

5.1 Advance Technologies in Monitoring and Data Management

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University of California, Irvine*



*11th Workshop of Precipitation Working Group (IPWG-11)
Tokyo Institute of Technology, Tokyo, Japan
15-18 July, 2024*

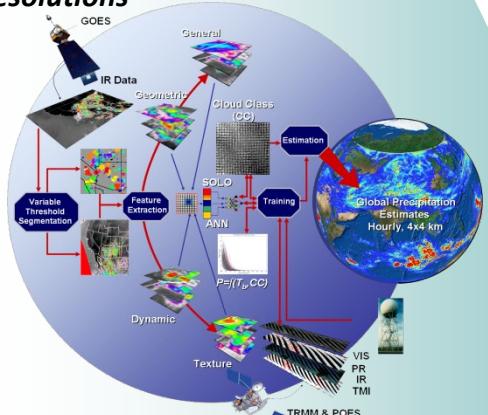


Outline

- *Satellite-based precipitation algorithms using machine learning methods at UC Irvine*
 - *Recent Development: PUnet—A near global rainfall estimation algorithm using U-Net machine learning tool*
 - *Precipitation Climate Data Record: PERSIANN-CCS-CDR*
 - *Summary*
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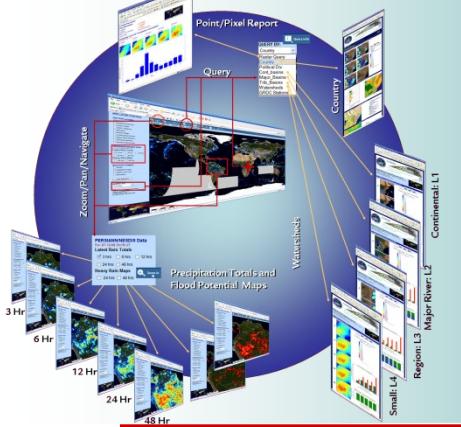
UCI CHRS Remote Sensing Precipitation

Develop state-of-the-art systems to estimate rainfall from satellite observations at global scale and high spatial and temporal resolutions



Information Technology to provide world-wide access to real-time global precipitation products:

<http://hydis.eng.uci.edu/gwadi/>



Goal:

High spatial and temporal resolution of precipitation measurements at global scale for hydrological applications:

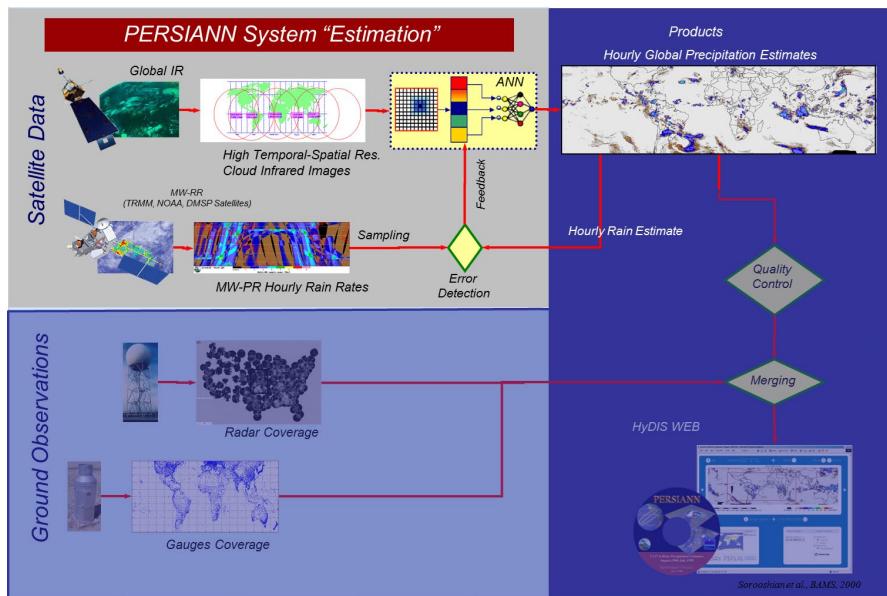
- Short-term operational applications
 - Flood forecasting
 - Data assimilation in numerical weather models
- Long-term climate extreme event analysis
- Hydro-climate studies
- Validation GCM models



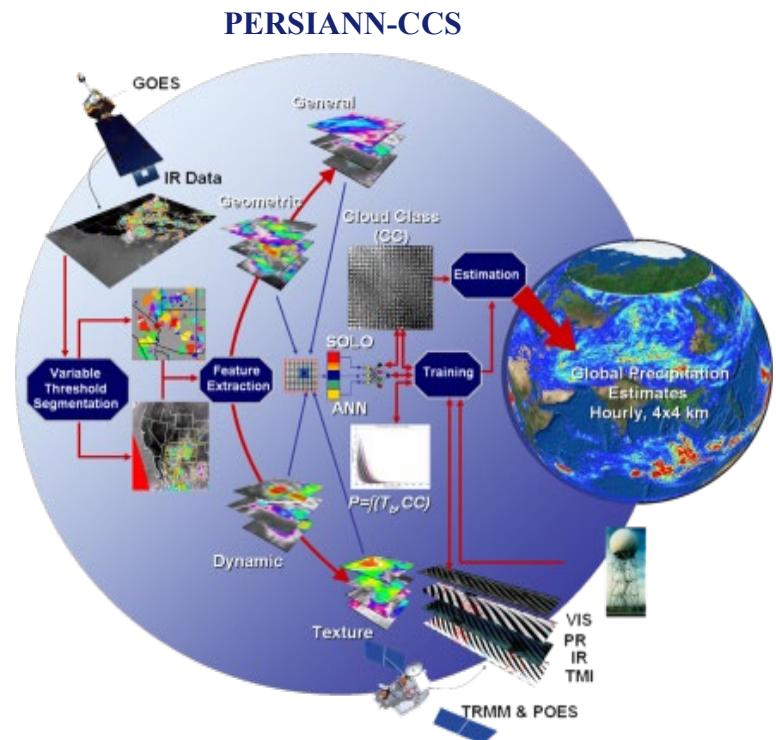
UCI CHRS Satellite Precipitation Algorithms and Products

Algorithm	Method	Input data	Spatial resolution	Temporal resolution
<u>PERSIANN</u> (Hsu et al. 1997)	SOFM	IR	0.25°	30 minutes
<u>PERSIANN-CCS</u> (Hong et al. 2004)	Cloud classification & SOFM	IR	0.04°	30 minutes
<u>PERSIANN-MSA</u> (Behrangi et al. 2009)	SOFM & PCA	IR, VIS	0.25°	30 minutes
<u>PERSIANN-CDR</u> (Ashouri et al. 2015)	PERSIANN & Bias-correction with GPCP	IR, GPCP	0.25°	daily
<u>PERSIANN-SDAE</u> (Tao et al. 2018)	Multiple DAE	IR, WV	0.08°	60 minutes
<u>PERSIANN-GAN</u> (Asanjan et al. 2019)	Generative Adversarial Networks	IR	0.25°	30 minutes
<u>PERSIANN-CNN</u> Sadeghi et al. 2019	Convolutional Neural Networks	IR, WV	0.04°	60 minutes
<u>PERSIANN-cGAN</u> (Hayatbini et al. 2019)	conditional Generative Adversarial Networks	GOES-Multiple channels	0.04°	30 minutes
<u>PDIR</u> (Nguyen et al. 2019)	PERSIANN-CCS + Dynamic Infrared - Rain rate model	IR	0.04°	30 minutes
<u>Deep-STEP</u> (Gorooh et al. 2022)	Convolutional Neural Networks	PMW + IR	0.04°	

Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN)

