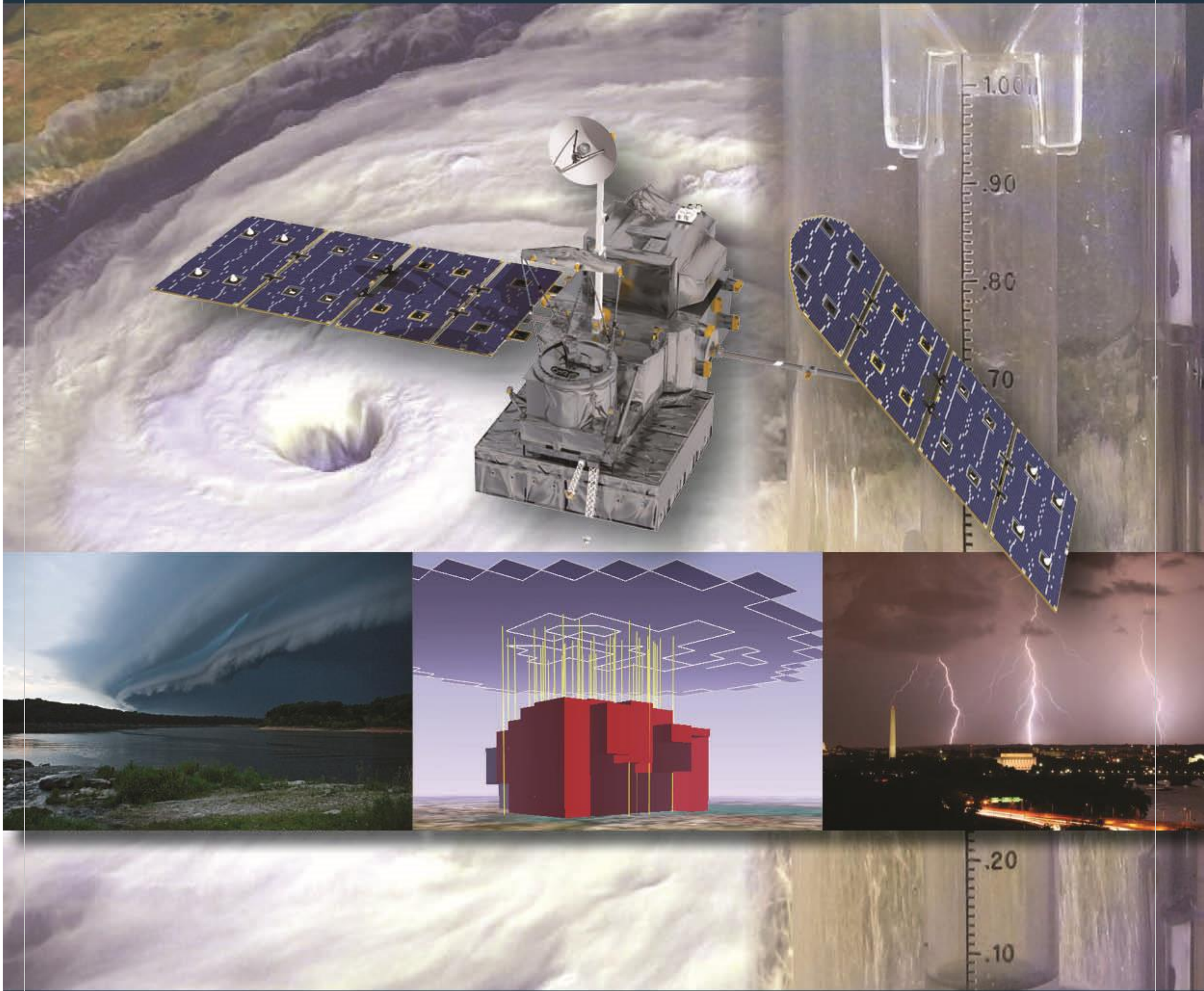
# 3rd NOAA User Workshop on the Global Precipitation Measurement Mission




Hosted by the National Oceanic and Atmospheric Administration
April 2, 2013 – April 4, 2013
College Park, MD

# Executive Summary

The international Global Precipitation Measurement (GPM) mission holds the promise of greatly enhancing the coverage and accuracy of space-borne precipitation information. NASA and JAXA will be setting new standards for precipitation measurements worldwide by launching the GPM Core Observatory which will unite a network of satellites to fulfill the GPM mission. NOAA, in anticipation of the mission and its potential benefits to its mission goals, has convened two previous User Workshops on GPM to identify user needs with respect to space-borne precipitation information and identify pathways of integrating the GPM data into its operations.

This 3rd NOAA User Workshop on GPM, which took place on 2-4 April 2013 in College Park, Maryland, built on the outcomes from the first two workshops and was aimed at forging a plan to use GPM data within NOAA through testbeds and proving ground concepts. More than 70 attendees from NOAA, NASA, academia and the private sector participated, either physically or remotely. In the workshop experts from NOAA and NASA, engaged through three Working Groups, addressed the following three topics: (i) NOAA Proving Ground needs; (ii) research needs and algorithm development; and (iii) training, education and outreach needs for use of GPM data within NOAA operations and applications. Each working group formulated recommendations and a set of actionable items and champions for those actions. The major recommendations from the workshop include the following:

1. NOAA should establish a GPM-focused Proving Ground (PG) that leverages existing PGs that are well established under the GOES-R program and are emerging from the JPSS program. This PG will engage and enhance planned testbed and PG focus activities in the short term while contributing to future activities related to precipitation and hydrological applications.

2. In order to enhance research activities related to precipitation data fusion, NOAA needs enhanced coordination across its line offices for GPM-era R&D related to satellite data fusion and fusion with radar and rain gauges, and improved reprocessing/archiving to maintain compatibility with current algorithms.

3. In order to improve GPM education, outreach and training, NOAA needs to coordinate with NASA, and form a Tiger team to address issues such as identifying priority of education and training for NOAA operational and applications users on the high priority, new NOAA-planned fused and blended precipitation products, and establishing a commitment to funding for GPM activities, including close cooperation with ongoing training and outreach activities within GOES-R and JPSS.

# Major Recommendations from the Working Groups

1. NOAA should establish a GPM-focused Proving Ground (PG) that leverages existing PGs that are well established under the GOES-R program and are emerging from the JPSS program. Attributes of this PG include:

    a. Governance adhering to existing NOAA PG by-laws, although it would benefit by having a new NOAA governing body (i.e., subset of the existing NOAA SGPMS [Steering Group on Precipitation Measurement from Space]).

    b. Priority on the products to be served captured in the GPM L1RD nearing completion.

    c. PG producers may include NOAA's WPC/OPC, NCEP, OHD and National Operational Hydrologic Remote Sensing Center (NOHRSC); NASA's SPoRT center; and new nodes at NOAA cooperative institutes.

    d. PG consumers should include previously-identified groups such as HMT and WPC as well as a closer connection to current/future planned PG focus activities such as those on atmospheric rivers, flash floods, and winter season precipitation.

    e. A precipitation PG satellite champion.

    f. A validation component.

    g. Sustained funding from within NOAA's major programs.

2. In order to enhance research activities related to precipitation data fusion, NOAA needs to:

    a. Vastly improve coordination across its line offices for GPM-era R&D related to satellite data fusion and fusion with ground radar and rain gauges.

    b. Create a collaborative computing framework across NOAA line offices (e.g., NESDIS, NWS, OAR) to provide a focus for fused data set R&D.

    c. Develop a committed strategy to perform episodic reprocessing of precipitation-relevant data archives that are consistent with both updates of input data and with algorithm upgrades, thus enhancing the usability of orbital data in blended precipitation products. To date, NOAA only reprocesses such data through its CDR program and this is typically after a satellite sensor has been in operation for more than a decade.

3. In order to improve GPM education, outreach, and training at NOAA, NOAA needs to:

    a. Better define its needs, its training targets, and requirements by forming a Tiger team to specifically address this topic.

    b. Provide for the Education and Training for NOAA operational and applications users on the high priority, new NOAA-planned fused and blended precipitation products.

    c. Establish a commitment to fund such activities, including close cooperation with ongoing training and outreach activities within GOES-R and JPSS.

    d. Coordinate activities with the well-established GPM outreach program at NASA.

# Acknowledgements

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# Table of Contents

# 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) and the European Meteorological Satellite (EUMETSAT) Microwave Humidity Sounder (MHS) *[Collectively flown on NOAA-18, NOAA-19, MetOp-A and MetOp-B]*, the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager/Sounder ( SSMI/S) *[flown on F-16, F-17 and F-18]*, the NASA Tropical Rainfall Measurement Mission (TRMM) Microwave Imager (TMI), the Department of Defense WindSat, the Advanced Technology Microwave Sounder (ATMS) *[flown on the Suomi National Polar-orbiting Partnership (SNPP)]* and the Microwave Analysis and Detection of Rain and Atmospheric Systems (MADRAS) and Sounder Atmospheric Profiling Humidity Radiometer (SAPHIR) *[flown on the Megha-Tropiques (M-T) satellite]*, and the Advanced Microwave Scanning Radiometer 2 (AMSR-2) *[flown on the GCOM-W1 Satellite]*. All of these sensors will be used together to fill in many 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) 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 (i.e., essentially those satellites mentioned in the previous paragraph as well as those missions planned in the next five years and beyond) 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 16$^{th}$ year of operation, but will expand its coverage to near-global. More details on the GPM mission can be found in the first and second workshop reports (Ferraro et al. 2011; 2012), 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-Ready Nation. Some 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 estimation (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)

## Objectives and Expected Outcomes

**Purpose:** This three-day meeting, co-sponsored by NESDIS, NWS and OAR, was intended to follow up on the highly successful previous two workshops (held in August 2010 and November 2011 – see http://www.star.nesdis.noaa.gov/star/meeting_GPM2011.php) with a focus on the development, functionality, and priorities of a new NOAA GPM Proving Ground.

The meeting objectives and anticipated outcomes for each topic were as follows:

### *Objective 1: Identify the Purpose of the NOAA GPM Proving Ground and How it Will Improve NOAA Precipitation Products and Services*

**Expected Outcomes:**

- A clear statement of the purpose and need for a NOAA GPM Proving Ground
- A plan describing how the Proving Ground will facilitate interaction among NESDIS, NWS, and OAR, as well as NASA, on GPM precipitation issues

## Objective 2: Identify Use of GPM Data in Research and Operational Algorithm Development

**Expected Outcomes:**

- Identify Proving Ground participants and timelines for the use of GPM-era precipitation products within NOAA
- Catalogue or list current operational products derived from the TRMM and passive microwave constellation
- Gather information on ongoing multi-sensor precipitation product development efforts for both continental and global scales
- Benchmark GPM-era algorithms at multiple space-time scales over the CONUS
- Establish a framework for multi-sensor fusion of precipitation products from satellites, radars, gauges, and numerical weather prediction model outputs that can be used across NOAA line offices
- Identify paths of research to operations, e.g., establish and evaluate methods to assimilate GPM products in numerical weather prediction models, and assess the operational values of GPM-based, multi-sensor fused precipitation products for climate, flood and water resources predictions
- Novel strategies for calibration of space-based microwave measurements using Multi-Radar Multi-Sensor System

## Objective 3: Identify Training Needs for Use of GPM Data in NOAA Operations (WFOs, RFCs, NHC, NCEP)

**Expected Outcomes:**

- Determine target audience – general users and operational entities
- Determine knowledge gaps relative to what most people know about current operational suite
- Evaluate available human resources for training – whom to approach and how

**Intended Participants:**

Current and future users of satellite-based precipitation, water cycle products and radiance data from government, private sector, and academia.

A summary of these talks is provided in Sections 1-4 in this report. All of the talks can be found at http://www.star.nesdis.noaa.gov/star/meeting_GPM2013_agenda.php.

# Summary of Presentations

## Session 1: Overview

**Session Chair:** Chandra R. Kondragunta, Office of Systems Development, NOAA/NESDIS

This session contains overview talks about the Global Precipitation Measurement (GPM) Mission and how it benefits NOAA in terms of enhancing its operational forecasting capability. The first few key note addresses were given by leaders in NOAA who charged the workshop participants to exploit the existing NOAA testbeds and proving grounds to demonstrate the utility of the GPM data to enhance NOAA's operational forecasting capability. The last three talks were given by NASA scientists who talked about the status of the GPM core observatory, precipitation processing system, and education and outreach activities.

