Rainfall Estimation with Polarimetric Radar Measurements for the storm on June 19, 2003 in Denver

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Outline

- Motivation
- Background
- June 19, 2003 storm in Denver
- Data and Methodology
- Results & Discussion
- Conclusions

Motivation

- To estimate rainfall rate using different estimators
- To understand the differences between estimators
- To compare the calculations with the observations

Background

- Polarimetric Radar Observables
  - Radar reflectivity

$$z_{hh} = \int_0^\infty D^6 N(D) dD$$

  - Differential reflectivity

$$Z_{DR} = 10\log(z_{hh} / z_{vv})$$

  - Specific differential phase

$$K_{dp} = \frac{180\lambda}{\pi} \int_0^\infty \mathrm{Re}\left[f_h(D) - f_v(D)\right] N(D) dD$$

Rain rate estimators

$$R = aZ^b$$

$$R = c10^{0.1aZ_h} 10^{0.1bZ_{dr}}$$

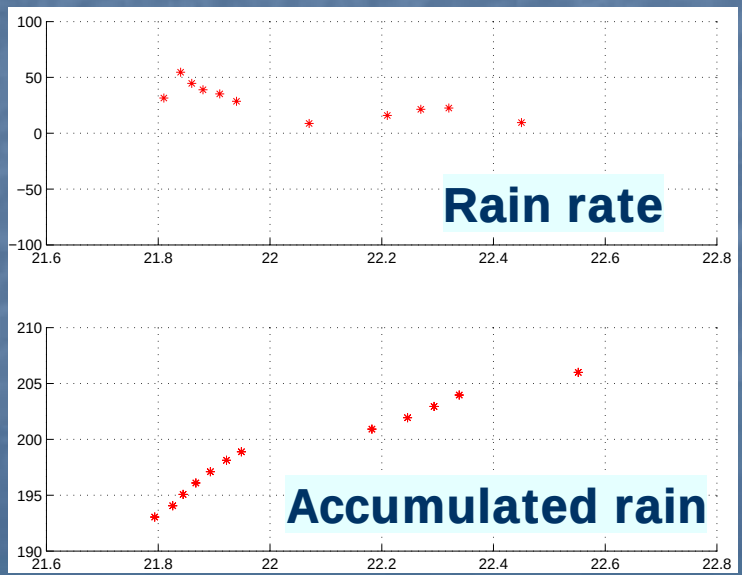
$$R = cK_{dp}^b$$

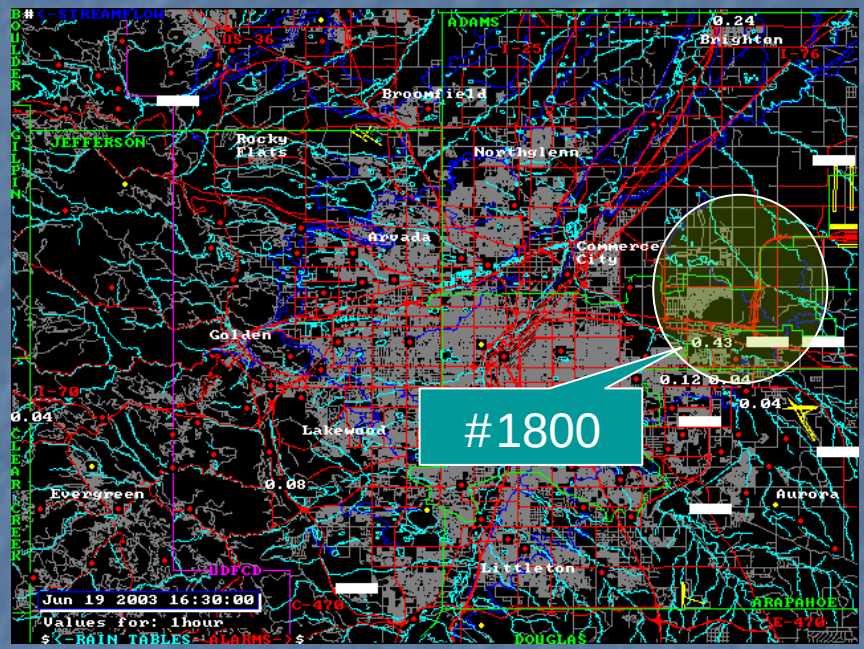
$$R = cK_{dp}^a 10^{0.1bZ_{dr}}$$

R(Z- Kdp)

Case: June 19, 2003 storm in Denver

- When
  - 21:27~22:28 UTC
- Where
- Rain Obs (gauge 1800)