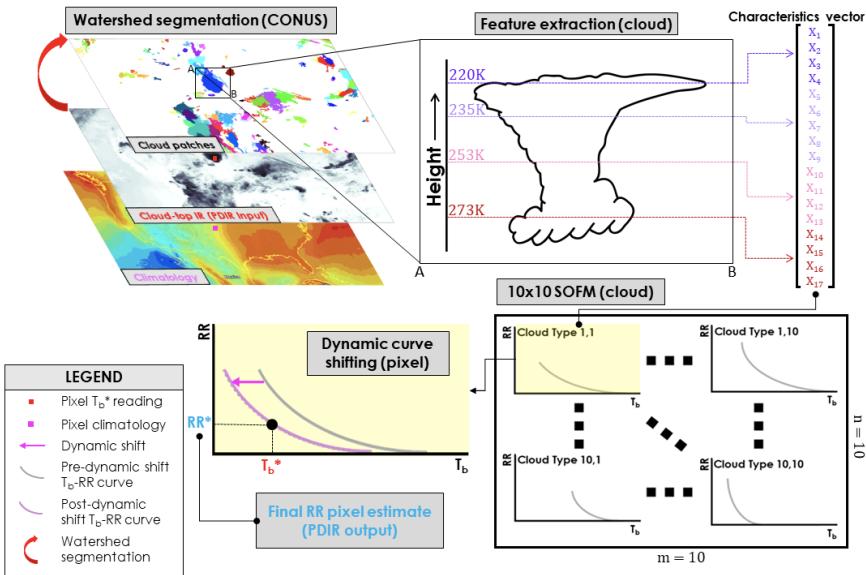


Hsu et al. 1997

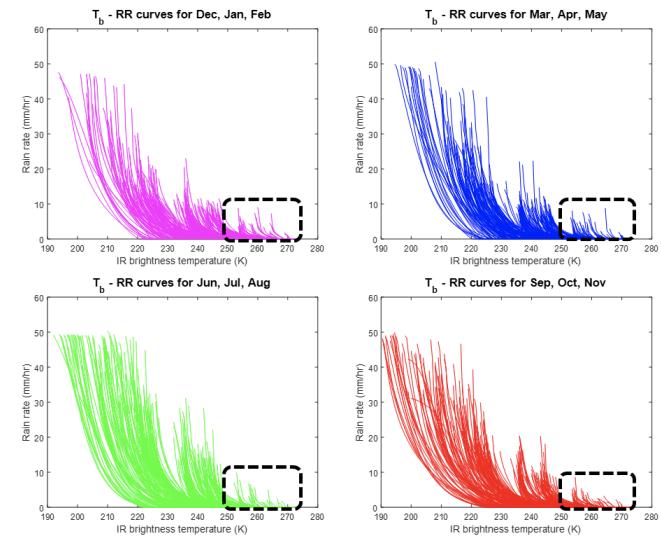


Hong et al. 2004

PERSIANN Dynamic Infrared - Rain rate model (PDIR)



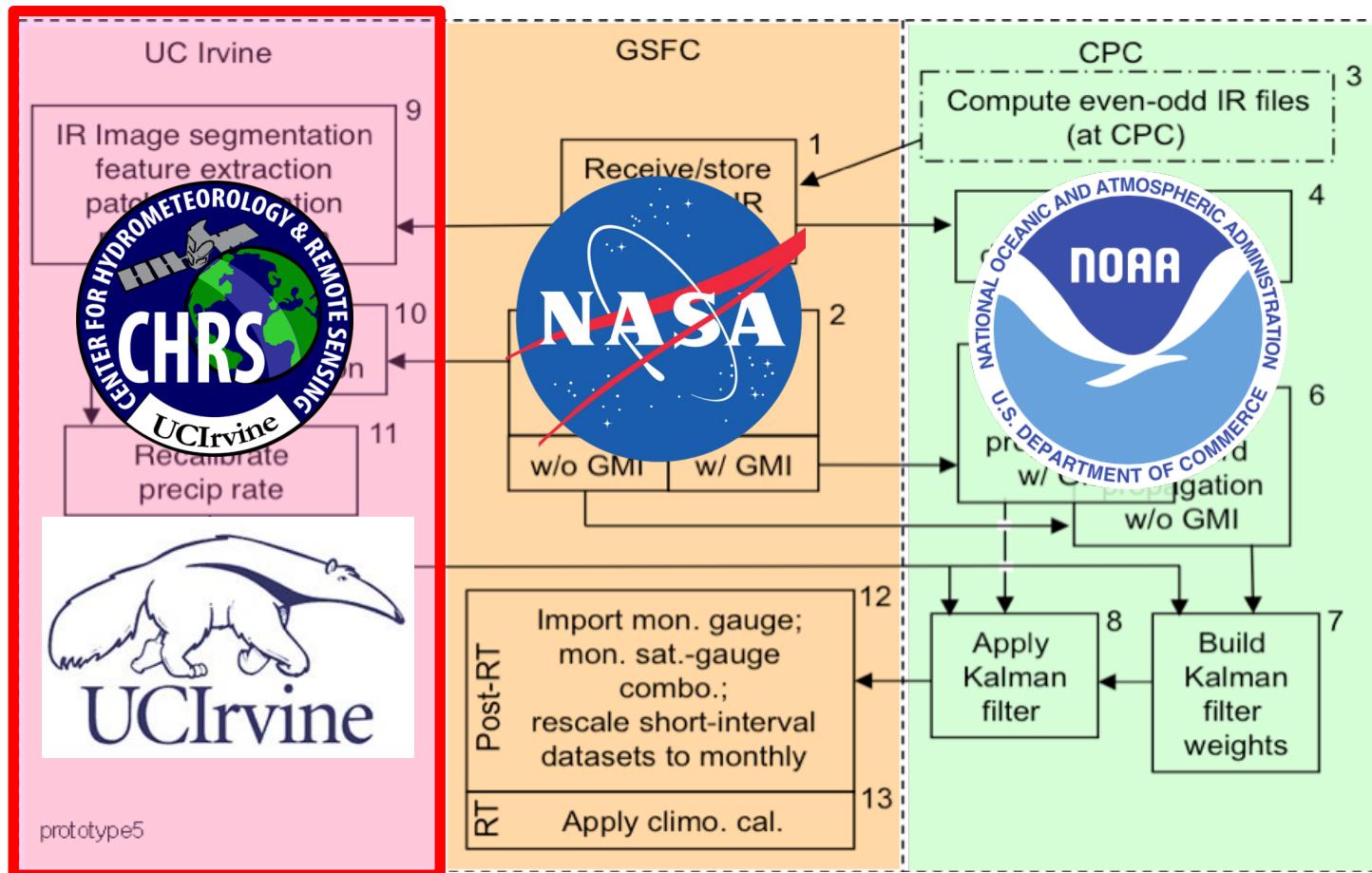
The workflow of PDIR from input to output



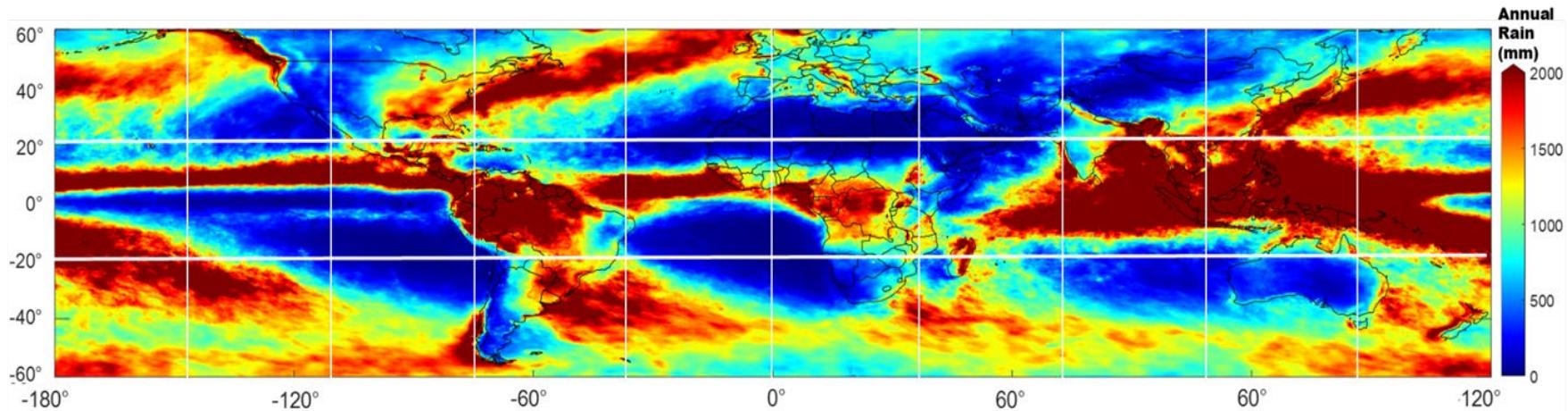
Seasonal plots of 300 Tb-RR curves produced by the monthly SOFMs. Note the presence of distinct clusters of rainfall curves and the capture of warm precipitation (black dashed boxes) in each season.

Nguyen et al., 2020

Integrated Multi-satellE Retrievals for GPM (IMERG)



Tiles vs Global

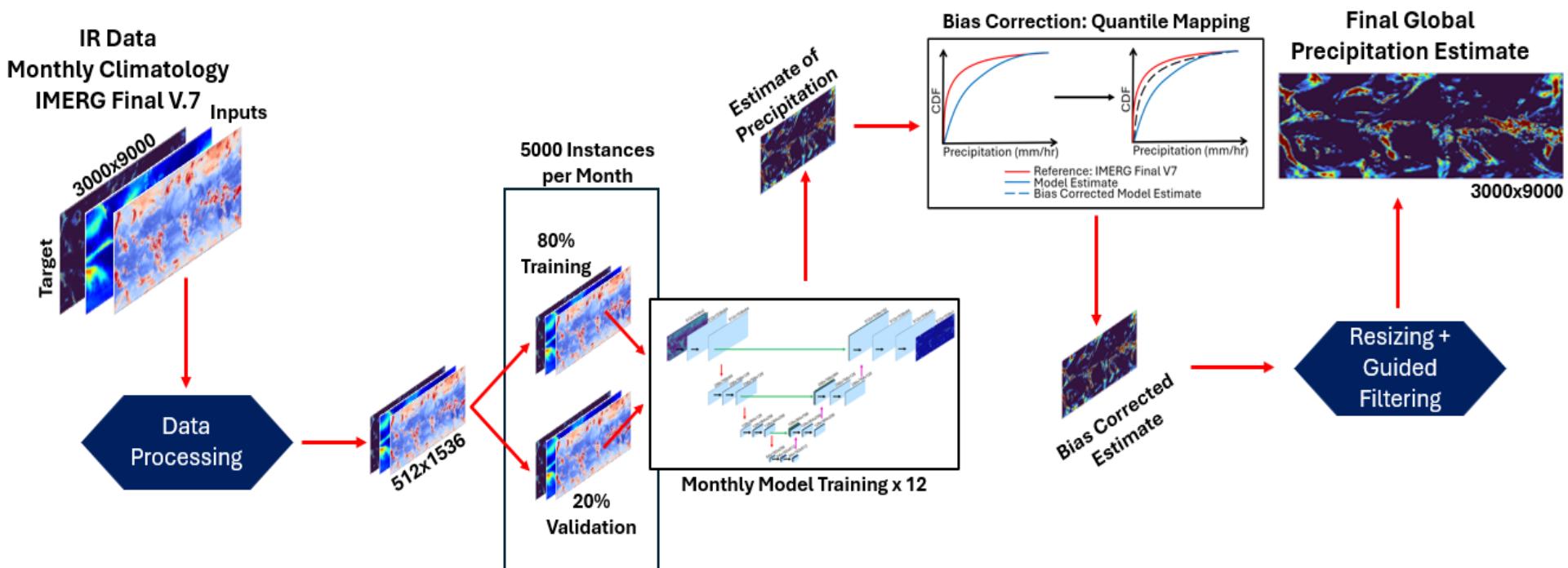


Challenges

Data Uncertainties, Data Displacement, Temporal Difference, Model Structures, Computing Resources

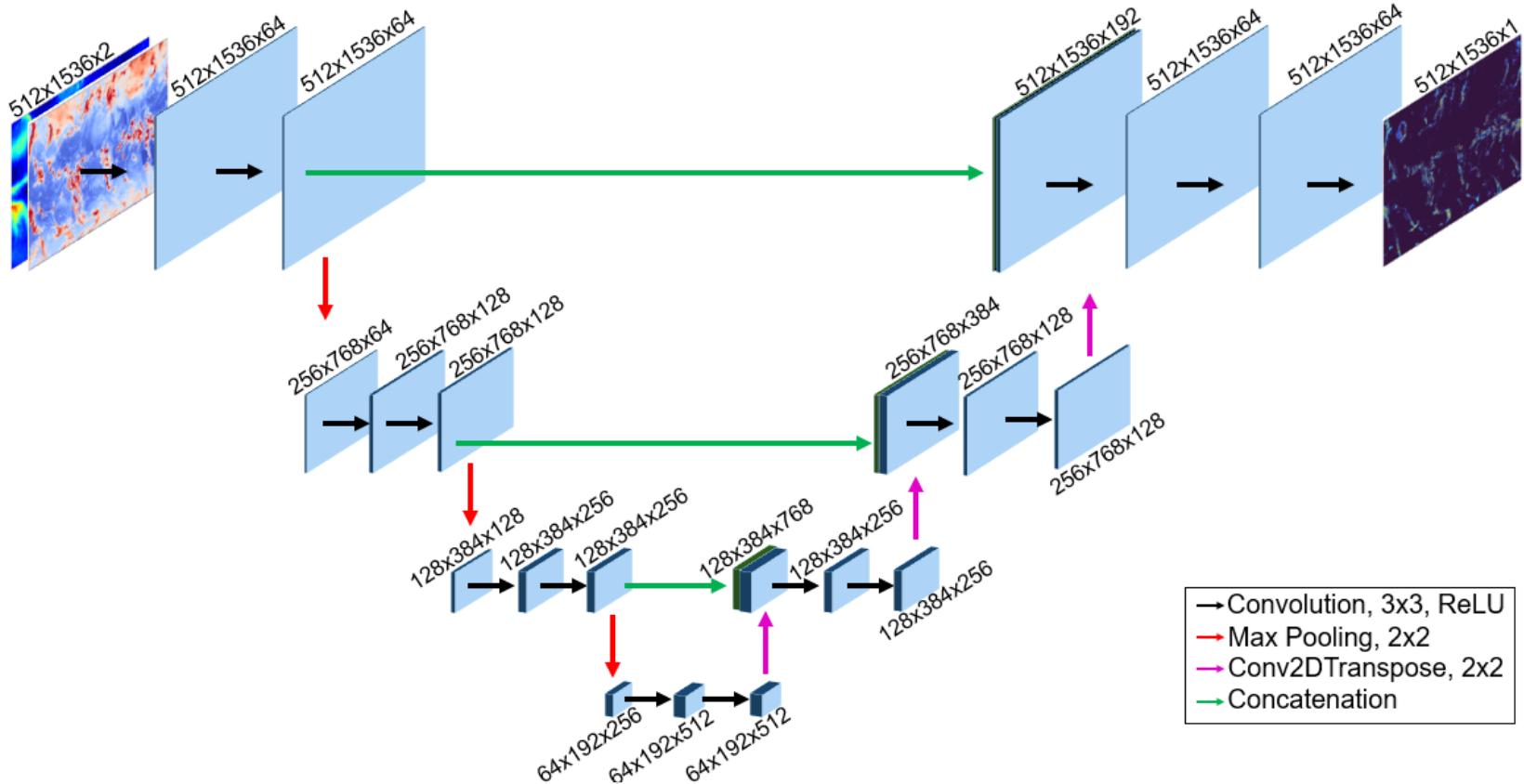
PERSIANN Global Precipitation Estimation Model using Unet (PUnet)

- Input: IR data; Output: rainfall rate mm/hr
- Reference data: IMERG Final V.7
- Upscale training
- Bias correction: Quantile mapping toward IMERG Final V7
- Downscale to $0.08^\circ \times 0.08^\circ$

