Deep learning for bias correction of satellite retrievals of orographic precipitation

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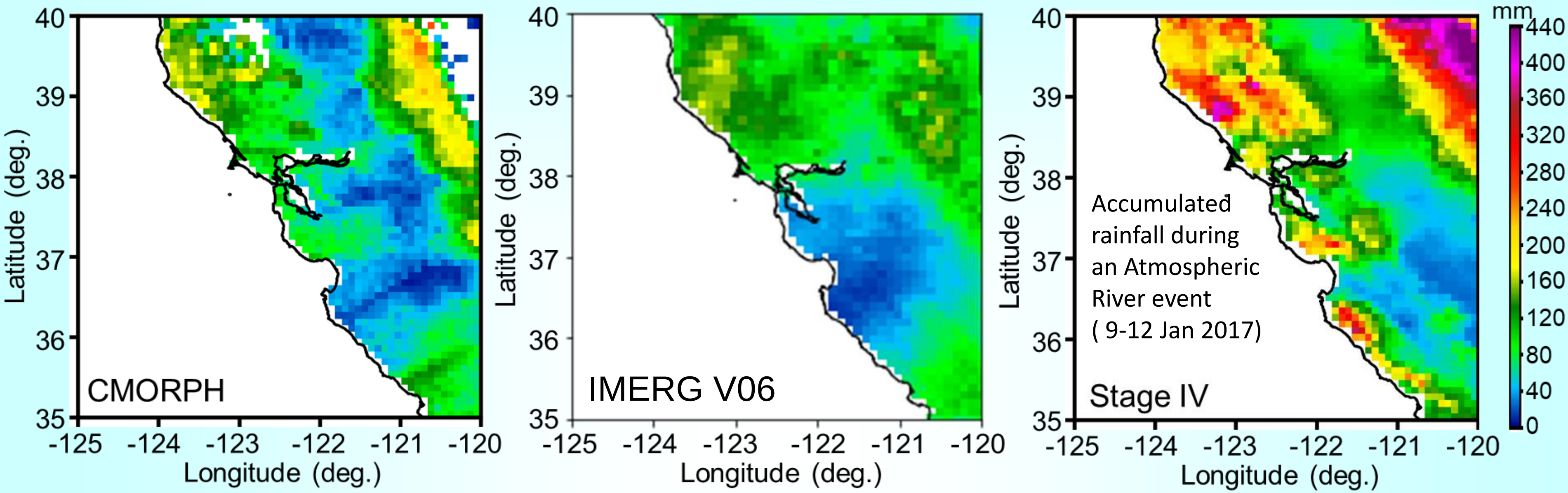
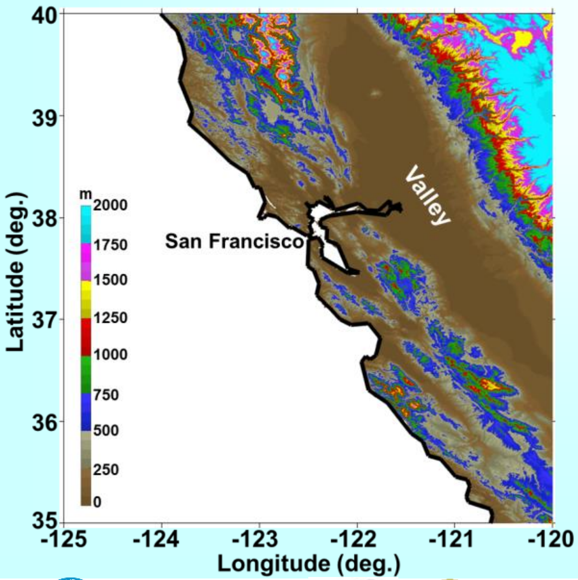
GPM Land Surface Working Group (LSWG) Meeting
4 August 2021