This session started with a talk by **Robert Cifelli** of Earth Systems Research Laboratory, Office of Oceanic and Atmospheric Research, NOAA, who reviewed NOAA's past GPM activities and progress made since the 2nd NOAA GPM User Workshop. He mentioned how NOAA actively engaged in GPM activities by forming the Steering Group on Precipitation Measurement from Space (SGPMS) (***Figure 1.1***), whose mission is to inform NOAA leadership and recommend research and development priorities across NOAA with regard to precipitation from space. He then talked about the recommendations from the 2nd NOAA GPM User Workshop and the progress made since. One of the key recommendations was for NOAA to prepare immediately to exploit GPM-era data products in NOAA operations. As part of the progress made, he mentioned the development of the Concept of Operations and Level-1 Requirements Documents for the NOAA Enterprise Precipitation Processing System (***Figure 1.2***). He also talked NOAA's participation on the NASA Precipitation Measurement Mission (PMM) Science Team and NOAA projects funded as a part of the PMM Science Team.

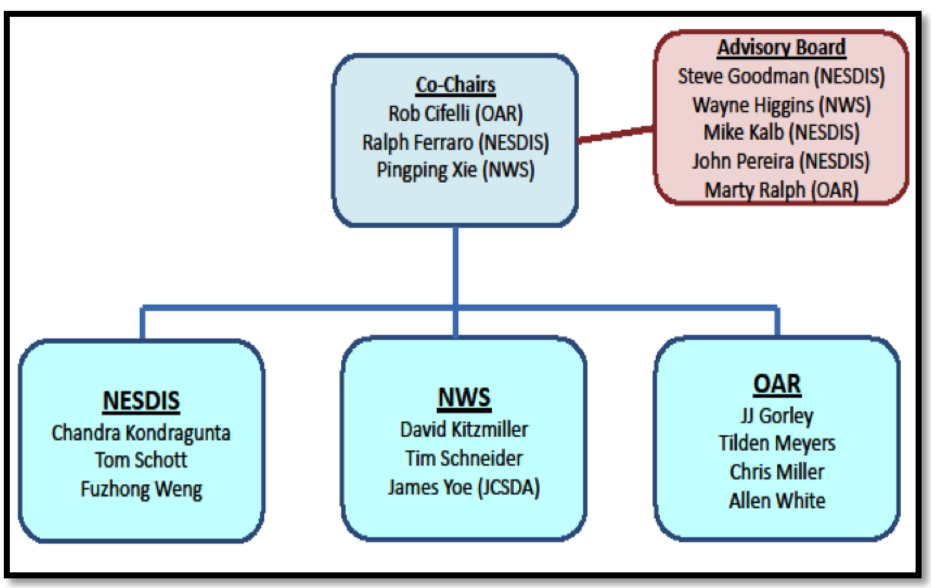



**Figure 1.1.** NOAA SGPMS and the Advisory Board.

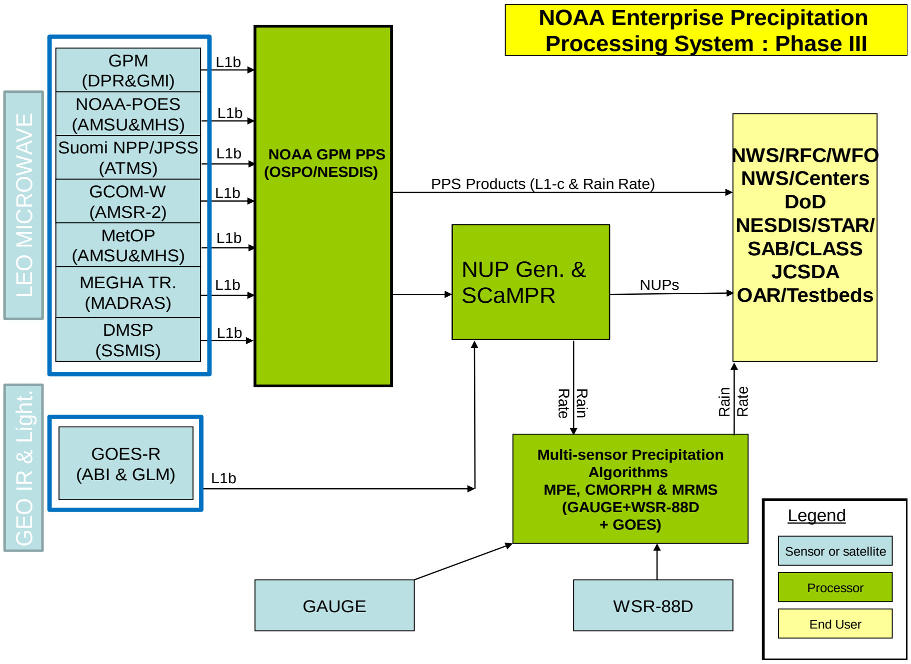



**Figure 1.2.** Final Stage of the proposed NOAA Enterprise Precipitation Processing System.

Next, **Mike Haas,** Acting Deputy Assistant Administrator for Systems of the National Environmental Satellite, Data and Information Systems (NESDIS) spoke about the importance of GPM from a NESDIS perspective. After briefly mentioning the innovation GPM offers in terms of enhancing the precipitation observing capability from space, he talked about how NOAA's satellite mission aligns with NOAA and DOC strategic plans and how GPM fulfills NESDIS priorities. He then discussed how GPM will help improve NOAA's ability to monitor and predict severe hydrological events such as hurricanes, flash floods, droughts, coastal evacuations, etc. He also talked about how the proposed NOAA Enterprise Precipitation Processing System—leveraging capabilities from the GPM—will improve the operational efficiency of precipitation processing within NOAA by consolidating several precipitation processing elements. Then he presented several examples where GPM can improve current operational precipitation products. Finally, he summarized his presentation by saying, "Mankind can live without many things, water is not one of them." He reminded the participants of the budget challenges around the globe and asked them to continue to be the champions of the GPM mission.

**The proposed NOAA Enterprise Precipitation Processing System -- leveraging capabilities from the Global Precipitation Measurement mission -- will improve the operational efficiency of precipitation processing within NOAA by consolidating several precipitation processing elements.**

**Laura Furgione,** Assistant Administrator of the National Weather Service, next talked about the role of GPM for the NWS. She said the NWS will use GPM data and products in the numerical weather prediction, NWS service center products, and NWS local forecasts and warnings. She also stated that the GPM will augment current multi-sensor Quantitative Precipitation Estimation (QPE) which is needed by National Centers for Environmental Prediction (NCEP) service

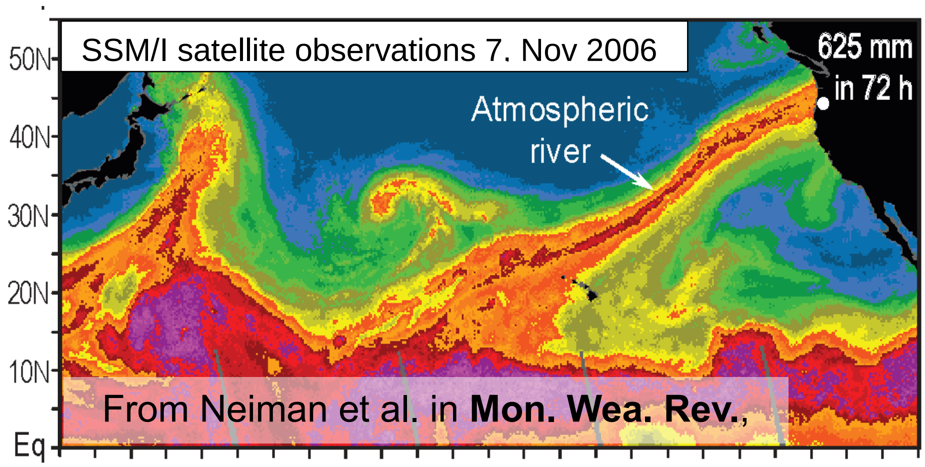



**Figure 1.3.** Example of atmospheric river derived from SSM/I for November 7, 2006 (Neiman et al., MWR, 2008)

centers such as Weather Prediction Center, National Hurricane Center (inland flooding causes the largest loss of life), and Climate Prediction Center. She then gave some examples where GPM data will be used. For example, GPM data will be used to improve tropical cyclone intensity forecasting. GPM data will also be used to augment other observing systems to detect and predict the location of Atmospheric Rivers (***Figure 1.3***) which can help provide longer lead times for those issuing flood warnings and other decision-makers. In summary, she charged the workshop participants to develop the most effective teams and plans using the expertise of NOAA, NASA, and other partners, and by collaborating with existing testbeds, proving grounds, and the NWS Office of Hydrologic Development.

Next, **Captain Barry Choy**, acting Director, Office of Hydrologic Development, NWS, talked about the importance of GPM in the NOAA Integrated Water Forecasting Program (IWFP). NOAA IWFP provides critical weather related forecasts and decision support services for the nation—river stages, river and flash flooding, water resource outlooks and climate extreme precipitation frequencies. He spoke of the requirements of precipitation for the water forecasting program and the current state of operations, limitations, and gaps in the current observing sources of precipitation such as radar, rain gauges, IR-based precipitation and NWP (see ***Figure 1.4***); and how GPM can fill some of those observational gaps. Finally, he talked about OHD's efforts to integrate GPM data in the integrated water forecasting program, and recommended the use of a testbed environment to demonstrate the utility of GPM-era QPE for a variety of water resources prediction needs.

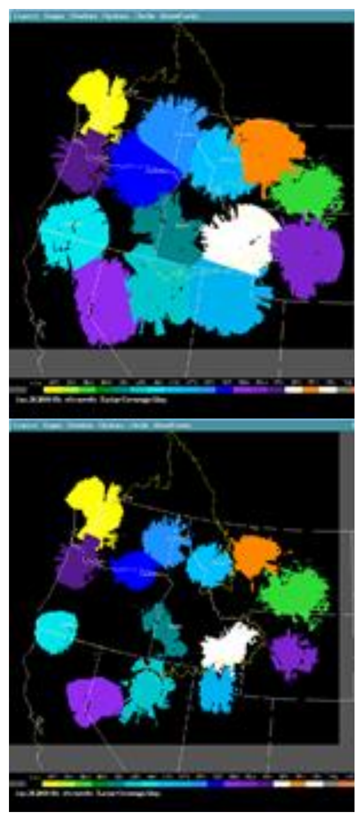


**Figure 1.4.** An example of gaps in WSR-88D effective radar coverage, for the North West River Forecast Center for summer (top) and winter (bottom).

Next, **Gail Skofronick Jackson**, GPM Deputy Program Scientist, Goddard Space Flight Center, NASA presented GPM

Program status. She began her presentation by giving the GPM constellation concept where a GPM core observatory, consisting of a microwave imager and a dual frequency radar and several microwave imagers from partner agencies around the world, will provide the next generation unified global precipitation products using GPM core observatory as reference. This GPM constellation (***Figure 1.5***) will dramatically improve the microwave sampling capability in 2015 – 80 to 90 percent are less than three hours apart at all latitudes, relative to sampling in 2012. She then gave several key milestones for science, ground validation and GPM core observatory spacecraft. The GPM at-launch algorithm codes were delivered on schedule in November 2012 for Operational Acceptance Test in 2013. The GPM core observatory integration and test are progressing on schedule. The launch readiness data is early 2014.

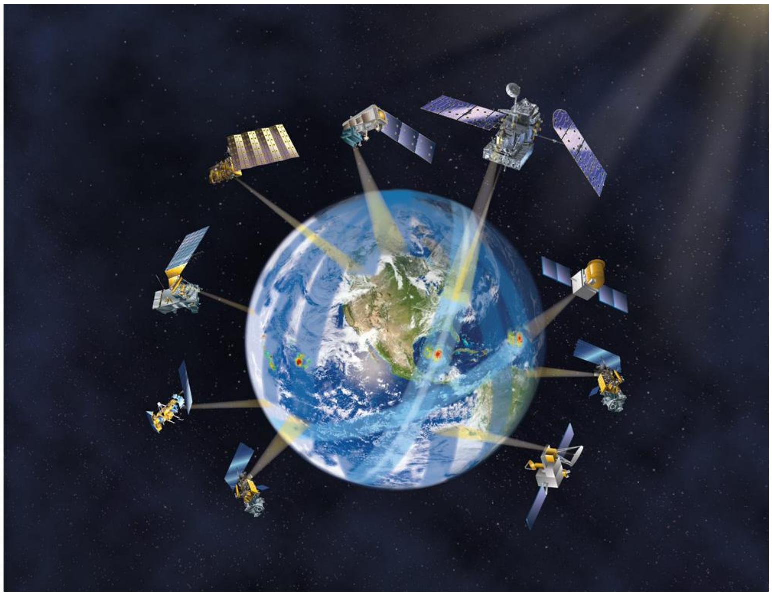
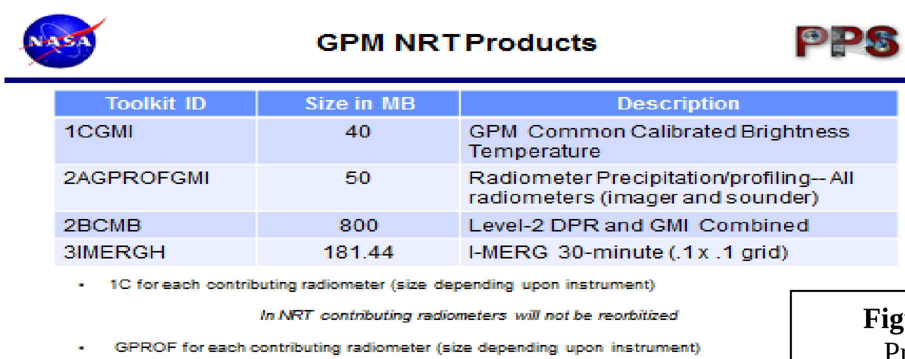


**Figure 1.5.** GPM core and constellation of satellites from partner agencies.

Next, **Erich Franz Stocker**, GPM Deputy Program Scientist for Data, Goddard Space Flight Center, NASA, presented the GPM Precipitation Processing System (PPS) architecture, status to launch, and GPM products. The GPM PPS architecture is composed of four independent subsystems/segments: Sensor Data Processing Segment (SDPS), Near-Real Time (NRT) subsystem, production, and algorithm code. All have different software and software architecture approaches and requirements for availability and latency. The PPS Operational Acceptance Test begins mid-October, 2013 and Operational Readiness Review in mid-November, 2013. He then presented a list of GPM Production Products (***Figure 1.6***). All GPM products will be produced in HDF5 (1.8 or later) format. Other formats are under investigation. The SDPS and NRT subsystems must have a 99.8% availability. He also spoke about Megha-Tropiques (M-T) and GCOM-W statuses. XCAL team is now working on at-launch inter-calibration coefficients for M-T and GCOM-W.

