NOAA's Participation in the Global Precipitation Measurement (GPM) Mission

Ralph Ferraro

Chief, Satellite Climate Studies Branch

Center for Satellite Applications and Research (STAR)
National Environmental Satellite, Data & Information Service (NESDIS)
National Oceanic and Atmospheric Administration (NOAA)
College Park, Maryland

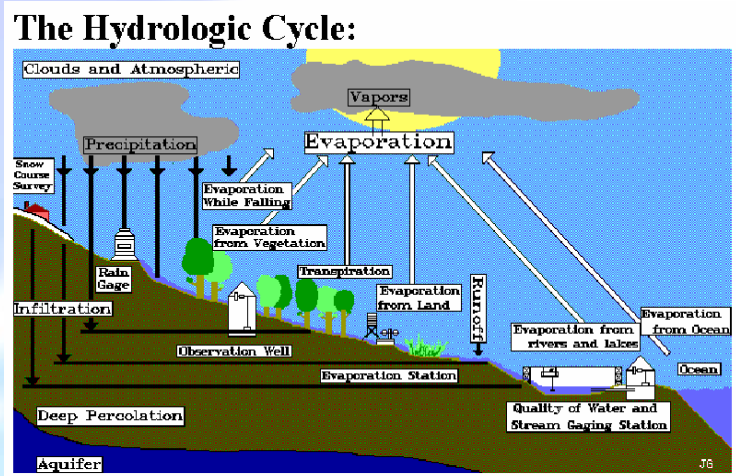
Outline

- Why Precipitation?
- What is GPM?
- NOAA's Interest in GPM
  - Linkages to mission goals
- Recent Activities
  - Continued activities with NASA
  - Draft NOAA GPM Transition Plan
  - National Research Council (NRC)/Board on Atmospheric Sciences and Climate (BASC) Study
- Science activities
- Summary and Future

Why Precipitation?

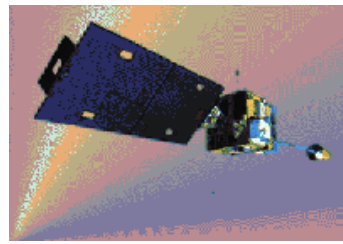
- Key component of the water cycle.
  - Societal importance
    - fresh water
    - agriculture
    - water management,

    i.e., droughts and floods
  - Scientific importance
    - latent heat release - affects storm dynamics, circulation and atmospheric structure
    - affects ocean salinity
    - Improved hydrological models
      - Regional process → global process → models



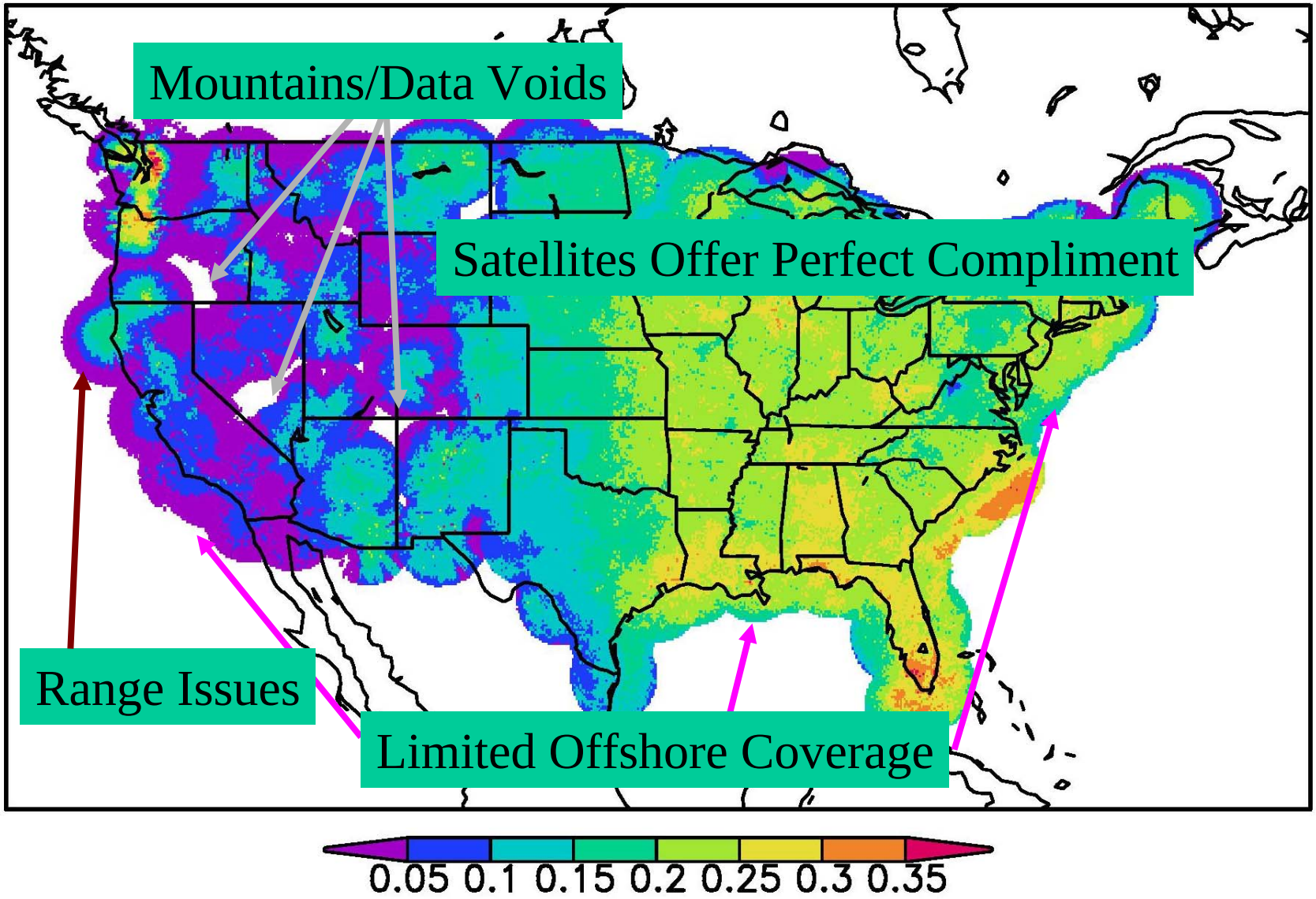
Role of satellites

- Limitation of **radar networks** and **sparse gauge coverage** require satellites for estimating precipitation
  - Polar orbiting satellites
    - Good global coverage –poor temporal sampling
    - Good choice of spectral intervals; IR, Vis, passive and active microwave
  - Geostationary satellites
    - IR and Vis , no MW channels
    - Excellent temporal sampling , regional spatial coverage
    - Provides excellent tool for estimates of extreme events, e.g., flash floods



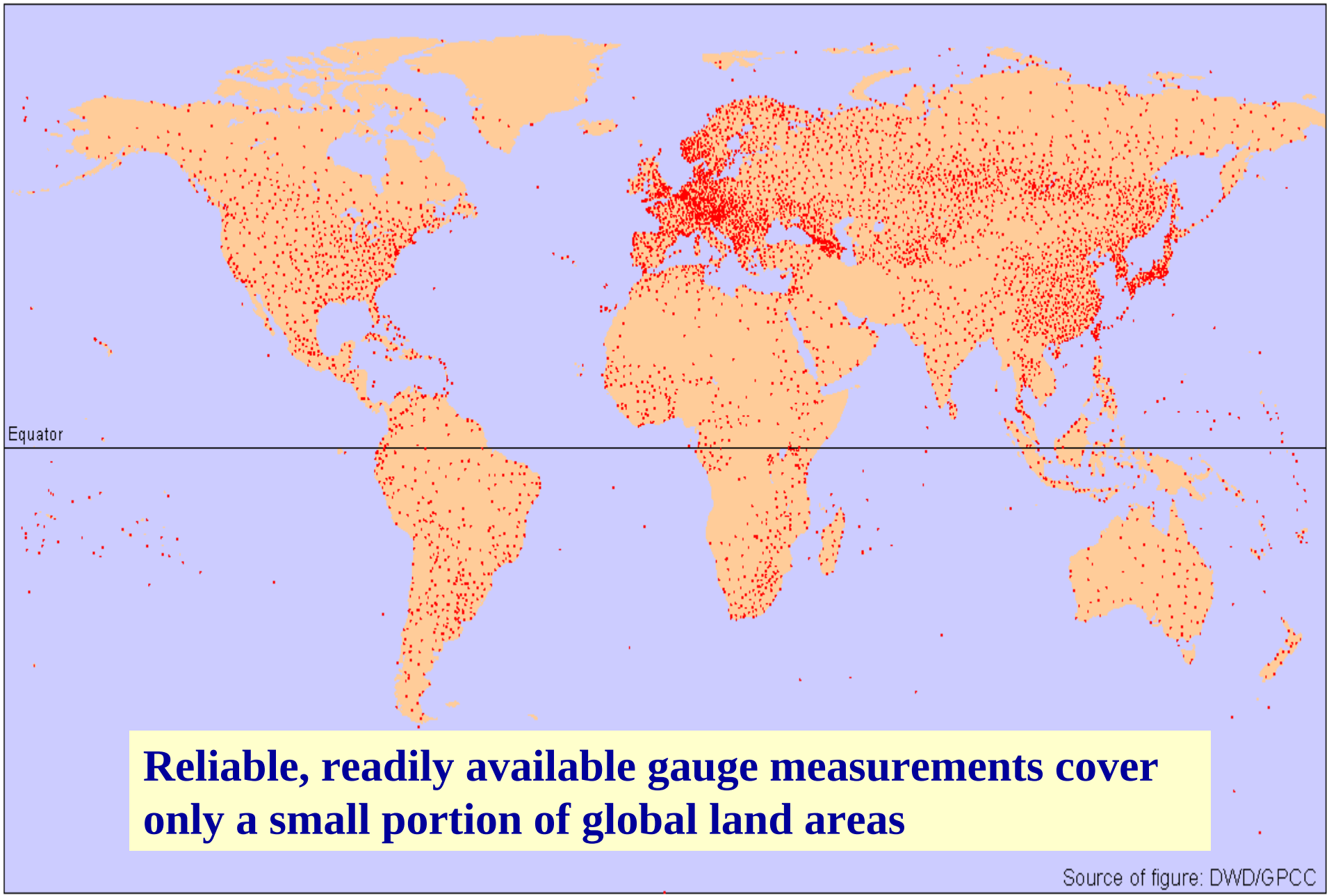
- Challenges
  - Utilization of GOES and POES data for best estimates of precipitation at all space and time scales

