1. Background
Precipitation in the form of rainfall and snowfall is the primary input to any hydrological system. The sourcing of accurate information on precipitation across many regions of the globe for hydrological applications is however problematic. While some regions of the world provide good surface data sets from rain gauge networks, many regions have inadequate coverage to reduce spatial and temporal sampling errors; the availability of snow gauge information and measured precipitation over the oceans is extremely sparse. Precipitation estimates derived from satellite observations have the potential to improve the quantification of precipitation at the surface, particularly over data-sparse regions.

In order for satellite precipitation products to be incorporated into hydrological models, more accurate instantaneous estimates, especially over land and during cold seasons, are required. This requires better spatial coverage and temporal sampling to reduce sampling errors and thus improve the estimation of precipitation accumulation. Alongside this requirement, some hydrological applications also require higher spatial and temporal resolutions for local-scale applications, particularly for flash-flood analyses. Ultimately, global precipitation data products are required that use all available satellite and ground-based measurements.

Although there have been significant advances in the development of quantitative precipitation estimates, particularly following the start of the Tropical Rainfall Measuring Mission (TRMM) era, further advances are needed. These require more capable space-borne sensors, more accurate retrieval algorithms and better utilization of available data through appropriate data merging techniques made possible through the coordinated effort to exploit the range of international precipitation-capable missions.

2. The GPM Mission Concept
The overarching concept of the joint NASA/JAXA GPM mission (see Neeck et al. 2010) is twofold. First, to provide, through partnerships, coordinated precipitation measurements through a constellation of microwave radiometers necessary to achieve global coverage and sampling. Second, to improve the accuracy and consistency of precipitation estimates from all the constellation radiometers through the combined active and passive observations of the GPM Core satellite. The GPM constellation satellites comprise of a number of operational and research and development satellites will help fulfill the requirements of the GPM concept. Satellites include (or will include) the operational US NOAA and European MetOp polar orbiting series, the US Defense Meteorological Program satellites, the US Joint Polar Satellite System, together with the Japanese GCOM-W1 mission and the French-Indian Megha-Tropiques mission.
The primary purpose of the GPM Core Observatory is to set a new standard for precipitation measurements from space. It will achieve this by providing a radiometric reference to reconcile differences among constellation radiometer using the GPM Microwave Image (GMI) as a transfer standard. The non sun-synchronous orbital characteristic of the Core satellite is such that will cross all of the orbital planes of the contributing satellites, enabling occasional co-temporal observations to be made. The GPM Core will improve the sampling of the GPM constellation by filling observational gaps between the individual partner satellites. The Core satellite, hosting both active and passive microwave instruments will be capable of providing an a priori observational hydrometeor database consistent with Dual-frequency Precipitation Radar (DPR) and GMI measurements to unify and improve precipitation estimates from the Core satellite and subsequently, the constellation (Hou, 2011).

The Core satellite (see figure 1) will be placed into a non sun-synchronous orbit with an inclination of 65° at an altitude of 407 km; this allows the core satellite cross the orbit planes of the other constellation satellites, and allows sampling across the full diurnal cycle.

![Figure 1: An artist’s impression of the GPM Core Observatory deployed in orbit. The GPM Microwave Imager instrument is to the left, the Dual-frequency Precipitation Radar is situated at the base of the satellite platform, while the TDRIS high-gain antenna is at the top.](image)

Two instruments will be carried on the GPM Core satellite. The GPM Microwave Imager (GMI; see Newell et al. 2010), a passive microwave radiometer observing frequencies ranging from 10 to 183 GHz, incorporates innovative features for improved sensor calibration (see Table 1). The Dual-frequency Precipitation Radar (DPR) operating at Ku and Ka bands, is the first of its kind (see Table 2; see Nakamura et al. 2010)). It builds upon the TRMM-heritage, but provides retrieval accuracy and higher sensitivity to light rainfall and snowfall detection relative to TRMM. In particular, it is capable of providing detailed microphysical information (DSD, mean mass diameter and particle number
density) and identification of liquid, ice, and mixed-phase regions (see Grecu et al, 2011; Seto & Iguchi, 2011; Liao & Meneghini, 2011; Minda & Chandrasekar, 2011).

Table 1: Characteristics of the GPM Microwave Imager (GMI)

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.65 GHz (V&amp;H)</td>
<td>19.4 x 32.2 km</td>
</tr>
<tr>
<td>18.7 GHz (V&amp;H)</td>
<td>11.2 x 18.3 km</td>
</tr>
<tr>
<td>23.8 GHz (V)</td>
<td>9.2 x 15.0 km</td>
</tr>
<tr>
<td>36.5 GHz (V&amp;H)</td>
<td>8.6 x 14.4 km</td>
</tr>
<tr>
<td>89.0 GHz (V&amp;H)</td>
<td>4.4 x 7.3 km</td>
</tr>
<tr>
<td>165.5 GHz (V&amp;H)</td>
<td>4.4 x 7.3 km</td>
</tr>
<tr>
<td>183.3±3 GHz (V)</td>
<td>4.4 x 7.3 km</td>
</tr>
<tr>
<td>183.3±7 GHz (V)</td>
<td>4.4 x 7.3 km</td>
</tr>
</tbody>
</table>

