Estimating uncertainties associated with quasi-global satellite infrared-based retrievals over land

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Abstract

An accurate characterization of the global hydrologic cycle is essential not only to study and forecast climate variations, but also for extreme event mitigation and agricultural planning. Since precipitation is the major driving force of the hydrological cycle, current and future satellite missions are critical to estimate precipitation globally. Error estimates associated with satellite precipitation retrievals are crucial to allow inferences about the reliability of such products in their operational applications. However, evaluating satellite precipitation error characteristics is challenging because of the inherent temporal and spatial variability of precipitation, measurement errors, and sampling uncertainties, especially at fine temporal and spatial resolutions. This study proposes to use a stochastic error model – PUSH (Probability Uncertainty in Satellite Hydrology) – for estimating uncertainties associated with fine resolution satellite precipitation products. The framework is tested on the daily IMERG (Integrated Multi-satellitE Retrievals for GPM) infrared-only (IR) precipitation component using a satellite-based radar product (the Level-3 Dual-frequency Precipitation Radar, 3DPRD) as reference. PUSH decomposes the error into four components and employs different modeling approaches for each case: correct no-precipitation detection; missed precipitation; false alarm; hit bias. PUSH is calibrated globally over land for different climatological regions. The calibrated parameters are validated using an independent period to verify whether they can be applied to estimate uncertainties associated with future IR retrievals without degrading the model performance. The four error components are then investigated as a function of climate region to study their spatial variability.

Estimating Uncertainties Associated with Quasi-Global Satellite Infrared-based Retrievals over Land

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Photography encouraged

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Rationale

Since precipitation is the major driving force of the hydrological cycle, current and future satellite missions with a focus on precipitation are critical to estimate hydrological variables globally. Error estimates associated with satellite precipitation retrievals are crucial to allow inferences about the reliability of such products in their operational applications. However, **evaluating satellite precipitation error characteristics is challenging** because of the inherent temporal and spatial variability of precipitation, measurement errors, and sampling uncertainties, especially at fine resolutions. This study proposes to use a **stochastic error model** – PUSH (Probability Uncertainties in Satellite Hydrology) – for estimating uncertainties associated with the GPM (Global Precipitation Measurement Mission) IMERG (Integrated Multi-satellite Retrievals for GPM) Infrared (IR) component.

Methodology

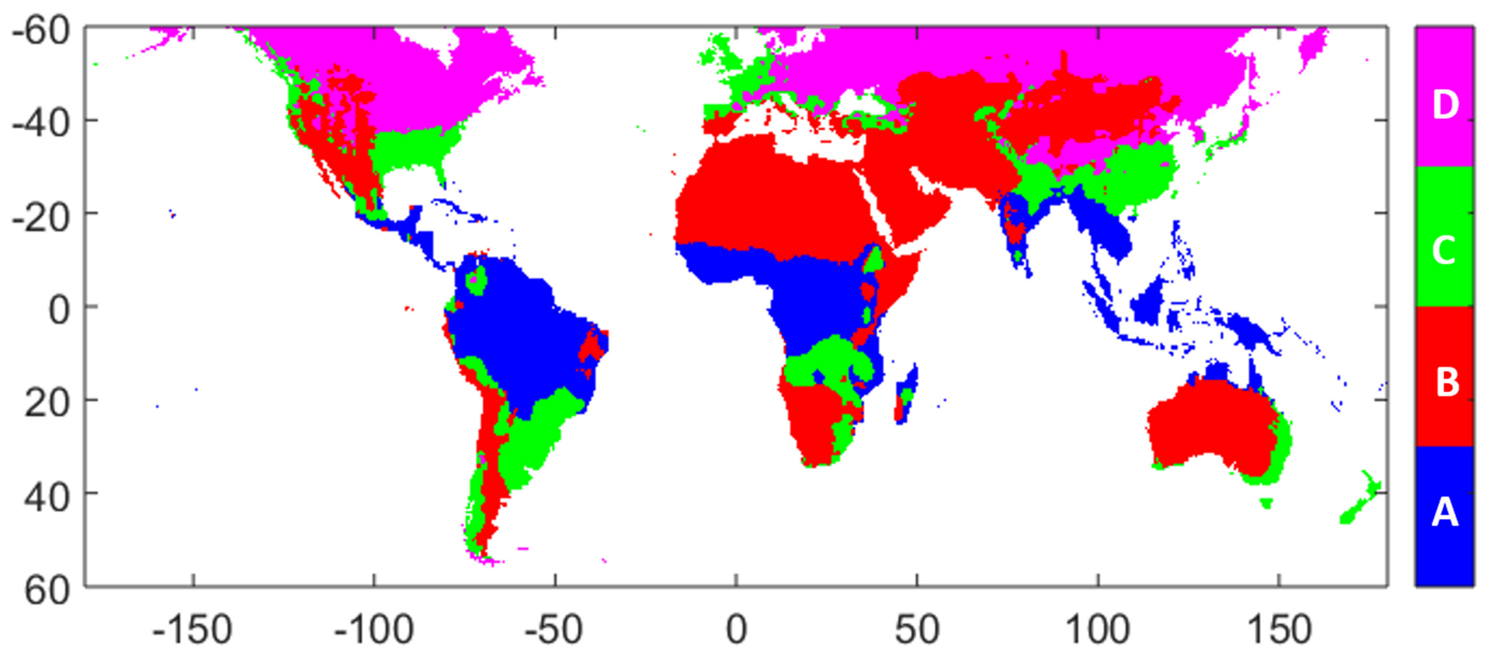
Dataset:
Evaluation product: GPM-IMERG IR V06 Level-3
Reference: 3DPRD V06
Resolution: 0.5°/Daily

Calibration Period: March 2014 – February 2017

Validation Period: March 2017 – February 2018

Study area: 60°N- 60° S

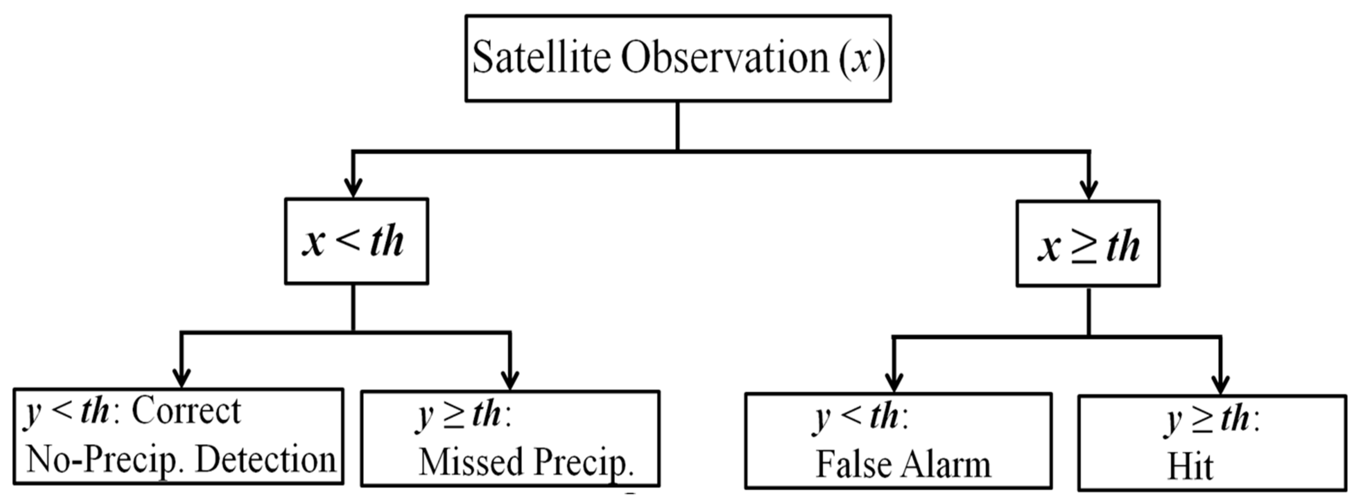
Koppen Climate Classification World Map:
A) Tropical;
B) Dry;
C) Temperate;
D) Continental Climate



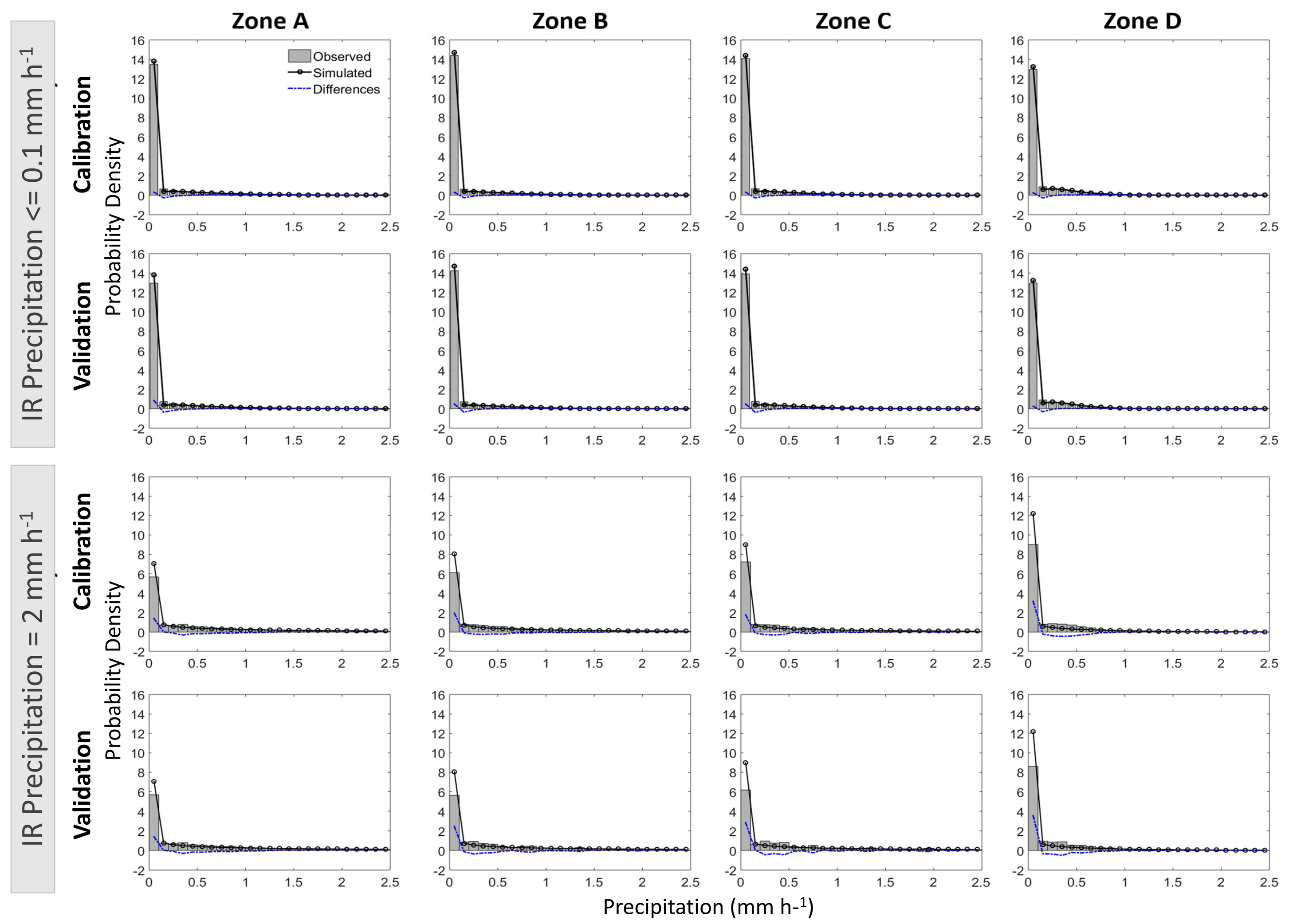
Sample size during the calibration period:

Threshold=0.1 mm h⁻¹		Case 0		Case 1	
Koppen-Zone	Total	Zeros	Misses	False	Hits
A	1,570,297	963,147	234,758	198,257	174,135
B	3,493,143	2,374,458	463,918	397,504	257,263
C	1,510,590	1,000,072	211,441	189,866	109,211
D	4,051,179	2,257,573	610,705	803,027	379,874