WSR-88D Frequency of Rainfall Occurrence for 1998 - 2000



Distribution of stations in the Point Data Bank of GPCC (GTS data only)

Month: July 1987; Total number of stations: 6328



Reliable, readily available gauge measurements cover only a small portion of global land areas

Source of figure: DWD/GPCC

The Global Precipitation Measurement (GPM) Mission

Objective: Unify and advance global precipitation measurements for research & applications

- *advanced active & passive microwave sensor measurements*
- *a consistent framework for inter-satellite calibration*
- *international collaboration on algorithm development and ground validation*

GPM Constellation Optimizer (NASA)
serving as a constellation coverage optimizer

- *Non-Sun-Synchronous orbit: ~40º inclination at 635 km*
- *Multi-channel radiometer with high-frequency capability (GMI)*
- *Improved near real-time hurricane monitoring & prediction*

Partner Constellation Satellites:

GCOM-W
DMSP-F18, F19
Megha-Tropiques
NOAA-N′
NPP
MetOp-B
NPOESS-C1

GPM Core Satellite (NASA-JAXA)
serving as a physics observatory and calibration reference

- *Non-Sun-Synchronous orbit: 65º inclination at 407 km*
- *Dual-frequency Precipitation Radar (DPR): Ku-Ka Bands (13.6, 35.5 GHz)*
- *Multi-frequency GPM Microwave Imager (GMI): 10.65, 18.7, 23.8, 36.5, 89.0, 166, 183.3 GHz*
- *GMI provides a reference standard for uniform calibration of brightness temperatures of Constellation sensors*
- *DPR & GMI together provide microphysical measurements and a common cloud database for rain & snow retrievals from Core & Constellation sensors*

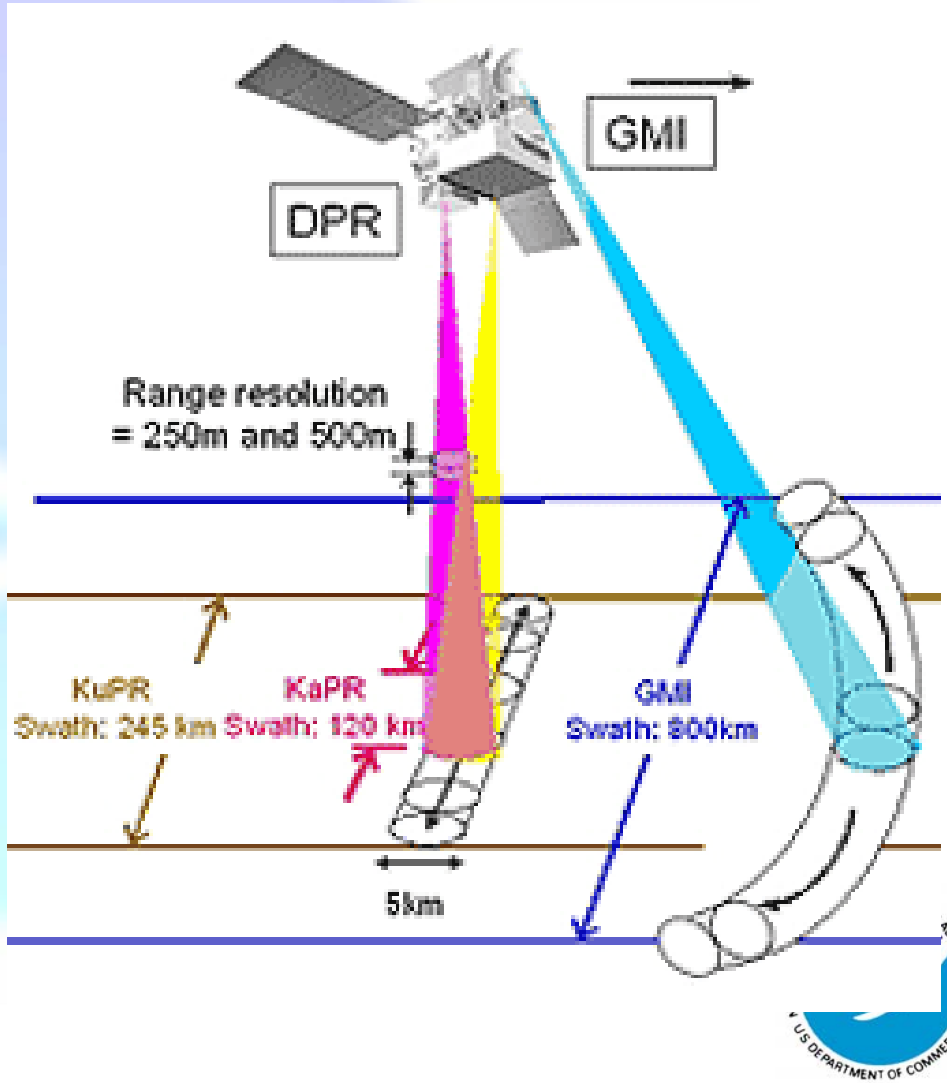
Courtesy of Arthur Hou, GPM Project Scientist, NASA/GSFC

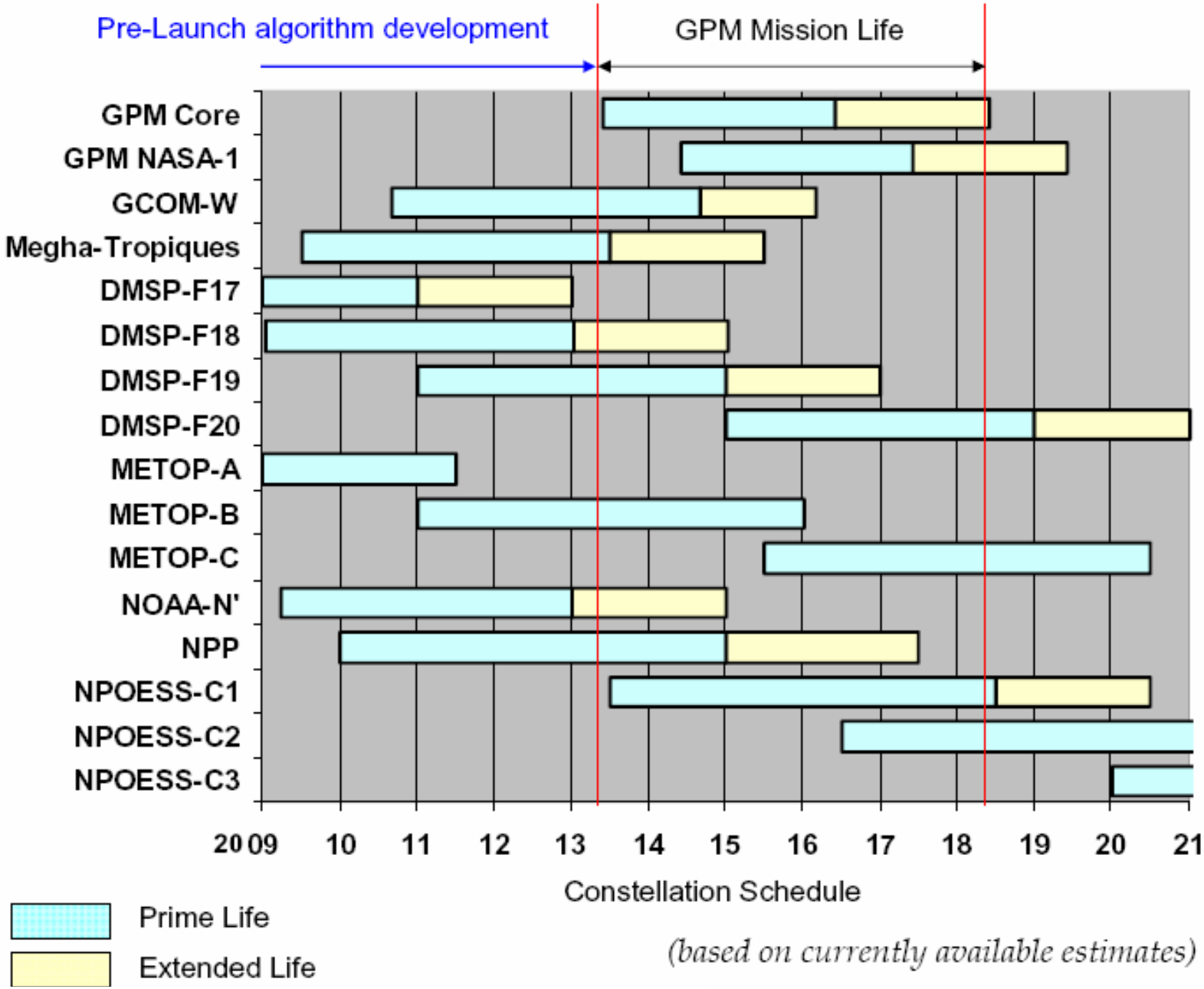
ARD SPACE FLIGHT CENTER

4

GPM Core Satellite

- Role of core satellite
  - Matchups between vertical hydrometeor profile and radiometer radiances
    - Build databases over wide range of precipitation systems
    - Utilized by constellation satellites/radiometer only
  - Most accurate, climate quality radiances
    - Serves as anchor to constellation members





