2009 Progress Report
To The
National Aeronautics and Space Administration
NASA Energy and Water Cycle Study (NEWS) Program

Proposal Title: The Challenges of Utilizing Satellite Precipitation Data for Hydrologic Applications
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1. Project Status and Progress:
The research objective of this project has been in the development of techniques to provide reliable precipitation estimation with scales suitable for hydrological applications. In the past several years, our research emphasis has been on improving the quality and evaluation of satellite-based precipitation estimates as well as on the application of satellite-based precipitation analysis in hydrologic studies. This report summarizes the activities and accomplishments during the period of year 2009, including:

(1) Investigation of the drought and flood events in the Southern Great Plains (SGP) during 2006-2007
(2) The development of bias adjustment approach of satellite precipitation estimation
(3) Continuing improvement of fine time scale satellite precipitation estimation using GEO & LEO satellite information
(4) Evaluation high resolution precipitation products (HRPP)

(1) Investigation of the Drought and Flood Events in SGP During 2006-2007
In part of the NEWS integrated activities on two year drought and flood analysis, we analyzed precipitation data from GPCP measurements near the Oklahoma region. As shown in Figure 1, the Palmer Drought Severity Index (PDSI) displays the dryness and wetness of the study period. Rainfall patterns from several precipitation measurements, including the Oklahoma Mesonet, GPCP monthly measurement, and TRMM over a 5x5 degree box (32.5-37.5N, 95-100W), are also presented. The anomalies with respect to its long-term average rainfall are also provided (see Figure 1(e)). The PDSI shows that the drought occurred in spring 2005 and was then terminated by moderate precipitation during summer 2005. Severe drought started in late fall 2005 and extended to the end of 2006. In 2006, precipitations are below average for most of the year. Other than year 2006, precipitations in year 2007 are largely above the average rainfall. More detail analysis can be found from Dong et al. 2009.
Figure 1. (a) Monthly Oklahoma state mean PDSI, (b) monthly accumulated precipitation measured over Oklahoma by Oklahoma Mesonet, and over a 5°x5° grid box (32.5-37.5°N, 95-100°W) by Global Precipitation Climatology Project (GPCP) and TRMM, and (c) the monthly anomalies relative to corresponding long-term averages.

(2) The development of Bias Adjustment Approach of Satellite Precipitation Estimation

Reliable precipitation measurement is a crucial component in hydrologic studies. Although satellite-based observation is able to provide spatial and temporal distribution of precipitation, the measurements tend to show systematic bias. In the study period, adjustment of satellite-based rainfall estimation using global GPCP rainfall estimation is explored. This approach enables the adjusted satellite-based rainfall estimation to match GPCP rainfall at monthly scale, and provide bias adjusted satellite-based rainfall at sub-daily scale. The preliminary results show effective in downscaling of low spatial and temporal GPCP rainfall estimation to sub-daily rainfall from PERSIANN estimation.

Figure 2 shows the effectiveness of the bias downscaling approach applied to daily PERSIANN estimates for May, 2007, which is then evaluated using NCEP gauge adjusted radar estimates at 0.25-degree. The left-hand panel of the figure shows the day-by-day evaluation statistics. The right-hand panel shows the daily rainfall of “before” (upper-left-hand figure) and “after” adjustment as well as the reference NCEP gauge
adjusted rainfall on May 6, 2007. Clearly the daily RMSE and BIAS are improved on
those few days with high bias, while daily CORRs remain about the same. The evaluation
on May 5, 2006, shows that the precipitation intensity and distribution of adjusted
PERSIANN rainfall is much better matching to the NCEP gauge adjusted rainfall. This
demonstrates that the bias adjustment at monthly scale and bias downscaling to the daily
scale can be effective.

The downscaling approach is planned to be used to retrospectively process PERSIANN
starting with 1983 for which the IR images from GEO satellites are available. We intend
to generate daily PERSIANN rainfall at 0.25-degree scale, which will be used to
downscale GPCP monthly precipitation to the daily scale using PERSIANN estimates.

