Unique Products.

References

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

Ferraro, R.R. and co-authors, 2011: First NOAA User Workshop on the Global Precipitation Measurement (GPM) Mission. August 18-19, 2010, College Park, MD

Appendix A: Workshop Participants

First	Last	Affiliation	Email
Bob	Adler	Univ. of Maryland	radler@essic.umd.edu
Mamadou	Ba	NOAA	Mamadou.Ba@noaa.gov
Shyam	Bajpai	NOAA	Shyam.Bajpai@noaa.gov
Charles	Baker	NOAA	Charles.S.Baker@noaa.gov
Alan	Basist	Weather Prediction, Corp.	Alan.Basist@weatherpredict.com
Ralf	Bennartz	Univ. of Wisconsin	bennartz@aos.wisc.edu
Mike	Bodner	NOAA	Mike.Bodner@noaa.gov
Sid	Boukabara	NOAA	Sid.Boukabara@noaa.gov
Ken	Carey	Noblis Corp.	kenneth.carey@noaa.gov
V	Chandrasekar	Colorado State Univ.	chandra@engr.colostate.edu
Robert	Cifelli	NOAA	Rob.Cifelli@noaa.gov
Mark	Donovan	Dept. of Defense	Mark.H.Donovan@usmc.mil
Ralph	Ferraro	NOAA	Ralph.R.Ferraro@noaa.gov
Brad	Ferrier	NOAA	Brad.Ferrier@noaa.gov
Richard	Fulton	NOAA	Richard.Fulton@noaa.gov
Brian	Gockel	NOAA	Brian.Gockel@noaa.gov
Ingrid	Guch	NOAA	Ingrid.Guch@noaa.gov
Jin	Huang	NOAA	Jin.Huang@noaa.gov
George	Huffman	NASA	George.Huffman@nasa.gov
Paul	Hwang	NASA	Paul.H.Hwang@nasa.gov
Min-Jeong	Kim	NOAA	Min-Jeong.Kim@noaa.gov
Dalia	Kirschbaum	NASA	Dalia.b.kirschbaum@nasa.gov
David	Kitzmiller	NOAA	David.Kitzmiller@noaa.gov
Chandra	Kondragunta	NOAA	Chandra.Kondragunta@noaa.gov
Bob	Kuligowski	NOAA	Bob.Kuligowski@noaa.gov
Chris	Kummerow	Colorado State Univ.	kummerow@atmos.colostate.edu
Sheldon	Kusselson	NOAA	Sheldon.Kusselson@noaa.gov
Bill	Lapenta	NOAA	Bill.Lapenta@noaa.gov
Stephen	Mango	NOAA	Stephen.Mango@noaa.gov
Joe	Mani	NOAA	Joseph.Mani@noaa.gov
Jeff	McCollum	FM Global Corp.	jeffrey.mccollum@fmglobal.com
Huan	Meng	NOAA	Huan.Meng@noaa.gov
Jesse	Meng	NOAA	Jesse.Meng@noaa.gov
Christopher	Miller	NOAA	Christopher.D.Miller@noaa.gov
Isaac	Moradi	Univ. of Maryland	imoradi@umd.edu
Brian	Motta	NOAA	Brian.Motta@noaa.gov
Leslie	Moy	NOAA	Leslie.Moy@noaa.gov
Brian	Nelson	NOAA	Brian.Nelson@noaa.gov
John	Pereira	NOAA	John.Pereira@noaa.gov
Shanna	Pitter	NOAA	Shanna.Pitter@noaa.gov
Bob	Rabin	NOAA	rabin@ssec.wisc.edu
Timothy	Schneider	NOAA	Timothy.Schneider@noaa.gov
Gail	Skofronick-Jackson	NASA	Gail.S.Jackson@nasa.gov
Tom	Schott	NOAA	Tom.Schott@noaa.gov
Bill	Sjoberg	NOAA	bill.sjoberg@noaa.gov
Tom	Smith	NOAA	Tom.Smith@noaa.gov
Erich	Stocker	NASA	Erich.F.Stocker@nasa.gov
Steven	Vasiloff	NOAA	Steven.Vasiloff@noaa.gov
Nai-Yu	Wang	Univ. of Maryland	nywang@essic.umd.edu
Allen	White	NOAA	allen.b.white@noaa.gov
Glenn	White	NOAA	Glenn.White@noaa.gov
Pingping	Xie	NOAA	Pingping.Xie@noaa.gov
Brad	Zavodsky	NASA	Brad.Zavodsky@nasa.gov
Yu	Zhang	NOAA	Yu.Zhang@noaa.gov
Limin	Zhao	NOAA	Limin.Zhao@noaa.gov

