Identifying Non-meteorological Signal Using Modified Fuzzy-logic Algorithm with Objectively Derived Weighting Matrix

Ju-Yu Chen[1], Wei-Yu Chang[2], Yu-Chieng Liou[1], Tai-Chi Chen Wang[1]
[1]Department of Atmospheric Sciences, National Central University, Jhongli, Taiwan
[2]Department of Atmospheric Sciences, Chinese Culture University, Taipei, Taiwan

National Central University
Radar Meteorology Laboratory

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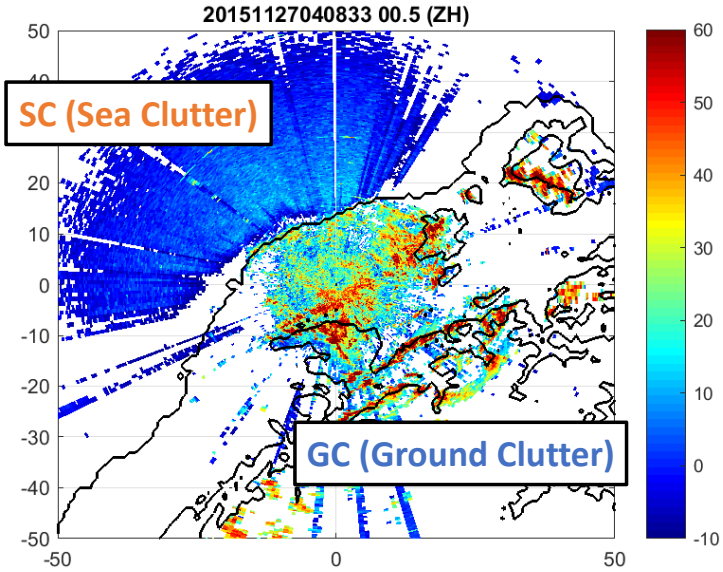
Introduction

