NASA/CP—2002–210012

Global Precipitation Measurement - Report 1
Summary of the First GPM Partners Planning Workshop

J.M. Shepherd, A.Mehta
E. A. Smith, W. J. Adams

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

April 2002

The NASA STI Program Office … in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the lead center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.
- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.
- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and mission, often concerned with subjects having substantial public interest.
- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at http://www.sti.nasa.gov/STI-homepage.html
- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA Access Help Desk at (301) 621-0134
- Telephone the NASA Access Help Desk at (301) 621-0390
- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076-1320

NASA/CP—2002–210012

Global Precipitation Measurement - Report 1
Summary of the First GPM Partners Planning Workshop

J. Marshall Shepherd, Amita Mehta, Lead Authors
NASA Goddard Space Flight Center, Greenbelt MD

Eric A. Smith and W. James Adams, Editors
NASA Goddard Space Flight Center, Greenbelt MD

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

April 2002

Available from:

NASA Center for AeroSpace Information
7121 Standard Drive
Hanover, MD 21076-1320
Price Code: A17

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Price Code: A10

Executive Summary

This report provides a synopsis of the proceedings of the First Global Precipitation Measurement (GPM) Partners Planning Workshop held at the University of Maryland, College Park, from May 16 to 18, 2001. GPM consists of a multi-member global satellite constellation (i.e., an international set of satellite missions) and the accompanying scientific research program, with the main goal of providing frequent, accurate, and globally distributed precipitation measurements essential in understanding several fundamental issues associated with the global water and energy cycle (GWEC). The exchange of scientific and technical information at this and subsequent GPM workshops between representatives from around the world represents a key step in the formulation phase of GPM mission development.

The U.S. National Aeronautics and Space Agency (NASA), the National Space Development Agency of Japan (NASDA), and other interested agencies from nations around the world seek to observe, understand, and model the Earth system to learn how it is changing and what consequences these changes have on life, particularly as they pertain to hydrological processes and the availability of fresh water resources. GWEC processes are central to a broader understanding of the Earth system. For example, quantifying the existence (or absence) of trends in the GWEC through analysis of observed global rainfall time series in relationship to other climatic variables, enables basic understanding and predictive capabilities in how the Earth's climate system functions. In fact, accurate measurement of precipitation variations and trends is central to improving understanding and prediction of climate change; storm life cycles and their influence on climate dynamics; hydrometeorological processes; ocean-atmosphere and land-atmosphere exchanges of energy and moisture; atmospheric latent heating; flood evolution; and availability of freshwater resources.

GPM is considered by NASA to be the centerpiece mission of its Global Water & Energy Cycle research program, but it has a wide, international scope so as to be responsive to the variety of specialized research needs of different nations focused on water issues. As a starting point for GPM, NASA and NASDA have entered into a partnership and have taken steps in the definition of preliminary science and technology concepts. This includes the development of a core satellite whose role will be to extend the accuracy and precision of satellite precipitation measurements to their fullest potential and act as a reference and transfer standard to other constellation members. However, successful mission formulation and implementation requires additional committed relationships beyond that between the United States and Japan. The First GPM Planning Workshop convened scientists, engineers, and policymakers from around the world to stimulate existing partnerships, establish new partnerships, provide input on science and technology issues, and develop the framework for an international GPM mission.

Herein, an overview of meeting objectives, plenary session presentations, break-out group summaries, and future plans have been presented. From this workshop, a set of critical action items was established consisting of: (1) seeking appropriate agreements with international, interagency, academic, and corporate partners; (2) determining needs of potential partners and stakeholders; (3) pursuing and assessing technological issues; (4) defining a technologically-sound and scientifically-credible mission concept; and (5) identifying additional mission-critical and supporting data streams. In addition, the workshop agenda and list of attendees is provided.

Table of Contents

List of Key Acronyms

AIRS	Atmospheric Infrared Sounder
AMSR	Advanced Microwave Sounding Radiometer
AMSU	Advanced Microwave Sounding Unit
ARMAR	Airborne Rain Mapping Radar
ASI	Agenzia Spaziale Italiana
BALTEX	Baltic Sea Experiment
BMRC	Bureau of Meteorology Research Centre
CAL/VAL	Calibration/Validation
CEOP	Coordinated Enhanced Observation Period
CERAD	Central European Weather Radar Network
CERES	Clouds and the Earth's Radiant Energy System
CMIS	Conical Microwave Imager Sounder
CNR	Consiglio Nazionale delle Ricerche
CNES	Centre National d'Etudes Spatiales
CRL	Communications Research Laboratory
DMSP	Defense Meteorological Satellite Program
DPR	Dual Frequency Precipitation Radar
DSD	Drop Size Distribution
EC	Environment Canada
ECMWF	European Center for Medium-Range Weather Forecasts
EGPM	Euro-GPM
ESA	European Space Agency
ETL	Environmental Technology Laboratory
F/O	Follow On
GEM	Geosynchronous Microwave Sounder/Imager
GEWEX	Global Water and Energy Cycle Experiment
GHCC	Global Hydrology and Climate Center
GMS	Geostationary Meteorological Satellite
GOES	Geostationary Operational Environmental Satellite
GPM	Global Precipitation Measurement

GSFC	Goddard Space Flight Center
GWEC	Global Water and Energy Cycle
INPE	National Institute for Space Research
IPO	Integrated Program Office
IR	Infrared
ISRO	Indian Space Research Office
JMA	Japanese Meteorological Agency
JPL	Jet Propulsion Laboratory
KMA	Korean Meteorological Agency
LOA	Letter of Agreement
LMD	Laboratoire de Meteorologie Dynamique
MIT	Massachusetts Institute of Technology
MSFC	Marshall Space Flight Center
MODIS	Moderate Resolution Imaging Spectroradiometer
MOU	Memorandum of Understanding
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
NCAR	National Center for Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar Orbiting Environmental Satellite System
NWP	Numerical Weather Prediction
NRL	Naval Research Laboratory
PMR	Passive Microwave Radiometer
PMW	Passive Microwave
POES	Polar Orbiting Environmental Satellite
POLDIRAD	Polarization Doppler Radar
PR	Precipitation Radar
SSM/I	Special Sensor Microwave/Imager
TRMM	Tropical Rainfall Measuring Mission
TMI	TRMM Microwave Imager
USDA	United States Department of Agriculture
VIS	Visible

1.0 Opening Session

After a brief orientation and overview of the workshop agenda by Global Precipitation Measurement (GPM) Project Manager, **Mr. J. Adams** (NASA Goddard), **Dr. M. Cleave** (NASA Headquarters) offered a welcome on behalf of NASA and presented the agency's interest in GPM. Dr. Cleave, representing **Associate Administrator Dr. G. Asrar** (NASA Headquarters), acknowledged the large turnout and level of international participation. Dr. Cleave highlighted the successful international partnership and science mission undertaken by NASA and NASDA for the Tropical Rainfall Measuring Mission (TRMM).

Dr. Cleave discussed how the advances of dual frequency radar and a constellation of radiometer-bearing satellites on GPM would improve weather and hydrology studies by providing more frequent measurements of precipitating systems. Such information would be useful not only by scientist or operational agencies but farmers, resource managers, and community planners. Dr. Cleave closed by emphasizing that GPM aims to be global in its observation and in its partnerships. She extended an invitation for countries around the world to contribute resources and expertise in all aspects of the GPM constellation, its ground systems, and associated scientific research. **Dr. Y. Furuhama** (NASDA) followed with an overview of NASDA's Earth Observation Program and the agency's interest in GPM.

2.0 Objectives and Opportunities

Prof. K. Nakamura (University of Nagoya) chaired the Session on Objectives and Opportunities. **Prof. P. Morel** (University of Maryland at Baltimore County) discussed the prospects for a Global Precipitation Observing System. Four broad concepts were addressed (Figure 1):

Why do we want to know global precipitation?

- To resolve a scientific question about the rate of cycling of water in the Earth system.
- To determine precipitation totals over continents in order to inform hydrologic models of water storage and river flow.
- To improve weather and rainfall forecasts through assimilation of instantaneous precipitation data.

Is the Global Water Cycle Accelerating?

- The rate of water cycling may be directly related to the frequency and intensity of storms and total rainfall amount.
- There is conflicting evidence from climate models (e.g. National Center for Atmospheric Research (NCAR) Climate System Model) and from observations (e.g. International Global Precipitation Project).

How can knowledge of water cycling be used to improve water system management?

- The <u>challenge</u> is merging information from satellite measurements, ground-based weather radar observations, and rain gauges to deliver optimal estimates of area-averaged rainfall rate and accumulation.
- The <u>goal</u> is to eventually provide reliable (statistical) prediction of area-averaged precipitation on time scales that most matter for strategic water system management.

Can weather forecasts be improved by assimilation of global precipitation data?

- Comparing model predictions with observed precipitation globally is a powerful diagnostic research tool for improving formulations of "wet processes" throughout the Earth system (i.e. evaporation and transformation, not just condensation).
- Assimilation of observed precipitation and latent heat release provides augmented predictability of future weather developments.

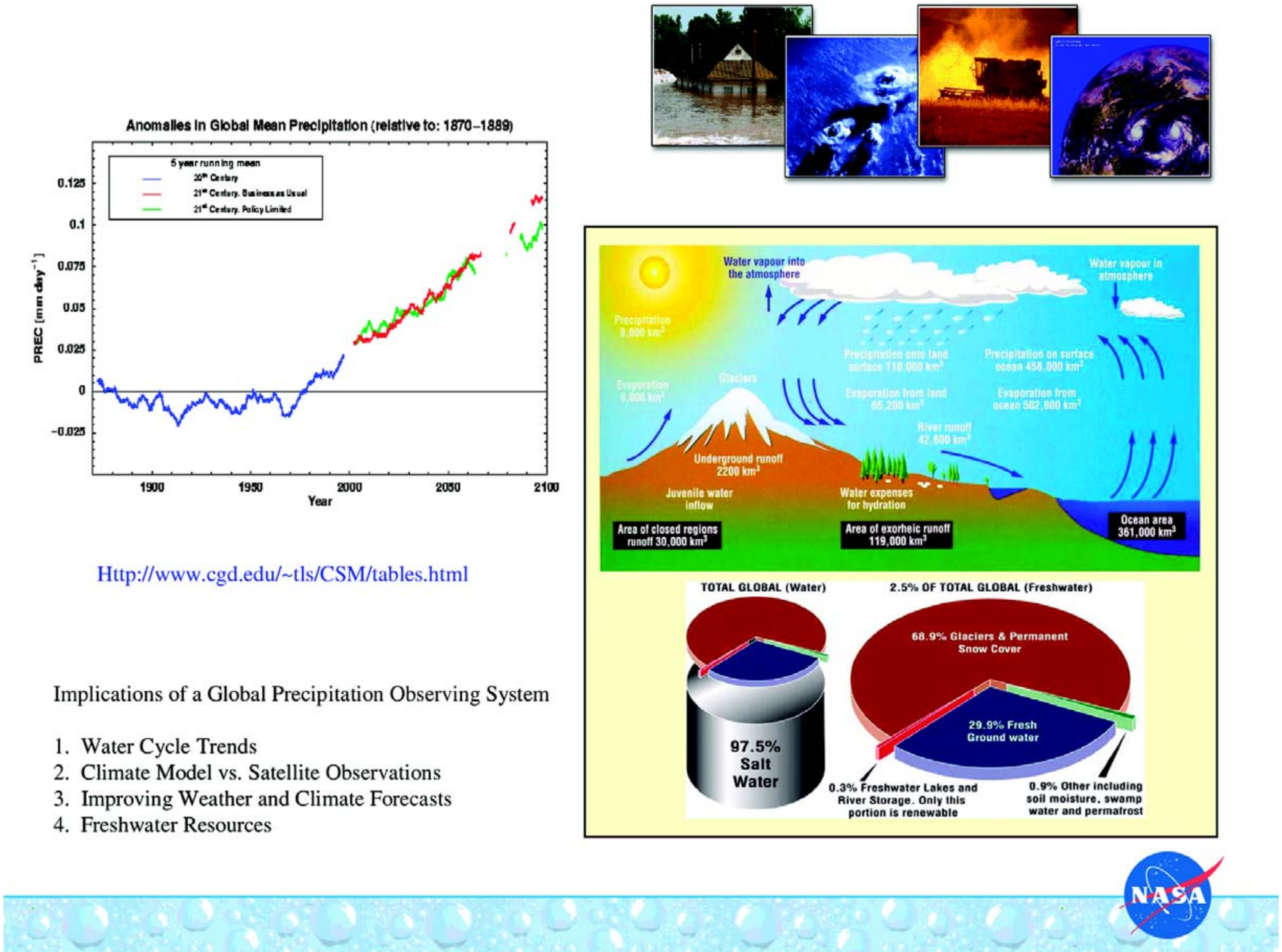

Figure 1. *Implications of a Global Precipitation Observing System.*

Dr. J. Simpson (NASA Goddard) discussed GPM's heritage to TRMM and highlighted its successes over the past three one-half years. She focused on TRMM's role in reducing uncertainty in tropical ocean rainfall estimates (from 50 percent to 25 percent), positively impacting mesoscale-cloud models, and contributing to improved monitoring of tropical cyclones. She also mentioned contributions in the fields of oceanography and hydrology.
Dr. Simpson offered some lessons learned from the TRMM.

