

vEGU21

Improvement of the early detection and quantitative risk prediction method with the three-dimensional wind field from multiple-doppler radar analysis

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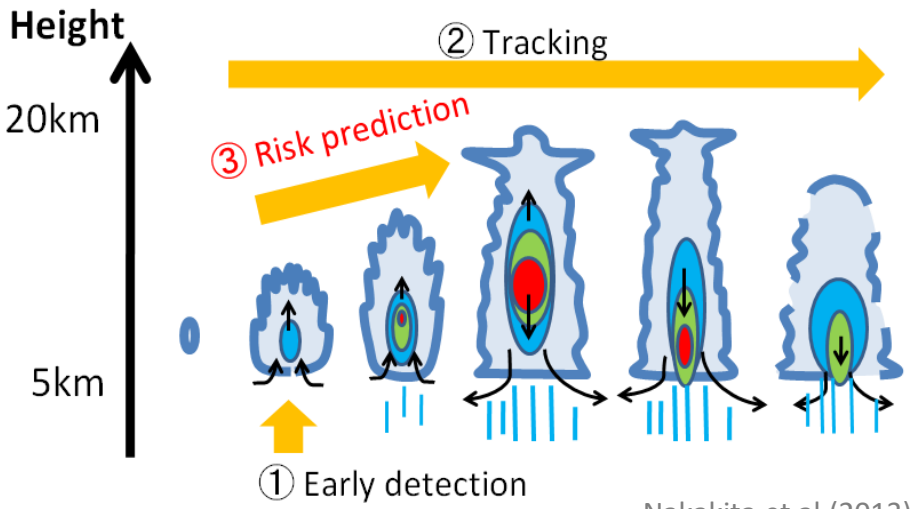
Contents

- Background
- Objective
- Study Area and Dataset
- Improvement of the quantitative risk prediction
- Conclusion and Future work

Background

Background

- Nakakita et al.(2013) developed a prediction system for localized heavy rainfall by using pseudo vorticity in a first echo aloft in 3-D volume scanning data of X-MP
- The current system could predict the Guerrilla heavy rainfall whether peak rainfall intensity would exceed **50 mm/hr or not in 30 min** ; only two risk categories
- Advanced warning at least 10 minutes before provided by early detection is critical to **saving lives** -> the early detection and quantitative risk prediction method



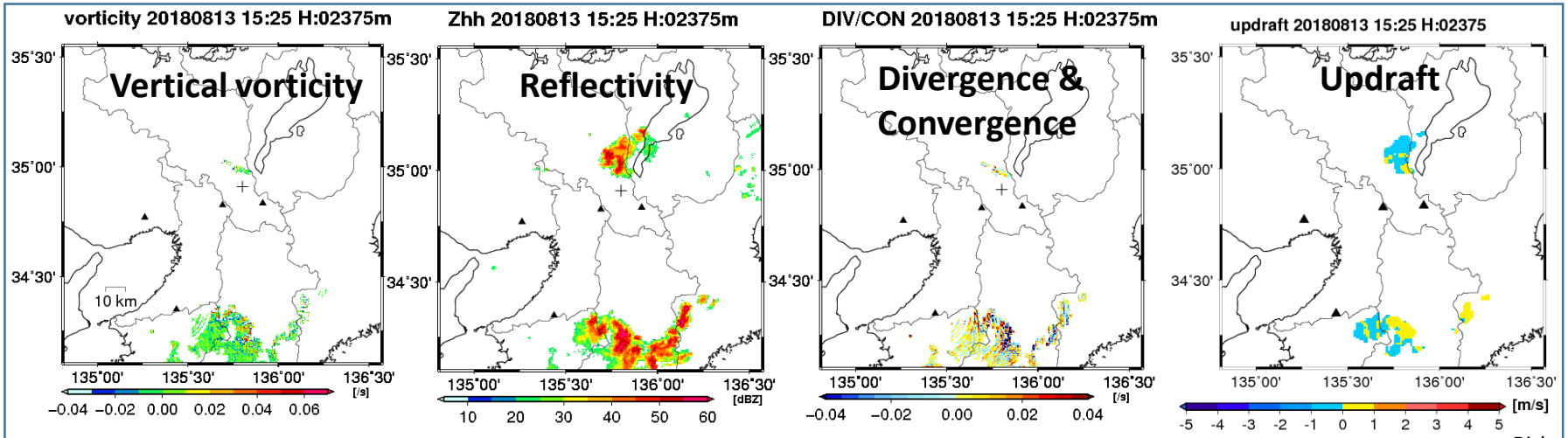
Nakakita et al.(2013)

