Precipitation Virtual Constellation (P-VC)

Recent relevant missions: objectives, early results, relationship with VC roadmap

Steven P. Neeck, NASA

Riko Oki, JAXA

VC/WG Working Day

CEOS SIT Technical Workshop

EUMETSAT, Darmstadt, Germany

16th September 2015

Precipitation Virtual Constellation (P-VC)

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Background: The CEOS Precipitation Virtual Constellation was established in 2007 with the participation of seven CEOS members as one of the four prototype CEOS Constellations.

Purpose: Its primary role is to establish an international framework to guide, facilitate, and coordinate the continued advancement of multi-satellite global precipitation measurement. Its original purposes included:

1. Facilitating implementation of the Global Precipitation Measurement (GPM) mission and encouraging more nations to contribute to the GPM constellation

2. Sustaining and enhancing an accurate and timely global precipitation data record including a Fundamental Climate Data Record fit for the purpose specified by GCOS for the monitoring of Precipitation as an Essential Climate Variable (ECV).

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What have we accomplished?

✓ Deployment and operationalization of GPM constellation

✓ Precipitation ECV support through response to the Global Climate Observing System (GCOS) Implementation Plan (IP) Action A8

✓ Support to GEOSS through numerous (19) actions/deliverables

✓ An active X-CAL WG for PMW sensors relevant to precipitation measurement and uniformly calibrated multi-satellite products

✓ The promotion of MWI on EPS-SG through the PMW Imager Availability Study

✓ Development of the P-VC Data Portal

✓ Additional space/ground segment, products and services deliverables as identified in the P-VC Terms of Reference (ToR)

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ToR Outcomes

❑ **P-VC Data Portal**

- Phase 1 of PVC Data Portal **completed**
- Phase 2 of PVC Data Portal **to be completed Sept 30th** (VC-17)

❑ **Precipitation ECV support – Response to GCOS Action A8 - Ensure continuity of satellite precipitation products**

- TRMM satellite was decommissioned in mid-April and reentered the Earth's atmosphere over the Indian Ocean on June 16 UTC. Its 17+ years of data substantially contributed to the P-VC and it served as the anchor for the ad hoc constellation prior to GPM's launch in 2014. (Deliverable #1)

- X-Cal WG met at UCF Orlando (USA) and CSU, Fort Collins (USA) as well as through weekly videocons. X-Cal WG analyzed and recommended the GMI calibration (<<1 K for the 13 channels) based on data from GPM Calibration Attitude Maneuvers (CAMs). (Deliverables #2, #3, #4, and #5).

- PPS/MOS achieved production and distribution of all GPM Standard Data Products to public users.

ToR Outcomes (cont.)

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- NASA IMERG multisatellite product became publicly available. The NRT version has a 3-4 hour latency (Deliverables #2, #3, #4, and #5).
- 7th GPM International GV Workshop was held in May in Seoul, Korea hosted by KMA (Deliverable #2).

❏ **Deployment of GPM phase constellation satellites**
  - GPM Core Observatory completed first year of baseline mission operations
  - GPM constellation satellites operating nominally
    - Early indications of aging – S-NPP/ATMS, GCOM-W1/AMSR2
  - Upcoming additions constellation are JPSS-1 (2017), MetOP-C (2018)
  - Concerns regarding MW Imager continuity (GCOM-W2, -W3, DMSP FO) and Precipitation Radar measurements following GPM Core

❏ **Advocacy of post-GPM phase PVC**
  - GPM FO meeting held on sidelines of 2015 PMM Science Team meeting as well as preparatory meetings

GPM's International Constellation
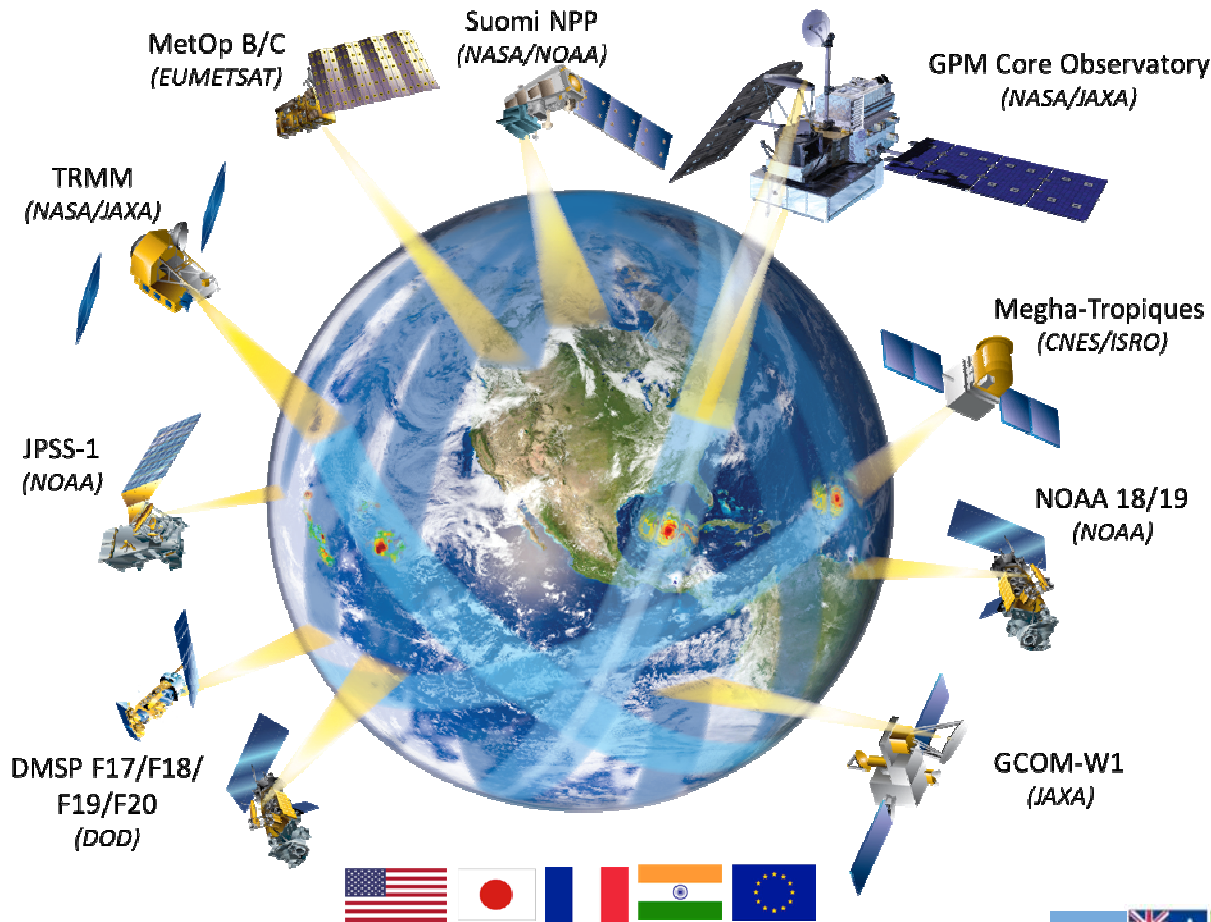
An international constellation of satellites providing uniformly-calibrated precipitation measurements every 3 hours globally