- Solid planning.
- Excellent collaborations with NASDA.
- Close teamwork between project and science teams.
- Early science team involvement with data systems.
- Reasonable algorithm results "at launch" due to prototype testing.
- Data reprocessing every 6 to 12 months with improved algorithms.
- Good data accessibility.

Dr. Simpson also commented on GPM's ability to remedy TRMM's two most serious problems of sampling (passive microwave cluster) and reflectivity-rain relationship (dual frequency radar).

The GPM Project Scientist, **Dr. Eric Smith** (NASA Goddard), outlined <u>three broad objectives</u> for the workshop.

(1) Stimulate existing partnerships and initiate new partnerships (This objective includes assessing partner readiness and identifying assets).
  - Scientist engagement.
  - Space hardware and associated data streams.
  - High quality validation super sites and associated data streams.
  - High quality regional rain gauge networks and associated data streams.
  - Precipitation and ancillary data streams.

(2) Exchange information on major scientific objectives.

(3) Discuss critical engineering and technical issues.
  - Orbit architecture.
  - Radiometer frequencies.
  - General algorithm design.
  - Radiation-cloud modeling.
  - Design/focus of validation system.

3.0 GPM Partnerships: Session 1

The session was chaired by **Prof. C. Kummerow** (Colorado State University) and consisted of presentations from NASA, NASDA, and the European Space Agency (ESA) on current and future planning for GPM. Several United States agencies also discussed their provisional interest or role in GPM.

Dr. R. Kakar (NASA Headquarters), GPM Program Scientist, discussed NASA planning for GPM within the context of questions composing the Earth Science Enterprise science plan:

(1) How is the Earth changing and what are the consequences for life on Earth?

(2) How is the global Earth system changing?

(3) What are the primary forcings of the Earth system?

(4) How does the Earth system respond to natural and human-induced changes?

(5) What are the consequences of changes in the Earth system for human civilization?

(6) How well can we predict future changes in the Earth system?

These six questions are further sub-divided into 23 specific questions. Of these questions, the relevant science plan questions for GPM are —

- How are global precipitation, evaporation, and the cycling of water changing?
- How are variations in local weather, precipitation, and water resources related to global climate variation?
- How can weather forecast duration and reliability be improved by new space-based observations, data assimilation and modeling?

In establishing a motivation for GPM, Dr. Kakar noted that in an era of climatic uncertainty, it should be possible to detect understand and react to early signs that rainfall patterns may be changing. The transient nature of rainfall makes the detection of subtle changes difficult. Rainfall information over approximately three-hourly time scales is needed to improve numerical prediction, data assimilation and flood forecast models. TRMM is limited to the tropics (35N to 35S) and a sampling frequency that at any point is limited to roughly 1 sample every 15 (50) hours for the radiometer (radar).

According to Dr. Kakar, future challenges will involve observing water in various states and the related fluxes well enough to close the hydrologic cycle; developing and implementing GPM; and modeling the global hydrologic atmospheric cycle well enough to distinguish natural variability from long term trends associated with climate change. Such challenges will only be met through the establishment of interdisciplinary, interagency, and international partnerships, and strong science teams. Kakar concluded with a discussion of key questions relevant for a new observing system like GPM. These questions were —

- How are the rainfall and rainfall structure responding to changes in the Earth's temperature and other climate variables and do we understand this response?
- How directly is the surface hydrology coupled to the rainfall/evaporation and do we understand the relationship well enough to be of predictive value?
- What is the effect of rainfall over the oceans upon ocean-atmosphere energy exchange and feedback mechanisms and can we understand this feedback?

Dr. R. Oki, **Dr. N. Takahashi**, and **Mr. K. Ohta** (NASDA) reviewed NASDA's participation in TRMM and development of the first space-borne Precipitation Radar (PR) in the world. Dr. Oki also provided the expectations for the TRMM Follow-On (F/O). The F/O would extend observations to a broader area and include provisions to observe rain or snow.

Dr. Oki also provided an overview of NASDA's current scenario of Earth observations from 2002 to 2017. Dr. Oki discussed the NASDA participation in the GPM concept and the GCOM-ATMOS-A1 and GPM core configurations. The ATMOS-A1 concept includes a Dual-Frequency Precipitation Radar (DPR). The Ka-band radar is important because it provides a sensitive measure of weak rainfall and snowfall. The dual-frequency analysis also provides accurate measurement of reflectivity and attenuation, drop size distribution estimates, and rain/ice discrimination. The DPR may also contribute to improved radiometer algorithms.

Dr. Oki also discussed the DPR timeline, launch options aboard the H-IIA rocket, and options for injecting GCOM-A1 and GPM core to proper orbits. In summary, the NASDA officials recommended merging NASDA's ATMOS-A1 and NASA's GPM because of the complementary nature of the missions.

Dr. P. Baptista (ESA) provided an overview of the Euro-TRMM Pilot Project, its composition of members, and objectives. Due to lessons-learned from Euro-TRMM, the European Center for

Medium-Range Weather Forecasts (ECMWF) is planning to assimilate precipitation data operationally from 2003.

An overview of ESA's Earth Observation Future Missions program was presented. The program has two components. Earth Watch is an operational, service-oriented set of missions. Earth Explorer is research-oriented and demonstrates new observation techniques. Dr. Baptista noted that ESA's Earth Sciences Advisory Committee recommended that ESA should work in precipitation missions (1996). ESA has established a GPM Science Preparatory Group taken from EuroTRMM. System studies for GPM drones started in November 2000 with Alenia Spazio (Italy) and Alcatel (France).

ESA's contribution could be implemented as an Earth Explorer Opportunity mission, however, a formal proposal must be submitted and approved. Expected European objectives for GPM would include improvement of numerical weather prediction, observation of mid- and high-latitude rain and snow, and covering observational gaps in the Mediterranean.

On behalf of **Deputy Director M. Colton**, **Dr. R. Ferraro** (National Oceanic and Atmospheric Administration (NOAA)) outlined specific NOAA requirements that GPM would benefit. Dr. Ferraro discussed how GPM's increased overpasses of passive microwave radiometers (PMR), reduction in coverage gaps, and collection of microphysical datasets would benefit NOAA requirements and applications related to data assimilation, tropical rainfall potential, west coast rainfall, frozen precipitation, and climate processes. For NOAA, GPM offers a potential bridge between the rainfall physics and temporal sampling gaps. In summary, Dr. Ferraro stated that NOAA has —

- Documented user requirements for atmospheric moisture.
- Expertise in rainfall remote sensing and operational product generation.
- Experience in remote sensing and collaborative efforts.
- A robust technology transfer.

The Naval Research Laboratory's (NRL) interest in GPM was presented by **Dr. J. Turk** and **Mr. J. Hawkins**. In examining GPM from an NRL perspective, the following points were made —

- Environmental data records from the Special Sensor Microwave Imager (SSM/I) are being archived.
- Requirements have shifted to a more regional scale anywhere on the globe.
- NRL has focused on geostationary and microwave-based applications.
- More frequent updates of microwave-based data would find use in nowcasting applications and model assimilation techniques.

The NRL utilizes the high resolution microwave imager, rainfall information, and retrieved wind data from TRMM (http://kauai.nrlmry.navy.mil/tc-bin/tc_home) for hurricane monitoring.

The NRL is also interested in capturing rapidly-evolving rain events using geosynchronous and low earth orbiting satellites as well as IR-MW blended products. Traditional limitations are cited as problems for the NRL applications: limited number of MW-based sensors, adequate temporal resolution from IR only, time gaps between successive MW overpasses relative to time scale of storm evolution, orographically-based events, and artifacts in the MW data (e.g. snow, poor geolocation, etc.) GPM would contribute to all of these research activities.

Dr. T. Jackson (United States Department of Agriculture (USDA)) spoke as a USDA scientist but was not an official representative of the agency. He spoke highly of the anticipated benefits that high temporal resolution rainfall data would provide in USDA applications. Particular areas of interest include measurements of soil moisture and precipitation and applications in hydrology.

Dr. S. Schneider and **Major M. Sorrells** (National Polar Orbiting Environmental Satellite System/ Integrated Program Office (NPOESS/IPO)) covered NPOESS/IPO's role in GPM. They began with an overview of the Integrated Program Office's structure, mission, and ongoing efforts to consolidate the Defense Meteorological Satellite (DMSP) and the Polar Orbiting Environmental Satellite (POES) programs into the NPOESS program. A summary of key instruments in NPOESS relevant to GPM and rainfall retrieval efforts was also presented. The summary provided a heritage, description, and schedule for the Conical Microwave Imager Sounder (CMIS) as a key component of the NPOESS mission. The presentation also discussed theoretical impacts of CMIS and NPOESS products on global numerical weather prediction and analysis. The presenters remarked, in summary, that NPOESS could be considered a part of the GPM constellation.

Dr. A. Gasiewski (NOAA/ETL) presented the interests of NOAA's Environmental Technology Laboratory (ETL) in GPM. This presentation provided an overview of a Geosynchronous Microwave Sounder/Imager (GEM) that could be used as a GPM interpolator. The GEM baseline system is composed of channels at 54, 118, 183, 380, and 424 GHz with a 2-m aperture. The equatorial resolution is approximately 20 km (15 km using over sampling) above 2-5 km altitude at highest frequency channels. The 380 and 424 GHz channels can map precipitation through most optically opaque clouds at sub-hourly intervals, and sounding channels penetrate clouds sufficiently to drive numerical weather prediction (NWP) models with hourly data. The estimated costs are $29M non-recurring plus ~26M per unit.

Dr. Gasiewski also demonstrated how higher frequency (> 89 GHz) channels can identify more convective cells, light rain, and snow. He proposed that GEM could be used as a cost-effective AMSU-class interpolator for GPM to obtain time-resolved observations of precipitation. A demonstration of an operational system is possible within GPM time frame.

Other NOAA ETL research interests for GPM include: GEM design and retrieval algorithm development, GPM passive microwave aircraft simulation (Polarimetric Scanning Radiometer), GPM validation and ground radar-based studies, application of GPM to Pacific coast precipitation, passive microwave radiance assimilation, and NOAA climate services initiatives.

Drs. A. Heymsfield, **J. Stith**, and **M. Moncrieff** (National Center for Atmospheric Research (NCAR)) discussed NCAR interests. The importance of warm/cold rain processes in precipitation evolution and the role of cloud dynamics in determining precipitation type can be addressed with GPM assets. GPM science would also benefit from NCAR research efforts to improve microphysical parameterization in cloud models. These efforts have implications for cloud model hydrometeor profiles used in rain retrieval and latent heating algorithms.

4.0 GPM Partnerships: Session 2

This session, chaired by **Dr. T. Nakazawa** (Japanese Meteorological Agency (JMA)), included presentations from several international representatives. In addition to the U.S. and Japan, representatives from Australia, Brazil, Canada, France, India, Germany, Italy, South Korea, Spain, and United Kingdom presented their countries' provisional interests and roles in participating in the GPM program.

Dr. M. Manton, (Bureau of Meteorology Research Centry (BMRC)), pointed out Australia's interests in GPM from points of view of rainfall analysis, verification of model rainfall, rainfall assimilation and ensemble prediction, and as a critical component of continental scale water budget. He provided a review of current rainfall observations and modeling projects in Australia, and outlined the future plans for rainfall observations in Australia. Dr. Manton pointed out that in addition to one of the TRMM ground validation radars at Darwin, a lidar, cloud radar, and wind profilers have also been planned. A possibility of dual frequency, dual polarization radar at Brisbane was also mentioned.

Dr. R. Calheiros and **Prof. C. Nobre** (National Institute for Space Research (INPE)) presented Brazil's interests in GPM. **Dr. R. Stewart** and **Mr. B. Goodison** (Environment Canada) provided an overview of how GPM can be useful in some of Canada's rain and snow-related issues, and how Canada can contribute to the GPM. Dr. Stewart emphasized the importance of water, particularly that of snow, in affecting flood and drought conditions, lake-levels, hydro-electricity, and transportation in Canada. He showed that measuring snowfall is a major challenge, in the northern part of Canada, because of inadequate surface observations. The rain/snow information obtained from GPM would be very useful over these poorly observed areas. Moreover, GPM measurements will be useful in understanding spatial and temporal distributions of precipitation over Canada, along with their potential applications in weather prediction and hydrological models. Dr. Stewart noted that Canadian radar and other monitoring networks would contribute to GPM for validation purposes.

Dr. J. Testud and **Dr. Michel Desbois** (University of Versailles and Laboratoire de Meteorologie Dynamique (LMD)) focused on the European component of GPM (E-GPM), and inclusion of nadir-pointing radar (NPR) in E-GPM. Among various NPR frequencies, Dr. Testud found 35 GHz, to be the best compromise between antenna size and dynamic coverage of rain. He suggested two possible uses of NPR measurements in E-GPM, 1) in calibrating the retrieval of microwave imager, and 2) in deriving rain-layer characteristics, which may be, used as an input to the retrievals from microwave imager. In his concluding remarks, Dr. Testud noted that inclusion of NPR in E-GPM would explore new technology for precipitation measurements from future operational satellites.

Dr. A.K.S. Gopalan (Indian Space Research Office (ISRO)) from India presented a synopsis of the Indian Space Research Program. He outlined India's future remote sensing space missions, including MeghaTropiques, a joint Indo-French mission designed to measure rainfall. Dr. Gopalan suggested further exploration of the possibility of India's participation in GPM.

