Effect of Variations in Reflectivity-Rainfall Relationships on Runoff Predictions

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Motivation

- To use weather radar data in hydrological applications, radar reflectivity (*Z*) need to be transformed into surface rainfall estimates (*R*).
- Estimation of the Z-R relationships is subject to several sources of uncertainties including the storm-to-storm and within the storm variations in raindrop size distributions (DSD).
- Previous studies demonstrated that accounting for temporal/spatial variability in DSD and Z-R relations affect the overall accuracy of rainfall estimates.

  - (e.g., Uijelenhoet et al. 2003; Lee and Zawadzki 2005)
- Despite the recognized effect of DSD and Z-R variability, less attention has been dedicated to their effect on hydrologic predictions.
- Some early analysis was reported (Winchell et al., 1998) but focused only on total aggregate runoff volumes.
- Most hydrologic modeling studies use a single Z-R relationship.
- It is not well understood how the variability in DSD and Z-R relationships affect the accuracy of the hydrologic predictions.

Overall Objective

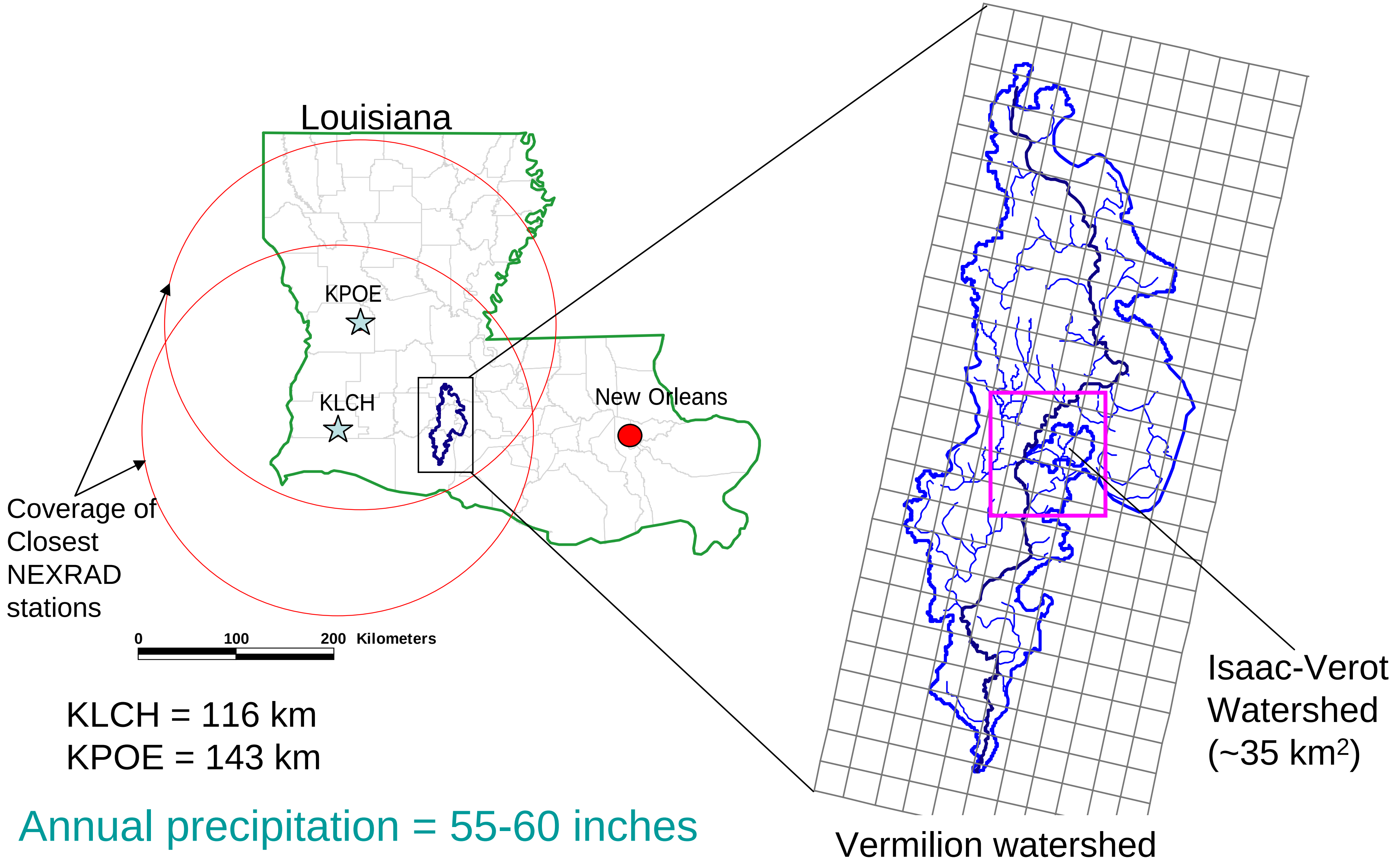
- Investigate the effect of intra-storm and inter-storm variability in Z-R relationships on predictions of stream-flow.

Approach

- Perform the analysis using high-resolution disdrometer measurements along with WSR-88D reflectivity data over an experimental watershed.

- Employ a physically-based hydrologic model to ensure the physical representation of rainfall-runoff processes.

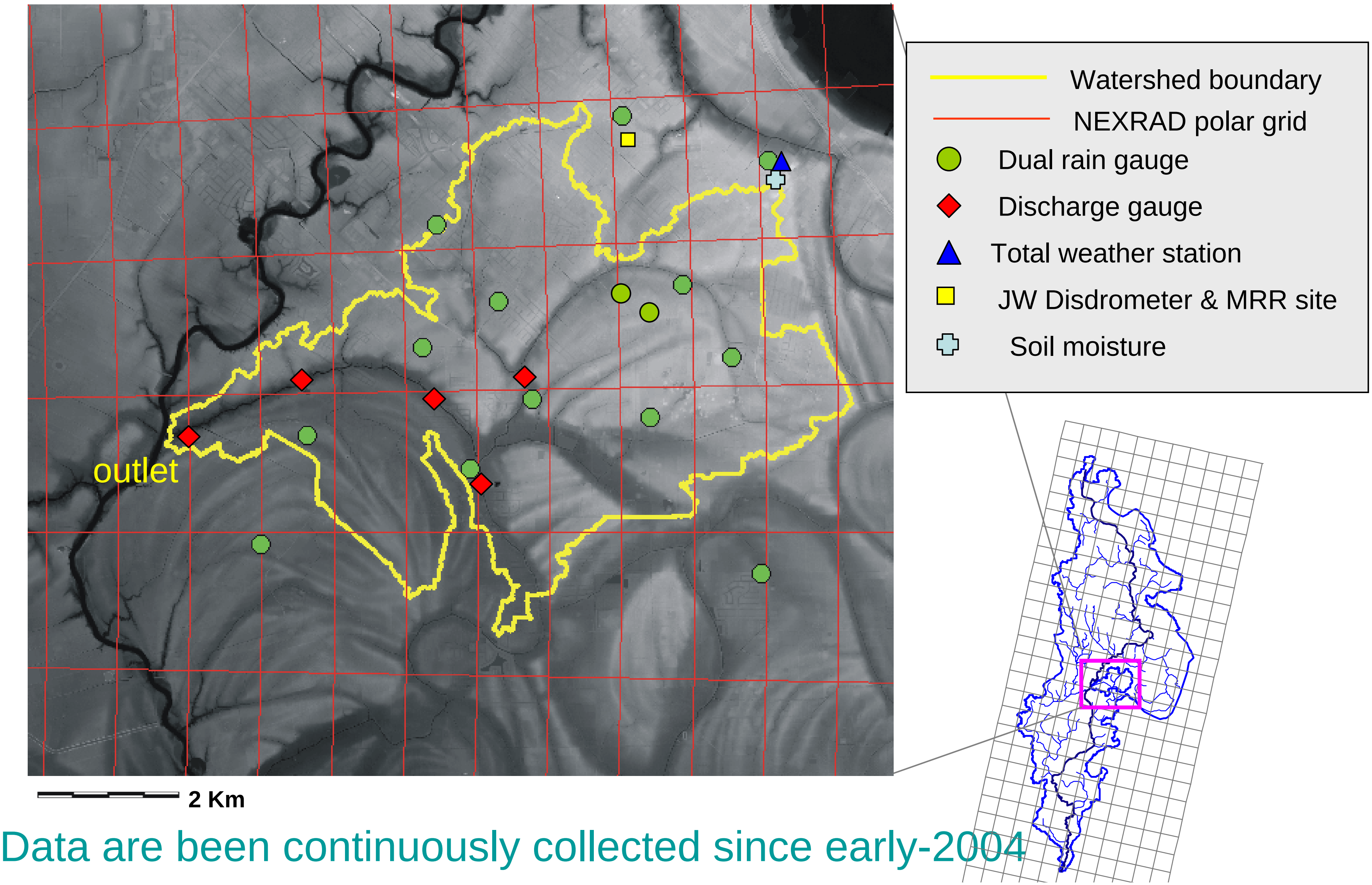
Experiment Site:
Isaac-Verot Watershed, Southern Louisiana