Flash Flood occurred during **30 min** caused by Guerrilla heavy rainfall

Objective

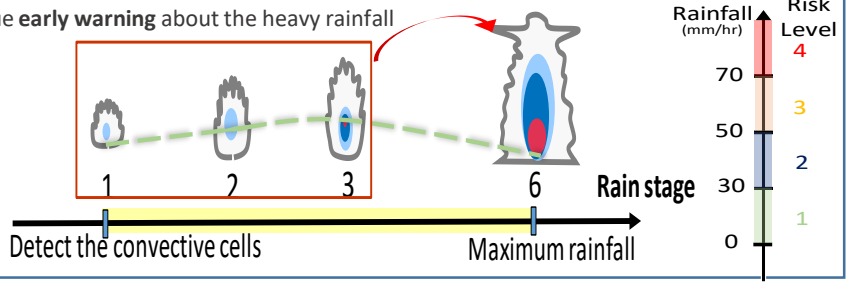
Objective

- If the the early detection and quantitative risk prediction method was considered for each rain stage, the method estimate more fitted risk level
- By using the multiple-doppler radar analysis, we can find the reliable wind field reflecting natural environment



$$Predicted\ Risk\ Level\_i\ (PRL_i) = C_{0_i} + C_{1_i} \cdot Z_{h\,i}(reflectivity) - C_{2_i} \cdot \zeta_{\_i}(vorticity) + C_{3_i} \cdot \omega_i(updraft) \cdots + C_{n\_i} X_{n\_i}$$

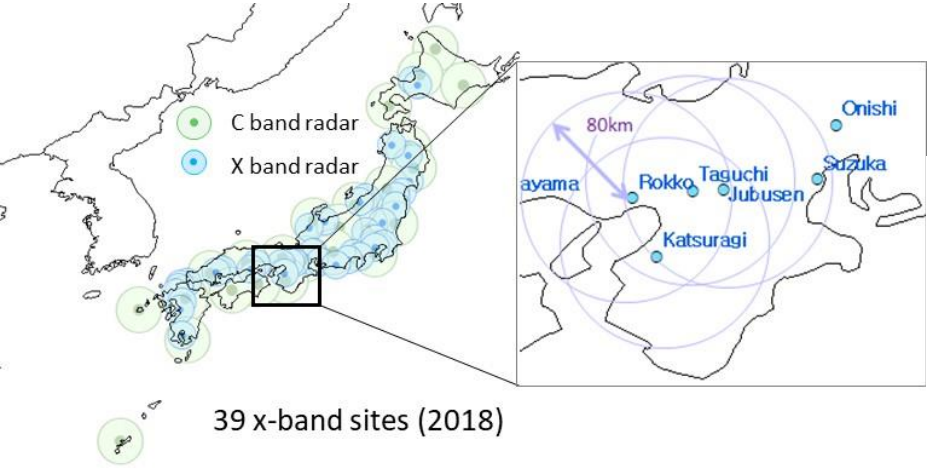
i is rain stage which represent the development of cumulonimbus cloud ($1 \leq i \leq 6$)



Study Area and Dataset

Study Area and Dataset

- **Kinki region in Japan**
  - The four X-band polarimetric RAdar Network (XRAIN) are used, named as Rokko, Katsuragi, Juubusan, and Tanokuchi
  - The three-dimensional volume scan data has the resolution of 250 and 500 m in the horizontal and vertical directions, respectively
  - From August 2013 to August 2018, 12 GHR events are selected



3D observation time	5min
Observation range	80km
No. elevation angles	12
Azimuth	300

Table 2 List of Guerrilla heavy rainfall events which selected 10 events for calibration and 2 events for verification

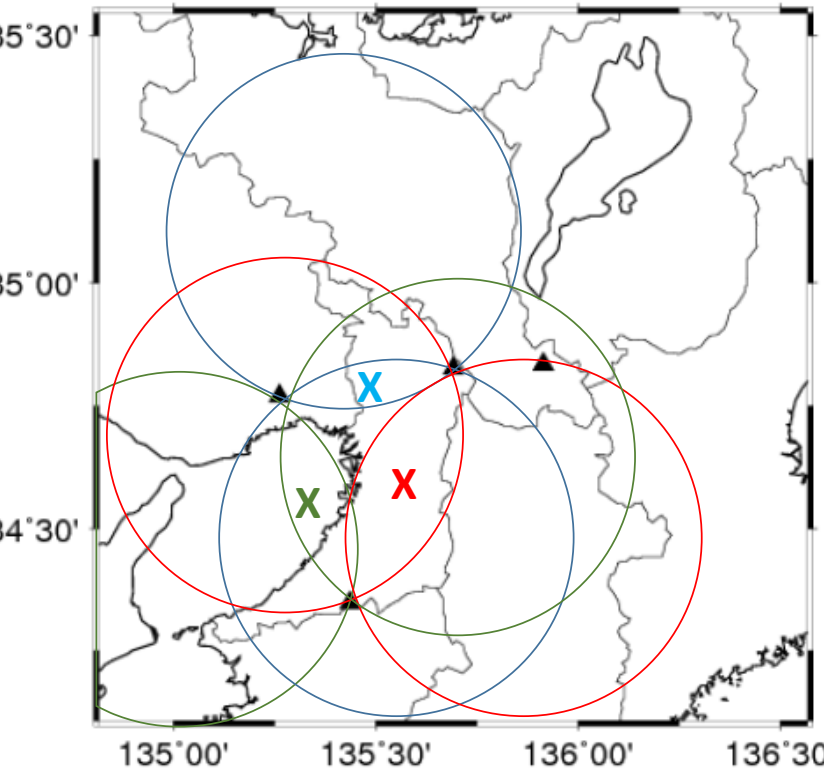
No.	Date	Longitude	Latitude	Time of Early detection	Time of maximum rainfall	Maximum rainfall intensity (mm/h)
1	2013-08-06	135.981	34.469	16:10	16:30	53.3
2	2013-08-07	135.747	34.930	16:50	17:05	191.1
3	2014-08-23	136.159	34.266	11:40	11:45	50.5
4	2014-08-23	135.584	34.240	11:40	11:50	47.7
5	2015-08-07	135.872	34.609	17:20	17:35	160.0
6	2015-08-29	135.752	34.177	14:35	14:40	145.2
7	2016-08-03	135.818	34.573	18:35	18:50	119.9
8	2016-08-25	135.660	34.267	13:15	13:30	117.3
9	2017-08-04	135.611	34.510	16:25	16:35	60.9
10	2018-08-13	135.353	34.992	15:30	15:50	94.2
1	2018-08-13	135.353	34.992	15:30	15:50	94.2
2	2018-08-28	135.900	34.772	12:05	12:15	82.7

Improvement of the quantitative risk prediction

Three-dimensional wind field from multiple-doppler radar analysis

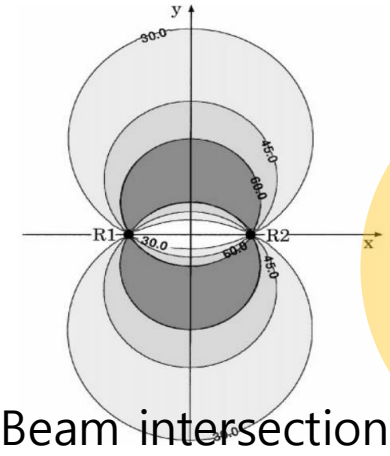
- The Vorticity, Divergence&Convergence is needed to calculate **wind vector**. Also, the vertical wind represents the **updraft** and **downdraft**

One of the method to calculate the 3D wind vector : **multiple-Doppler radar analysis**

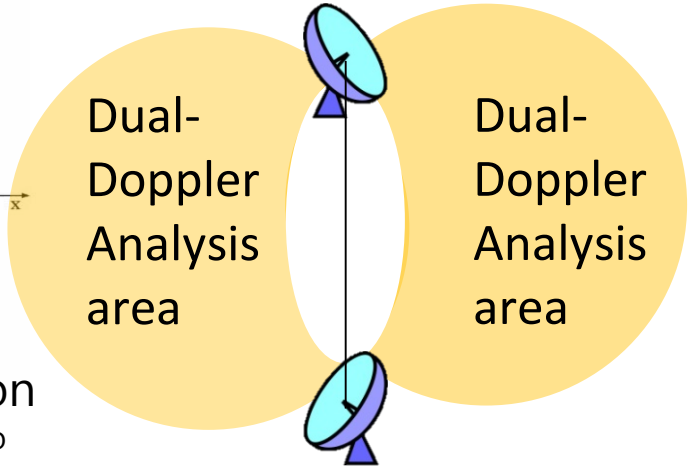


protat et al. (1999) & Shimizu and Maesaka (2006)

1. Use radial velocity of two radar in CAPPI data
2. Use 3-D variational method to optimize cost function
3. Calculate the horizontal and vertical wind (u, v / w)

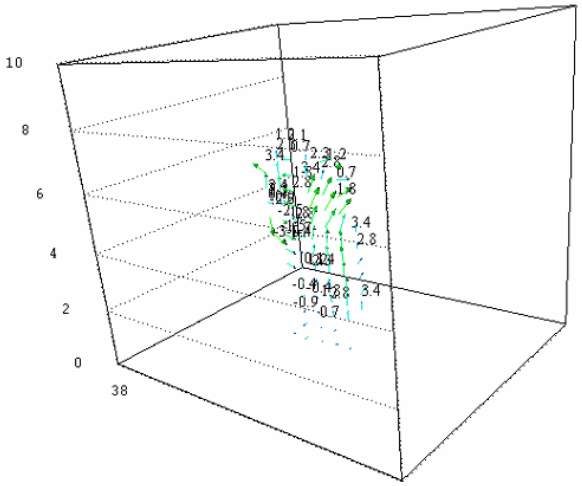


Beam intersection angle (θ) > 20°

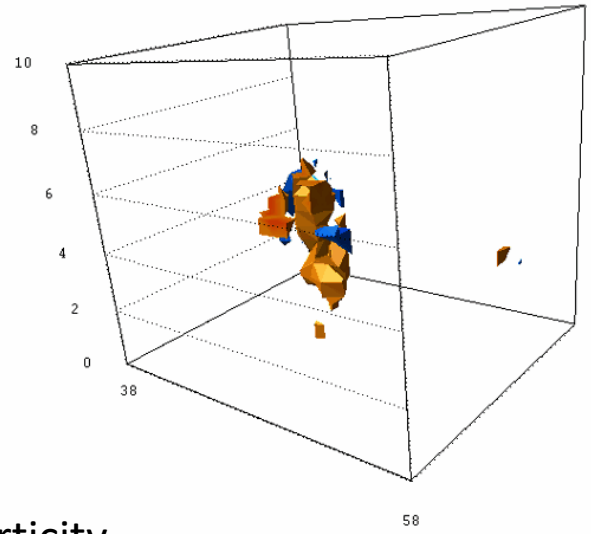


Improvement of the quantitative risk prediction

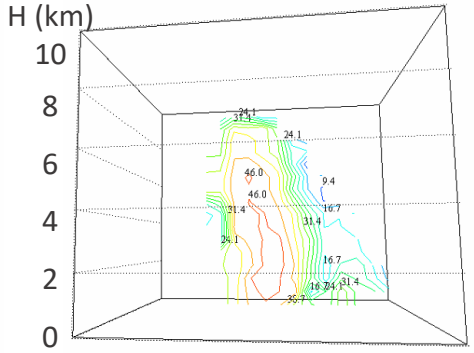
Three-dimensional wind field from multiple-doppler radar analysis

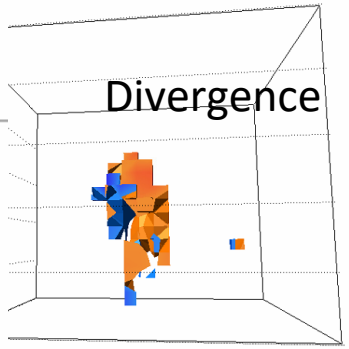


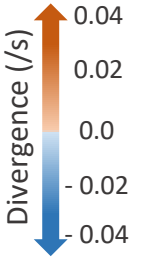
Wind direction



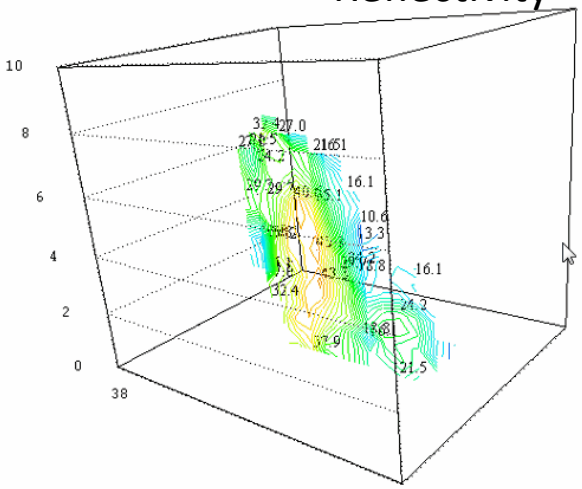
Vorticity



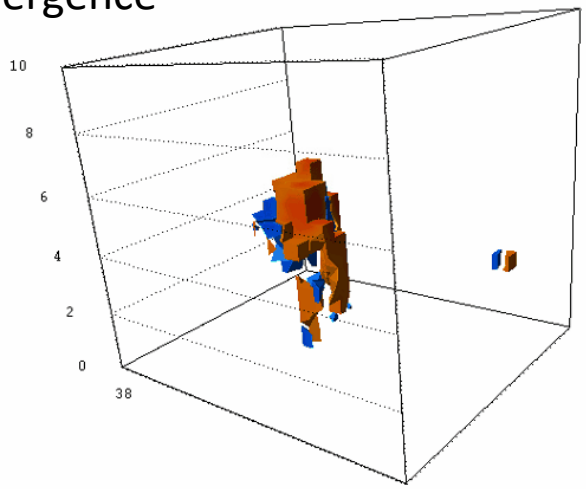




Reflectivity



Divergence



$$|V|\mathrm{COV} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

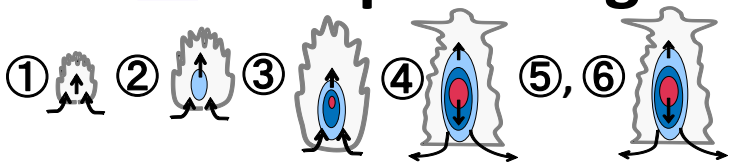
1.49E-2

-0.58E-2

Improvement of the quantitative risk prediction

Single regression $PRL_{all} = r(Z_h, \zeta)$ S

Compare single reg

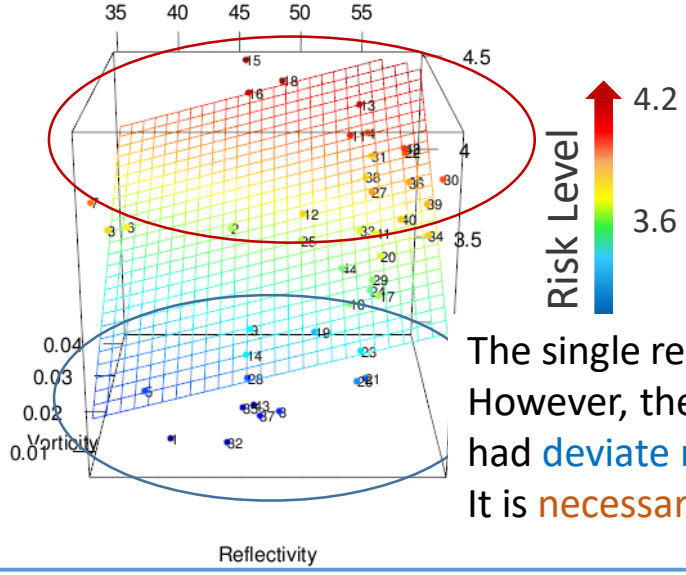


Coefficients						
Model		Unstandard Coefficients		Standard Coefficients	t	Sig.
		B	Std.Error	Beta		
1	(Constant)	2.55	0.31		8.21	0.00
	Zh	0.02	0.01	0.67	4.04	0.00
	vorticity	8.10	3.30	0.41	2.45	0.02

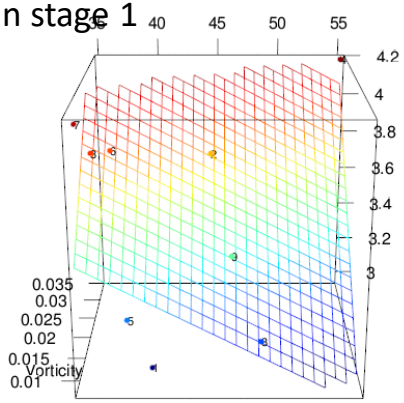
$$PRL = 2.55 + 0.02 \cdot Z_h + 8.10 \cdot \zeta$$

where, PRL : Predicted Risk Level,

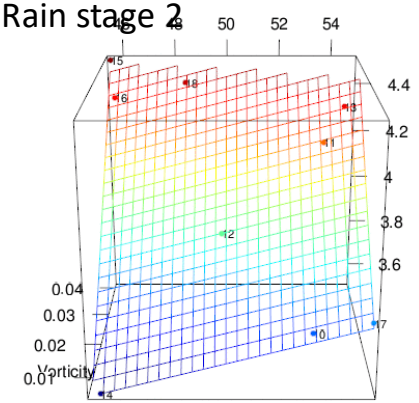
Z_h : Reflectivity , ζ : Vorticity



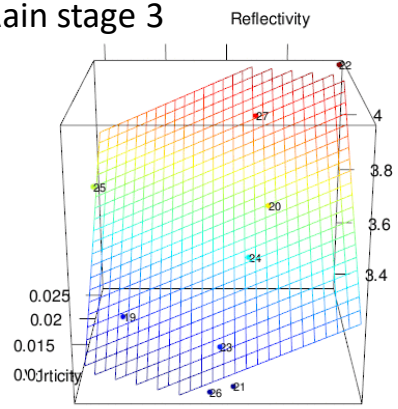
Rain stage 1



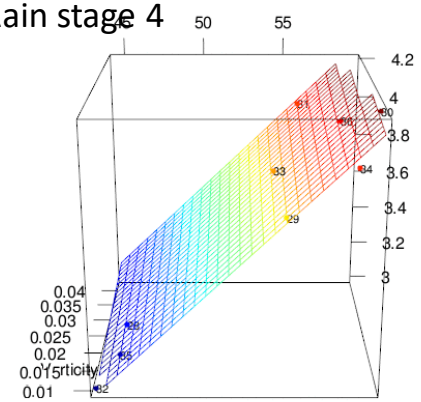
Rain stage 2



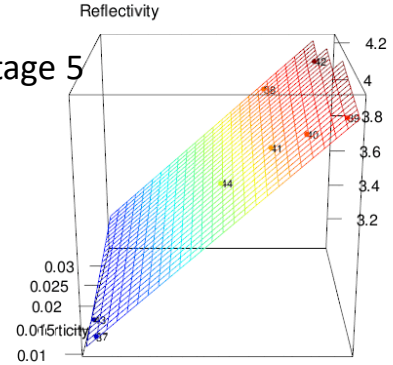
Rain stage 3



Rain stage 4



Rain stage 5



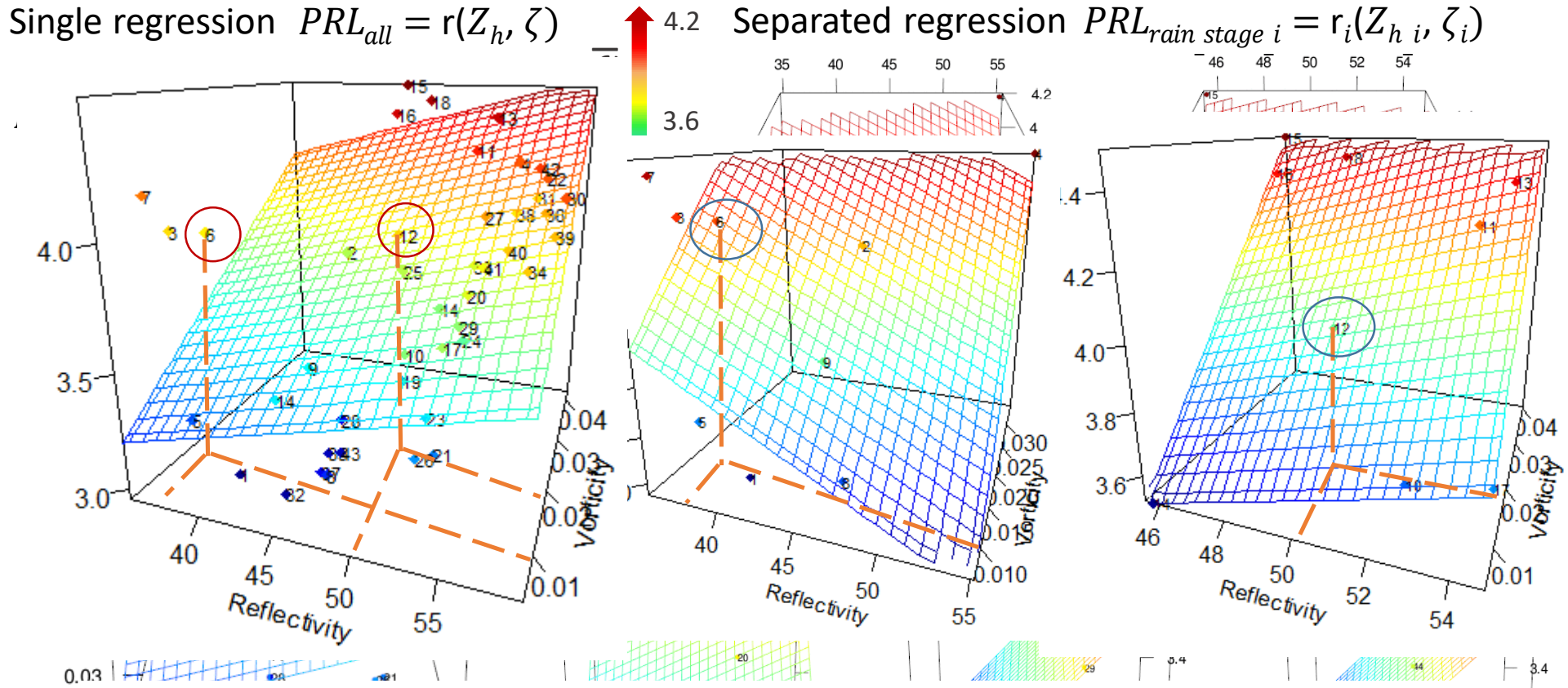
The single regression plane fits well the variables.
However, the risk level were underestimated and had deviate much than separate regression
It is necessary to make regressions separately.

Improvement of the quantitative risk prediction

Compare single regression & separated regression

Single regression $PRL_{all} = \mathrm{r}(Z_h, \zeta)$

Separated regression $PRL_{rain\ stage\ i} = \mathrm{r}_i(Z_{h\ i}, \zeta_i)$



At RS 2, the single regression predict little higher risk level than separated regression

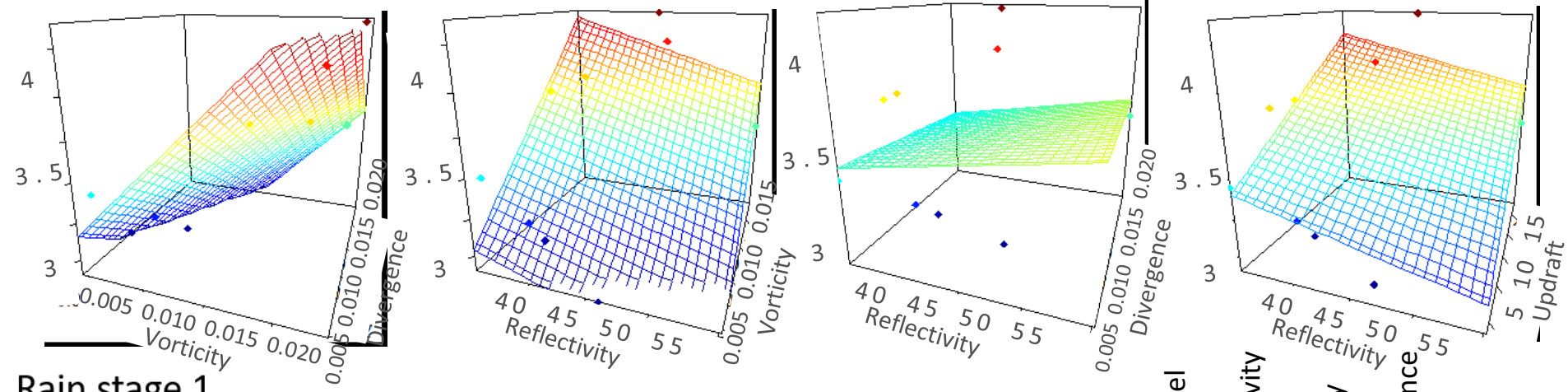
At RS 1 3 4 5, the single regression predict little smaller risk level than separated regression

It depends on the value of variables at each rain stage but allowedly the separated regression have small difference with the estimated risk level

Improvement of the quantitative risk prediction

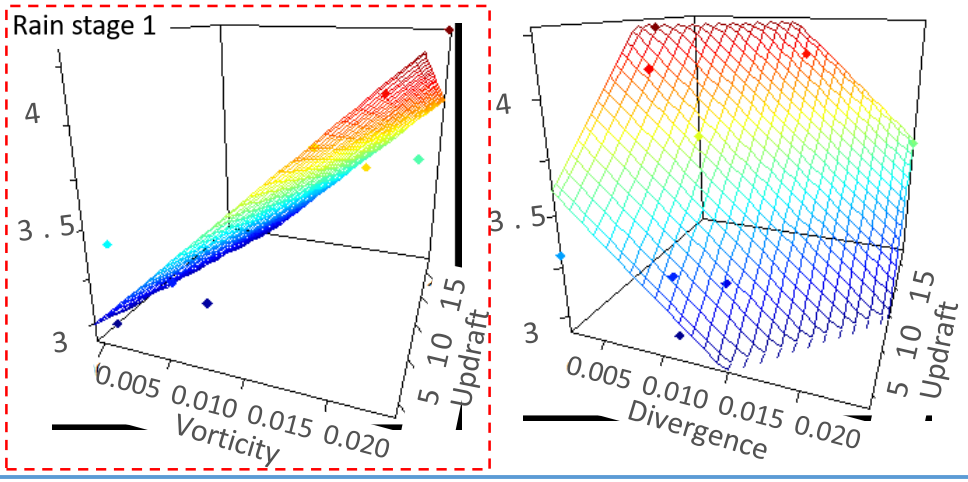
Z_h, ζ: Vorticity of multi-Doppler radar analysis , D: Divergence of multi-Doppler radar analysis, w

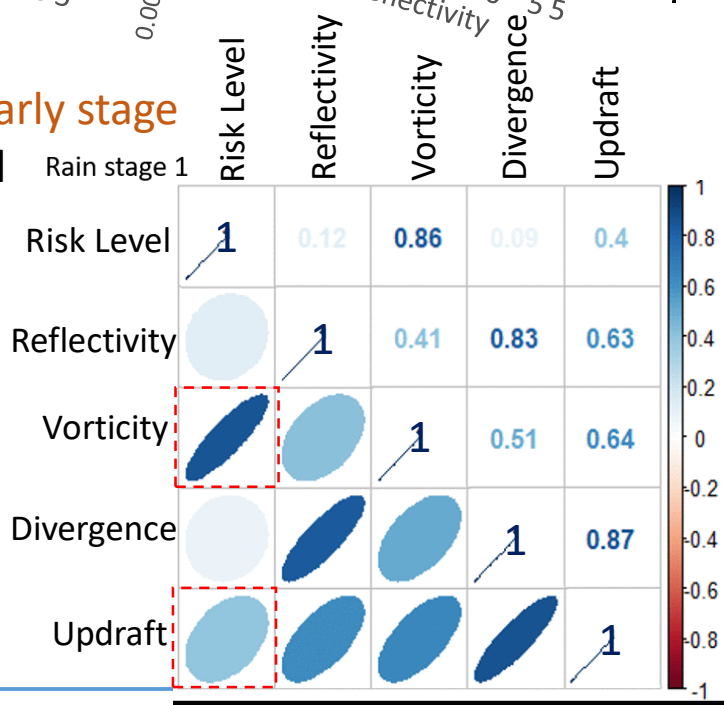
The relationship between the risk level and the variables



Rain stage 1

- Vorticity and Updraft do the very important role at the early stage
- The relationship btw vorticity and updraft explain RL well





Improvement of the quantitative risk prediction

Z_h, ζ: Vorticity of multi-Doppler radar analysis , D: Divergence of multi-Doppler radar analysis, w

The relationship between the risk level and the variables

① Coefficients

Model		Unstandard Coefficients		Standard Coefficients	t	Part Correlation
		B	Std.Error	Beta		
1	(Constant)	2.40	1.25		1.92	
	Reflectivity	0.03	0.04	0.35	0.67	0.18
	Vorticity	124.44	57.55	0.77	2.16	0.58
	Updraft	0.09	0.10	0.61	0.93	0.25
	Divergence	-231.64	167.33	-1.14	-1.38	-0.37

② Coefficients

Model		Unstandard Coefficients		Standard Coefficients	t	Part Correlation
		B	Std.Error	Beta		
1	(Constant)	4.01	1.31		3.07	
	Reflectivity	-0.02	0.03	-0.17	-0.88	-0.17
	Vorticity	100.27	56.49	0.96	1.77	0.34
	Updraft	0.04	0.03	0.45	1.43	0.27
	Divergence	-74.75	32.39	-0.97	-2.31	-0.44

③ Coefficients

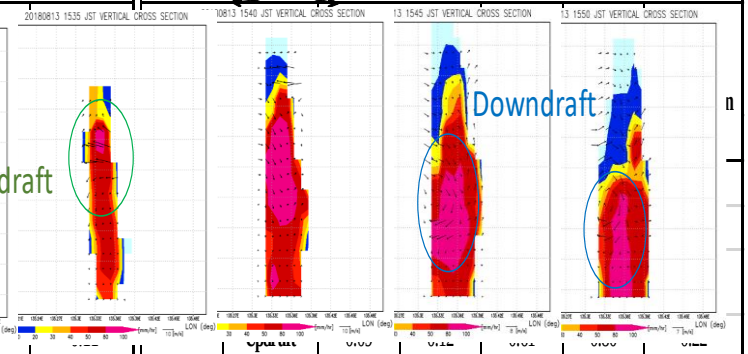
Model		Unstandard Coefficients		Standard Coefficients	t	Part Correlation
		B	Std.Error	Beta		
1	(Constant)	-9.38	12.87		-0.73	
	Reflectivity	0.23	0.24	0.98	0.96	0.26
	Vorticity	237.70	177.98	2.79	1.34	0.36
	Updraft	0.01	0.08	0.09	0.12	0.03
	Divergence	-200.09	151.35	-2.63	-1.32	-0.36

④ Coefficients

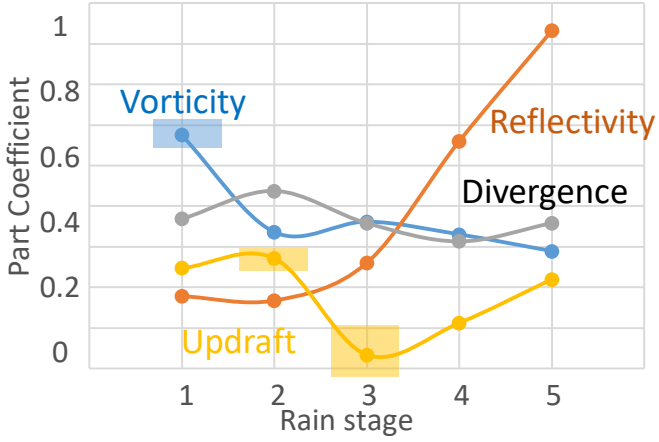
Model		Unstan Coeffic				
		B				
1	(Constant)	-2.90				
	Reflectivity	0.12				
	Vorticity	179.45				
	Updraft	-0.03				
	Divergence	-151.58	78.14	-1.17	-1.94	-0.31

⑤, ⑥ Coefficients

	Divergence	110.04	84.01	1.15	1.31	0.36



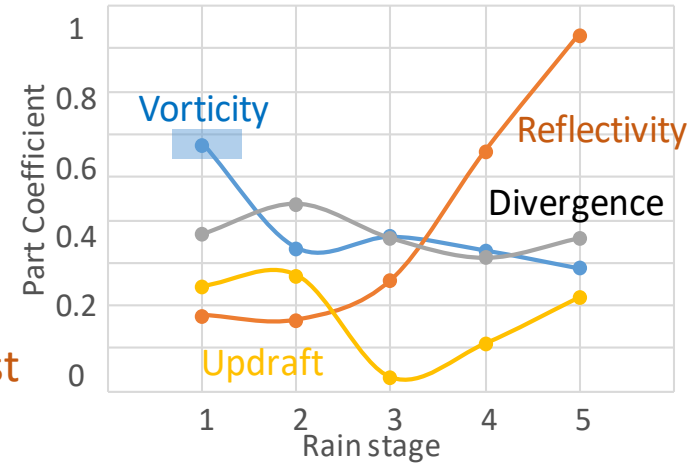
The vorticity has the most effective variable at early stage
There are the significant change of peak on updraft



Conclusion and Future works

Conclusion

- By using the three-dimensional wind field from multiple-Doppler radar analysis, the reliable wind field reflecting natural environment was calculated
- At the early stage, the part coefficients of vertical vorticity have high value -> the vorticity has the most important in the dependent variable



- The predicted risk level by using separated regression didn't deviate much than single regression

Future study

- By using the equation, I check the accuracy by using the ROC curve on the linear regression equation.
- Then, compare the accuracy between single and separated regression

$$Predicted\ Risk\ Level\ (PRL) = C_0 + C_1 \cdot Z_h(reflectivity) - C_2 \cdot \zeta(vorticity) + C_3 \cdot \omega(updraft) \cdots + C_n X_n$$

- Apply the quantitative risk prediction method to flash flood

Thank you for listening