Dr. R. Bennartz (Free University of Berlin and University of Kansas) presented Germany's provisional programmatic and scientific interest/role in GPM. Dr. Bennartz provided an overview of current precipitation-related projects in Germany including ongoing TRMM-related research and use of EUROTRMM and EURAINSAT. He also commented on their research related to Polarization Doppler Radar (POLDIRAD), Central European Weather Radar Network (CERAD), and Global Water and Energy Cycle Baltic Sea Experiment (GEWEX/BALTEX). Dr. Bennartz indicated Germany's interest in using GPM products for assimilation in medium range forecasting models, and for understanding high latitude cloud and precipitation physics. He pointed out a need for high frequency passive microwave channel (i.e. 150 GHz) in GPM for observing ice and mixed phase precipitation. He also suggested that BALTEX radar network/Data Center can be used as a GPM validation site.

Dr. A. Mugnai and **Professor Franco Prodi** (Consiglio Nazionale delle Ricerche (CNR) and University of Ferrara) outlined Italy's interest/contribution to GPM. Dr. Mugnai presented a summary of European and Italian mission studies specifically designed in support of GPM. Dr. Mugnai also commented on EuRainSat project in context of GPM. According to Dr. Mugnai, the European mission of 1-2 drone satellites (EGPM), and Italian mission of 1 drone satellite (IGPM), would carry microwave radiometers in sun-synchronous orbits. He mentioned that the EGPM might also carry a radar on-board. Dr. Mugnai indicated strong interest of the Italian scientific community in GPM products because of their potential use in —

- Observing mid-latitude precipitation and cloud systems.
- Understanding microphysical structure of storms that produce flash-floods and hazardous conditions.
- Getting frequent and reliable precipitation measurements necessary for hydrological predictions.
- Validating of and assimilating of precipitation in numerical weather prediction models.
- Determining the air-sea energy exchange and fresh water budget in ocean basins such as Adriatic and Aegean Seas.

Dr. Hyo-Sang (Korean Meteorological Agency (KMA)) talked about South Korea's interest/role in GPM. He focused on the extensive ground validation system that South Korea could contribute for regional validation of GPM products.

On behalf of **Profs. M. C. Lasat** and **D. Sempre-Torres**, **Dr. A. Amitai** (NASA Goddard) presented Spain/Catalonia's Provisional interest/role in GPM. This presentation described how measurements available in Spain could be used in the GPM ground validation efforts.

Drs. C. Kidd and J. Goddard (University of Birmingham and Chilbolten Lab) offered United Kingdom's provisional interest/role in GPM. Some of the outstanding issues about temporal and spatial samplings for rain measurements, importance of infrared (IR) and visible (VIS) measurements in addition to passive microwave (PMW) rain retrievals, and measurements of weak rainfall, were discussed. It was suggested that several UK groups would be involved in the key GPM activities through hardware and technology contribution, algorithm development, and data validation and analysis. Particularly, their interests in developing improved IR/VIS and PMW algorithms for GPM, and providing dual-polarized Doppler radar data, and other surface data for ground validation, were mentioned. A possible cold season field experiment in support of GPM validation was also mentioned.

5.0 GPM Partnerships: Session 3

This session, chaired by **Dr. R. Adler** (NASA Goddard), focused on planned contributions from NASA, Communications Research Laboratory (CRL), and the European Center for Medium-Range Weather Forecasts (ECMWF).

Dr. A. Hou (NASA Goddard), on behalf of **Dr. F. Einaudi** (NASA Goddard), provided an overview of TRMM-related research at GSFC, and commented on how it can be extended with GPM. Dr. Hou noted that because of the TRMM heritage, Goddard has developed expertise and experience in algorithm development for rain retrieval from active and passive microwave measurements, merging rainfall retrieved from various satellites to produce consistent data sets, satellite data assimilation in numerical models, and climate analysis and process studies. Goddard also has expertise in land, ocean, atmosphere models, and cumulus ensemble models. In these areas, Goddard would contribute to advancing GPM science goals and applications. In addition, Dr. Hou noted, Goddard would use GPM data in data assimilation to improve mesoscale simulation and forecast, and to improve physical parameterization in models.

Dr. H. Masuko and **T. Iguchi** Communications Research Laboratory (CRL) presented CRL's planned contribution to GPM. Dr. Masuko emphasized that in addition to the tropical rainfall, GPM measurements of precipitation at higher latitudes would be very useful for climate studies and for water and energy cycle studies. Moreover, he emphasized the need for accurate observations of a wide range of precipitation, i.e. from strong rainfall over the tropics to weak rainfall and snowfall over higher latitudes, by dual-frequency (14 and 35

GHz) radar. Dr. Masuko presented CRL's plan to collaborate with NASDA in developing a 35 GHz-band system and showed tentative specifications of the radar. CRL's contribution in developing retrieval algorithm for the 35 GHz band, and in calibration and validation of retrievals were also mentioned.

Dr. V. Marecal, **J.–F. Mahfouf**, and **P. Bauer** European Center for Medium-Range Weather Forecasting (ECMWF) outlined their requirements from GPM and their plans for using the GPM data in ECMWF model. Currently, ECMWF uses a variety of satellite data for assimilation in the model. Among these, wind vectors from METEOSAT, Geostationary Meteorological Satellite (GMS), and Geostationary Operational Environmental Satellite (GOES), water vapor from SSM/I, and surface wind vectors from SSM/I and ERS-2 are operationally used. Current and near future plans also involve assimilation of rain rates (or direct radiance) in the model. Dr. Marcel showed results of an experiment in which rain rates derived from TRMM TMI, and combined TMI-PR were assimilated in the model. The results, shown in terms of intensity and track forecast of Hurricane Bonnie, indicated that the forecast was sensitive to the rain rates used. From their analysis, it was shown that forecast errors were due to the rain detection and rain rate errors, and accurate rain rates would help improve forecast. In addition, errors due to spatial and temporal mismatch and retrieval stability among various instruments/satellites were also found to be partially responsible for the forecast errors. Based on some these experiments, it was noted that ECMWF would need accurate rain-rates from GPM in real-time and with ~30 Km resolution for improved forecasting.

Dr. F. Robertson (with **H. Michael Goodman**, **S. Goodman**, **S. Graves**, **R. Hood**, **G. Jedlovec**, **K. Knupp**, **C. Laymon**, and **R. Spencer**) from NASA Marshall and the Global Hydrology and Climate Center (GHCC) presented their planned role in GPM. Dr. Robertson outlined a number of projects being carried out at Marshall GHCC, which may be useful in the GPM mission. For example, GHCC has been one of the data centers for SSM/I products and would serve as a data center for generation, archival, and distribution of microwave radiometer data products from GPM as well. He pointed out that GHCC's strength in field measurements including aircraft-based and ground-based instruments, science mission management such as CoHMEX, CAMEX 3 and 4, and data management data mining, would also make it an important ground validation center for GPM data.

Dr. E. Im and **Z. Haddad** (Jet Propulsion Laboratory (JPL)) described their planned contribution to the GPM. JPL's involvement and accomplishments in development of rain radar technology, such as Airborne Rain Mapping Radar (ARMAR) which operated with TRMM PR geometry and frequency, and Cloud Profiling Radar developed for the CloudSat mission, were mentioned. As presented by Dr. Im, JPL will build a new dual frequency radar (15 and 35 GHz) for the GPM mission. Dr. Im gave an overview of the dual-frequency rain radar scheduled to fly in CAMEX-4 with the planned GPM geometry and frequency. JPL's plans for the radar ground testing, algorithm development, and calibration/validation were also outlined. Particularly, JPL plans to provide preliminary assessment of GPM precipitation radar-only and radar/radiometer combined algorithms. In addition, JPL and Goddard plan to support GPM on trade studies of various mission architecture concepts, reviews of the eventual baseline mission concept, and development of impact metrics on technology utilization.

6.0 Session on GPM Concept

Prof. T. Wilheit (Texas A & M) chaired the session discussing the GPM concept. **Mr. J. Adams** (NASA Goddard) began with a conceptual overview of GPM. He began with a timeline of the evolution of international precipitation satellites that would comprise GPM (Figure 2). He also provided the reference concept for the GPM constellation and a general discussion of the constituents of the “core” and constellation satellites (Figure 3).

A comparison of GPM to TRMM was shown to illustrate the basic differences between the missions. The comparison also illustrated critical science and application capabilities gained by the GPM configuration and relevant technology and data system issues. A more in-depth overview of GPM partner contributions was presented with “draft” timelines.

Mr. Adams discussed the objectives of the GPM Advanced Study.

- Define mission requirements.
- Examine options, define partnerships.
- Gain agency approval to proceed into formulation with a single concept.

An additional goal is to complete an independent assessment to determine if options were fully explored and that sufficient justification was established for proceeding with the recommended option.

A final goal of the Study is to select a mission concept and proceed to define and scope an instrument suite to meet science requirements with the intention of providing the rationale to begin preliminary acquisitions. The presentation also provided a synopsis of the formulation plan, system engineering issues, trade space issues.

Current science formulation activities include encouraging participation via meetings, workshops, and announcements of opportunity (AO); refining primary science requirements; establishing a systematic measurement approach; and conducting sensitivity studies in support of trades. The primary measurement trade space factors for the GPM radiometers include frequency selection (10.7, 19, 22, 37, 85, ???), scan method (conical vs. cross track), antenna size (orbit altitude, spatial resolution, cost and complexity), and technology readiness assessment. For the radar, accommodations and technology readiness assessment are the primary trade space factors.

Adams continued with a discussion of the TMI+ (GPM radiometer candidate). The main points are that —

- TMI+ nomenclature is only temporary.
- U.S. industry ideas are being sought and results will be due in late June.
    - -Multiple phase B to start January 2002
    - -Phase C/D 2003
- Current TMI+ functionality similar to TRMM TMI in terms of frequency, scan strategy, and resolution.
- After science workshop, 150 GHz channel and possible auxiliary single channel cross-track scanner (matched to Dual Frequency Precipitation Radar (DPR) footprint) will be considered.

Adams noted that the Advanced Study is also investigating ways to potentially enhance technology. These options include a low power transceiver, sensor web “smart node”, synthetically thinned array radiometer, innovative flight dynamics (constellation management and coverage optimization), composite propellant tanks, composite structure, autonomous navigation, design for disposal, and advanced propulsion techniques.

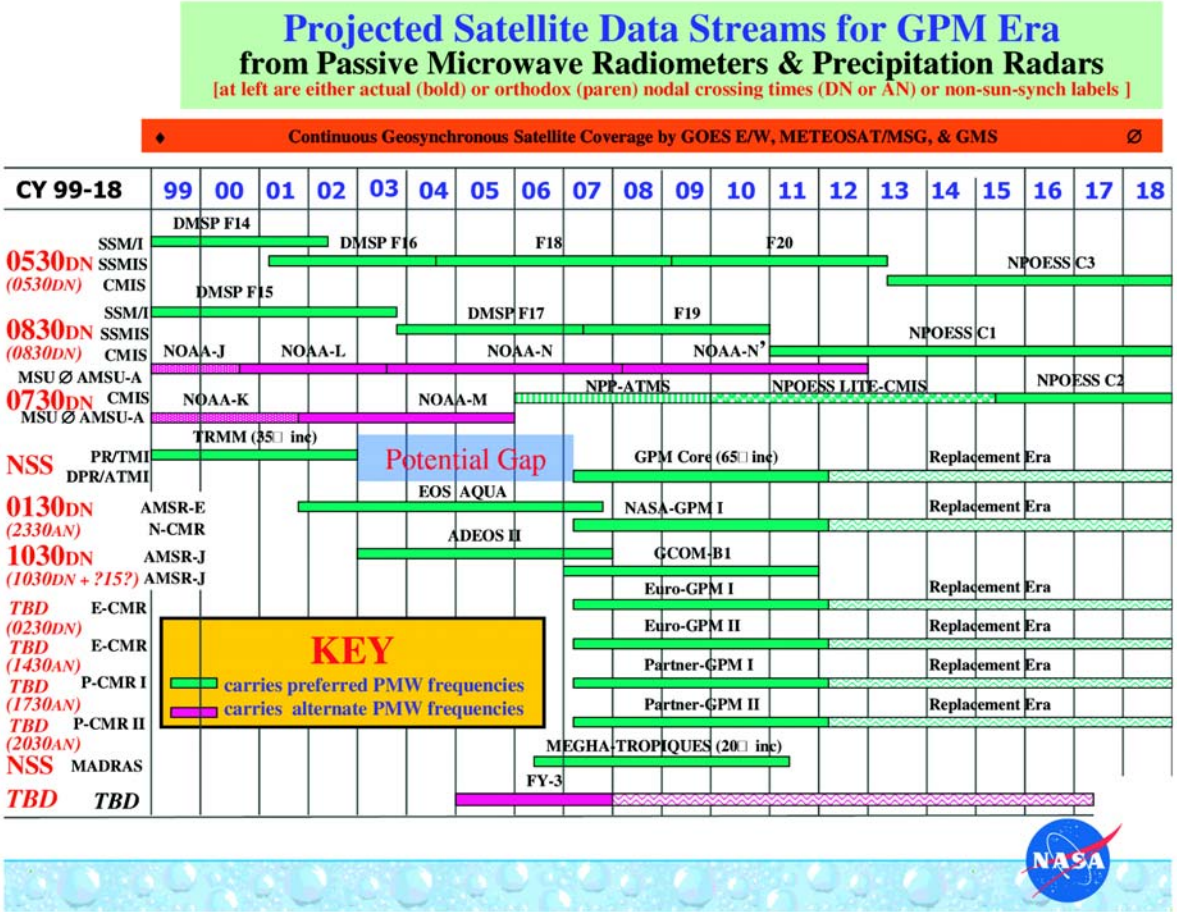

Figure 2. *Projected timeline of the evolution of GPM era constellation and data streams.*

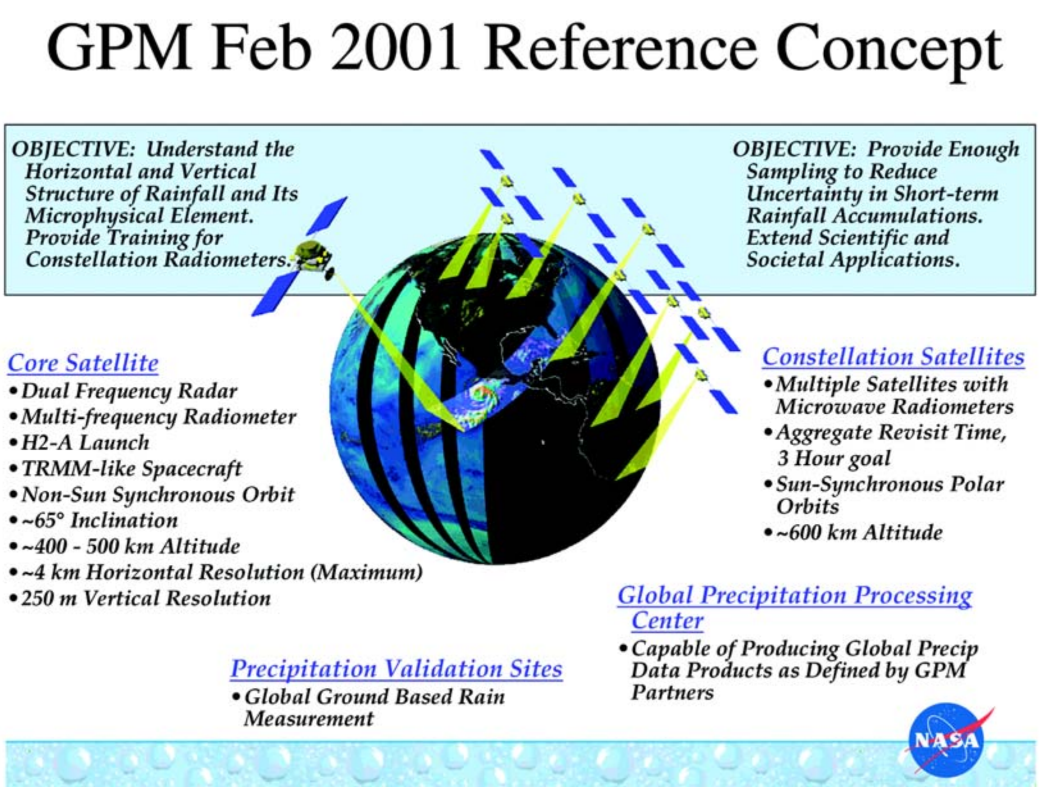

Figure 3. *GPM reference concept.*

Adams closed the presentation with a discussion of the prospect of worldwide coverage of precipitation every 3 hours. He noted that even with satellites there are large coverage gaps. He also remarked that GPM would not operate as a fixed constellation due to satellites being at different altitudes with varying coverage. High spatial resolution and broader coverage are competing objectives at GPM altitudes. For instance, good coverage can be achieved with few satellites with higher altitude, while good resolution can be achieved with a small (aperture) instrument at lower altitude. Additionally, other factors could drive the choice of altitude and inclination.

Mr. E. Stocker (NASA Goddard) discussed the GPM data management system. He stated *E Pluribus Unim-From Many One* is the guiding data management principle. Stocker presented a diagram illustrating the reference GPM real-time data flow and the reference GPM 3hr and climate data flow (Figures 4 and 5). With GPM, there are many partners, cultures, satellites, instruments, field of views, data sources, data streams, processing systems, processing environments, hardware/software configurations, science discipline interest, and applications.

Coordination is the key merging the "manys" to one. It is important that there is early acceptance of a governing entity such as a GPM Joint Science Team (GJST). Coordination and agreement on core mission goals and objectives are also critical.

Prof. C. Kummerow (Colorado State) gave the US science perspective and reiterated the reference GPM concept. He also placed GPM in the context of being a critical for answering key questions about prediction of climate change, improvement of next generation climate models, and understanding trends in the global water cycle. Kummerow's discussion referenced earlier concepts discussed by Prof. Pierre Morel earlier in the workshop.

Prof. Kummerow demonstrated current problems in flood assessment and suggested that GPM synergy with future soil moisture missions could lead to better understanding of the impact of soil moisture on flood/drought prediction, weather forecasting, and agriculture. Prof. Kummerow also touched on potential synergy wit future salinity and wind lidar missions. Such collaborative science has implications for understanding freshwater forcing on ocean processes, assessing hurricane dynamics and evolution, improving atmospheric and oceanic numerical modeling, and closing hydrometeorological water budgets.

Prof. Kummerow offered insight into what the community must do for GPM. He stated that the community must answer relevant questions concerning science objectives and technology issues and address the GPM-enabled outreach and applications that will be utilized by communities broader than science. GPM rainfall information, for example, could be viewed by 100 million people per day if the data is properly formatted for media outlets. GPM must be disseminated in a timely fashion. Additionally, he argued that rainfall forecast models for public consumption must be developed.

Prof. Kummerow also stated what GPM must do for the community. It must provide reliable and continuous observations of rainfall with uncertainty. It must make methods and data available to the community (e.g. improve on monolithic data system). It must validate products. When necessary, GPM must see beyond confines of the "Mission" to provide data that users really need or want.

Mr. Y. Tahara (JMA) illustrated why Japan has such a great interest in rain by illustrating the various types of meteorological systems that impact Japan with rainfall. From here, a timeline evolution of JMA's plans for numerical weather prediction was presented. JMA NWP activities encompass the spectrum from global to regional to mesoscale to cloud scale.

Expectations from GPM for NWP purposes.

- GPM is expected to contribute more accurate global rainfall and moisture analysis.

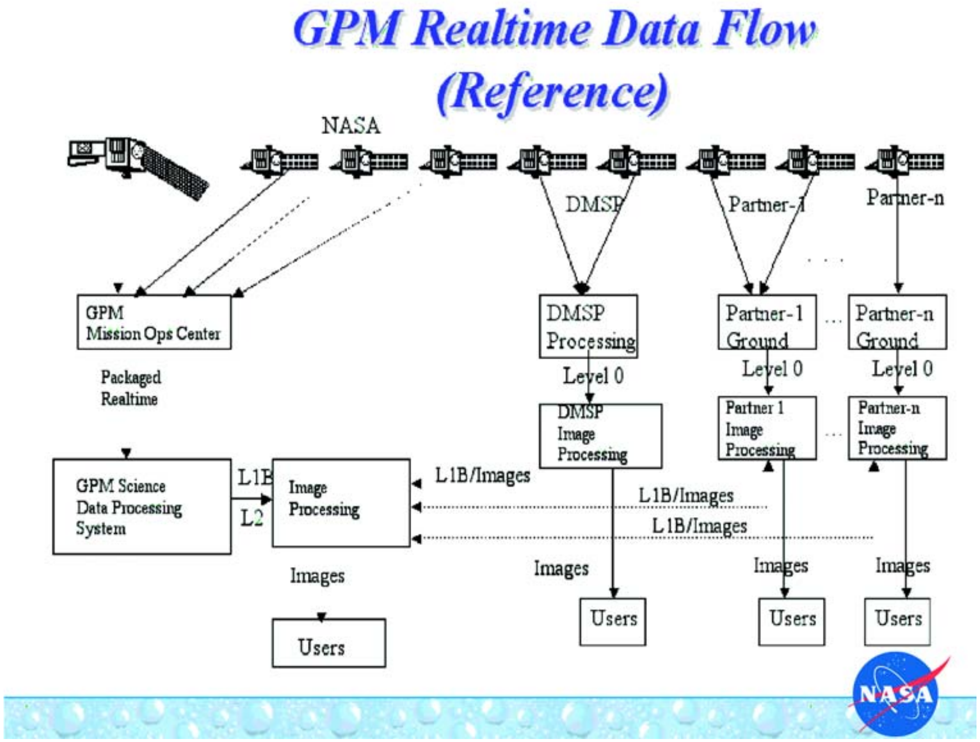

Figure 4. *GPM reference realtime data flowchart.*

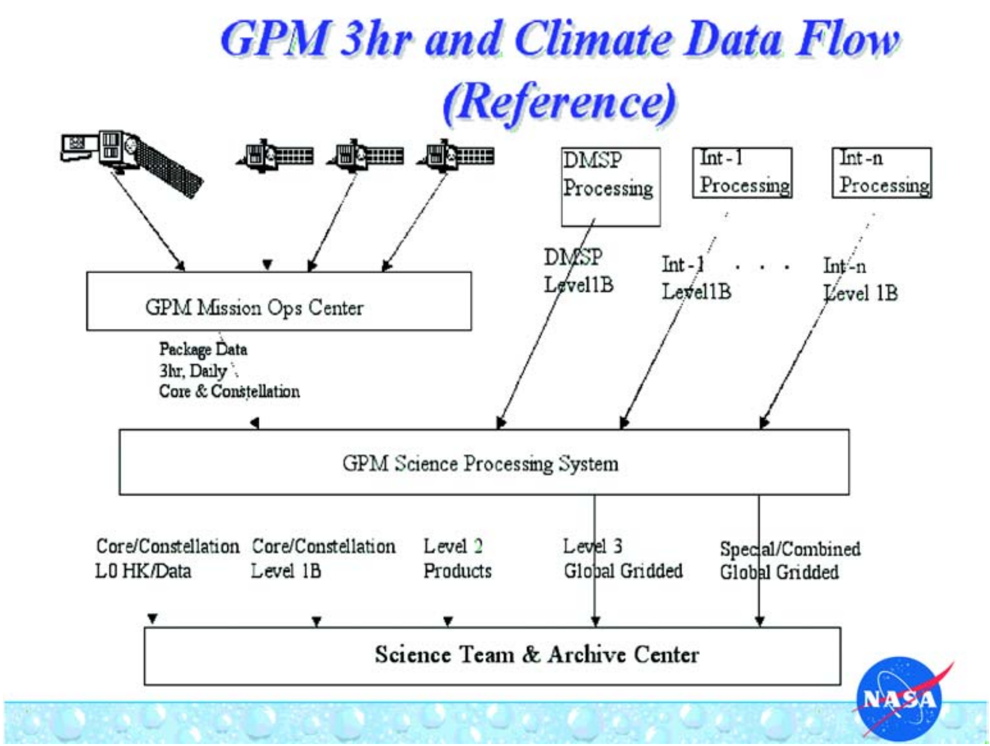

Figure 5. *GPM reference 3-hour and climate data flowchart.*

- GPM is expected to contribute frequent and accurate observation/analysis of severe weather systems including tropical cyclones.
- GPM-improved analyses will lead to better long-term forecasts at all scales.
- GPM is expected to contribute developments and improvements in NWP cloud, rain, and snow schemes (and parameterizations).

Dr. T. Nakazawa (JMA) offered the Japan perspective on the GPM science program. He discussed TRMM's heritage to GPM and highlighted some of TRMM's contributions to science. Dr. Nakazawa proceeded to show science results from TRMM focusing on contributions to understanding El Nino, tropical/monsoon variability, large-scale and cloud dynamics, diurnal cycle, and water cycle in the tropics. According to Dr. Nakazawa, GPM may provide precise global rainfall estimation, improved understanding of the water cycle, and forecast improvements through data assimilation.

7.0 Session on Research Opportunities in Hydrology and GWEC Science

In this session chaired by **Prof. C. Vorosmarty** (University of New Hampshire), a number of presentations focused on potential use of GPM rain products in hydrology and GWEC.

Dr. K. Nakamura (Nagoya University) outlined a number of research areas in which precipitation observations from GPM would be useful on global as well as regional scales. For example, issues such as assessment of global water budget, role of ocean-land atmosphere interactions and role of Asian-Australian monsoon in the global water cycle, require accurate global scale precipitation observations. On the regional basis, precipitation observations are crucial for water resources management and river control. Under the GEWEX Asian Monsoon Experiment, several regional scale water cycle observation experiments are currently being carried out in Siberia (Lena River), China (Huaihe River), and Thailand (Chao Praya River), and several future experiments are planned over Siberia, Mongolia, China, western Pacific, and Indonesia under CEOP (Coordinated Enhanced Observation Period). Dr. Nakamura suggested that GPM's contribution would be useful in these experiments.

Prof. F. Siccardi, (University of Genova) talked about flood hazards in the Mediterranean Basin. **Prof. E. Foufoula-Georgiou** (University of Minnesota) talked about the need for high resolution global observations to understand water, energy, and carbon cycles. Particularly, she showed that in understanding and modeling hydrological processes, precipitation observations play a key role. Also, it is important to assess how water and energy fluxes vary as a result of small-scale variations of precipitation. Dr. Foufoula-Georgiou suggested that multi-sensor rain observations as proposed in GPM, optimally merged at desired scales, would help understand some of the outstanding issues in hydrological processes.