KLCH = 116 km
KPOE = 143 km

Annual precipitation = 55-60 inches

Watershed Instrumentation



Data are been continuously collected since early-2004

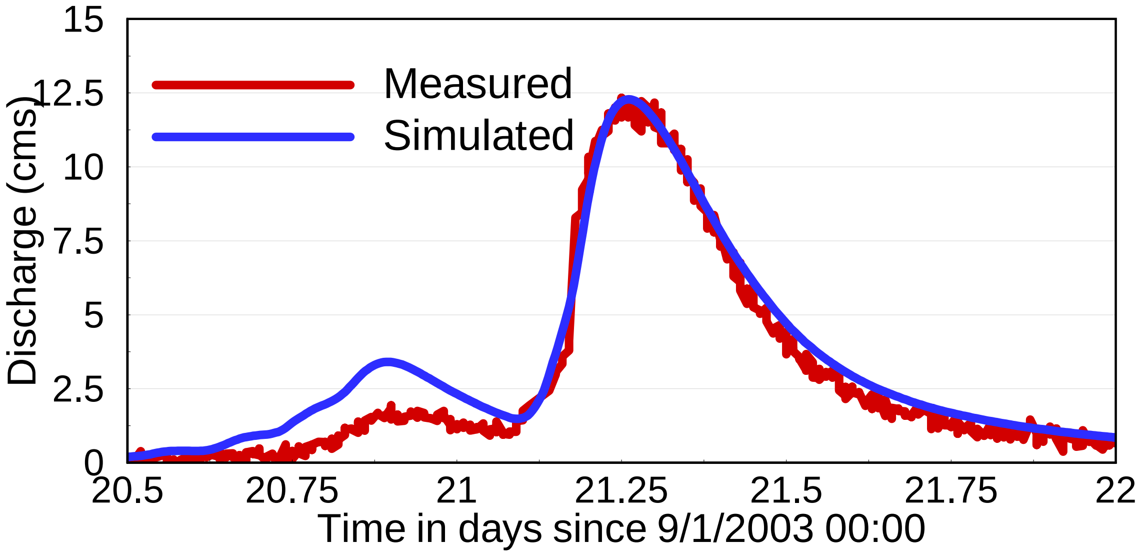
Hydrologic Model:

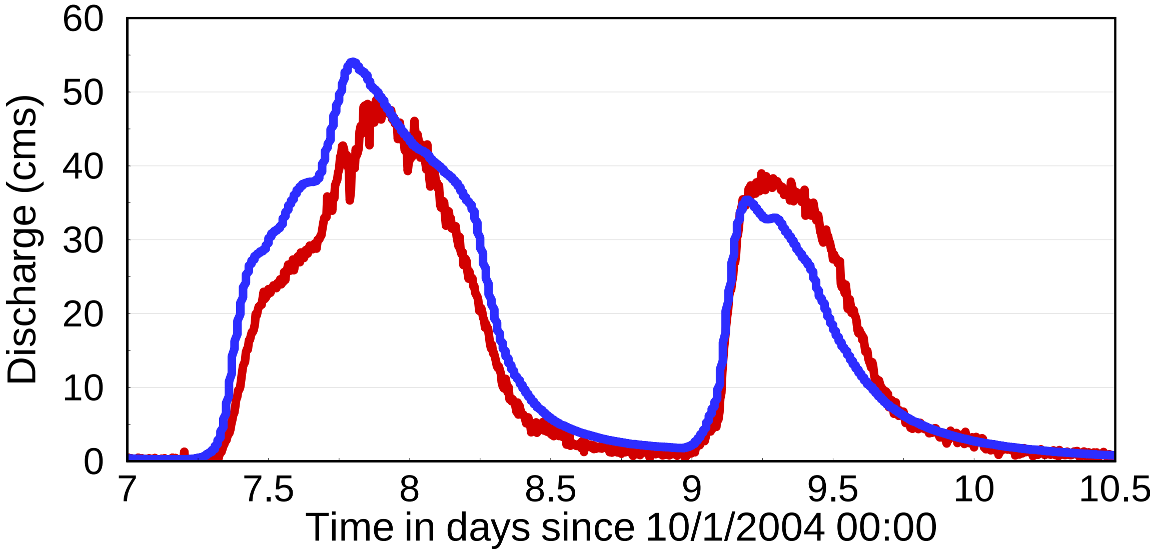
Gridded Surface Subsurface Hydrologic Analysis (GSSHA)

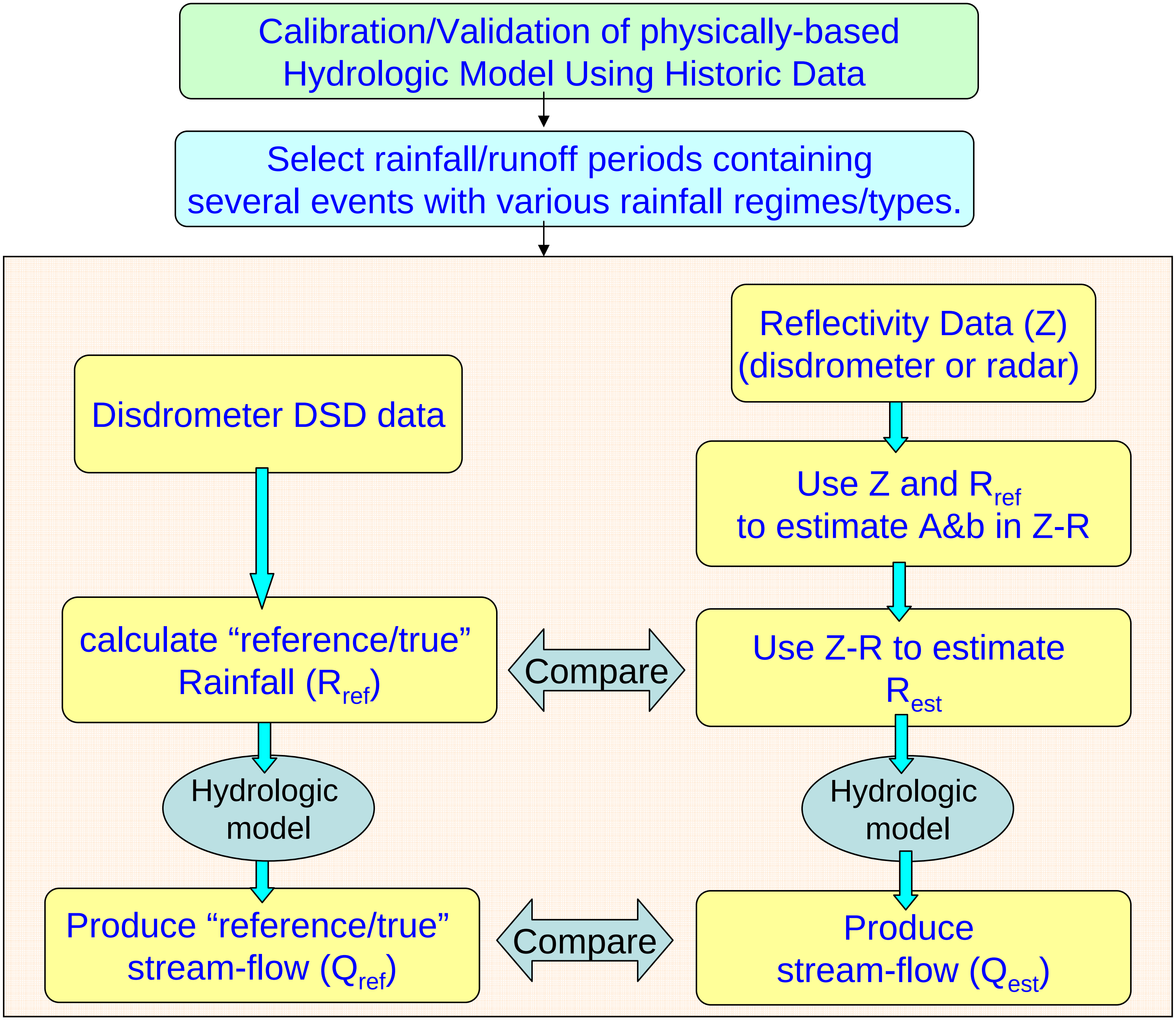
- GSSHA is a physically-based fully distributed hydrologic model (Ogden and Downer, 2002).
- GSSHA uses finite difference and finite volume methods to simulate different hydrologic processes.
- The modeling setup used in our study included:
  - two-dimensional diffusive wave for overland flow
  - one-dimensional explicit diffusive wave method for channel flow
  - Penman-Monteith equation for evapotranspiration.
  - Green and Ampt infiltration with redistribution method (Ogden and Saghafian, 1997) for flow simulation in the unsaturated zone.
  - This infiltration method includes soil moisture accounting and allows for a continuous long-term simulation of the selected periods that contain multiple runoff events.

Model Calibration/Validation Results

Prior to being used in further analysis,
the model was rigorously calibrated and validated.







Calibration/Validation of physically-based Hydrologic Model Using Historic Data

Select rainfall/runoff periods containing several events with various rainfall regimes/types.

Disdrometer DSD data

calculate “reference/true” Rainfall (R_{ref})

Hydrologic model

Produce “reference/true” stream-flow (Q_{ref})

Compare

Compare

Reflectivity Data (Z) (disdrometer or radar)

Use Z and R_{ref} to estimate A&b in Z-R

Use Z-R to estimate R_{est}

Hydrologic model

Produce stream-flow (Q_{est})

Methodology (You can delete this slide if you like the previous one)

- Select rainfall/runoff periods that contain several events with various rainfall regimes/types.
- Use the disdrometer DSD data to calculate “reference/true” rainfall
- Use the reference rainfall to drive the hydrologic model and produce “reference/true” stream-flow
- Calculate Z from disdrometer DSD
- Estimate A and b for Z-R using:
  - different scales for the estimation (e.g., climatological, event, storm, sub-storm)
  - different estimation methods (e.g., least-squares regression, min RMSE)
- Run the hydrologic model with each of the estimated rainfall to predict runoff
- Assess how estimated rainfall and streamflow compare to the reference values
- Repeat the analysis using Z from radar

Different Time Scales for Estimating Coefficient and Exponent of $Z = A R^b$

- Climatological:
  - – Estimate A and b using combined long-term disdrometer data (e.g., one year).
- Storm scale:
  - – Estimate A and b using Z-R data from each storm.
- Event scale:
  - – Estimate A and b for each event with a storm.
- Sub-event scale:
  - – Split the event into convective/stratiform/transitional periods and estimate A and b for each period.

Different Methods for Estimating Coefficient and Exponent of $Z = A R^b$

- Least Squares Fit (LSF):
  - Estimate A and b using *linear* least squares regression fitting.
- Bias corrected LSF:
  - Fix b (e.g., 1.2 or 1.4) and estimate A by removing the overall bias.
- BIAS_RMSE:
  - Estimate A and b by removing the bias and optimization for minimum RMSE.
- Default:
  - $Z=300 R^{1.4}$; $Z=250 R^{1.2}$

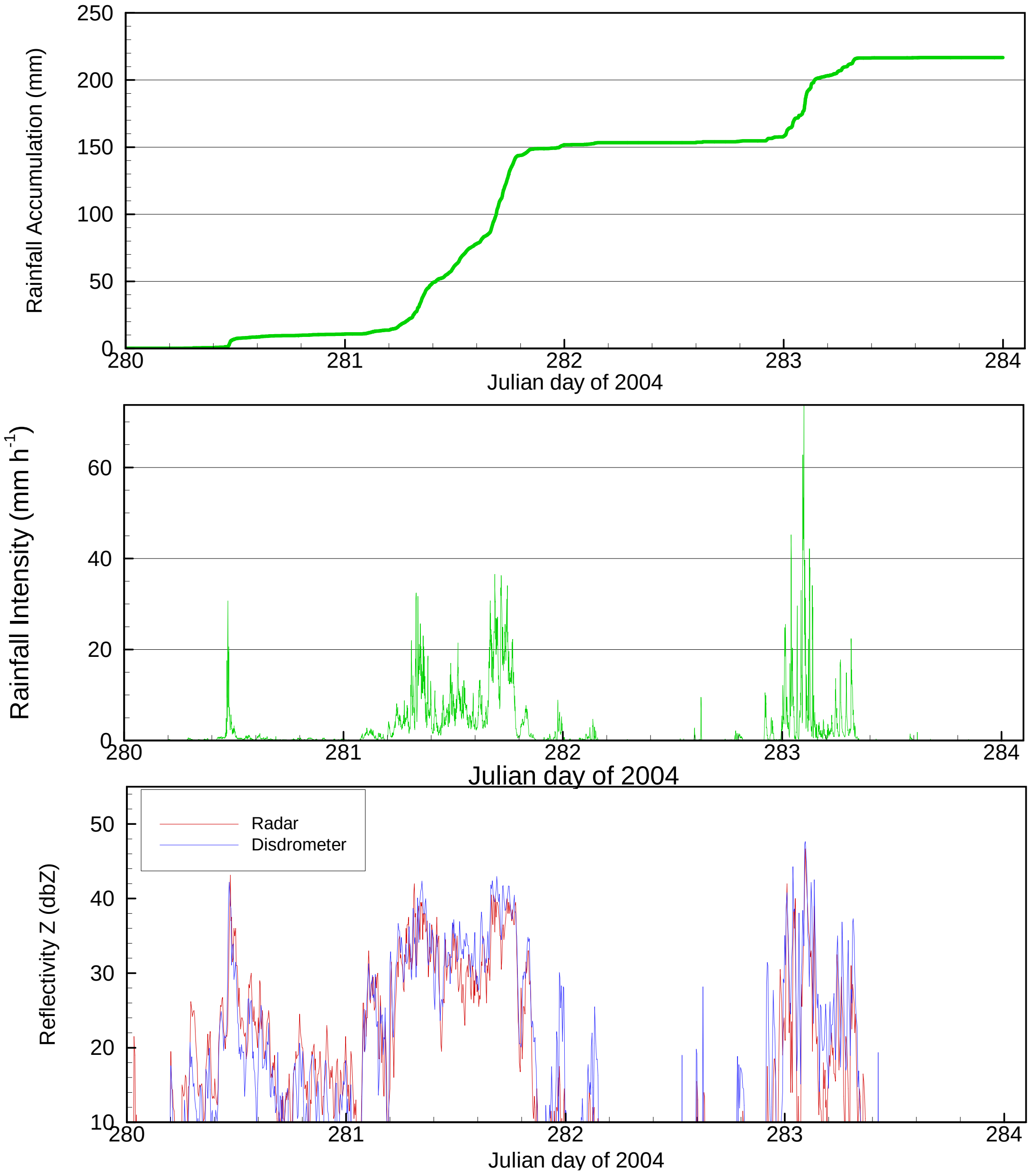
Selected Storms

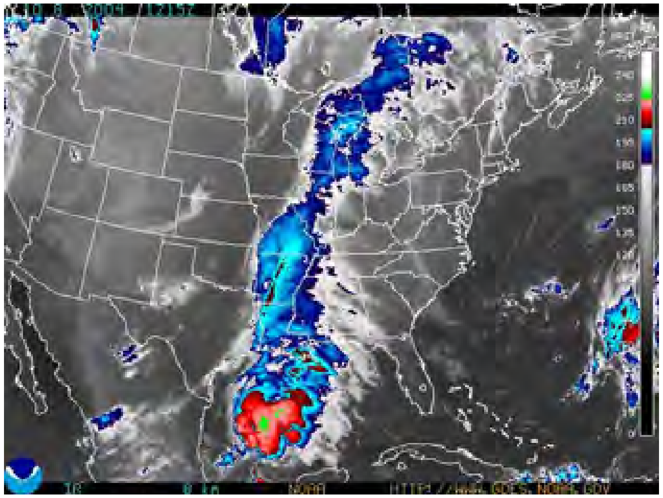
- June 22-27, 2004:
  - included of a sequence of high-intensity and short-duration convective squall line storms.
  - A total of ~ 7 inches of rainfall accumulations.

- October 7-10, 2004:
  - includes Tropical Storm Matthew (10 inches of rain).
  - Storm Matthew resulted in significant runoff as high as 2.6 m^3/sec/km^2.