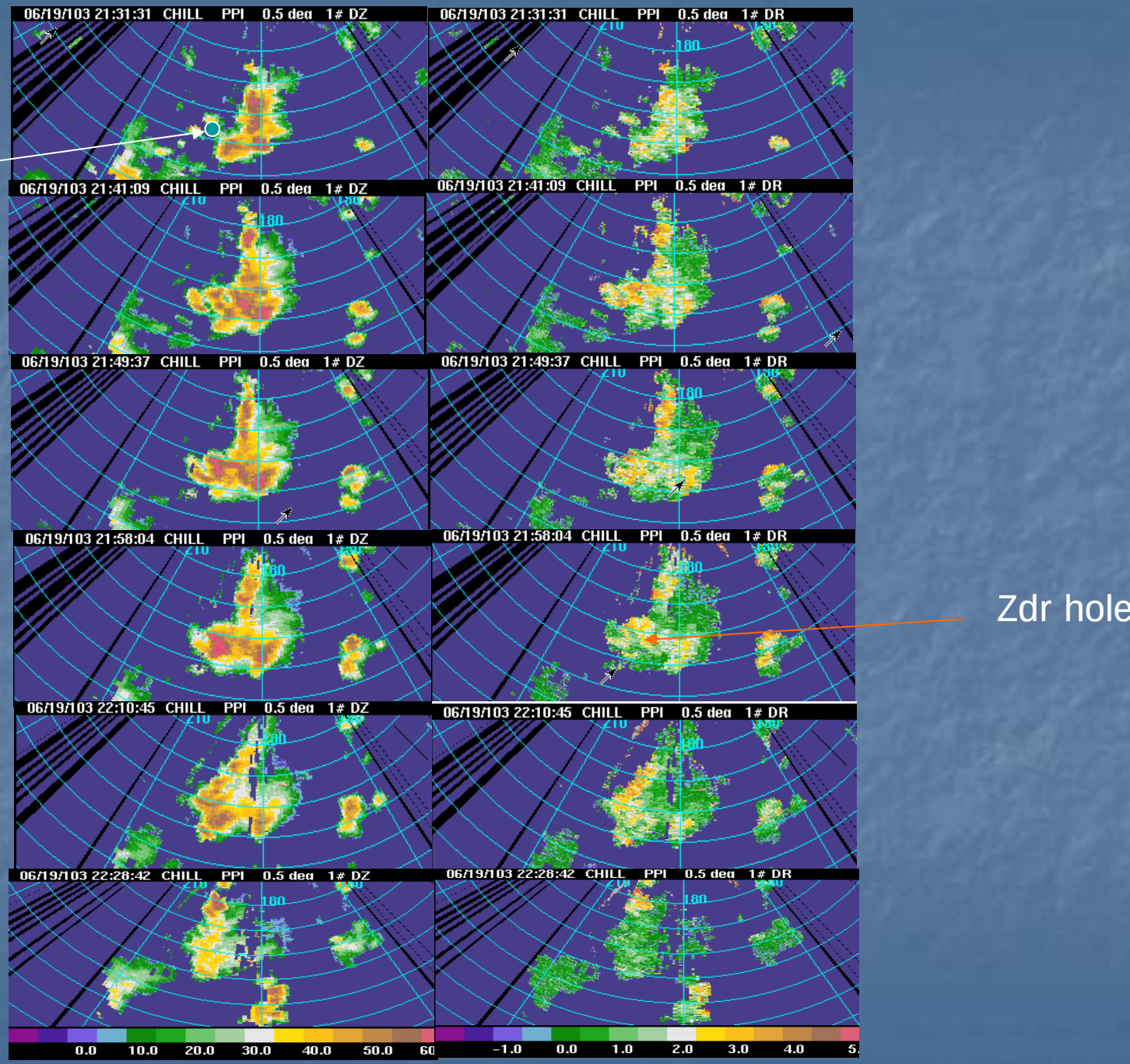
1h rain at 22:30 on June 19 2003 in Denver area

Radar Data

- CSU-Chill Radar
  - Dual-polarized
  - Frequency 2.725GHz (wavelength ~10cm)
  - Location (40.446N 104.637W)

Rain Gauge location (39.756N 104.831W)

Z
Zdr
Kdp
Ve


Z
Zdr
06/19/103 21:31:31 CHILL PPI 0.5 deg 1# DZ
06/19/103 21:31:31 CHILL PPI 0.5 deg 1# DR
21:31 UTC
Rain Gauge
06/19/103 21:41:09 CHILL PPI 0.5 deg 1# DZ
06/19/103 21:41:09 CHILL PPI 0.5 deg 1# DR
21:41 UTC
06/19/103 21:49:37 CHILL PPI 0.5 deg 1# DZ
06/19/103 21:49:37 CHILL PPI 0.5 deg 1# DR
21:29 UTC
06/19/103 21:58:04 CHILL PPI 0.5 deg 1# DZ
06/19/103 21:58:04 CHILL PPI 0.5 deg 1# DR
21:58 UTC
Zdr hole
06/19/103 22:10:45 CHILL PPI 0.5 deg 1# DZ
06/19/103 22:10:45 CHILL PPI 0.5 deg 1# DR
21:19 UTC
06/19/103 22:28:42 CHILL PPI 0.5 deg 1# DZ
06/19/103 22:28:42 CHILL PPI 0.5 deg 1# DR
22:28 UTC
0.0 10.0 20.0 30.0 40.0 50.0 60
-1.0 0.0 1.0 2.0 3.0 4.0 5.

