Application of Satellite Data to Drought Monitoring and Analysis

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Introduction

Improving our understanding of weather and climate, along with the development of reliable and uninterrupted precipitation measurement techniques are essential for the proper assessment of droughts. Precipitation plays a dominant role in the global hydrologic cycle and is one of the key variables in drought monitoring and analysis. In recent years, the emergence of various satellite-retrieved precipitation products with high spatial resolutions and global coverage have resulted in new sources of precipitation estimates. However, satellite-based estimates are not well integrated into operational and decision making applications due to lack of information on the associated uncertainties and reliability of these products. The Standardized Precipitation Index (SPI), commonly used in drought analysis, is derived based on long-term rain-gauge measurements. However, rain gauges are sparsely spatially distributed and suffer from lack of areal representation of precipitation, which can be quite limiting for various drought-related analyses, including deriving the spatial extent of drought, and its spatial dependence structure. Given inherent advantages of remote sensing data in terms of spatiotemporal resolution and large area coverage in comparison with traditional in-situ observations, satellite-based data have been widely used for monitoring hydrological processes and land use change variables. This study presents an example implication of the Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN) data and Global Precipitation Climatology Project (GPCP) for drought monitoring and analysis.

PERSIANN Satellite Precipitation Data

The PERSIANN precipitation algorithm applies neural network classification and approximation procedures to infrared (IR) brightness temperature data, derived from geostationary satellites, to estimate precipitation. The PERSIANN algorithm integrates passive microwave data from Low Earth Orbit platforms to calibrate IR–based estimates from Geostationary Earth Orbit (GEO) satellites. The main motivation to integrate infrared and passive-microwave data is to benefit from the strengths and compensate the weaknesses of both types of sensors. The operational version of the PERSIANN algorithm generates precipitation estimates at the 0.25° spatial resolution and every 30 minutes.