Active Joint Projects (19 PI's from 13 countries)

Science Objectives and Applications

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Scientific Objectives:

- *New reference standards for precipitation measurements from space*
  - *Active and passive microwave sensors*
- *Improved knowledge of water cycle variability and freshwater availability*
  - *Accurate description of space-time variability of global precipitation*
- *Improved numerical weather prediction skills*
  - *Better instantaneous precipitation information and error characterization*
- *Improved climate prediction capabilities*
  - *Better knowledge of latent heat, precipitation microphysics, and surface water fluxes*
- *Improved predictions for floods, landslides, and freshwater resources*
  - *Better hydrological modeling & high-resolution precipitation data via downscaling*
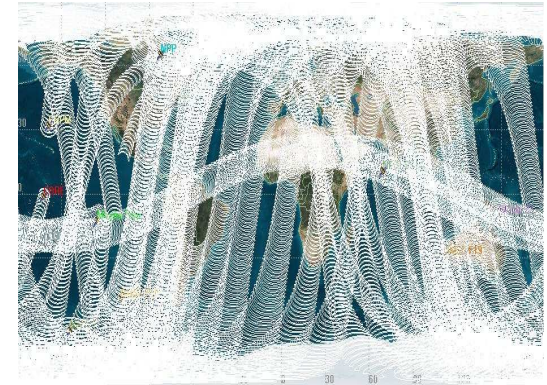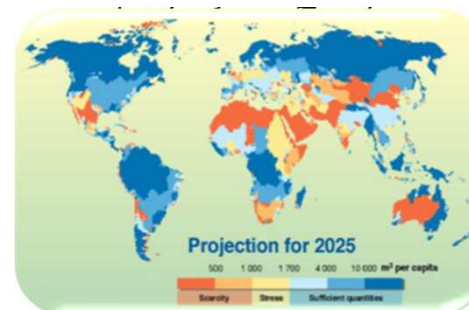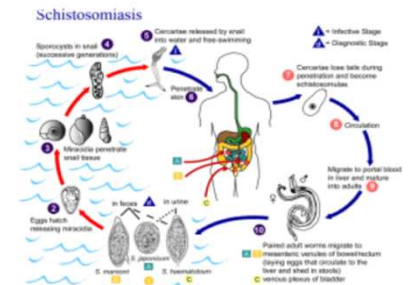
Societal Benefits:

Floods and Landslides

Extreme Events

Freshwater Availability/

World Health

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GPM Status

- GPM Project is in Phase E (Operations)

- All GPM L1, L2, and L3 data products are in routine production and are publicly available through the NASA Precipitation Processing System (PPS) and JAXA Mission Operations System (MOS)

- Several NRT multi-satellite precipitation estimates are being produced
  - *NASA IMERG (global, 4 hour latency with 30 minute updates)*
  - *JAXA GSMaP NRT (global, 4 hour latency with 60 minute updates)*
  - *JAXA GSMaP NOW (MTSAT area, 1 hour latency with 60 minute updates)*
  - *NOAA bRR (global, 12 hour latency with 30 minute updates)*

- As well as NRT multi-satellite flood and landslide prediction products
  - *UMD Global Flood Monitoring System (GFMS) (IMERG based)*
  - *JAXA/MLIT Global Flood Alert System (GFAS) (Indus-IFAS in development)*