Table 2 Characteristics of the GPM Dual-frequency Precipitation Radar (DPR)

<table>
<thead>
<tr>
<th></th>
<th>KuPR</th>
<th>KaPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>13.6 GHz</td>
<td>35.55 GHz</td>
</tr>
<tr>
<td>Swath</td>
<td>245 km</td>
<td>120 km</td>
</tr>
<tr>
<td>Resolution</td>
<td>5 km</td>
<td>5 km</td>
</tr>
<tr>
<td>Range resolution</td>
<td>250 m</td>
<td>250/500 m</td>
</tr>
<tr>
<td>Minimum detection</td>
<td>&lt;0.5 mmh⁻¹</td>
<td>&lt;0.2 mmh⁻¹</td>
</tr>
</tbody>
</table>

3. GPM Supporting activities

The GPM concept also extends beyond the satellite systems to the advancement of techniques to better utilise the satellite-derived precipitation estimates and the understanding of the processes associated with the formation of precipitation. A few examples are included below.

3.1 Enhancing precipitation estimates

It is recognized that for many hydrological applications that there is a requirement for a ‘best available’ product, together with the necessity for such products to be available at a fine temporal and spatial resolution. Many satellite observations also require additional processing and information to ensure consistency as well as an improvement in the resolution. It is therefore desirable to generate a global precipitation product through the fusion of satellite and ground measurements. Research is being undertaken, within the framework of probabilistic estimation and sparse representation, to address these issues. One avenue of research is exploring the statistical characterisation of observation errors at native scales, as a function of surface type, geographic location, season, and rain intensity, to provide measures of errors and uncertainties within the precipitation products. Another path will directly addresses the spatial resolution issue uses optimal non-Gaussian estimation and filtering using wavelet decomposition that preserves precipitation extremes at native measurement scales, enabling finer-scale precipitation estimates to be generated. Data fusion techniques using precipitation (and ancillary) data at multiple-scales is also being explored, incorporating information of uncertainties of individual data types (see Wen et al, 2011; Tian & Peters-Lidard, 2010).
3.2 Hydrology
Hydrology remains one of the key uses of precipitation data sets, requiring information from both surface and satellite instrumentation. The utility of improving the spatial resolution of precipitation estimates has been shown by Nikolopoulos et al (2010) in an analysis of uncertainty propagation of satellite rainfall. The study focused on a number of drainage basins (116 km$^2$ to 1200 km$^2$) over northeast Italy, and found that the resolution of the rainfall products were critical in the determining the hydrologic error propagation. The resolution of the satellites estimates for hydrological modeling was also highlighted by Gourley et al. (2011). Other hydrological-related studies have included estimating and predicting soil moisture (e.g. Maggioni et al. 2011; Serpetzoglou et al. 2010) and the generation of landslide maps based upon surface information and satellite-derived precipitation estimates (see Kirschbaum et al. 2012; Liao et al. 2012; Kirschbaum et al. 2009).

3.3 GPM Field Campaigns
As part of the pre-(and post)-launch activities a concerted effort has been made to study, compare and evaluate observations and measurements made by coincident surface and satellite measurements. A number ground-validation campaigns have been organized in preparation for the GPM mission (see Schwaller & Morris, 2011). These include the 2010 Pre-CHUVA campaign located in Alcântara, Brazil, to study warm rain retrieval; the Light Precipitation Validation Experiment (LPVEx) centered on Helsinki, Finland, to study light rain, shallow liquid/solid/mixed phase precipitation (2010-2011); the mid-Latitude Continental Convective Clouds Experiment (MC3E) in central Oklahoma (2011) and; the GPM Cold-season Precipitation Experiment (GCPEX) in Ontario, Canada (early 2012). Future GPM ground validation will include GPM participation in the HyMeX special observation period in late 2012/3 together with campaigns planned for 2013-16.

4. Conclusions
GPM will offer more accurate instantaneous precipitation estimates through the use of new instrumentation and exploitation of multi-satellite observations. The GPM Core satellite will host advanced radar and radiometer sensors with higher sensitivity to light rain and solid precipitation together with the capable to derive estimates of particle-size distribution parameters from the radar. Better retrieval algorithms have been developed through focused ground validation campaigns to ensure that the new observations are fully exploited, together with the development of the next-generation multi-satellite global precipitation products. Through the inter-calibration of radiometric data from a constellation of passive microwave sensors, unified precipitation retrievals, using a common hydrometeor database, will be possible that is consistent with combined active/passive sensor measurements. For hydrological applications, the generation of high-resolution downscaled regional/global precipitation products through dynamical/statistical downscaling of satellite precipitation observations is seen as critical to improve surface rainfall estimates over regions with ungauged catchments. In addition, the availability of near real-time global data will be very beneficial for operational and societal applications.

5. References:


