Integrating Multi-scale Data for Seamless QPE in the AQPI System

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The AQPI QPE System Architecture

The National Oceanic and Atmospheric Administration (NOAA) and collaborating partners are building an Advanced Quantitative Precipitation Information (AQPI) system aimed at improving monitoring and forecasting of precipitation, streamflow, and coastal flooding in the San Francisco Bay Area.

As part of the AQPI program, high-frequency (i.e., X-band) high-resolution gap-filling radars are being deployed over the Bay Area to augment observations from the NEXRAD network, improve quantitative precipitation estimates (QPE), and resolve the detailed precipitation microphysics (see Poster A53L-3073 by Cifelli et al.).

This paper presents the integrated QPE system built upon the AQPI radar observations and existing NEXRAD product for seamless high-resolution rainfall mapping over the entire Bay Area.

Fig. 1. The layout of AQPI radar network. For more information about AQPI, see Poster A53L-3073.
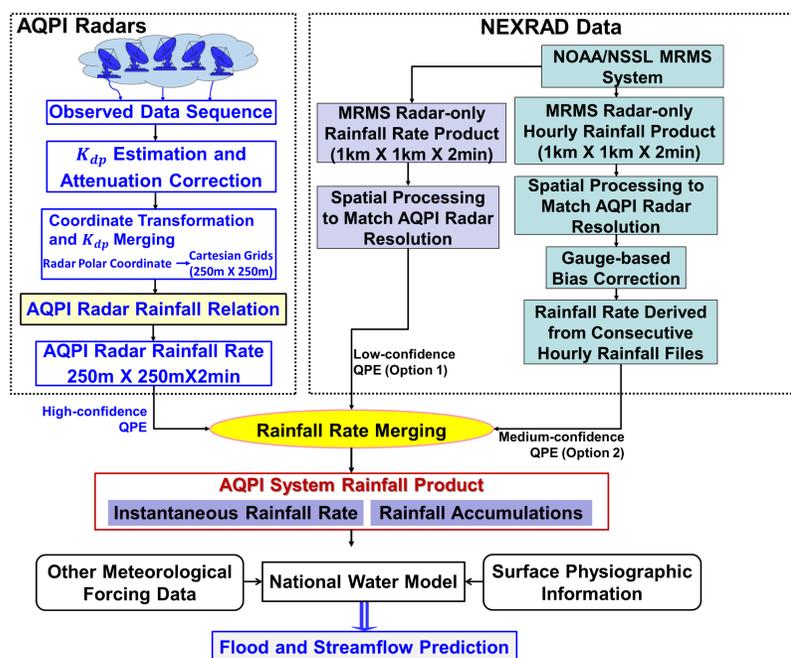

Fig. 2. Integrated AQPI radar QPE system.

Bias Correction of NEXRAD Rainfall Product

$T(s, t)$: gauge measurement (precipitation "truth") at site s and time t

$R(s, t)$: radar rainfall estimate at site s and time t; Ideally, the bias corrected radar estimate should be close to $T(s, t)$.

The conditional probability of T given that radar estimate R is available can be expressed as follows:

$$P(T|R) \propto P(R|T)P(T)$$

where $P(T|R)$ is the posterior probability of T occurring given that R is true; $P(R|T)$ is the likelihood of R occurring given that T is true; $P(T)$ is the prior probability of T. In applications, it is reformulated in a continuous form: $f(T|R) \propto f(R|T)f(T)$

$$R|T \sim D(\boldsymbol{\theta})$$

where D stands for the conditional distribution of $R|T$ derived from various distribution families, and $\boldsymbol{\theta} = (\theta_1, \theta_2, ..., \theta_n)$ indicates the associated collection of n distribution parameters.

Each conditional distribution D can be expressed to incorporate the spatial and temporal covariates: $\boldsymbol{\theta} \to g(\boldsymbol{\beta}; T, \boldsymbol{\gamma})$, where g is the linked function; $\boldsymbol{\beta}$ represents the parameter set of the linked function; $\boldsymbol{\gamma}$ is the collection of covariates (i.e., radar rainfall estimates, and/or terrain and wind information).

The q-quantiles of the posterior predictive distribution of T^* is used to correct R^*, the radar estimates at the new site and/or time. The posterior distribution of T^* given R^* occurring is:

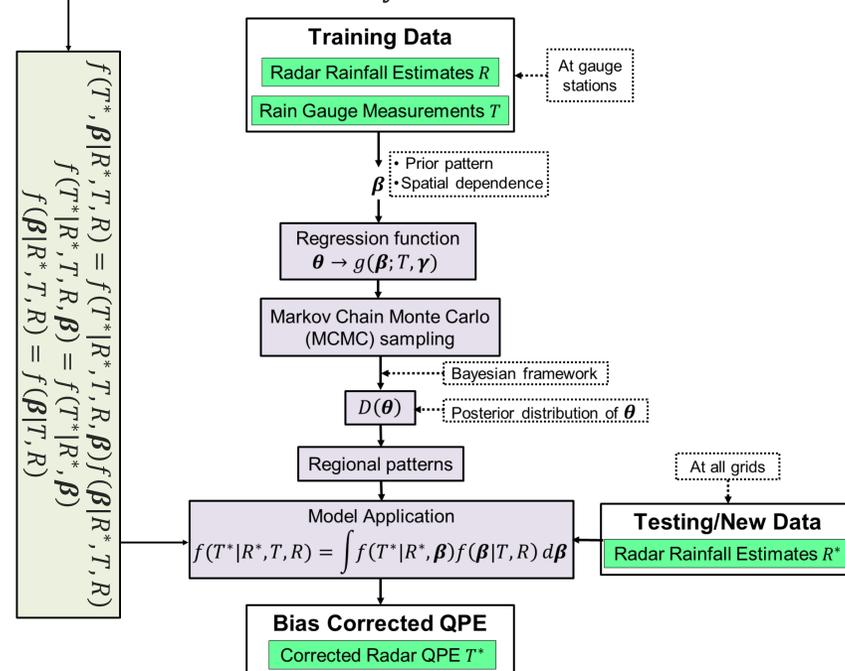$$f(T^*|R^*, T, R) = \int f(T^*, \boldsymbol{\beta}|Y^*, T, R)d\boldsymbol{\beta}$$

Fig. 3. Overall diagram of the Bayesian framework for NEXRAD QPE bias correction. For details, see Chen et al. (2019, *Journal of Hydrometeorology*).
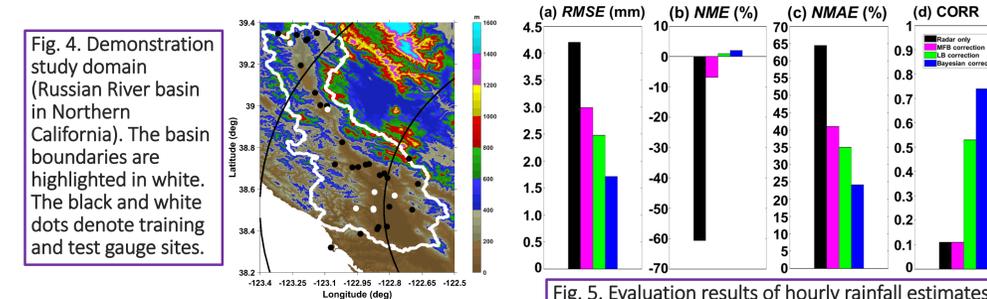

Fig. 4. Demonstration study domain (Russian River basin in Northern California). The basin boundaries are highlighted in white. The black and white dots denote training and test gauge sites.

Fig. 5. Evaluation results of hourly rainfall estimates during the 7 February 2017 precipitation event.

(a) RMSE (mm)   (b) NME (%)   (c) NMAE (%)   (d) CORR
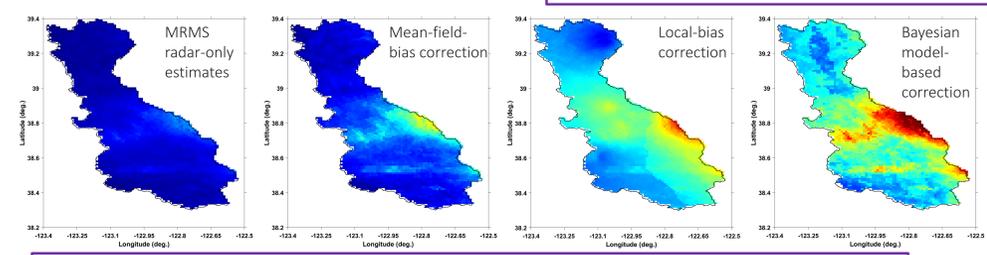
Fig. 6. Radar-derived hourly rainfall over the Russian River watershed on 07 February 2017, at 13UTC.

MRMS radar-only estimates · Mean-field-bias correction · Local-bias correction · Bayesian model-based correction

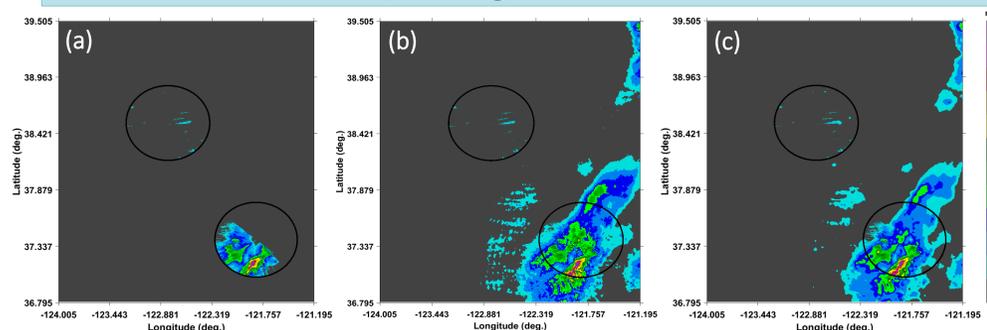## Real-time, Integrated QPE Product

Fig. 7. Hourly rainfall at 2019-02-14 21UTC: (a) AQPI radar only; (b) combined AQPI radar with NEXRAD product without bias correction; (c) combined AQPI radar with bias corrected NEXRAD product.
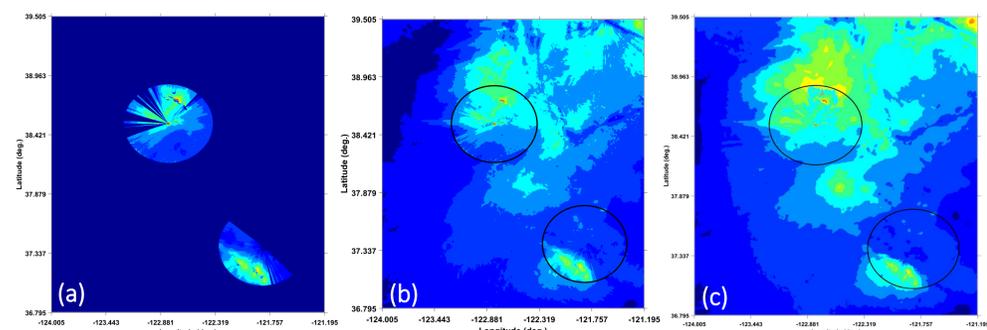

Fig. 8. Rainfall total for the 2019 Valentine's event (96 hrs from 2019-02-13 00UTC): (a) AQPI radar only; (b) combined AQPI radar with NEXRAD product without bias correction; (c) combined AQPI radar with bias corrected NEXRAD product.

Summary

- A downscaling procedure is applied to the NEXRAD rainfall product in order to match the high-resolution AQPI radar observations;
- A Bayesian model is developed for bias correction of NEXRAD rainfall product using surface rain gauge measurements;
- An integrated QPE system is designed based on multi-scale data over the Bay Area;
- The integrated QPE is being implemented into the real-time AQPI system.