- GPM multi-satellite data are also being utilized in operational weather forecasting and for applications in additional Societal Benefit areas
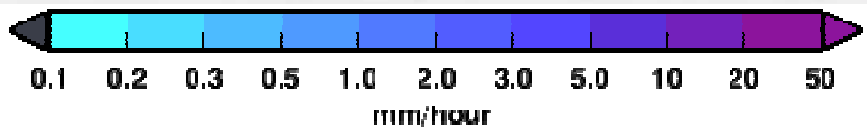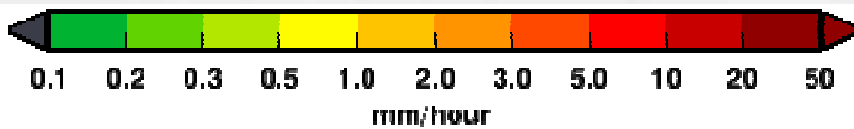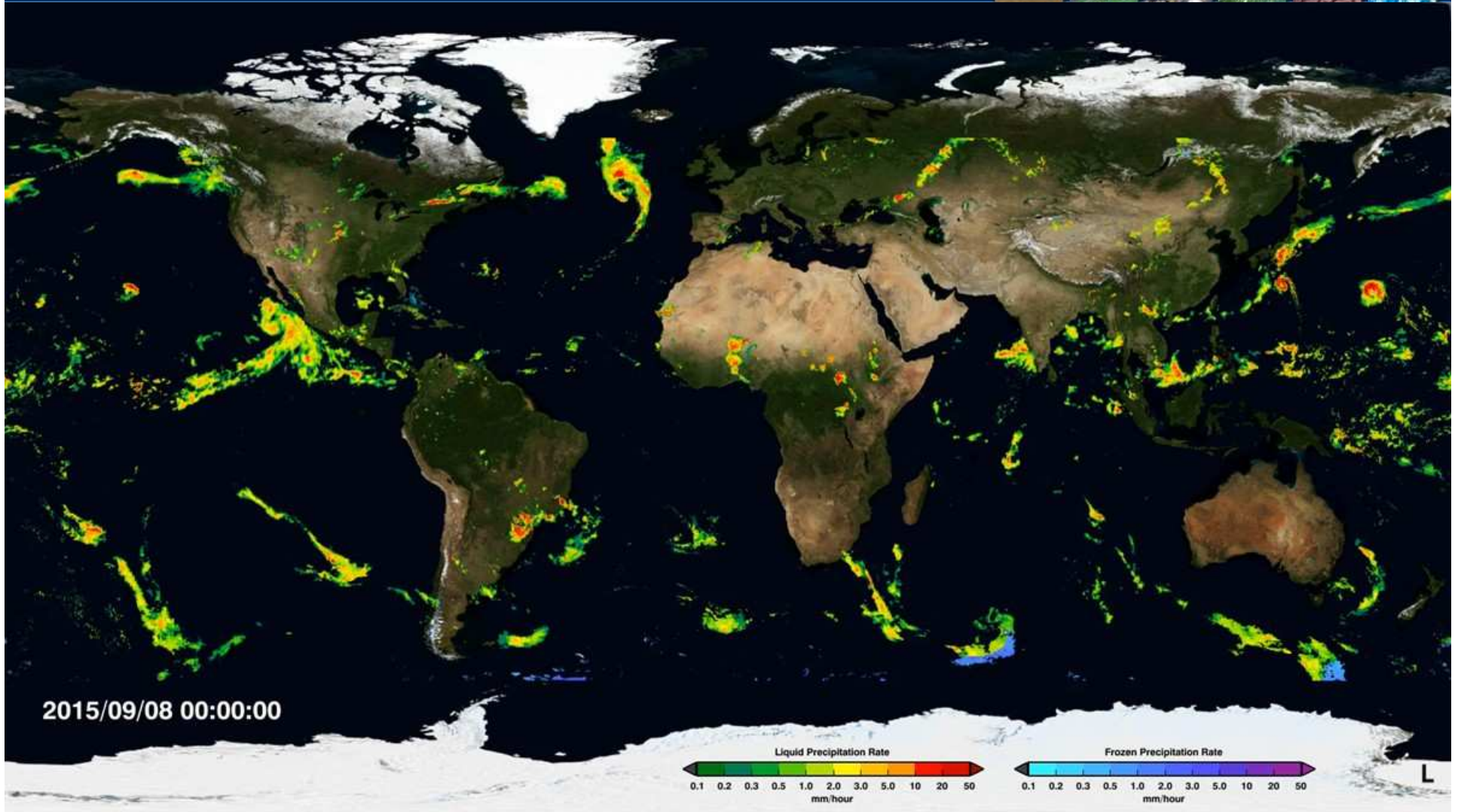
Flood and Landslide Predictions

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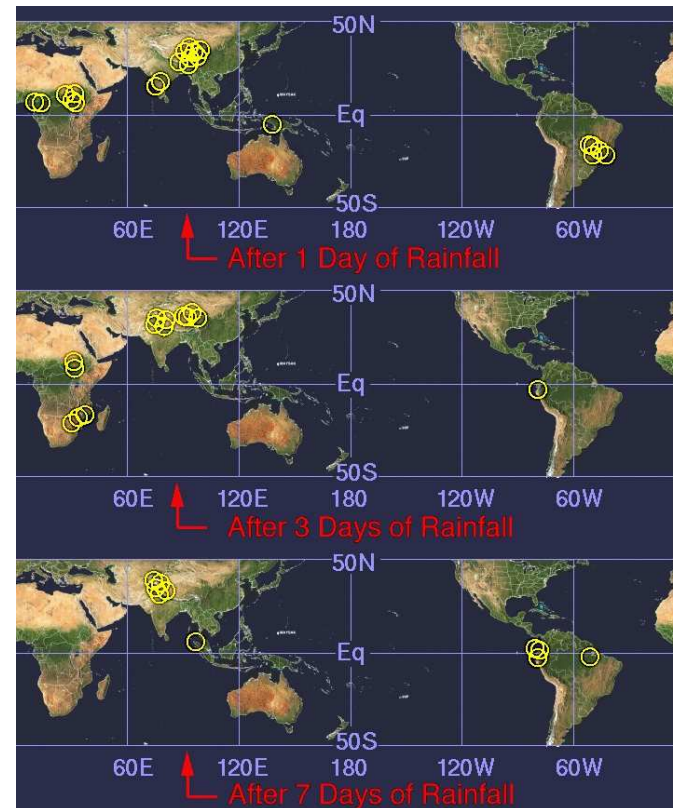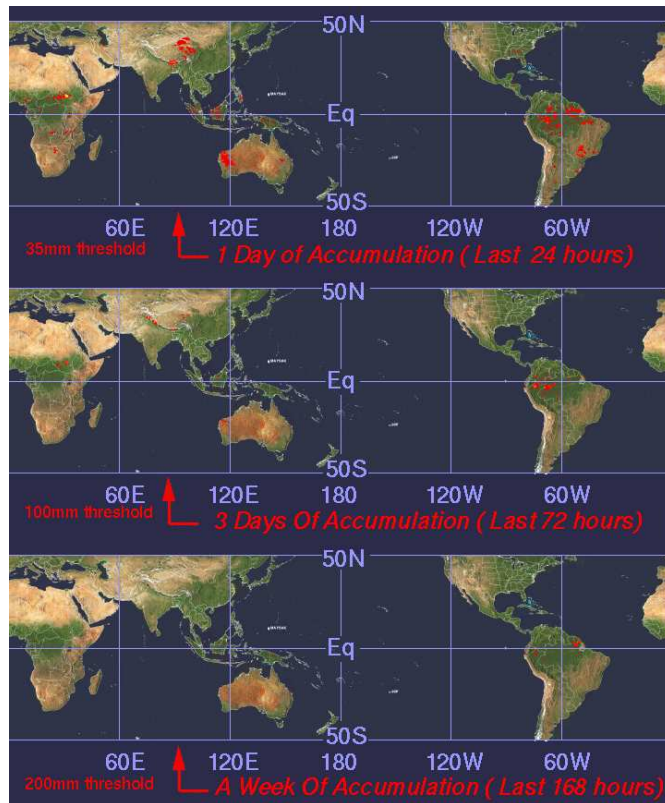16th September 2015