Methodology

Rain Rate Estimators

- R(Z)

$$R = 0.0365 \times 10^{(0.1 \times 0.625 \times Z)}$$

(6)

- R(Z-Zdr)

$$R = 0.0067 \times 10^{0.1 \times 0.93 \times Z} 10^{0.1 \times (-3.43) \times Z_{dr}}$$

- R(Kdp)

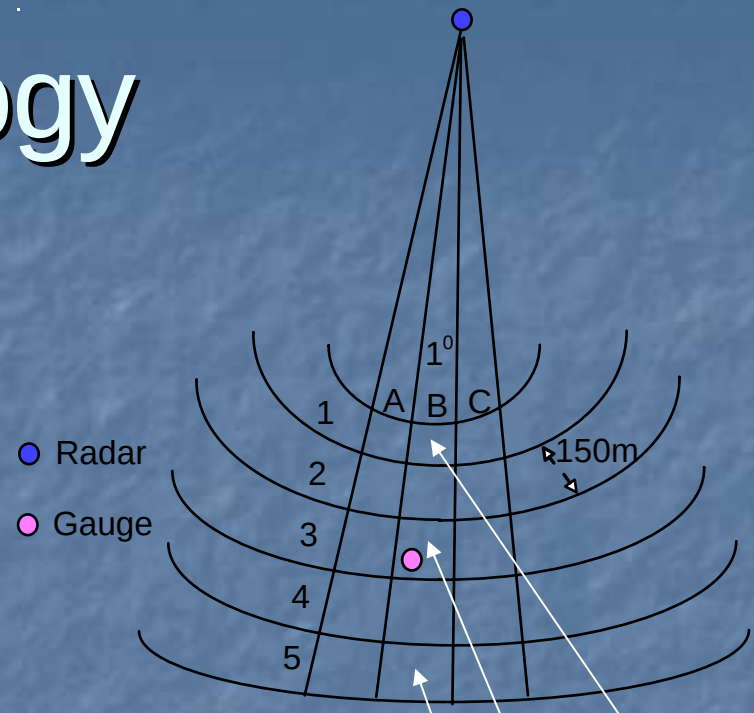
$$R = 50.7 \times K_{dp}^{0.85}$$

- R(Zdr-Kdp)

$$R = 90.8 \times K_{dp}^{0.93} 10^{0.1 \times (-1.69) \times Z_{dr}}$$

- R(Z-Kdp)

$$R = \begin{cases} 0.0365 \times 10^{(0.1 \times 0.625 \times Z_h)} & K_{dp} < 0.4^\circ km^{-1} \quad Z_h > 25dBZ \\ 50.7 \times K_{dp}^{0.85} & K_{dp} \geq 0.4^\circ km^{-1} \end{cases}$$



- R(Z/Z-Zdr)

$$R = \begin{cases} 0.0365 \times 10^{(0.1 \times 0.625 \times Z_h)} & Z_{dr} < 1.5dB \\ 0.0067 \times 10^{0.1 \times 0.93 \times Z} 10^{0.1 \times (-3.43) \times Z_{dr}} & Z_{dr} \geq 1.5dB \end{cases}$$

Features of 15 Points averaged radar variables

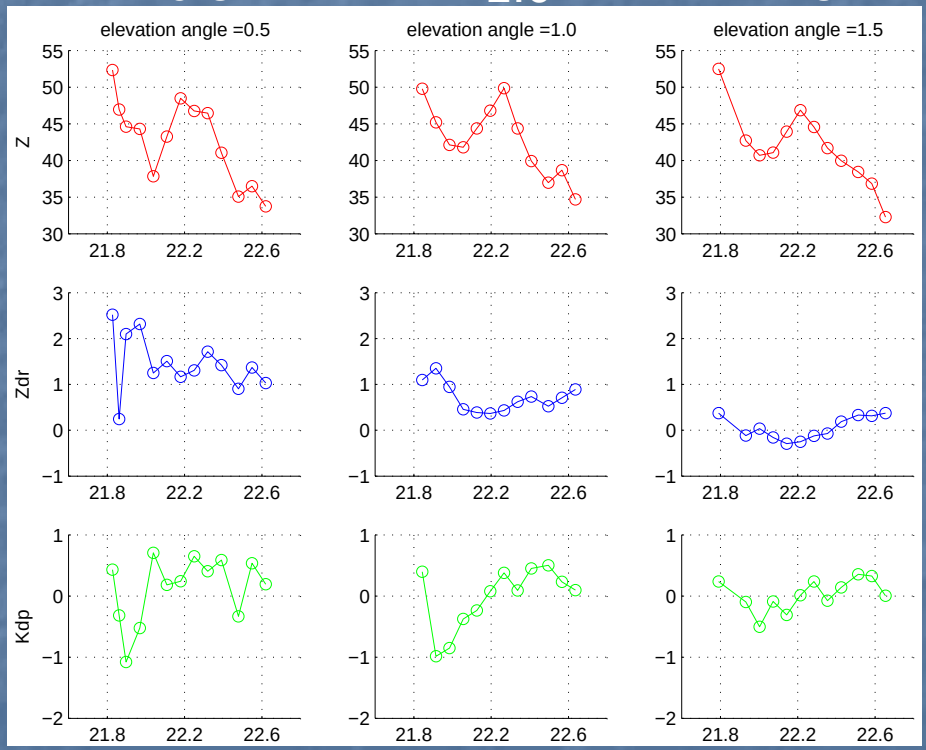
Radar elevation angle (degree)

