THE FOURTH INTERNATIONAL PRECIPITATION WORKING GROUP WORKSHOP

BY CHRIS KIDD, RALPH FERRARO, AND VINCENZO LEVIZZANI

Quantitative precipitation estimates (QPEs) on a global scale are only possible from satellite observations or through numerical weather prediction (NWP) model analyses. Satellite observations, available from a range of sensors that have different spectral, spatial, and temporal characteristics, may be used to generate precipitation products. Techniques used to retrieve rainfall from such observations vary, ranging from relatively simple empirical relationships to physical retrieval techniques. The resulting products are used across many applications such as hydrology, water resource management, and for monitoring temporal and regional changes in precipitation related to climate variability. The International Precipitation Working Group (IPWG) provides a focus for scientists from across the world to advance the measurements of precipitation from space and subsequently exploit the derived precipitation datasets.

BACKGROUND. Satellite observations of the atmosphere are routinely collected from both low-earth-orbiting (LEO) and geostationary (GEO) satellite systems. The LEO observations are exploited primarily for their observations in the passive microwave (PMW) portion of the spectrum and complement the more frequent GEO visible (VIS) or infrared (IR) observations. Simple relationships may be established between the satellite observations and surface datasets, although physical retrieval schemes, based on radiative transfer calculations, are capable of providing additional information such as vertical profiles of precipitation. Over the last decade, the development of such techniques has been greatly aided by the availability of datasets online, enabling algorithm developers to generate products in near-real time. In particular, there has been significant development of multisensor techniques that bring together information from many different observations to improve the accuracy of the satellite QPEs. The use of multisensor observations has also improved the temporal and spatial sampling so that products can be routinely produced at scales commensurate with many user requirements [e.g.,

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WHAT: More than 80 participants representing 18 countries gathered to discuss the latest research and developments in spaceborne quantitative precipitation estimates (QPEs) through 66 oral and poster presentations.
WHEN: 13–17 October 2008
WHERE: Beijing, China

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the Global Precipitation Climatology Project (GPCP) 1° daily product; Huffman et al. 1997]. Today, many techniques produce precipitation estimates at resolutions of 0.25° daily, or finer.

The fourth workshop of the IPWG, arranged over four days, included oral and poster sessions on QPEs from satellite observations and model analyses. Two working group breakout sessions were organized around four topical areas: validation, applications, research, and new technologies. The following sections summarize the meeting highlights as well as the working group recommendations.

HIGHLIGHTS. The first session of the workshop focused on international projects and satellite programs. An initial talk outlined the importance of using satellite precipitation products operationally, particularly for disaster mitigation through the timely dissemination of products. While many precipitation techniques and derived products are available, it was noted that such data use relies on the satellite data being available in real time (or very near real time) and, perhaps more importantly, that the user community is aware that such products are available and can use them effectively. The session continued with a number of updates on current and future programs, such as the Global Precipitation Measurement (GPM) mission, due to launch in mid-2013, and the newly launched Chinese Fengyun-3 (FY-3) satellite. The Chinese mission represents a major milestone in the future of spaceborne precipitation measurement, sending into orbit both passive and active microwave sensors to provide improved quantitative measurements of precipitation. This was complemented by presentations introducing new precipitation products and datasets, such as those of the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Satellite Applications Facility on Support to Operational Hydrology and Water Management (H-SAF) and Japan's Global Satellite Mapping of Precipitation (GSMaP) project.