Appendix B: Workshop Agenda

29 November 2011

Times	Topic	Speaker(s)	Organization
0800 - 0830 a.m.	Registration/Sign In/Continental Breakfast (Provided)		
0830 - 1030 a.m.	**Session 1 - Overview (Chair - K. Carey)**		
0830 - 0835 a.m.	Introductions, Welcome, Logistics, Goals, Format, etc.	R. Ferraro; A. Busalacchi	NESDIS & UMD
0835 - 0845 a.m.	1st Workshop Summary and Progress	R. Ferraro	NESDIS
0845 - 0900 a.m.	Importance of GPM from NESDIS Perspective	C. Baker	NESDIS
0900 - 0930 a.m.	NOAA Keynote Speaker - GPM's Role at NCEP	B. Lapenta	NWS
0915 - 0930 a.m.	GPM Status	G. Skofronick-Jackson	NASA
0930 - 0945 a.m.	GPM Applications	D. Kirschbaum	NASA
0945 - 1000 a.m.	Q&A Session for keynote speakers		
1000 - 1030 a.m.	Coffee Break + Group Photo		
1030 - 1200 p.m.	**Session 2 - Enhancing R&D and Innovation of GPM-era Data at NOAA Panelists: B. Ferrier (NWS); C. Kummerow (Colo. St. Univ.); P. Xie (NWS); M. Kim (JCSDA); D. Kiztmiller (NWS); R. Bennartz (Univ. of Wisconsin)**		
1030 - 1035 a.m.	Session Introduction	A. White	OAR
1035 - 1100 a.m.	Panelist Presentations		
1100 - 1200 p.m.	Panel Discussion and Q&A from participants		
1200 - 0100 p.m.	Lunch (Provided)		
0100 - 0245 p.m.	**Session 3- Accelerating GPM Data Use at NOAA Panelists: J. Huang (NWS); T. Schott (NESDIS); R. Cifelli (OAR); G. White (NWS); B. Motta (NWS); B. Zavodsky (NASA)**		
0100 - 0105 p.m.	Session Introduction	T. Schneider/P. Xie	OAR & NWS
0105 - 0130 p.m.	Panelist Presentations		
0130 - 0230 p.m.	Panel Discussion and Q&A from participants		
0230 - 0245 p.m.	Coffee Break		
0245 - 0415 p.m.	**Session 4 - Data Fusion Panelists: V. Chandrasekar (Colo. State. Univ.); G. Huffman (NASA);Y. Zhang (NWS); B. Kuligowski (NESDIS)**		
0245 - 0250 p.m.	Session Introduction	R. Cifelli	OAR & NESDIS
0250 - 0315 p.m.	Panelist Presentations		
0315 - 0415 p.m.	Panel Discussion and Q&A from participants		
0415 - 0530 p.m.	**Session 5 - Data delivery and formats Panelists: J. Mani (NESDIS); B. Gockel (NWS); B. Nelson (NESDIS); L. Zhao (NESDIS)**		
0415 - 0420 p.m.	Session Introduction	C. Kondragunta	NESDIS
0420 - 0445 p.m.	Panelist Presentations		
0445 - 0530 p.m.	Panel Discussion and Q&A from participants		
0530 p.m.	Workshop Ends for Day		
0600 p.m.	Group Dinner (TBD)		

30 November 2011

Times	Topic	Speaker	Organization
0800 - 0830 a.m.	Continental Breakfast (Provided)		
0830 - 1000 a.m.	**Session 6 - Working Group Plenary**		
0830 - 0845 a.m.	GPM Status - Precipitation Processing Systems	E. Stocker	NASA
0845 - 0930 a.m.	Working Group Formation, Format, Rules of engagement, Background Information	R. Ferraro/K. Carey	NESDIS; Noblis
0930 - 1000 a.m.	Move to Working Groups and initial organization		
1000 - 1030 a.m.	Coffee Break		
1030 - 1200 p.m.	Working Groups Meet		
1200 - 0100 p.m.	Lunch (provided) and engage other working groups		
0100 - 0500 p.m.	**Session 7 -Working Group Session I**		
0100 - 0300 p.m.	Working Group Meets		
0300 - 0315 p.m.	Coffee Break		
0315 - 0400 p.m.	Group Plenary - Are there common themes? Any reorganization?		
0400 - 0500 p.m.	Working Group Meets		
500 p.m.	Workshop Ends for the Day		

