A Quick Look On X-band Radar Utilization For Spatial Rainfall Monitoring In The Area Of Merapi Volcano

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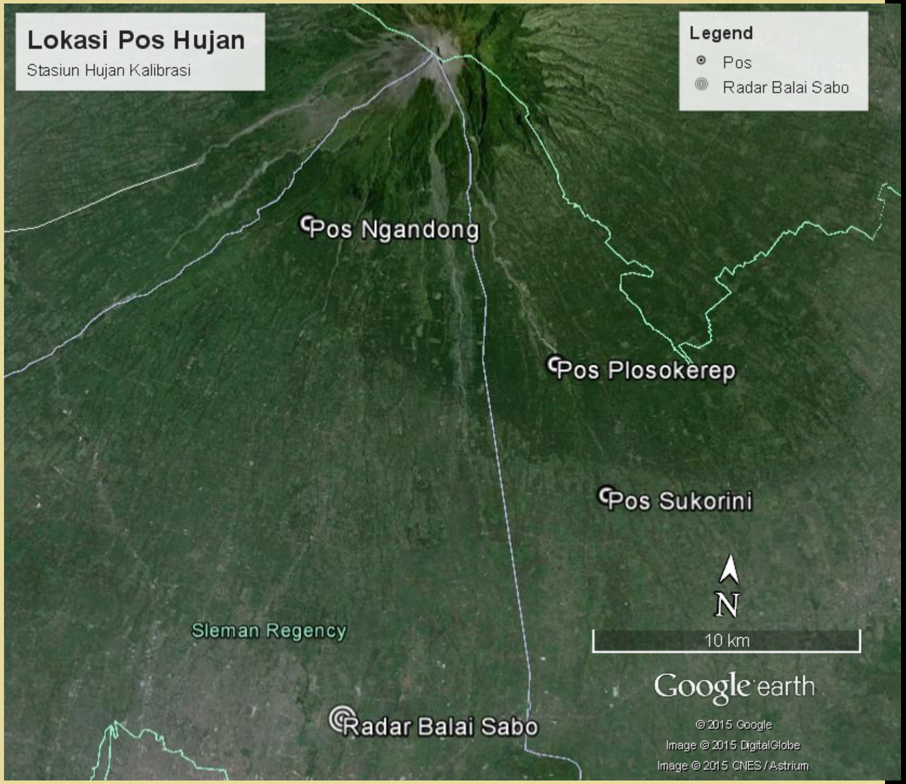
Background

Rain Gauge	Radar
Point measurement	Spatial measurement
Must place in the field	Could be place in the remote area
Real rainfall measurement	Cloud/ Raindrops measurement
More prone to direct hit by eruption	Less prone to direct hit by eruption
Cheap	Expensive
Relatively simple maintenance and skilled persons	Needs high skilled persons to operate and maintain
Less time to alert warning	More time to alert warning

List of Rain Gauge Stations and Data Selection

No	Name of Rain Station	Location	Coordinate	Elevation (m MSL)
1	Ngandong	Dsn. Ngandong, Ds. Girikerto, Kec. Turi, Kab. Sleman	110°24'27,60" E, 07°35'43,80" S	840
2	Plosokerep	Dsn. Plosokerep, Ds. Ngemplak seneng, Kec. Ngemplak, Kab. Sleman	110°29'36,25" E, 07°38'11,35" S	530
3	Sukorini	Dsn. Woro, Ds. Sukorini, Kec. Kembang, Kab. Klaten	110°30'49,70" E, 07°40'44,40" S	327

No	Date	Rain Gauge Station
1	April 14th 2014	Ngandong
		Plosokerep
		Sukorini
2	May 14th 2014	Plosokerep
		Sukorini
3	November 14th 2014	Sukorini



Rain gauge stations used to calibration processes

Method for correlation

Cross correlation for two radar data x and y at elevation z meter and elevation z+n meter for N time can be written with the equation below.

$$XCorr(x_{i,j}, y_{i,j}) = \sum_{t=0}^{N-1} x_t \, y_{t+\tau}$$

with x and y are radar data at elevation z and z+n at grid i,j.