The last speaker of the session, **Dalia Kirschbaum**, GPM Application Scientist and Education and Outreach Coordinator, Goddard Space Flight Center, NASA, gave a GPM applications overview and talked about the education and public outreach activities. Some of the applications of rain and snow data gathered from the TRMM already provide a rich set of data and applications, and GPM will extend our capability to study a wide range of applications such as flooding, fresh water availability, agriculture/famine early warning, landslides, land surface and climate modeling, extreme events and world health. GPM's orbit will enable observation of tropical cyclones (***Figure 1.7***) as they progress from tropical to mid-latitude systems. Then she talked about data to end user connection and end user issues. She discussed education and outreach activities in which the GPM project is engaged, examples of which are: working with teachers to develop a curriculum based on GPM themes, working with college students to develop K-12 activities, providing stipends to National Parks, Fish and Wildlife Centers to develop activities for their parks, Science on a Sphere show, Social Media, Websites, photo contests, Anime Character Challenges, videos, feature stories, Google+ Hangouts, LEGO Models, and Family Science Nights, etc. Finally she gave some web sites where GPM (http://pmm.nasa.gov) and education (http://pmm.nasa.gov/education) information can be found.

**GPM will extend our capability to study a wide range of applications such as flooding, freshwater availability, agriculture/famine early warning, landslides, land surface and climate modeling, extreme events and world health. GPM's orbit will enable observations of tropical cyclones as they progress from tropical to mid-latitude systems.**



GPM NRT Products

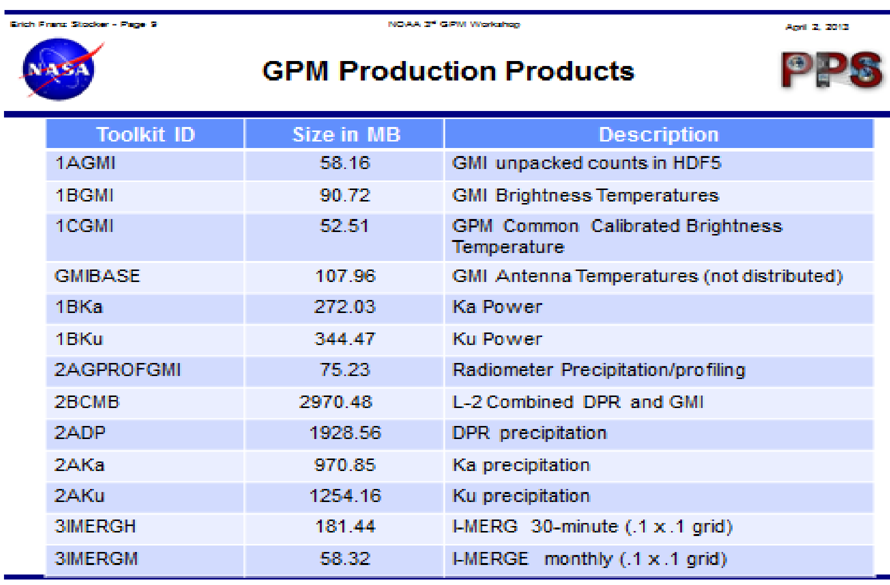
| Toolkit ID | Size in MB | Description |
|---|---|---|
| 1CGMI | 40 | GPM Common Calibrated Brightness Temperature |
| 2AGPROFGMI | 50 | Radiometer Precipitation/profiling-- All radiometers (imager and sounder) |
| 2BCMB | 800 | Level-2 DPR and GMI Combined |
| 3IMERGH | 181.44 | I-MERG 30-minute (.1 x .1 grid) |

- 1C for each contributing radiometer (size depending upon instrument)

*In NRT contributing radiometers will not be reorbitized*

- GPROF for each contributing radiometer (size depending upon instrument)

**Figure 1.6.** List of Precipitation Products of the NASA GPM Precipitation Processing System



GPM Production Products

| Toolkit ID | Size in MB | Description |
|---|---|---|
| 1AGMI | 58.16 | GMI unpacked counts in HDF5 |
| 1BGMI | 90.72 | GMI Brightness Temperatures |
| 1CGMI | 52.51 | GPM Common Calibrated Brightness Temperature |
| GMIBASE | 107.96 | GMI Antenna Temperatures (not distributed) |
| 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) |

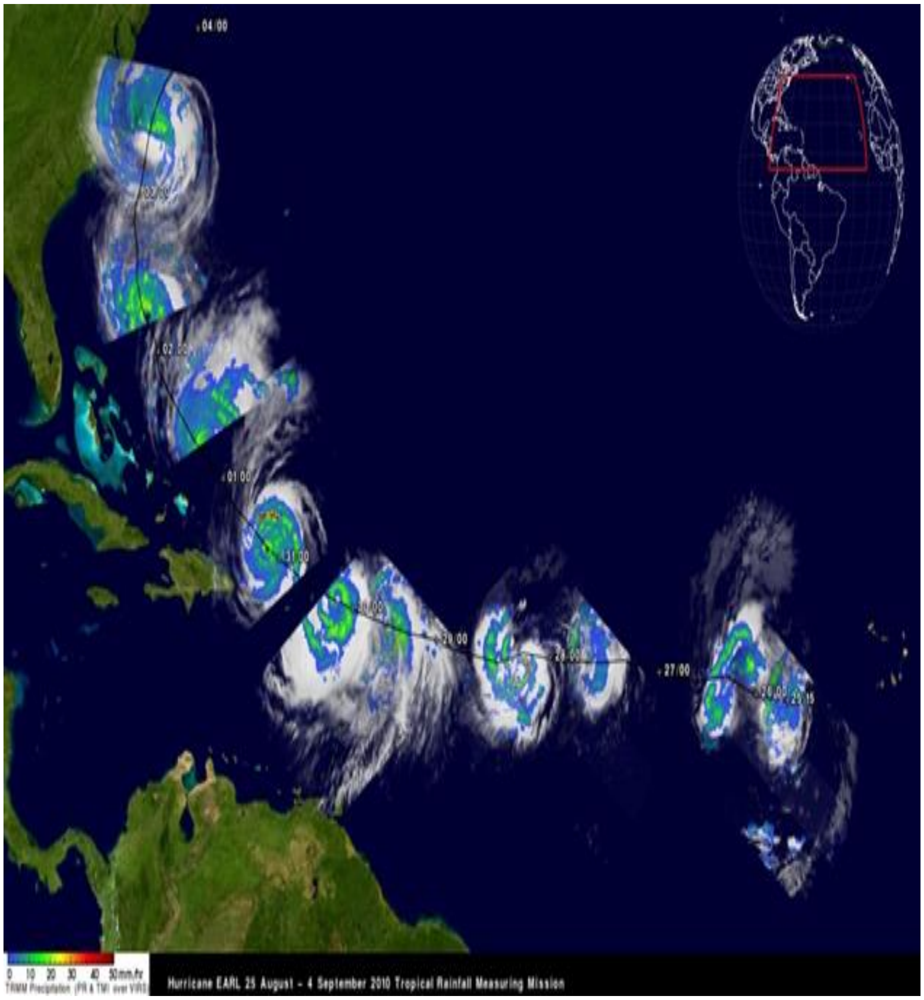



**Figure 1.7.** An example of TRMM data used for forecasting the location and intensity of a tropical cyclone.

## Session 2: NOAA GPM Proving Grounds and Testbeds

**Session Chair:** Rob Cifelli, NOAA/OAR/ESRL/PSD

This session focused on understanding the role of testbeds and proving grounds within NOAA and how a potential NOAA GPM proving ground could leverage existing resources across the organization. Although it would have been desirable to learn about all of the NOAA testbeds and proving grounds, time constraints dictated that only a subset could participate in this session. The testbeds/proving grounds represented in this session included:

- GOES-R Proving Ground
- JPSS Proving Ground
- Hydrometeorology Testbed
- Climate Testbed

Each speaker was asked to address one or more of the following questions in their presentation in order to provide a foundation for the working group discussions:

- What is the purpose/mission of the testbed/proving ground?
- How does the testbed coordinate with other NOAA testbeds/proving grounds and outside organizations?
- What strategy(s) are used to conduct research to operations (R2O)/operations to research (O2R)?
- Example(s) of R2O/O2R

The GOES-R Proving Ground presentation was given by Steve Goodman, NESDIS/GOES-R. The GOES-R Proving Ground engages NWS in pre-operational demonstrations of selected capabilities of next generation GOES. The intended outcomes are Day-1 readiness and maximum utilization for both developers and users of GOES-R products, and an effective transition to operations. In addition to the questions above, Steve described the GOES-R product suite, GOES-R partnerships across NOAA and other organizations, and future directions for the proving ground. GOES-R supports a number of precipitation algorithm development and validation activities and it was clear that there is strong synergy and potential for collaboration with the

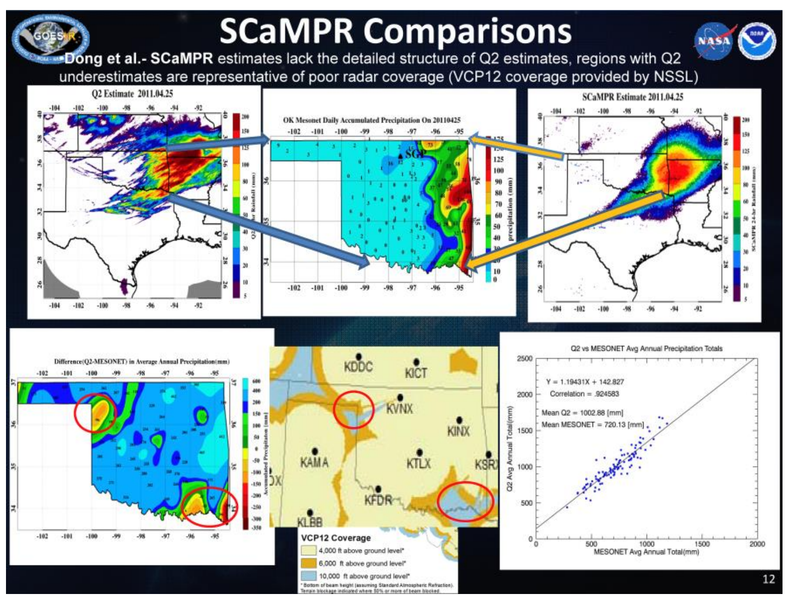



**Figure 2.1.** Comparison satellite-based precipitation estimates from Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR) with ground based estimates from the Multi-Radar Multi-Sensor (MRMS) system.

GPM Proving Ground. An example of one of the GOES-R products is shown in **Figure 2.1**.

**Ingrid Guch**, NESDIS/STAR, described the JPSS Proving Ground and Risk Reduction Program. This included an overview of hydrologic environmental data record (EDR) products available from Suomi NPP and JPSS. The primary purpose of the JPSS Proving Ground is to ensure that the NPP/JPSS products are ready for end user applications. There were several recommendations for the GPM Proving Ground including the need for approval of planned NOAA GPM activities, a NOAA GPM program scientist, and to seek official guidance regarding NOAA testbed activities.