0.5 1.0 1.5

Z

Zdr

Kdp

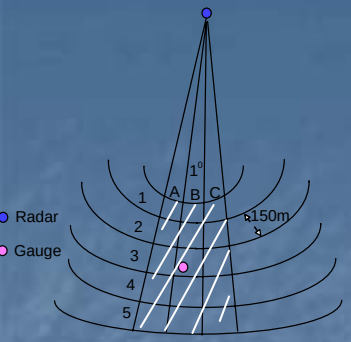


Time (hour)

Z is not sensitive to the elevation angle (height)

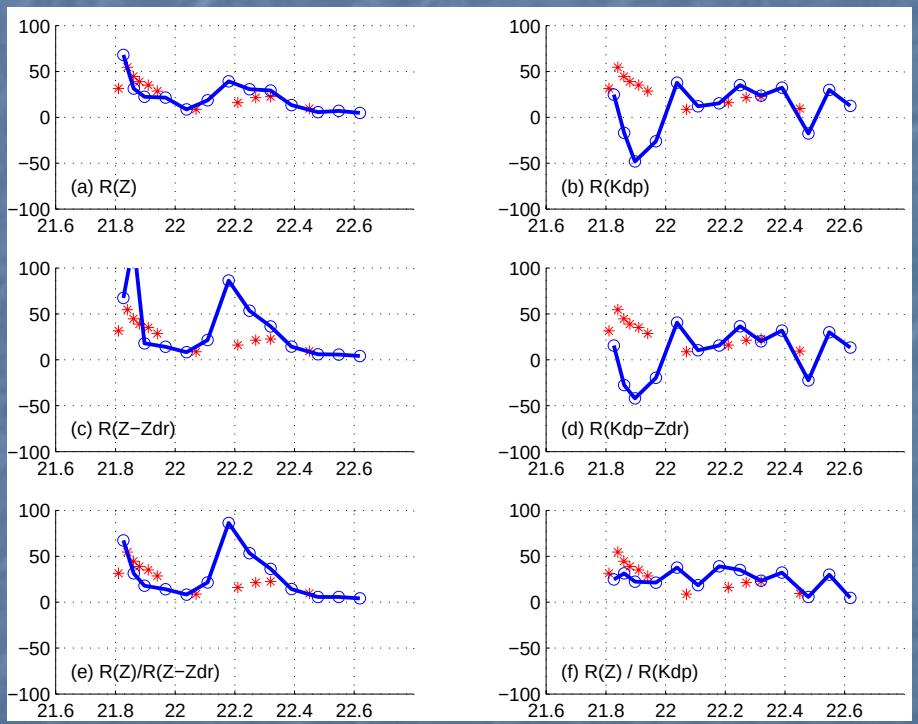
Zdr decreases with the height

Kdp is noisy and some negative values presents.