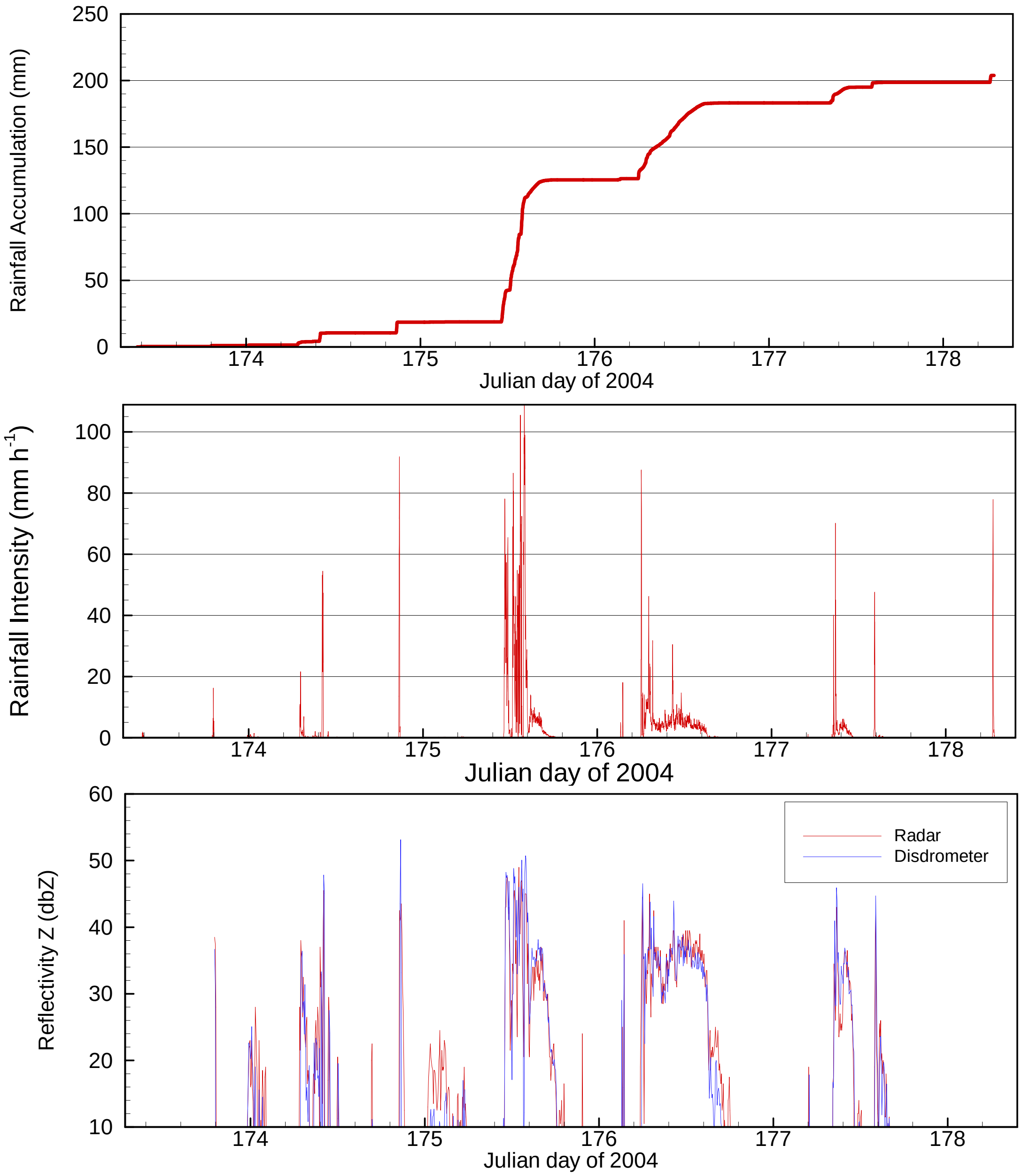
- November 17-27, 2004:
  - An extensively wet period of scattered and squall line storms.
  - Five distinct rain storms are observed in this period.
  - A total of ~ 6 inches of rainfall accumulations.
  - Runoff generated not very high but had consistent response to rainfall.

October 2004 Storm (TS Matthew)

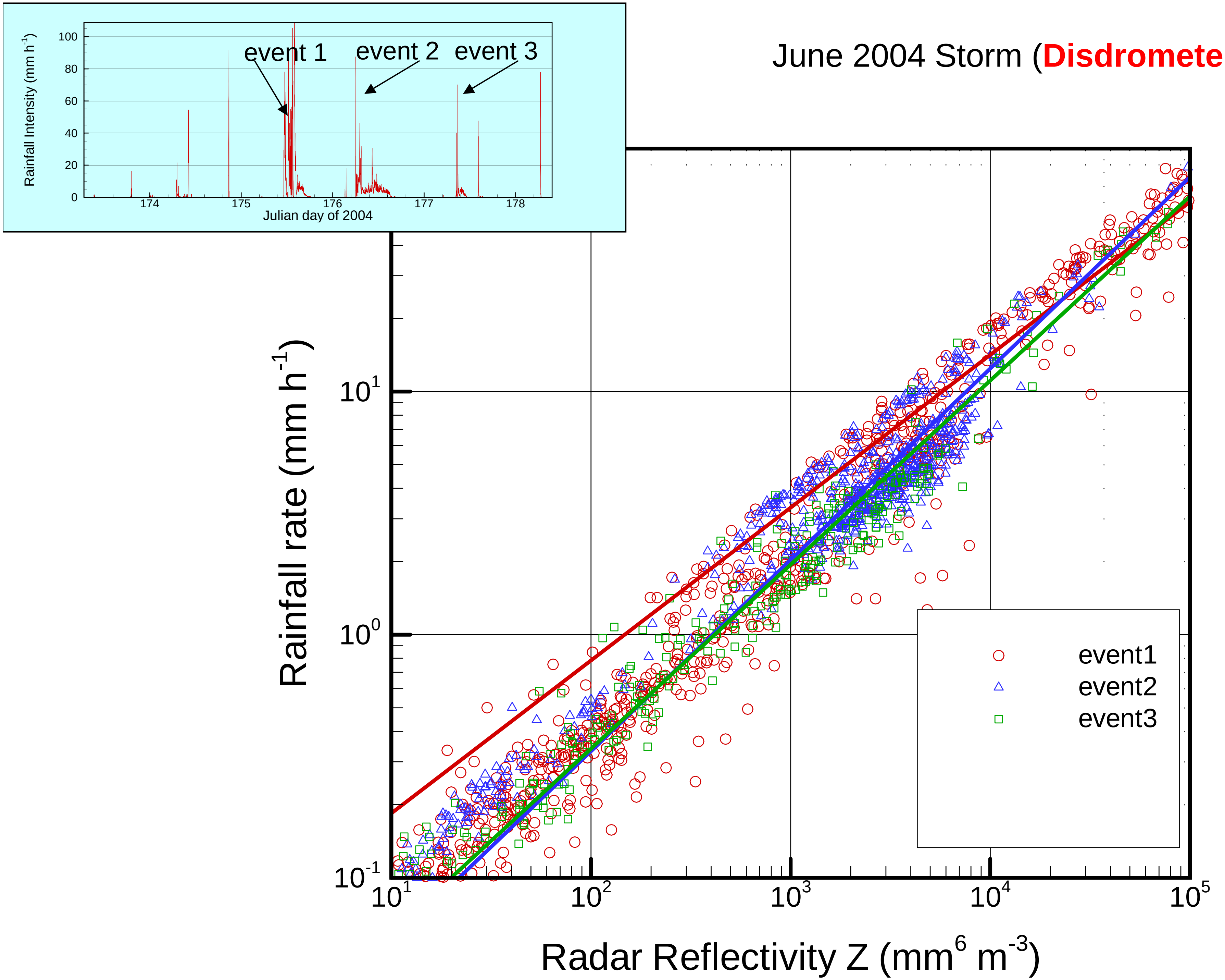




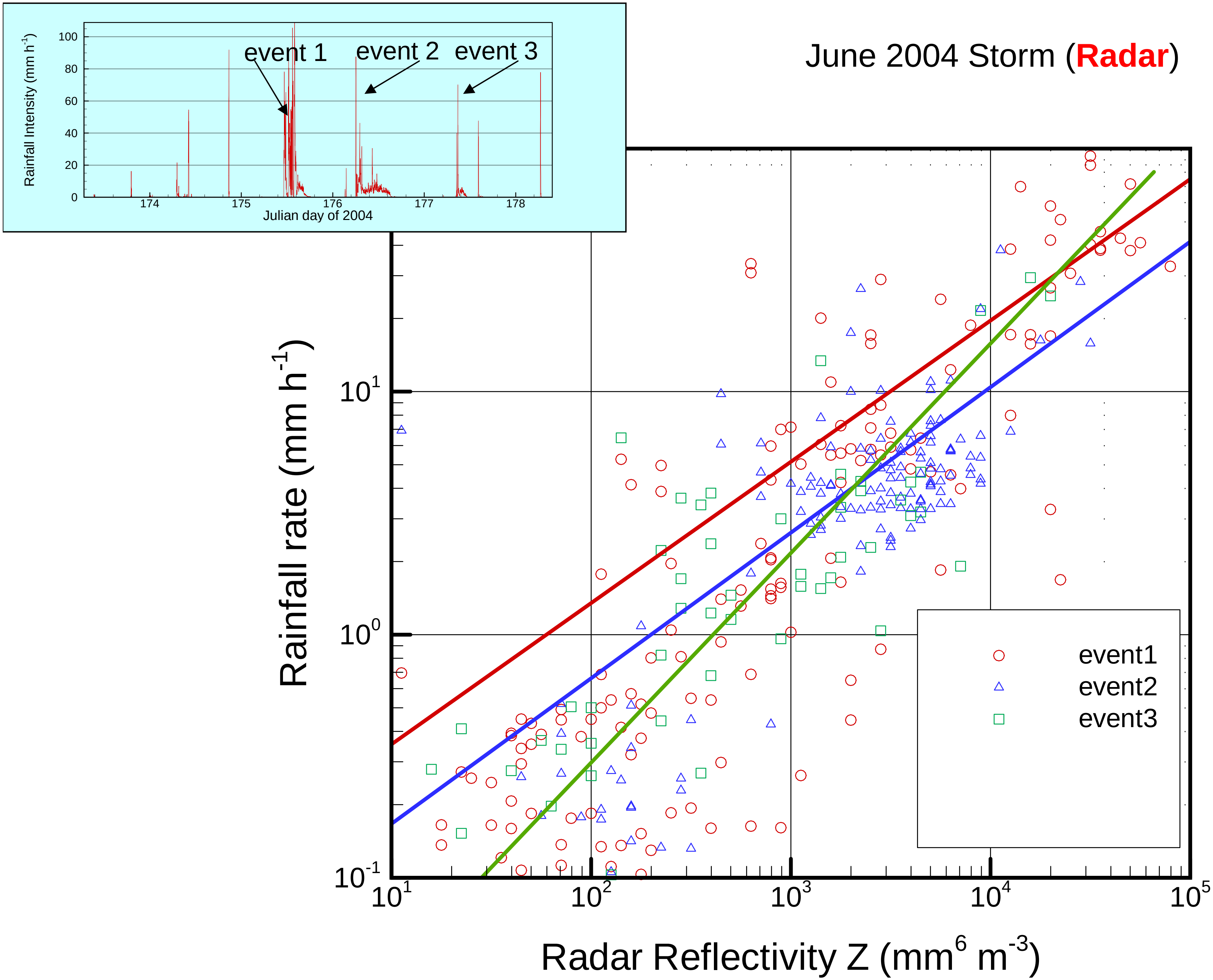
June 2004 Storm



June 2004 Storm (**Disdrometer**)