**Rob Cifelli**, OAR/ESRL, and **Wallace Hogsett**, NWS/WPC, provided a joint overview of the Hydrometeorology Testbed (HMT), which emphasizes improved understanding and prediction of precipitation events that lead to flooding. Although the Physical Sciences Division (PSD) provides the overall leadership of HMT, the testbed is implemented both at ESRL in Boulder, CO and at WPC in College Park, MD. The two organizations have complementary roles: PSD emphasizes the research component and WPC emphasizes the operations side of HMT. Together, the two organizations have an effective strategy to achieve R2O and O2R. The emphasis of HMT on heavy precipitation provides a conduit to test, validate, and improve GPM algorithms.

The PSD talk provided an overview of research activities in the western U.S. (HMT-West), including atmospheric rivers (ARs) (***Figure 2.2***), quantitative precipitation estimation (QPE), quantitative precipitation forecasting (QPF), hydrologic and land surface processes (HASP), and snow information. A brief overview of the new HMT Southeast Pilot Study (HMT-SEPS) was also provided.

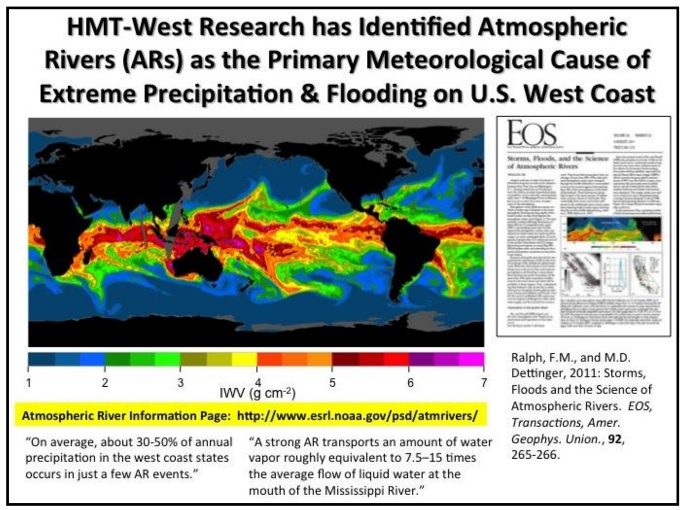



**Figure 2.2.** Description of the role of ARs in producing heavy precipitation in the western US.

The WPC talk emphasized the role of forecast experiments (both real-time and retrospective) in training forecasters and providing new insights on model performance and decision support tools (DSTs) for improved prediction of warm and cool season heavy precipitation events. A recent example included the Atmospheric River Retrospective Forecast Experiment (ARRFEX), which brought together forecasters and researchers to better understand AR phenomena and determine which forecast models provided the best guidance for such events (***Figure 2.3***).

**Mike Halpert**, NWS/CPC, wrapped up the session with an overview of the Climate Testbed (CTB). The CTB has three priorities: (1) provide improved climate forecast tools and products; (2) accelerate evaluation and improvement of the Climate Forecast System (CFS); and (3) leverage the National Multi-Model Ensemble (NMME) to improve forecasts on intraseasonal to interannual timescales. The role of the Climate Prediction Center (CPC) Morphine Technique (CMORPH) algorithm in providing verification of NCEP prediction models was described as well as the importance of GPM data in developing the new pole-to-pole CMORPH for improved climate monitoring. The talk concluded with an emphasis on the role of CTB as a testing platform for GPM products in NOAA operations.

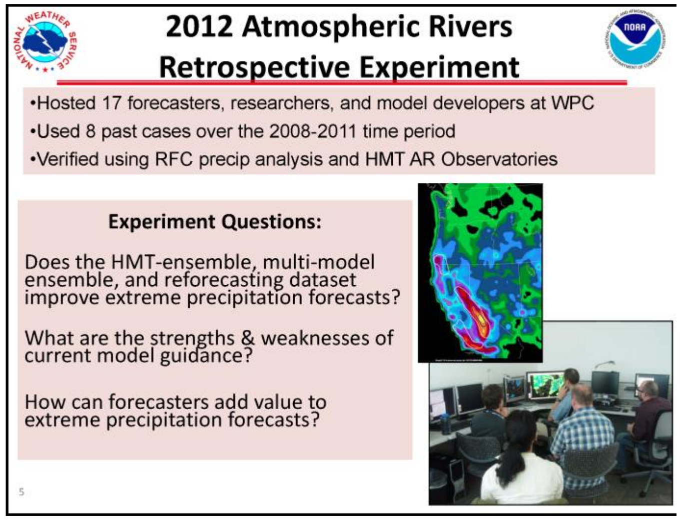



**Figure 2.3.** Description of the ARRFEX forecast experiment hosted by WPC.

## Session 3: NOAA GPM Research and Algorithm Development

**Session Chair:** Yu Zhang, NOAA/NWS/OHD

**Presenters/Panelists:**

1. David Kitzmiller (NWS/OHD)
2. Pingping Xie (NWS/NCEP/CPC)
3. Bob Rabin (OAR/NSSL)
4. Yu Zhang (NWS/OHD
5. George Huffman (NASA/GSFC)
6. V. Chandrasekar (CSU)

Session 3 focused on the operational context of NOAA precipitation information and the R&D challenges that GPM algorithm developers need to address in order for the GPM products to be transitioned into operation. This session featured six presentations, including one impromptu "elevator speech" Dr. George Huffman from NASA was asked to make. The presentations were followed by a discussion among the panelists and audience on the NOAA priorities with respect to

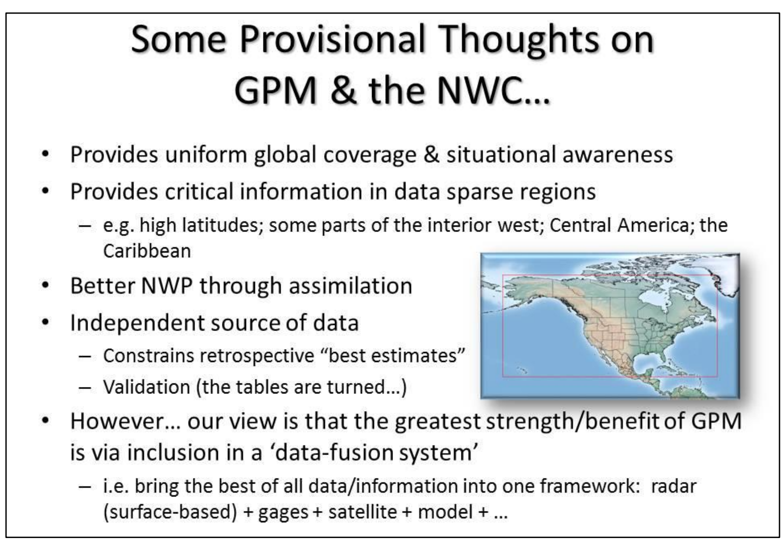



**Figure 3.1.** The potential use of GPM data (Schneider et al).

fused satellite precipitation and satellite-radar-gauge products and their applications.

The first session presentation was provided by **David Kitzmiller** from NWS OHD (authored by Timothy Schneider and Greg Fall) on NOAA Integrated Water Resources Science and Services (IWRSS), and the potential role of GPM-era satellite QPE in the production of precipitation data in the National Water Center Operations. (***Figure 3.1***).

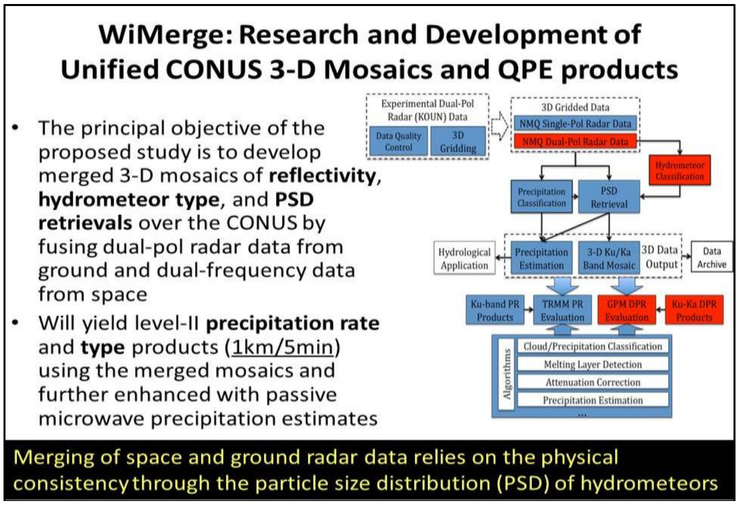



**Figure 3.2**. The flow diagram for the WiMerge: a framework that combines ground radar and GPM radar data to produce high resolution precipitation products.

The second talk, entitled "NOAA Satellite Data Fusion: Current Status and Future Plan" (authored by Pingping Xie and Bob Kuligowski), was delivered by **Pingping Xie** from CPC. This talk focused on the planned fusion activities at CPC and NESDIS/STAR, through the CPC-Morphing (CMORPH) and the Self-calibrating multivariate precipitation retrieval (SCaMPR) frameworks (***Figure 3.2***). Both mechanisms will be used to generate low latency (< 1h), high resolution (2 km) regional products for the NA by combining microwave and multi-channel GOES-R observations.

**NOAA has taken steps to fuse GPM products with its ground sensor products. Existing fusion/blending platforms include:**

- **Multi-sensor Precipitation Estimator (NWS/OHD)**
- **WiMerge (OAR/NSSL)**
- **CMORPH (NWS/NCEP)**

The third talk was entitled "WiMerge: Mosaicking NEXRAD Dual-Pol and GPM DPR Products for Hydrometeor Retrievals and QPE over the CONUS". The talk was prepared and delivered by **Bob Rabin, Pierre-Emmanuel Kirstetter,** and **J J Gourley** of NSSL/UOK. This talk touched upon the MRMS framework,

TRMM-PR evaluation using

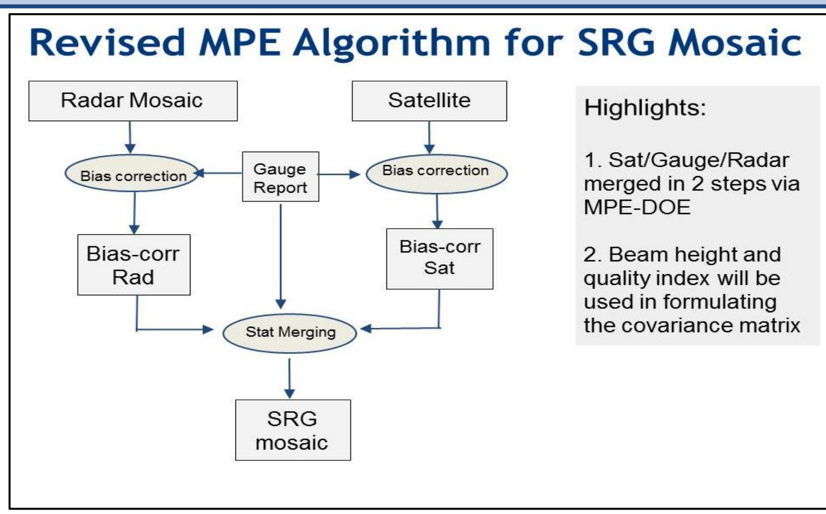



**Figure 3.3.** Flow diagram of revised Multisensor Precipitation Estimator (MPE) that allows the ingest of GPM-era satellite QPE.

Q2 and the proposed WiMerge framework that utilizes the GPM dual-frequency radar data to augment the hydrometeor classification mechanism from the dual polarimetric ground radars to create 3-D mosaicked reflectivity and hydrometeor types (***Figure 3.2***).

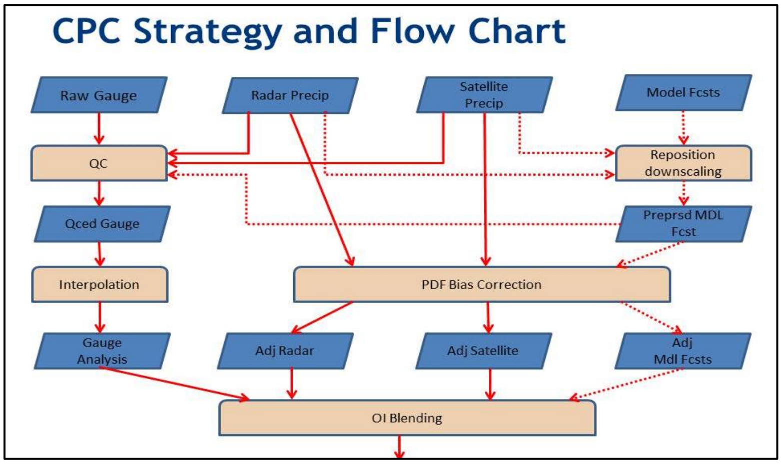



**Figure 3.4.** CPC strategy of creating high resolution multisensory blended products with GPM as one of ingredients.

The fourth talk, entitled "Fusing GPM and Ground Observations for Hydrologic and Climate Applications," was authored by Yu Zhang, David Kitzmiller at OHD and Pingping Xie from CPC, and delivered by **Yu Zhang**. This talk discussed the planned methodologies for bias correction and producing satellite-radar-gauge fusion products via the augmented CMORPH and the Multisensor Precipitation Estimator (MPE) algorithm package (***Figure 3.3***). The point that the fusion algorithms should be gauged by their impacts on hydrologic predictions was raised during the discussion. **Figures 3.4 and 3.5** depict CPC's strategy of using GPM to create high resolution blended products.