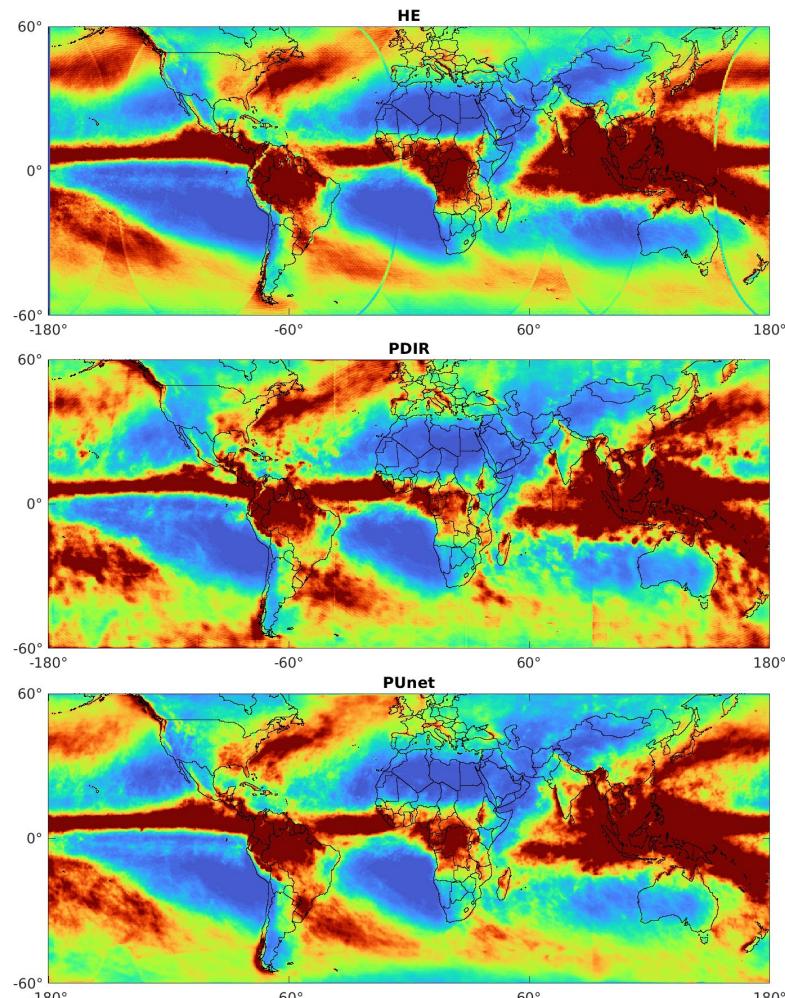


U-Net Architecture

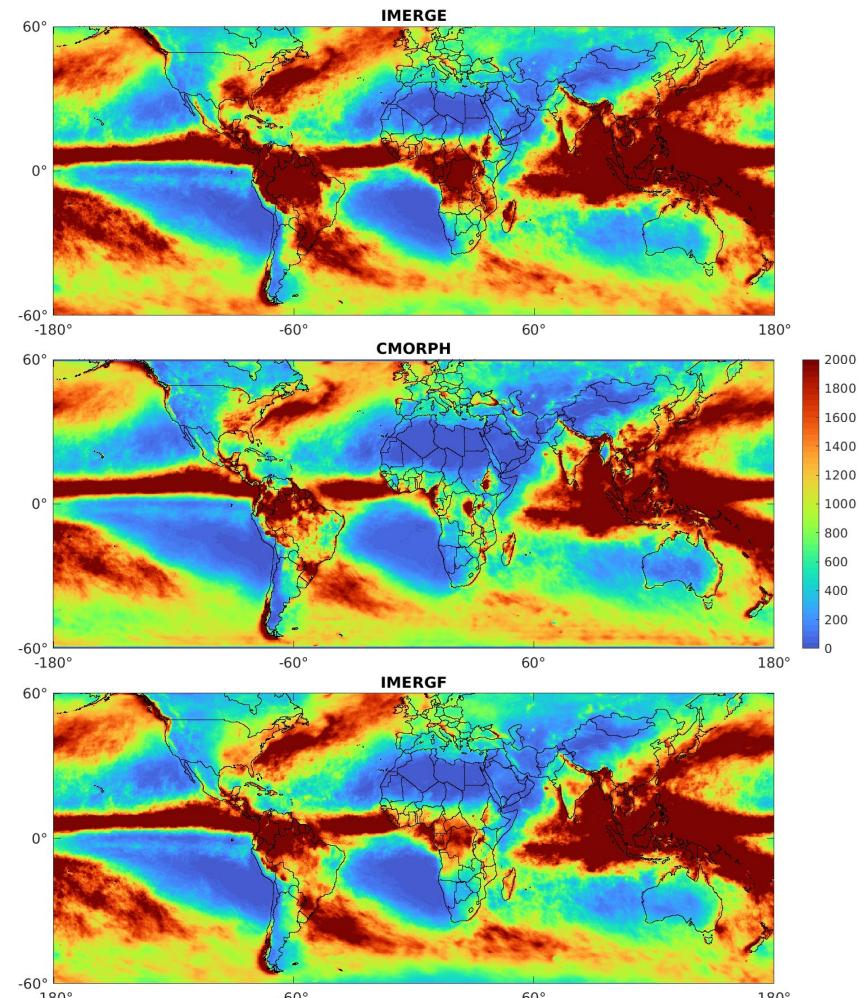
- *A very popular used deep neural network model*
- *Excellent tool for image classification and mapping at high resolution*



Global Evaluation: Annual Precipitation 2022-2023



HE: HydroEstimator
PDIR: PERSIANN Dynamic Infrared
PUnet: PERSIANN Unet



IMERGE: IMERG-Early Version
CMORPH: CPC Morphing
IMERGF: IMERG Final Version

Annual Evaluation 2022-2023

	HE	PDIR	PUnet	IMERGE	CMORPH
<i>Continuous</i>					
CC	0.90	0.93	0.97	0.97	0.94
RMSE (mm)	366.78	298.28	188.22	205.83	275.57
BIAS	0.01	0.01	-0.03	0.08	-0.08

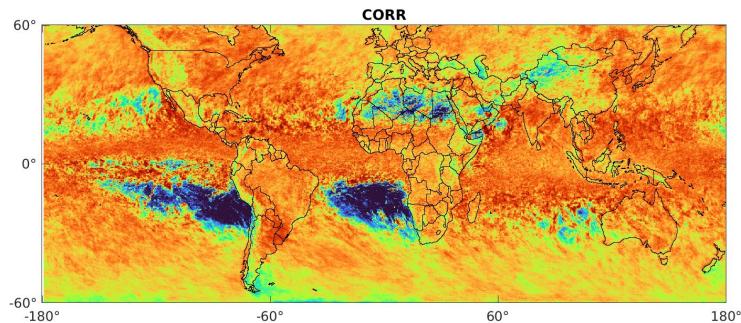
- *PS: Reference to IMERG-Final*

HE: HydroEstimator
PDIR: PERSIANN Dynamic Infrared
PUnet: PERSIANN Unet

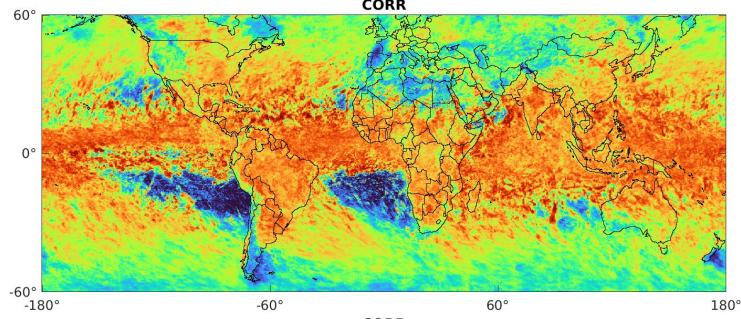
IMERGE: IMERG-Early Version
CMORPH: CPC Morphing
IMERGF: IMERG Final Version

Daily Evaluation 2022-2023: CORR

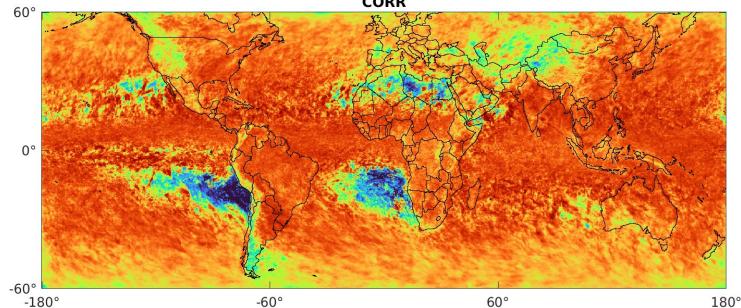
HE



PDIR

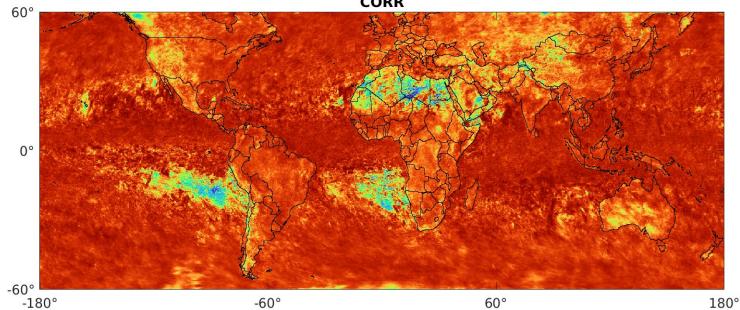


PUnet

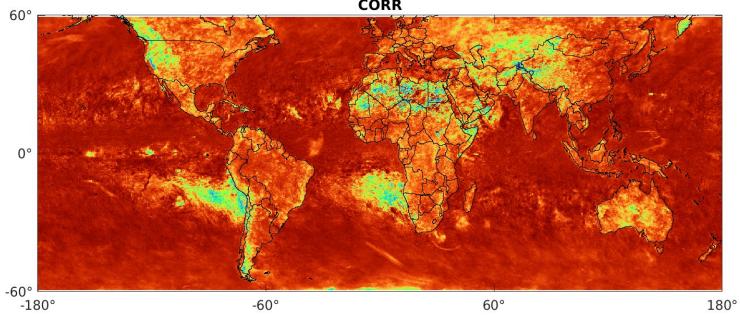


HE: HydroEstimator
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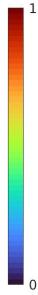
CORR



IMERGE

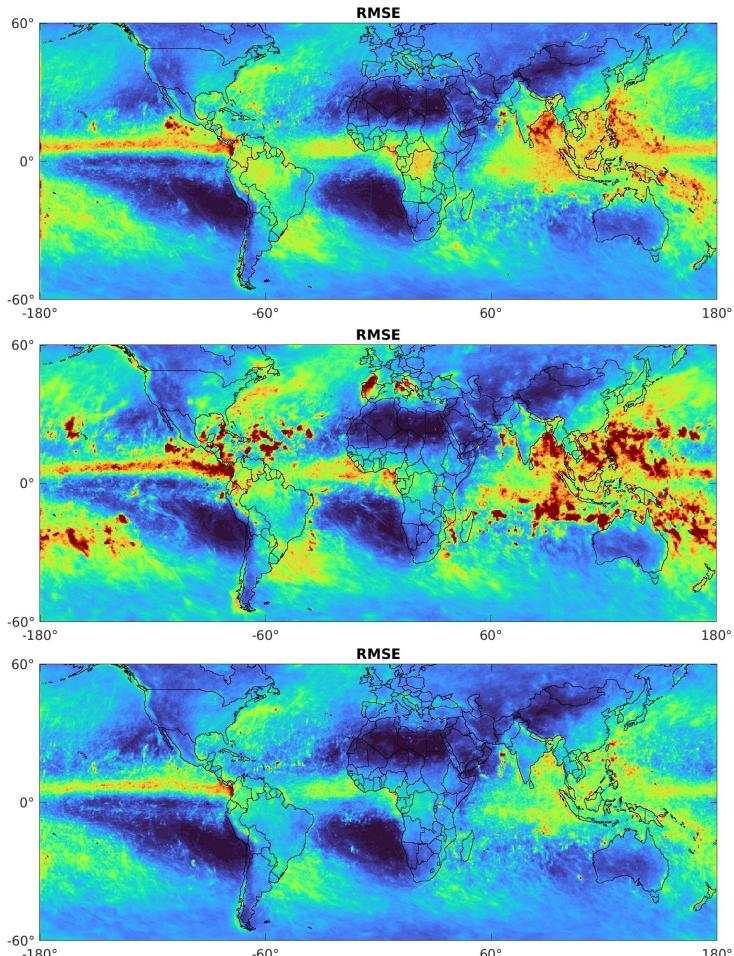


CMORPH

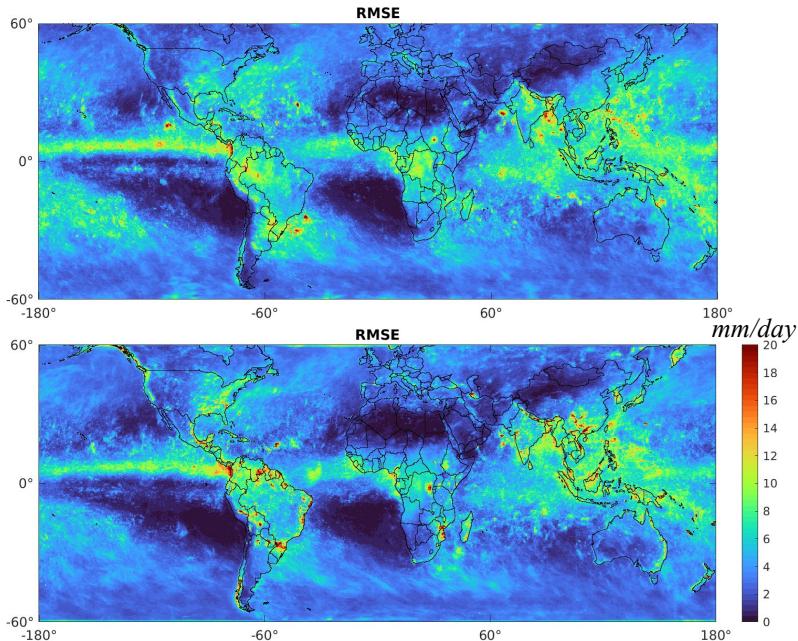


IMERGE: IMERG-Early Version
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Daily Evaluation 2022-2023: RMSE



HE: HydroEstimator
PDIR: PERSIANN Dynamic Infrared
PUnet: PERSIANN Unet



IMERGE: IMERG-Early Version
CMORPH: CPC Morphing
IMERGF: IMERG Final Version

Daily Evaluation 2022-2023

	HE	PDIR	PUnet	IMERGE	CMORPH
<i>Continuous</i>					
CC	0.66	0.56	0.71	0.84	0.86
RMSE (mm)	5.95	7.14	5.32	4.23	3.93
BIAS	0.01	0.13	-0.02	0.17	-0.03
MAE	7.88	12.88	4.96	4.08	3.83
<i>Categorical</i>					
POD	0.64	0.75	0.71	0.89	0.83
FAR	0.25	0.36	0.23	0.19	0.21
CSI	0.52	0.52	0.60	0.74	0.66

HE: HydroEstimator

PDIR: PERSIANN Dynamic Infrared

PUnet: PERSIANN Unet

IMERGE: IMERG-Early Version

CMORPH: CPC Morphing

IMERGF: IMERG Final Version

PERSIANN-CDR

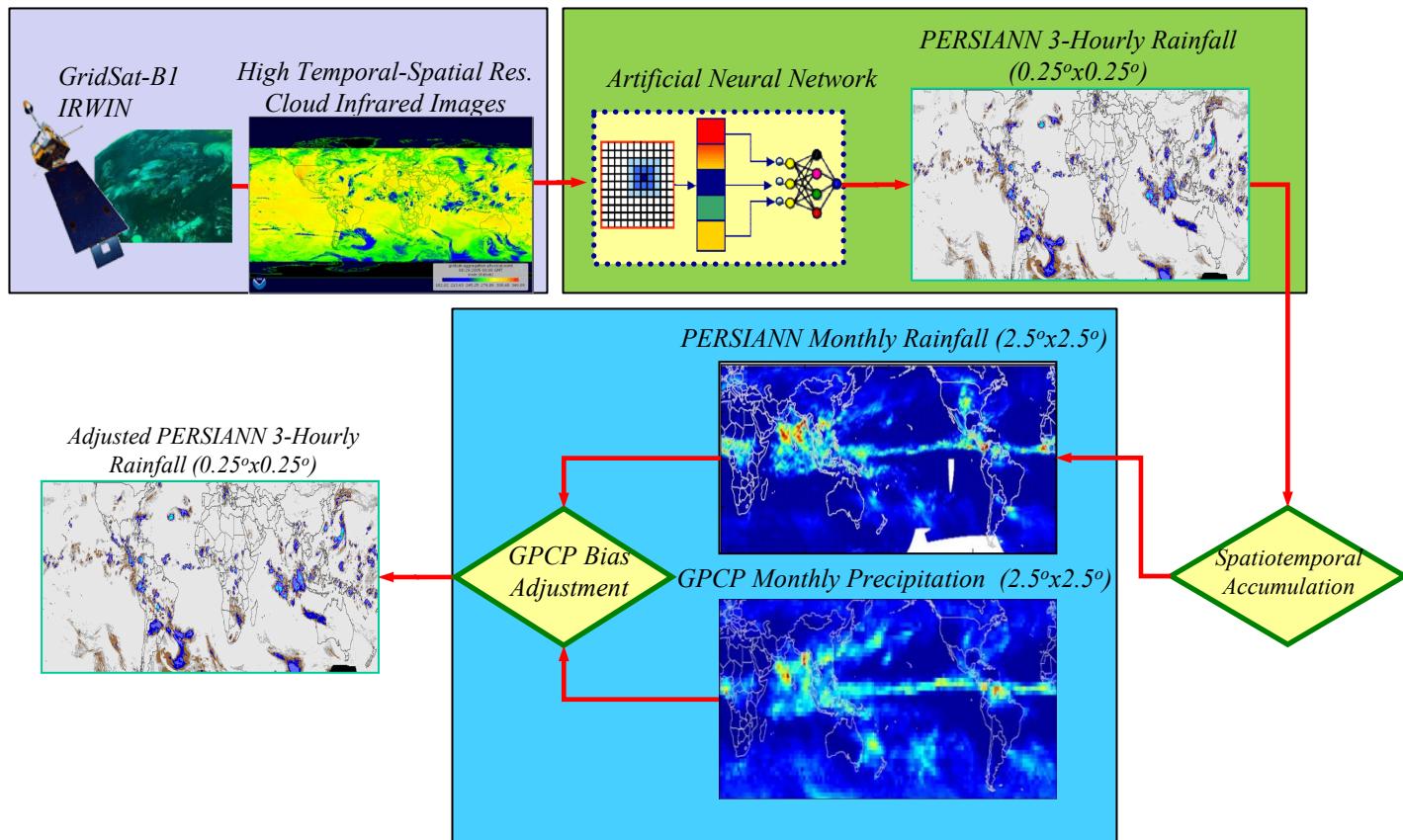
*Precipitation Estimation from Remotely Sensed Information using
Artificial Neural Networks -Climate Data Record*

*Reconstruction of 30+ years of
daily precipitation data (1983 ~2023)*



PERSIANN-CDR

- PERSIANN estimation at 0.25° every 3-hr from GridSat B1 IRWIN
- Monthly accumulation and bias adjusted using GPCP monthly estimation at 2.5°
- Bias adjustment of short-term 3-hr estimation