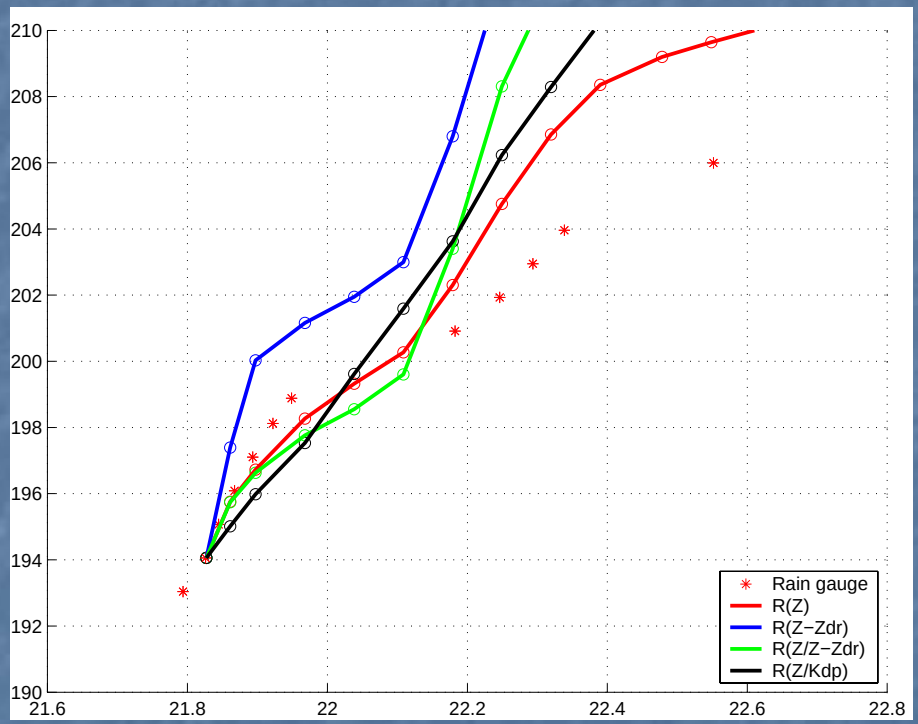


Estimated Rainfall
(15 points average)

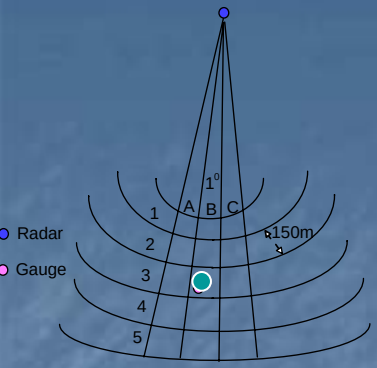
Rain Rate



Rain Accumulations

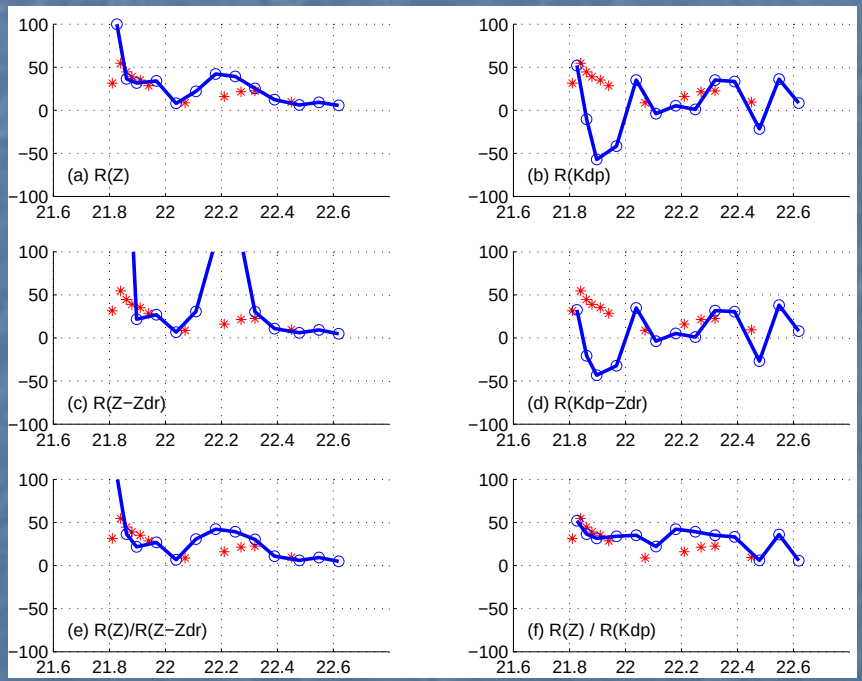


1),R(Z) works best in this case. 2),Sharp peaks in the RR estimation by using R(x-Zdr) R(x,Kdp) are caused by the near zero or negative values of Zdr and Kdp. 3),Rain rate is overestimated, especially for the period 22:19~22:30.