Motivations



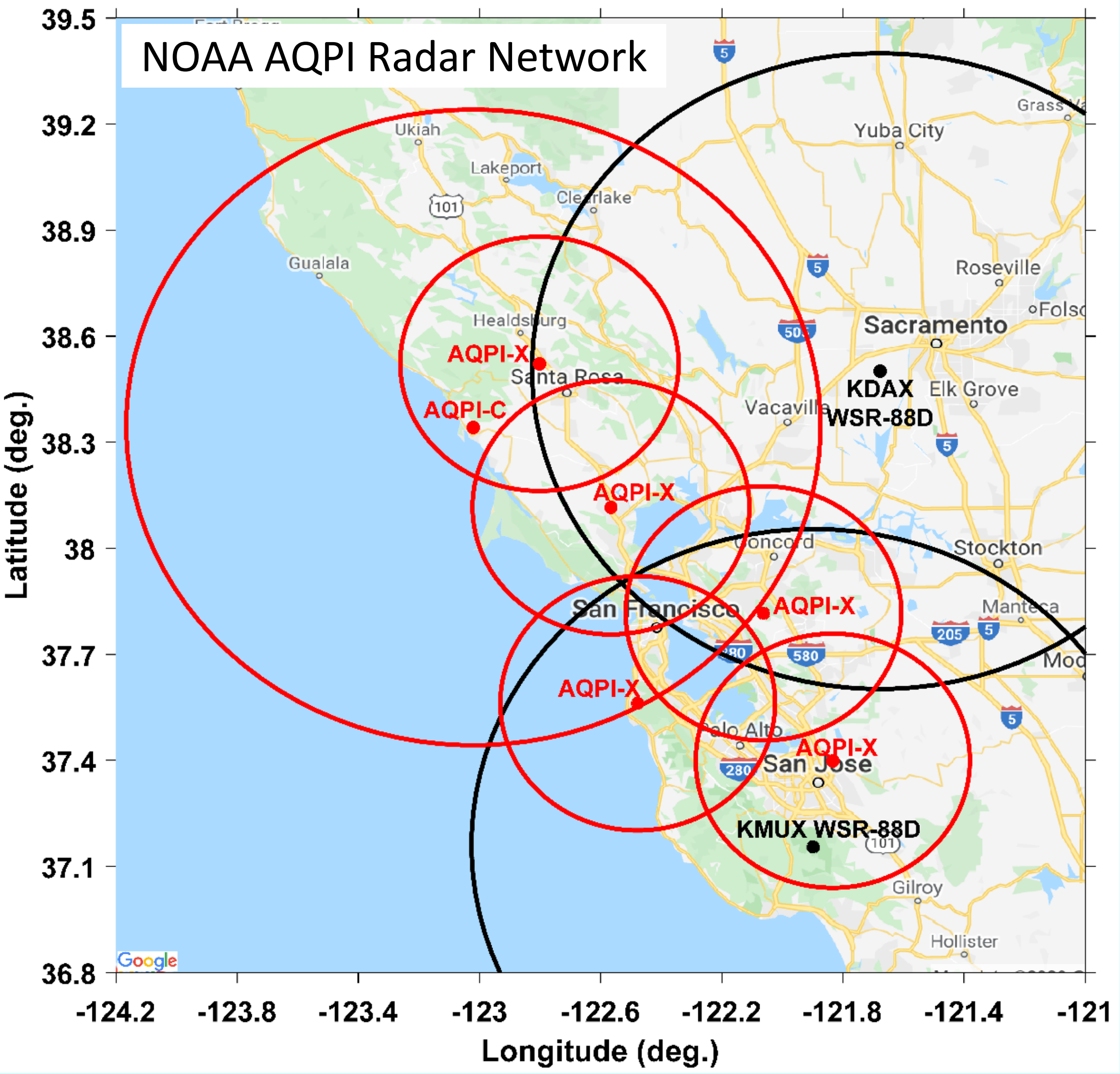


- Large differences exist between the various satellite-based QPE products over complex terrain regions (Bytheway et al. 2020).
- Operational radars do not have good coverage in complex terrain regions, resulting in poor QPE (e.g., MRMS) (Chen et al. 2019; 2020).

