

**TERMS OF REFERENCE FOR THE CEOS
PRECIPITATION VIRTUAL CONSTELLATION
VERSION 1.0
LAST UPDATED: 19 DECEMBER 2013**

CONSTELLATION NAME: The Precipitation Virtual Constellation (P-VC)

MISSION STATEMENT & OBJECTIVES

The P-VC exists to sustain and enhance a systematic capability to observe and measure global precipitation. These observations are central to understanding the distribution and characteristics of precipitation, its role in the hydrological/water cycle and its impact on the climate system.

Accurate and timely knowledge of global precipitation is needed for improving predictive skills of high-impact weather events such as hurricanes, floods, droughts, and landslides, as well as the management of freshwater resources. The spatial and temporal variability of precipitation necessitates the combination of data from multiple satellites to ensure representative sampling across the range of scales (spatially and temporally) required by the research and operational user communities.

The P-VC has the following strategic objectives to address this aim:

- 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.

CHARACTERISATION OF THE MEASUREMENTS AND DATA COLLECTIONS WITHIN SCOPE

The geophysical parameters concerning the P-VC relate to liquid and solid precipitation (e.g. profile, rate, accumulation). For example, a global gridded long-term product of hourly accumulated precipitation at 25-km resolution, or finer in some areas, is needed to satisfy directly the full range of requirements for precipitation measurements according to the Global Climate Observing System (GCOS) Satellite Supplement (2010 Update).

Precipitation measurements from multiple satellite sensors are currently being utilised by the P-VC to address current action items. These include passive microwave (imager, sounder) sensors and active microwave (radar) systems in low Earth orbit. Visible/infrared systems on low Earth orbiting platforms and on geostationary platforms are also of interest. Data from many recently completed missions are also utilized, such as those from the Meteosat, GMS, AMSR, AMSR-E and AMSU sensors. Other 'historic' data sets should also be considered as having a potential for precipitation studies, such as the 10-year record of SMMR. Other sensors have the potential to contribute data, particularly current multi-spectral visible/infrared sensors such as MODIS, additional channels on the sensors providing VIS/IR and sensors on future missions, such as GCOM-C. Other satellite-based precipitation-capable observations are

currently collected, such as those from Russian and Chinese passive microwave sensors, yet are not routinely available or disseminated

CHARACTERISATION OF THE SPACE SEGMENT CONCERNED

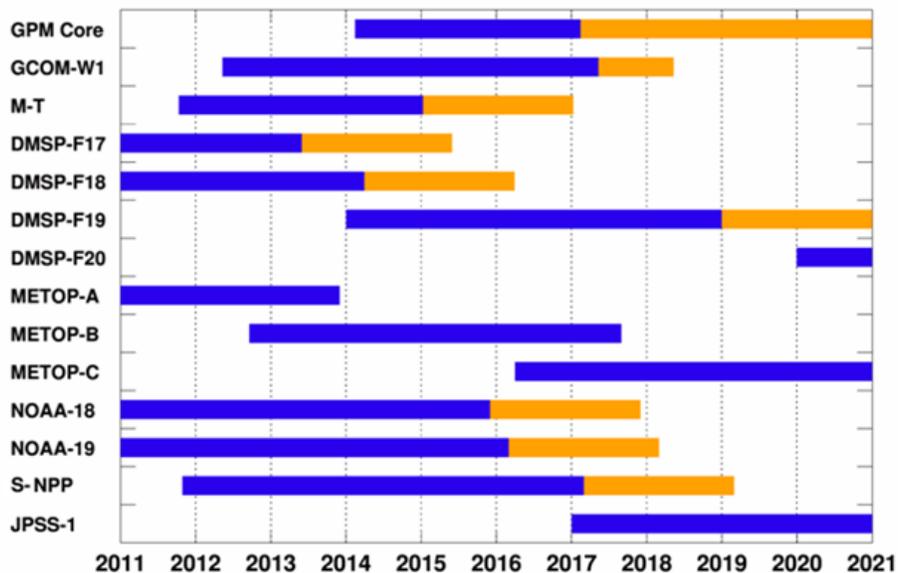
The core missions (current & future) that are currently the priority for coordination efforts by the P-VC are:

- GPM Core (DPR, GMI)
- TRMM (TMI, PR, VIRS);
- GCOM-W1/-W2/-W3 (AMSR-2);
- Megha-Tropiques (MADRAS, SAPHIR);
- DMSP-17/-18/-19/-20 (SSMI and SSMIS);
- NOAA-19 (AVHRR, MHS);
- S-NPP (VIIRS, ATMS);
- MetOp B/C (AVHRR, MHS);
- JPSS-1/-2 (VIIRS, ATMS);
- EPS-SG-a/-b (MWI, MWS, METImage).