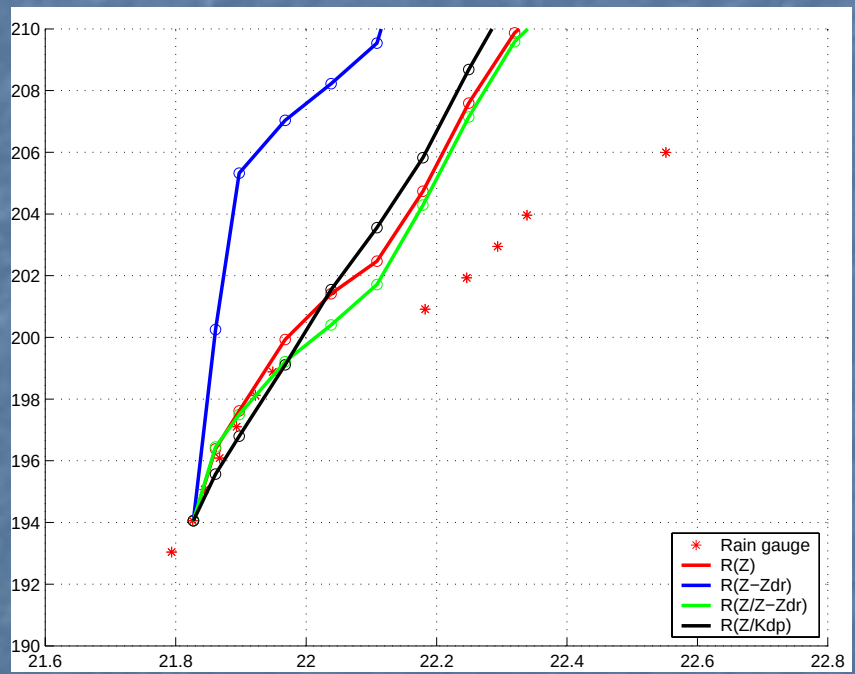


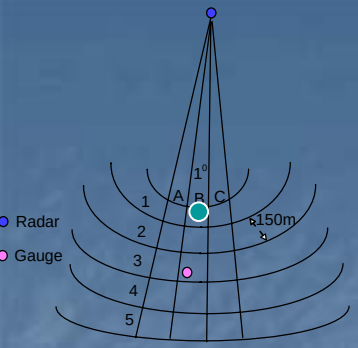
Estimated Rainfall (Mid Point B3)