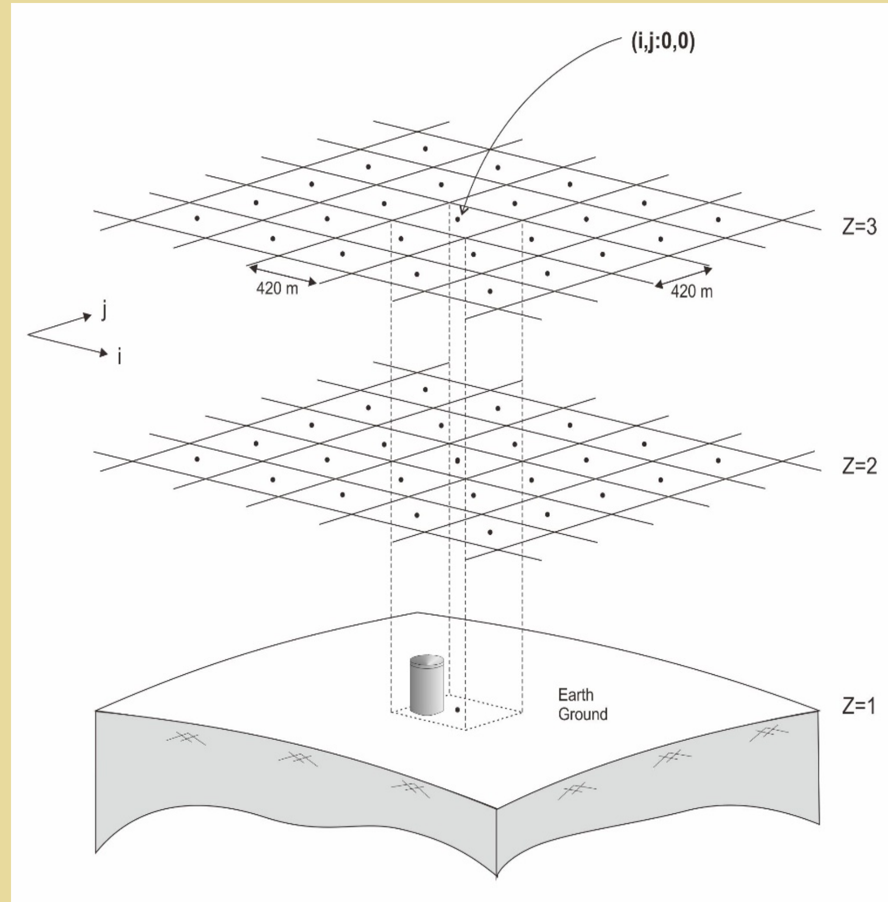


Illustration of cross correlation method concept

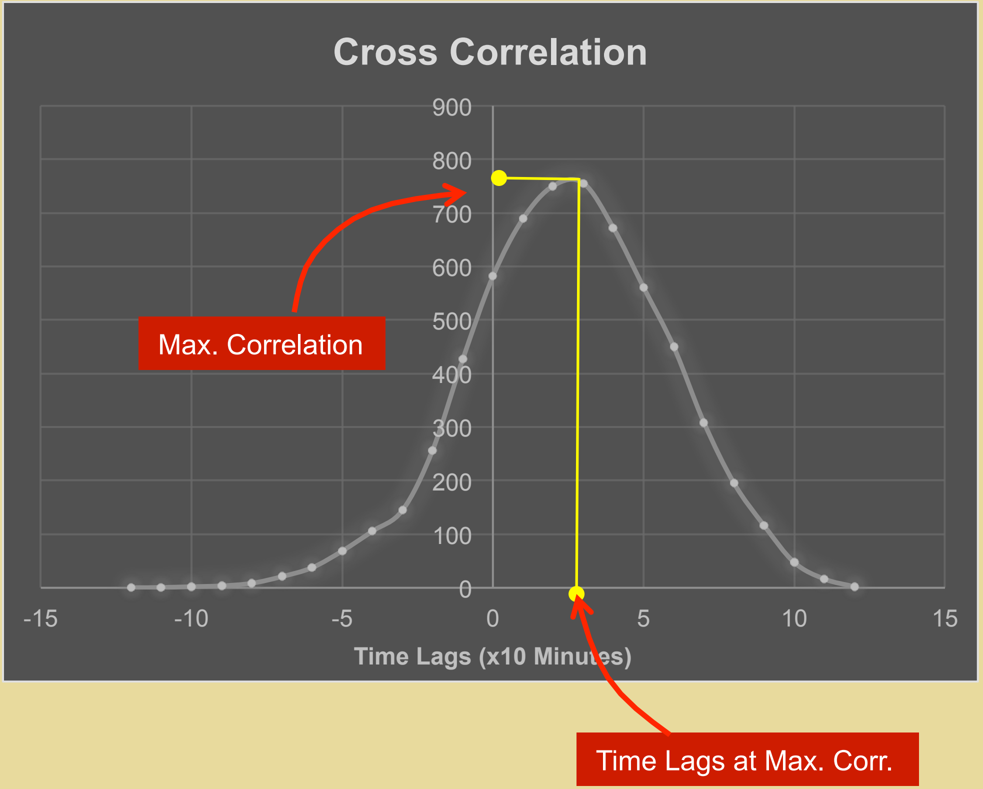
Data arrangement for analysis

An example of radar data and rainfall data arrangement at Ngandong Station can be seen at the table below.