Objective

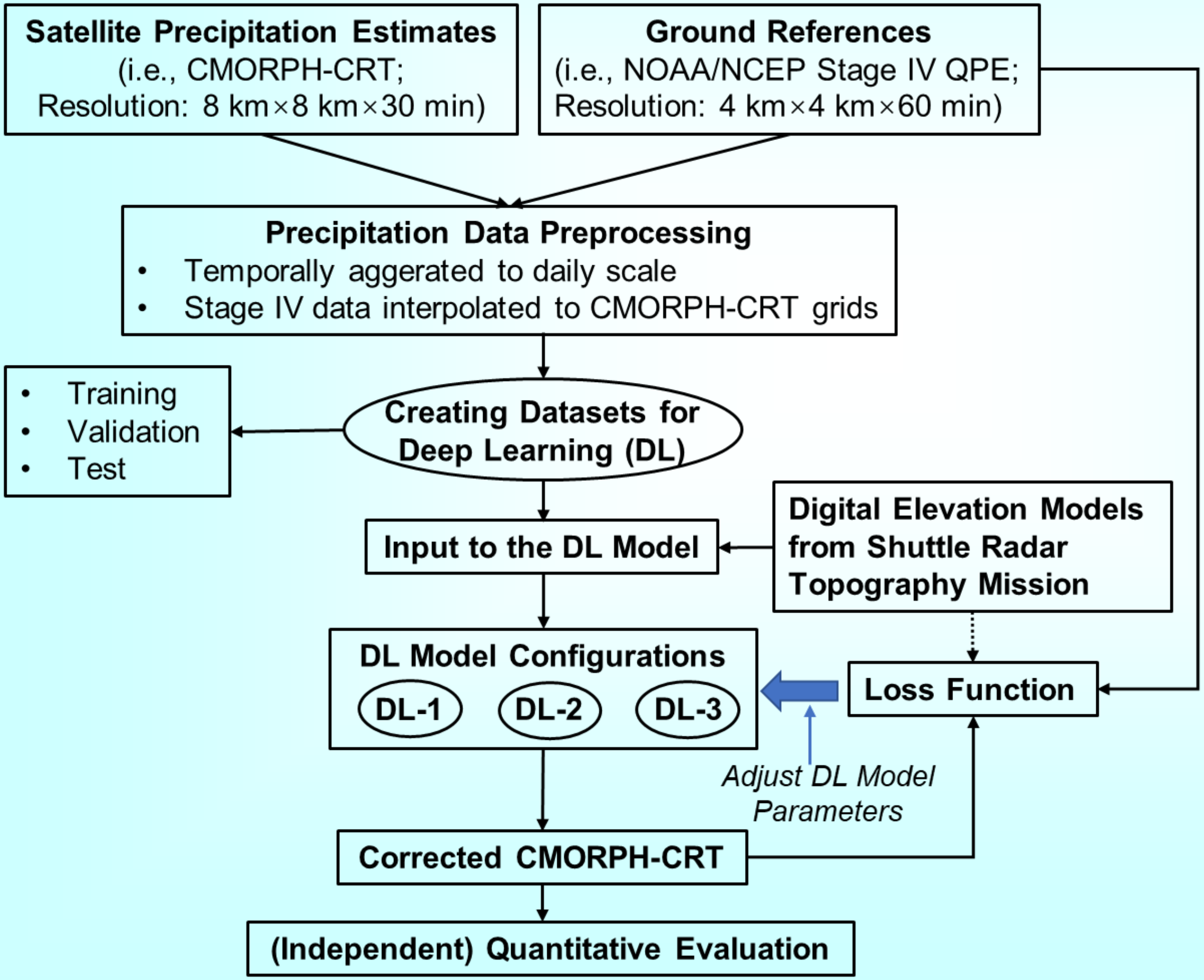
Develop a deep learning framework for bias correction of satellite retrievals of coastal orographic precipitation.

- Start from CMORPH, but the framework is applicable to other satellite precipitation products such as IMERG.
- Use Stage IV QPE as references in training the machine learning model and evaluating the bias correction performance.



Bias Correction of Satellite Retrievals of Orographic Precipitation

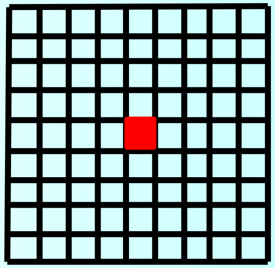
Conceptual diagram of the bias correction framework