- Multi-satellite flood and landslide predictions
  - *UMD Global Flood Monitoring System (GFMS) (TMPA RT evolving to IMERG)*
    - Publicly available
    - http://trmm.gsfc.nasa.gov/publications_dir/potential_flood_hydro.html

GSMaP NOWCAST version (GSMaP_NOW) in preparation

- ❑ To reduce latency from 4-hr to nowcast
  - ■ Using data that is available within 1-hour (GMI, AMSR2 direct receiving data, AMSU direct receiving data and MTSAT) to produce GSMaP at 1-hr before (observation).
  - ■ Applying 1-hour forward extrapolation (future direction) by cloud moving vector to produce GSMaP at current hour (nowcast).

GSMaP in Flood Analysis

- Under UNESCO-IHP project, JAXA and ICHARM is developing with Pakistan Meteorological Department (PMD) to develop operational flood analysis system.
- After calibration of GSMaP product with ground-based stations in Pakistan, correlation coefficients are increased from 0.5 to 0.7, and can be used in the Indus Integrated Flood Analysis System (Indus-IFAS) developed by ICHARM.
- The system will be in operation in 2015 by PMD, and plan to extend the system to larger regions is underway.
- Similar system is in operation in Bangladesh and Philippines under ADB project.

Rainfall by GSMaP

River discharge output using GSMaP
(increasing as rainfall in upper stream increased)

Before Flood

Discharge of main river is normal (green) before flood

INPUT

During Flood

Discharge of main river is largely increased (red) during flood
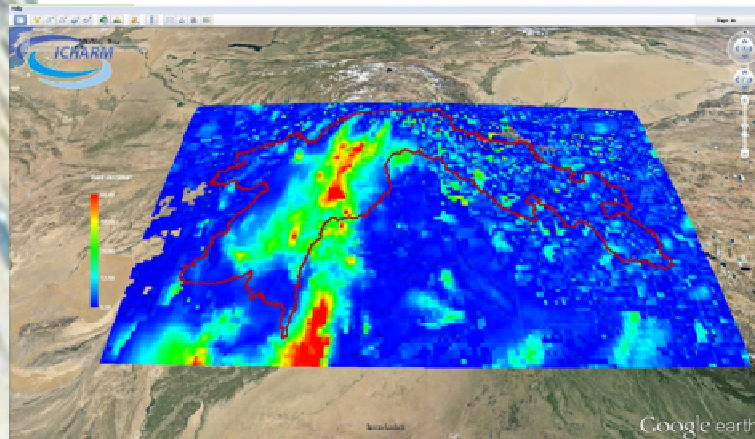
(Area within red line is Indus river basin)
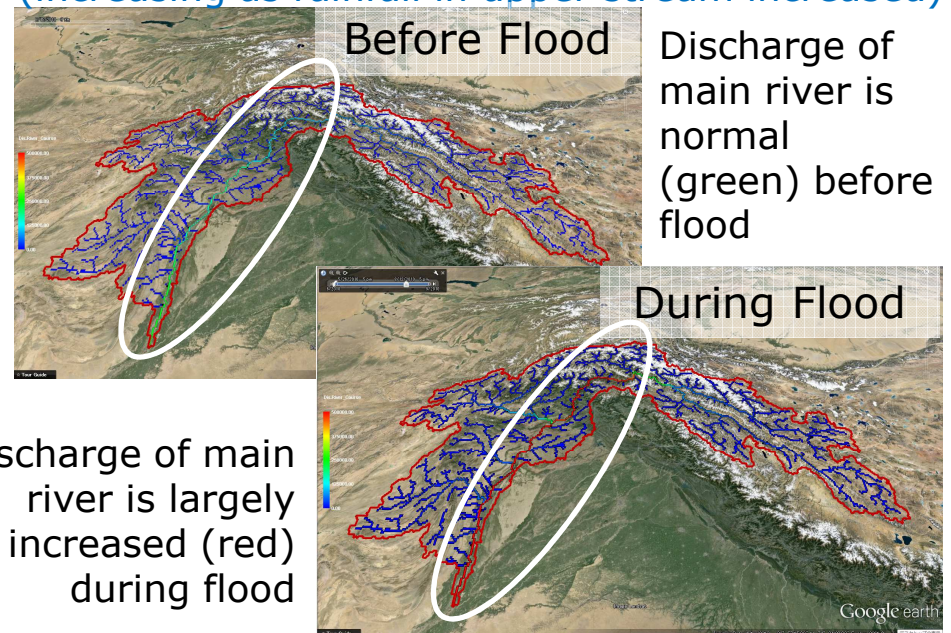
Example of Indus-IFAS in Pakistan (Image provided by ICHARM)