HOURS	Rainfall	1		2		3		~		49	
	10 Minute	110.3985	-7.5842	110.3985	-7.588	110.3985	-7.5918			110.4212	-7.5843
19.10-19.20	1.0	1.43089		1.43089		2.050483				0.748783	
19.20-19.30		3.741111		4.100966		4.452644				7.464903	
19.30-19.40	2.0	2.725382		2.762436		2.968536				20.437483	
19.40-19.50	20.0	2.429409		2.46684		2.650885				4.930821	
19.50-20.00	7.0	1.300198		1.877665		2.663092				1.497566	
20.00-20.10	2.0	1.957721		2.043749		1.987883				1.609298	
20.10-20.20	2.0	0.834944		0.776976		0.689273				0.995239	
20.20-20.30	1.0	0.638069		0.65847		0.665274				0.785705	
20.30-20.40	1.0	1.271307		1.170944		1.084032				1.721436	
20.40-20.50		1.42619		1.117869		0.861842				2.330065	
20.50-21.00		0.81291		0.609596		0.510222				1.793876	
21.00-21.10		0.364633		0.293837						1.366157	
21.10-21.20										0.873559	
21.20-21.30										0.904974	
21.30-21.40										0.293837	

Correlation Analysis Result

- **Selection of representative coordinate radar data**
  The coordinate which resulting closest value to self correlation of rainfall data were chosen.
- **Lag time**
  Lag time obtained from the positive shift time at the greatest correlation value at each coordinate point.



No	Radar Data Elevation (m DPL)	Correlation Value Σx^2/Lag Time (minutes)					
		Plosokerep (April 14th 2014)	Ngandong (April 14th 2014)	Sukorini (April 14th 2014)	Plosokerep (May 14th 2014)	Sukorini (May 14th 2014)	Sukorini (November 14th 2014)
1	1000	358.2596/40	466.0783/20	672.6970/10	338.0874/30	402.7742/0	224.1433/30
2	2000	362.7713/40	416.6932/20	610.6006/30	334.6095/30	396.4964/0	253.8070/30

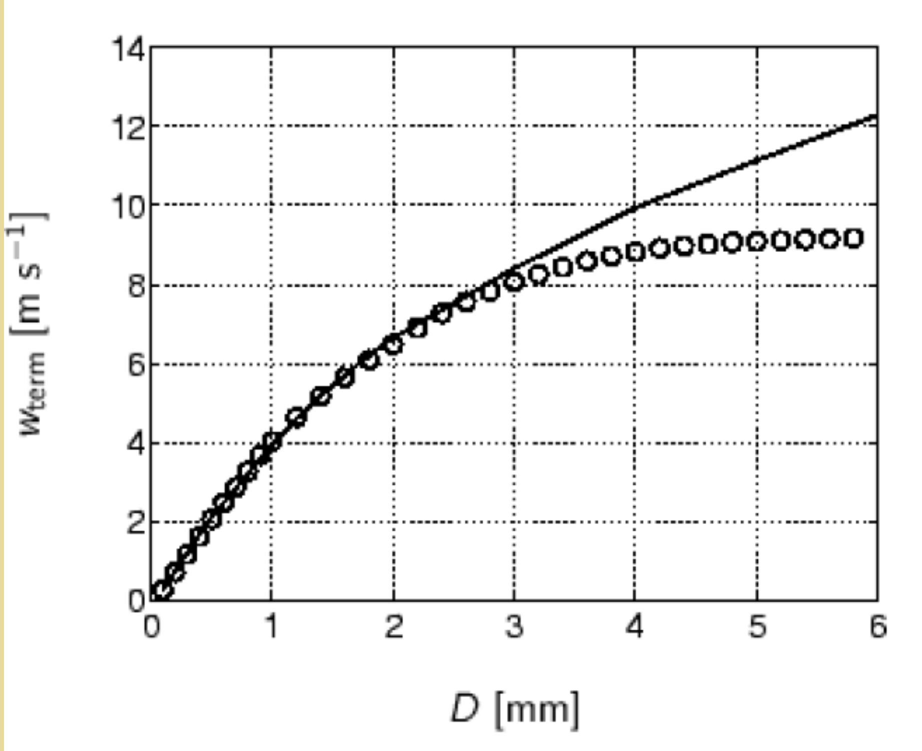
Correlation Analysis Result

- Raindrops Velocity
  By using lag time, raindrops velocity can be estimated by dividing the distance difference of elevation of radar readings and ARR equipment elevation with the lag time that give the greatest correlation value.