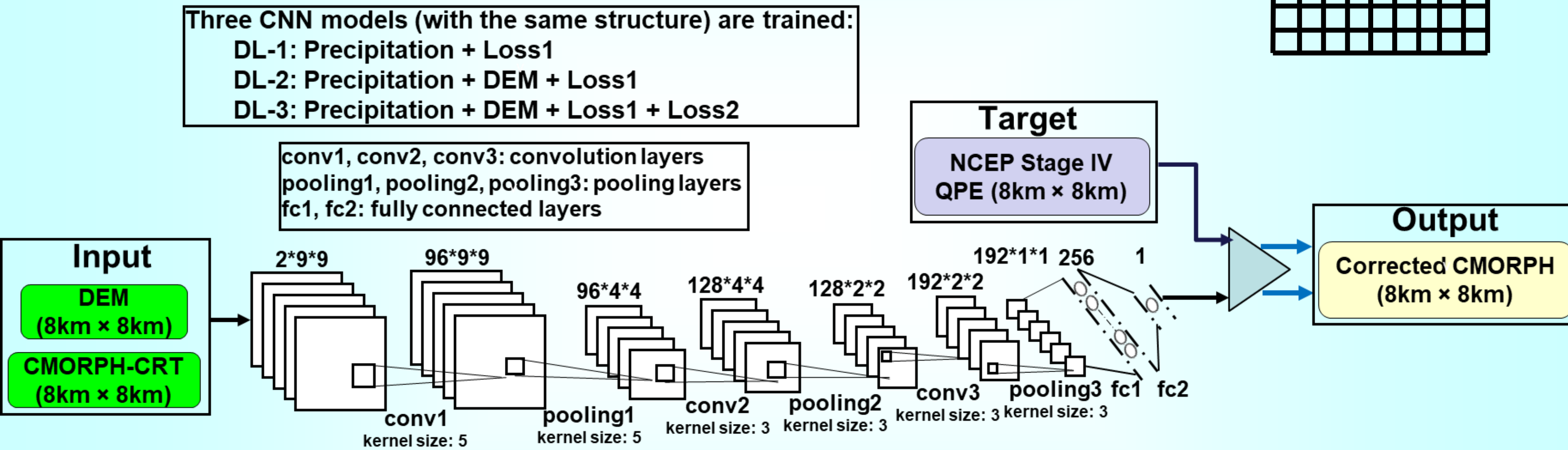


- Spatial and temporal alignment between CMORPH and State IV QPE
  - Stage IV QPE remapped to CMORPH grids
  - Correction is performed at daily scale
- We will quantify the impact of terrain on satellite QPE through different model configurations.

Bias Correction of Satellite Retrievals of Orographic Precipitation

Detailed CNN structure





- Paddings for conv1, conv2, and conv3 are 2, 2, and 1, respectively.
- Strides in conv1, conv2, and conv3 are 2, 1, and 1, respectively.
- Paddings for pooling1, pooling2, and pooling3 are 1, 0, and 1, respectively.
- Stride is 2 for all the pooling layers.

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Detailed CNN structure: Loss functions for DL-1, DL-2, and DL-33

Loss functions

DL-1: $\mathrm{W1} \cdot \mathrm{MSE}(\mathrm{Precipitation})$

DL-2: $\mathrm{W1} \cdot \mathrm{MSE}(\mathrm{Precipitation})$

DL-3: $\mathrm{W1} \cdot \mathrm{MSE}(\mathrm{Precipitation}) + \mathrm{W2} \cdot \mathrm{MSE}(DEM / 25)$

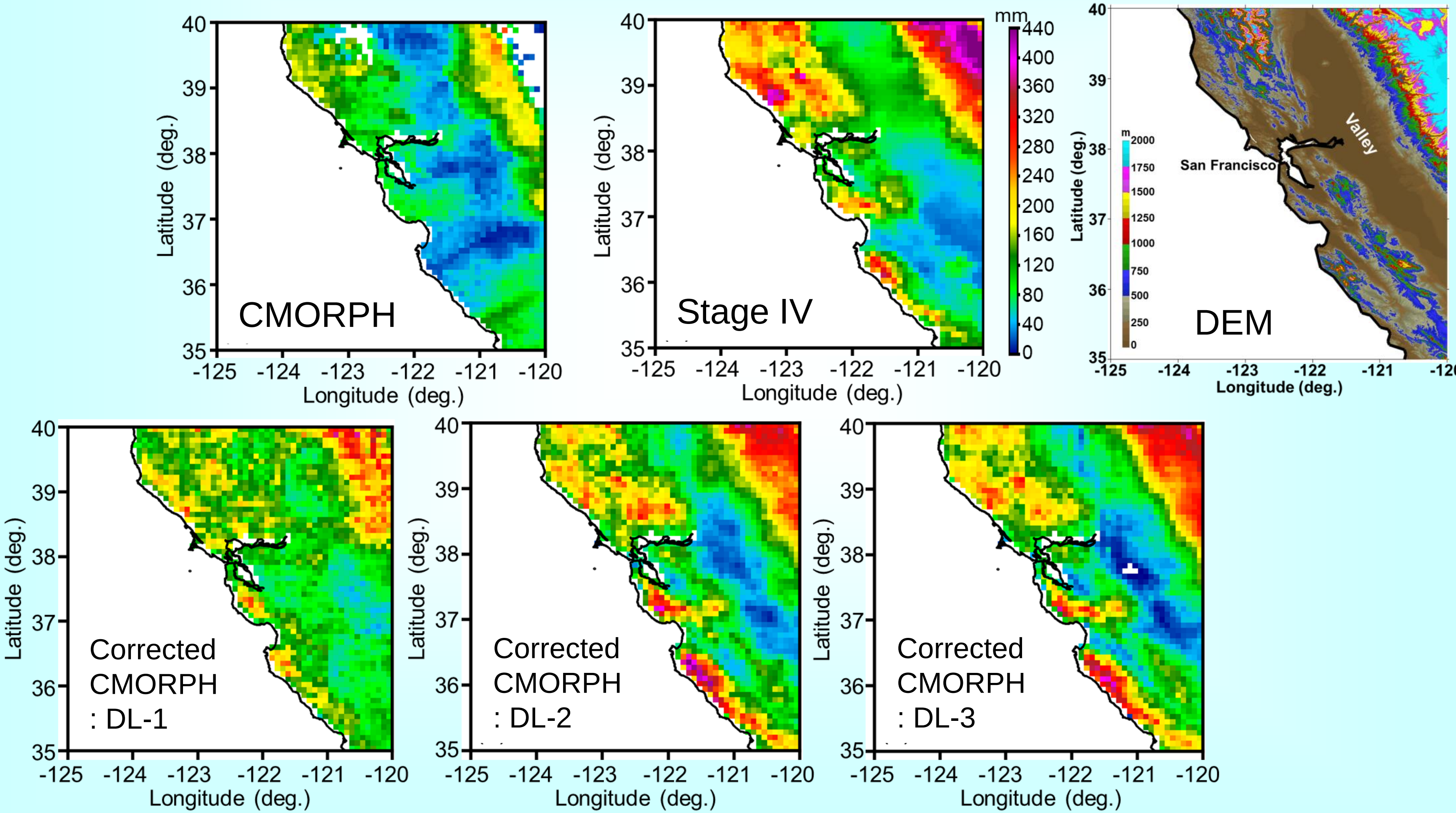
$$MSE = \frac{1}{N}\sum_{i=1}^{N}(X_L - X_{DL})^2 \qquad \mathrm{W1} = \begin{cases} 2, & 0 < \mathrm{x} \le 20 \\ 5, & 20 < \mathrm{x} \le 40 \\ 10, & 40 < \mathrm{x} \le 60 \\ 20, & 60 < \mathrm{x} \le 80 \\ 30, & \mathrm{x} > 80 \end{cases}, \quad \mathrm{W2} = \begin{cases} 2, & 0 < \mathrm{x} \le 500 \\ 3, & 500 < \mathrm{x} \le 1000 \\ 4, & 1000 < \mathrm{x} \le 1500 \\ 5, & 1500 < \mathrm{x} \le 2000 \\ 6, & \mathrm{x} > 2000 \end{cases}$$

Model Training, Validation, and Test

- Ten-month data: January - February (2016-2019), March (2018, 2019)
- The total number of precipitation samples is 90,448, which is divided into training (90%) and validation (10%) subsets.
- Four precipitation events are excluded from the dataset for independent test: 9-12 January 2017, 21-23 March 2018, 13-16 February 2019, 25-28 February 2019.