Prof. C. Vorosmarty (University of New Hampshire) presented a strategy in monitoring the dynamics of the hydrosphere through Global HydroNET, which would be useful in conjunction with the GPM measurements. **Prof. T. N. Krishnamurti** (Florida State University) talked about the potential role of GPM rain retrieval and assimilation in super-ensemble model prediction.

Prof. D. Lettenmaier (University of Washington) gave an overview of how GPM would contribute to the U.S. water cycle study. The central scientific issues in the water cycle study are: to quantify variability of water cycle and understand mechanisms underlying the variability, and distinguish human induced and natural variability in the water cycle. Prof. Lettenmaier emphasized that estimation of precipitation from GPM, particularly over land, and its diurnal cycle would be essential in understanding water cycle variability and its predictability.

Dr. A. Gazi (European Comm./Biodiversity and Global Change Unit) talked about climate change and natural hazards. He also discussed the importance of GPM to organizational efforts addressing these issues.

8.0 Breakout Group 1: Engineering Issues

Mr. J. Adams (NASA Goddard) and **Dr. T. Igushi** (CRL) chaired the breakout group discussing engineering and data system issues. **Mr. D. Everett** (NASA Goddard) began with a discussion of issues that must be considered in formulating orbit optimization. Key questions include —

- What should be optimized?

  -Sample interval? Worst case? Average? Hits per time bin?

  -Coverage? Over what period? To what percent?
- What weighting function(s), if any, should be applied?
- Is relative phasing a problem?
- Is diurnal aliasing a concern?
- Does a sample's value change with sample interval?
- What is the value of short sample intervals, e.g. clusters from multiple satellite coverage?
- What are the constraints on the Drone satellites?
  - Required footprint, Launch vehicle (e.g. shared or multiple launch), Radiometer aperture, and Inclination

In addition to these questions, there are trade-offs that must be realized. For example, broader community/international participation could render uniform data sets difficult. Yet, this level of participation is critical to GPM's success. There are also trade-offs related to calibration.

Mr. M. Goodman (NASA Marshall), in discussing new data information systems, stated that data processing strategy is strongly dependent on the science requirements. Both science requirements and data products need to be defined. GPM goals to serve broader outreach and applications communities suggest that direct distribution has to be considered.

Dr. T. Iguchi (CRL) established the relevance of the DPR to GPM. It would provide measurement of storm structure, rainfall rates, drop-size distribution (DSD), path-integrated attenuation, and other useful parameters. The DPR is composed of a Ku-band and Ka-band radar. The Ku-band radar is essentially the same as the TRMM Precipitation Radar (PR). The Ka-band radar provides high sensitivity to weak rain and snow. The Ka-band radar is more accurate for drop-size distribution parameters. Dr. Iguchi provided an overview of tentative specifications for the DPR and selected sensitivity calculations.

Dr. Iguchi emphasized that the Ka-band radar cannot satisfy all requirements of high sensitivity, wide swath, high range resolution, and high accuracy. A compromise is needed, given the constraints of mass, size, power consumption, and budget. Thus, it must be determined whether sensitivity or matched sampling volumes is more important. Additionally, consideration must be given to whether a range resolution of 250 m or 500 m is employed or both.

In terms of scan strategy, there is still a degree of uncertainty on how many beams should be matched. Matching scattering volumes is crucial in dual frequency (DF) algorithms, but how well the two beams should be matched is debatable at this point. For example, is 0.1° (~700 m) acceptable? For range bin matching, it must also be determined whether 250 m for the Ku-band radar and 500 m for the Ka-band radar are acceptable. The answer depends on the type of DF algorithm under consideration. Dr. Iguchi stated that it must be determined how well does the DF algorithm work to obtain DSD information. Simulations with realistic, non-uniform rain and errors in beam matching are needed.

Mr. S. Neeck (NASA Headquarters) provided an overview of required radiometer attributes. The group concluded that a definition of a minimum radiometer measurement standards is required. In current planning, the United States target benchmark is TRMM Microwave Imager (TMI) performance at constellation altitudes. Science input is required as radiometer attributes continue to evolve. Engineers are interested in exploring additional attributes beyond the current radiometer configuration: 150 GHz channel and cross-track scan capability.

9.0 Breakout Group 2: Retrieval and CalVal Requirements

Dr. Z. Hadadd (Jet Propulsion Laboratory) presented the role of a radar/radiometer combined algorithm in GPM. He remarked that because TRMM has a combined algorithm, it is desirable for GPM to have a combined algorithm for continuity of rain estimates. Also, measurements combined from radar and radiometer may be more effective in distinguishing hydrometeor phase than any individual instrument. **Dr. C. Kummerow** (Colorado State) presented the overall algorithm strategy and the challenges facing a GPM concept. **Dr. S. Rutledge** (Colorado State) talked about relevance and values of validation super sites (Figure 6). It was emphasized that the validation of GPM products must be directly linked to algorithm development. Moreover, the ground validation sites must represent precipitation systems from tropical and mid-latitude ocean and land, from warm and cold seasons, and those from orographic origin. **Dr. G. Tripoli** (University of Wisconsin) presented the future of cloud-radiation models for use in the GPM algorithms. Tripoli talked about the importance of including a variety of cloud types in cloud-radiation models. He suggested that cloud-radiation models should be available to GPM algorithm developers with model state parameters and precipitation parameters. He also recommended that cloud-radiation models should include microphysical processes and should be nested with global models to ensure cloud and precipitation simulation in appropriate atmospheric conditions.

Dr. T. Wilheit (Texas A &M) addressed the use of physical validation principles within the broader validation program.

10.0 Breakout Group 3: Interdisciplinary Science Requirements

In this group, potential use of GPM in a variety of interdisciplinary research areas ranging from basin-scale hydrology to global ocean was discussed (Figure 7). **Dr. S. Ackerman** (Wisconsin) talked about using GPM measurements for cloud-radiation research. Ackerman noted that GPM observations would be important in studying lifecycle of cloud systems. Also, cloud-resolving models would be a strong bridge between GPM and cloud-radiation studies. Ackerman also commented that GPM, in its current design, might not adequately detect non-precipitating clouds. It was recommended that GPM collaborate with other missions planned for cloud research, or modify one of its instruments to include a frequency that is sensitive to non-precipitating clouds. **Dr. A. Barros** (Harvard) talked about need for accurate precipitation for closing basin-scale water budget, while **Dr. H. Cooper** (Florida State) outlined how GPM can be useful in hydrometeorology and carbon assimilation models. **Dr. V. Mehta** (NASA Goddard) described how precipitation from GPM, along with other data sets, would be helpful in understanding global water transport. He also noted that GPM observations would be important for modeling ocean salinity. **Dr. B. J. Sohn** (Seoul National University) talked about how precipitation data from GPM can be useful in understanding water vapor transport. **Dr. P. Robertson** (NASA Marshall) pointed out that GPM, along with TRMM, and other historical surface instruments and satellites, may be useful in detecting climate change.