Rain Rate



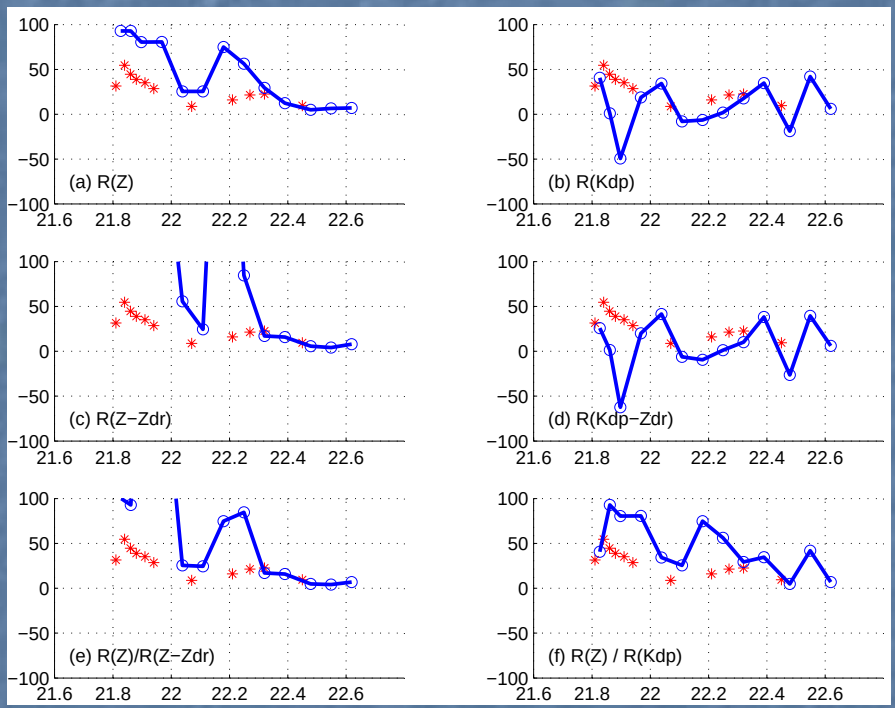
Rain Accumulations



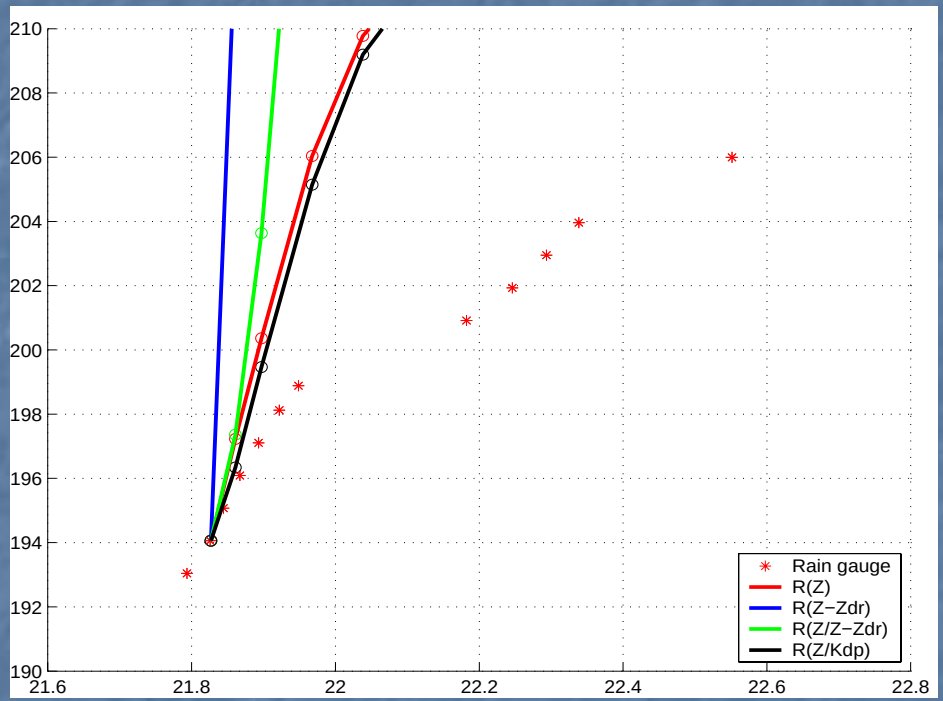


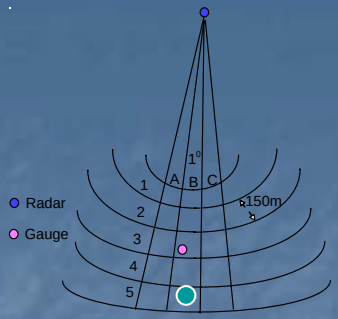
Estimated Rainfall (Upper Point B1)

Rain Rate



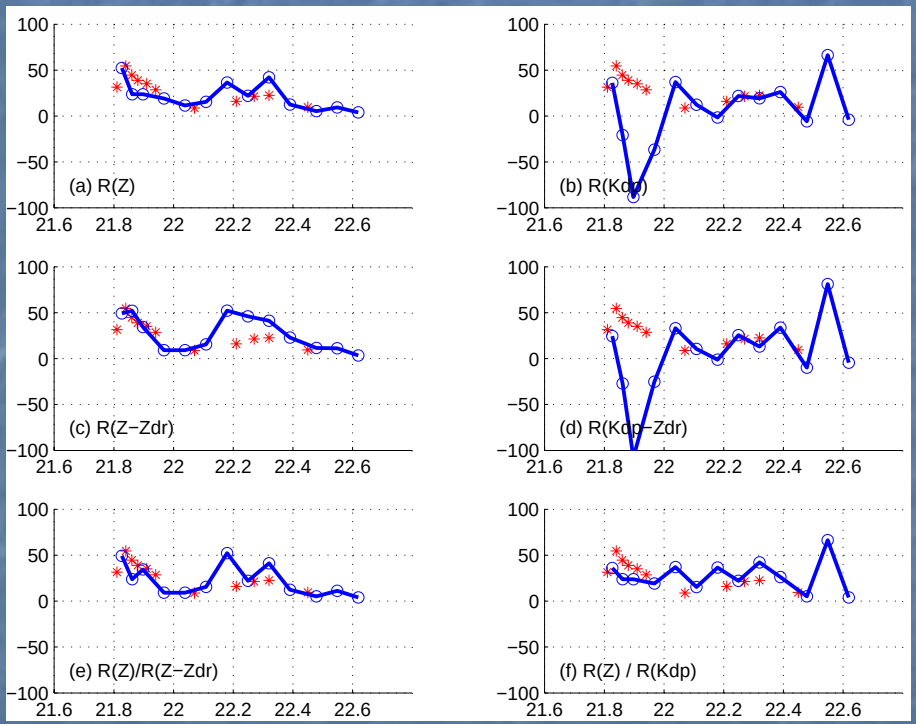
Rain Accumulations



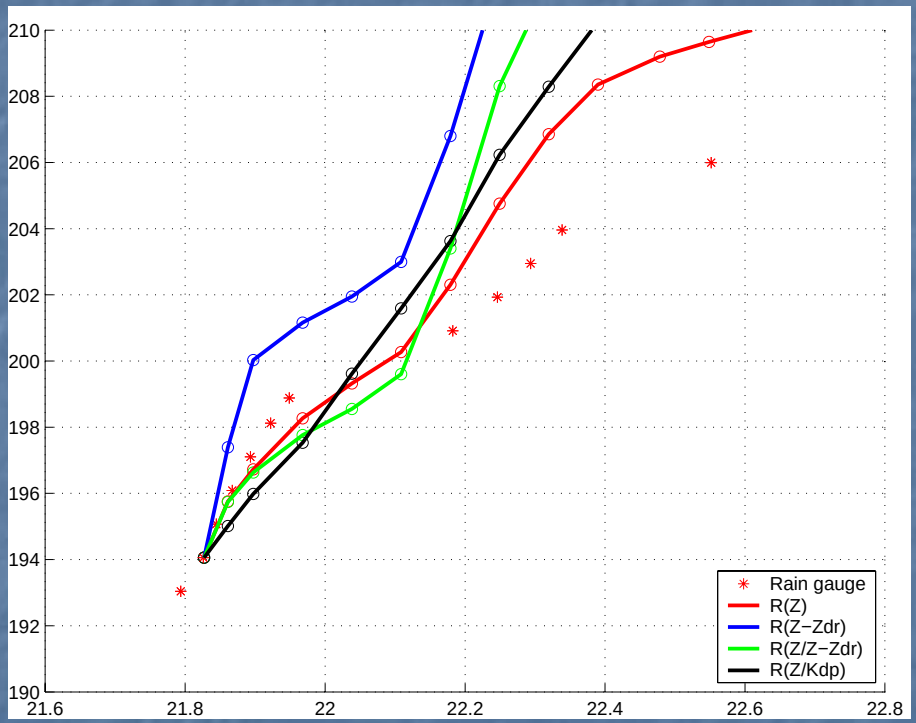


Estimated Rainfall (Lower Point B5)