Bias Correction of Satellite Retrievals of Orographic Precipitation

Case studies: 9-12 January 2017



Precipitation accumulations during 9-12 January 2017

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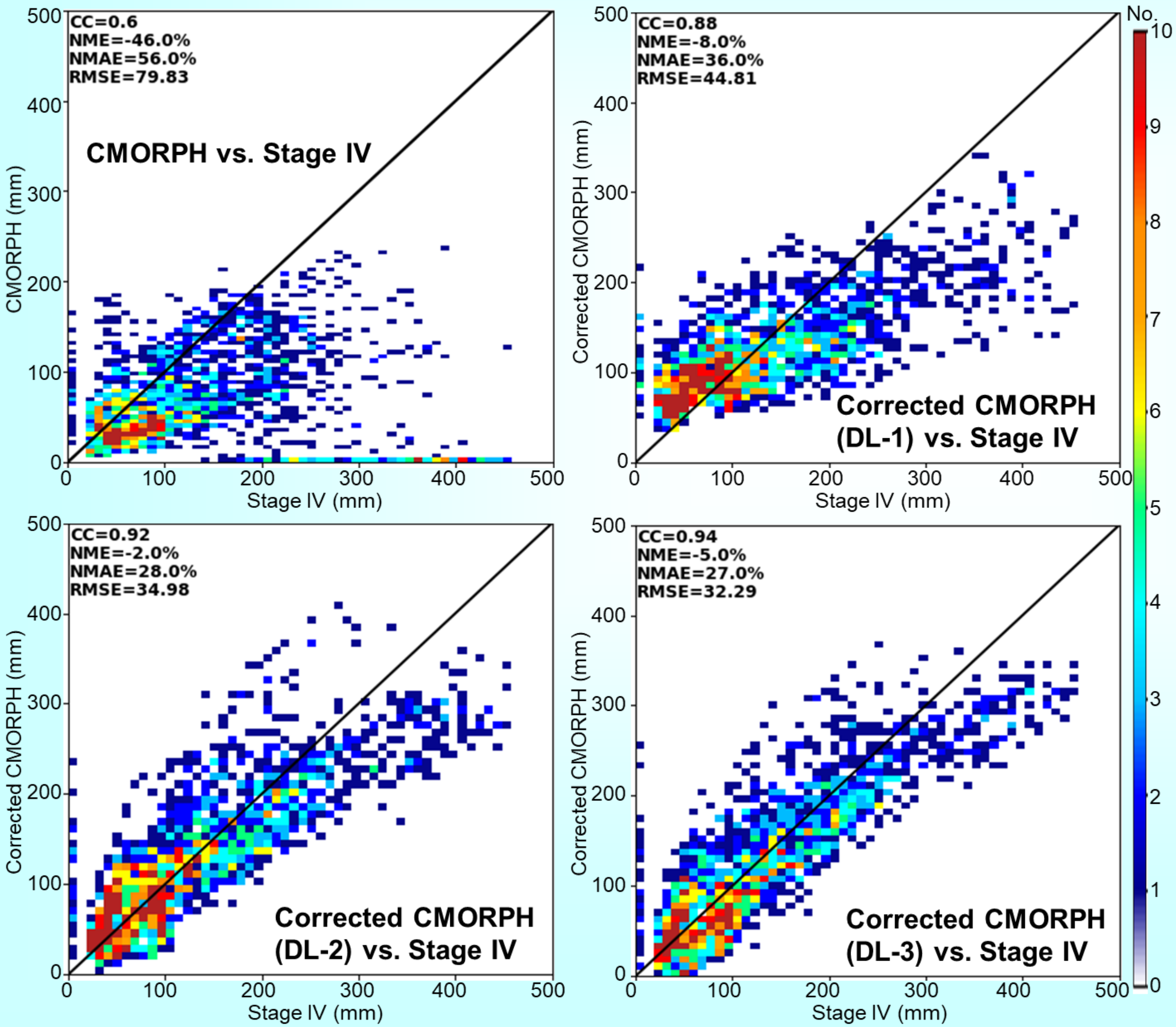
Case studies: Precipitation accumulations during 9-12 January 2017



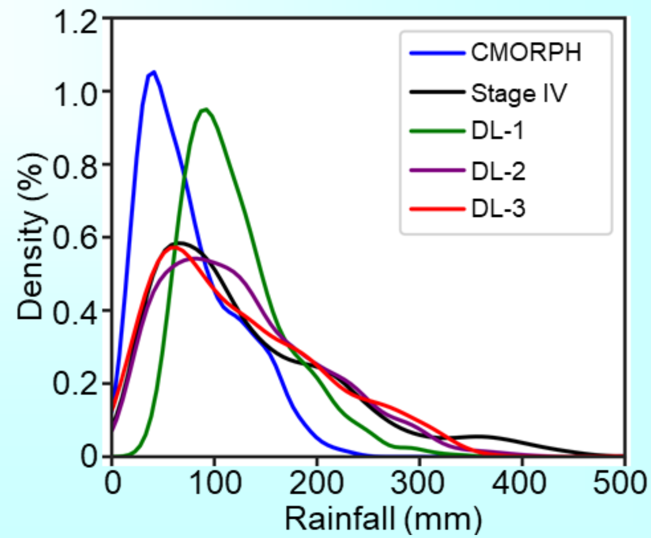
$$CC = \frac{\sum[(R_S - \langle R_S \rangle)(R_G - \langle R_G \rangle)]}{\sqrt{\sum(R_S - \langle R_S \rangle)^2}\sqrt{\sum(R_G - \langle R_G \rangle)^2}}$$