The fifth talk was from **George Huffman** from NASA on the GPM IMERG mechanism and product **(Figure 3.6)**. IMERG will subsume the TMPA, CMORPH, and PERSIANN mechanisms to create GPM multi-satellite products with and without regional gauge data. A major R&D issue being raised concerns error estimation.

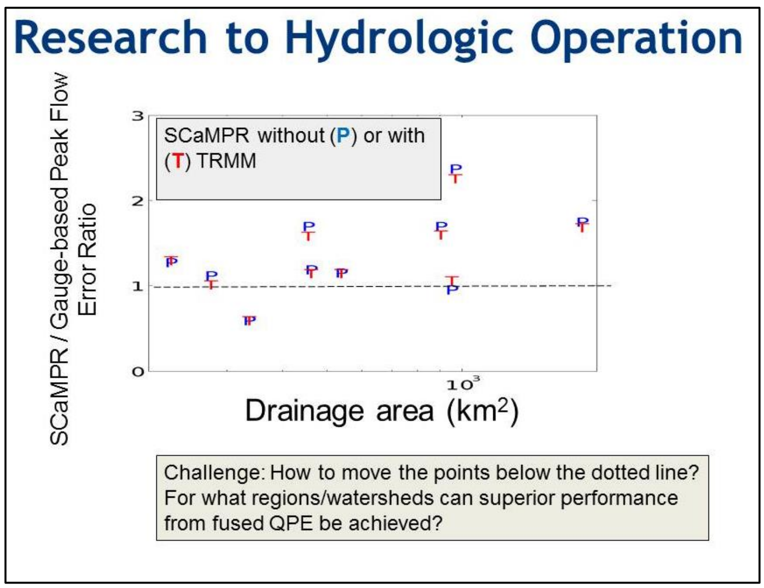



**Figure 3.5.** There is a need to assess the impacts of infusing GPM on low-latency operational satellite QPEs. Note TRMM ingest broadly improves SCaMPR quality as shown in a previous study.

**Key issues in R2O transition of GPM products:**

**1. Benefits of GPM to multi-satellite fused products such as SCaMPR and CMORPH**

**2. Latency and accuracy, and GPM-era satellite QPEs versus that of ground sensor products**

**3. Error characteristics of GPM-era satellite QPEs.**

The last talk featured **V. Chandraseka** from Colorado State University on different fusion paradigms and science issues. Fusion mechanisms at image level, data level, and sensor level, were discussed with examples provided.

The presentations prompted a number of questions from the audience. Bob Adler from University of Maryland raised the issue about the practicality of the fusion mechanism and advocated for a simpler approach that would serve as a starting point. Yu Zhang echoed George Huffman's call for better error estimation in order to build more robust multisensor merging mechanisms, but also stressed that such a task is often challenging and needs good metrics for success. Rob Cifelli from OAR/ESRL suggested that perhaps MRMS should be the platform on which any future SRG fusion mechanism should be implemented. A few additional questions revolved around the operational prospect of MPE, CMORPH, and MRMS systems; difficulties in estimating error field; and the most rigorous methods for data fusion. Ralph Ferraro, NESDIS/STAR, relayed the message from Chris Kummerow at CSU on the next generation physically based fusion (assimilation) mechanism.

**IMERG DESIGN – Requirements/Goals**

- Resolution – 0.1° [i.e., roughly the resolution of microwave, IR footprints]
- Time interval – 30 min. [i.e., the geo-satellite interval]
- Spatial domain – global, initially covering 60° N-60° S
- Time domain – 1998-present; later explore entire DMSP era (1987-present)
- Product sequence – early sat. (~4 hr), late sat. (~12 hr), final sat.-gauge (~2 months after month) [more data in longer-latency products]
- Sensor precipitation products intercalibrated to TRMM before launch, later to GPM
- Global, monthly gauge analyses including retrospective product – explore use in submonthly-to-daily and near-real-time products
- Error estimates – still open for definition
- Embedded data fields showing how the estimates were computed
- Precipitation type estimates – probability of liquid
- Operationally feasible, robust to data drop-outs and (strongly) changing constellation
- Output in HDF5 v1.8 – compatible with NetCDF4
- Archiving and reprocessing for near- and post-RT products

**Figure 3.6.** IMERG products requirements and goals (G. Huffman).

## Session 4: Outreach and Applications Needs and Goals

**Session Chair:** Stephen Mango, NOAA/NESDI/OSD and Stephen A. Mango, Consulting

The formal presentations in Session 4 represented a portion of the NOAA National Weather Service centers. The session presentations and discussions served as a prelude to the discussions and deliberations of Working Group 3 (WG3) on Training, Education, and Outreach.

**Greg Story,** NOAA/NWS/West Gulf River Forecast Center (WGRFC), Hydrometeorological Analysis and Support (HAS) forecaster, indicated the WGRFC need for satellite precipitation estimates in near real-time in fast responding river basins subject to flooding where there are perpetual or temporary gaps in ground radar coverage and/or precipitation gauges. (***Figure 4.1***.)

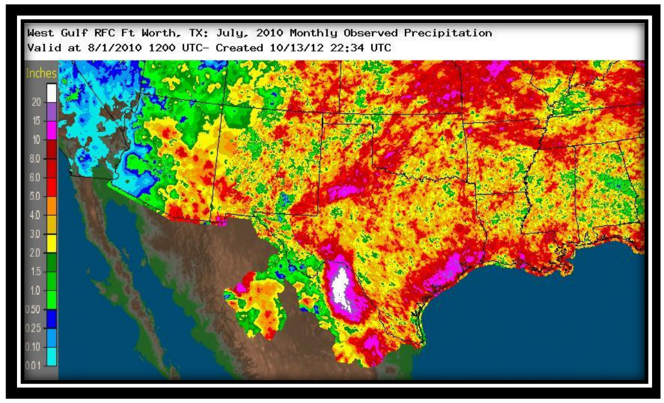



**Figure 4.1**. WGRFC and the Need for Satellite Precipitation Estimates (Gregory Waller and Greg Story, NOAA/NWS/WGRFC HAS, Fort Worth, TX).

**GPM Data would help WGRFC with "big" events in places with less than ideal radar coverage, over flashy basins, or both – e.g. Hurricane Alex – July 2010. "We do not know exactly how much rain fell in Northern Mexico. As a result of this rainfall, WGRFC extended flood operations for the Rio Grande/Rio Bravo well into August."**

Greg Story emphasized the need for training on the details of the GPM project – its strengths, its weaknesses and its operations (especially with respect to its delivery times and its availability in MPE, multi-sensor precipitation estimator), as well as when to use and when not to use satellite data.

**Michael Brennan**, NWS National Hurricane Center (NHC), gave several of the anticipated uses of GPM data and products at NHC in their operations for tropical cyclone (TC) evolution, analysis and prediction based on their existing uses of TRMM data and products and the large number of satellite, passive microwave imagers and sounders data and products. (***Figure 4.2***.)

He indicated how GPM would be one important tool in a large toolbox of existing tools to estimate the position (i.e., center), the intensity, and the structure of a given TC. The authors gave demonstrations of the impact of microwave imagery – the impact of spatial resolution especially for locating the low-level center and the ability to resolve low to mid-level eyewall structure; the impact on monitoring TC core evolution, and its rapid intensification, eyewall replacement, annular hurricanes and the impact of rainband structure and evolution (***Figure 4.3***.).

Brennan (and Jack Bevin) stated clearly two of the important lessons from ongoing proving grounds were:

**Ensuring that data are available in the operational decision support platform is critical (NAWIPS to AWIPS2) … Providing training on product details and interpretation, including comparisons to imagery and data from other platforms, facilitates the adoption and use by forecasters.**

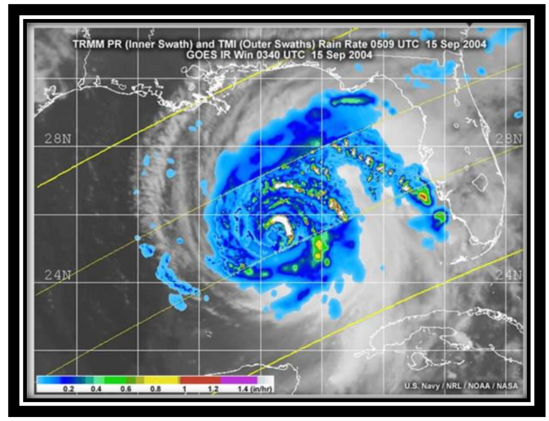



**Figure 4.2.** The Use of GPM Data and Products at NHC (Michael Brennan and Jack Beven).

**Brian Motta**, Forecast Decision Training Branch (FDTB), NOAA/NWS/OCWWS, gave some important definitions, clarifications and examples from the perspective and heritage of the NWS FDTB of the fundamental terms: Outreach, Education and Training. These fundamental terms would set the initial stage for the Workshop's Working Group 3 (WG3) on Training, Education and Outreach in the GPM-era. He delineated both the International and the NOAA/NASA collaborative training communities and the synergies to be garnered. (***Figure 4.4***).

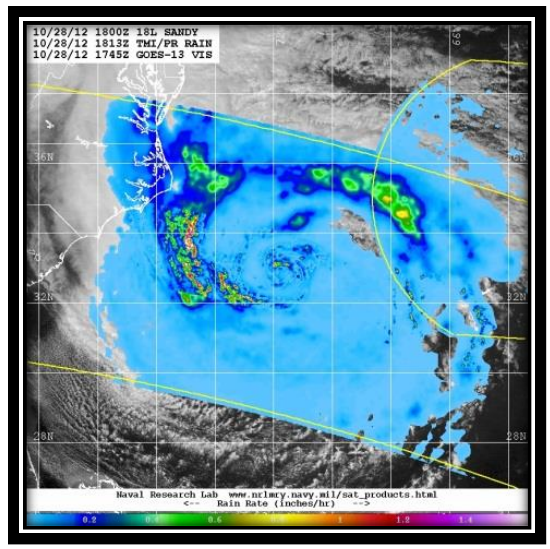



**Figure 4.3.** Rainband Evolution of Hurricane Sandy – 1813 UTC 28 Oct. 2012.

The status and progress made in outreach, education or training were presented for the Suomi –National Polar-orbiting Partnership (S-NPP) program, the GOES-R Proving Ground evaluation partners efforts and the future Geostationary Operational Environmental Satellite (GOES-R Series) and the Joint Polar Satellite System (JPSS) programs. The authors described the NWS Learning Center (LC), which includes the essentials of the VISIT (Virtual Institute for Satellite Integration), Training with a focus on a satellite proving ground and the UCAR/COMET® Training with its extensive number of training modules for the NWS Learning Center categories in meteorological education (MetEd) and hydrology (HY) education. (***Figure 4.5***.)