Courtesy of Arthur Hou, GPM Project Scientist, NASA/GSFC

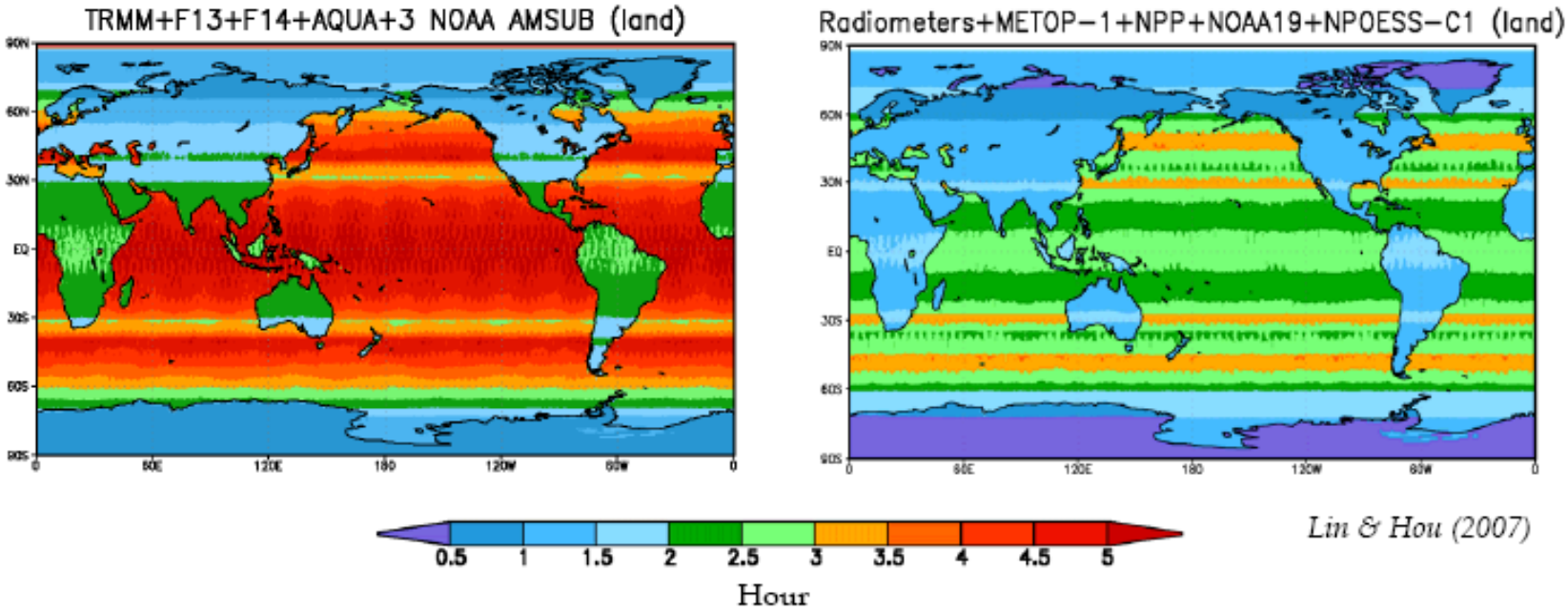
Constellation Revisit Time: GPM in 2014 vs. Current Capability

4 Conical-Scanning Imagers plus 3 Cross-track Sounders Over Land

(≤ 3h over 45% of globe)

6 Conical-Scanning Imagers Plus 4 Cross-track Sounders Over Land

(≤ 3h over 92% of globe)



Lin & Hou (2007)

TMI, F13, F14, Aqua + 3 NOAA AMSU-B's over land

GPM Core, NASA-1(40º), F18, F19, GCOM-W, Megha-Tropiques + (MetOp-B, NPP, NOAA-N', & NPOESS-C1) over land

Courtesy of Arthur Hou, GPM Project Scientist, NASA/GSFC

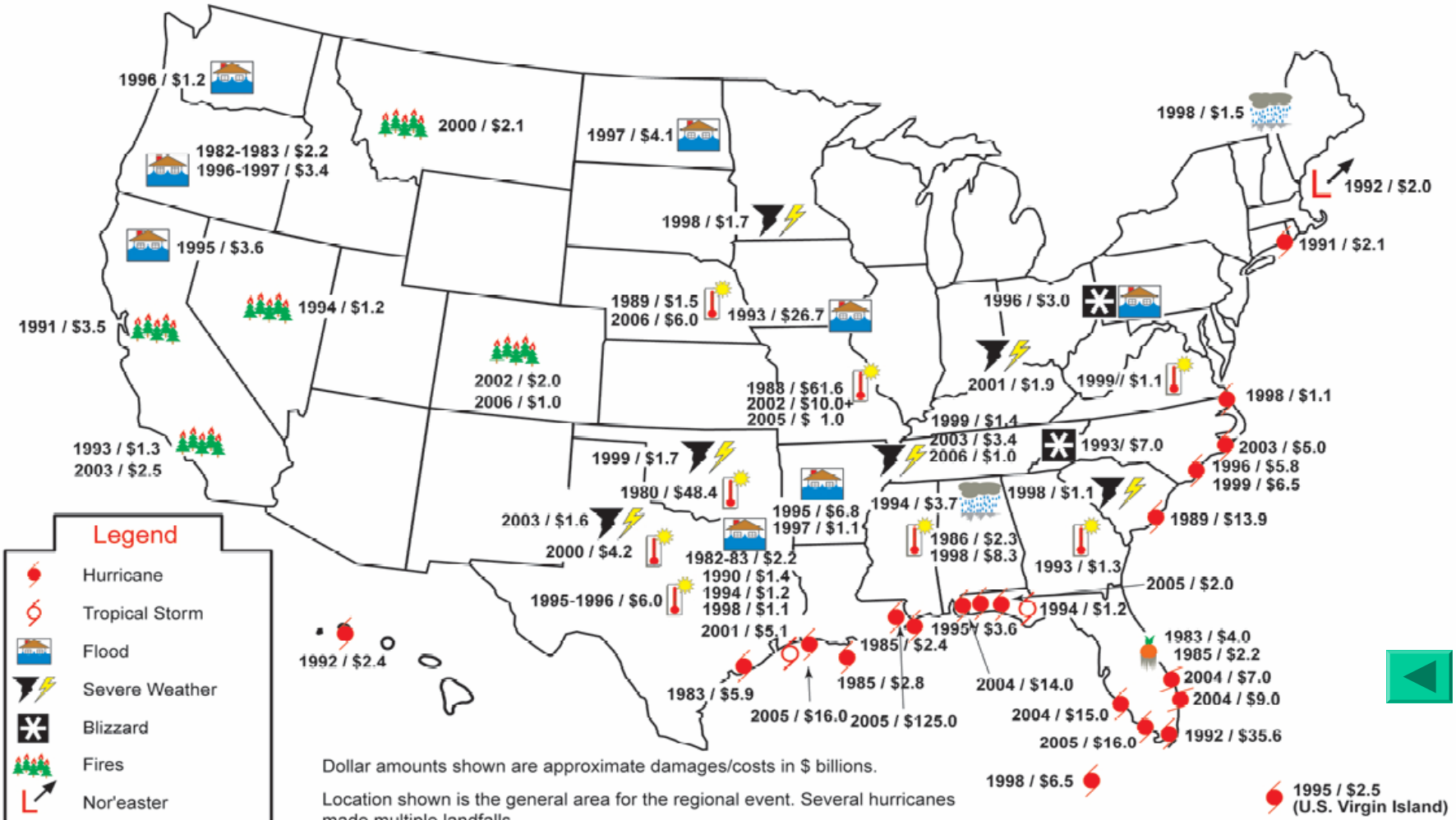
GPM has strong linkages to NOAA Mission Goals - W&W, Climate

- Example: Flooding and storm related damage account for $11 billion annually in U.S.

- Examples: NOAA's goals:
  - Climate: Describe and understand the state of the climate system through integrated observations, analysis, and data stewardship
  - W&W: Increased accuracy and lead time for warnings

- Examples: Strategies to accomplish these goals include:
  - Increased observations from NOAA & non-NOAA systems
  - Increase number of new research findings
  - Shorten cycle time from research into operations

Billion Dollar Weather Disasters 1980 - 2006



Dollar amounts shown are approximate damages/costs in $ billions.

Location shown is the general area for the regional event. Several hurricanes made multiple landfalls.

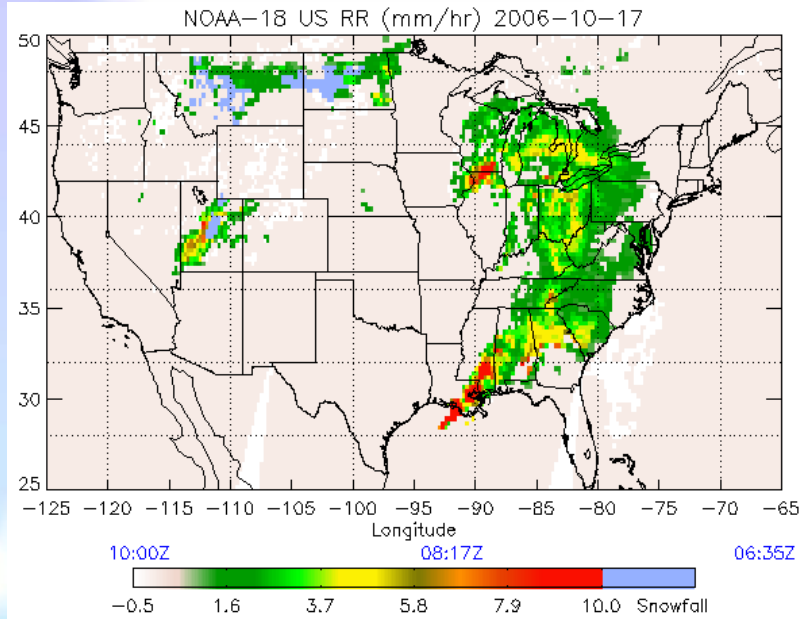
Additional information for these events is available at NCDC WWW site www.ncdc.noaa.gov/ol/reports/billionz.html

The U.S. has sustained 70 weather related disasters over the last 27 years with overall damages/costs exceeding $1.0 billion for each event. 58 of the disasters occured during or after 1990. Total costs for the 70 events were greater than $560 billion using an inflation/wealth index.