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



ACTIVITIES, OUTCOMES AND DELIVERABLES

The activities of the P-VC fall within the two following areas:

- Global precipitation products that are of the highest-quality, exhibiting long-term stability, and are suitable for climate studies: *To sustain and enhance an accurate and timely global precipitation data record, fit for the purpose specified by GCOS for the monitoring of precipitation as an essential climate variable (ECV). Note this supports GEO tasks DA-07-03, AR-09-02, and IN-01-C2.*

- Improving precipitation retrievals through multi-sensor data inter-calibration, prototyping uses of merged data products from multiple sensors, the evaluation of different multi-sensor precipitation products and establishing the standard merged precipitation products.

Specific outcomes and deliverables are:

1. P-VC Data Portal and links to CEOS Water Portal: the P-VC is developing a data portal in support of GEO Tasks WA-01-C1_3 and WA-01-C1_4

2. Precipitation ECV support: The P-VC is providing the CEOS Response to GCOS Action A-8 - Ensure continuity of satellite precipitation products with the following 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 P-VC radiometer.
- #3 Inter-calibrated brightness temperature (Tc) products by applying the GPM Core Observatory reference standard.
- #4 Precipitation retrievals using a physically based *a priori* database constructed from combined radiometer/radar measurement.
- #5 Global monthly PDF of precipitation intensity based on the above.

3. Deployment of GPM phase constellation satellites and maintaining continuity with TRMM: The current focus of the P-VC is completing the GPM Phase constellation of satellites with the GPM Core Observatory as the crucial inter-calibration reference while avoiding a gap with the TRMM measurements initiated in 1997.

4. Advocacy of the post-GPM phase P-VC: The P-VC is concerned with promoting the sustainment and enhancement of satellite global precipitation measurements following the GPM phase of the P-VC.

The P-VC has identified the following high-level outcomes and deliverables on 3- and 5-year horizons.

	3-year horizon	5-years or more horizon
Space Segment	<ul style="list-style-type: none"> • Global Precipitation Measurement (GPM) mission with partner satellites (the “GPM phase” of the P-VC) in operation substantially fulfilling main user requirements. 	<ul style="list-style-type: none"> • Development and launch of precipitation-measurement- satellite missions with increased capabilities for light and solid high latitude precipitation, integrated precipitation/clouds, and GEO high temporal passive microwave measurements.

		<ul style="list-style-type: none"> Sustainment of passive microwave measurements in mid-morning, early-afternoon, and inclined orbits through the development and operations of the GCOM-W2/-W3, EPS-SG, and JPSS series and a GPM FO.
Ground Segment & Information Systems	<ul style="list-style-type: none"> NASA Precipitation Processing System (PPS) and JAXA MOSS data system development completed and in operation producing GPM T_b, T_c, precipitation, and other radar data products for research and operational users. GCOM-W, Megha-Tropiques, MetOp-A/-B, S-NPP, DMS/POES, and TRMM data systems in operation producing T_b and precipitation data products for research and operational users. Provide improved methodology for the cross-calibration of T_b products from multiple LEO satellite missions through the X-Cal Working Group. 	<ul style="list-style-type: none"> EPS-SG and JPSS data systems development completed and in operation producing T_b and precipitation data products for research and operational users. Data systems for legacy missions (GPM, GCOM-W, MetOp-B/-C, S-NPP, Megha-Tropiques, DMS/POES) in operation producing T_b, T_c, precipitation, and other radar data products for research and operational users. Provide improved methodology for cross-calibration of T_b products from multiple satellites extending these techniques to include GEO passive microwave measurements.
Products & Services	<ul style="list-style-type: none"> Cross-calibrated multi-sensor precipitation products including deliverables produced in response to GCOS Action A-8 - Ensure continuity of satellite precipitation products. These products include calibrated brightness temperature (T_b) products and inter-calibrated brightness temperature (T_c) products from each P-VC radiometer, multi-satellite climate quality and NRT precipitation rate and accumulation products, precipitation retrievals using a physically based a priori database constructed from combined radiometer/radar measurements, and a global monthly PDF of precipitation intensity. Completion of Phase 2 P-VC Data Portal providing free and open availability of precipitation products in support of CEOS-GEO Actions WA-01-C1_3 and WA-01-C1. P-VC data products utilized in analytical models/tools with societal benefits in Water (LDAS), Weather (NWP), Climate, Disasters (JTCW, GFAS, GFMS, Landslide hazard forecasting), Health (MMS/GSAT), and Agriculture (FAS, FEWS, AGRMET) areas. 	<ul style="list-style-type: none"> Enhanced Cross-calibrated multi-sensor products including deliverables produced by the PC in support of the Precipitation ECV and GCOS. Development of a long-term strategy for observations, data assimilation and modelling. Expanded use of P-VC data products in analytical models/tools for societal benefits and applications.

