Potential application of CloudSat cloud classification maps and MODIS multi-spectral satellite imagery in identifying false rain from satellite images

Nasrin Nasrollahi; Kuolin Hsu; Soroosh Sorooshian– University of California, Irvine
nasrin.n@uci.edu , kuolinh@uci.edu, soroosh@uci.edu

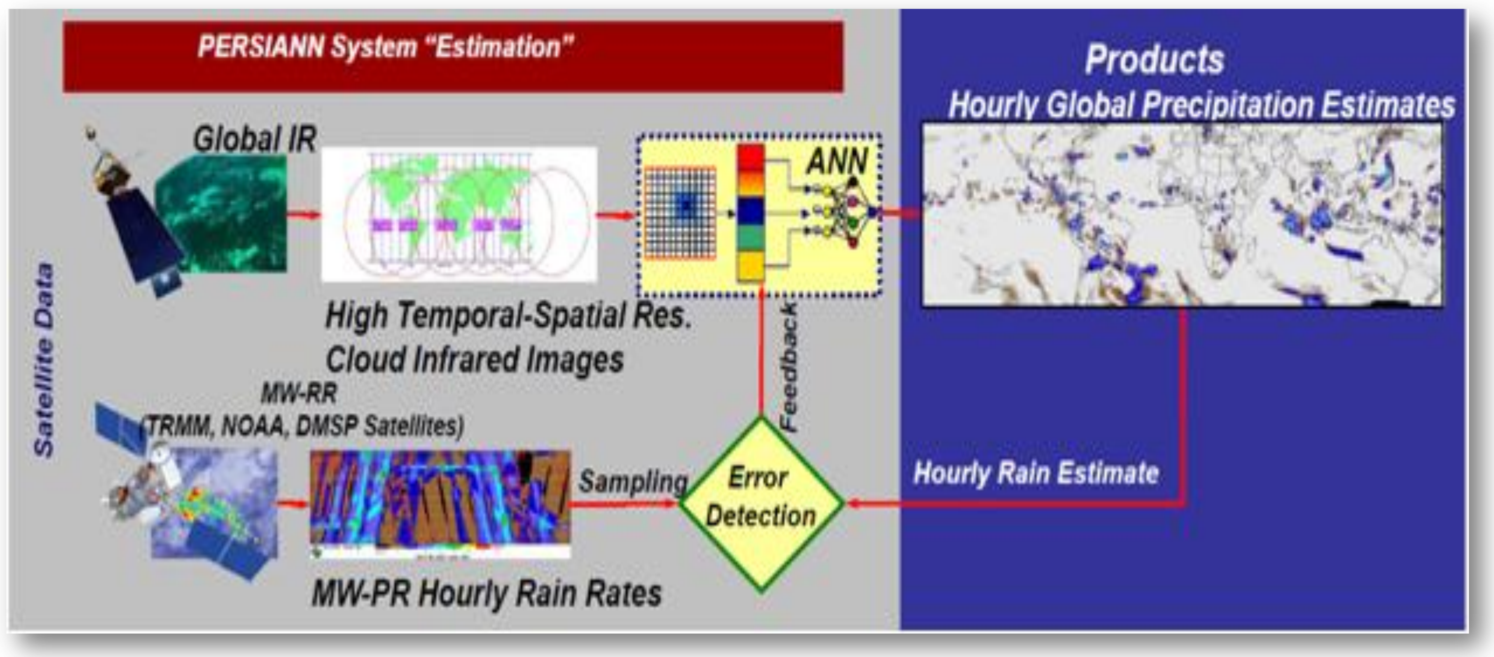
Introduction

Precipitation plays a significant role in the hydrologic cycle and human lives. Floods and droughts, two extremes of precipitation, happen in different parts of the world and can threaten people's lives. Reliable estimation of precipitation is important to predict and manage water resources. However, Spatial and temporal variability of precipitation makes it difficult to rely on gauge point measurements. Higher spatial and temporal resolutions of satellite observations are the main advantages of remotely sensed precipitation estimates over in-situ measurements.



PERSIANN Precipitation Algorithm

Precipitation Estimation from Satellite Observation using Artificial Neural Network (PERSIANN) is based on an adaptive Artificial Neural Network model that estimates precipitation using IR satellite imagery and ground surface information. It also benefits from microwave data obtained from LEO satellites for calibration and adjustments.