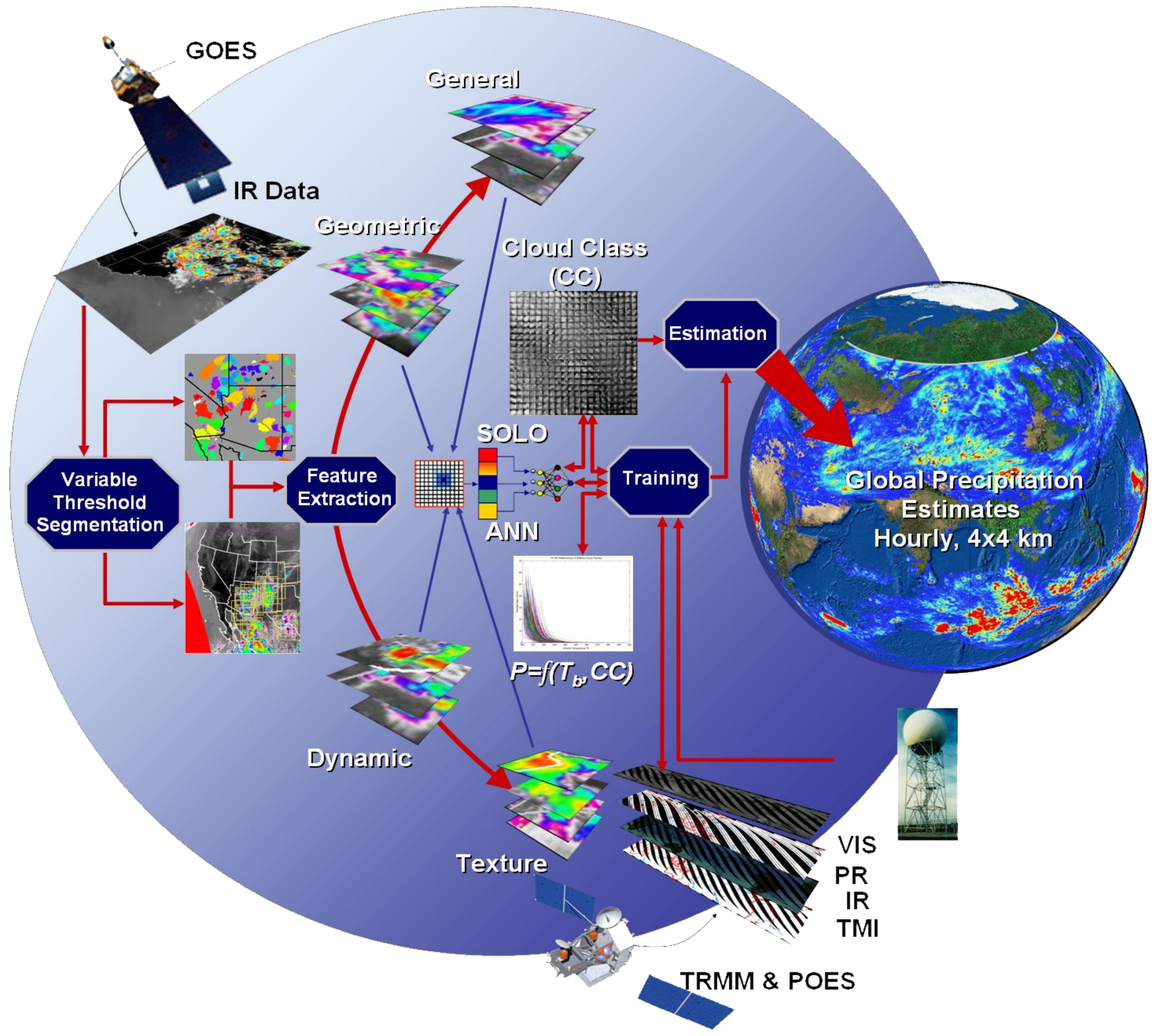

Figure 1 – Components of the PERSIANN Cloud Classification System (CCS) algorithm

In order to improve the precipitation estimates from the GEO satellites, a cloud patch-based classification system has been integrated with the PERSIANN algorithm, allowing precipitation retrieval with a higher resolution of 0.04◦ (see Figure 1). In this algorithm, the retrieval is performed in cloud patch scale instead of pixel scale. In other words, clouds are categorized to patches based on their top temperature levels.

Remote Sensing Precipitation for Drought Analysis

We present an example of applying PERSIANN rainfall to drought analysis. The SPI is derived for each 0.25° pixel across the contiguous United States using data from 2000 to 2010 and Global Historical Climatology Network (GHCN) gauge climatology data. The SPI is designed to identify precipitation deficits at various time scales (3-, 6-, 12-, 24-, and 48-month). To obtain SPI, the precipitation record is fitted to a gamma distribution, and the accumulated gamma probability is then transferred to a normal-distributed cumulative. Figure 2 displays the SPI estimates using PERSIANN satellite data (left panels), and the National Climatic Data Center (NCDC) Global Historical Climatology Network (GHCN) gauge data set (right panels). In the figure, the upper, middle and lower panels show 1-month (June 2008), 3-months (April-June 2008), and 6-month (January-June 2008) SPIs, respectively. Notice that the NCDC analyses (left panels) are in climate division scale, while the figures SPI analyses, shown in the left panels, are performed in pixel scale. One can see that the general patterns of wet and dry conditions are similar in both types of analysis. For example, the figure shows that both 6-month (lower right panel) satellite-based and gauge-based SPI values indicate wet conditions across northeastern United States. This indicates that satellite estimates have the potential to be used in drought monitoring and analysis, particularly over remote areas where no other means of reliable information is available.