For regions where daily gauge precipitation measurements are available, the local
downscaling approach can be used to further adjust PERSIANN-CCS estimation bias.
In our report, Boushaki et al, (2009) introduced a grid-based precipitation merging
procedure in which satellite estimates are adjusted by the Climate Prediction Center
(CPC) daily rain-gauge analysis. The hourly satellite PERSIANN-CCS estimates
were spatially and temporally accumulated to the daily $1^\circ \times 1^\circ$ scale to match the resolution of
CPC rain-gauge analysis. The daily PERSIANN-CCS bias was then downscaled to the
hourly temporal scale to correct hourly estimates. Figure 3 shows a comparison of
diurnal rainfall pattern in July and August over the USDA-ARS Walnut Gulch
Experimental watershed near Tucson Arizona, during the year 2002, 2004, 2006, and
2001-2006 average from the gauge network, the CCS, and the adjusted CCS estimates
(CCSA). Although this figure shows a similar pattern of late afternoon peak from all

Figure 2. NCEP Gauge adjusted radar rainfall data are used to evaluate the effectiveness of
GPCP adjusted PERSIANN rainfall. Right panel displays rainfall from the original PERSIANN,
GPCP adjusted PERSIANN rainfall, and gauge adjusted radar rainfall at daily and 0.25-degree
resolution. Left panel shows the day-by-day evaluation statistics (CORR, RMSE, and BIAS).
precipitation sources, the over estimation of rainfall by the PERSIANN-CCS is observed. As shown in Figure 3, the phase of the monsoon season rainfall shows it is consistent between the gauge and satellite measurement. In addition, it demonstrated that the overestimation from PERSIANN-CCS is improved significantly using daily CPC gauge analysis.

Figure 3. Rainfall diurnal variation for the July and August period of (a) 2002, (b) 2004, (c) 2006, and (d) 2001 to 2006 average over the Walnut Gulch Watershed.

(3) Improvement of Satellite Precipitation Estimation using GEO & LEO Satellite Information

Building on our experience in static mapping of cloud-rainfall fields using GEO and LEO satellite imagery, we continue developing dynamic cloud-motion detection and microwave-IR calibration strategies for near real-time rainfall estimation. This proposed approach, named LMODEL, is based on synergy of recent developments in satellite rain retrieval, cloud modeling and cloud pattern tracking, and sequential filtering theory. The LMODEL concept and preliminary results of the approach has been summarized in two papers accepted for publication in the Journal of Hydrometeorology (Bellerby et al, 2009; Hsu et al, 2009).

Figure 4 shows the rainfall estimation from NEXRAD radar, passive microwave (PMW), and LMODEL. The hourly radar rainfall of 23:00-23:59 UTC on August 27 2006 is shown in Figure 4(a), while the first-half and second-half hour rainfall rate from PMW is listed in Figure 4(b) & 4(c) and from LMODEL rainfall listed in Figure 4(d) & 4(e). As
shown in Figure 4(b)-(c), PMW can only provide limited observation within each 30-minute period, while the LMODEL rainfall estimates (see Figure 4(d)-(e)) may provide extensive estimation of rainfall within sub-hour period.

Figure 4. (a) Hourly rainfall estimated from NEXRAD and 30-minute rainfall estimated from (b) & (c) passive microwave (PMW) and (d) & (e) LMODEL.

(4) Evaluation of high resolution precipitation data through the Pilot Evolution of High Resolution Precipitation Products (PEHRPP) program.

We have started on the PEHRPP suite 4 investigations of large scale features of high resolution rainfall which involves aggregating the PEHRPP datasets and comparing them with existing large scale datasets such as the Global Precipitation Climatology Project (GPCP) and the CPC Merged Analysis of Precipitation (CMAP) across the global domain. Results of this work were presented at the IPWG meeting. Additionally, we continue to provide support to international PEHRPP partners, with ongoing assistance going to colleagues at the South African Weather Service who are in the process of conduction validation activities using a South African gauge dataset. Results of these activities were presented at the 4th IPWG meeting.

2. Collaboration with NEWS Group Scientists

NEWS provides a framework for the integration of research data and models to explain the water and energy cycle at global scale. We are committed to work closely with NEWS science team members in providing unique precipitation observations for the land surface modeling and numerical weather simulation as well as validation activities. In order to provide better quality precipitation observations, we plan our research activities to improve the quality of PERSIANN rainfall data, to address the uncertainty of estimates, and to provide add-on value to using remote sensing precipitation observations for hydrologic applications at the catchment scales.
Collaboration with NEWS investigators is identified and the research collaborations are continuing. NEWS investigations relevant to our activity are listed below:

- **R. Adler** (NASA): NASA Precipitation Measurement Missions
- **R. Koster** (GSFC): Land-Atmospheric Coupling Strength and Soil Moisture Initialization Uncertainty on Subseasonal Rainfall and Temperature Prediction
- **M. Rodell** (GSFC): Integration of Energy and Water Cycle Research Products in Global Land Surface Modeling and Assimilation System

3. **Publications:**

The research results are summarized in a number of reports published or to be published in the peer reviewed journals. Few papers accepted and submitted for publication in the study period are listed below:


