ADVANCING THE REMOTE SENSING OF PRECIPITATION

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Precipitation is the primary driver of the hydrologic cycle and the main input of hydrometeorological models and climate studies. The accuracy of hydrometeorological predictions significantly relies on the quality of observed precipitation intensity, pattern, duration, and areal extent. Rain-gauge data have been the main source of precipitation measurements for hydrometeorological applications. But rain-gauge networks are insufficient on land and nonexistent over the oceans, plus they vary in quality across the globe. Weather radars can provide high-resolution precipitation data in space and time, supplementing the ground-based precipitation observations, but their spatial extent is inadequate to detect global precipitation, much less evaluate weather and climate models at global and continental scales.

The limitations of rain gauges and weather radar systems highlight the importance of satellite-based global precipitation data in forecasting applications and for weather and climate studies. Remotely sensed precipitation estimation has been around since the 1970s, and a number of satellite precipitation retrieval algorithms have been developed over the years for practical applications. Despite significant developments in measuring and characterizing precipitation using remote-sensing observations over the past four decades, however, satellite observations of precipitation remain inadequate at spatial and temporal scales relevant for hydrologic and climate studies.

There are a number of issues that require the development of advanced concepts to address key challenges in satellite-based observations of precipitation. Recent discussions during the Advanced Concepts Workshop on Remote Sensing of Precipitation at Multiple Scales at the University of California—Irvine saw the following research priorities emerge:

- Quantification of uncertainties of individual sensors and their propagation into multisensor products warrants a great deal of research. The application of ensemble generators, data assimilation techniques such as ensemble Kalman filtering, and multivariate statistical simulation methods are highly desirable areas of research to pursue.
- Future improvements in satellite-based precipitation retrieval algorithms rely on more in-depth research on error properties in different climate regions, storm regimes, surface conditions, seasons, and altitudes. Given such information, precipitation algorithms for retrieval, downscaling, and data fusion can be optimized for different situations, leading to more accurate precipitation estimates.
- Based on currently available data, global multichannel precipitation estimates with spatial and temporal resolutions of 4 km and 30 min can be considered as the target dataset that can be achieved in the near future. That is a significant improvement over today's precipitation products, which are most commonly at 0.25° and 3 hourly resolution. At high resolutions, however, achieving desirable accuracy is the main challenge. Extensive development and validation efforts are required to make such a dataset available to the community for research and applications.

- The development of metrics for validation and uncertainty analysis are of great importance. Various metrics with emphasis on different aspects of performance are required so that users can decide which product best fits their purposes/applications. Furthermore, developing diagnostic statistics (shifting, rotation) will help to capture the systematic deficiency inherent in precipitation retrieval algorithms.
- Bias removal—particularly probability distribution function (PDF)-based adjustment—deserves more in-depth research. Ignoring the distribution information in the bias adjustment procedure could result in a loss of information, especially in the tails of the distribution. Near-real-time bias adjustment along with the integration of heterogeneous airborne and ground-based precipitation estimates are the key goals.
- Development of a near-real-time probabilistic uncertainty model for satellite-based precipitation estimates is highly desirable. Currently, there is no operational precipitation uncertainty model available. More research needs to be devoted to developing reliable and near-real-time uncertainty models in order to integrate quantitative uncertainty assessment as a part of the precipitation retrieval algorithm.

Additionally, there was general consensus among the experts and users of remotely sensed precipitation products that further research efforts should concentrate on the following challenges to enhance the application of satellite data in engineering and decision-making:

a) Moving toward higher resolution through the downscaling of satellite-based precipitation products in combination with data assimilation techniques;
b) Improving the latency/timeliness of receiving satellite precipitation products. Given the fact that this latency is one of the primary obstacles in nowcasting, future efforts should be focused to reduce this time lag to less than 30 min;

PHIL CAMPBELLS RESCUE PHIL CAMPBELL

This spring, 19 people named "Phil Campbell" converged on the town of the same name in Alabama to celebrate its 100th anniversary. It wasn't the first time a group of Phils and Phyllises had visited, but it turned into the first relief effort after the town was struck by a tornado on 27 April, killing 28 residents. When the Phils arrived from all over the world, donning their "I'm with Phil" T-shirts, they were more than happy to help. "It was a massive knock on the door to have the chance to come here to help others and to tie things up for me personally," comments Phil Campbell of Glasgow, Scotland. He was particularly able to relate to the town's situation after a storm had wrecked his home years earlier, inspiring him to write a song, "The Tornado Blues." This was the third reunion of Phils, which was originally instigated by a Phil Campbell of Brooklyn, New York. He first heard about the town, which is named for the railroad engineer who built a depot there, on TV and became obsessed with gathering together as many Phil Campbells as possible. The town is likely more than grateful this year. Not only did they aid in the cleanup effort, but the Phils also were able to raise almost $40,000. "I never knew we had so many neighbors around the world," says Phil Campbell, Alabama, Mayor Jerry Mays. (Source: Reuters)

c) Systematic satellite data processing with user options for various data formats (e.g., ASCII, binary, or ArcGIS) is vital for faster integration of satellite data in practical applications, and should be pursued;
d) Ensemble streamflow modeling seems to be the future direction for hydrologic modeling based on remote-sensing data, particularly when uncertainty in streamflow output is of interest. With this in mind, future studies should focus on the development of near-real-time precipitation ensemble generation.

Future research efforts in the aforementioned areas will advance remote sensing of precipitation and will deliver more accurate precipitation estimates with quantified uncertainties. Such reliable remotely sensed precipitation estimates provide a unique opportunity to model the Earth system more accurately.