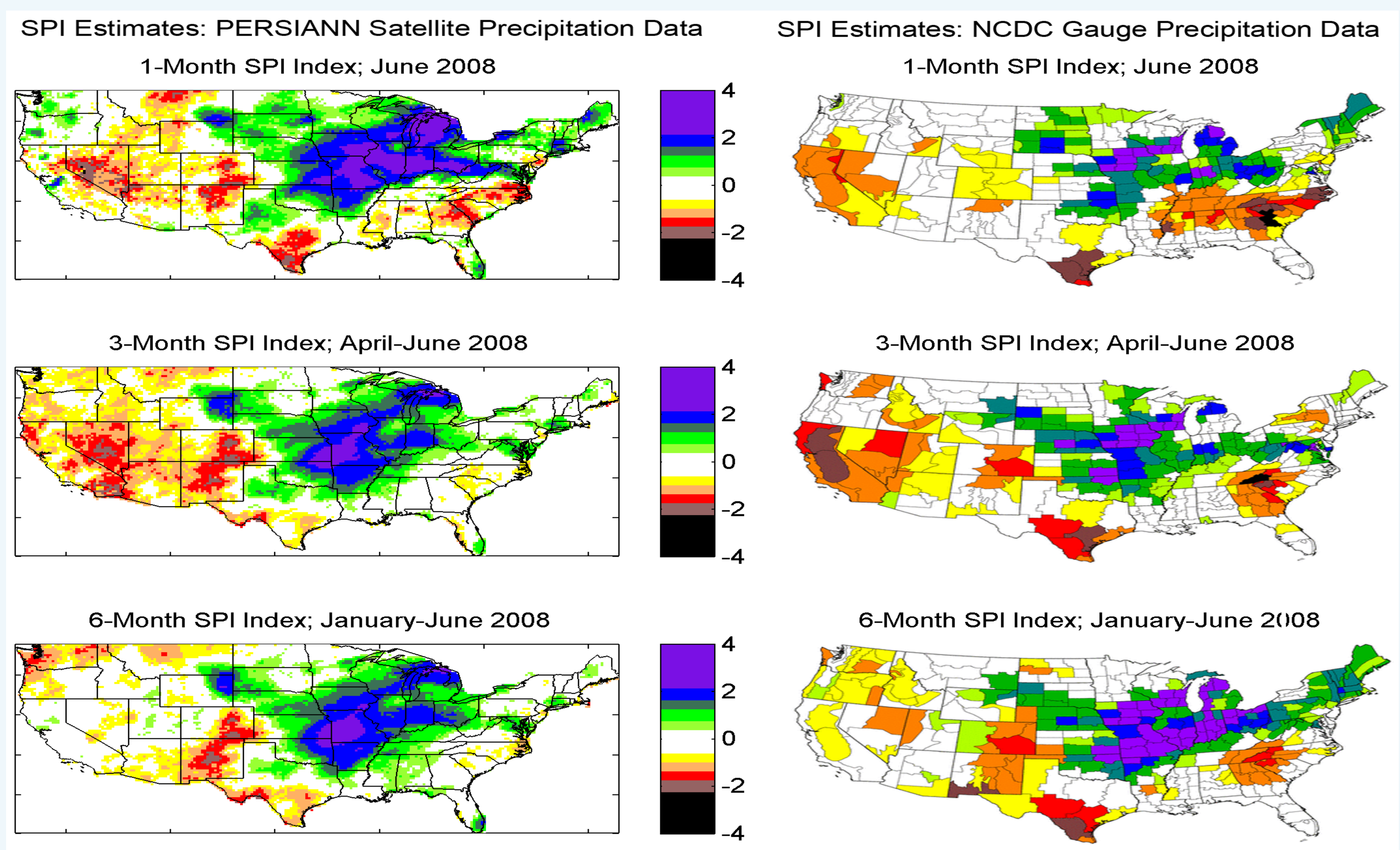

Figure 2. SPI estimates using PERSIANN satellite data (left panels), and the NCDC Global Historical Climatology Network (GHCN) data set (right panels).