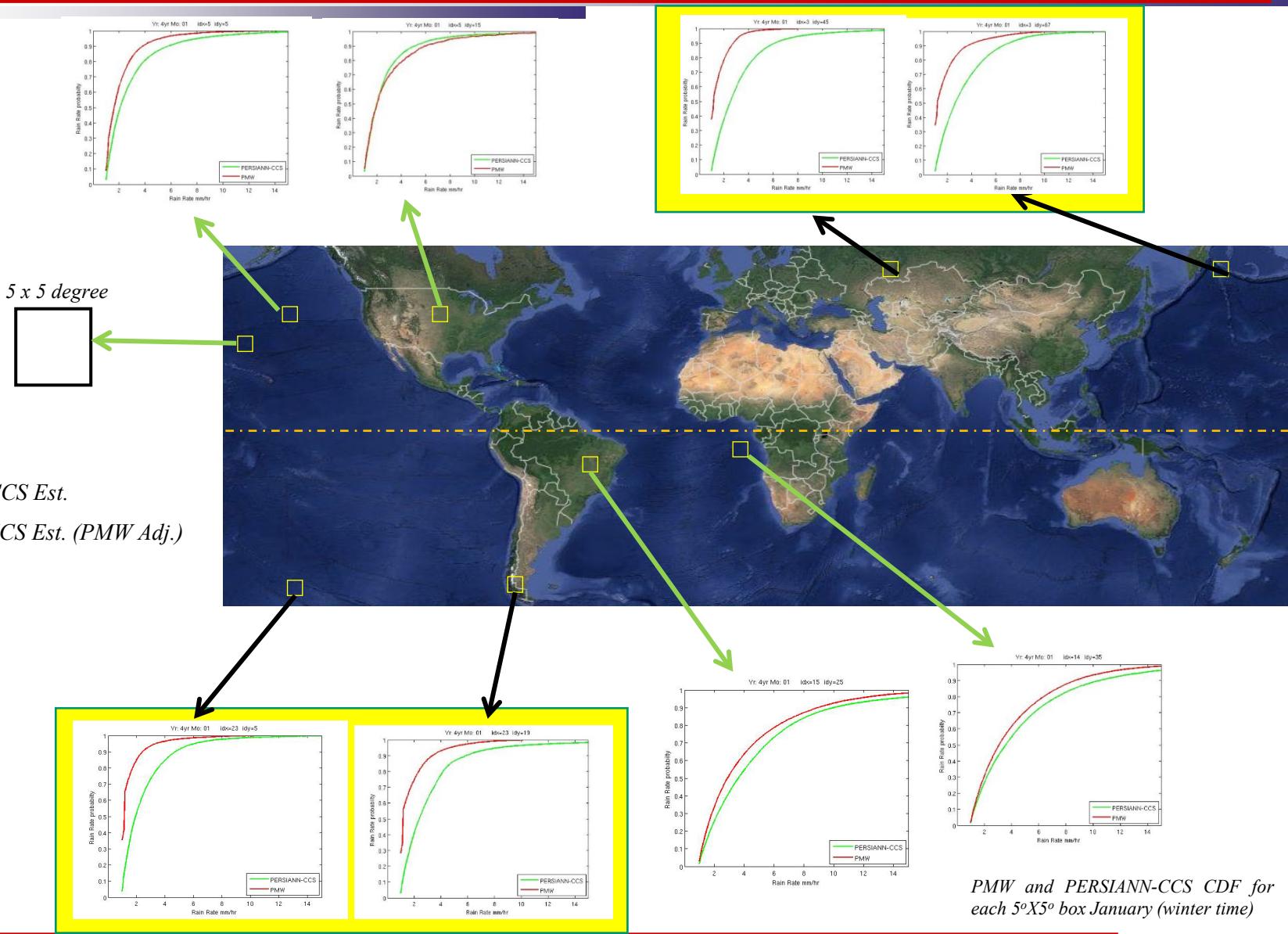
PERSIANN CCS-CDR

PERSIANN Cloud Classification System-Climate Data Record

- *PERSIANN-CCS estimation at $0.04^{\circ} \times 0.04^{\circ}$ lat-long scale*
- *Bias adjustment of CCS estimation using passive microwave rainfall estimation*
- *Bias adjustment of estimation using GPCP estimation at 2.5 degree monthly*

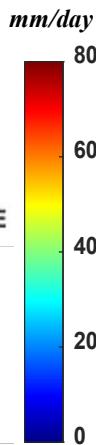
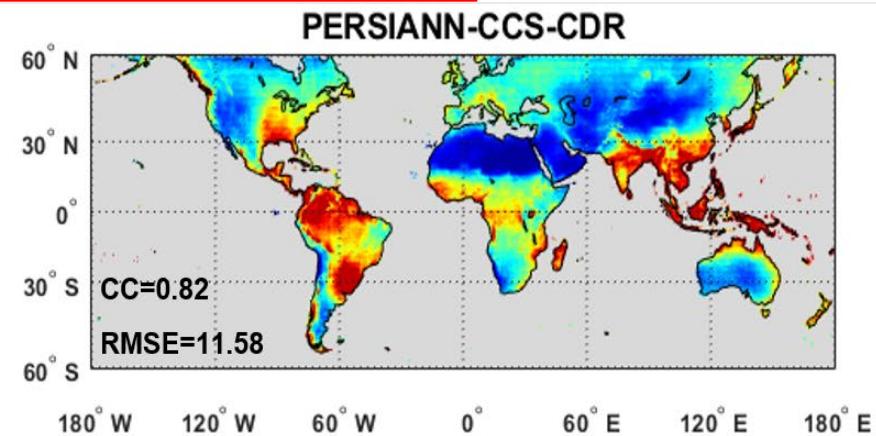
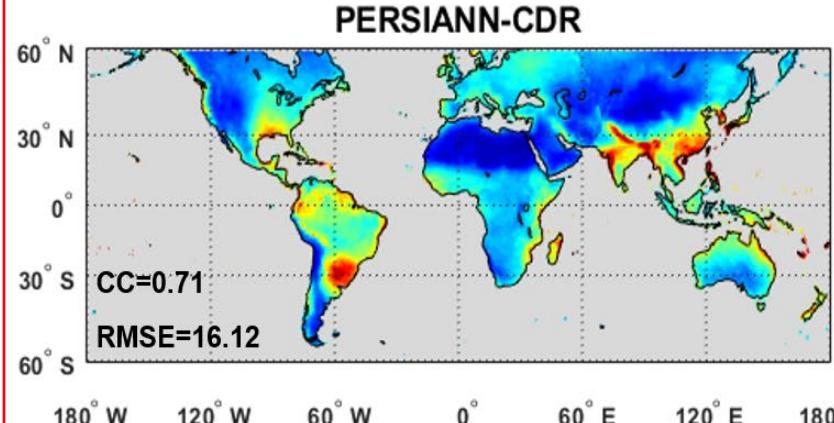
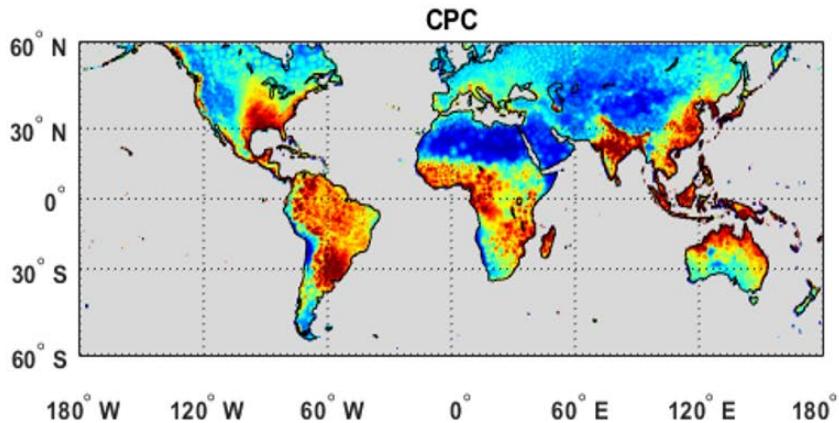