1 December 2011

Times	Topic	Speaker	Organization
0800 - 0830 a.m.	Continental Breakfast		
0830 - 1200 p.m.	**Session 8 - Working Group Session 2**		
0830 - 0900 a.m.	**Group Plenary/Updates from WG Chairs (5 min each)**	**Ken Carey**	**Noblis Corp.**
0900 - 1200 p.m.	Working Groups Meet		
1200 - 0100 p.m.	Lunch		
0100 - 0300 p.m.	**Session 9 - Final Group Plenary**		
0100 - 0120 p.m.	WG 1 Report		
0120 - 0140 p.m.	WG 2 Report		
0140 - 0200 p.m.	WG 3 Report		
0200 - 0220 p.m.	WG 4 Report		
0220 - 0300 p.m.	Final Discussions/Wrap Up		

Appendix C: Panel Discussions

Working Group 1: Enhancing R&D and Innovation of GPM-era data at NOAA

Overview: Collaborative R&D between NOAA and its partners will be necessary to fully exploit GPM-era measurements. At the same time, burgeoning methods for quantitative precipitation information need to be evaluated in context of NOAA's data assimilation activities and operational forecasting at the NWS. For example, the 1st NOAA User Workshop on the GPM Mission recommended that NOAA support R&D 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. It was also noted during the Workshop that R&D on data assimilation methods for cloudy and precipitating atmospheres is needed for both passive and active microwave measurements. Another R&D effort is to determine how GPM can best take advantage of existing partnerships between NOAA and NASA (e.g., membership on the PMM Science Team) and of the NOAA testbeds (Hydrometeorology, Joint Hurricane, Climate, etc.), in addition to the JCSDA. To help frame discussion on these topics, your facilitators have come up with the following questions for the panelists and WGs to consider. It is possible that these questions will be refined for the working groups on Day 2 of this meeting as the facilitators discern what they have learned from the panel discussions on the first day.

Expected Outcome: A prioritized list and action plan of envisioned R&D which will utilize GPM-era data.

Questions for Panelists to Consider:

- What new products using GPM data are needed to enhance NOAA science and services?
- Where in NOAA is the greatest need for GPM data?
- What GPM products are anticipated to have the greatest impact on NOAA precipitation products?
- Is GPM data needed for validation, assimilation, or both purposes in NOAA forecast models?
- What steps are needed prior to the GPM launch to ensure optimal use of the data?
- In what areas should NOAA partner with GPM science community to achieve maximum benefit from GPM?

Working Group 2: Accelerating GPM Data Use at NOAA

Overview: This purpose of this group was to explore and examine ways to accelerate the use of GPM data in NOAA. We believe that the fundamental challenge in this regard is to prepare NOAA to be able to develop and use new precipitation information from GPM and other satellite-based systems before they come online. To achieve this we need to understand where we are with regard to both the requirements and the usage of the current and future GPM products, quickly establish one or more "test teams", which comprise both product developers as well as end users, and to implement and test products and services end-to-end. We also envision ample use being made of testbeds, such as NOAA's Hydrometeorology Testbed (HMT) and Climate Testbed (CTB), to facilitate and evaluate this process.

Expected Outcome: An overall plan of the infusion with suggestions on infrastructure and a short list of products /services.

Questions for Panelists to Consider:

- What are the current uses of satellite, especially TRMM products in your organizations / projects?
- What are the requirements for GPM products? Please list 2-3 items of expected GPM products / services with detailed requirements.
- What do you think are the key requirements for the GPM products / services you need?
- What are the potential obstacles against accelerating the use of GPM products for your organizations / projects?
- How we may accelerate the GPM infusion? How should we take advantage of the existing testbeds? Or do we need a new infrastructure (e.g. proving ground) for the GPM products transition?

Working Group 3: Data Fusion

Overview: How can NOAA integrate GPM-era satellite data into "merged" products (e.g., Q2, MPE, CMORPH, etc.) and move toward a "One NOAA" suite of precipitation products?

Expected Outcome: An action plan describing how GPM data could be utilized for multi-sensor precipitation estimation and the anticipated benefit to current NOAA precipitation product(s).

Questions for Panelists to Consider:

- What lessons can NOAA learn from the outside research community in terms of multi-sensor QPE/data fusion techniques?
- What GPM data are anticipated to have the greatest impact on NOAA data fusion products (precipitation, SST, TPW, etc.)?
- Where and when will GPM data be most effective for blended NOAA products?
- What steps are needed to achieve a one NOAA suite of precipitation products?
- In what areas should NOAA partner with the PMM science community to achieve maximum benefit for data fusion?
- How can the PMM community and other researchers' best engage with NOAA to develop optimal multi-sensor QPE products?