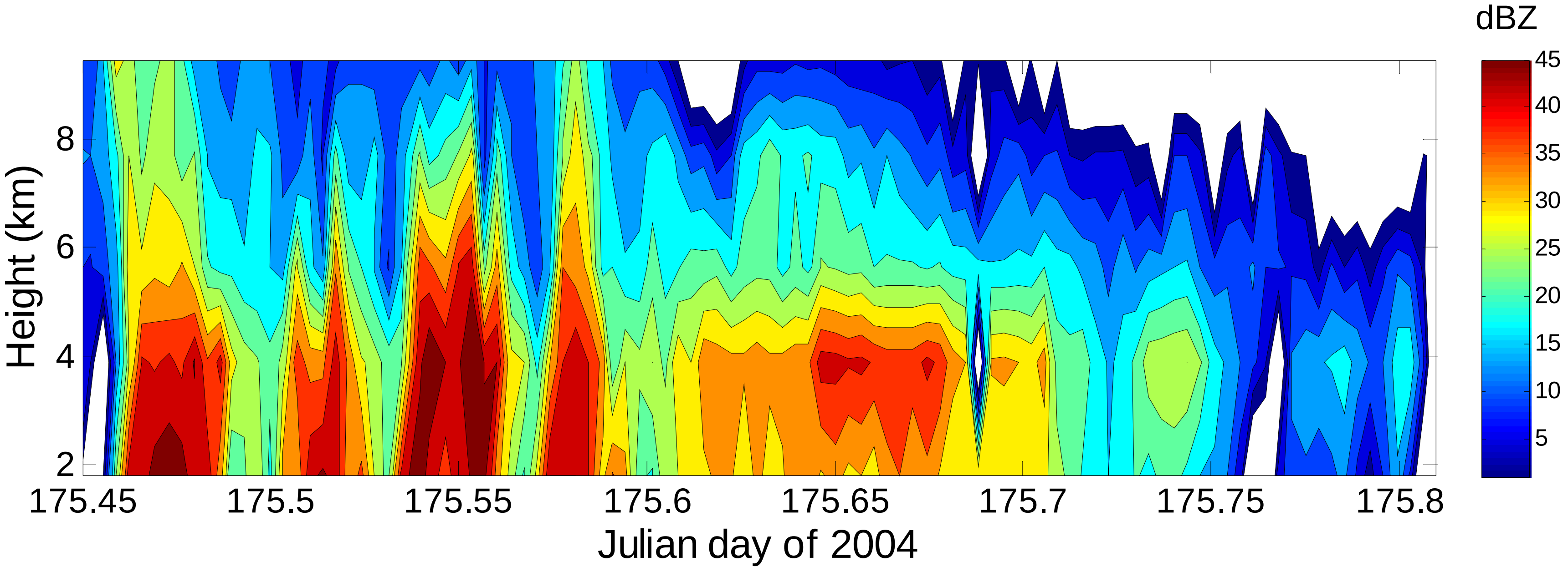


June 2004 Storm (**Radar**)