CDF: CCS Est. Before/After PMW Adjustment

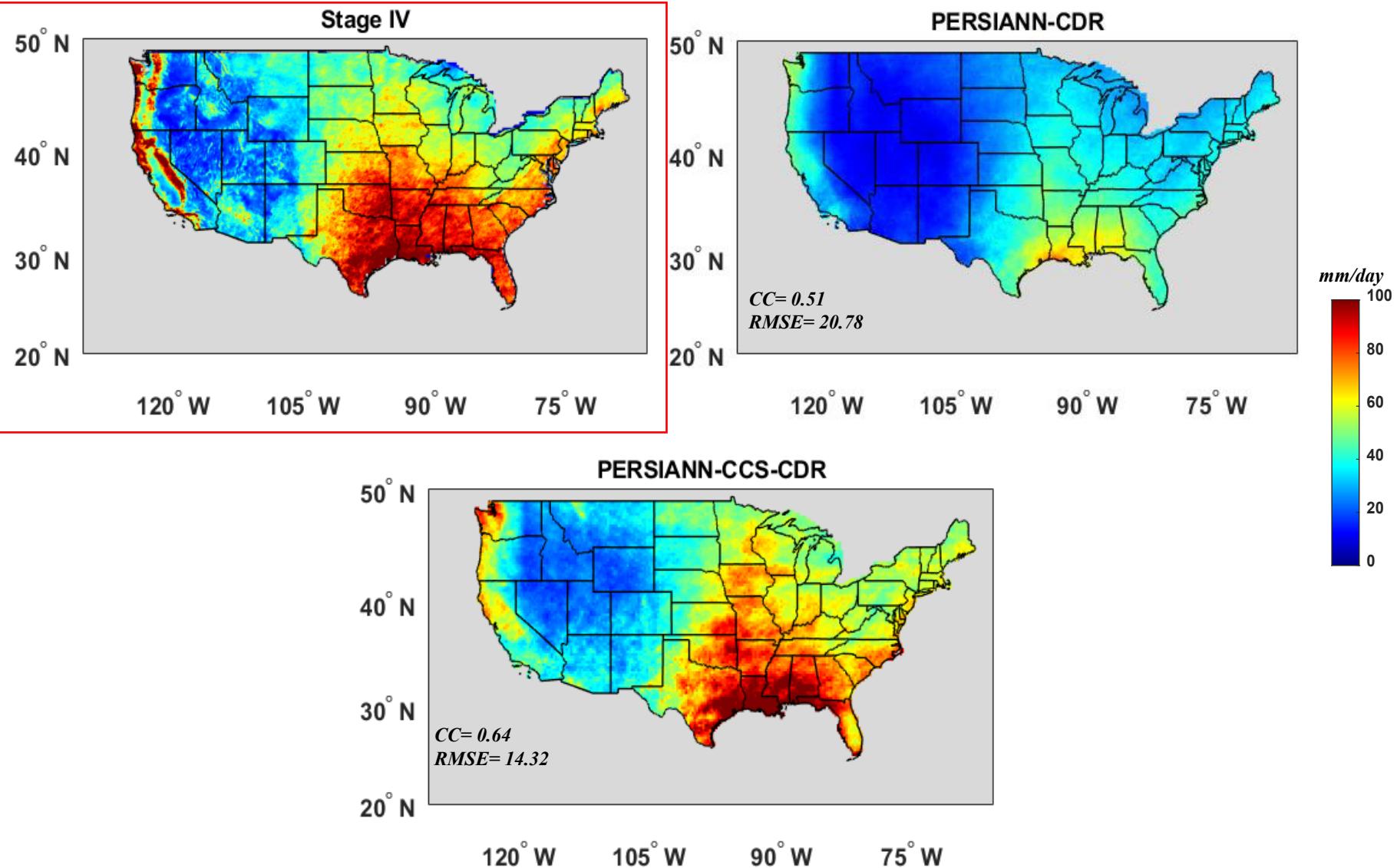


99 Percentile Daily Rainfall: RR99p

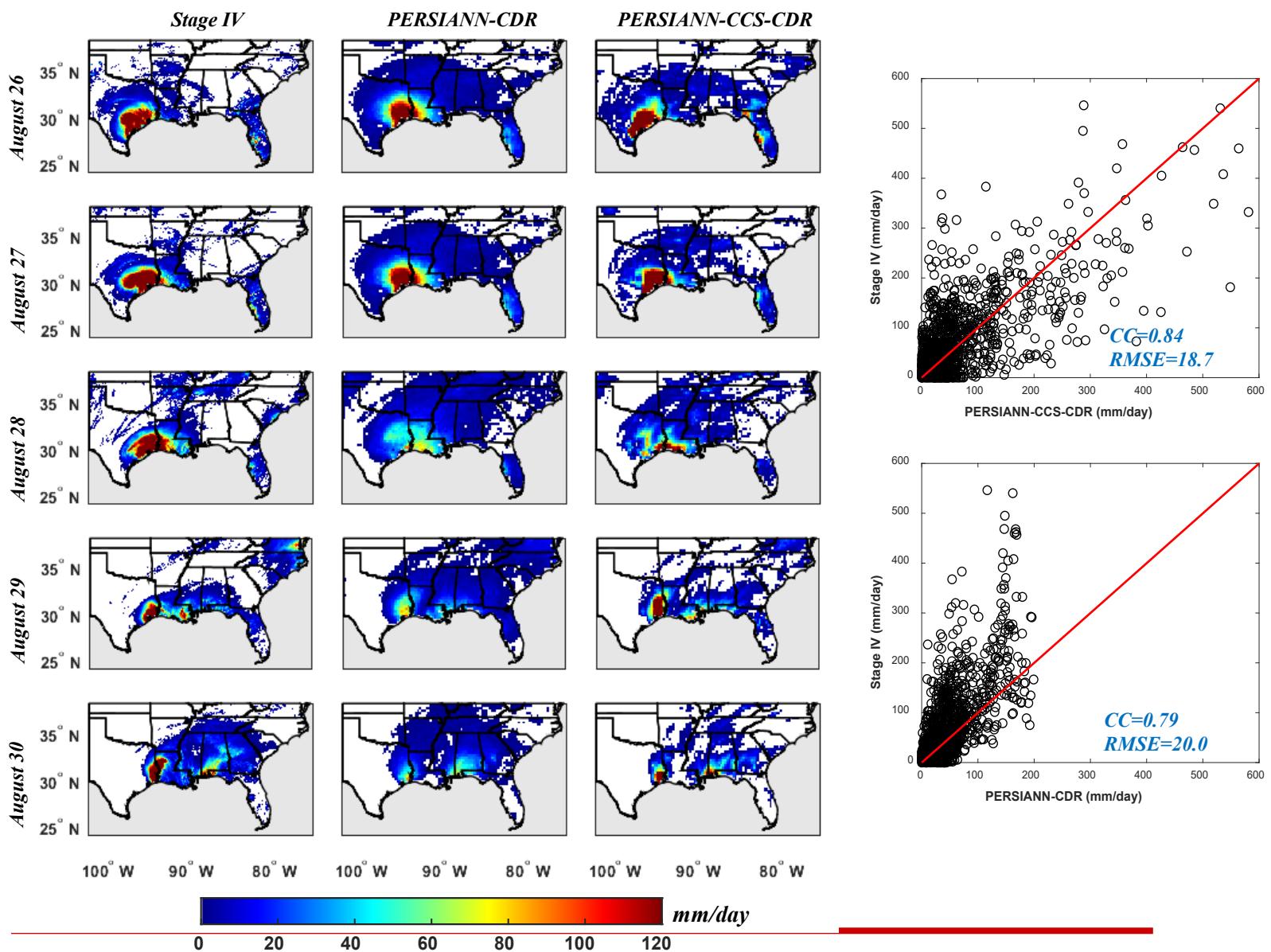
RR99p: The 99th percentile of daily precipitation on wet days (days with daily precipitation ≥ 1 mm)