The next session focused on programmatic activities of the IPWG, including meetings spawned from IPWG initiatives. The IPWG has established regional validation sites in Australia, the United States, Europe, South America, and Japan (see Table 1). These are tasked with comparing 0.25° daily satellite, model, and surface precipitation estimates in near-real time to quantify their differences and identify systematic errors that algorithm developers need to address. These regional sites focus on the representativeness of relatively large-scale precipitation datasets and can be thought of as providing the backdrop to more intensive ground validation studies. Pertinent issues related to the requirements of such validation sites remain, not the least of which is that all are operated voluntarily and on a zero budget but need to meet the requirements of the user community and of the algorithm developers. The validation of precipitation datasets at finer spatial and temporal resolutions—specifically addressed in a meeting report of the first Program to Evaluate High Resolution Precipitation Products (PEHRPP) workshop (see Turk et al. 2008)—was shown in an example of rainfall products over the Pacific Ocean. The performance of the techniques was not consistent across the ocean region, and no single technique was found to be best. The retrieval of precipitation at high latitudes and, in particular, the quantification of falling snow (as opposed to fallen snow) is a major problem for most satellite retrieval techniques. A report from the Second International Workshop on Space-Based Snowfall Measurement (IWSSM) concluded that there is a need for a greater understanding of the complexities of the physical interactions between the radiation stream and the ice/snow particles together with the need for greater model–observational coupling.

The second day of the workshop concentrated on the development and refinement of new algorithms and their applications, including the improved utilization of current data sources and the exploitation of new datasets. Several of the presentations described high-frequency PMW datasets, such as those available from the Advanced Microwave Sounding Unit-B (AMSU-B) instrument, which provides a unique capability for retrieving precipitation over problematic surface backgrounds such as snow/ice and

Table 1. IPWG Web pages.

Main Web page	www.isac.cnr.it/~ipwg/
Regional intercomparison/validation sites	
Australia	http://cawcr.gov.au/projects/SatRainVal/validation-intercomparison.html
United States	http://cics.umd.edu/~johnj/us_web.html
Europe	http://kermit.bham.ac.uk/~ipwgeu/
South America	http://cics.umd.edu/~dvila/web/SatRainVal/dailyval.html
Japan	www-ipwg.kugi.kyoto-u.ac.jp/IPWG/sat_val_Japan.html

coastal regions. The inclusion of the AMSU-B datasets, along with the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager/Sounder (SSMIS) observations, provides important information concerning the generation of many precipitation products, particularly those that combine multisensor and multifrequency information. There are now numerous techniques available to combine these observations, including Kalman filter approaches, which are capable of coping with the range of diverse temporal samples from individual satellite observations.

Of note are the emerging studies into the use of long-term precipitation datasets for climate studies, together with an assessment of dataset continuity and error analysis. Although some of the instrument records are now well established, there are known errors originating from both the individual sensors themselves (such as scan-angle dependencies) and from the orbital drift of the satellites that need to be accounted for. Much ongoing and new research is needed, not only to establish and further the use of suitable methodologies to incorporate data from multiple sensors, but also to ensure that data from the same sensor are correctly spliced together to generate long-term datasets suitable for climate studies.

Validation, new applications, and modeling activities were addressed on day 3 of the workshop. Activities outside the core validation regions of the IPWG were prominent together with the validation of individual techniques. The first validation results of the EUMETSAT H-SAF precipitation products showed that over a Poland test site, the varying techniques used tended to overestimate December–February rainfall and slightly underestimate March–May rainfall. However, it was noted that, in common with findings elsewhere, the identification of precipitation was not necessarily consistent among the different techniques and therefore no single technique was necessarily superior to any other. Similarly, an intercomparison of satellite and surface rainfall products over China at 0.25° 3-hourly resolution showed good correlation statistics (up to ~0.65). Further analysis over South America showed that although the correlations against gauge data were good, regional biases (e.g., interior versus coastal) and system dependency (i.e., convective versus stratiform precipitation) exist. A summary of results from the Tropical Rainfall Measuring Mission (TRMM) was presented, including the development of high-spatial-resolution (4 km) rainfall climatologies. Such products reveal small-scale precipitation features closely linked to orography as well as persistent larger-scale features. They also provide useful information for geomorphological processes that are often rainfall dependent.