Transition of L3 IMERG Data to Forecasters

Image by: Matt Smith (UAH)

Hurricane Blanca
2100 UTC 4 June 2015

[IMERG] Rain Rate   Thu 21:00Z 04-Jun-15
* Visible Satellite   Thu 21:00Z 04-Jun-15
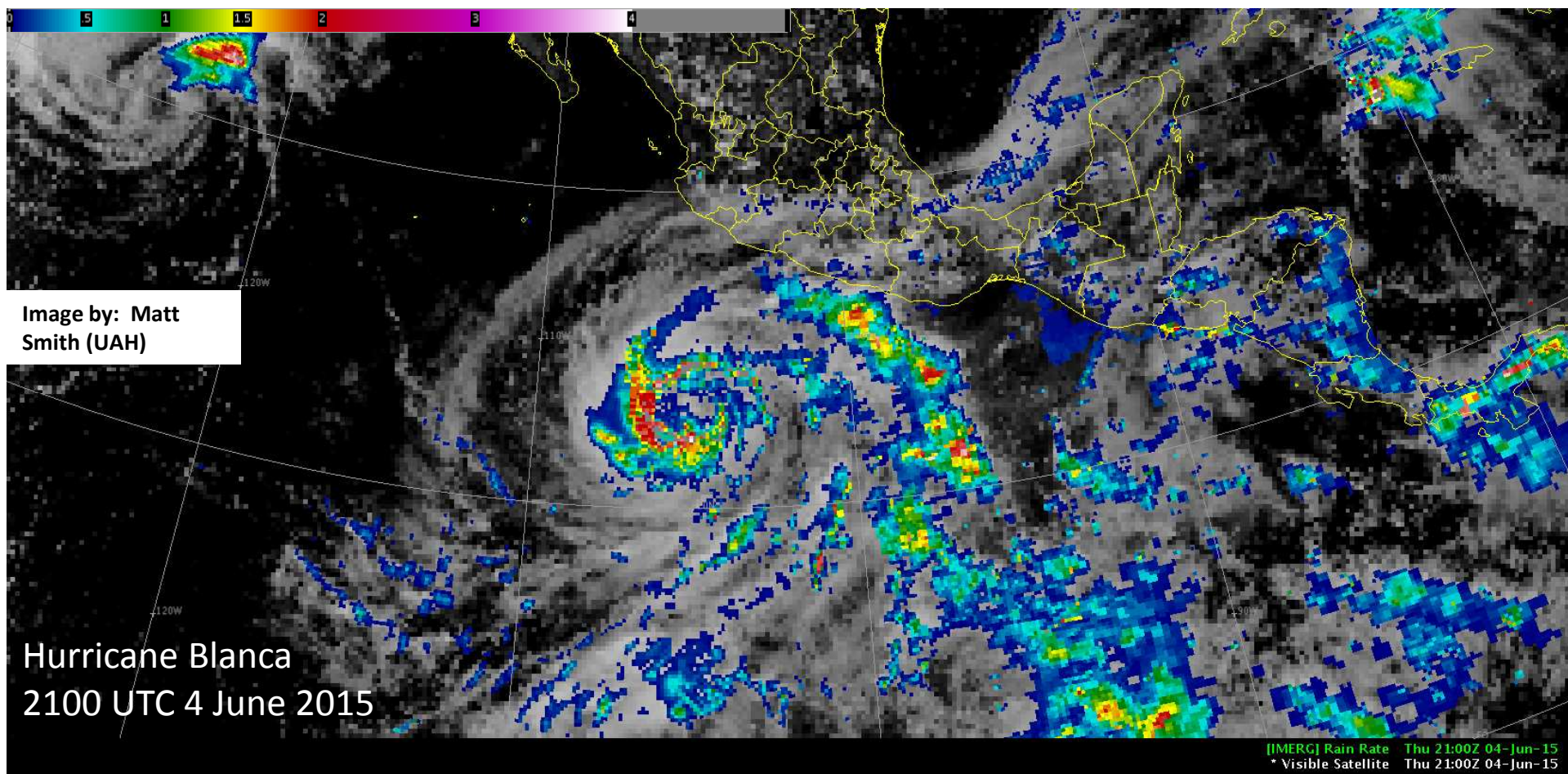
- SPoRT obtains real-time IMERG data from the GPM Processing System, formats for AWIPS II, and disseminates to forecasters via LDM
- Due to latency, most useful for hydrologic applications to pinpoint areas of heaviest rainfall outside of radar coverage
- Evaluation planned for this fall with River Forecast Center forecasters in Southern Alaska

GSMaP in Agricultural Insurance

- Japanese insurance company has developed Weather Index Insurance in Myanmar using GSMaP rainfall data, and plans to sell it in 2015
- In Myanmar, agriculture makes up 40% of GDP, but natural disasters such as droughts happens often recently.
- Overview of the insurance
  - Assured persons: farm houses in the assured regions
  - Assured crops: rice, sesame
  - Assured regions: Arid regions in the central Myanmar
  - Assured risks: drought (risk of less rainfall in rainy season)
- Plan to expand the insurance to other disaster risks (cyclone, heavy rainfall) in Myanmar, and to other countries in South-East Asia

GSMaP Rainfal data

Planning insurance

Set the criteria of accumulated rainfall during certain period, calculated from past data

When estimated rainfall by GSMaP is less than the criteria, insurance will be paid.