NOAA's
National Climatic Data Center

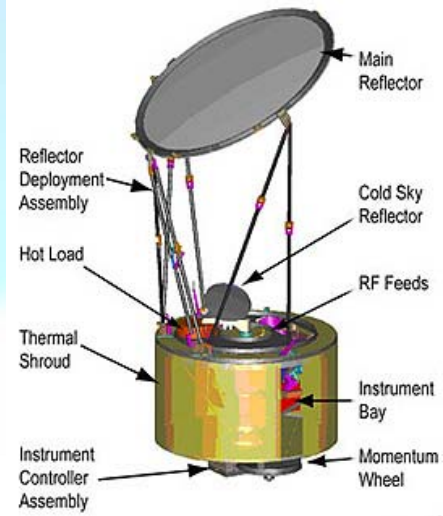
Recent GPM activities (1)

- Participation on NASA's PMM science team
  - Four NOAA PI's selected to new PMM science team, jointly funded between NASA and NOAA (FY07 – FY09)
    - Janowiak (NWS) – Merged MW/IR Precipitation Retreivals
    - Ferraro (NESDIS)- Advanced Land Precipitation Retrievals
    - Kuligowski (NESDIS) – TRMM Hydrology Applications to support HPC
    - Williams (OAR) - Advanced Radar Systems to describe precipitation microphysics



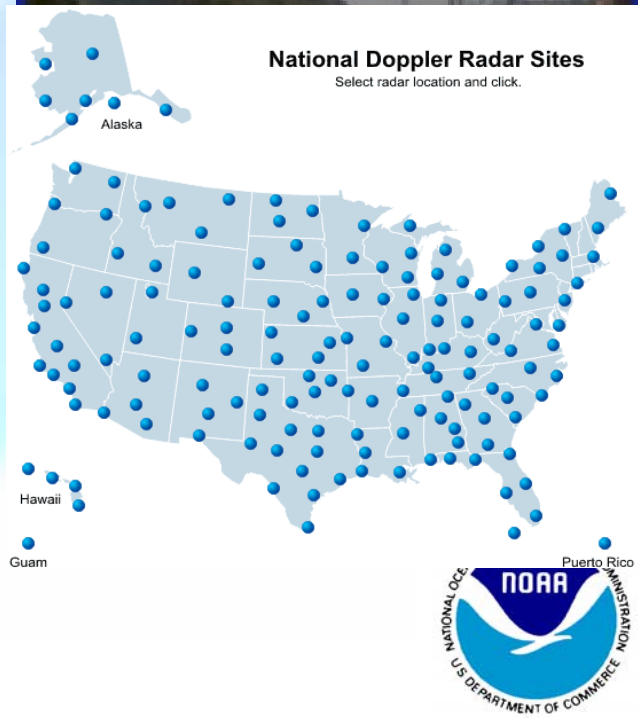
- Science justification for high frequency measurements for GMI

- Radiometer calibration study team to identify common methodology for Level 1C concept



Recent GPM Activities (2)

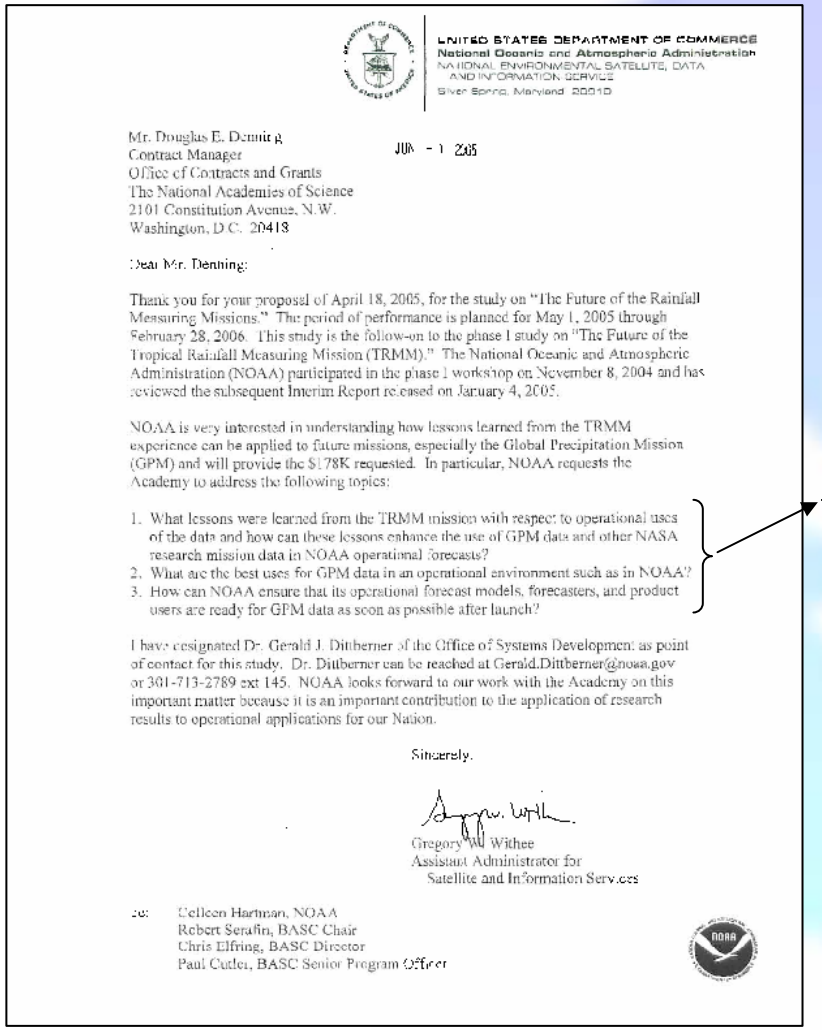
- Joint NASA-NOAA "Research & Operations" working group
  - GPM identified as a program for partnership
  - Continuing discussions in 2007
- CEOS Precipitation Constellation (PC)
  - Scoping paper workshop – May 2007
  - Mary Kicza – Overseeing PC planning
- GPM Ground Validation (GV) activities:
  - NOAA scientists on NASA GV Advisory Panel
  - Developing coordination activities between NASA GV and NOAA's Hydrometeorological Testbed (HMT)
    - Joint NOAA-NASA planning for HMT-East
  - Future coordination on NOAA's NEXRAD upgrade deployment schedule



NRC Phase II Study - Background

- 1997 - TRMM Launched November 7
- 2004 - Phase I Study commissioned by NASA
- 2004 - TRMM products available in timely manner for use in NOAA operational forecasts
- January 5, 2005 Phase I Report: *"Assessment of the Benefits of Extending the Tropical Rainfall Measuring Mission: A Perspective from the Research and Operations Communities"*
  - Benefits include advancing NWP, uses in weather forecasting, and climate monitoring….
- 2005 - Phase II Study commissioned by NOAA/NESDIS
- 2005 - TRMM operations extended through FY 2009
- October 2006 – Phase II Study completed: "*NOAA's Role in Space-Based Precipitation Estimation and Application*" (Final Draft – April 2007)

Objectives of Phase II Study



UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE
Silver Spring, Maryland 20910

Mr. Douglas E. Denning
Contract Manager
Office of Contracts and Grants
The National Academies of Science
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

JUN - 1 2005

Dear Mr. Denning:

Thank you for your proposal of April 18, 2005, for the study on "The Future of the Rainfall Measuring Missions." The period of performance is planned for May 1, 2005 through February 28, 2006. This study is the follow-on to the phase I study on "The Future of the Tropical Rainfall Measuring Mission (TRMM)." The National Oceanic and Atmospheric Administration (NOAA) participated in the phase I workshop on November 8, 2004 and has reviewed the subsequent Interim Report released on January 4, 2005.

NOAA is very interested in understanding how lessons learned from the TRMM experience can be applied to future missions, especially the Global Precipitation Mission (GPM) and will provide the $178K requested. In particular, NOAA requests the Academy to address the following topics:

1. What lessons were learned from the TRMM mission with respect to operational uses of the data and how can these lessons enhance the use of GPM data and other NASA research mission data in NOAA operational forecasts?
2. What are the best uses for GPM data in an operational environment such as in NOAA?
3. How can NOAA ensure that its operational forecast models, forecasters, and product users are ready for GPM data as soon as possible after launch?

I have designated Dr. Gerald J. Dittberner of the Office of Systems Development as point of contact for this study. Dr. Dittberner can be reached at Gerald.Dittberner@noaa.gov or 301-713-2789 ext 145. NOAA looks forward to our work with the Academy on this important matter because it is an important contribution to the application of research results to operational applications for our Nation.

Sincerely,

Gregory W. Withee
Assistant Administrator for
Satellite and Information Services

cc: Colleen Hartman, NOAA
Robert Serafin, BASC Chair
Chris Elfring, BASC Director
Paul Cutler, BASC Senior Program Officer

1. What <u>lessons were learned</u> from the TRMM mission with respect to operational uses of the data and how can these lessons enhance the use of Global Precipitation Mission (GPM) data and other NASA research mission data in NOAA operational forecasts?