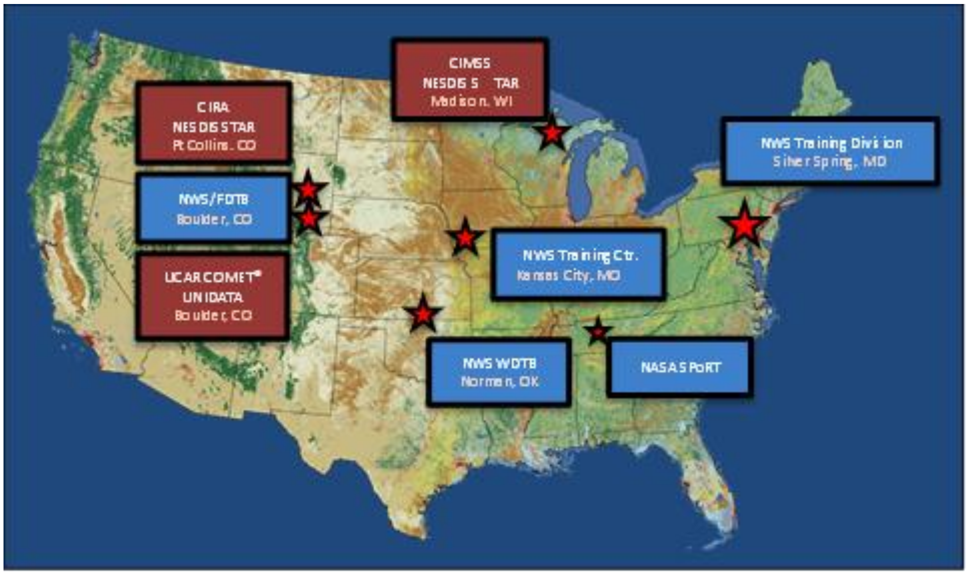



**Figure 4.4.** NOAA/NASA Collaborative Training Community.

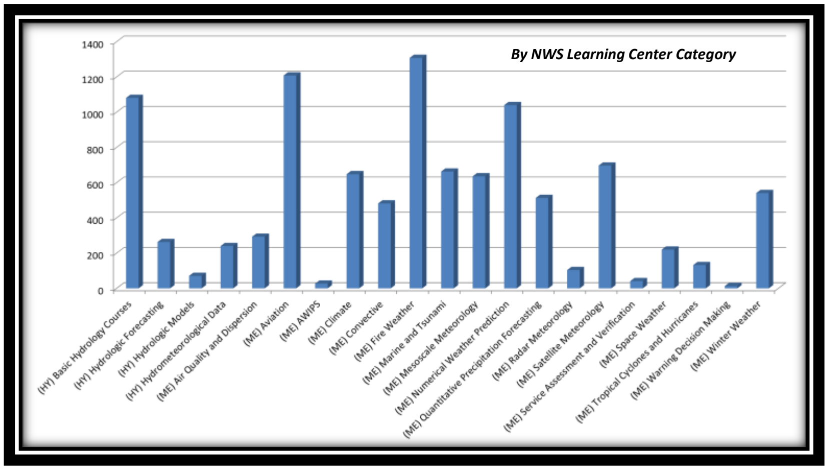



**Figure 4.5.** NWS Learning Center COMET Module Completions (Feb 2012 – Jan 2013). (Brian C. Motta, NOAA/NWS, Office of Climate, Water, and Weather Services Forecast Decision Training Branch, Boulder, CO).

## Session 5: Working Group Formation and Charge to the Working Group

Three Working Groups (WGs) were formed centered around the main overarching themes that resulted from the previous workshop in 2011: The NOAA GPM Proving Ground, Research and Development focused on data fusion, and Education and Outreach. The workshop organizers prepopulated the WGs based on workshop registration and also the background of the participant; the goal was to achieve some "balance" within the WGs. Each WG lead developed a set of "starting points" for the discussions and solicited input from the WG members. Unfortunately, many of the participants pre-identified were unable to participate in the WGs, and therefore many of them were assigned to WGs in the first WG plenary session on the second day of the workshop.

Each WG was 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 WGs were asked to consider work that can be done with in-house NOAA resources, e.g., FTEs.  Each WG was assigned a chair and a rapporteur. Their findings follow.

# Working Group Reports

## *Working Group 1: NOAA Proving Ground Needs*

**Chair:** Ralph Ferraro, NOAA/NESDIS/STAR

**Rapporteur:** David Kitzmiller, NOAA/NWS/OHD

**Members:** Robert Adler (University of Maryland); Mike Bodner (NOAA/NWS); R. Cifelli (NOAA/OAR); Rich Fulton (NOAA/NESDIS); Mike Johnson (NOAA/NWS/OST); Jesse Meng (NOAA/NWS); Dennis Miller (NOAA/NWS); Scott Rudlosky (NOAA/NESDIS); Bill Sjoberg (NOAA/JPSS); Ali Tokay (NASA); Allen White (NOAA/OAR); Limin Zhao (NOAA/NESDIS)

**Overview:** The focus of the Working Group (WG) one was to define the attributes of a new NOAA Proving Ground (PG) dedicated to GPM. This was an action that was specified as a high priority item as an outcome of the second workshop. The WG consisted of a well-rounded group from NESDIS, NWS and OAR as well as academia and NASA. A set of overarching questions was developed by the WG chair to help facilitate and focus the ensuing discussions during the second day of the meeting:

- How do we develop a NOAA GPM Proving Ground and what are its attributes?
- Who would be the primary PG producers?
- Who would be the primary PG consumers?
- What products should the PG produce?

***Proving Ground Development***

The group wrestled with the question of whether to fold the GPM proving ground into one or more existing NOAA proving grounds or whether a new proving ground needed to be created. It was determined that it would be advantageous for the NOAA GPM proving ground to leverage existing PGs established by the GOES-R program and those emerging out of the JPSS program. (It was noted that there is a strong likelihood that the PGs from these two programs would merge in the near future.) Future discussions with the project scientists from both of those programs are needed to further evolve this concept, including, perhaps, a "retrofit" of existing hydrology risk reduction projects from both satellite programs into a "Precipitation Enterprise Proving Ground" that could encompass the requirements of the GPM PG. The WG noted that any new PG must adhere to the existing rules of governance of all NOAA PGs, including having committed users of the products (see www.testbeds.noaa.gov). The group noted that there are several "low hanging fruits" within NOAA's testbeds that are "ripe" for GPM-era hydrological product, including Hydrometeorology, Hurricane, and Climate, as well as the Weather Prediction Center/Ocean Prediction Center. Specific roles for each of these potential activities still need to be clearly defined. Additionally, the WG discussed the importance of having a "Satellite Champion" to work closely with the PG users as this model has been highly successful in a number of locations (i.e., Michael Folmer was noted as a highly successful satellite champion working at the WPC/OPC PG at the NCWCP in College Park, MD). One last unique component of a GPM or Precipitation focus PG would be an explicit validation part, where the performance of the various products could be routinely performed and be utilized by both the PG producers and consumers.

***PG Producers and Consumers***

If the goal is to leverage existing entities, then the group concluded that centers such as NASA's SPoRT or the NOAA WPC/OPC were the logical choices; both are closely connected to NOAA PGs that are guided by a NOAA-wide Executive Board. The WG also discussed if it made sense to simply ask the NASA PPS group to try to produce some of their products in the necessary NOAA formats such as NetCDF, BUFR, and HDF5. Additionally, the WG felt that if any NOAA entity (i.e., a specific NESDIS or OAR unit or related cooperative institute) wanted to develop some in-house capability for R&D purposes, they should move forward in that regard and then develop relationships with one of the above mentioned official NOAA PGs. Follow up discussions are needed to flesh out this idea via a GPM PG Tiger Team.

In terms of PG data users, it was recognized that there are several immediate users where initial interest in GPM era data/products has already been established, e.g., Hydrometeorology Testbed, Hurricane Testbed, Climate Testbed as well as others with strong interest based on this workshop, e.g., Western Gulf RFC, North West RFC, Alaska Region and WPC/OPC. The group also discussed whether a GPM PG should consider global applications and users, but no specific conclusions were drawn although groups such as the Joint Typhoon Warning Center were mentioned. Again, the GPM PG Tiger Team would specify users with immediate desire for the GPM-era data and products, and then coordinate this with the NWS Operations Application Team (NOAT).

***What Should be Produced***

There are number of products right now that can be made available through the GPM PG. This includes the NOAA CMORPH "suite" of products, NESDIS' SCaMPR, NASA's TMPA as well as NOAA Unique Products (NUPs) such as the blended TPW (bTPW), blended Rain Rate (bRR). The group also considered MW brightness temperatures (TBs) from the LEO constellation as well as even synthetic GPM Microwave Imager (GMI) TBs. Following the GPM core launch, the actual GPM products (e.g., IMERG, L1C TBs) would then be served. Specific requirements were previously collected while the GPM L1RD and CONOPS were generated by C. Kondragunta so the L1RD and CONOPS would need to be consulted. Needed formats were also discussed (e.g., NetCDF, HDF5, BUFR, GRIB, etc.). Finally, validation data sets should also be generated, with coordination with the NOAT recommended.

***Better Connectivity into Planned/Ongoing Experiments at NOAA TBs***

It was learned that the existing NOAA PGs and Testbeds have conducted focused experiments that should be better connected to the goals of the GPM PG. An example of such an experiment was one that focused on Atmospheric Rivers at HPC in late 2012. It was noted that an NCEP/WPC flash flood evaluation is planned (called FFAIR) for 2013, as well as a follow-on to HMT West (CalWater 2, Marty Ralph, OAR). It was suggested that the GPM PG get involved in the planning of such events in the future. One way to do this is to start participating at the monthly NWS-NESDIS PG/Testbed tag-ups organized by Kathryn Mozer.

***Better Promotional Material for NOAA GPM PG***

As the GPM PG develops and evolves, it needs to be better promoted and also coordinated within NOAA and with NASA. It was noted that some promotional information be developed, including graphics indicating the relationship with ongoing activities at NOAA.

***Specific Actions:***

| Group 1: Collect Information | | | |
|---|---|---|---|
| **Task/Milestone** | **Champion(s)** | **Steps Needed to Accomplish** | **Funding Source or Targets** |
| GPM product proving ground | R. Ferraro<br>R. Cifelli<br>C. Kondragunta | 1. Discuss PG opportunities within GOES-R (S. Goodman) and JPSS (M. Goldberg)<br>2. Identify potential PG satellite champion<br>3. Product requirements from L1RD | Use existing resources |

| Group 1: Near-Term Issues | | | |
|---|---|---|---|
| **Task/Milestone** | **Champion(s)** | **Steps Needed to Accomplish** | **Funding Source or Targets** |
| Engage NWS-NESDIS PG/Testbed Monthly Meetings | R. Ferraro | Contact Kathryn Mozer to get on their regular meeting list and agenda | Use existing resources |
| Pursue the development of AWIPS type PG research arms as NOAA Cooperative Institutes | S. Rudlosky<br>R. Cifelli | Identify hardware needs and costs (J. Zajic of NWS), as well as connectivity with possible consumers. | Use existing resources/seek funding from PGRR programs |
| Seek formal funding for new PG | R. Ferraro<br>Y. Zhang | Develop proposal for consideration for FY14 GOES-R PGRR proposals (due date: July 2013) | GOES-R PGRR |
| GPM PG Tiger Team | R. Ferraro<br>R. Cifelli<br>M. Bodner | Form GPM PG Tiger Team by October 2013 to formalize its role and details for the PG, including validation data sets and leveraging off of existing STAR Cal/Val Center, HMT ground data and NMQ radar products | Use existing resources plus seek continued resources for HMT, NMQ and Cal/Val |

## *Working Group 2: Research Needs and Algorithm Development*

**Chair:** George J. Huffman, NASA/GSFC

**Rapporteur:** Pingping Xie, NOAA/NWS/CPC

**Members:** Bob Adler (UMCP/ESSIC); George Huffman (NASA/GSFC); Mike Johnson (NOAA/NWS/OST); Kelly Mahoney (NOAA/OAR/ESRL); Brian Vant Hull (NOAA CREST); Pingping Xie (NOAA/NWS/NCEP/CPC);Yu Zhang (NOAA/NWS/OHD); Limin Zhao (NOAA/NESDIS)

**Overview:** The objective of the group was to "identify use of GPM data in research and operational algorithm development" specifically for NOAA. By its nature, "precipitation" is a cross-cut of numerous NOAA components. Most users don't care where the precipitation numbers come from, so as the field matures it is critical to focus on results, not institutional boundaries. The GPM constellation and attendant data fusion emphasis aligns with this point of view, even as we all fully recognize and support the detailed work that is required to develop and manage each observing system, including precipitation gauges, surface radars, and individual satellite systems. We note that there is a wide range of users, from internal, high-end/high-band-width customers at various NOAA centers, to the very resource-constrained WFOs, to the diverse external user communities. Finally, it is still the case that precipitation estimation is a work in progress, and there is no assurance that all user requirements can be satisfied, even after additional development work, and even merging all possible data sources.

**Specific Actions:** The discussion surfaced numerous issues, which seemed to fall into three general areas: Collect Information, Near-Term Issues, and Long-Term Issues, as summarized in the following tables. In order to enhance research activities related to precipitation data fusion, NOAA needs to:

1. Vastly improve coordination across its line offices for GPM-era R&D related to satellite data fusion and fusion with ground radar and rain gauges.
2. Create a collaborative computing framework across NOAA line offices (e.g., NESDIS, NWS, OAR) to provide a focus for fused data set R&D.
3. Develop a committed strategy to perform episodic reprocessing of precipitation-relevant data archives that are consistent with both updates of input data and with algorithm upgrades, thus enhancing the usability of orbital data in blended precipitation products. To date, NOAA only reprocesses such data through its CDR program and this is typically after a satellite sensor has been in operation for more than a decade.

Three issues were passed to other working groups:

***WG1***

Identify PG participants to design the operational NOAA products.

***WG3***

There is a future need for training on products moving into AWIPS2.

There is an immediate need for training on the distinction between precipitation time/space grid resolution and the useful (or effective) product resolution. Most acutely, some grid sizes are or will be smaller than the input microwave footprints, but it also includes the distinction between snapshots and time-averages, and point observations versus footprints/grid boxes.