Problem Statement

One way to estimate precipitation is using visible (VIS) and infrared (IR) wavelengths. VIS and IR data are available from geostationary (GEO) satellites and have high spatial and temporal resolution. However, they do not measure precipitation directly. One limitation of IR-based algorithms is that non-precipitable cold clouds at high altitudes are often falsely identified as precipitable clouds. The mis-classification of rain/no-rain clouds one of the major issues that IR-based algorithms deal with.

Results of comparison between PERSIANN and ST-IV data (radar based gauge adjusted from the National Center for Environmental Prediction (NCEP) for time period from 2005 to 2008 are presented here.

To investigate how PERSIANN data compares with ground based measurements, the equitable threat score is employed.

POD=H / (H+M)

FAR=F / (H+F)

BIAS=(H+F) / (H+M)

		Observed	
		Yes	No
Satellite	Yes	H	F
	No	M	Z

FAR is the ratio of falsely identified rainy pixels to the total number of rainy pixels in satellite data, whereas POD measures the fraction of observed precipitation that was correctly forecast. POD is defined as the ratio of total number of times that rainfall was correctly forecast to the total number of observed rainy pixels .

The results (Fig. 3 a) show higher false alarm ratio and low probability of detection over western and central United States. Fig.3 also presents the results for summer and winter seasons separately. Generally, satellite precipitation estimates seem to be better during summer, perhaps due to dominance of convective storms. False alarm ratio is very high during winter time because of the presence of non-precipitable high cold clouds.

Problem Statement

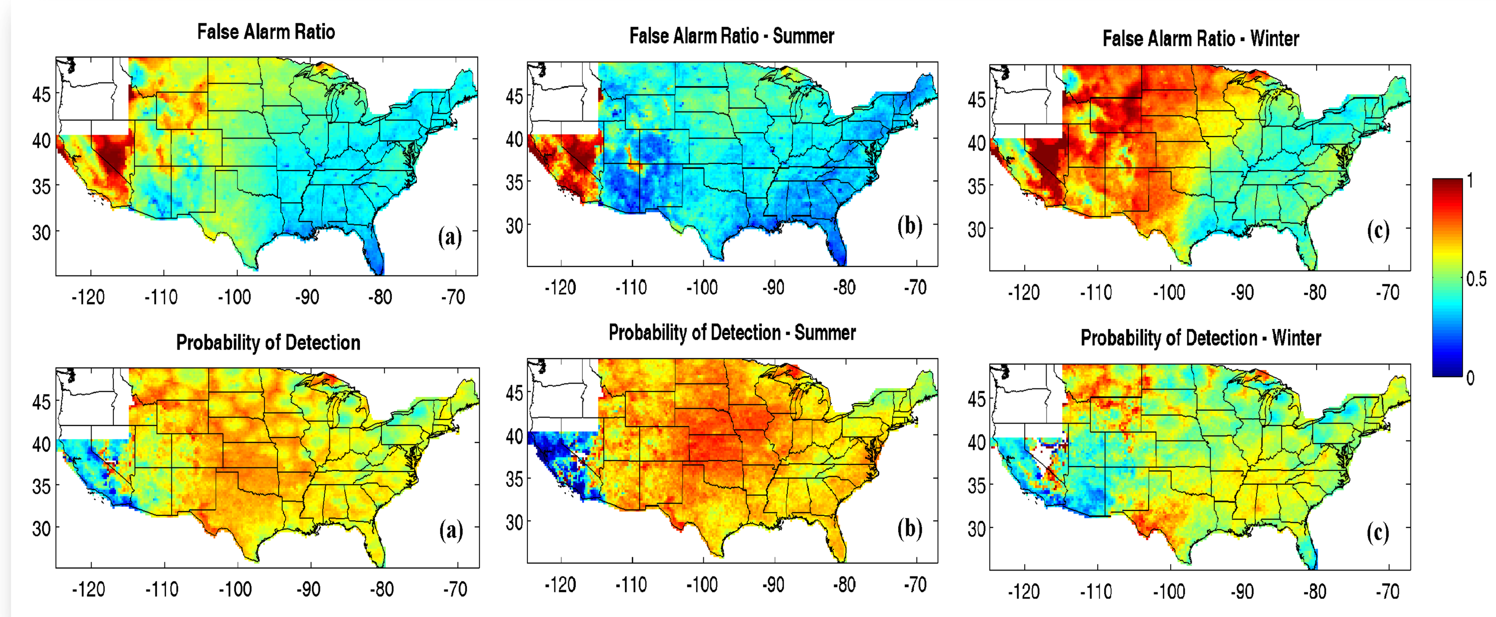
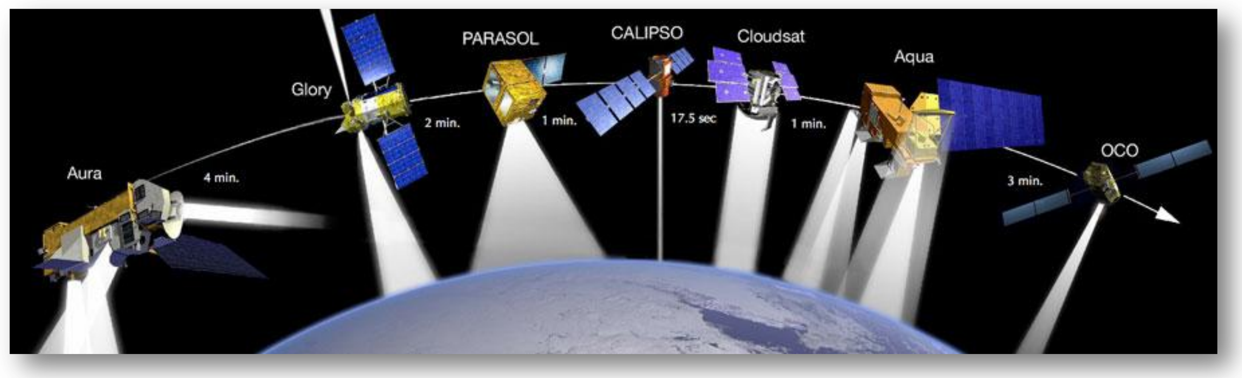