Working Group 4: Data Delivery and Formats

Overview: NOAA requires GPM-era data with minimal data latency and provided in formats that will be suitable for immediate use across NOAA. Additionally, NOAA Unique Products can be generated from the GPM radiometer constellation.

Expected Outcome: Identify needed actions to prepare for a potential transition of relevant portions of NASA's ground processing segment for GPM (e.g., PPS- Precipitation Processing System) and to determine specific NOAA-needs from the PPS and its related components (e.g., communication lines, computing power, etc.).

Questions for Panelists to Consider:

- What is the expected data latency of GPM core and constellation member L1 and L2 data? How do these compare to TRMM? Are there ways to improve on these nominal values (i.e., enhance com lines between NASA and NOAA, direct downlink, etc.) and at what cost?
- How might NOAA improve its product processing and delivery to users through the elimination of "stove pipes"? What are the benefits and obstacles to this approach?
- What are the expected data formats for the GPM data from NASA and what are the data format plans at NOAA?
- What are the most important aspects of the PPS transition to NOAA - L1? L2? L3?
- How can NASA and NOAA operate the PPS in a synergistic manner?
- How can GPM be leveraged to generate NOAA Unique Products?

Appendix D: List of Acronyms

AMSR	Advanced Microwave Scanning Radiometer
AMSU	Advanced Microwave Sounding Unit
ATMS	Advanced Technology Microwave Sounder
AWC	NOAA's Aviation Weather Center
AWIPS	Advanced Weather Interactive Processing System
BUFR	Binary Universal Form for the Representation of Meteorological Data
CDR	Climate Data Record
CMORPH	Climate Prediction Center Morphing Technique
CPC	NOAA's Climate Prediction Center
CPO	Climate Program Office
CRTM	Community Radiative Transfer Model
CTB	Climate Testbed
DMSP	Defense Meteorological Satellite Program
DPR	Dual-frequency Precipitation Radar
EMC	NOAA's Environmental Modeling Center
ESRL	NOAA's Earth System Research Laboratory
ESPC	NOAA's Environmental Satellite Processing Center
ESSIC	Earth System Science and Interdisciplinary Center, University of Maryland
EUMETSAT	European Meteorological Satellite
FOC	Full Operating Capability
GCOM	Japan's Global Change Observation Mission
GFS	Global Forecast System
GOES	Geostationary Operational Environmental Satellite
GMI	GPM Microwave Imager
GPM	Global Precipitation Measurement Mission
GRIB	Gridded Binary Format
GSFC	NASA's Goddard Space Flight Center
HMT	NOAA's Hydrometeorology
HPC	NOAA's Hydrometeorological Prediction Center
IMERG	Integrated Multi-satellitE Retrievals for GPM
IOC	Initial Operating Capability
IWRSS	Integrated Water Resources Science and Services
JAXA	Japanese Aerospace Exploration Agency
JCSDA	Joint Center for Satellite Data Assimilation
JPSS	Joint Polar Satellite System
L1RD	Level 1 Requirement Document
LEO	Low Earth Orbiting
LORWG	Low Earth Orbiting Requirements Working Group
MADRAS	Microwave Analysis and Detection of Rain and Atmospheric Systems
MHS	Microwave Humidity Sounder
MPE	NOAA's Multisensor Precipitation Estimator

MW	Microwave
MSFC	NASA's Marshall Space Flight Center
M-T	Megha-Tropiques
NAM	North American Mesoscale
NASA	National Aeronautics and Space Administration
NCDC	NOAA's National Climatic Data Center
NCEP	NOAA's National Centers for Environmental Prediction
NESDIS	NOAA's National Environmental Satellite, Data and Information Service
NHC	National Hurricane Center
NOSC	NOAA Observing System Council
NPP	National Polar-orbiting Partnership
NSOF	NOAA Satellite Operations Facility
NWP	Numerical Weather Prediction
NWSFO	National Weather Service Forecast Office
OCWWS	Office of Climate, Water and Weather Services
OHD	Office of Hydrologic Development
OS&T	Office of Science and Technology
OSPO	Office of Satellite and Product Operations
PMW	Passive Microwave
PPS	Precipitation Processing System
QPE	Quantitative Precipitation Estimates
R&D	Research and Development
R2O	Research to Operations
SAPHIR	Sounder Atmospheric Profiling Humidity Radiometer
SEID	Systems Engineering and Integration Division
SPoRT	Short-term Prediction Research and Transition
STAR	Center for Satellite Applications and Research
TPW	Total Precipitable Water
TRMM	Tropical Rainfall Measurement Mission
USGS	United States Geological Survey
WG	Working Group
WRF	Weather Research and Forecasting