No	Radar Data Elevation (m DPL)	Velocity ($m\ s^{-1}$)					
		Plosokerep (April 14th 2014)	Ngandong (April 14th 2014)	Sukorini (April 14th 2014)	Plosokerep (May 14th 2014)	Sukorini (May 14th 2014)	Sukorini (November 14th 2014)
1	1000	0.49	3.19	2.50	1.18	~	1.06
2	2000	0.94	2.31	2.12	1.56	~	1.47

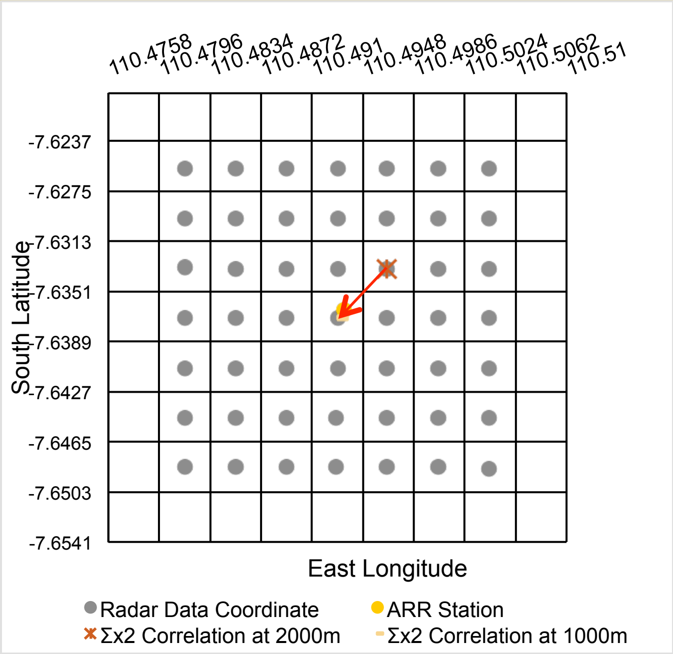
Correlation Analysis Result

- Raindrops size
  Raindrops sizes estimated from plotting velocity data on graphic made by Morsi and Alexander (1972) and measurement from Gunn and Kinzer (1949).
  From the raindrops size, the correlation of radar measurement can be calculated. Thus, the equation which convert db data to dbz data can be corrected to make it appropriate of actual condition

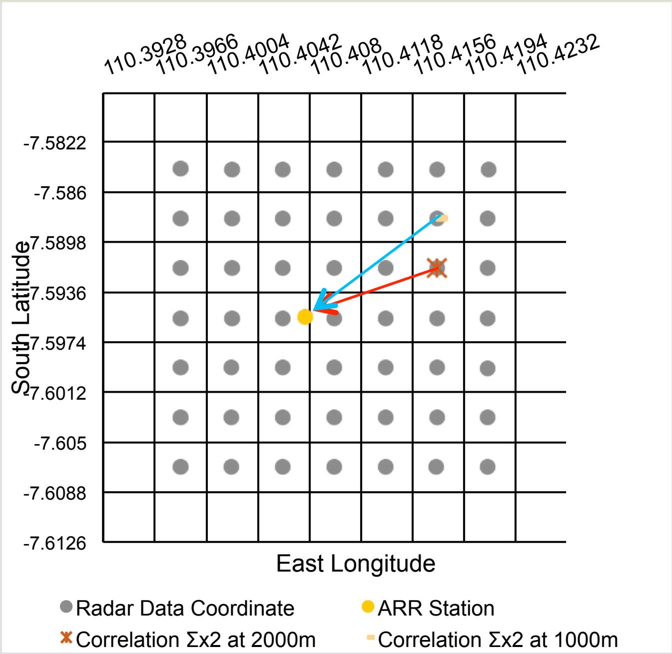


No	Radar Data Elevation (m DPL)	Velocity (m s^{-1})/ Raindrops Size (mm)					
		Plosokerep (April 14th 2014)	Ngandong (April 14th 2014)	Sukorini (April 14th 2014)	Plosokerep (May 14th 2014)	Sukorini (May 14th 2014)	Sukorini (November 14th 2014)
1	1000	0.49/0.1	3.19/0.8	2.50/0.6	1.18/0.3	~	1.06/0.3
2	2000	0.94/0.3	2.31/0.6	2.12/0.5	1.56/0.4	~	1.47/0.4