Fig3- False alarm ratio (top panel) and probability of detection (bottom panel) of PERSIANN precipitation data over contiguous USA (2005 to 2008). Panel (b) and (c) represent the results for summer and winter, respectively.

Methodology and Data Sources

In recent years, advanced techniques in remote sensing has provided much valuable information specially about cloud structure and properties that are currently not being used in satellite precipitation retrieval algorithms. The utility of multi-spectral bands in capturing microphysical properties of clouds has been the subject of many investigations. In this study, multispectral data for rain/no-rain (R/NR) detection has been investigated.



Moderate Resolution Imaging Spectro-radiometer (MODIS) with 36 spectral bands and 250 m to 1km spatial resolution, and CloudSat can be used as additional sources of information for better satellite precipitation retrieval. CloudSat, consists of a 94GHz Cloud Profiling Radar, is designed to measure vertical structure of clouds from space. CloudSat and MODIS are both part of the A-Train Constellation with 60 s delay in retrieval.

CloudSat Cloud-type classification:
Cumulus (Cu),
Strato-cumulus (Sc),
Stratus (St),
Alto-cumulus (Ac),
Nim-bostratus (Ns),
Deep convective cloud.
High cloud
Alto-stratus (As), => Non-precip cloud

Fig. 5(a) demonstrates CloudSat overpass through a precipitation event on August 13, 2008 (0545 UTC). The second panel in the figure shows the vertical profile of clouds with different cloud types obtained from 2B-CLDCLASS product. PERSIANN precipitation data (panel c) and radar observation (panel d) corresponding to CloudSat track are presented.
Panel (e), shows that the lowest value of BT11 appears at the location of high clouds and coincides with high precipitation estimations from PERSIANN product.
Fig. 5(f) represents the ability of multi-spectral data to identify different types of clouds. MODIS (BTD[8.5-11]) is strong positive greater than 2K for high ice clouds and greater than 1K for alto-stratus clouds.

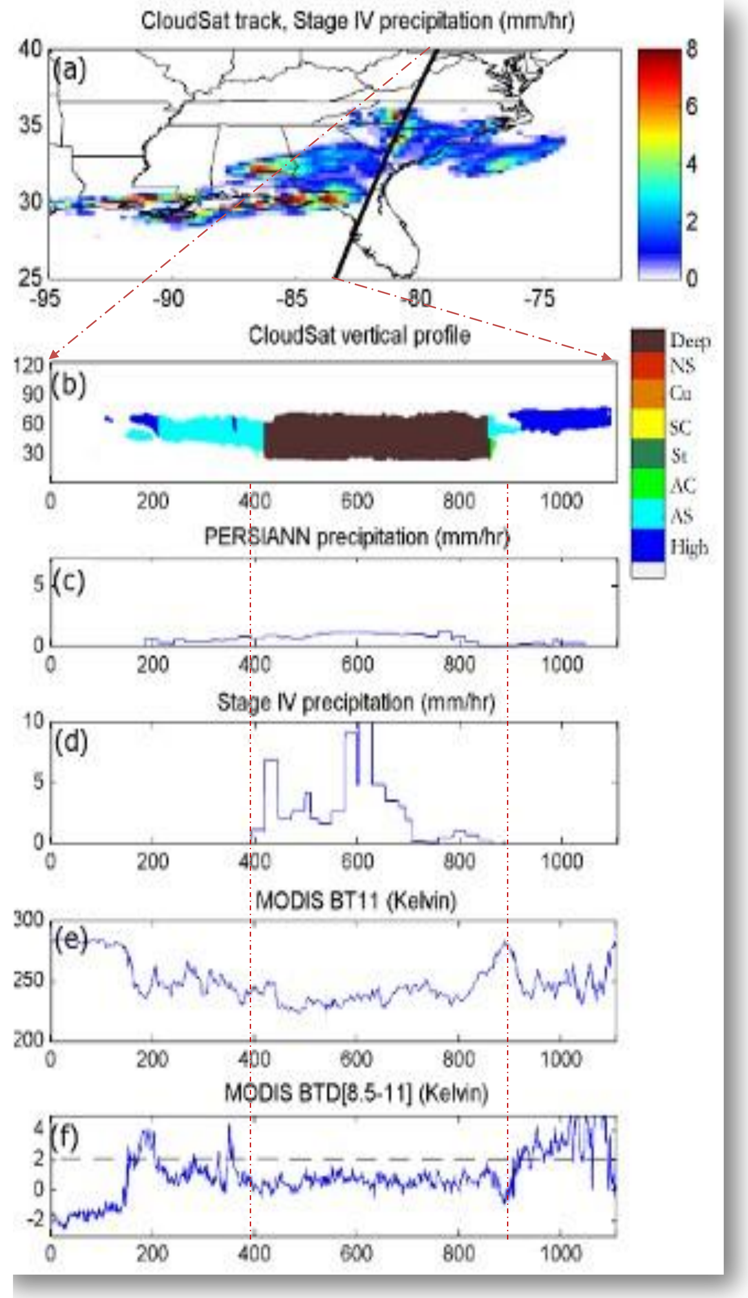


Fig 5- PERSIANN, CloudSat and MODIS data

False rain identification

Artificial neural networks (ANNs), are used to find empirical relationships between a set of 'input' variables and some corresponding 'output' variables. Having multi-spectral data available from MODIS and non-precipitating clouds, recognized with CloudSat Cloud classification product, a 1 layer feed forward, back propagation neural network was employed to identify false rain estimation from satellite imagery.

6 MODIS infrared and water vapor channels , (6.75, 7.325, 8.55, 9.7, 11.03, 12.02 μm wavelength) are set an input variables to the ANN model to recognize different pattern of rain and no-rain clouds. The trained ANN model was then applied to the MODIS satellite imagery to find the non-precipitable cloud coverage in each MODIS retrieval. Fig. 6 shows the result of applied technique for non-precipitating cloud identification that corresponds to the false rain estimation.

Fig.6 (a) shows precipitation estimation by Stage IV precipitation for Aug. 13, 2008 (0545 UTC) on the left and Jul. 22, 2008 (0805 UTC) on the right. Panel (b) on the figure represents corresponding PERSIANN estimation (mm/hr). Figure 6(c) demonstrates the false alarm precipitation that can be removed using the proposed method. Data in panel (c) are from 2 consequent MODIS granules with about 5 minute delay from each other(region between solid black lines). Pixels with false precipitation are shown with red and blue. Blue color highlights the location of high cirrus clouds that are detectable using the proposed method (ANN). From the total number of pixels with false precipitation, more than 86 and 89 percent of pixels are identified with the current method.

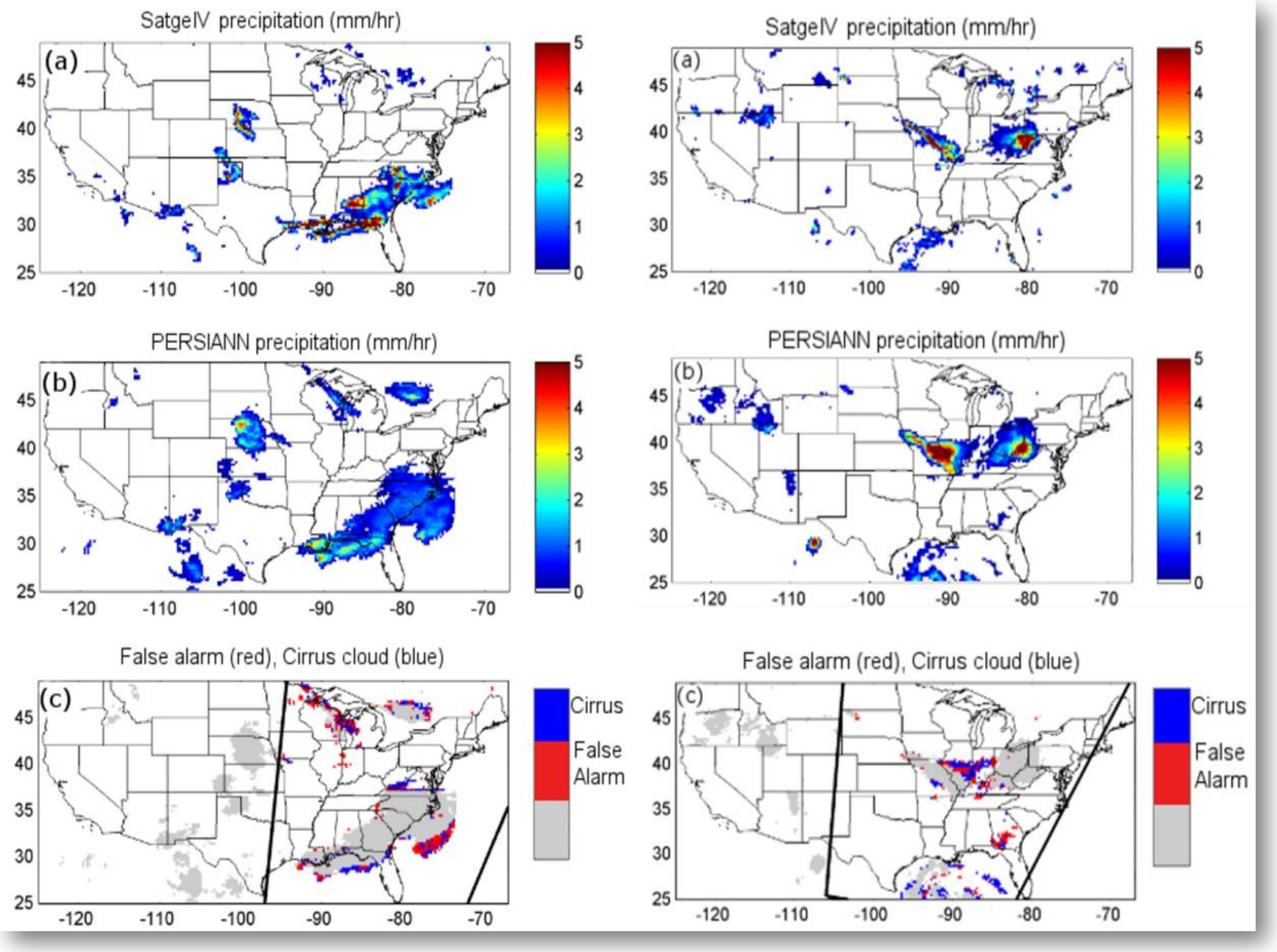


Fig 6. False alarm detection using MODIS 6 spectral bands and CloudSat CLD-CLASS August 13, 2008 (0545 UTC) and July 22, 2008 (0805 UTC), respectively

Conclusion & Acknowledgement

Using cloud classification maps from CloudSat satellite data along with multispectral data from MODIS shows promising results in non-precipitating high cloud detection that cause false alarm of precipitation in satellite precipitation algorithms.
An artificial neural network technique was used to learn from CloudSat cloud classification data and identify non-precipitating clouds. 6 infrared and water vapor channels from MODIS was used as input data to the ANN model to train the algorithm. The model then employed to filter non-precipitating clouds in actual MODIS imagery. This technique showed false alarm removal of 86 and 89 percent for 2 case studies investigated in this research.
The proposed technique has the potential to be integrated into near real-time satellite precipitation estimation to reduce false rain from the precipitation algorithms. We expect that reducing false rain will significantly improve the quality of satellite precipitation product for practical applications (e.g. flood forecasting and water resources management).

In future, there is a possibility to include multispectral data from Advanced Baseline Imager (ABI) sensor aboard future GOES-R satellite to overcome the limited retrievals of MODIS.

This research was supported by NASA grant number NNX11AL33H.