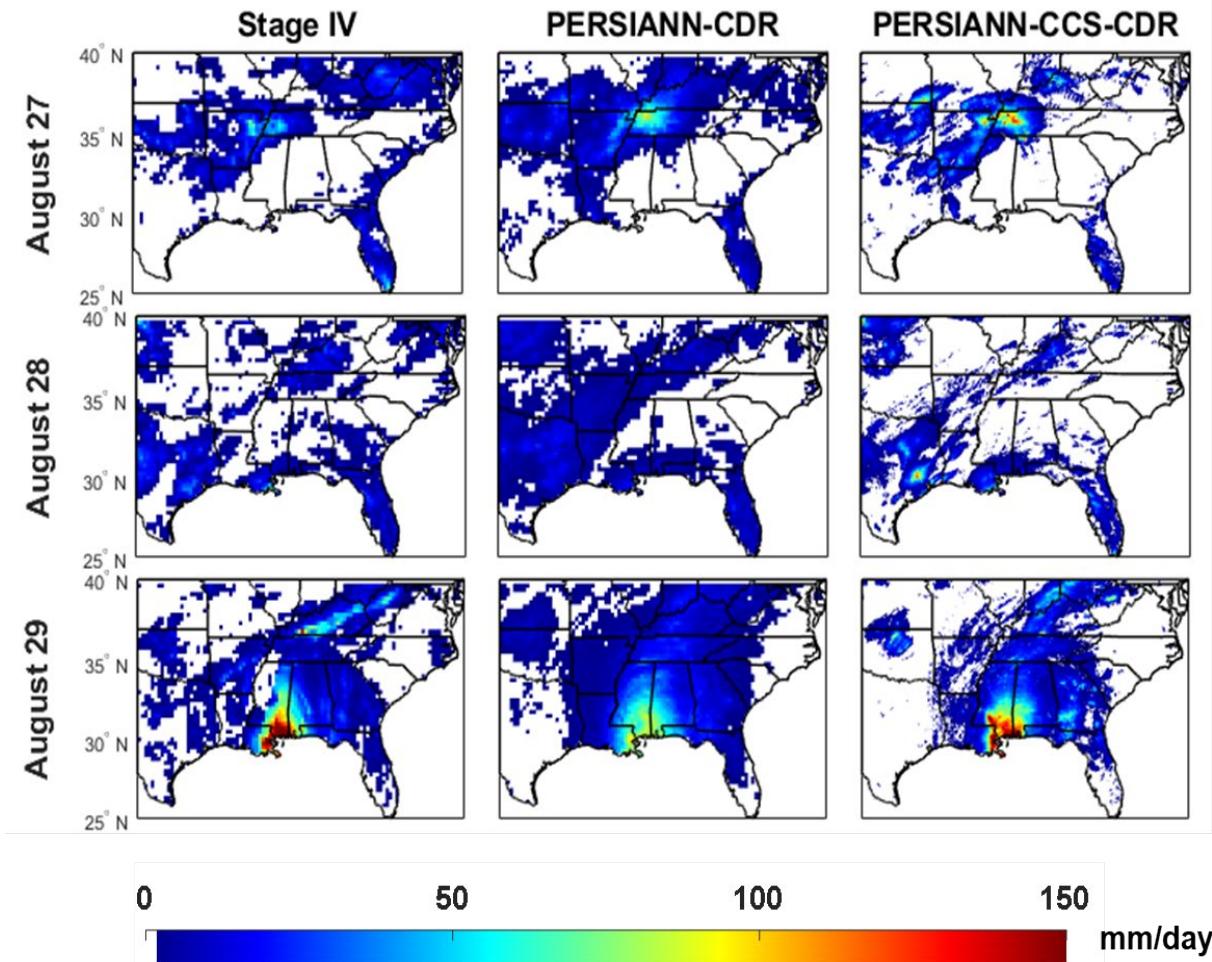
99 Percentile Daily Rainfall: RR99p



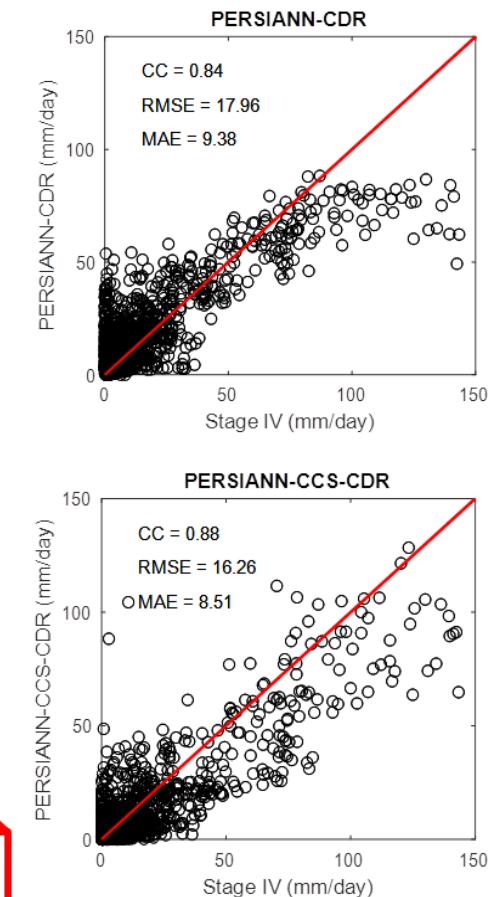
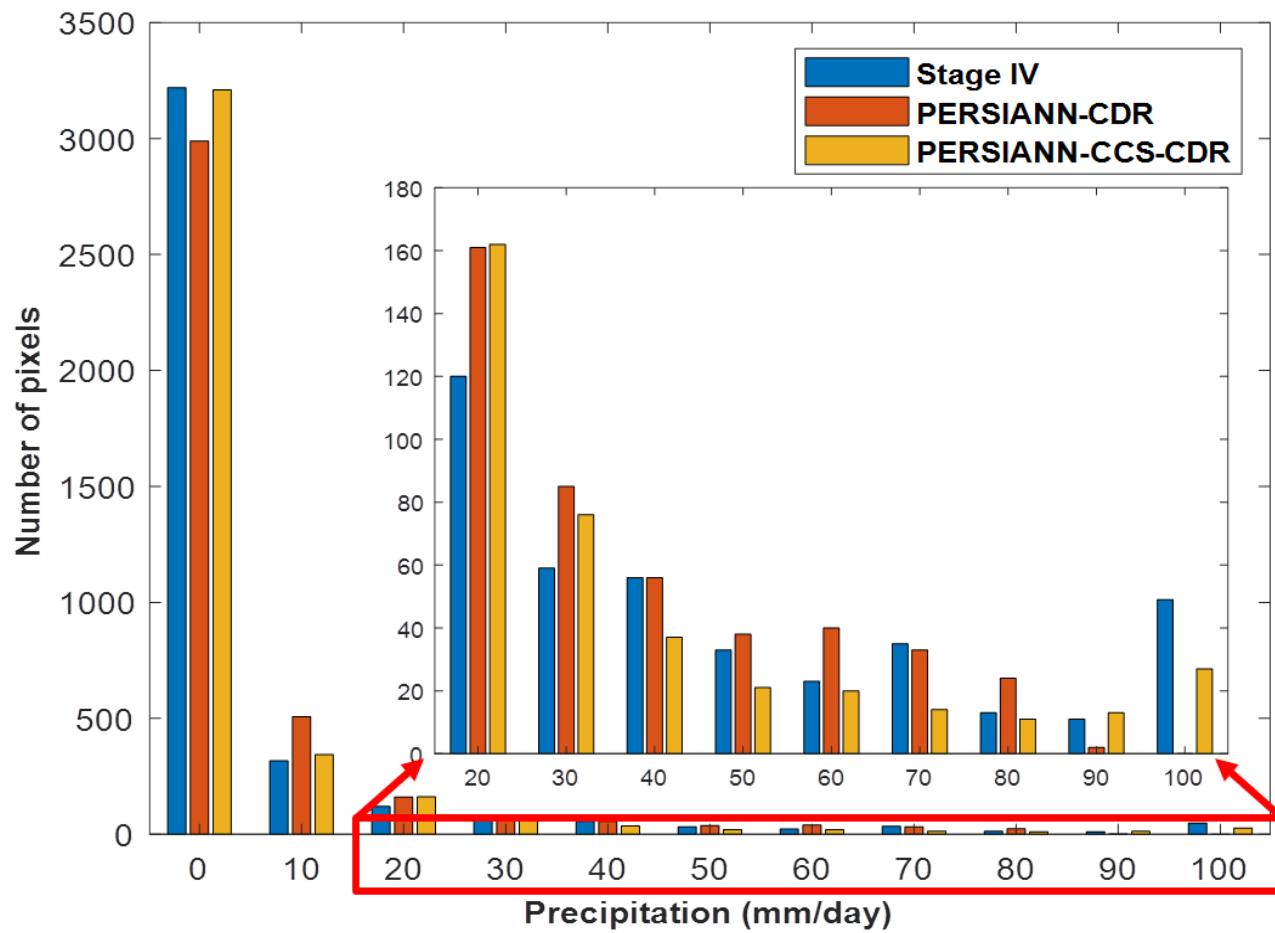
Hurricane Harvey (2017)



Hurricane Katrina (27-29, August 2005)

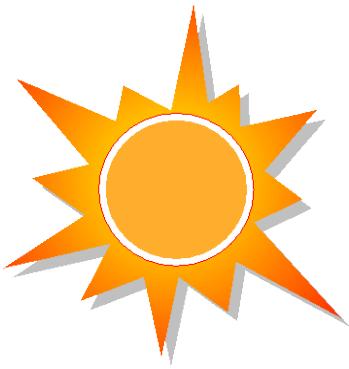


Hurricane Katrina (27-29, August 2005), 0.25° Resolution



Conclusions

- **Recent development:**
 - Recent development of machine learning models to improve rainfall estimation from GEO-satellite sensors and imagers is introduced
 - **PERSIANN-CCS CDR**
 - A long-term precipitation data (1983~) is developed for hydroclimate studies
 - Will provide high resolution precipitation data for hydroclimate studies
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Thank You For Listening !!