Two presentations summarized the usefulness of satellite precipitation products in data assimilation. The work of the Joint Center for Satellite Data Assimilation (JCSDA) was outlined, and in particular the Assimilating Satellite Observations of Clouds and Precipitation science priority. At present only 0.6% of received satellite data are assimilated into models because of a number of issues. The need for better sensor corrections was highlighted, not only to avoid intersensor biases, but also to reduce or eliminate individual sensor biases, such as the emissive reflector biases, found on the TRMM Microwave Imager (TMI). Improved cloud detection and better assimilation of cloudy radiances was also seen as a priority. The European Centre for Medium-Range Weather Forecasts (ECMWF) already assimilates rain- and cloud-affected radiances (although only the total column water vapor is currently used) and has shown a positive impact on forecasting tropical moisture and winds. Comparisons between model reanalysis and satellite precipitation datasets show significant long-term differences in the trends of global precipitation as well as year-on-year biases; for example, the GPCP analysis produces an average of 2.6 mm day^{-1} globally compared with the National Centers for Environmental Prediction (NCEP) reanalysis of ~3.2 mm day^{-1}. Importantly, most satellite-based, long-term precipitation studies show little or no trend in global precipitation, even when incorporating corrections for multisatellite and/or multisensor datasets.

Current state-of-the-art missions were exemplified by the CloudSat mission with a 94-GHz cloud profiling radar (CPR). Although this radar is primarily aimed at providing cloud profiles, it has proved very useful in the identification of light rain and snow. In particular, the greater sensitivity of the CPR has shown that it produces a greater occurrence of precipitation compared with the TRMM Precipitation Radar (PR). For rain rates less than 0.8 mm h^{-1}, the CPR rainfall occurrence is nearly 3 times that of the TRMM PR. The improved sensitivity of the CPR to light rainfall means that a more representative distribution function of precipitation can be produced.

The afternoon of the final day was devoted to the presentation of working group summaries and recommendations (next section). Lastly, the meeting ended with an open-floor discussion to raise outstanding issues and to identify the key recommendations to be put to the Coordination Group for Meteorological Satellites (CGMS).

RECOMMENDATIONS. Participants in the four IPWG sections—applications, validation, research, and new technologies—met both formally and informally during the workshop and presented a summary of their discussions on the final day. Each working group highlighted specific recommendations to help focus the future direction of precipitation research, both internally within the group and also to CGMS members. A summary of their recommendations follows.

Data. All groups noted that it was of critical importance that satellite datasets are made available in near-real time and are of high quality. In particular, the continuation of the Global-IR dataset (Janowiak et al. 2001), used in many techniques, is considered a necessity. This and other datasets require permanent archives and reprocessing where necessary. In addition to existing datasets, new satellite datasets should be exploited, particularly making use of the higher frequencies now routinely available (e.g., 54, 150, and 183 GHz). Protecting these PMW frequencies from radio frequency interference caused by other users remains an ongoing issue, particularly for climate-related studies (see Kidd 2006). Other datasets, such as model data and satellite data from nonprecipitation missions, should be explored to provide additional background information for the retrieval methodologies and techniques.

Precipitation products. The routine generation of satellite precipitation products for the user community was highlighted, particularly the need to mainstream satellite precipitation products into operational use. This could be achieved by raising the visibility of the IPWG activities through its Web pages, distributing the precipitation products through existing networks such as GEONETCast (a global network of satellite-based data dissemination systems), making retrieval software for new algorithm developers readily available, standardizing file names and data structures, and providing data products in commonly used formats together with suitable conversion tools. In particular, since relatively little data are exploited, precipitation products would be better utilized through data assimilation. This technique is somewhat limited, although it has shown improvements in model forecast accuracy in the 6-h to 1-day time frame.