2. What are the <u>best uses</u> for GPM data in an operational environment such as in NOAA?

3. How can NOAA <u>ensure</u> that its operational forecast models, forecasters, and product users are <u>ready</u> for GPM data as soon as possible after launch?

G. Withee Letter to D. Denning, June 1, 2005

Phase II Study Team

COMMITTEE ON THE FUTURE OF RAINFALL MEASURING MISSIONS

Board on Atmospheric Sciences and Climate
Division on Earth and Life Studies

Eugene M. Rasmusson
University of Maryland (retired)

Nancy L. Baker
Naval Research Laboratory

V. Chandrasekar
Colorado State University

Carol Anne Clayson
Florida State University

Jeffrey D. Hawkins
Naval Research Laboratory

Kristina B. Katsaros
National Oceanic and Atmospheric Administration (retired)

M. Patrick McCormick
Hampton University

Matthias Steiner
Princeton University

Graeme L. Stephens
Colorado State University

Christopher S. Velden
University of Wisconsin

Ray A. Williamson
George Washington University

Staff

Paul Cutler
Program Officer
pcutler@nas.edu

Leah Probst
Research Associate
lprobst@nas.edu

Rob Greenway
Project Assistant
rgreenwa@nas.edu

Mailing Address

Board on Atmospheric Sciences and Climate
The National Academies
500 Fifth Street, NW
Washington, DC 20001

Phone: 202-334-3512
Fax: 202-334-3825


NOAA'S ROLE IN
SPACE-BASED GLOBAL PRECIPITATION
ESTIMATION AND APPLICATION

Committee on the Future of Rainfall Measuring Missions
Board on Atmospheric Sciences and Climate
Division on Earth and Life Studies

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NOAA Preparation for GPM: 11 Categories*

1. NASA-NOAA Cooperative Research and Development Activities
2. Data Exchange
3. Calibration
4. Ground Validation Support
5. Data Products
6. Data Archiving and Distributing
7. Infusion of New Technology
8. Data Assimilation
9. Model Physics Development
10. Data Impact Evaluation
11. User Education and Training

*Information extracted from NRC/BASC report

Moving Forward on NOAA-NASA Partnership*

- Establish a NOAA steering group on space-based precipitation missions √
- Support NASA-NOAA Precipitation Measurement Missions science team √
- Support International Precipitation Working Group (IPWG) √
- Support the NOAA-NASA GPM Research and Operations Group √

*Information extracted from NRC/BASC report

The Three Phases of GPM*

The three phases of GPM and how they relate to the broader context of NOAA and NASA activities and to the constellation of satellites

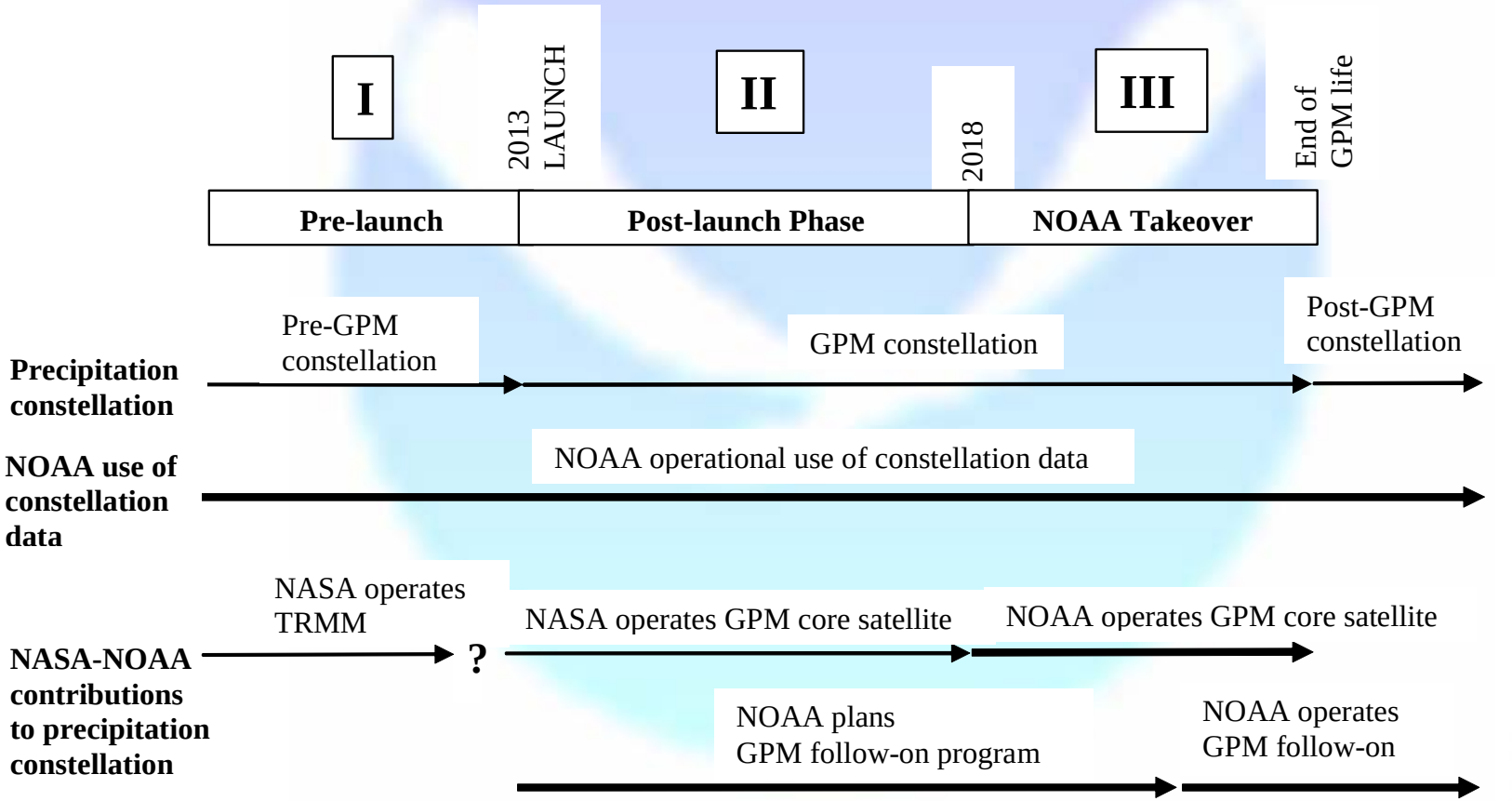


*Figure extracted from NRC/BASC report – we interpret "operates" as "responsible for operation"

Planning within NOAA for GPM (1)

- Formally within W&W, ST&I (WWS), Capability A – R&D for Water Resources Observing and Forecasting Information (RDW), Capacity NESDIS-03: GPM
  - No funds identified; is within 100% program, hopeful for FY10 funding
  - Emphasis is integration of satellite measurements within blended precipitation products (e.g., Q2)
  - Linkages to HMT program for improved QPE/QPF

Planning within NOAA for GPM (2)

- A draft transition plan has been developed:
  - Submitted to NOAA's Transition Board and undergoing revisions
  - Recently included in "Satellite Services" Mission Support goal

- GPM Transition at NOAA includes:
  - Satellite algorithms, products, real-time distribution
  - Contribute towards NOAA supported GPM GV activities
  - Participation on NASA's PMM science team

Global Precipitation Measurements (GPM) from Satellites

Research to Operations Transition Plan

DRAFT - October

Revision Date: 13 October 2006

Prepared by:

U.S. Department of Commerce
National Oceanic and Atmospheric Administration (NOAA)
National Environmental Satellite, Data, and Information Service (NESDIS)
Office of System Development (OSD)
Center for Satellite Applications and Research (STAR)

Global Precipitation Measurements from Satellites Execution - FY07 3rd Quarter Review

Overview of Transition Project

Name of Goal/Goals responsible for planning/programming for project: Mission Support/Satellite Services; Weather and Water; Climate

Name of Program/Programs responsible for planning for project:
Still under development; closest linkage is W&W/STIP/Water Resources

Name of LO/LOs responsible for budgeting and execution of project:
NESDIS, OAR

Name of Transition Project Team lead: Ralph Ferraro/NESDIS, Chandra Kondragunta/NESDIS; John Janowiak/NWS, Pingping Xie/NWS

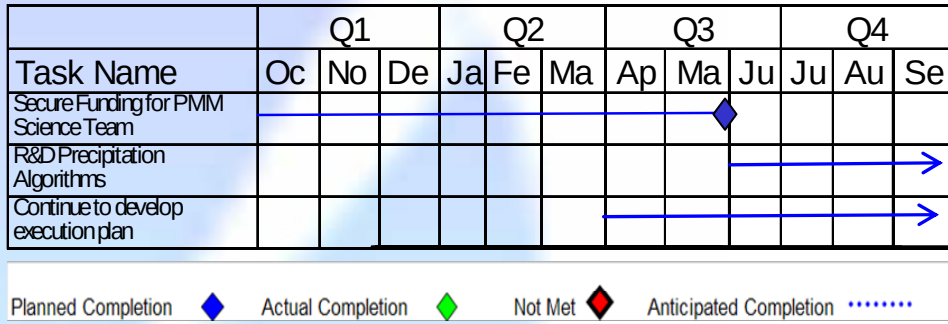
Transition Step: Step 1

Purpose: Implement and transition state of the art retrieval algorithms developed under the auspices of the NASA Precipitation Measurement Missions (PMM) Science Team into NESDIS operations for use with all available passive microwave sensors, including SSMIS, AMSR-E, TRMM and WindSat. Also, prepare for GPM core launch (2013) to expedite transition from research into operations. All activities also help NOAA's contribution to the CEOS precipitation constellation supporting GEOSS (GPM has been identified as a prototype).

Requirements and Transition Process: NOAA relies on passive microwave precipitation estimates to support its *Weather and Water* and *Climate* mission goals. Leveraging off the algorithms developed by the PMM science team will benefit NOAA by providing a consistent physical retrieval scheme that can be used in an operational environment (current utilization of such products have been restricted to an experimental mode). SPSRB Transition Process and guidelines established via the NDE project.

Transition Schedule (FY2007)

Milestones Planned = 3	Milestones Met = 1



Key Issues/Risks

Issue: No resources have been identified beyond FY09 to support this activity
- **Impact:** NOAA will not have near-real time access to such products and latest algorithms
- **Mitigation:** Identify resource opportunities within Satellite Services and within Weather & Water and Climate goal teams.

Issue: Data access, reformatting and delivery
- **Risks:** Lack of computer resources; obtaining near-real time access to all data streams; providing NOAA customers of various data formats
- **Mitigation:** Identify computer needs; Develop/enhance MOU's with NASA and FNMOC; Assess required formats and resource requirements.

Issue: Algorithm upgrades and maintenance
- **Risks:** Unable to keep up with algorithm updates
- **Mitigation:** Provide resources for NOAA participation on PMM science team and dedicated NESDIS staff of maintenance programmers

Transition Projects Costs

Only funding identified comes is through NASA's PMM Science Team, which is jointly funded between NOAA and NASA for FY07 – FY09.

	FY07	FY08	FY09	FY10
Research Funding				
NESDIS	174	174	175	0
OAR	154	159	165	0
CPO	100	120	135	0
NASA	82	72	95	0
TBD				475*
Transition Funding				
TBD	0	0	300*	425*
Operations Funding				
TBD	0	0	0	125*
Total	510	525	870	1025*

*Indicates Shortfall

R – Major Management Attention Required | Y – Potential Management Attention Required | G – On Target

Linkages needed to Climate Program…

- Logical link to Climate extremes and objectives of NOAA HMT
  - Atmospheric Rivers!
- Linkages between Climate and Mission Support/Satellites?
- Strongest link - SDS/Precipitation CDR's
  - TRMM/GPM era will serve as the primary period for benchmarking entire satellite precipitation time series:
    - Community consensus calibration methodology
    - Community consensus inter-satellite calibration methodology
    - Development of enhanced precipitation retrieval algorithms via a variety of methodologies
  - Perhaps SDS considers supporting projects within GPM for CDR creation?
  - CPO is contributing to PMM science team…
- Others?

NOAA's Scientific Data Stewardship (SDS) Program

Climate Data Records

Data (Direct & Remotely Sensed)

Time-tagged
Geo-Referenced

Sensor Data Records (SDRs)

Converted to Bio-Geophysical Variables

Environmental Data Records (EDRs)

Homogenization and Calibration

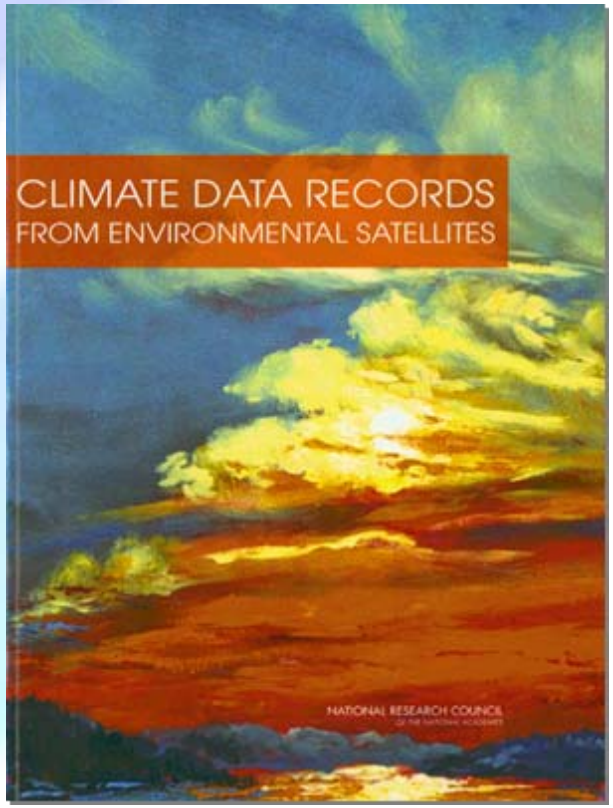
Fundamental Climate Data Records (FCDRs)

Converted to Bio-Geophysical Variables

Thematic Climate Data Records (TCDRs)

Climate Data Records or Homogenized Time Series

National Research Council, 2004



NOAA – GPM Synergy
One Example: The West Coast Connection

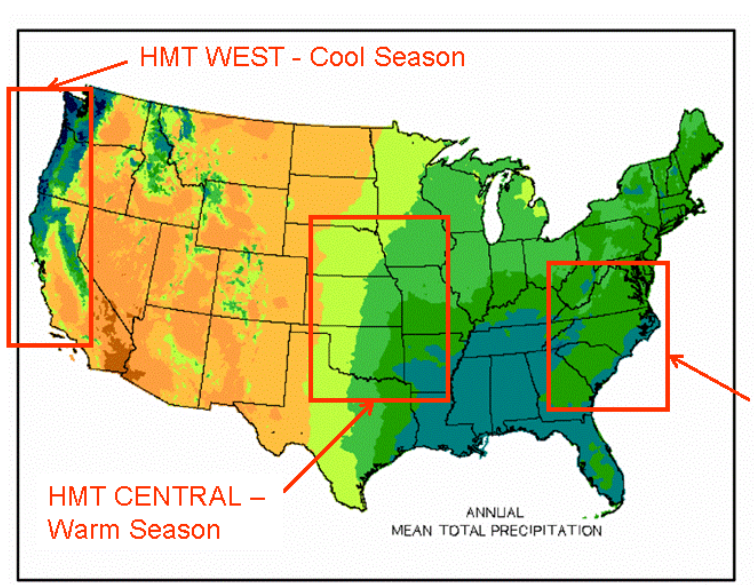
- Winter storm and flood forecasting on the U.S. West Coast are particularly challenging for NOAA's operational forecasters because:
  - Upstream observations are sparse
  - Mountain barriers force long fetches of moist air from the Pacific Ocean to rise abruptly and condense
  - Rugged topography channels runoff into concentrated torrents
  - Summer fires commonly remove vegetation and heighten vulnerability to flooding and debris flows

Photo: Paul Neiman, NOAA/ETL

HMT as a GPM Facilitator

- NOAA's **Hydrometeorology Testbed** (**HMT**) accelerates the transfer of new technologies from research to operations.
- The Science & Technology Infusion Program (STIP) lists HMT as a new R&D strategy for improving forecasts of heavy precipitation and flooding.
- HMT can contribute to NASA's GPM GV program by providing specialized measurements and infrastructure for information on precipitation microphysics.
  - HMT will operate in each focus area for 2-3 years
  - HMT West started in 2006

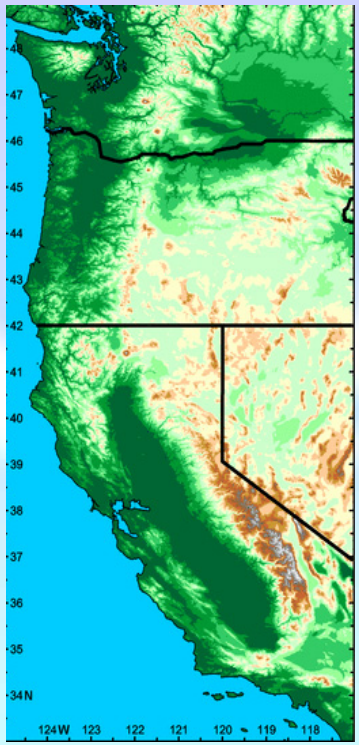
Regional Implementation Strategy



The national Hydrometeorological Testbed program will be implemented incrementally in different regions of the U.S.

GPM Can Help West Coast Forecasters by …

- Providing rainfall information in areas where upstream observations are sparse
  - No rain gauges over ocean
  - Limited radar coverage
- Enhancing existing satellite observations over the Pacific Ocean.

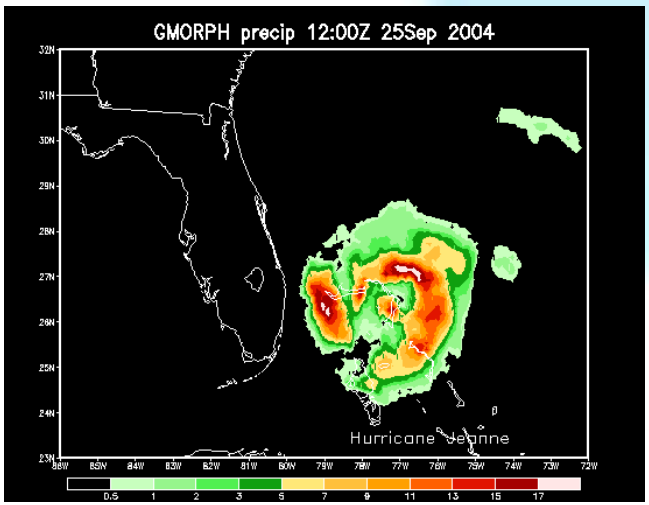


Improvement and Validation of a Multi-Satellite, Multi-Sensor Precipitation Estimation Algorithm: A Prototype 'Day 1' GPM

John Janowiak, Bob Joyce, Pingping Xie
Climate Prediction Center/NCEP/NWS

Objectives: 1) Extend record back to 2000 (in progress)
2) Incorporate global rain gauge observations (regional prototype made)
3) Improve estimation algorithm (in progress)

'CMORPH' Hourly Rainfall Estimates
For Hurricane Jeanne



CMORPH Description

8 km (at equator) every ½ hour

Uses IR or model winds to propagate & 'morph' precip. derived by existing passive microwave algorithms

Dec 2002 – present

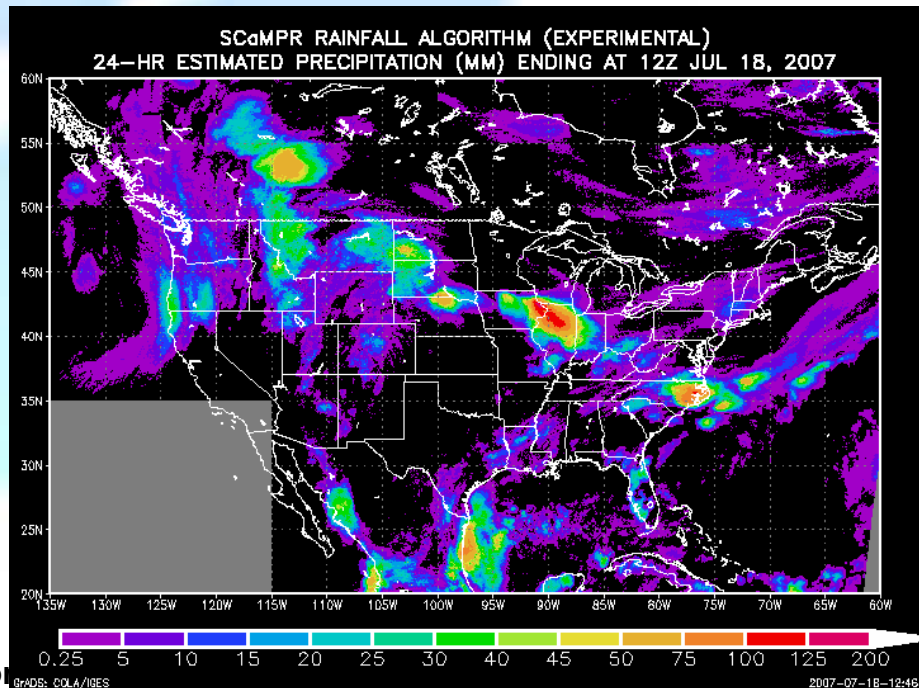
Utilizing TRMM Precipitation Products in Operational Hydrology through Multi-Satellite and Multi-Sensor Quantitative Precipitation Estimation (QPE)

PI: Bob Kuligowski (NOAA/NESDIS)
Co-I's: David Kitzmiller (NWS/OHD), Dong-Jun Seo (NWS/OHD, UCAR)

Objective: assess and demonstrate the value of TRMM/GPM precipitation products for quantitative hydrologic forecasting in NOAA/NWS by infusing these data into an integrated framework of multi-satellite and multi-sensor precipitation estimation and hydrologic validation:

- Integrate TRMM PR and TMI data into the Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR) GEO-LEO rainfall algorithm;
- Assess impact of the data on hydrologic forecasts driven by multisensor precipitation fields.

Status: acquiring contract support for SCaMPR work.



PI: Christopher R. Williams, Collaborator: Sergey Matrosov
University of Colorado & NOAA Earth System Research Laboratory, Physical Science Division (NOAA/ESRL/PSD)

Title: Vertical Structure of Precipitation Retrieved from Multi-Frequency Profiling Radars for Validating Satellite-based Precipitation Products

Objective: Analyze vertically-pointing profiler and polarimetric scanning radar observations to quantify the vertical and spatial structure of raindrop size distributions (DSDs).

Method:

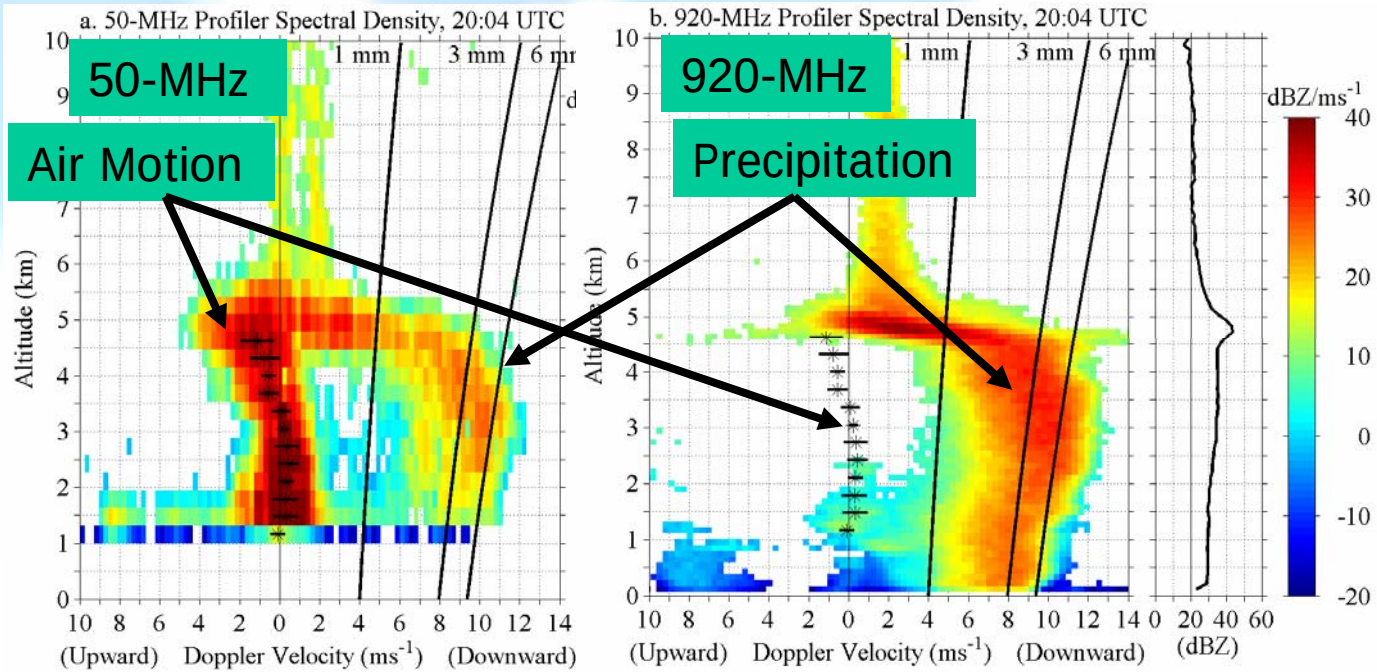
(1) Use multiple years of profiler observations from Darwin, Australia, and California producing a data base with tens-of-thousands of vertical air motion and DSD profiles in Tropical and mid-latitude rain regimes.

(2) Use multiple years of X-band polarimetric radar observations from HMT to analyze the spatial and temporal variability of DSD parameters around the vertically-pointing profilers.

Status:

(1) Developed uncertainty estimates of DSD parameters so data base profiles consist of *Estimate* plus *Uncertainty*

(2) Processing Darwin 50- and 920-MHz profiler observations from 2005/2006 monsoon season

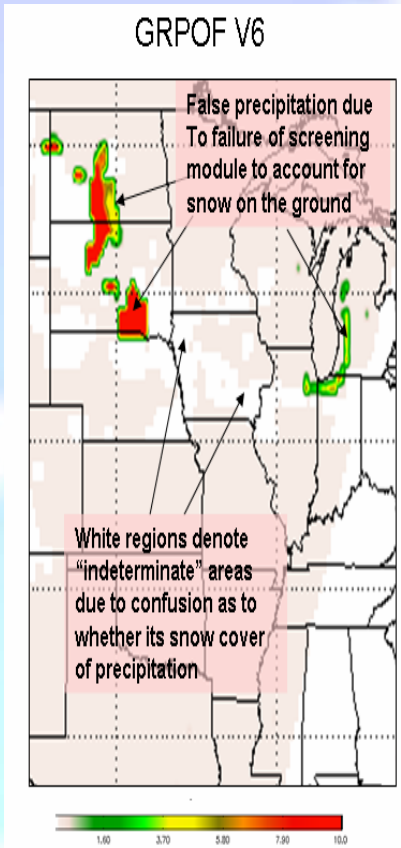


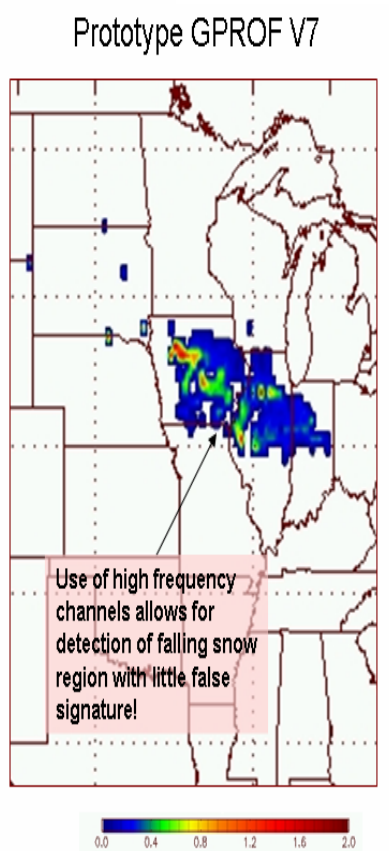
27 September 2007

Precipitation over Land

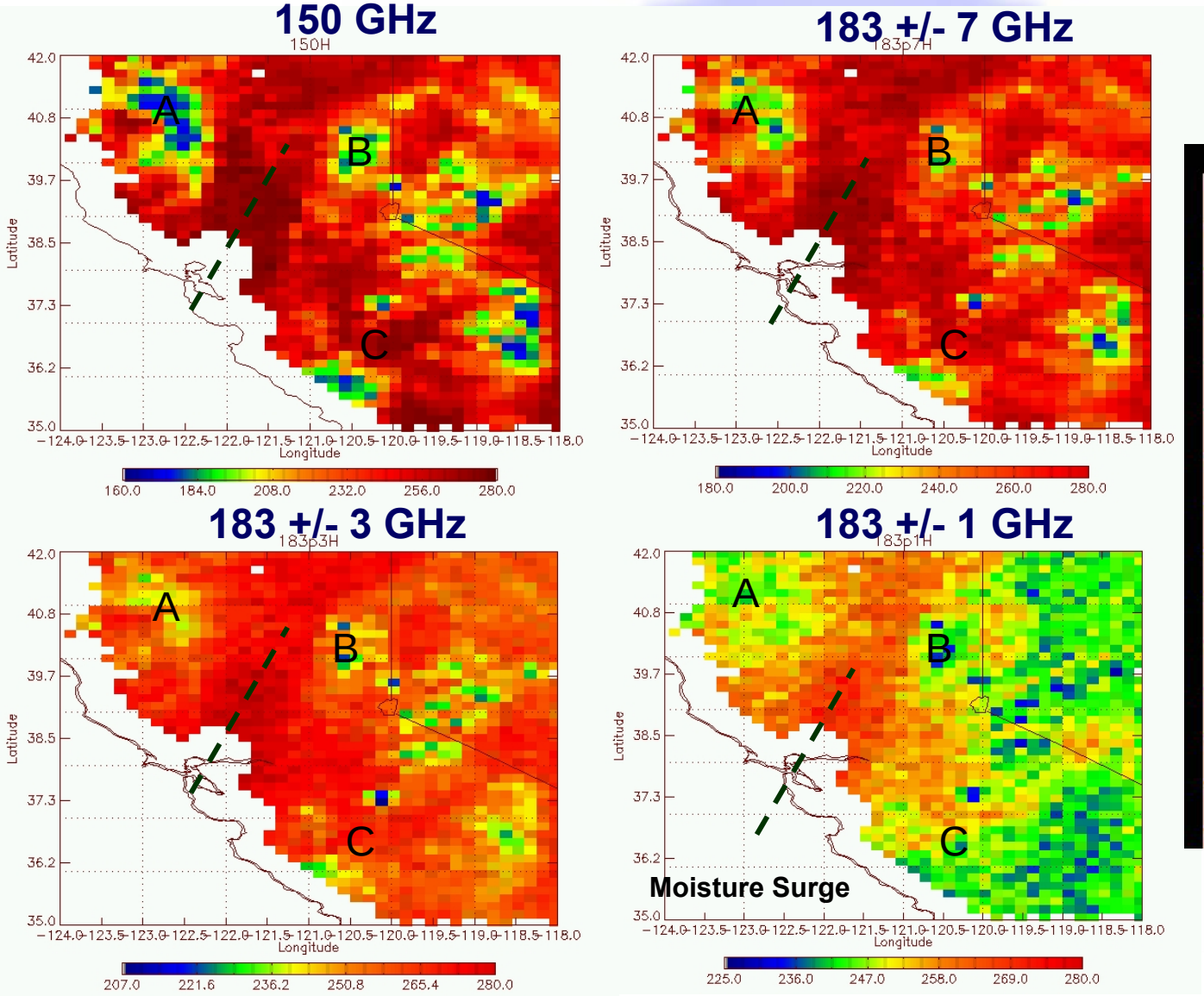
Ralph Ferraro (NOAA/NESDIS) and Nai-Yu Wang (CICS/Univ. of Maryland)

- Research activities focusing on microwave sounding and high frequency above on/above 85 GHz
  - Expanding precipitation detection from tropics to high latitude, cold season, including light rain and snowfall
  - Physically-based radiative transfer model based, profiling type retrieval algorithm
  - Improved surface screening method, filtering ground snow cover from precipitation

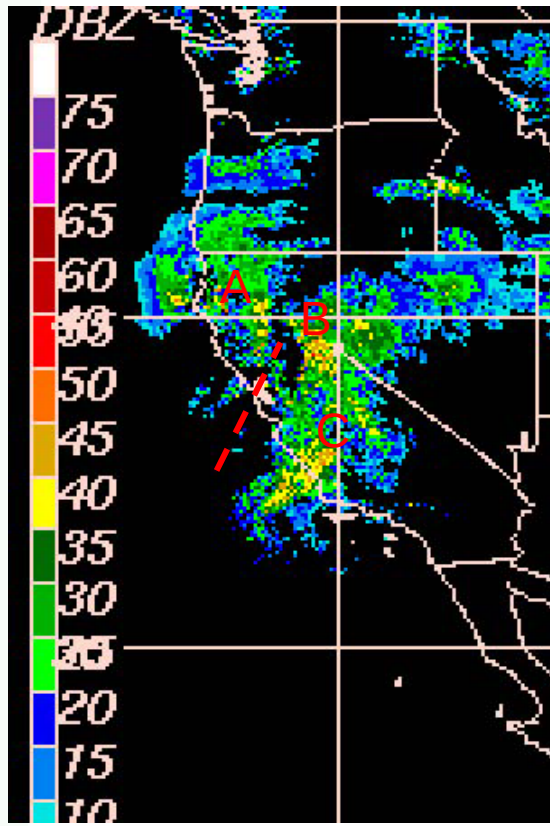




SSMIS Precipitation Signature Over Land – Winter Storm



NEXRAD
30 Dec 2005

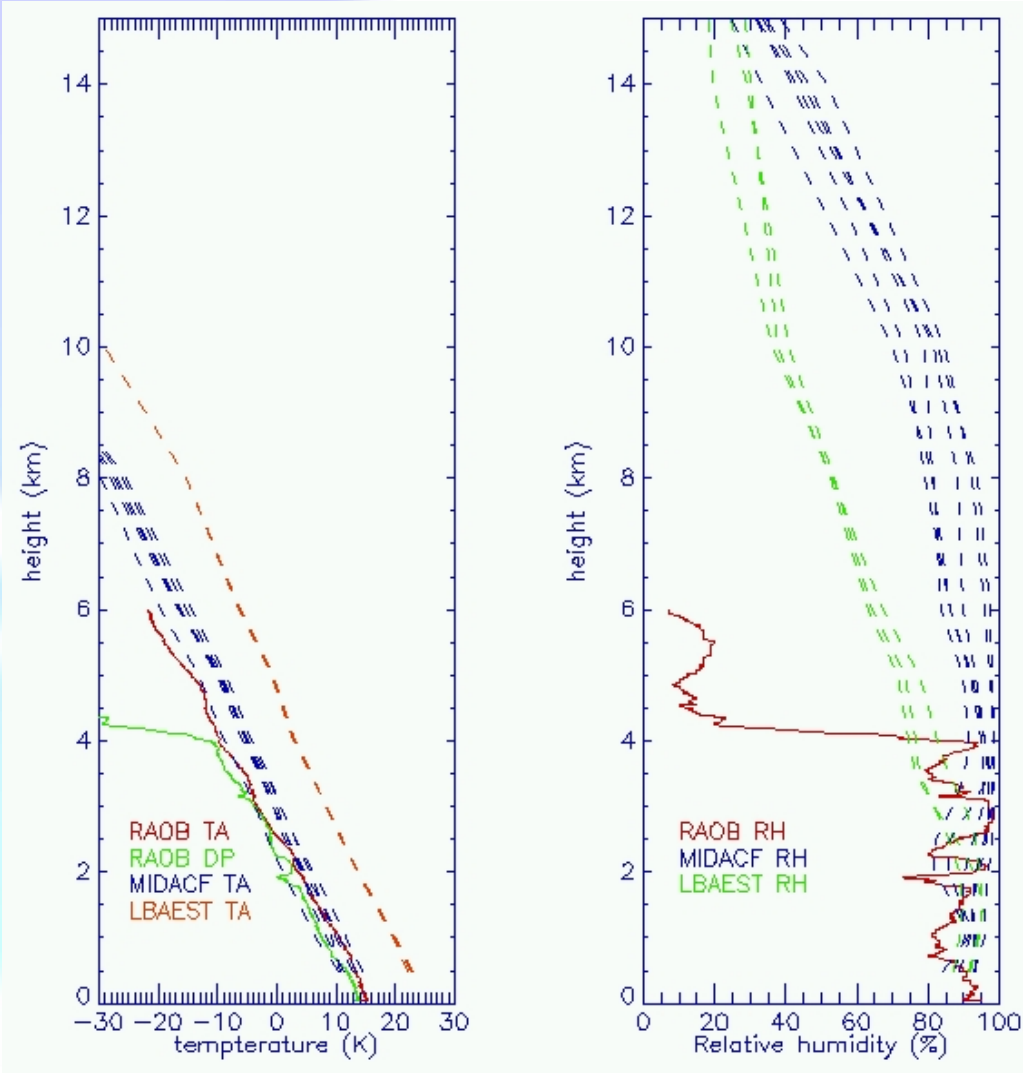


Expanded Channel Bayesian Retrievals

- Utilize all MW channels on POES & DMSP
  - Improve under constrained retrievals
  - Improve GPROF data base
    - Precipitation Regimes
      - Cold season land!
    - Use of temperature/moisture profiles
      - Cloud base and depth
      - Freezing level
  - Reduce surface effects by relying on opaque channels
  - Improved coastline retrievals

GPROF Database issues

- Scarcity of Land-based hydrometeor database
- Need to get out of the tropics!
  - Current databases biased towards just a few regimes
  - Scarcity of information on land, winter regimes
- Accuracy of CRM microphysical details
- Database lacks information on wide array of constellation members



Summary

- NOAA is excited about GPM:
  - Help fulfill NOAA mission goals and save lives
  - Pathfinder for potential future/follow-on operational missions
- NOAA has begun partnering activities with NASA:
  - Research, development and applications
  - Validation assets
  - Transition plans
- NOAA will continue to prepare for GPM:
  - Develop strategies based on NRC/BASC study
  - Budget and planning process
  - Continue to utilize TRMM and other constellation satellites
    - Be ready for GPM core launch in 2013/14 timeframe