Rain Rate



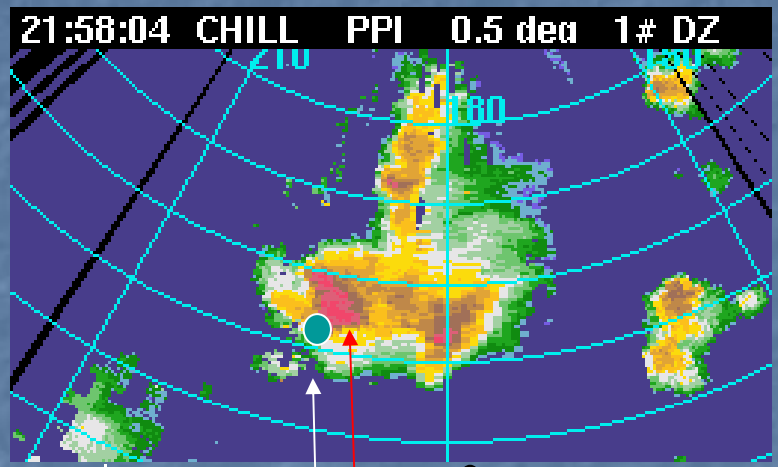
Rain Accumulation

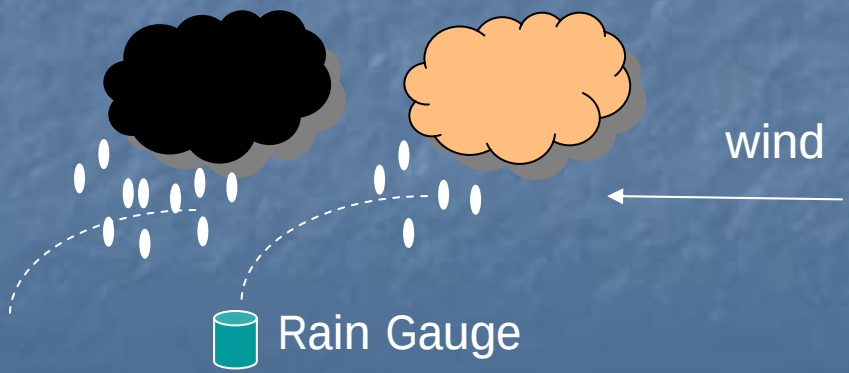


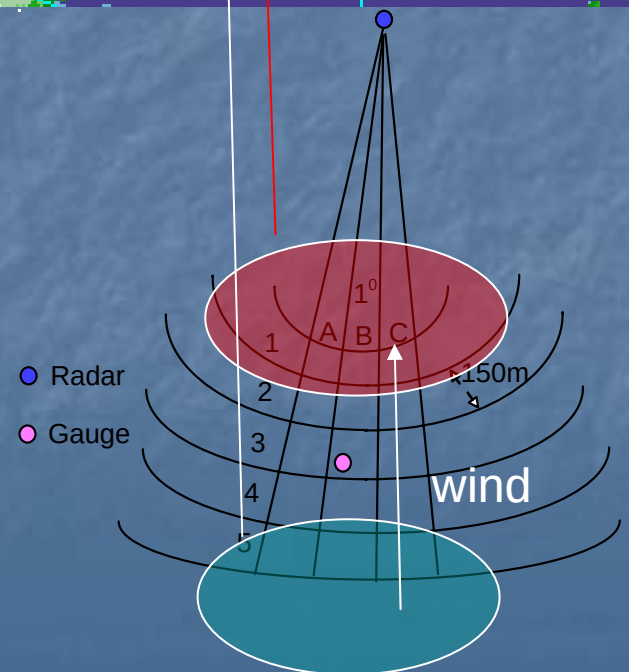
1),Matches the rain gauge observation better than both upper point, mid point result and 15 points average result, especially for the period 22:19~22:30

Horizontal advection

15 point averaged radial velocity







Conclusions

- Among various Rain rate estimators, R(Z) works better than others.
- Not like other estimators, R(Z) is not sensitive to elevation angle.
- Due to the low rain rate (<50mm/h) R(x-Kdp) doesn’t work well.
- When there is uniformly distributed horizontal wind, the horizontal advection of rain must be considered in rain gauge comparison.

Thank You

- Questions?