For reliable climate research, including drought analysis, long-term global precipitation observations are of primary importance. As mentioned earlier, one of the limitations of the satellite-derived precipitation estimates is their relatively short length of the data. The narrative of satellite precipitation estimation is one of continuous progress toward increasingly better quality and resolution. The NASA's Global Precipitation Climatology Project (GPCP), with global coverage and long-term monthly data, has contributed greatly to weather and climate change studies. However, the data is available with time delay of 3 to 12 months. This, limits application of long-term satellite data to real-time drought monitoring. In this study, as shown in Figure 3, the long-term GPCP satellite data is merged with real-time PERSIANN estimates for drought analysis.

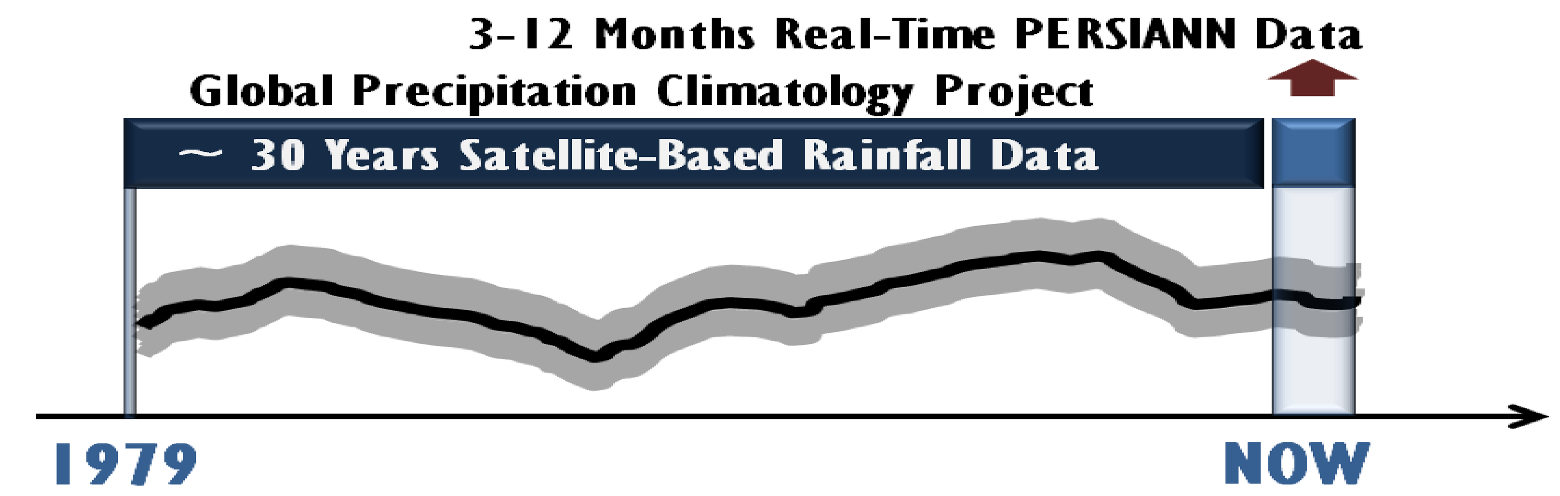

Figure 3. Merging GPCP and PERSIANN data for drought analysis.

In the merged dataset, the climatology is driven by GPCP data and the near past data (3 to 12 months) is based on high resolution PERSIANN data aggregated into 2.5° degree and monthly resolution. Figure 4 displays and example global drought maps derived using this approach.