Insurance payment to farm houses

(from press release from Sompo Japan Nipponkoa & RESTEC in Dec. 2014) 14
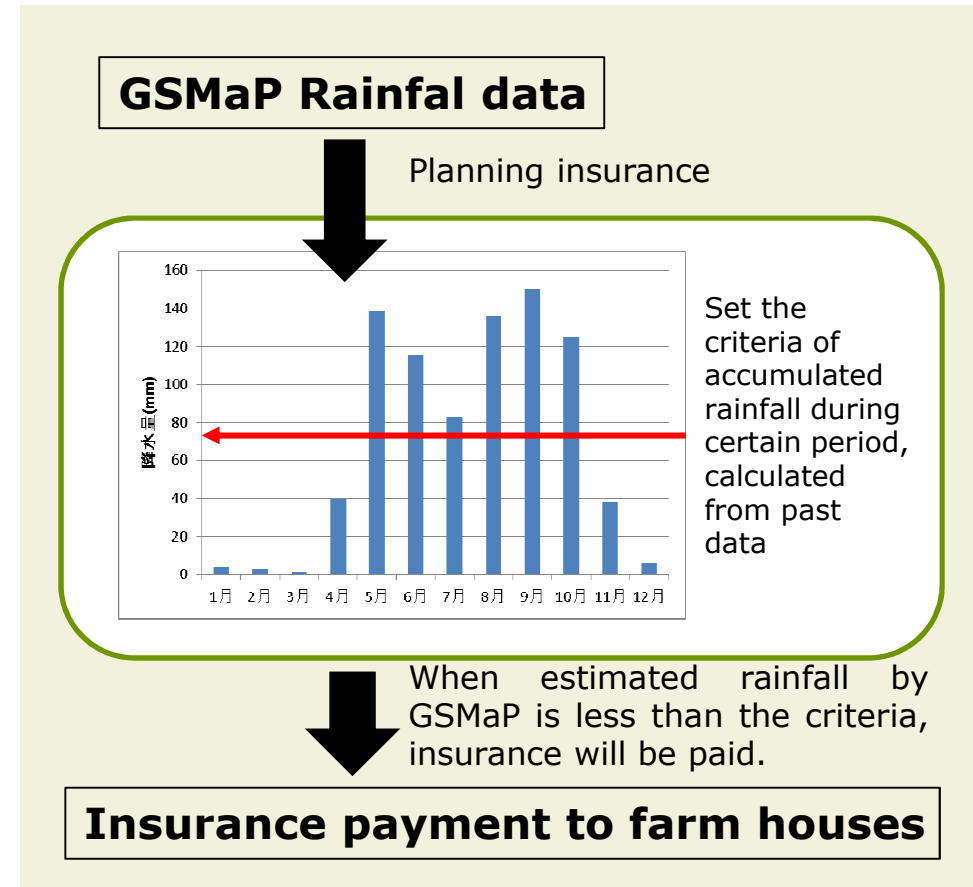
USDA Crop Explorer

(Every 10 days displays weather, soil moisture & time series graphs over major crop regions)

Explore by Crop

Source: USDA/FAS Crop Explorer
http://www.pecad.fas.usda.gov/cropexplorer/

USDA/FAS/OGA/IPAD

Maps and time-series graphs for:

- **Precipitation & Min/Max Temperature**
  - *WMO Station (global)*
  - *AFWA-* USAF 557th Weather Wing
  - *NOAA/CMORPH*
  - *NASA-TMPA-RT = to be replaced with GPM*
  - *NexRAD (USA Only)*
- Dekad (10-day) precipitation & temperatures compared to climate normals

- **Soil Moisture & Crop Models**
  - Modified two-layer Palmer soil moisture
  - *Behind firewall:* Crop calendars for wheat, corn, & sorghum and hazard/alarm models.

- **NDVI 10-day (8-day) Composites**
  - AVHRR/GAC (8-km)-10-days composite
  - Proba-V/SPOT-VEG (1-km)-10-days
  - MODIS-Aqua/Terra (250-m)-8-days

- **Daily MODIS**
  - Aqua and Terra (250-m)

- **Lake/Reservoir Water Heights**
  - TOPOX/Poseidon, Jason-1, OSTM/Jason-2

Societal Benefit

## Extreme Events and Disasters

- **Landslides** (NASA Hazard Mapping)
- **Floods** (Global Flood Monitoring System-UMD, International Flood Network-IFNet)
- **Tropical cyclones** (Joint Typhoon Warning Center, National Hurricane Center-NOAA, U.S. Military, Air Force Weather Agency-AFWA)
- **Multi-hazard situational awareness** (Pacific Disaster Center, International Red Cross, World Bank)
- **Re-insurance** (Swiss Re)

Water Resources and Agriculture
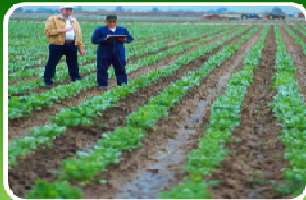
- **Famine Early Warning System** (USGS-USDA-FEMA)
- **Drought Monitoring** (US Drought Monitor-U of Nebraska-Lincoln-NOAA-USDA, NOAA CPC, NCEP)
- **Water resource management** (USGS, USDA, NOAA)
- **Agricultural monitoring** (Agricultural Meteorological Modeling System, USDA, AFWA)

## NWP, Climate & Land Surface Modeling
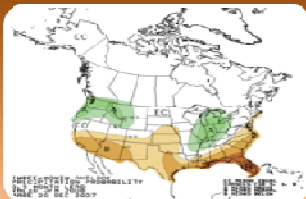
- **Numerical Weather Prediction** (ECMWF, National Weather Service, The Weather Company)
- **Land Data Assimilation System Modeling** (NASA Land Information System, AFWA, USDA, International Center for Biosaline Agriculture-ICBA, Universities)
- **Global Climate Modeling and Assimilation** (NASA-GMAO, NOAA)

Public Health and Ecology

- **Disease tracking** (National Center for Atmospheric Research-NCAR, Universities)
- **Animal migration** (Universities, MoveBank.Org)
- **Food Security** (USDA, FAO, World Bank, International Red Cross)

P-VC Roadmap

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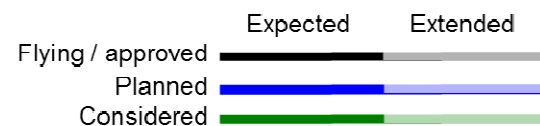EUMETSAT, Darmstadt, Germany
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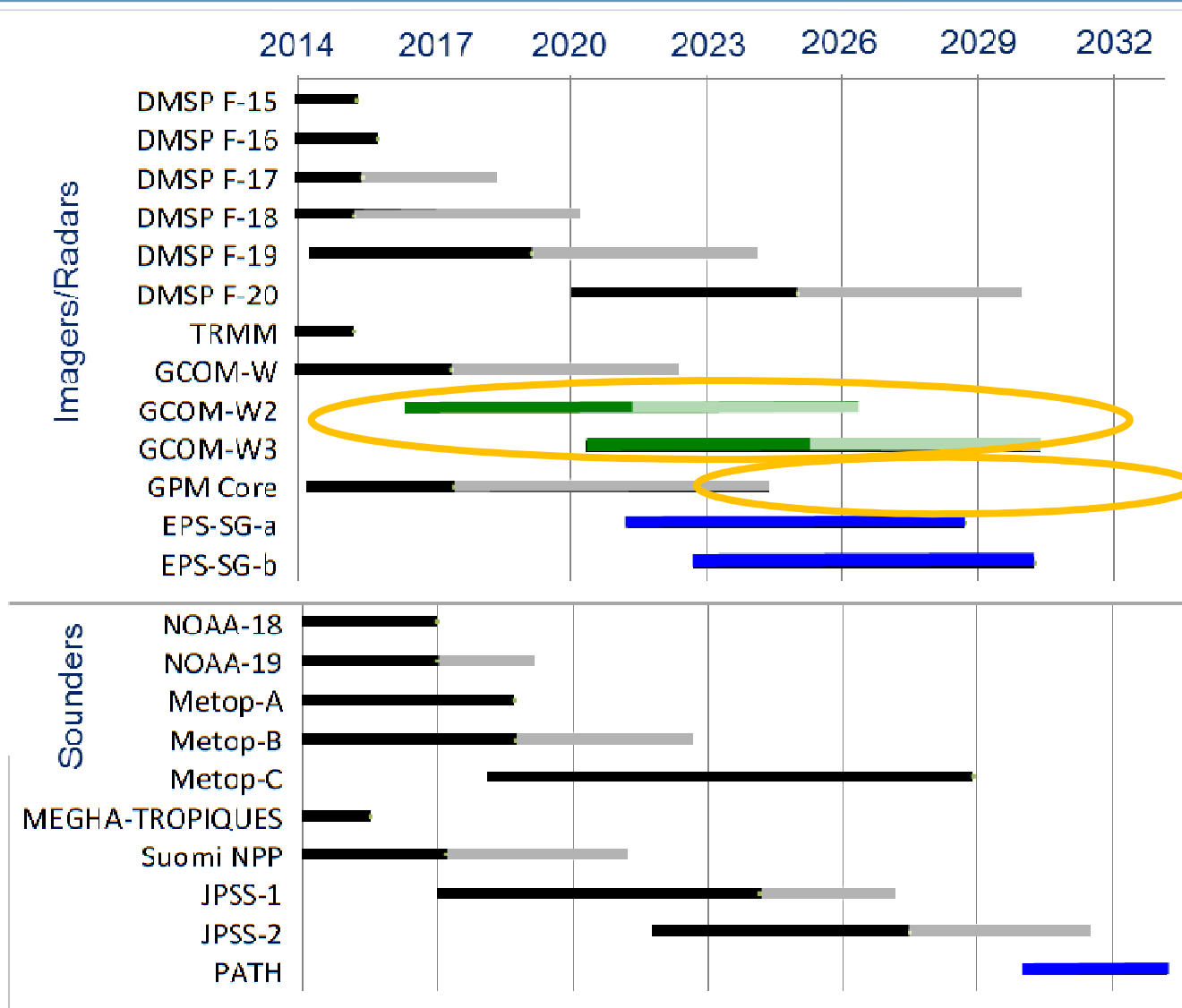
Other missions of interest are:

Current: Cloudsat (CPR), MSG/Meteosat-9/-10 (SEVIRI), GOES 13/14/15 (Imager), MTSAT-2 (Imager/MTSAT), FY-3B/C (MWRI), Meteor-M N1 (MTVZA).

Future: EarthCARE (CPR), MTG-I1 (FCI), GOES-R/S/T (NOAA), DMSP FO (MWI), FY-3 D/F (MWRI), Meteor M N2-1/-2 and N3 (MTVZA), Meteor M3 series (Advanced MTVZA), PATH, ACE, GPM FO

Backup

P-VC Strategic Objectives

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- Providing a coordination mechanism to harmonize precipitation satellite, data processing and calibration/validation infrastructures

- Serving as a programmatic point of contact for precipitation measurements, addressing issues which go beyond the individual mission programmes

- Collecting, processing, and delivering data to develop and improve the knowledge and understanding of precipitation (rain and snow) processes, the distribution of precipitation and the changes in precipitation over time on a global basis

- Supporting and engaging the scientific and operational user communities

- **The implementation of CEOS P-VC is in four phases***

year	2007	2008	2009	2010	2011	2012-2013	2014	2015	2016	2017	2018	2019	2020
phase	study phase	GPM preparatory phase					GPM phase					post - GPM phase	
								GPM					

*CEOS Precipitation Virtual Constellation 10-year Implementation Plan (2007) – needs updating

P-VC Phase Descriptions

- ✓ **Study Phase (2007)**
  - o Startup activities and survey existing PVC member multi-satellite products: NASA TRMM 3B42, JAXA GSMaP, NOAA CMORPH/QMORPH, NRL-Blend SRE, EUMETSAT MPE
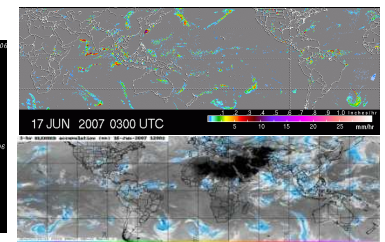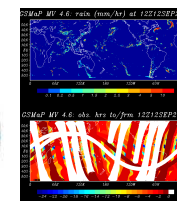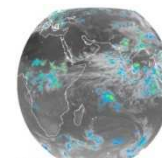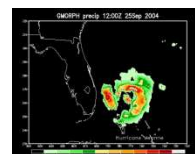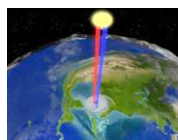
- ✓ **GPM preparatory phase (2008-2013)**
  - o Comparison of different methods of inter-calibration for generating uniform precipitation estimates from diverse types of precipitation sensors
  - o Evaluation of different multi-sensor precipitation products
  - o The prototyping of uses of merged data products from multiple sensors as well as evaluation of tools to support such use

- ✓ **GPM phase (2014-2018)**
  - o Launch and operation of GPM, the first constellation-focused mission that will improve precipitation estimates through extensive intercalibration and the use of a reference standard

- • **Post-GPM phase (after 2018)**
  - o Beyond timeframe of GEOSS 10-Year Implementation Plan
  - o Lessons learned from GPM and other PVC activities will serve to guide the planning and further evolution of CEOS PVC

Response to GCOS Action A8 - *Ensure continuity of satellite precipitation products*

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Deliverables

1. Sustainment and enhancement of constellation of satellites carrying microwave radiometers (both imagers and sounders) and moderate inclination satellite carrying microwave imager and precipitation radar.

2. Well characterized and stable Level 1B calibrated, geolocated brightness temperature (Tb) products from each PC radiometer.

3. Inter-calibrated brightness temperature (Tc) products by applying the GPM core observatory reference standard.

4. Precipitation retrievals using physically based a-priori database constructed from combined radiometer/radar measurement.

5. Global monthly PDF of precipitation intensity based on the above.

P-VC Governing Documents

- **CEOS 2015-2017 Work Plan, March 2015**

- **Terms of Reference for the CEOS Precipitation Virtual Constellation Verions 1.0, 9 November 2013**

- **The Response of the Committee on Earth Observation Satellites (CEOS) to the Global Climate Observing System Implementation Plan 2010 (GCOS IP-10), 24 September 2012**

- **2011-2013 Work Plan, November 2011**

- **CEOS Precipitation Virtual Constellation 10-year Implementation Plan (2007)**

Participation

- **Lead Agencies:**
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Participation (cont.)

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  - **Canada – Environment Canada: Paul Joe, paul.joe@ec.gc.ca**

- **User Community Representatives:**
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- **Gail Jackson/NASA GSFC**
- **Erich Stocker/NASA GSFC (SEO POC, Data Systems)**
- **Scott Braun/NASA GSFC (Visualization POC)**
- **Xiaopeng Hu/NASA GSFC (P-VC Data Portal)**
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- **Bob Adler/ University of Maryland Baltimore County**
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- **Joe Turk/JPL**
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- **Keizo Nakagawa, JAXA**
- **Misako Kachi, JAXA (Visualization POC)**
- **Toshiaki Takeshima, JAXA**
- **Kengo Aizawa, JAXA**
- **Keiji Imaoka, JAXA**
- **Kazuo Umezawa, JAXA**
- **Mitsuhiko Fuda, JAXA (P-VC Data Portal)**
- **Yukari Takayabu, University of Tokyo**
- **Toshio Iguchi, NICT**
- **Ken'ichi Okamoto, Osaka Prefecture University**
- **Toshio Koike, University of Tokyo**
- **Jun Matsumoto, Tokyo Metropolitan University**
- **Kazuhiko Fukami Public Works Research Institute**
- **Yoshiaki Takeuichi, Japan Meteorological Agency**
- **Yoshiyuki Chihara, Ministry of Education, Culture, Sports, Science and Technology**

P-VC POCs

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P-VC Approach

- Develop a consistent framework to produce inter-calibrated precipitation sensor measurements and retrieval products

- Identify key points of agreement for space agency co-operation in order to meet the needs of both the data producer and user communities

- Be results-focused, identifying what steps are necessary by space agencies (and other groups responsible for product generation, in-situ observations etc) to develop the constellation data sets and information services. CEOS PVC should also encourage the development and evaluation of precipitation products produced from the constellation data. This should include inter-comparisons and validation against high quality ground data.

- Recognize the Constellation member's national plans for implementing their respective Earth observing programs (e.g. the U.S. Decadal Survey).

- Have strong collaboration with the CEOS Working Group on Calibration and Validation (WGCV) and the CEOS Working Group on Information Systems and Services (WGISS)

Constellation of Satellites provides:

- *Coordinated precipitation measurements to achieve global coverage and sampling.*

  - *> 50% of observations are less than 1 hr apart at all latitudes*

  - *< 3 hr mean revisit time over 100% of globe*

Core Observatory provides:

- *A radiometric reference to constellation radiometers using the GMI as a transfer standard.*

- *An a priori observational hydrometeor database consistent with DPR and GMI measurements to unify and improve precipitation estimates from all constellation radiometers.*