IMPLEMENTATION AND COORDINATION ISSUES TO BE ADDRESSED

Achievement of the P-VC objectives requires the following implementation and coordination issues to be addressed by SIT:

1. The necessary CEOS agency participation in coordination of mission-planning and continuity: operation and continuation of a constellation of space-based measurements of global precipitation; configuration and maintenance of such a constellation in a “rolling-wave’ fashion ensuring measurement continuity through planned future missions and coordination of orbits. Specific near-term actions are to:
 - a. Initiate GCOM-W2 development with objective to provide AMSR2 measurement continuity with GCOM-W1 (JAXA).
 - b. Initiate development of Microwave Imager (MWI) for METOP SG (EUMETSAT).
 - c. Develop a timeline for development and deployment of the geostationary PATH radiometer (NASA).
 - d. Conduct concept study of light/solid precipitation measurement capability in the ACE Cloud Profiling Radar (NASA).
 - e. Conduct concept study of GPM FO mission (JAXA, NASA) including potential broadening to an integrated global precipitation and clouds mission concept.
2. Support for data exchange and access – asking relevant agencies to make PC data and related information continuously and easily available to potential users through international cooperation and co-ordination activities, making products easily available to operational users including researchers, weather and climate forecast modelers, operational agencies and decision makers. Specific near-term actions are to:
 - a. Develop and implement approach to obtain FY-3 MWRI data on a routine and timely basis (EUMETSAT, NOAA, NASA, NSMC/CMA).
 - b. Develop and implement approach to obtain Meteor M N2 MTVZA data on a routine and timely basis (EUMETSAT, NOAA, NASA, Roshydromet)
3. CEOS agency participation in the provision of a common framework for data processing hardware systems, software, data and data exchange.
4. Participation in programmes for improvement of global precipitation products (with respect to algorithm development, outputs and user requirements) using multi-satellite and multi-agency data through co-ordination between PC partners; make products easily available to operational users including researchers, weather and climate forecast modelers, operational agencies and decision makers.

SCHEDULE

Activity (or outcome)	Milestone	Target Date
Space segment implementation	Launch of the GPM Core Observatory, corresponding post-launch engineering activities together with refinement of precipitation algorithm development. Integration of new observations into existing framework of observations from operational and scientific/research satellites, particularly with respect to cross-calibration work for precipitation primarily for global coverage at short time scales, as well as an essential climate variable.	Feb 2014
	Ongoing studies into requirements for a post-GPM precipitation mission, to be proposed for the next NASA Earth Science Decadal Survey. Monitor/encourage other agencies for planned/scheduled precipitation missions. Hold international workshop.	Aug 2014
Data access	Completion of Phase 2 P-VC Data Portal with “query/results order based” interface	Dec 2014

MEMBERSHIP AND LEADERSHIP

Current Co-Leads are:

- JAXA, Riko Oki (oki.riko@jaxa.jp)
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And the following CEOS agencies are actively involved in P-VC:

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The P-VC is seeking increased participation from CMA/NSMC and Roshydromet. The U.S. Naval Research Laboratory (NRL) is also an active participant in the P-VC but is not a CEOS agency. Researchers in the academic community are also active within the PC, participate and support many of the PC projects. The user community is represented within the PC by members of CGMS-IPWG, GEWEX, WCRP/IGWCO, and GCOS.

RESOURCES

P-VC projects receive funding from relevant agency mission science teams and competitive research opportunities. These include NASA PMM, NASA Applied Sciences Program, NASA MEaSURES, NOAA, ESA/EUMETSAT, JAXA, CNES, ISRO, INPE, and GPCC. Other groups, such as the IPWG, provide a focus for the developer and user community activities.