Validation activities. The IPWG has a strong intercomparison/validation record, with a number of regional sites producing near-real-time comparisons of the satellite and model precipitation products (see Ebert et al. 2007). It was suggested that a subcommittee be set up to oversee the operation of PEHRPP, together with a specific validation program aimed at evaluating precipitation products at subdaily time scales. Model precipitation products should ultimately be sought through the involvement of the Working Group for Numerical Experimentation (WGNE). Additional high-quality validation datasets, outside the main regional sites, would be sourced to enable members to evaluate their products over a wide range of climatological regimes; greater involvement from national weather institutions in providing high-quality surface datasets was requested. In addition, a quality index should accompany all validation data to enable the results to be interpreted more appropriately. It was agreed that a white paper would be written on the usefulness of different validation tools to better describe the performance of the range of products now available. Lastly, the group recommended that hydrological impact studies also be used as a means of validating the precipitation products since these are often at spatial scales similar to those used in precipitation validation techniques.

IPWG

Since its establishment in 2001 as a permanent Working Group of the CGMS, the IPWG[1] has initiated four biannual workshops to foster the development of better spaceborne precipitation measurements for numerical weather prediction, hydrometeorology, and climate studies. The workshops focus on the improvement of QPE utilization and address a number of key measurement issues and challenges while also helping participants foster international partnerships (see Turk and Bauer 2006). The IPWG continuously facilitates the development and validation of satellite QPE techniques, even in between the workshops, and acts as a focal point for the user community whereby algorithm developers can make their products available, often in near-real time, to other users. Through this, the developers gain information on the performance of their products, allowing them to address any shortcomings and permitting improvements to be made. Comparison of the satellite QPEs, NWP model outputs, and surface datasets is carried out through a number of regional validation sites in Australia, the United States, Europe, South America, and Japan (Table 1), giving the algorithm developers and user community the ability to monitor and assess the relative performances of the different methodologies.

[1] The IPWG is cosponsored by CGMS and the World Meteorological Organization (WMO)

Improving precipitation retrievals. Foremost among the improvements in the retrieval of precipitation from satellite observations is the identification and retrieval of frozen precipitation. It was noted that modeling chains could be used to understand the relationship between snowfall and radiative transfer interactions, while a better use of emissivity databases from the AMSU of the Television and Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS), developed by the International TOVS Working Group (ITWG), would benefit snowfall retrievals at high latitudes. The combined use of active and passive observations (e.g., CloudSat, AMSR-E, and AMSU-B) is an important area for future research, although sensitivity to low-level precipitation remains an issue; for instance, future spaceborne radars need to be capable of detecting reflectivity to within 100–200 m of the surface with a sensitivity of –20 to –30 dBZ.

New technologies. A number of new satellites and sensors are planned with the potential to improve precipitation retrievals. The groups recognized the importance of a long-term commitment to spaceborne precipitation radars, particularly with the success of the TRMM PR and the CloudSat CPR, and the upcoming radars on the European Space Agency (ESA) Earth Clouds, Aerosols, and Radiation Explorer (EarthCARE) and the GPM-core satellites. Future radar measurements could be further enhanced through the development of spaceborne Doppler systems (e.g., EarthCARE). Lightning data have also proved to be useful in precipitation retrievals, and the members look forward to the new lightning systems to be carried on geostationary satellites such as the U.S. Geostationary Operational Environmental Satellite-R (GOES-R), the European Meteosat Third Generation (MTG), and the Chinese FY-4. The IPWG also views the development of geostationary microwave systems with interest since they would provide observations at time and space scales commensurate with precipitation.

FUTURE PLANS. The IPWG community continues to provide a central focus for precipitation research. Future directions include greater links with the other CGMS working groups (such as soundings and winds) and working with the user community to best exploit the available precipitation products. Two new incoming cochairs who will lead the IPWG over the next two years were appointed at the end of the meeting: George Huffman of Science Systems and Applications, Inc. (SSAI) and the National Aeronautics and Space Administration's (NASA) Goddard Space Flight Center (GSFC), and Christian Klepp of the University of Hamburg. All interested parties are invited to participate in the IPWG; the latest information is on the IPWG Web site (www.isac.cnr.it/~ipwg/).

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