***Specific Actions:***

| Group 2: Collect Information | | | |
|---|---|---|---|
| **Task/Milestone** | **Champion(s)** | **Steps Needed to Accomplish** | **Funding Source or Targets** |
| Identify a "current status" task force | NOAA SGPMS | Pull in dataset experts for short-term study | Use in-house NOAA resources |
| Catalogue or list current operational products derived from the TRMM and passive microwave constellation | NOAA SGPMS | • Use relevant parts of IPWG precipitation datasets list<br>• Create a list of NOAA (satellite) precipitation products (Levels 2 and 3) | Use in-house NOAA resources |
| Gather information on | "current status" | Interview product developers | Use in-house NOAA |

| | | | |
|---|---|---|---|
| ongoing multi-sensor precipitation product development efforts for both continental and global scales | task force | | resources |
| Develop Level 2 user requirements for NOAA-specific GPM-era satellite precipitation products | "current status" task force | • Level 1 requirements are done<br>• Presumably need to follow NESDIS procedures<br>• These should include requirements from all aspects of NOAA operations, services, and R&D for snowfall information | Use in-house NOAA resources |
| Develop a corresponding "state of the science" assessment of current and near-term capabilities to gauge the realism of satisfying the user requirements | "current status" task force | Interview product developers | Use in-house NOAA resources |

| Group 2: Near-Term Issues | | | |
|---|---|---|---|
| **Task/Milestone** | **Champion(s)** | **Steps Needed to Accomplish** | **Funding Source or Targets** |
| Assure the necessary archiving and data-release facilities for the NOAA GPM-era satellite precipitation products (both single- and multi-sensor) | NOAA GPM leadership | Work with NOAA and NESDIS leadership to ensure that the administrative permissions and practical support are in place to enable the NOAA and NESDIS archive sites to handle the range of NOAA GPM-era satellite precipitation products | NESDIS |
| Assure the resources necessary to perform reprocessing for the NOAA GPM-era satellite precipitation products (both single- and multi-sensor) when new algorithms and algorithm versions are made operational | NOAA GPM leadership | Work with NOAA and NESDIS leadership to put forward the user perspective that consistent archives of data are critical and to develop the resources and computer bandwidth to perform the necessary reprocessing | NESDIS |
| Design a GPM-era NOAA precipitation product suite | "Current status" task force | • Consider the different requirements for global vs. CONUS precipitation analyses/ estimates<br>• Include components, accuracy, coverage, resolution, latency, etc.<br>• Examine the possibility of including other related products (e.g., water vapor, snow coverage) as part of the product suite | |
| Determine the timelines for the use of GPM-era precipitation products in NOAA | "Current status" task force | estimate the timing for release of the various products | |
| Establish a framework for multi-sensor fusion of precipitation products from satellites, radars, gauges and numerical weather prediction model outputs that can be used across | HMT, developers' task force | • Coordinate activities to establish a collaborative (perhaps virtual) computing platform on which various NOAA centers<br>• Can work together toward a system for improved NOAA multi-sensor fused regional precipitation analyses<br>• Taking advantage of existing and emerging | |

| | | |
|---|---|---|
| NOAA line offices | | techniques |
| Use the collaborative computing platform to evaluate innovations such as the use of the Multi-Radar Multi-Sensor System for calibration of Passive Microwave sensor precipitation estimates | Innovation developers | Implement innovations on the platform, then use the environment for testing |
| Identify paths of research to operations for assimilating precipitation products in numerical weather prediction models | NOAA GPM Workshop Organizers | • Improve communications with the Joint Center for Data Assimilation on the use of GPM constellation observations for global and regional data assimilation<br>• The fusion products developers, in particular, need to continue interactions and collaborations with NOAA land surface modelers to improve usage of GPM-era precipitation products for operational land surface models |

## *Working Group 3: Training, Education and Outreach Needs for Use of GPM Data in NOAA Operations and Applications*

**Chair:** Kenneth Carey, ERT, Inc.

**Rapporteur:** Stephen Mango, NOAA/NESDIS/OSD and Stephen A. Mango, Consulting

**Members:** Mamoudou Ba (NOAA/NWS); Li-chuan Chen (NOAA/NWS): David Furlong (NOAA/NESDIS); Mike Johnson (NOAA/NWS/OST); Dongsoo Kim (NOAA/NESDIS); Dalia Kirschbaum (NASA/GSFC); Chandra Kondragunta (NOAA/NESDIS/OSD); Sheldon Kusselson (NOAA/NESDIS); Brian Motta (NOAA/NWS/OCWWS); Robert Rabin ( NOAA/OAR); Roshan Shrestha (NOAA/NWS/EMC)

**Overview:** Each of the three WGs was tasked to address one of the three fundamental objectives of this Workshop. The objective of WG3 was to identify the training, education and outreach needs for the use of GPM data in NOAA operations and applications. This was the first time a WG was convened for the serious consideration and identification of approaches and methods to meet these needs. In addition to WG3 identifying independent training, education and outreach needs it would also look to the other two WGs for critical training required to assure that NOAA would be able to improve their precipitation products and services from WG1, and to implement any of the research or operational algorithms that would be developed from WG2.

**Summary:** WG3 decided that it needed to go beyond the primary focus of this 3rd Workshop on the development, functionality and priorities of a new NOAA GPM Proving Ground as the other two WGs (WG1 and WG2) were tasked to consider. WG3 would consider a broader scope of NOAA applications' and operational training and outreach needs, each of these with its associated education needs. WG3 realized that this broader scope for the training, education and outreach needs would be necessary because of the:

1. Envisioned diversities of the applications and operations for GPM data and the continuity of traditional and legacy products;

2. Considered new fused and blended products for NOAA applications and operations;

3. Planned diverse, but complementary, active and passive sensor GPM data;

4. Availability of GPM data that could be utilized at regional, mesoscale and global spatial scales that each would probably require different levels of training and outreach, each with the appropriate level of education;

5. Proposed far-reaching applications, even on longer-term temporal scales suitable for climate monitoring and applications.

The limitations of funding in the pre-launch and near-term periods, and possibly in the longer-term, were deemed to drive the idea of WG3 first providing a broad scope of training, education and outreach needs and then, later, to provide guidance for decisions on the priorities of these needs, in terms of their potential impact, the time period for satisfying these needs and the estimated costs so that the implementation of any methods could be cost-effectively selected within the budgetary allocation for any period of time.

WG3 focused on the training and outreach for the use of GPM data and products in operations and applications using the following separation:

- **Training** (and its explicit and implicit "education" primarily for discipline experts and for the science-literate, non-GPM experts who are potential users of the GPM data/products)
- **Outreach** (and its explicit and implicit "education" [but a different education then in the Training category above])

WG3 established the three categories of the "Who" that are the targeted groups or GPM users:

- **GPM Expert Users** (such as forecasters [government, institutional/academic, and private sector] planning to use GPM data and products for NOAA operations and applications to support the NOAA Weather-Ready Nation objective; NOAA and NASA decision-makers for GPM data/products; international partners (esp. JAXA Japan) [special needs for multi-sensor data/products]
- **Non-Expert GPM Users** (science-literate types who are potential and/or planned users of GPM data and/or products) [international partners/entities, government and industry energy communities, insurance industries, corps of engineers]
- **General Public/External Users** (such as for K-12 or higher level educational purposes, media awareness, social applications).

The results for the WG3 identification of the users of GPM data/products and the associated Training and Outreach are summarized in the matrix below.

WG3 recognized significant efforts and experience in training, education and outreach, and was fortunate to have participation from representatives in the Workshop and in WG3, to include contributions from three important stakeholders, NOAA/NWS, NASA, and NOAA/NESDIS:

1. NOAA/NWS: Forecast Decision Training Branch and Office of Climate, Water, and Weather Services (see Brian Motta, *"Outreach, Education and Training Opportunities"*, Session 4 of this 3rd NOAA GPM User Workshop);

2. NASA: GSFC (see Dalia Kirschbaum, *"GPM Outreach and Applications,"* Session 1 of this 3rd NOAA GPM User Workshop);

3. NOAA/NESDIS: Sheldon Kusselson, a NESDIS operational satellite analyst, with his participation and contributions to a workshop with EUMETSAT in South Africa and virtual talks on polar-orbiting microwave applications and precipitation applications.

WG3 discussed initiatives to leverage these experiences of NOAA/NWS, NASA and NOAA/NESDIS, and possibly to partner with NASA on the significant commitments and progress that NASA has already made in GPM Mission outreach and education.

| Working Group 3 – Users of GPM Data/Products | | | |
|---|---|---|---|
| | **General/External Users** | **Non-expert GPM Users** | **GPM Expert Users** |
| Training and Education | • Global Farming/Agriculture<br>• Transportation industries<br>• Recreational activities<br>• Recreational sports | • Corps of Engineers<br>• Private sector civil engineers,<br>• Civil water departments,<br>• Dept. of Agriculture<br>• Dept. of Interior–wild fires, Google Earth/Microsoft Bing/ Yahoo!/World Weather Online/etc.<br>• Transportation industry<br>• Water Resources Management | • NWS WFO/RFC forecasters<br>• Environmental modelers, Data fusion/blended product experts<br>• Technology transfer<br>• Expert Users Forecasters/ COMET<br>• Hurricane/Tropical Cyclone<br>• Other Weather and Climate forecasters<br>• Mud-slide & Debris Flow forecasters<br>• NCDC Weather & Climate Analyses<br>• Decision Makers: Agencies, e.g., NOAA, NASA etc., Private Sector |
| Outreach and Education | • K-12 (and higher level) Education<br>• General Public,<br>• Global community [Group on Earth Observations (GEO), CEOS, WMO etc.] | • Insurance Industry<br>• Energy Industry (government and private sector)<br>• Disaster Management<br>• Water Resources Management | • Military /Intelligence<br>• Applications (e.g., trafficability)<br>• National geospatial analysis,<br>• Professional Societies /<br>• Communities |

**Specific Actions:**

| Group 3: Collect Information | | | |
|---|---|---|---|
| Task/Milestone | **Champion(s)** | **Steps Needed to Accomplish** | **Funding Source or Targets** |
| GPM Training, Education and Outreach Tiger Team | K. Carey<br>D. Kirschbaum<br>S. Mango<br>B. Motta | Form GPM Training, Education and Outreach Tiger Team to conduct a needs analysis, and to leverage existing and planning activities | Use existing resources, to include PGs, conferences and technical workshops. |

| Group 3: Near-Term Issues |
|---|

| Task/Milestone | Champion(s) | Steps Needed to Accomplish | Funding Source or Targets |
|---|---|---|---|
| Participate in the planning an execution of the NASA Applications Workshop | K. Carey<br>D. Kirschbaum<br>C. Kondragunta<br>B. Motta | Coordinate with Dalia Kirshbaum, participate in the planning activities | Use existing resources |
| Seek formal funding for training and education focused exclusively on GPM | R. Ferraro<br>Y. Zhang<br>C. Kondragunta<br>B. Motta | • Develop proposal for consideration for FY14 through GOES-R and JPSS.<br>• Pursue COMET module development.<br>• Identify GPM-specific funding for training and education should be part of the GPM Program. | • GOES-R PGRR<br>• JPSS<br>• NOAA/NASA |

## Summary and Next Steps

The 3rd NOAA User Workshop on GPM was held on April 2-4, 2013, at College Park, Maryland. Over 70 attendees from NOAA, NASA, academia and the private sector - physically and remotely- participated and discussed strategies of further advancing the operational testing and use of GPM data in NOAA through test-beds and proving ground concepts.

During the workshop, NESDIS and NWS leadership addressed the potential utility of GPM data to NOAA operations; NASA scientists provided updates on GPM mission status; and NOAA focal points for test-beds (TBs) and proving grounds (PGs) offered perspectives on the testing of GPM data in quasi-operational contexts within the established TBs and PGs. The participants further discussed on-going NOAA efforts of integrating and testing GPM data.

Three working groups (WGs) were convened during the workshop by experts from NOAA and NASA to address i) the purpose of the NOAA Proving Ground and how it will improve NOAA precipitation products and services, (ii) use of GPM data in research and operational algorithm development, and (iii) training needs for the use of GPM data in NOAA operations (WFOs, RFCs, NHC and NCEP). Each working group provided a set of recommendations, actionable items and champions for those actions. The major recommendations from the workshop are summarized below:

1. NOAA should establish a GPM-focused Proving Ground (PG) that leverages existing PGs that are well established under the GOES-R program and are emerging from the JPSS program. Attributes of this PG include:

    a. Governance adhering to existing NOAA PG by-laws, although it would benefit by having a new NOAA governing body (i.e., subset of existing NOAA SGPMS).

    b. Priority on the products to be served captured in the GPM L1RD nearing completion.

    c. PG producers may include NOAA's WPC/OPC, NCEP, OHD and National Operational Hydrologic Remote Sensing Center (NOHRSC); NASA's SPoRT center; and new nodes at NOAA cooperative institutes.

    d. PG consumers should include previously-identified groups such as HMT and WPC as well as a closer connection to current/future planned PG focus activities such as those on atmospheric rivers, flash floods, and winter season precipitation.

    e. A precipitation PG satellite champion.

    f. A validation component.

    g. Sustained funding from within NOAA's major programs.