Raindrops Direction Estimation

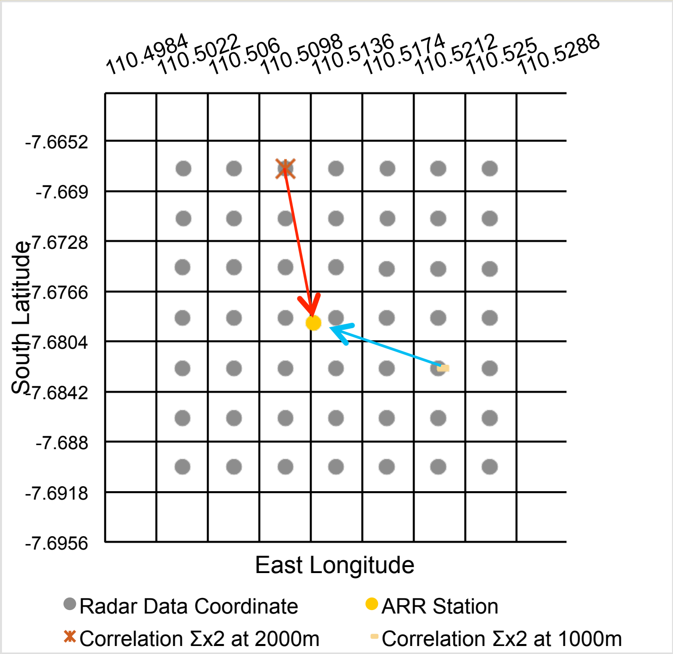


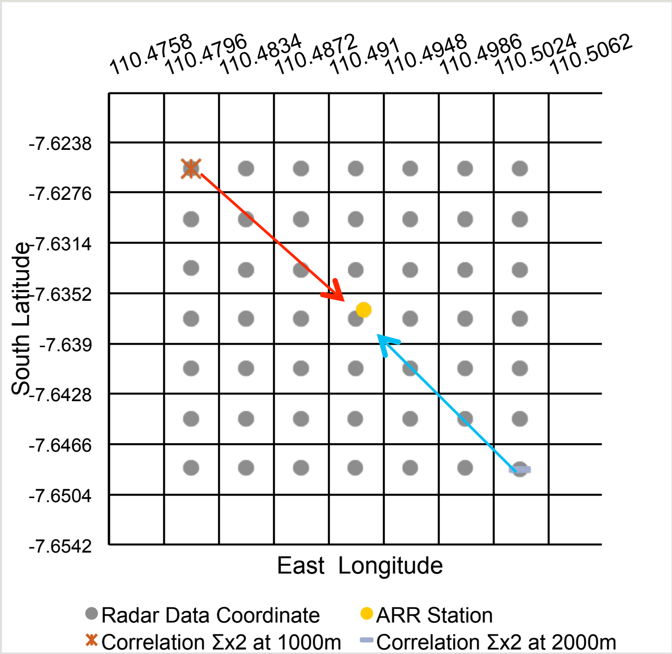
1. Raindrops direction estimation at Plosokerep rainfall station on April 14th 2014.



2. Raindrops direction estimation at Ngandong rainfall station on April 14th 2014.

Raindrops Direction Estimation (2)