$$NME = \frac{\langle R_S - R_G \rangle}{\langle R_G \rangle}$$

$$NMAE = \frac{\langle |R_S - R_G| \rangle}{\langle R_G \rangle}$$

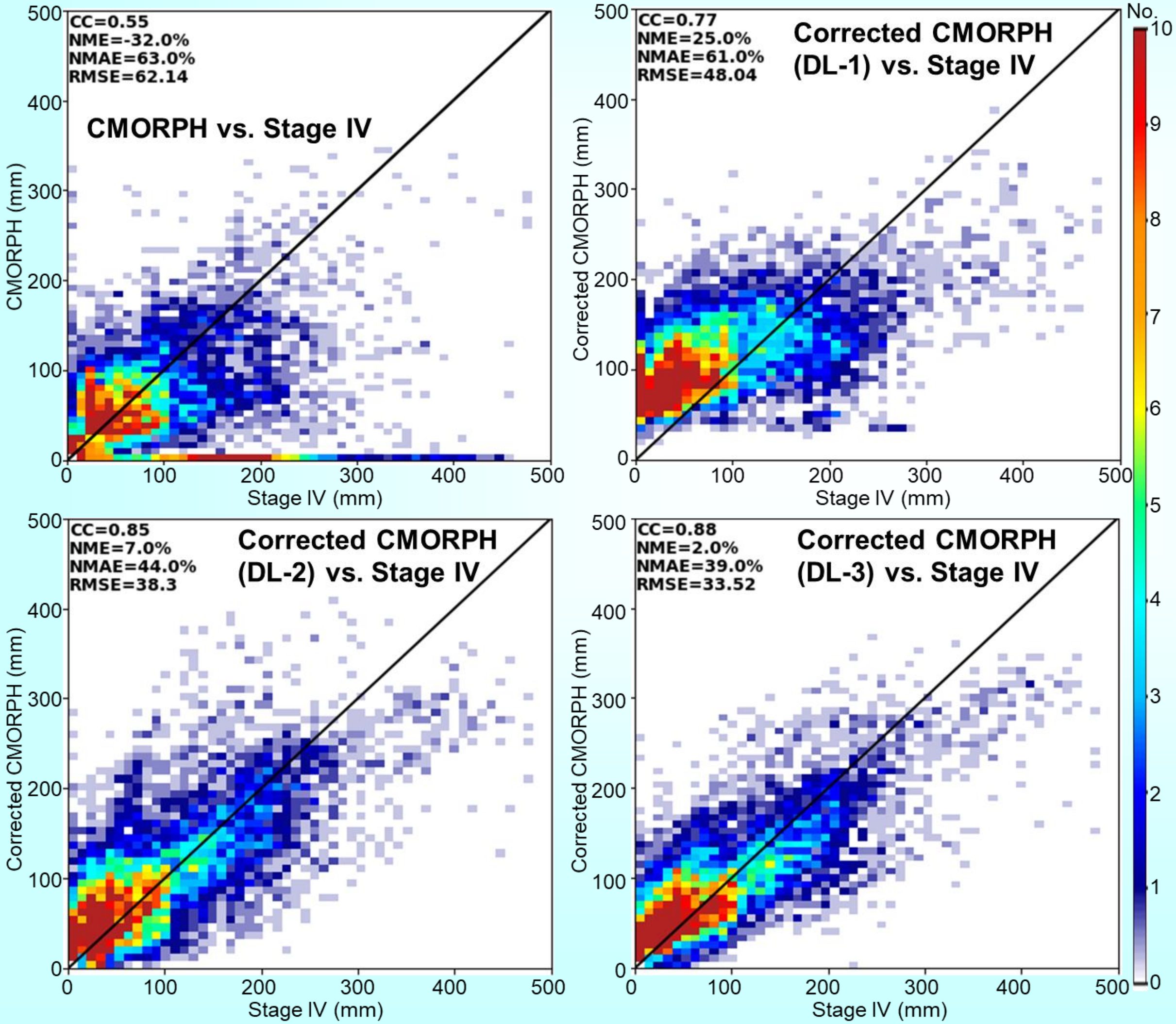
$$RMSE = \sqrt{\langle (R_S - R_G)^2 \rangle}$$

where the angle brackets stand for sample average; R_S and R_G denote the estimated rainfall using CMORPH and Stage IV, respectively.