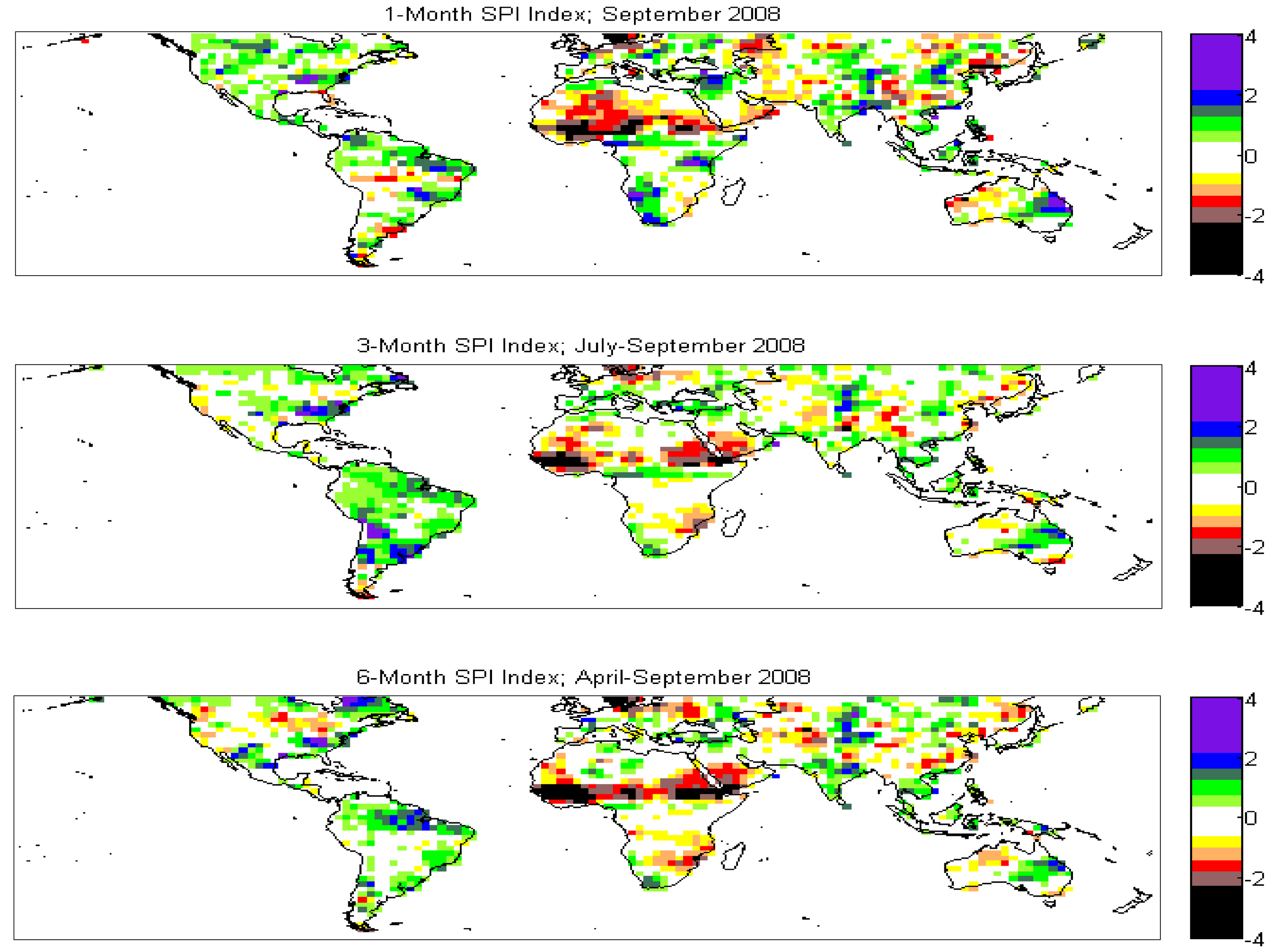

Figure 4. Example global satellite-based drought maps: 1-month (upper panel); 3-month (middle panel); 6-month (bottom panel).

Conclusions

For reliable climate research, including drought analysis, long-term global precipitation observations are of primary importance. As mentioned earlier, one of the limitations of the satellite-derived precipitation estimates is their relatively short length of the data. On the other hand, Long-term satellite-based gauge-adjusted data sets such as GPCP are not available in near real-time for timely drought monitoring. This study intends to merge multiple data sets in order to provide real-time satellite-based drought conditions. Currently, efforts are underway to develop an uncertainty model for the merged data set so that the drought conditions can be expressed probabilistically.

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