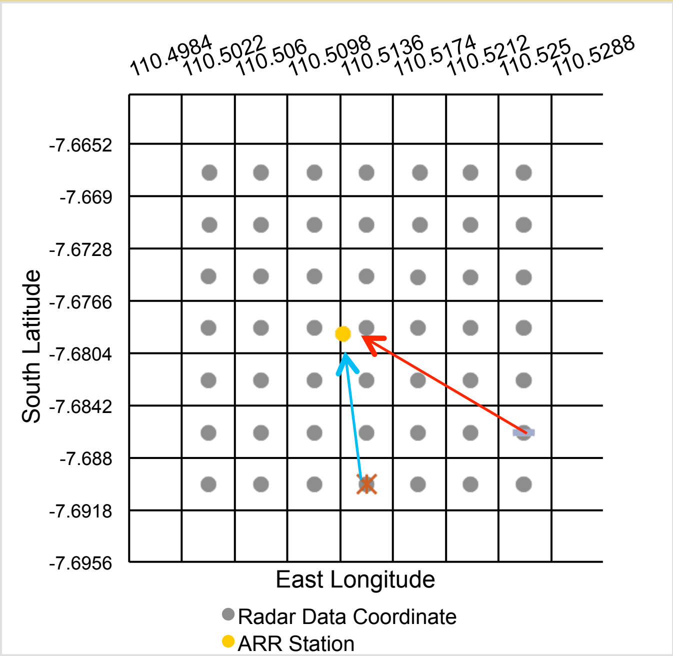


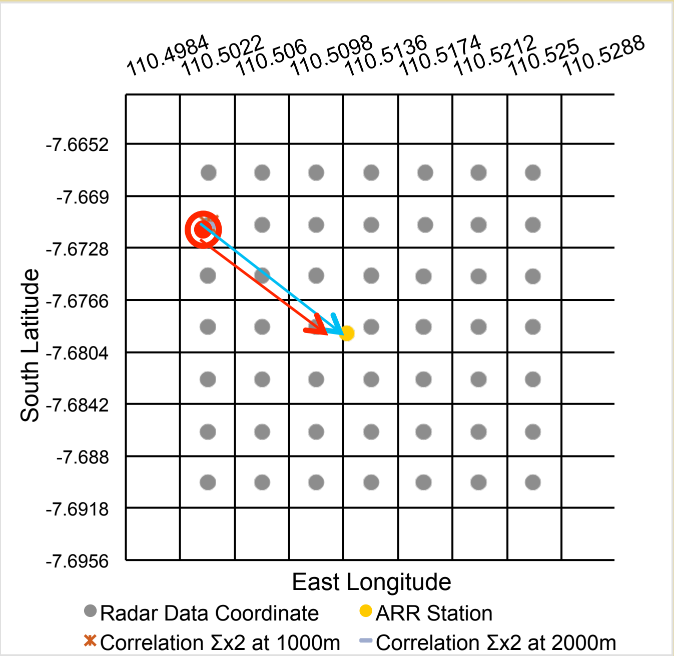


3. Raindrops direction estimation at Sukorini rainfall station on April 14th 2014.

4. Raindrops direction estimation at at Plosokerep rainfall station on May 14th 2014.

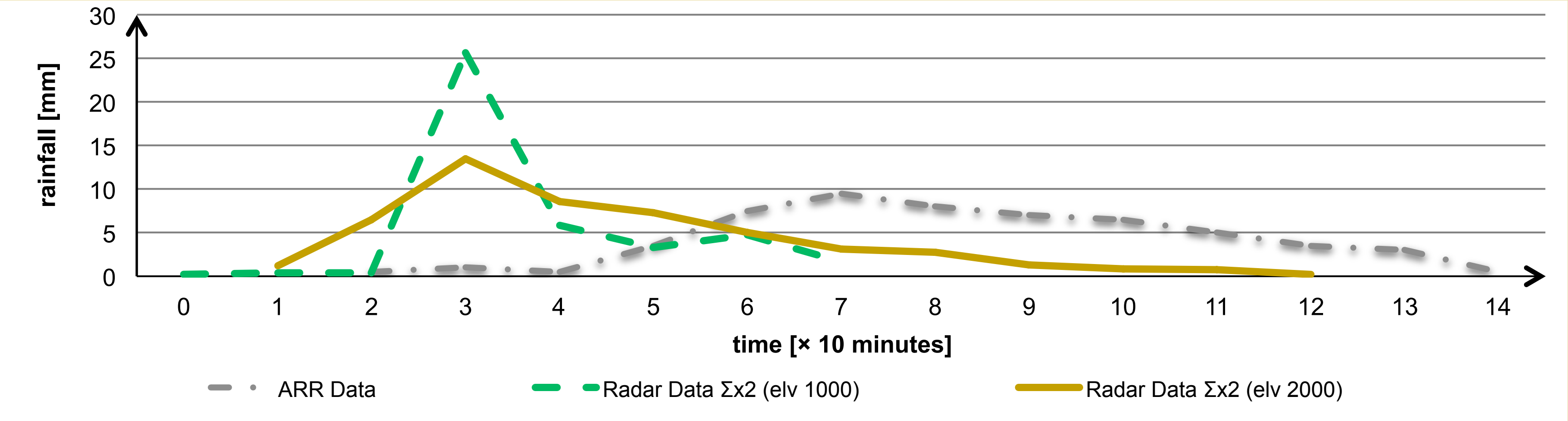
Raindrops Direction Estimation (3)



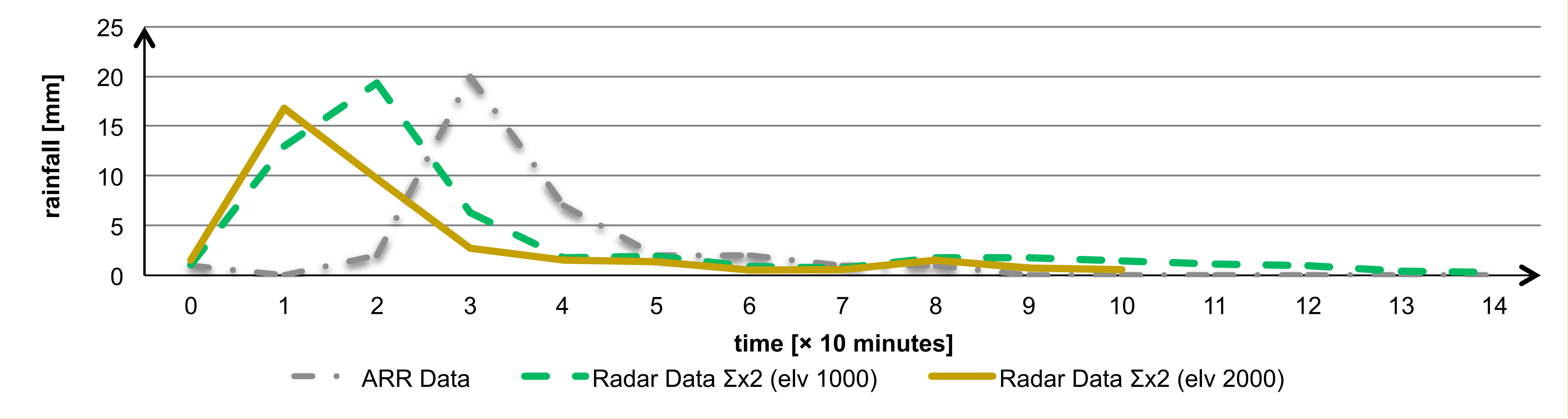


5. Raindrops direction estimation at Sukorini rainfall station on May 14th 2014.
6. Raindrops direction estimation at at Sukorini rainfall station on November 14th 2014.

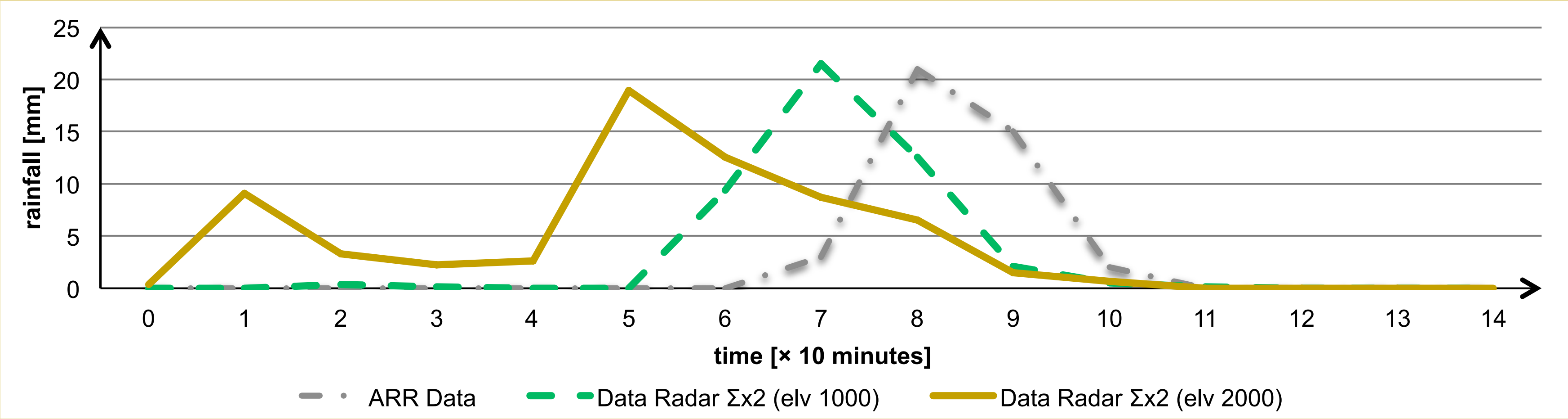
Data series at Plosokerep Rainfall Station on April 14th 2014



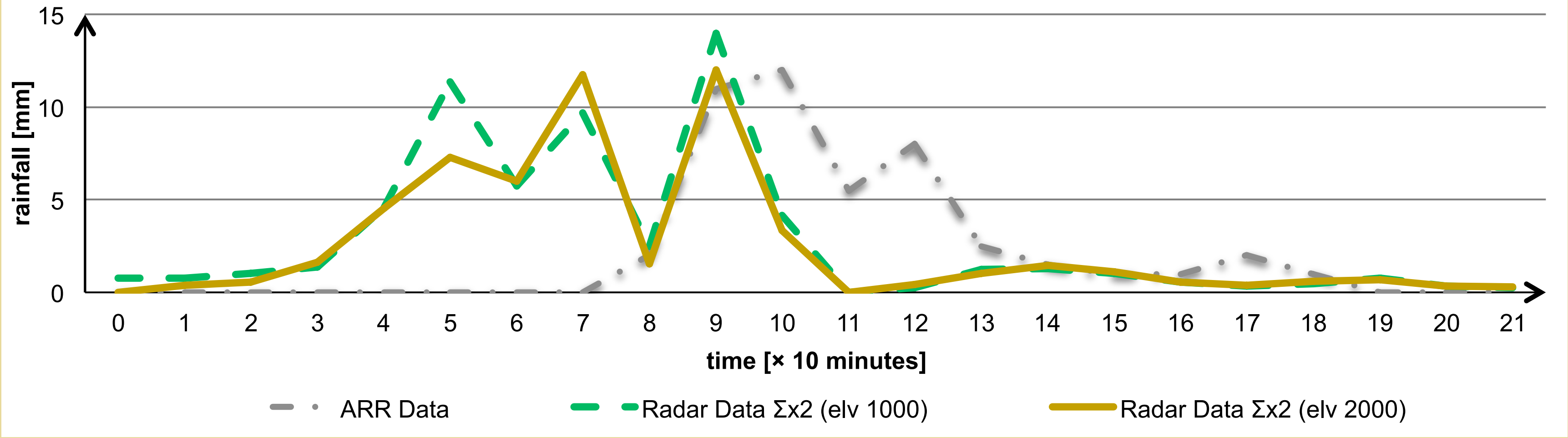
Data series at Ngandong Rainfall Station on April 14th 2014



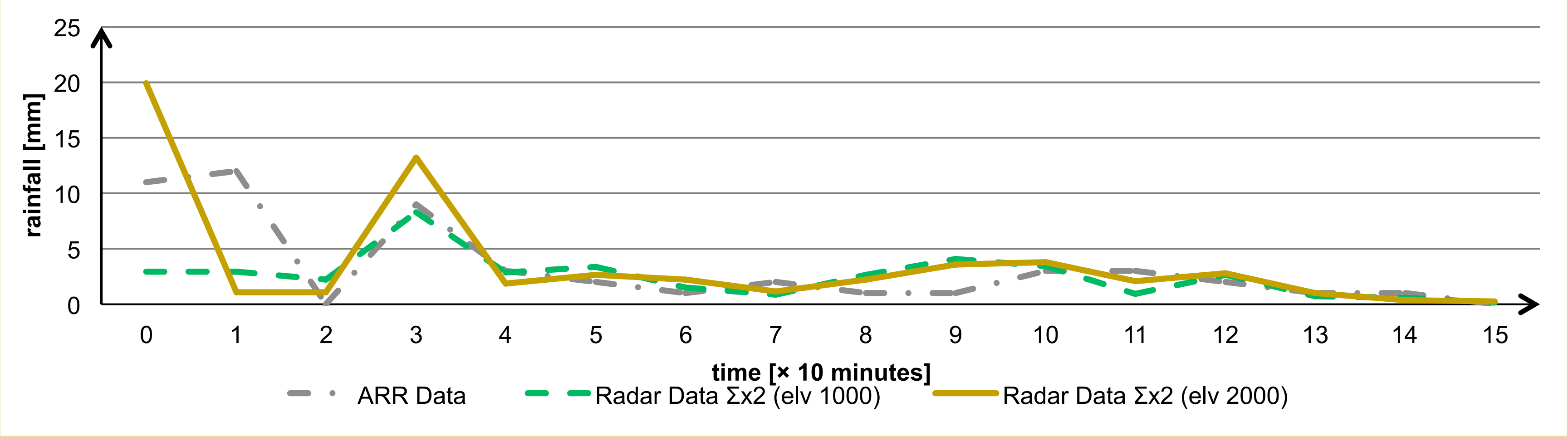
Data series at Sukorini Rainfall Station on April 14th 2014



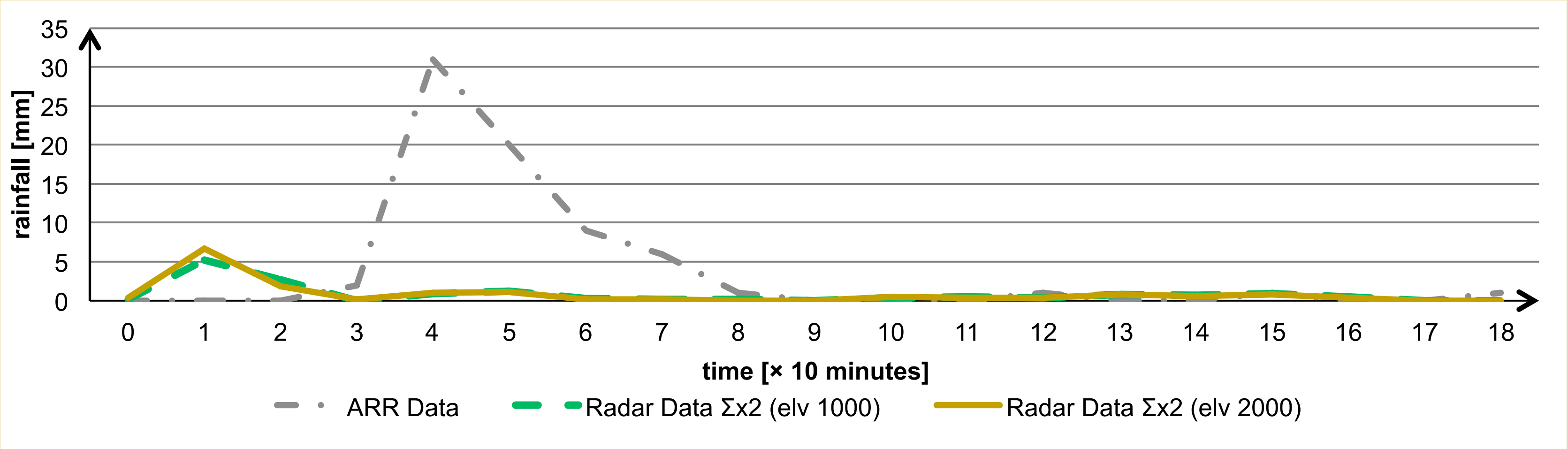
Data series at Plosokerep Rainfall Station on May 14th 2014



Data series at Sukorini Rainfall Station on May 14th 2014



Data series at Sukorini Rainfall Station on November 14th 2014



Conclusion

1. The coordinate radar data which is closest to self correlation of rainfall data is not always close to rainfall station.
2. The raindrop direction of each elevation can be different even at the same time.
3. Radar data can predict the rainfall intensity from data series.
4. The diameter of raindrops can be estimated by its velocity.

Future Research

1. Analysis using more pairs of radar data and rainfall data.
2. Formula correction of the raindrop diameter reflectivity.
3. Calibrating using Furuno Radar provided by SATREPS Project for attenuation effect and make algorithm to reduce it.

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Arigato Gozaimasu
Thank You