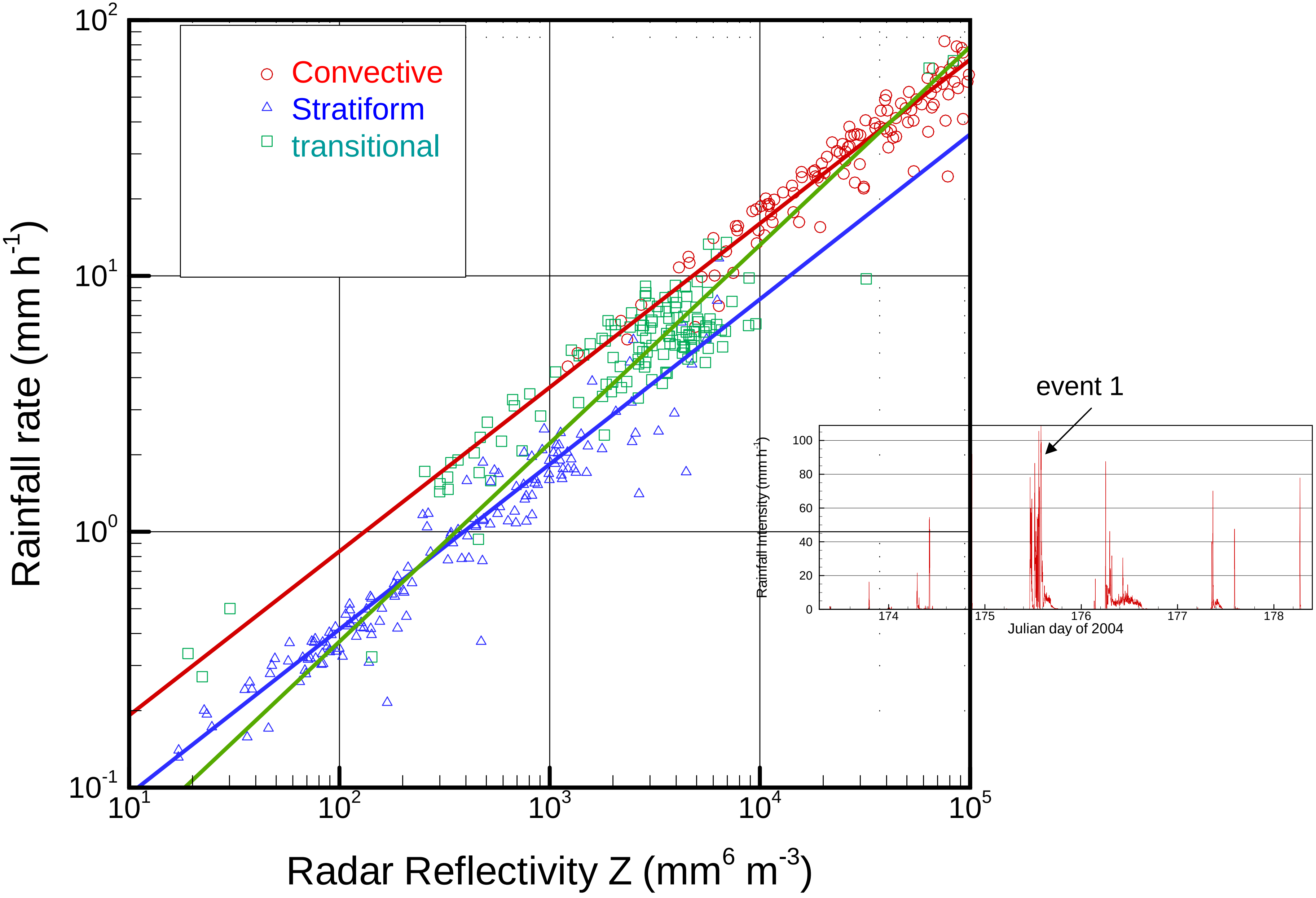


Vertical Profile of Reflectivity

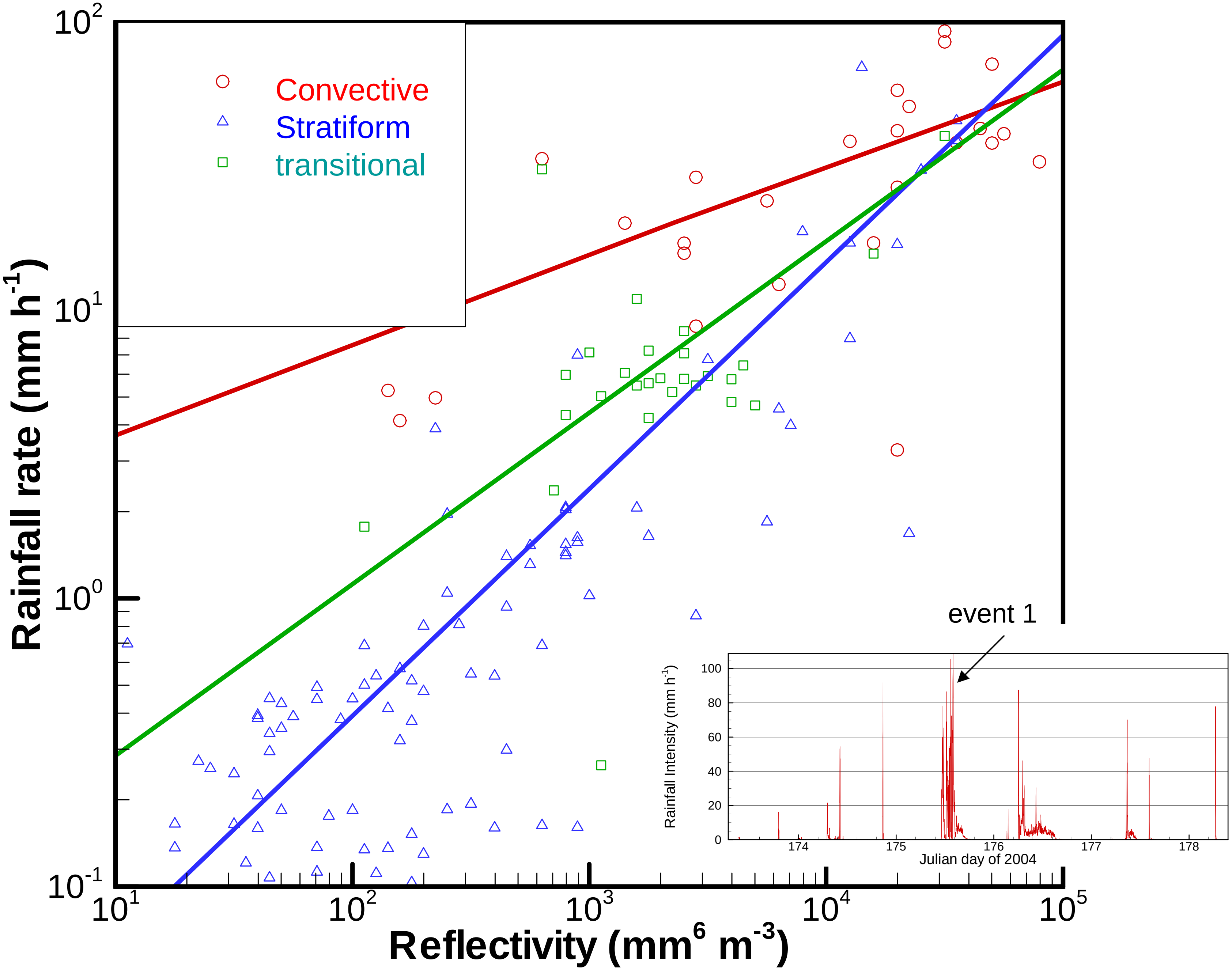
June 2004



June **event 1**, 2004 (Disdrometer)

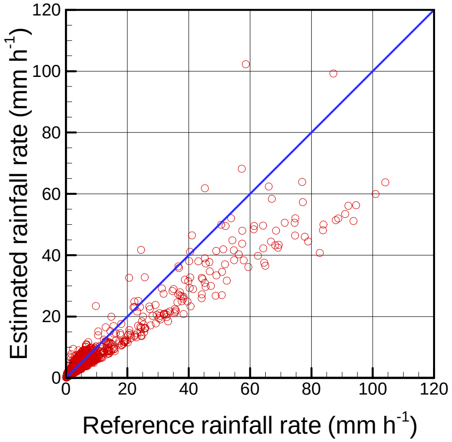


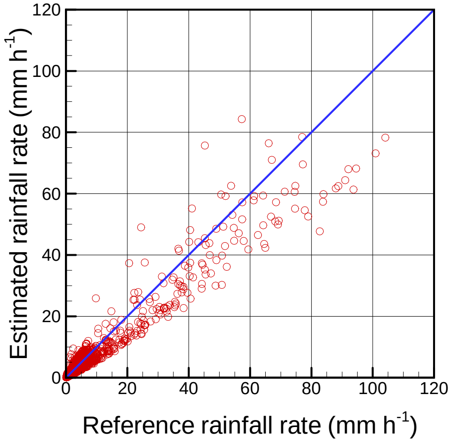
June **event 1**, 2004 (Radar)

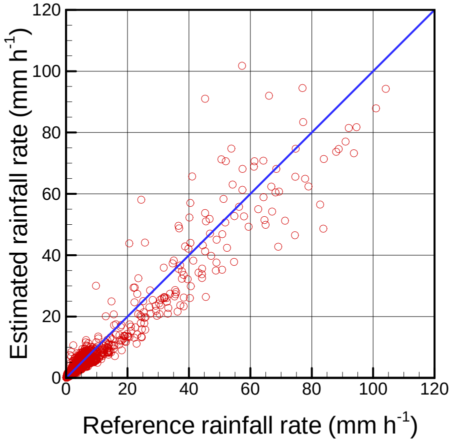


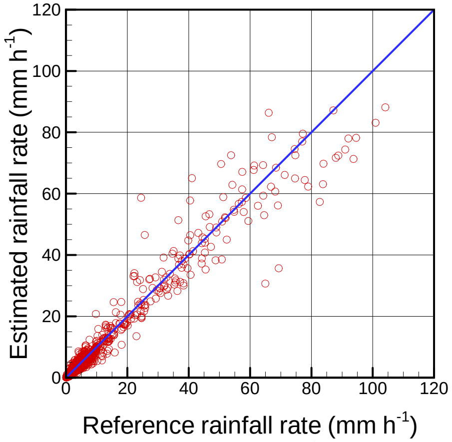
June 2004 Storm (Disdrometer)

(LSF estimation method)