2. In order to enhance research activities related to precipitation data fusion, NOAA needs to:

    a. Vastly improve coordination across its line offices for GPM-era R&D related to satellite data fusion and fusion with ground radar and rain gauges.

    b. Create a collaborative computing framework across NOAA line offices (e.g., NESDIS, NWS, OAR) to provide a focus for fused data set R&D.

c. Develop a committed strategy to perform episodic reprocessing of precipitation-relevant data archives that are consistent with both updates of input data and with algorithm upgrades, thus enhancing the usability of orbital data in blended precipitation products. To date, NOAA only reprocesses such data through its CDR program and this is typically after a satellite sensor has been in operation for more than a decade.

3. In order to improve GPM education, outreach, and training at NOAA, NOAA needs to:

   a. Better define its needs, its training targets, and requirements by forming a Tiger team to specifically address this topic.

   b. Provide for the Education and Training for NOAA operational and applications users on the high priority, new NOAA-planned fused and blended precipitation products.

   c. Establish a commitment to fund such activities, including close cooperation with ongoing training and outreach activities within GOES-R and JPSS.

   d. Coordinate activities with the well-established GPM outreach program at NASA

The immediate next steps will be to execute the specific tasks identified by the each WG listed under *Specific Actions* sections under WG discussions. Noteworthy among these are to:

(i) identify potential PG satellite champions
(ii) discuss Proving Ground opportunities with the GOES-R and JPSS program managers;
(iii) form a GPM PG Tiger Team by October 2013 to formalize its role and details for the PG;
(iv) develop Level-2 user requirements for NOAA specific GPM-era satellite precipitation products;
(v) coordinate activities to establish a collaborative (perhaps virtual) computing platform on various NOAA centers for multi-sensor fusion of precipitation products from satellites, radars, gauges and numerical weather prediction model outputs that can be used NOAA Line Offices;
(vi) improve communication with the Joint Center for Satellite Data Assimilation for assimilating GPM precipitation products in numerical weather prediction models, and
(vii) form a GPM Training, Education and Outreach Tiger Team to conduct a needs analysis;
(viii) leverage existing and planning activities; and participate in the planning and execution of the NASA Applications Workshop which will take place in November 2013.

Most of the next steps identified in this report can be achieved using NOAA in-house funding and/or existing resources. The champions for these specific tasks are identified in the Working Group *Specific Actions* sections (pages 22, 23-25, and 27-28). Where applicable, the champions for the specific tasks will be asked to provide periodic updates to the NOAA Steering Group on Precipitation Measurement from Space.

## References

Ferraro, R.R. and co-authors, 2012: Second NOAA User Workshop on the Global Precipitation Measurement (GPM) Mission. November 29, 2011 – December 1, 2011, College Park, MD

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

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

Neiman, P. J, F. M. Ralph, G. A. Wick, Y-H Kuo, T-K Wee, Z. Ma, G. H. Taylor, and M. D. Dettinger, 2008: Diagnosis of an Intense Atmospheric River Impacting the Pacific Northwest: Storm Summary and Offshore Vertical Structure Observed with COSMIC Satellite Retrievals, MWR, 136, 4398-4420.

## Appendix A: Workshop Participants

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# Appendix B: Workshop Agenda

**3rd NOAA GPM User Workshop**
**April 2-4, 2013**
**ESSIC Building, Room #4102**
**5825 University Research Court, College Park, MD**
**Telecon #(866) 804-8142 passcode: 2937055**

**1st Day - Apr 2nd**

| 04/02/13 | Topic | Speaker(s) | Organization |
|---|---|---|---|
| 800 - 820 am | Registration/Sign In/Continental Breakfast | | |
| **SESSION 1 - OVERVIEW (Chair - Chandra Kondragunta)** | | | |
| 820 - 825 | Introductions, Welcome, Logistics, Goals, Format, etc. | R. Ferraro; A. Busalacchi | NESDIS & UMD |
| 825 - 840 | 2nd Workshop Summary and Progress; NOAA PMM Project Summary | R. Cifelli | OAR |
| 840 - 855 | Importance of GPM from NESDIS Perspective | M. Haas | NESDIS |
| 855 - 910 | NOAA Keynote Speaker - GPM's Role at the NWS | L. Furgione | NWS |
| 910 - 925 | NOAA Keynote Speaker - GPM's Role at Hydrology Program | B. Choy | NWS/OHD |
| 925 - 940 | GPM Program Status | G. Skofronick-Jackson | NASA |
| 940 - 955 | GPM Ground System Status | E. Stocker | NASA |
| 955 - 1010 | GPM Outreach and Applications | D. Kirschbaum | NASA |
| 1010 - 1030 | **COFFEE BREAK + GROUP PHOTO** | | |
| | | | |
| **SESSION 2- NOAA GPM Proving Grounds and Testbeds (Chair - Rob Cifelli)** | | | |
| 1030 -1035 | Intro: Purpose of session: ongoing NOAA Proving Grounds: Purpose, links to testbeds, and stategies to accomplish R2O/O2R | R. Cifelli | OAR |
| 1035 -1050 | GOES-R Proving Ground | S. Goodman (TBC) | NESDIS |
| 1050 -1105 | JPSS Proving Ground | I. Guch | NESDIS |
| 1105 - 1125 | Hydrometeorology Testbed PSD / HPC | A. White /R. Cifelli / W. Hogsett | OAR / NWS |
| 1125 - 1140 | Climate Testbed CPC | M. Halpert/J. Huang | NWS/CPC |
| 1140 - 1200 | Discussion, summary and plans for the WG | Group | |
| 1200 - 100 pm | **LUNCH** | | |
| | | | |
| **SESSION 3- NOAA GPM Research and Algorithm Development (Chair - Yu Zhang)** | | | |
| 100 - 115 | IWRSS and data fusion needs (summary from 2012 workshop) | Tim Schneider/D. Kitzmiller | OHD |
| 115 - 130 | NOAA Satellite Data Fusion | P. Xie/Kuligowski | NCEP/NESDIS |
| 130 - 145 | GPM-Radar - Gauge Fusion via MRMS | J. Gourley/B. Rabin | OAR |
| 145 - 200 | Data blending via MPE/CMORPH | Y. Zhang/P. Xie | OHD/UTA |

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|---|---|---|---|
| 200 - 215 | Multi-Satellite Algorithms (Integrated Multi-satellite Retrievals for GPM: IMERG), | G. Huffman | NASA |
| 215 - 230 | New fusion paradigms | V. Chandrasekar | CSU |
| 230 - 240 | Discussion - /common testbed/coordination and priorities/data sources | Group | |
| 240 - 300 | **COFFEE BREAK** | | |
| | | | |
| **SESSION 4 - Outreach and Applications Needs and Goals (Chair - Stephen Mango)** | | | |
| Hydrometeorology | | | |
| 310 - 330 | WGRFC and the Need for Satellite Precipitation Estimates | Greg Waller/Greg Story | NWS/WGRFC |
| 330 - 350 | The Use of GPM Data and Products at NHC | M. Brennan/Jack Beven | NWS/NHC |
| 350 - 410 | Outreach, Education and Training Opportunities | Brian Motta | NWS/OCWWS |
| | | | |
| | | | |
| **SESSION 5 - Summary, Working Group Formation and Initial WG Tag Ups** | | | |
| 415 - 500 | Session Introduction | | |
| 500 pm | **WORKSHOP ENDS FOR THE DAY** | | |
| **600 pm** | **Group Dinner (TBD)** | | |
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| | | | |
| **2nd Day - Apr 3rd** | | | |
| **04/03/13** | **Topic** | **Speaker** | **Organization** |
| **SESSION 6 - WORKING GROUPS - PLENARY AND DISCUSSIONS** | | | |
| 800 - 830 | Continental Breakfast | | |
| 830 - 845 | Working Group Plenary | | |
| 845 - 1000 | Working Groups Meet | | |
| 1000 - 1030 | **COFFEE BREAK** | | |
| | | | |
| 1030 - 1200 | Working Groups Meet | | |
| 1200 - 100 pm | **LUNCH and engage other working groups** | | |
| | | | |
| **100 - 130** | Working Group Plenary | | |
| 100 - 300 | WORKING GROUPS MEET | | |
| 300 - 315 | **COFFEE BREAK** | | |
| | | | |
| 315 - 500 | WORKING GROUPS MEET | | |
| 500 pm | **WORKSHOP ENDS FOR THE DAY** | | |
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| 3rd Day - Apr 4th | | | |
|---|---|---|---|
| **04/04/13** | **Topic** | **Speaker** | **Organization** |
| **WORKING GROUP SESSION/PLENARY** | | | |
| 800 - 830 am | Continental Breakfast | | |
| 830 - 900 | WG 1 report | | |
| 900 - 930 | WG 2 report | | |
| 930-1000 | WG 3 report | | |
| 1000-1130 | Working group plenary/Wrap up | | |
| 1130-1200 | Plans for focus group sessions in the pm | | |
| 1200 - 100 pm | **LUNCH/Workshop Ends** | | |
| | | | |
| **Focus Group Meetings (To Be Arranged)** | | | |

# Appendix C: List of Acronyms

| | |
|---|---|
| AMSR | Advanced Microwave Scanning Radiometer |
| AMSU | Advanced Microwave Sounding Unit |
| ATMS | Advanced Technology Microwave Sounder |
| AWIPS | Advanced Weather Interactive Processing System |
| bRR | Blended Rain Rate |
| bTPW | Blended Total Precipitable Water |
| BUFR | Binary Universal Form for the Representation of Meteorological Data |
| CMORPH | Climate Prediction Center Morphing Technique |
| CONOPS | Concept of Operations |
| CPC | NOAA's Climate Prediction Center |
| 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 |
| ESSIC | Earth System Science and Interdisciplinary Center, University of Maryland |
| EUMETSAT | European Organisation for the Exploitation of Meteorological Satellites |
| GCOM | Japan's Global Change Observation Mission |
| 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 |
| HDF5 | Hierarchical Data Format 5 |
| HMT | NOAA's Hydrometeorology |
| IMERG | Integrated Multi-satellitE Retrievals for GPM |
| IWFP | Integrated Water Forecasting Program |
| 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 Requirements Document |
| LEO | Low Earth Orbiting |
| MADRAS | Microwave Analysis and Detection of Rain and Atmospheric Systems |
| MetOp | EUMETSAT polar-orbiting Meteorological Operational satellite |
| MHS | Microwave Humidity Sounder |
| MPE | NOAA's Multisensor Precipitation Estimator |
| MW | Microwave |
| M-T | Megha-Tropiques |
| NASA | National Aeronautics and Space Administration |
| NCDC | NOAA's National Climatic Data Center |
| NetCDF | Network Common Data Format |
| NCEP | NOAA's National Centers for Environmental Prediction |
| NESDIS | NOAA's National Environmental Satellite, Data and Information Service |

| | |
|---|---|
| NHC | National Hurricane Center |
| NOAT | NWS Operations Application Team |
| NOHRSC | National Operational Hydrologic Remote Sensing Center |
| NPP | National Polar-orbiting Partnership |
| NUP | NOAA Unique Product |
| NWP | Numerical Weather Prediction |
| NWS | NOAA's National Weather Service |
| OAR | NOAA's Office of Oceanic and Atmospheric Research |
| OCWWS | Office of Climate, Water and Weather Services |
| OHD | Office of Hydrologic Development |
| O2R | Operations to Research |
| PG | Proving Ground |
| PMM | Precipitation Measurement Missions |
| PMW | Passive Microwave |
| PPS | Precipitation Processing System |
| QPE | Quantitative Precipitation Estimation |
| QPF | Quantitative Precipitation Forecasting |
| R&D | Research and Development |
| R2O | Research to Operations |
| SAPHIR | Sounder Atmospheric Profiling Humidity Radiometer |
| SCaMPR | Self-Calibrating Multivariate Precipitation Retrieval |
| SGPMS | Steering Group on Precipitation Measurement from Space |
| SPoRT | Short-term Prediction Research and Transition |
| SSMI/S | Special Sensor Microwave Imager / Sounder |
| STAR | Center for Satellite Applications and Research |
| TB | Test Bed |
| TMI | TRMM Microwave Imager |
| TMPA | TRMM Multi-satellite Precipitation Analysis |
| TPW | Total Precipitable Water |
| TRMM | Tropical Rainfall Measurement Mission |
| WG | Working Group |
| WPC | NOAA's Weather Prediction Center |