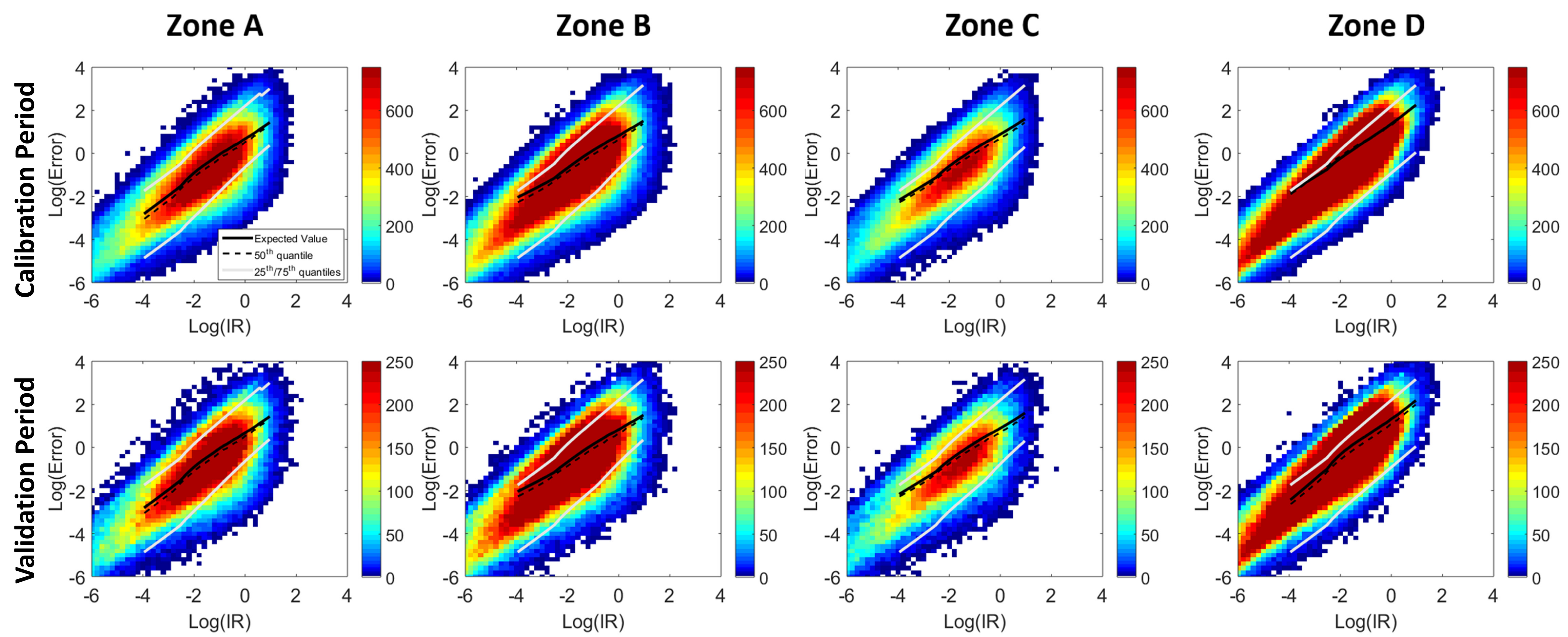
Model:
The **PUSH Error Model Framework** (Maggioni et al. 2014*) decomposes the error into four components and employs different modeling approaches for each case.