Bias Correction of Satellite Retrievals of Orographic Precipitation

Case studies: 2017/1/9-12, 2018/03/21-23, 2019/2/13-16, 2019/2/25-28

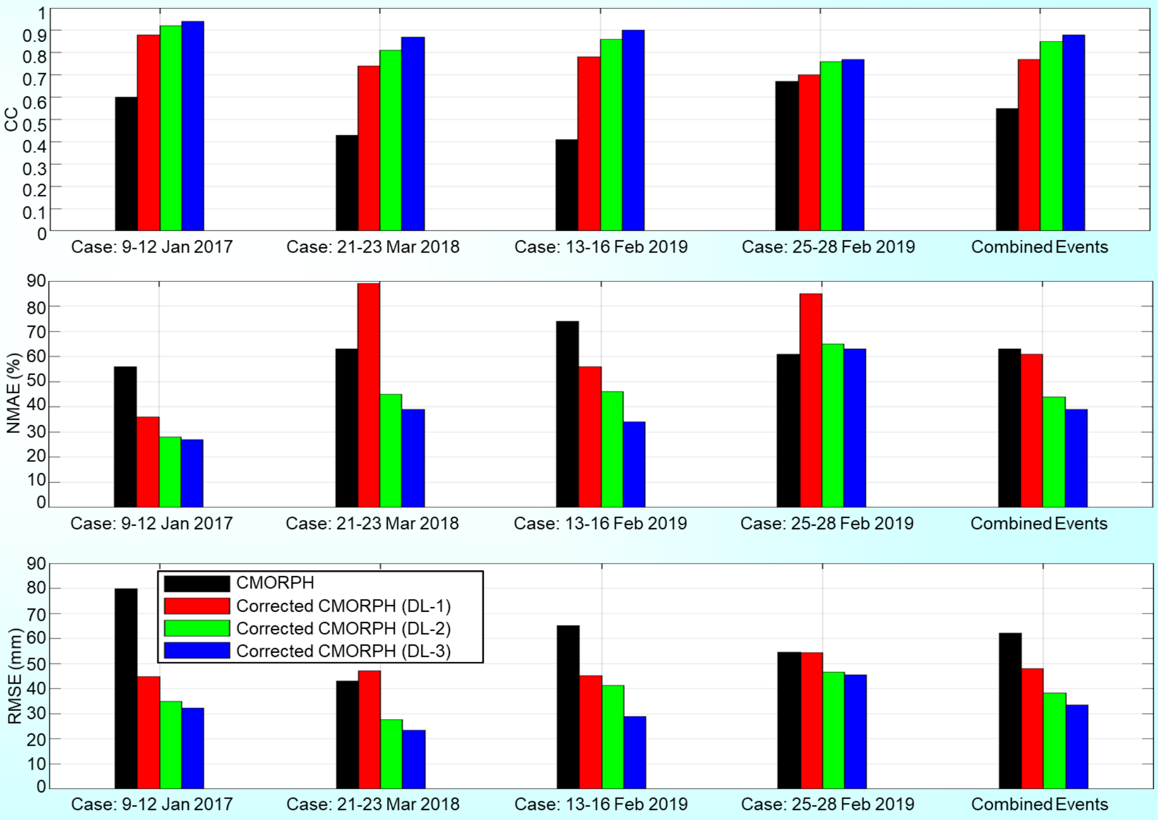


Scatter plots of CMORPH vs. Stage IV QPE during the four independent test events

Summary

- Satellite retrieval of orographic precipitation remains a formidable challenge, especially during shallow precipitation processes.

- This study has developed a machine learning framework to characterize and correct the biases associated with satellite precipitation product, with an emphasis on quantifying the impact of orographic enhancement.



- Case studies in coastal mountain regions in Northern California demonstrated the great performance of the bias correction scheme.

- Future work will focus on the generalization capability of this DL-based bias correction approach (in different regimes and for enhancing other products such as IMERG).

Thank you for your attention!

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Chen, H., L. Sun, R. Cifelli, and P. Xie, 2021: Deep learning for bias correction of satellite retrievals of orographic precipitation. *Transactions on Geoscience and Remote Sensing*, (under review)