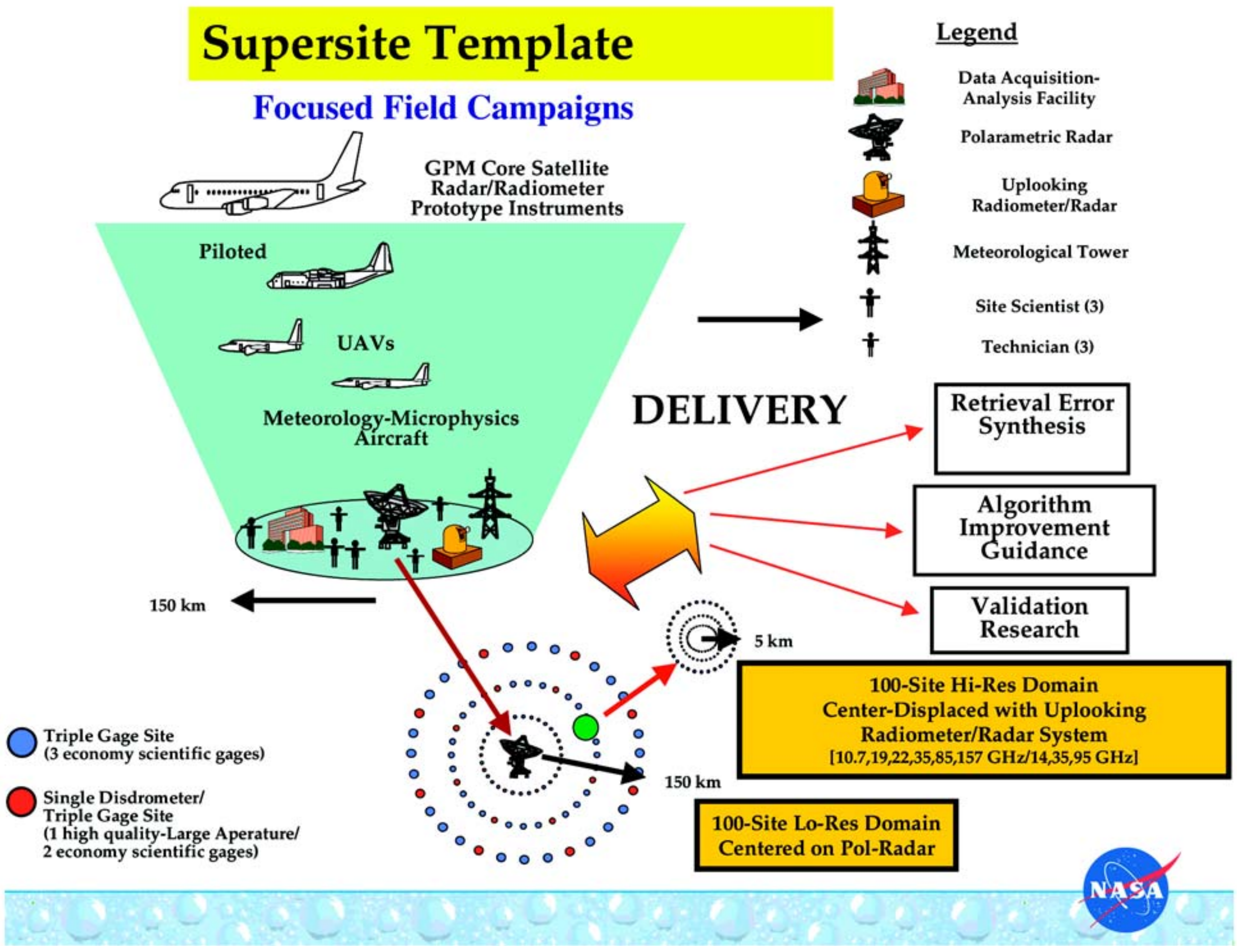

Figure 6. *Illustration of supersite for GPM validation.*

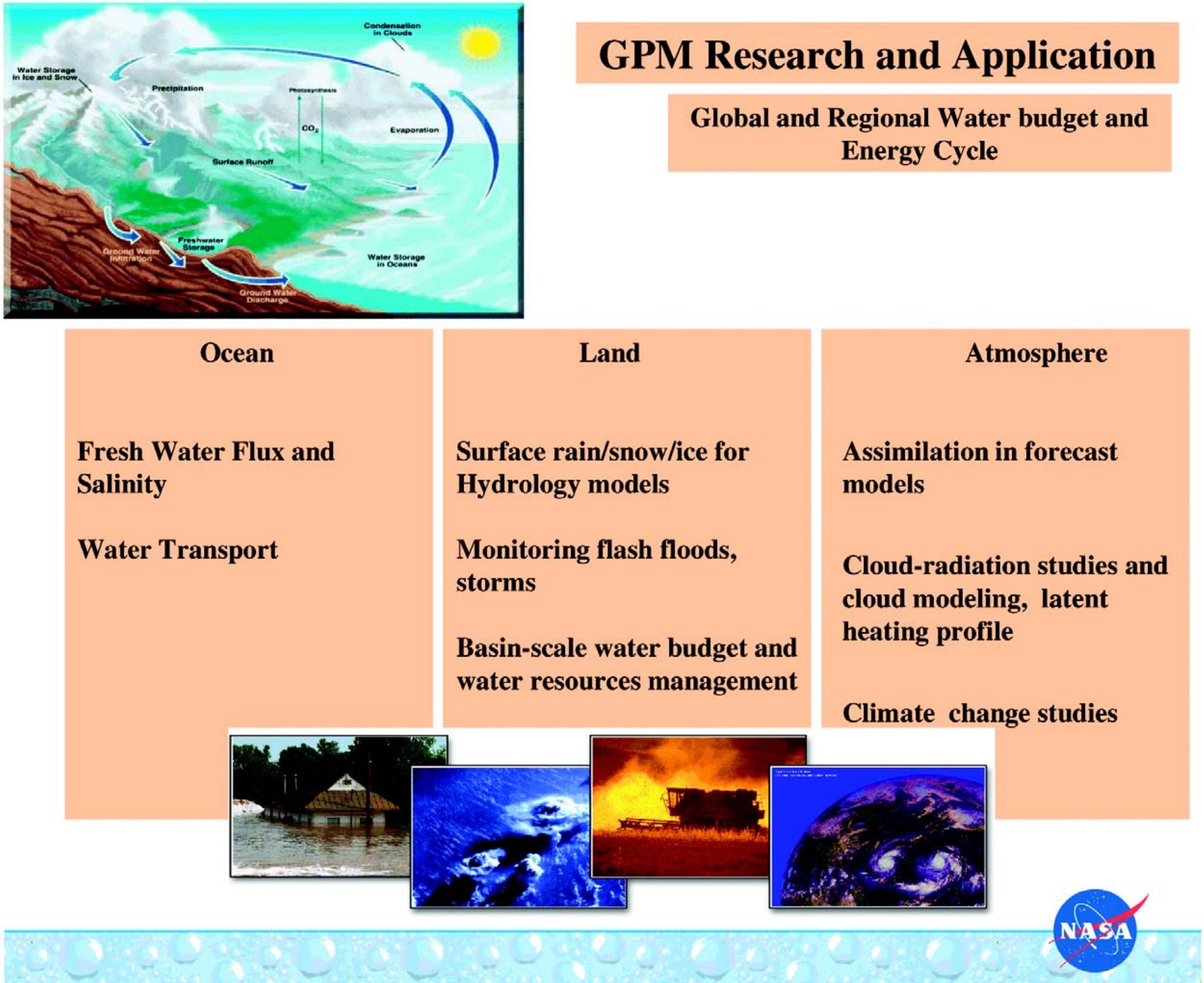

Figure 7. *Key research and application themes that GPM might address.*

11.0 Partnership and Science Progress

Prof. G. Stephens (Colorado State University) provided critical thoughts on how GPM might enhance cloud radiation research and on how cloud-radiation research contributes to GPM. He began by establishing that clouds dominate the radiation heating/cooling budget (Q_R) and thus intimately determines whether or not the hydrological cycle is accelerating. He also established that a necessary condition for improving numerical prediction of precipitation is credible cloud parameterizations. Also, Prof. Stephens pointed out that different hydrometeor profiles corresponding to different rain rates can have “the same” microwave brightness temperature. Microwave radiance ambiguity is largely influenced by the cloud profile.

Prof. Stephens continued by highlighting key cloud research initiatives relevant to the GPM era. These include CloudSat, Advanced Microwave Sounding Radiometer (AMSR), PICASSO (aerosol optics), Moderate Resolution Imaging Spectroradiometer (MODIS), Atmospheric Infrared Sounder (AIRS), and Clouds and Earth’s Radiant Energy System (CERES). CloudSat is relevant to GPM and could contribute in several ways. CloudSat will detect and quantify drizzle and light rain. It will also detect heavy rain and solid precipitation. CloudSat will also provide cloud profile information that can test and evaluate microwave retrievals. With AMSR, CloudSat provides an important opportunity to test GPM-like retrievals on the diversity of precipitation regimes encountered globally.

Prof. Stephens concluded by posing whether it is better to observe clouds and precipitation as part of a single system (e.g. 94 GHz cloud radar observations along with CORE radar observations of GPM). **Prof. R. Bras** (Massachusetts Institute of Technology, MIT) provided a critical assessment of GPM and its likely ability to contribute and extend our understanding of the water cycle.

In concluding the GPM workshop, **Dr. E. Smith** (NASA Goddard) provided a snapshot assessment as of May 2001 on the progress of partnerships (Figure 8).

a. Scientific Engagement: Various space agencies, national and international government agencies, and national and international academic institutions are engaged.

Action Items:

(1) Seek letter of agreements (LOAs) with NOAA, NRL, and NCAR.

b. Space Hardware and Associated Data Streams: TRMM, AQUA, and ADEOS II represent initial assets in preparation for GPM era. NASA will partner with NASDA for GPM core satellite. NPOESS/IPO will join in partnership with two SSMIS instruments and three CMIS instruments. Additionally, NASDA will provide GCOM-B1, and NASA will provide one or two constellation members. ESA is seeking to partner with one or two constellation members, and ISRO/CNES is willing to partner with MeghaTropiques. There is interest within the Argentinean, Brazilian, Chinese, and South Korean space agencies to examine possible partnership arrangement for one constellation member.

Action Items:

(1) Secure LOA with NASDA

(2) Explore LOA with NPOESS/IPO

(3) Continue collaboration with EGPM group through EEOM proposal process

(4) Information exchange meetings with ASI, CNES, CSA, and EC

(5) Continue discussions with ISRO/CNES on MeghaTropiques

(6) Continue discussions with Argentinean, Brazilian, Chinese, and South Korean space agencies concerning constellation spacecraft.

c. High Quality Validation Super sites and Associated Data Streams: NASA in support of GPM, is currently carrying budget support for two validation super sites. Australia, Brazil, Canada, England, France, Germany, India, Italy, Japan, Spain and Taiwan have all indicated interest in supporting validation super sites.

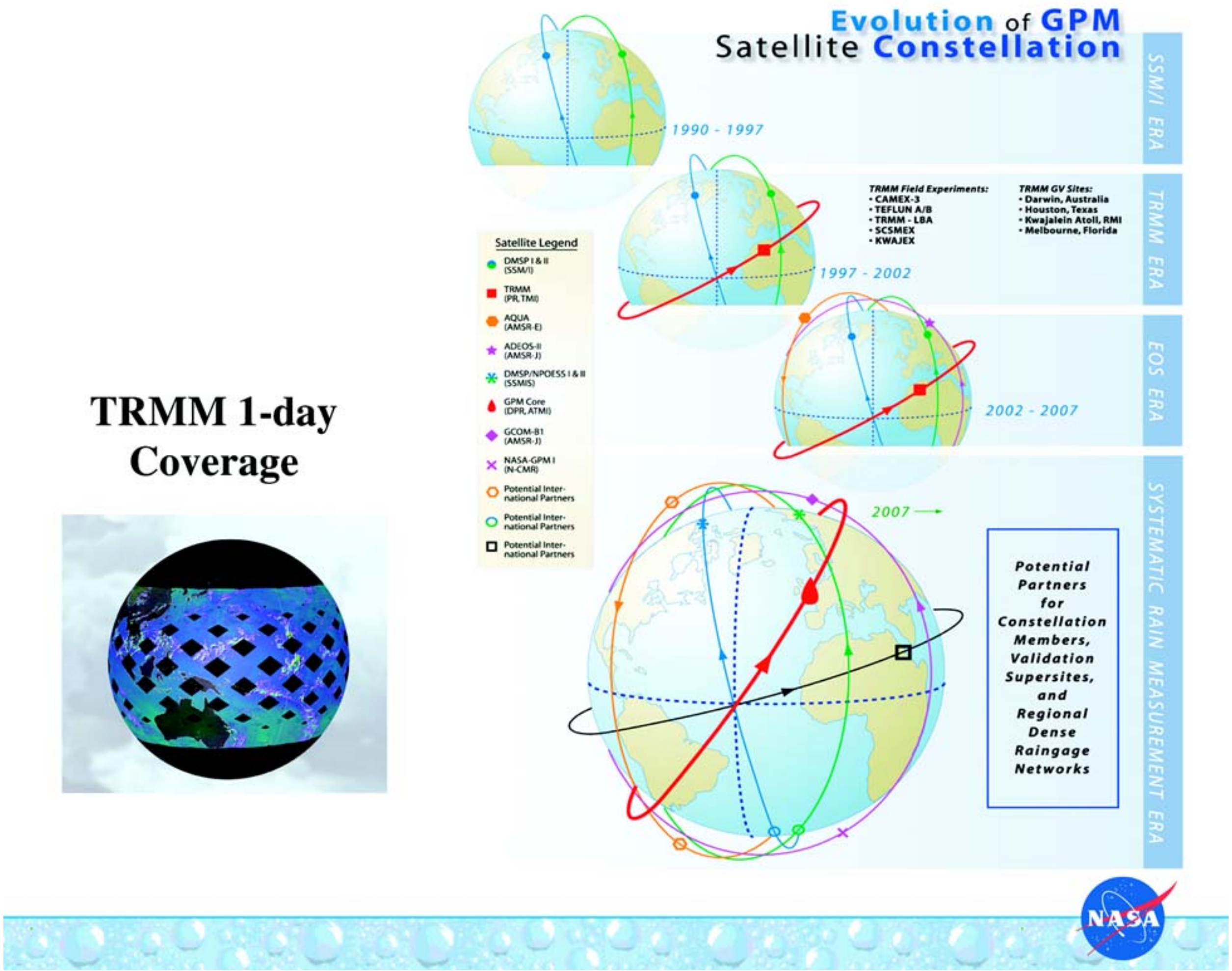

Figure 8. *Evolution of GPM era satellite constellation.*

Action Items:

(1) To pursue agreements with interested international agencies.

d. High Quality Regional Rain gauge Networks and Associated Data Streams: United States and Japan will provide these datasets. South Korea/ KMA has indicated strong interest in developing a partnership in this area.

Action Items:

(1) To pursue MOU with KMA.

e. Additional Precipitation and Ancillary Data Streams: BALTEX, etc.

Action Items:

(1) Examine participant inputs to determine additional data streams.

12.0 Future Plans

GPM is the centerpiece of NASA's GWEC initiative, but the focus of this broad mission and research program is inherently global. NASA and NASDA have entered into a partnership and have taken steps in the organization of preliminary science and technology concepts. However, successful mission formulation and implementation requires broad and committed relationships beyond the United States and Japan. The first GPM Planning Workshop convened scientists, engineers, and policymakers from around the world to stimulate existing partnerships and establish new partnerships; acquire input on science and technology issues, and develop the framework for mission formulation.

This report has presented an overview of meeting objectives, plenary session presentations, break-out group summaries, and future plans. From this workshop, a set of critical action items were established.

- Seek appropriate agreements with international, interagency, academic, and corporate partners.
- Determine needs of potential partners and stakeholders.
- Pursue and assess technological issues.
- Identify a technologically-sound and scientifically-credible mission concept.
- Determine additional mission-critical and supporting data streams.

A series of GPM reports will document the ongoing and future steps as the GPM Advanced Study progresses through mission formulation.

Appendix A: Workshop Agenda

<u>Wednesday, May 16, 2001 - Plenary (Rooms 2101/2103/2105)</u>

Opening Session

08:30 am	Orientation and Agenda	Mr. James Adams, NASA GSFC
08:40 am	Welcome and NASA's Interest in GPM	Dr. Mary Cleave, NASA HQ
08:55 am	NASDA's Earth Observation Program and GPM	Dr. Yoji Furuhama, NASDA

Session on Objectives and Opportunities (Prof. Kenji Nakamura, session chair)

09:10 am	Prospects for Global Precipitation Observing System	Prof. Pierre Morel, UMBC
09:30 am	GPM's Heritage to TRMM	Prof. Joanne Simpson, NASA GSFC
09:40 am	Purpose of Meeting	Prof. Eric Smith, NASA GSFC

09:50 ***BREAK & POSTER SET-UP***

GPM Partnerships: Session 1 (Prof. Christian Kummerow, session chair)

10:15 am	NASA Planning for GPM	Dr. Ramesh Kakar, NASA HQ
10:30 am	NASDA Planning for GPM	Drs. Riko Oki, Nobuhiro Takahashi, and Mr. Kazuo Ohta, NASDA
10:45 am	ESA's Programs for TRMM and GPM	Dr. Pedro Baptista, ESA/ESTEC
11:00 am	NOAA's Provisional Interest/Role in GPM	Drs. Ralph Ferraro and Marie Colton, NOAA
11:10 am	NRL's Provisional Interest/Role in GPM	Dr. Joe Turk and Mr. Jeffrey Hawkins, NRL/Monterey
11:20 am	Synergy of Soil Moisture and Precipitation Measurements	Dr. Thomas Jackson, USDA
11:30 am	NPOESS/IPO's Planned Contribution to GPM	Dr. Stanley Schneider and Major Mark Sorrells, NPOESS/IPO

12:00 noon *COMPLIMENTARY* ***LUNCH and POSTER SET-UP*** (Mount Clare Café)

<u>Wednesday, May 16, 2001 - Plenary (Rooms 2101/2103/2105) (Continued)</u>

GPM Partnerships: Session 2 (Dr. Tetsuo Nakazawa, session chair)

01:00 pm	Australia/BMRC's Provisional Interest/Role in GPM	Dr. Michael Manton, BMRC
01:15 pm	Brazil's Provisional Interest/Role in GPM	Dr. Roberto Calheiros and Prof. Carlos Nobre, INPE
01:30 pm	Canada's Provisional Interest/Role in GPM	Drs. Ron Stewart and Barry Goodison, Environment Canada
01:45 pm	France's Provisional Interest/Role in GPM	Prof. Jacques Testud and Dr. Michel Desbois, U-Versailles & LMD
02:00 pm	India's Provisional Interest/Role in GPM	Dr. A.K.S. Gopalan, ISRO
02:15 pm	Germany's Provisional Interest/Role in GPM	Dr. Ralf Bennartz, Free University of Berlin
02:30 pm	Italy's Provisional Interest/Role in GPM	Dr. Alberto Mugnai and Prof. Franco Prodi, CNR and U-Ferrara
02:45 pm	South Korea/KMA's Provisional Interest/Role in GPM	Dr. Hyo-Sang Chung, KMA
03:00 pm	Spain/Catalonia's Provisional Interest/Role in GPM	Dr. Eyal Amitai on behalf of Profs. Maria Carmen Llasat and Daniel Sempre-Torres