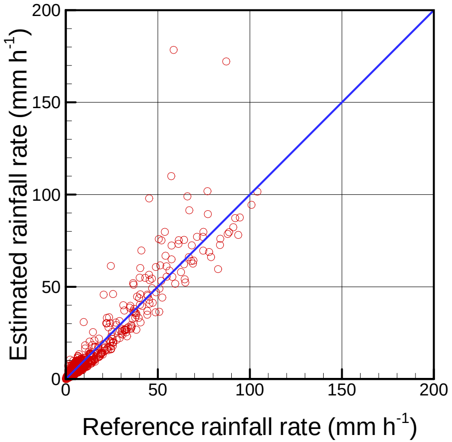


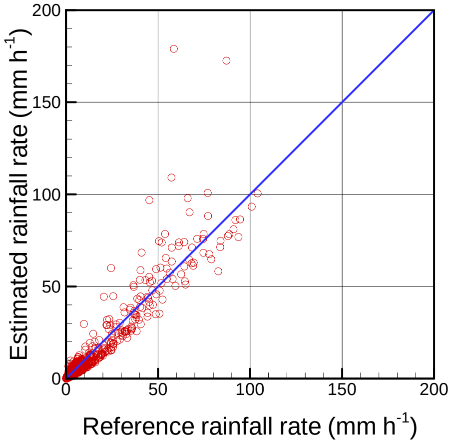
climatologial scale

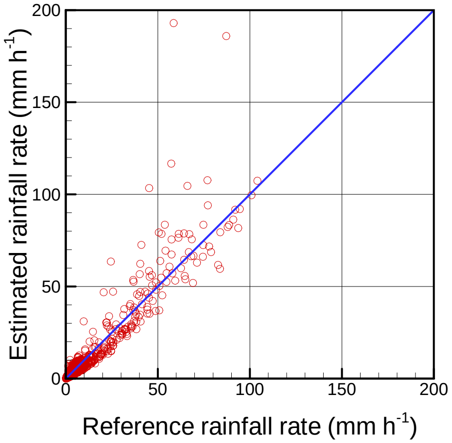
storm scale

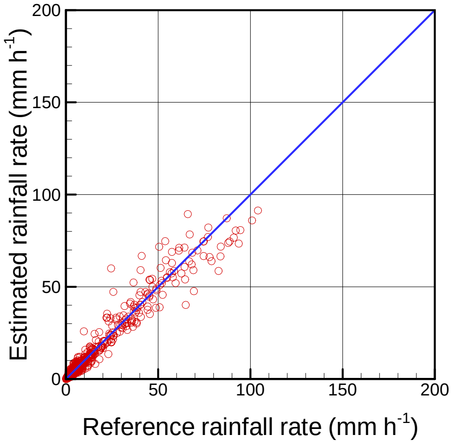
event scale

Sub-event scale





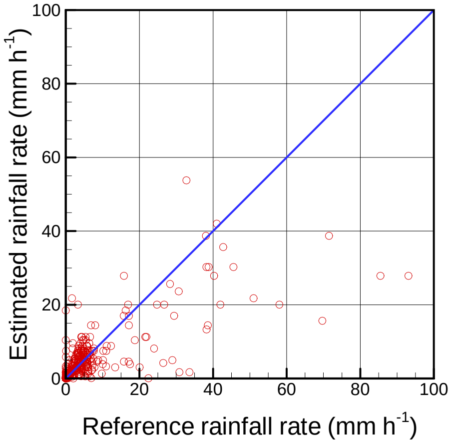


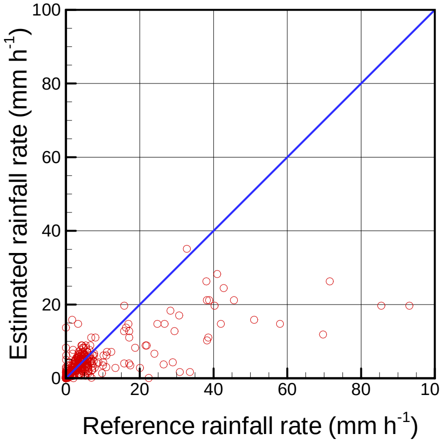


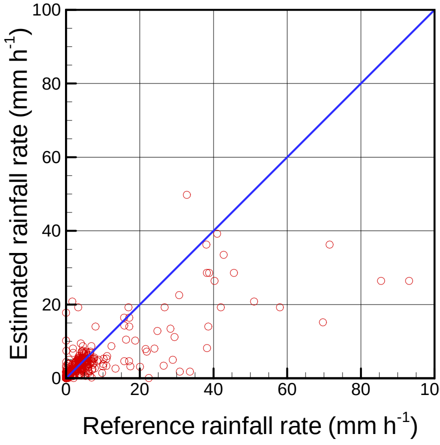
BIAS_RMSE estimation method

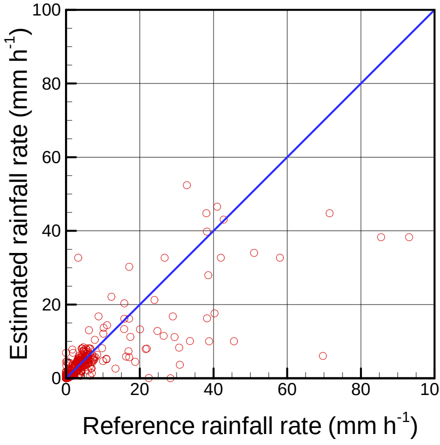
June 2004 Storm (radar)

(LSF estimation method)







