Mean areal rainfall improvement using radar rainfall estimation technique by considering geographic character for dam operation

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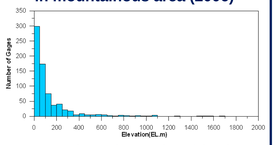
1. Introduction

Necessity

- Rational dam operating is necessary to secure water resources and respond to floods. The amount of dam inflow should be accurately calculated for the dam operation. Rainfall information is essential for estimating and predicting the amount of dam inflow therefore rainfall should be observed accurately. However, it is difficult to observe the rainfall due to the low density of rain gauges because of the dam is located in the mountainous region. Moreover, as recent changes in rainfall characteristics increase the frequency of local rainfall, raingauge-based rainfall observations have limitations.

Flood damage in mountainous area (2006)



Number of AWS by altitude (50m interval)

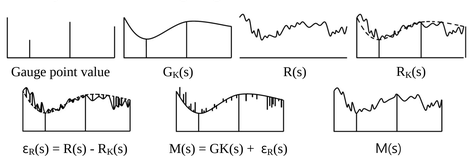
- The advantage of radar is that it can obtain high-resolution grid rainfall data because radar can observe the spatial distribution of rainfall. The radar rainfall measurements are quantitatively less accurate than rain gauge measurements because of several error factors.
- For improving the accuracy of radar rainfall estimates, many adjustment methods using rain gauges, have been suggested. For dam basin, because the density of rain gauge is low, there are limitations when apply the bias adjustment methods using rain gauges. Especially, the localized heavy rainfall occurred in the mountainous area depending on the topography.

Objective

- To develop a radar rainfall adjustment method considering the orographic effect
- To estimate the mean areal precipitation for hydropower dam basin
- To compare and evaluate the results of various adjustment methods techniques in terms of mean areal precipitation

2. Conditional merging considering the elevation

- Conditional merging technique extracts information from the observed data by using ordinary kriging and combines it with radar rainfall data to improve radar rainfall estimates (Ehret 2002;Pegram 2002)
- Proposed method considers the elevation to obtain kriged rainfall and apply conditional merging method for improving the accuracy of the radar rainfall estimates.
  1) To perform the standardization of primary (rainfall) and secondary (elevation) variables to the same zero mean and unit variance for avoiding errors that can result from difference in scales
  2) To estimate the rainfall distribution field(rain gauge and radar data) by considering the elevation using the cokriging
  3) To conditional merge to take into account the area that is not monitored by the radar or gauge

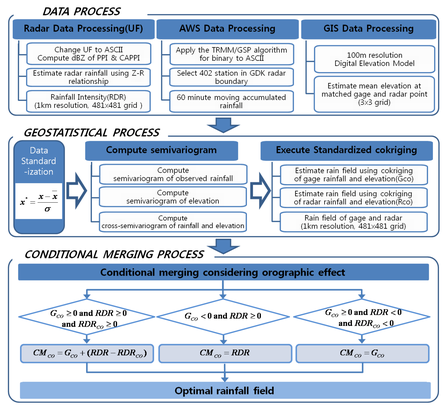


Concept of the conditional merging method (modified from Sinclair and Pegram, 2005)

$$M(s) = G_K(s) + [R(s) - R_K(s)], G_K(s), R(s), R_K(s) \geq 0$$

$$M(s) = G_K(s), G_K(s) \geq 0, R(s), R_K(s) < 0$$

$$M(s) = R(s), G_K(s) < 0, \text{and } R(s) \geq 0$$

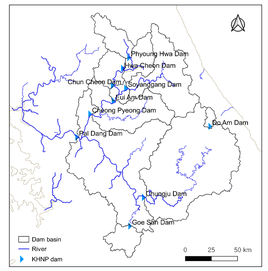


Procedure for conditional merging by considering elevation(Yoon and Bae, 2013)

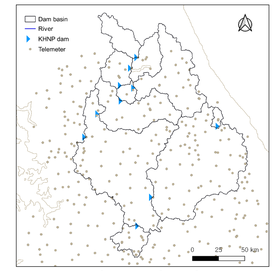
3. Applications and results

Study Area: Dam basins in Han river

- The mountain range spreads to the east of the central district and runs in the north–south direction; parts of the mountain range have heights greater than 1000 m above mean sea level.
- Multipurpose dams and hydroelectric dams, which are important for water resource management and flood forecasting, are located in the Han River basin and in the Taebaek Mountain Range.



Study area (dam basins, stream)



Telemeter location

Applications and Results

- Weather data
  - Telemeter 604 stations (10 min. ASCII)
  - Composited radar rainfall (10 min. Netcdf)
- QPE methods
  - To estimate radar rainfall using dual-polarized radar. variables(Z_H, Z_{DR}, K_{DP})
  - JPOLE algorithm(Ryzhkov et al., 2005) is used.

JPOLE (Ryzhkov et al., 2005)

Rainfall estimation method using differential reflectivity

$$R(Z, Z_{DR}) = 6.70 \times 10^{-3} Z^{0.714} \times Z_{DR}^{-3.43}$$

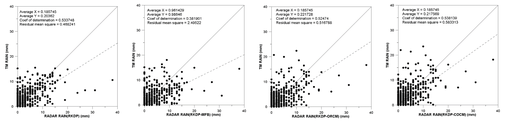
Rainfall estimation method using specific differential phase

$$R(K_{DP}) = 44.0 \times |K_{DP}|^{0.822} Sign(K_{DP})$$

$$R = R(Z) / f_1(Z_{DR}) \quad \text{if} \quad R(Z) < 6\text{mm/hr}$$
$$R = R(K_{DP}) / f_2(Z_{DR}) \quad \text{if} \quad R(Z) < 50\text{mm/hr}$$
$$R = R(K_{DP}) \quad \text{if} \quad R(Z) > 50\text{mm/hr}$$

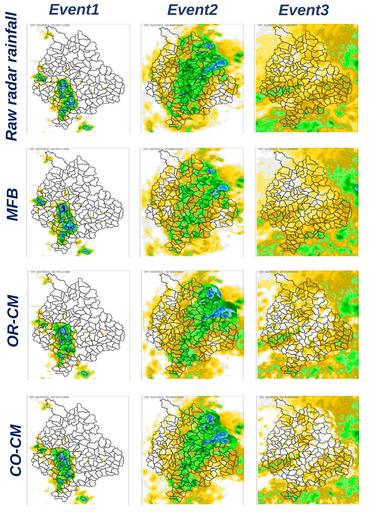
$$f_1(Z_{DR}) = 0.4 + 5.0\overline{Z_{DR}}^{-3}, \; f_2(Z_{DR}) = 0.4 + 3.5\overline{Z_{DR}}^{-3.7}$$
$$\overline{Z_{DR}} = 10^{0.1 Z_{DR}(dB)}$$

- The used radar rainfall adjustment methods
  - Mean field bias adjustment(MFB)
  - Original conditional merging(OR-CM)
  - Conditional merging considering the elevation (CO-CM)
- Scatter diagrams of radar rainfalls

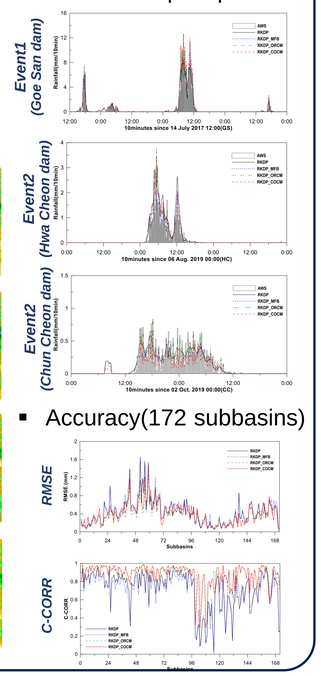


Raw radar *MFB* *OR-CM* *CO-CM*

- Rain events
  - 2017/07/14 12:00-07/17 23:50
  - 2019/08/06 00:00-08/08 23:50
  - 2019/10/02 00:00-10/04 23:50
- Rainfall distribution



- Mean areal precipitation



- Accuracy(172 subbasins)

4. Conclusion

- This study presents a radar rainfall adjustment method that considers the elevation in mountainous regions. Gauge rainfall and radar rainfall field data are modified by using standardized ordinary cokriging considering the elevation, and the conditional merging technique is used for combining the two types of data.
- For evaluating the proposed technique, the hydroelectric dam area in Han River basin was selected; a high correlation between rainfall and elevation. The proposed technique was compared with the mean field bias and original conditional merging techniques.
- The proposed method has a lesser tendency to oversmooth the rainfall distribution when compared with the other methods, and the optimal mean areal rainfall is very similar to the value obtained using gauges.
- It reveals that the proposed method can be applied to an area with significantly varying elevation, such as the Han River basin, to obtain radar rainfall data of high accuracy.

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