03:15 pm	United Kingdom's Provisional Interest/Role in GPM	Drs. Christopher Kidd and John Goddard, U-Birm. and Chilbolten Lab

03:30 pm ***BREAK and POSTER VIEWING*** (Posters available for viewing in Rooms 2109, 2117, 2129 and main hallway)

GPM Partnerships: Session 3 (Dr. Robert Adler, session chair)

04:00 pm	NASA Goddard 's Planned Contribution to GPM	Drs. Arthur Hou and Franco Einaudi, NASA GSFC
04:15 pm	CRL's Planned Contribution to GPM	Drs. Harunobu Masuko and Toshio Iguchi, CRL
04:30 pm	Outlook from ECMWF	Drs. Peter Bauer and Jean-Francois Mahfouf, ECMWF
04:45 pm	NASA/MSFC's Planned Contribution to GPM	Dr. Franklin Robertson and Mr. Michael Goodman, MSFC
05:00 pm	NASA/JPL's Planned Contribution to GPM	Drs. Eastwood Im and Ziad Haddad, NASA JPL

05:15 pm **Adjourn Plenary for Day 1**

06:00 pm **Dinner** - Chesapeake Room
Introductions: Mr. A. V. Diaz, NASA GSFC
Speakers: Drs. Yoji Furuhama, NASDA and Ghassem Asrar, NASA HEADQUARTERS

Thursday, May 17, 2001 - Plenary (Rooms 2101/2103/2105)

Session on GPM Concept (Prof. Thomas Wilheit, session chair)

08:30 am	GPM Mission Conceptual Overview	Mr. James Adams, NASA GSFC
08:50 am	GPM Data Management Concept	Mr. Erich Stocker, NASA GSFC
09:00 am	US Perspective on GPM Science Program	Profs. Christian Kummerow and Eric Smith, CSU and NASA GSFC
09:30 am	Japan Perspective on GPM Science Program	Drs. Harunobu Masuko Toshio Iguchi, and Tetsuo Nakazawa, and Mr. Yoshihiko Tahara, U-Nagoya, CRL, JMA/MRI, and JMA/NPD

10:15 am ***BREAK and POSTER VIEWING*** (Posters available for viewing in Rooms 2109, 2117, 2129 and main hallway)

Session on Research Opportunities in Hydrology and GWEC Science (Prof. Charles Vorosmarty, session chair)

10:45 am	Understanding Global Water Resources	Prof. Kenji Nakamura, U-Nagoya
11:00 am	Flood Hazards in Mediterranean Basin	Prof. Franco Siccardi, U-Genova/ CIMA
11:15 am	Modeling Hydrological Variability	Prof. Efi Foufoula-Georgiou, U-Minn
11:30 am	Global HydroNet	Prof. Charles Vorosmarty, UNH
11:45 am	Role of Rain Retrievals in Super-Ensemble Prediction	Prof. Tiruvalum Krishnamurti, FSU
12:00 noon	Contribution of GPM to US Water Cycle Plan	Prof. Dennis Lettenmaier, U-Washington
12:15 pm	Climate Change and Natural Hazards	Dr. Anver Ghazi, European Comm./Biodiversity and Global Change Unit

12:30 pm	*COMPLIMENTARY* ***LUNCH*** **(**Mount Clare Café)	
2:00 pm	Geosynchronous Microwave Sounder Imager	Dr. Albin Gasiewski, NOAA ETL
2:10 pm	NCAR's Provisional Interest/Role in GPM	Drs. Andrew Heymsfeld, Jeffrey Stith and Mitch Moncrieff, NSF/NCAR

Thursday, May 17, 2001 - Plenary (Rooms 2101/2103/2105) (Continued)

Breakout Groups (Rooms 2101/2103/2105, 2109, and 2117)

02:20 pm Charge to Breakout Groups (3)Prof. Eric Smith

Working Group 1: **Room 2109** (**Engineering Issues**)	Mr. James Adams and Dr. Toshio Iguchi, Co-Chairs
Working Group 2: **Room 2117** (**Retrieval and CalVal Requirements**)	Profs. Christian Kummerow & Kenji Nakamura, Co-Chairs
Working Group 3: **Rooms 2101/2103/2105** (**Interdisciplinary Sci. Requirements**)	Drs. Alberto Mugnai and Tetsuo Nakazawa, Co-Chairs

03:30 pm ***BREAK and POSTER VIEWING*** **(**Posters available for viewing in Rooms 2109, 2117, 2129 and main hallway)

04:00 pm **Re-Convene Three (3) Breakout Groups**

05:00 pm **Adjourn Day 2**

Friday, May 18, 2001 - Plenary (Rooms 2101/2103/2105)

Partnership and Science Progress and Breakout Group Reports (Prof. Graeme Stephens, session chair)

08:30 am	Can GPM Enhance Cloud-Radiation Research? Prof. Graeme Stephens, CSU	
08:50 am	Can GPM Advance Our Understanding of Global Water Cycle? *A Critical Examination*	Prof. Rafael Bras, MIT
09:10 am	Report on Partnership Progress Prof. Eric Smith, NASA GSFC	
09:30 am	Report from Breakout Group 1 (**Engineering Issues**)	Mr. James Adams, NASA GSFC
09:50 am	Report from Breakout Group 2 (**Retrieval and CalVal Requirements**)	Prof. Chris Kummerow, CSU
10:10 am	Report from Breakout Group 3 (**Interdisciplinary Science Requirements**)	Dr. Tetsuo Nakazawa, JMA/MRI

10:30 am ***BREAK and POSTER VIEWING*** **(**Posters available for viewing in Rooms 2109, 2117, 2129 and main hallway)

Concluding Session (Prof. Eric Smith, session chair)

11:00 am	Concluding Discussion and Action Items	All Participants
12:00 noon	*ADJOURN WORKSHOP and POSTER BREAKDOWN*	
12:15 pm	*COMPLIMENTARY* ***LUNCH*** **(**Mount Clare Café)	

Appendix B: List of Attendees

Ackerman	Steven	UW-CIMSS	stevea@ssec.wisc.edu
Adams	Jim	NASA Goddard Space Flight Center	jadams@pop400.gsfc.nasa.gov
Adler	Robert	NASA Goddard Space Flight Center	Robert.Adler@gsfc.nasa.gov
Amitai	Eyal	NASA Goddard Space Flight Center	eyal@radar.gsfc.nasa.gov
Anagnostou	Emmanouil	University of Connecticut	manos@engr.uconn.edu
Asrar	Ghassem	NASA Headquarters	gasrar@hq.nasa.gov
Atlas	David	Atlas Concepts	datlas@radar.gsfc.nasa.gov
Barros	Ana	Harvard University	barros@deas.harvard.edu
Bauer	Peter	ECMWF	peter.bauer@ecmwf.int
Bell	Thomas	NASA Goddard Space Flight Center	bell@climate.gsfc.nasa.gov
Bennartz	Ralf	University of Kansas	bennartz@ukans.edu
Berg	Wesley	Colorado State University	berg@atmos.colostate.edu
Bras	Rafael	MIT	rlbras@mit.edu
Braun	Scott	NASA Goddard Space Flight Center	braun@agnes.gsfc.nasa.gov
Calheiros	Roberto	INPE-AEB/IPMET-UNESP	calheiros@www.radar.ipmet.unesp.br
Cao	Mzngkuz	University of Maryland	mkcao@glue.umd.edu
Chagnon	Frederic	Mass Inst. of Tech	frederic@mit.edu
Chamberlain	Katherine	CSC - NASA/WFF	krchambe@pop800.gsfc.nasa.gov
Chandra	Chandrasekar	Colorado State University	chandra@engr.colostate.edu
Chang	Alfred	NASA Goddard Space Flight Center	achang@rainfall.gsfc.nasa.gov
Chang	Dong-Eon	NASA Goddard Space Flight Center	dechang@synth.gsfc.nasa.gov
Chiu	Long	NASA Goddard Space Flight Center	chiu@daac.gsfc.nasa.gov
Chung	Hyosang	Metri/KMA	hschung0@metri.ve.kv
Cleave	Mary	NASA Headquarters	mcleave@hq.nasa.gov
Condes	Al	NASA Headquarters	acondes@hq.nasa.gov
Connerion	Bob	NASA Goddard Space Flight Center	rconnert@pop500.gsfc.nasa.gov
Cooper	Harry	Florida State University	cooper@huey.met.fsu.edu
Cuddapah	Prabhakara	NASA Goddard Space Flight Center	cuddapah@climate.gsfc.nasa.gov
Cusick	Leslie	NASA Goddard Space Flight Center	leslie.cusick@gsfc.nasa.gov
Desbois	Michel	LMD & University of Versailles	Desbois@lmd.polytechnique.fr
Diaz	Al	NASA Goddard Space Flight Center	avdiaz@gsfc.nasa.gov
Einaudi	Franco	NASA Goddard Space Flight Center	einaudi@carioca.gsfc.nasa.gov
Everett	David	NASA Goddard Space Flight Center	david.everett@gsfc.nasa.gov
Farrar	Mike	US Airforce Weather Agency	michael.farrar@afwa.af.mil
Ferraro	Ralph	NOAA/NESDIS	Ralph.R.Ferraro@noaa.gov
Fisher	Brad	SSAI	fisher@radar.gsfc.nasa.gov
Flaming	Mark	NASA Goddard Space Flight Center	gilbert.m.flaming.1@gsfc.nasa.gov
Folta	Dave	NASA Goddard Space Flight Center	david.folta@gsfc.nasa.gov
Fotopoulos	Fotios	MIT	ffotop@mit.edu
Foufoula-Georgian	Efi	University of Minnesota	efi@to.umn.edu
Fowler	Laura	Dept. of Atmospheric Science (CSU)	laura@atmos.colostate.edu
Frulla	Laura	CONAE	lfrulla@conae.gov.ar
Fuentes	Jose	University of Virginia	jf6s@virginia.edu
Furuhama	Yoji	NASDA	furuhama.yoji@nasda.go.jp
Gadian	Alan	UMIST, Physics' Department	alan.gadian@umist.ac.uk
Gage	Kenneth	NOAA	kgage@al.noaa.gov
Gao	Xiaogang	University of Arizona	gao@hwr.arizona.edu
Gasiewski	Al	NOAA Research - ETL	al.gasiewski@noaa.gov
Gerlach	John	NASA Goddard Space Flight Center	gerlach@osb1.wff.nasa.gov
Ghazi	Anver	European Commission	anver.ghazi@cec.eu.int
Goddard	John	Chilbolten Lab & University of Birmingham	j.w.f.goddard@rl.ac.uk
Goodison	Barry	Environment Canada	barry.goodison@ec.gc.ca
Goodman	Michael	NASA Marshall Space Flight Center	michael.goodman@msfc.nasa.gov
Gopalan	Alwonihinnojan	Indian Space Research Organ.	gopalanaks@vediffmail.com
Gorgucci	Eugenio	Istituto di Fisica dell'Atmosfera (CNR)	gorgucci@radar.ifa.rm.cnr.it
Grody	Norman	NOAA/NESDIS	norman.grody@noaa.gov
Grecu	Mircea	University of Connecticut	mgrecu@engr.uconn.edu
Haas	Mike	Aerospace	mike.haas@noaa.gov
Hack	James	NCAR	jhack@near.ncar.edu
Haddad	Ziad	Jet Propulsion Lab	zsh@titan.jpl.nasa.gov