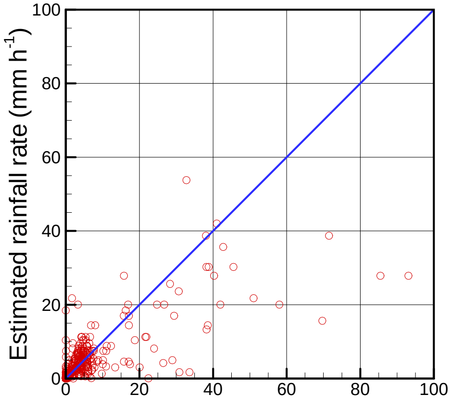


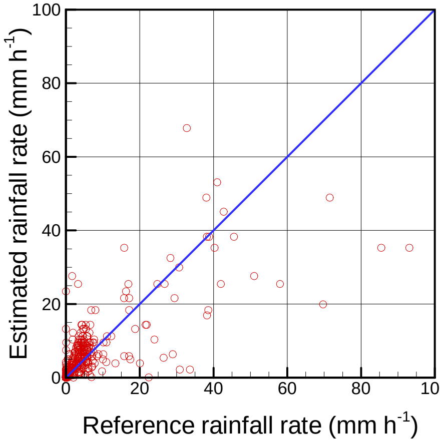
climatologial scale

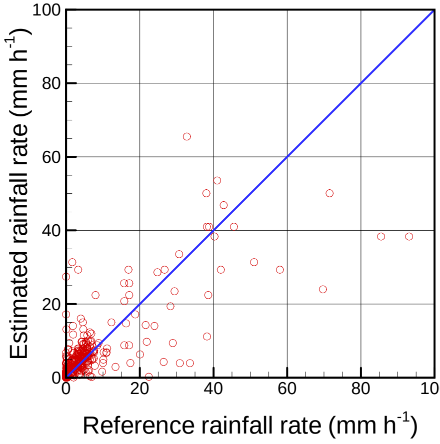
storm scale

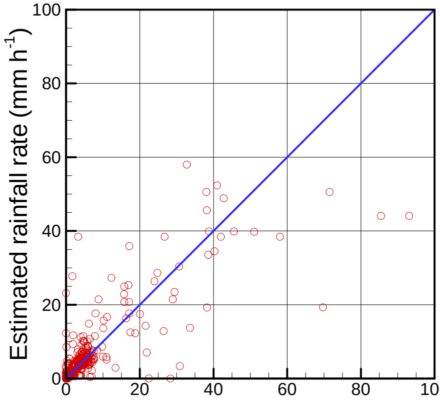
event scale

Sub-event scale



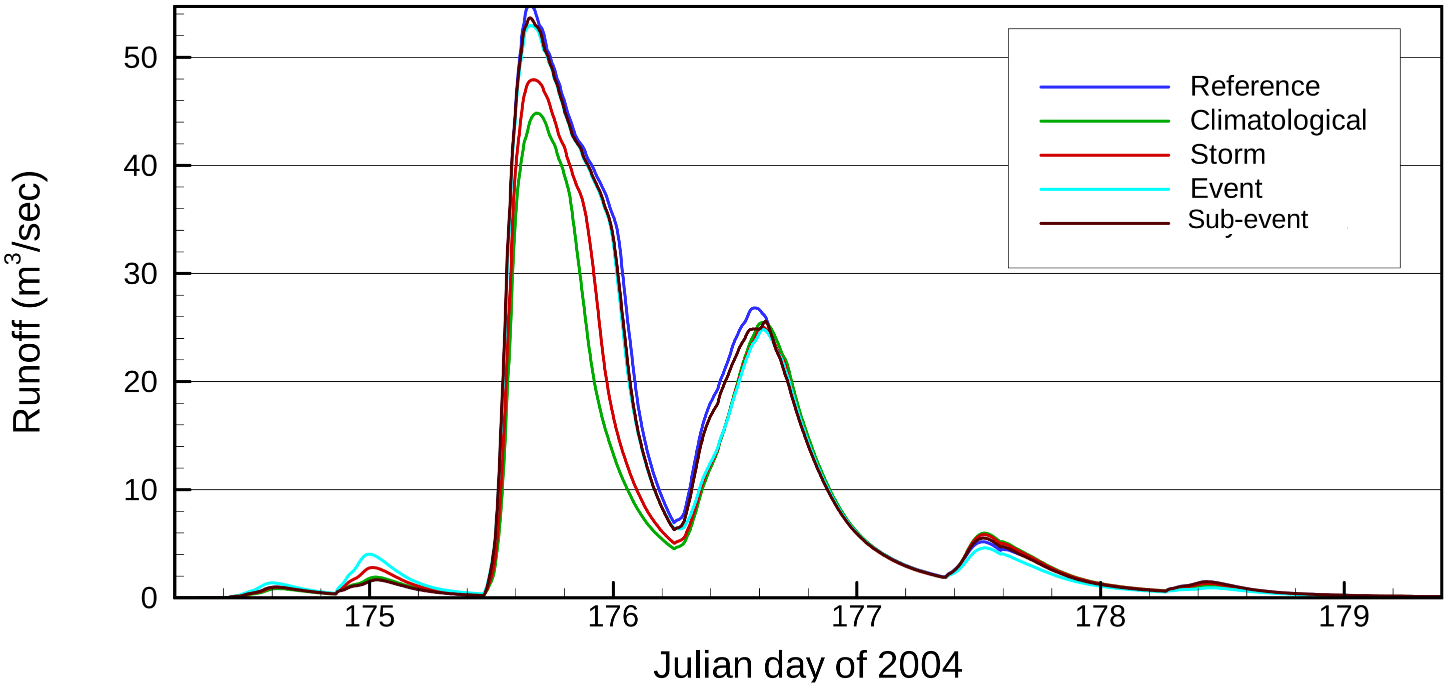




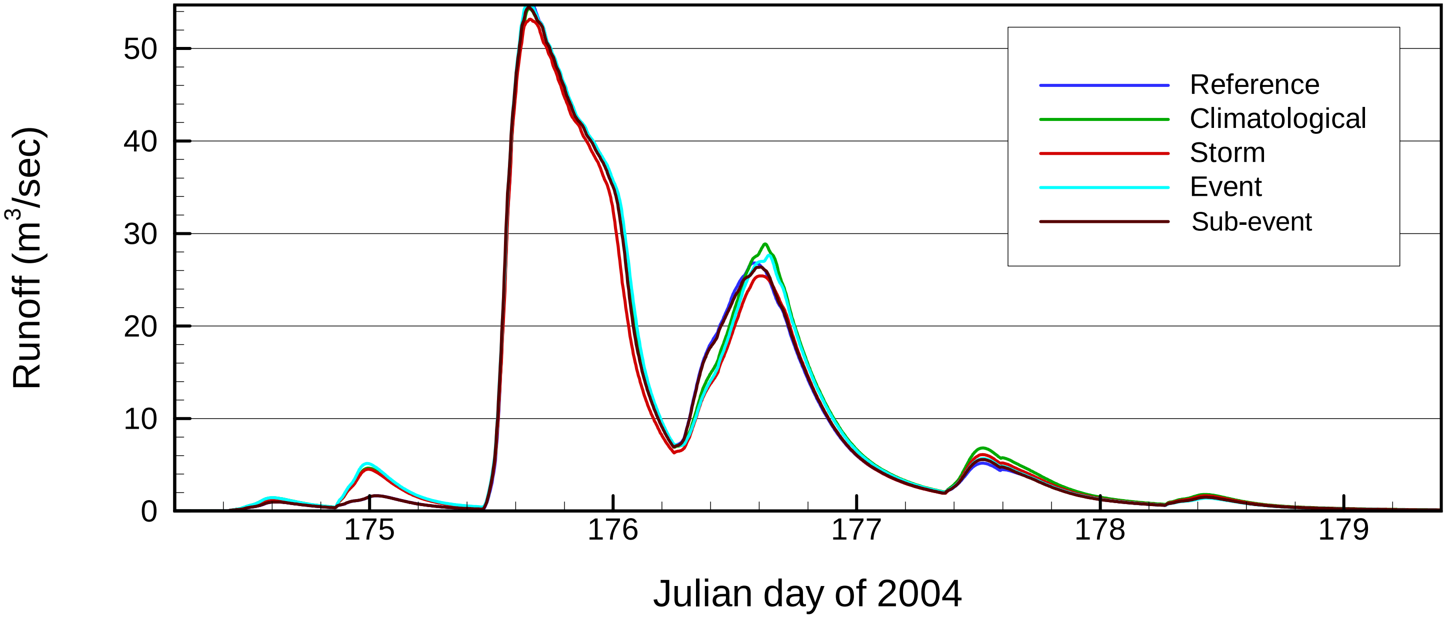


BIAS_RMSE estimation method

June 2004 (Disdrometer)

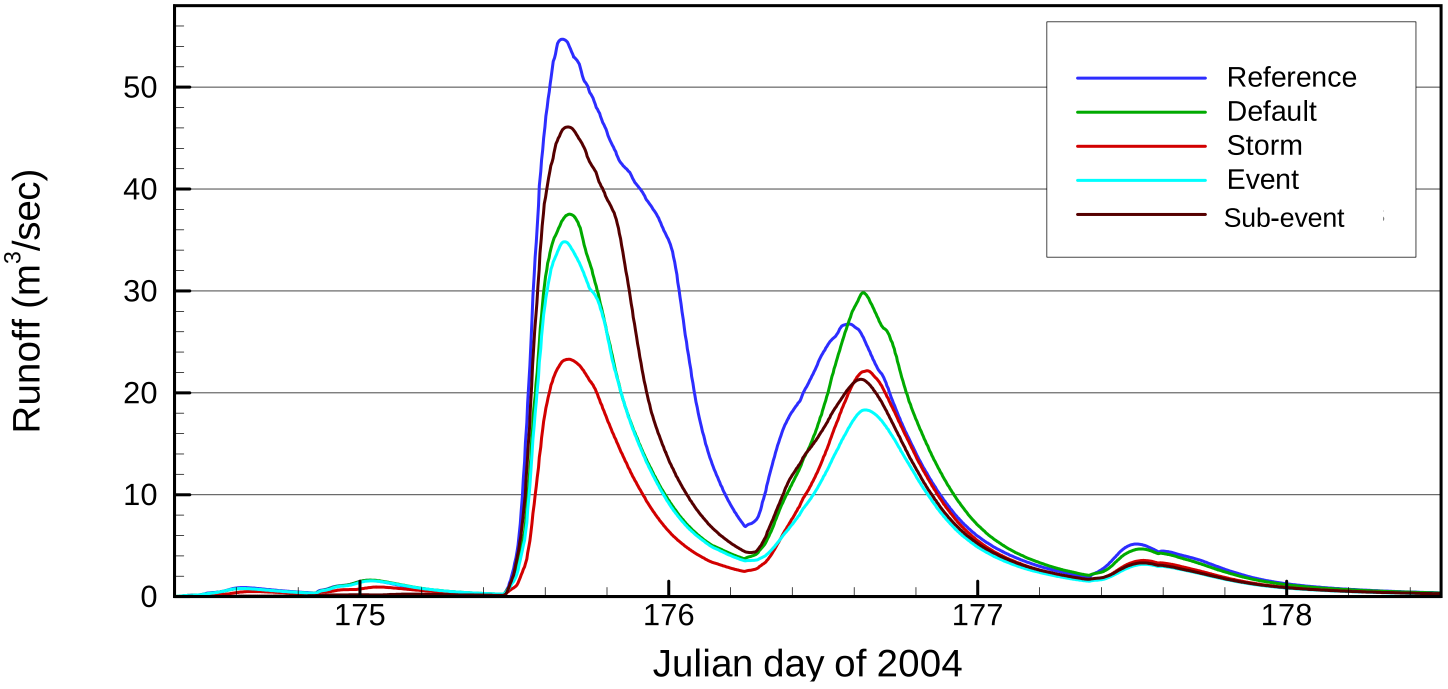


LSF

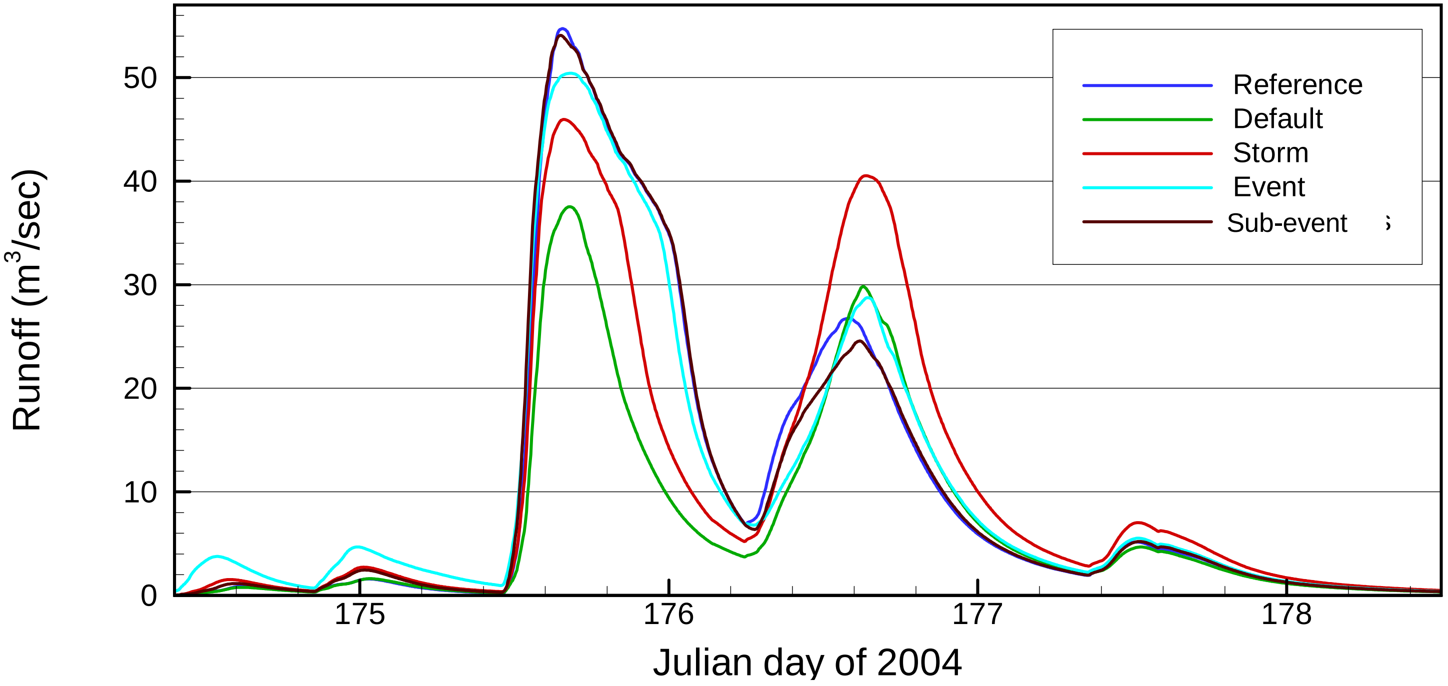


BIAS_RMSE

June 2004 (Radar)



LSF



BIAS_RMSE

Conclusions

- Z-R parameters show strong dependence on the estimation time scale and on the method of estimation.
- Use of least-squares fitting resulted in relatively inaccurate rainfall estimates and poor runoff predictions especially when coarse estimation time scales were used (e.g., storm or event).
- The least-squares fitting method gives improved results only when the estimation is performed on a sub-event time scale that accounts for convective/stratiform classification.
- Estimation based on bias removal and minimization of random differences (BIAS_RMSE) shows superior accuracy even when using coarse estimation time scales.
- Estimation time-scales that account for variations in the sub-event rainfall physical processes do not necessarily result in significant improvements in runoff predictions.
- A simple estimation method based only on bias removing and selection of a climatological representative exponent has resulted in acceptable runoff predictions.

Thank You!

For further questions

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