Results

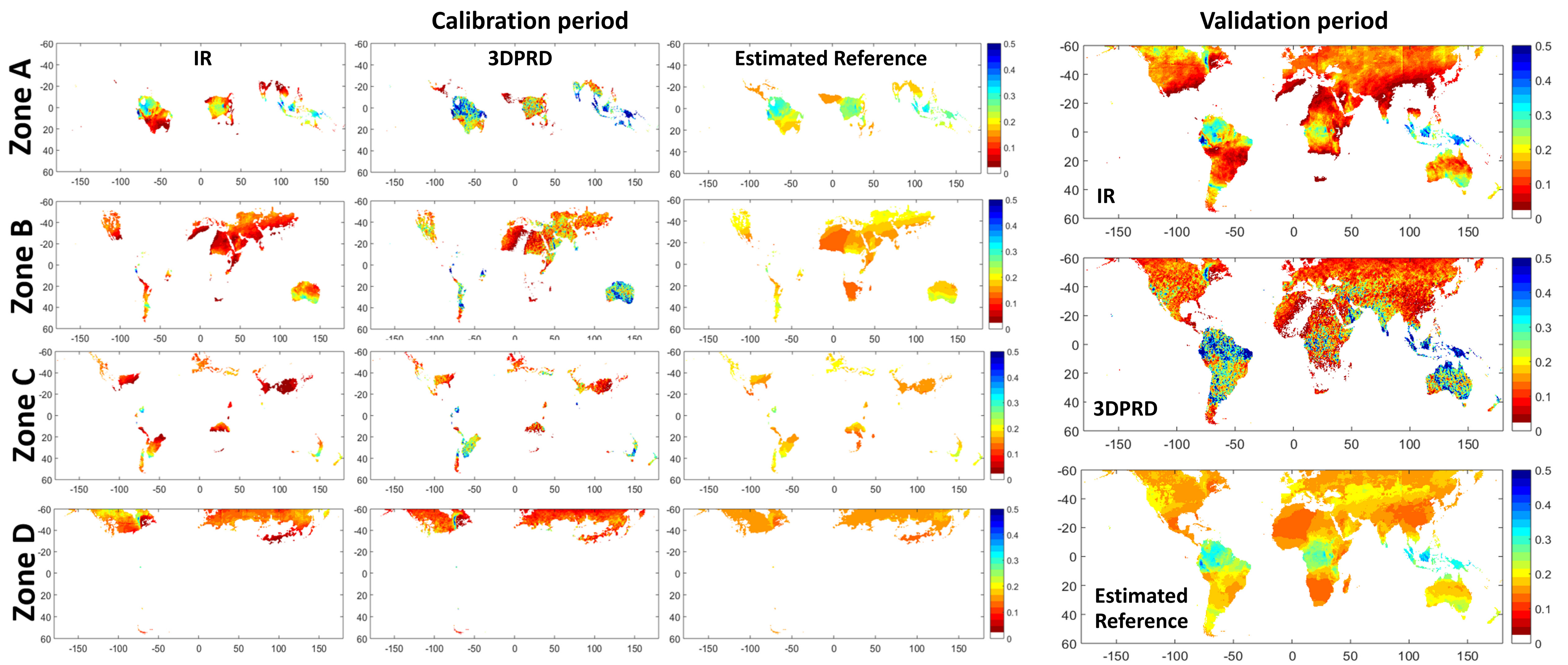


PDFs of 3DPR rainfall (histogram) and rainfall simulated by the error model (black lines). Blue dashed lines represent the difference between the two.



Two-dimensional histograms of observed errors (defined as IR/3DPRD) vs IR precipitation estimates. The x- and y- axes are both in log-scale. The estimated expected value and quantiles (25th, 50th, and 75th) of the error distribution (black and grey lines) lie on top of the most populated areas of the scatterplots for all four climate zones and during both calibration and validation periods.

Average precipitation maps (mm h⁻¹)



- The error generated by PUSH is defined as the ratio between IR and the expected value of the estimated reference distribution
- This estimated error is evaluated against the observed error (IR/3DPRD) in terms of bias, unbiased RMSE, and correlation coefficient

Koppen Zone	Bias	ubRMSE	Correlation Coefficient
	Calibration/*Validation*	Calibration/*Validation*	Calibration/*Validation*
A	0.45/*0.46*	2.7/*2.6*	0.44/*0.43*
B	0.41/*0.38*	2.4/*2.3*	0.49/*0.48*
C	0.39/*0.32*	2.2/*2.0*	0.50/*0.52*
D	0.27/*0.28*	2.1/*2.2*	0.60/*0.57*

Conclusions

- PUSH generates errors estimates at each grid box (0.5°) and time step (1 day) for the IMERG IR component for four Koppen climate zones.
- Precipitation rates < 0.1 mm h⁻¹ are the most common in all four Koppen climate zones.
- Model performance is nearly independent of the calibration dataset and can be generalized to independent period.
- PUSH overestimates light precipitation (< 0.1 mm h⁻¹) and slightly underestimates precipitation between 0.1 mm h⁻¹ and 1 mm h⁻¹ , dominant in the Continental Climate Zone.
- A climate-zone specific error product is developed that provides the full distribution of the error associated with each IR estimate.

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*Maggioni, V., Sapiano, M.R., Adler, R.F., Tian, Y. and Huffman, G.J., 2014. An error model for uncertainty quantification in high-time-resolution precipitation products. *Journal of Hydrometeorology*, *15*(3), pp.1274-1292.