Haferman	Jeff	ENMOC U.S. Navy	haferman@fnmoc.navy.mil
Haggerty	Julie	NCAR	haggerty@ucar.edu
Hamilton	Robert	Mentor Technologies, Inc	hamilton@tsdis.gsfc.nasa.gov
Han	Daeso	NASA Goddard Space Flight Center	han@radar.gsfc.nasa.gov
Heymsfield	Gerald	NASA Goddard Space Flight Center	heymsfield@agnes.gsfc.nasa.gov
Heymsfield	Andy	NCAR	heyms1@hcar.ucar.edu
Hildebrand	Peter	NASA Goddard Space Flight Center	peter.hildebrand@gsfc.nasa.gov
Hisas	Fernando	CONAE	futuro@pagina12.com.ar
Hood	Robbie	NASA Marshall Space Flight Center	robbie.hood@msfc.nasa.gov
Hou	Arthur	NASA Goddard Space Flight Center	arthur.hou@gsfc.nasa.gov
Iacovazzi	Robert	NASA Goddard Space Flight Center	robert@cloud.gsfc.nasa.gov
Iguchi	Toshio	Communications Research Laboratory	iguchi@crl.go.jp
Im	Eatwood	Jet Propulsion Lab	eastwood.im@jpl.nasa.gov
Inoue	Toshiro	MRI/JMA	tinoue@mri-jma.go.jp
Jackson	Thomas	USDA ARS Hydrology and RS Lab	tjackson@hydrolab.arsusda.gov
Jenkins	Gregory	Penn State University	gsj1@psu.edu
Ji	Yimin	TSDIS/NASA	yii@tsdis.gsfc.nasa.gov
Joe	Paul	Environment Canada	paul.joe@eglc.gc.ca
Johnson	Daniel	NASA Goddard Space Flight Center	djohnson@agnes.gsfc.nasa.gov
Jones-Selden	Felicia	NASA Goddard Space Flight Center	fselden@pop700.gsfc.nasa.gov
Joseph	Everette	Howard University	ejoseph@physics1.howard.edu
Jung-Moon	Yoo	SSAI - NASA Goddard Space Flight Center	yoo@climate.gsfc.nasa.gov
Kakar	Ramesh	NASA Headquarters	rkakar@hq.nasa.gov
Kaye	Jack	NASA Headquarters	Jack.kaye@hq.nasa.gov
Kelly	Owen	George Mason University	owen.kelley@gsfc.nasa.gov
Kennedy	Pat	Honeywell	Pkennedy@pop500.gsfc.nasa.gov
Kidd	Chris	University of Birmingham	C.Kidd@bham.ac.uk
Kidd	Ludie	NASA Goddard Space Flight Center	ludie.kidd@gsfc.nasa.gov
Koichi	Oshimura	NASA Goddard Space Flight Center	koichi@rattler.gsfc.nasa.gov
Kowaleski	Mark	NASA Headquarters	mark.kowaleski@hq.nasa.gov
Krishnamurti	Tiruvalam	Florida State University	tnK@io.met.
Kucera	Paul	The University of Iowa	pakucera@mail.iihr.uiowa.edu
Kuligowski	Bob	NOAA/NESDIS/ORA	bob.kuligowski@noaa.gov
Kummerow	Christian	Colorado State University	burke@atmos.colostate.edu
Kwiatkowski	John	GMU/TSDIS	johnk@tsdis.gsfc.nasa.gov
Lagerloef	Gary	Eartth & Space Research	Lager@esr.org
Lang	Stephen	SSAI	lang@gilbert.gsfc.nasa.gov
Lang	Roger	George Washington University	lang@seas.gwu.edu
Lawford	Rick	NOAA OGP	lawford@ogp.noaa.gov
Lawrence	Richard	NASA Goddard Space Flight Center	rlawrence@pop400.gsfc.nasa.gov
Lettenmaier	Dennis	University of Washington	dennisl@u.washington.edo
Li	Guo-Qing	Inst. of Atmos Phys. Academy of China	liguogin@public.east.on.net
Liao	Liang	Caelum Research	lliao@priam.gsfc.nasa.gov
Liu	Guosheng	Florida State University	liug@met.fsu.edu
Liu	Quanhua	NOAA NESDIS	Quanhua.liu@noaa.gov
Lobl	Elena	VAH/MSFC	elena.lobl@msfc.nasa.gov
Lochan	Rajeev	Embassy of India	lochan@hotmail.com
Lau	William	NASA Goddard Space Flight Center	lau@climate.gsfc.nasa.gov
Mahfouf	Jean-Francois	ECMWF	mahfouf@ecmwf.int
Makoto	Kajii	NASDA	kajii.makoto@nasda.go.jp
Mango	Stephen	NPOESS Intergrated Program Office	stephen.mango@noaa.gov
Manton	Michael	Bureau of Meterology Research Centre	m.manton@bom.gov.au
Maresvina	Marco	Politecnics Di, Torino	gabeffa@polito.it
Martner	Brooks	NOAA/ETL	brooks.martner@noaa.gov
Masuko	Harunobu	Communications Research Laboratory	masuko@crl.go.jp
Matthias	Steiner	Princeton University	msteiner@princeton.edu
McCollum	Jeff	University of Maryland	Jeff.McCollum@noaa.gov
McCumber	Michael	NASA Goddard Space Flight Center	mccumber@tsdis.gsfc.nasa.gov
Mehta	Amita	JCET	amita@radar.gsfc.nasa.gov
Mehta	Vikram	Univ. of Maryland	mehta@climate.gsfc.nasa.gov
Meischner	Peter	DLR, Institute of Atmospheric Physics	peter.meischner@dlr.de
Mendelsohn	Chad	NASA Goddard Space Flight Center	chad.mendelsohn@gsfc.nasa.gov

Meneghini	Robert	NASA Goddard Space Flight Center	bob@priam.gsfc.nasa.gov
Michaud	Rejean	Canadian Space Agency	rejean.michaud@space.gc.ca
Moncrieff	Mitch	NSF/ NCAR	moncrief@ncar.ucar.edu
Morales	Carlos	Colorado State University	cmorales@engr.uconn.edu
Morel	Pierre	UMBC	morel@hsb.gsfc.nasa.gov
Mugnai	Alberto	Istituto di Fisica dell'Atmosfera / C.N.R.	Alberto.Mugnai@ifa.rm.cnr.it
Nakamura	Kenji	Nagoya University	nakamura@ihas.nagoya-u.ac.jp
Nakazawa	Tetsuo	Meteorological Research Institute	nakazawa@mri-jma.go.jp
Nance	Louisa	NOAA/ETL	louisa.nance@noaa.gov
Neeck	Steven	NASA Goddard Space Flight Center	steve.neeck@gsfc.nasa.gov
Negri	Andrew	NASA Goddard Space Flight Center	negri@agnes.gsfc.nasa.gov
Nystuen	Jeff	University of Washington	nystuen@apl.washington.edu
Ohta	Kazuo	NASDA	Ohta-K@eorc.nasda.go.jp
Oki	Riko	NASDA	oki.riko@nasda.go.jp
Olson	Bill	JCET/University of Maryland Baltimore County	olson@agnes.gsfc.nasa.gov
Paules	Gran	NASA Headquarters	gpaules@hq.nasa.gov
Poiares Baptista	J. Pedro	ESA/ESTEC	pedro.baptista@esa.int
Prodi	Franco	University of Ferrara	f.prodi@isao.bo.cnr.it
Pu	Zhao-Xia	University of Maryland, Baltimore	pu.agnes@gsfc.nasa.gov
Ralf	Bennartz	University of Kansas	bennartz@ukans.edu
Reale	Oreste	Center for Ocean-Land-Atmosphere Studies	reale@cola.iges.org
Rickenbach	Tom	NASA Goddard Space Flight Center	ricken@trmm.gsfc.nasa.gov
Ridner	Alberto	CONAE	aridner@conae.gov.ar
Rincon	Rafael	GMU	rrincon@gmu.edu
Robertson	Pete	NASA Marshall Space Flight Center	pete.robertson@msfc.nasa.gov
Rolf	Joan	NASA	jrolf@hq.nasa.gov
Rose	Lynn	AEROMET, INC.	lynnr@aeromet.com
Ruf	Chris	University of Michigan	cruf@umich.edu
Rutledge	Steven	Colorado State University	rutledge@atmos.colostate.edu
Satoh	Shinsuke	Communications Research Laboratory	satoh@crl.go.jp
Scheider	Stan	NPOLESS/NASA	sschneid@ipo.noaa.gov
Schiffer	Robert	NASA Headquarters	rschiffer@hq.nasa.gov
Sekelsky	Stephen	Univ. of Mass	sekelsky@mirsl.ecs.umass.edu
Shepherd	Marshall	NASA Goddard Space Flight Center	shepherd@agnes.gsfc.nasa.gov
Shin	Dong-Bin	Colorado State University	dshin@atmos.colostate.edu
Siccardi	Franco	CIMA - University of Genova	franco@cima.unige.it
Simpson	Joanne	NASA Goddard Space Flight Center	simpson@agnes.gsfc.nasa.gov
Skofronick Jackson	Gail	UMBC/GEST	Gail@sensor2.gsfc.nasa.gov
Smith	Eric	NASA Goddard Space Flight Center	easmith@pop900.gsfc.nasa.gov
Sohn	Byung-Ju	Seoul National University	sohnbj@snu.ac.kr
Sorrells	Markus	NPOESS/ IPO	Msorrells@ipo.noaa.gov
Spencer	Roy	NASA Marshall Space Flight Center	roy.spencer@msfc.nasa.gov
Starobin	Caron	No affiliation	Mstarobi@pop200.gsfc.nasa.gov
Starobin	Michael	NASA Goddard Space Flight Center	mstarobi@pop200.gsfc.nasa.gov
Starr	David	NASA Goddard Space Flight Center	starr@agnes.gsfc.nasa.gov
Stephens	Graeme	Colorado State University	lini@atmos.colostate.edu
Stewart	Ronald	Environment Canada	Ron.Stewart@ec.gc.ca
Stith	Jeff	NCAR	stith@ucar.edu
Stocker	Erich	NASA Goddard Space Flight Center	Erich.Stocker@gsfc.nasa.gov
Stout	John	George Mason University	stout@tsdis.gsfc.nasa.gov
Stuhlmann	Rolf	EUMETSAT	stuhlmann@eumetsat.de
Sumi	Akimasa	University of Tokyo	sumi@ccsr.u-tokyo.ac.jp
Summers	Robert	NASA Goddard Space Flight Center	bsummers@pop500.gsfc.nasa.gov
Tahara	Yoshihiko	UCAR	Yoshihiko.Tahara@noaa.gov
Takahashi	Nobuhiro	NASDA	takahashi.nobuhiro3@nasda.go.jp
Tao	Wei-Kuo	NASA Goddard Space Flight Center	tao@agnes.gsfc.nasa.gov
Teng	William	NASA Goddard Space Flight Center	teng@daac.gsfc.nasa.gov
Testud	Jacques	CNRS	testud@cetp.ipsl.fr
Tilman	Justin	NASA Headquarters	Jtilman@hq.nasa.gov
Tokay	Ali	JCET/UMBC	tokay@radar.gsfc.nasa.gov
Tompkins	Steve	NASA Goddard Space Flight Center	steve.tompkins@gsfc.nasa.gov
Toutsi	Tom	NASA Goddard Space Flight Center	ttoutisia@pop300.gsfc.nasa.gov
Treadon	Russ	Environmetal Model Center/NCEP/NWS	russ.treadon@noaa.gov

Tripoli	Gregory	Unv. of Wisconsin, Madison	tripoli@meteor.wisc.edu
Try	Paul	International GEWEX Project Office	gewex@cais.com
Turk	Joe	Naval Research Lab	truk@hrlmry.navy.mil
Unninayar	Sushel	NASA Goddard Space Flight Center/GEST	sushel@pop900.gsfc.nasa.gov
Vane	Deb	Jet Propulsion Lab	duane@mail.com
Velden	Chris	University of Wisconsin - CIMSS	chrisv@ssec.wisc.edu
Vicente	Gilberto	QSS Group, Inc.	vicente@daac.gsfc.nasa.gov
Vivekanandan	Jothiram	NCAR	mcgaffic@ucar.edu
Vorosmarty	Charles	University of New Hampshire	www.watsys.sr.unh.edu
Wang	James	NASA Goddard Space Flight Center	wang@sensor2.gsfc.nasa.gov
Wang	Jingfeng	MIT	jfwang@mit.edu
Wang	Jian-Jian	NASA Goddard Space Flight Center	jwang@radar.gsfc.nasa.gov
Weinman	Jim	NASA Goddard Space Flight Center	weinman@sensor.gsfc.nasa.gov
West	Susan	NASA Headquarters	Swest@hq.nasa.gov
Wilheit	Thomas	Texas A&M University	wilheit@tamu.edu
Williams	Earle	MIT	carlew@ll.mit.edu
Wolff	David	NASA Goddard Space Flight Center	wolff@radar.gsfc.nasa.gov
Xie	Pingping	NOAA Climate Prediction Center	pingping.xie@noaa.gov
Xu	Liming	NASA Goddard Space Flight Center	xu@agnes.gsfc.nasa.gov
Yang	Song	JCET	ysong@agnes.gsfc.nasa.gov
Yoo	Jung	NASA Goddard Space Flight Center	yoo@climate.gsfc.nasa.gov

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	April 2002	Conference Publication

4. TITLE AND SUBTITLE

Global Precipitation Measurement - Report 1

Summary of the First GPM Partners Planning Workshop

5. FUNDING NUMBERS

912

6. AUTHOR(S)

J. M. Shepherd, A. Mehta

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS (ES)

Goddard Space Flight Center
Greenbelt, Maryland 20771

8. PEFORMING ORGANIZATION REPORT NUMBER

2002-01690-0

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS (ES)

National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

CP—2002-210012

11. SUPPLEMENTARY NOTES

E. A. Smith and W. J. Adams, Editors

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Unclassified–Unlimited
Subject Category: 47
Report available from the NASA Center for AeroSpace Information,
7121 Standard Drive, Hanover, MD 21076-1320. (301) 621-0390.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report provides a synopsis of the proceedings of the First Global Precipitation Measurement (GPM) Partners Planning Workshop held at the University of Maryland, College Park, from May 16 to 18, 2001. GPM consists of a multi-member global satellite constellation (i.e., an international set of satellite missions) and the accompanying scientific research program, with the main goal of providing frequent, accurate, and globally distributed precipitation measurements essential in understanding several fundamental issues associated with the global water and energy cycle (GWEC). The exchange of scientific and technical information at this and subsequent GPM workshops between representatives from around the world represents a key step in the formulation phase of GPM mission development.

The U.S. National Aeronautics and Space Agency (NASA), the National Space Development Agency of Japan (NASDA), and other interested agencies from nations around the world seek to observe, understand, and model the Earth system to learn how it is changing and what consequences these changes have on life, particularly as they pertain to hydrological processes and the availability of fresh water resources. GWEC processes are central to a broader understanding of the Earth system.

14. SUBJECT TERMS

global precipitation measurement, global water cycle, hydrologic cycle, precipitation, rainfall, climate, freshwater resources, satellite constellations, latent heating,NASA, NASDA

15. NUMBER OF PAGES

21

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39.18
298-102