☐ Non-meteorological signal

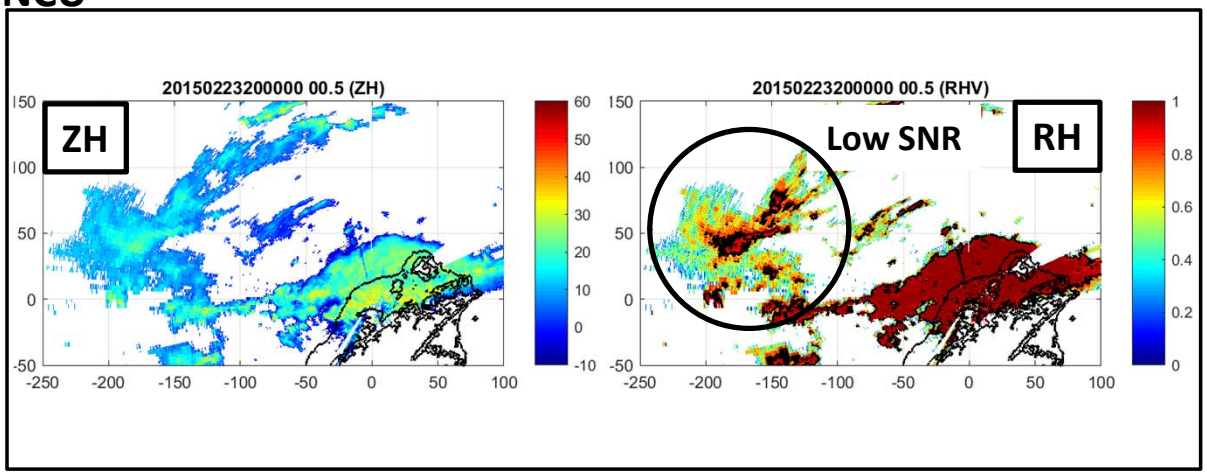


☐ Threshold-Based method-

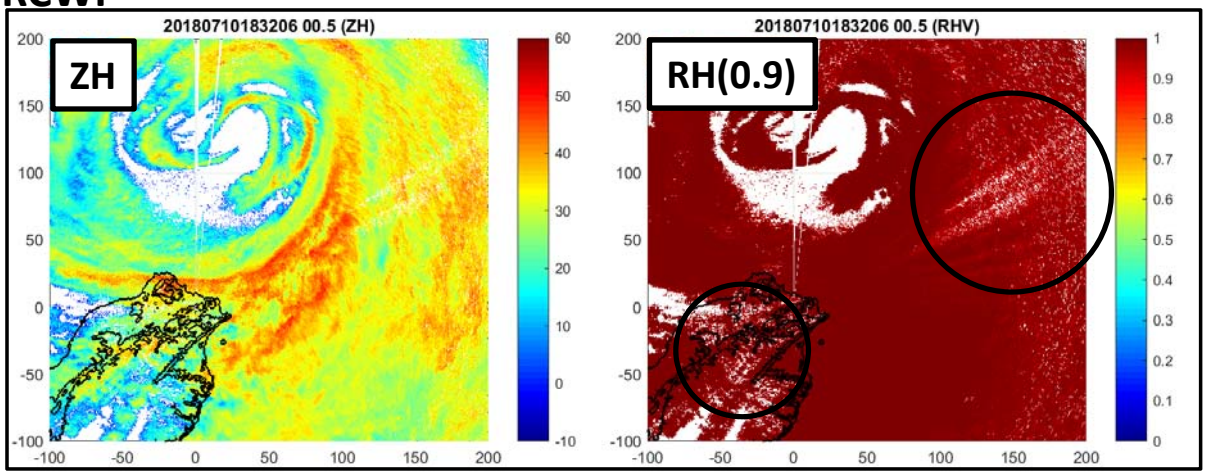
✓ case dependently

✓ Low SNR leads to low RHV

NCU

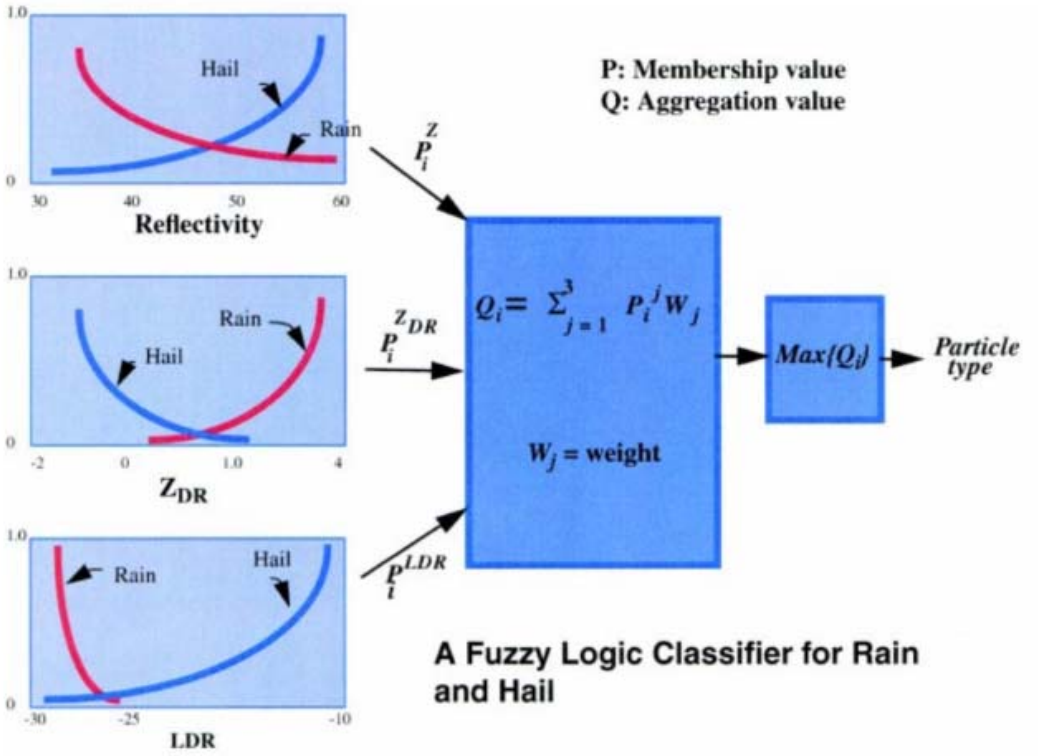


RCWF



Introduction

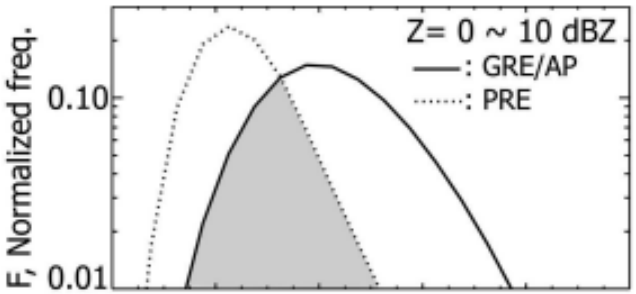
Fuzzy logic algorithm



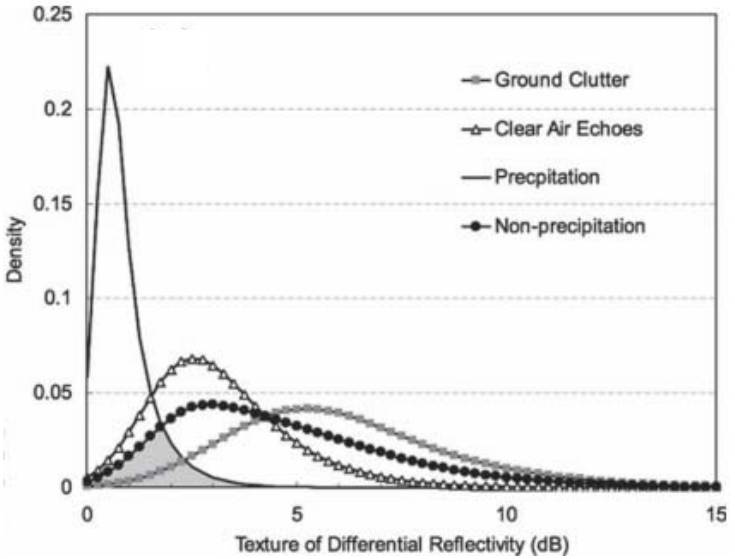
Vivekanandan J. (1999)

Introduction

☐ **Review : 1D weighting**



✓ **two MFs only (non- and meteorological signals) (Cho et al. 2006)**



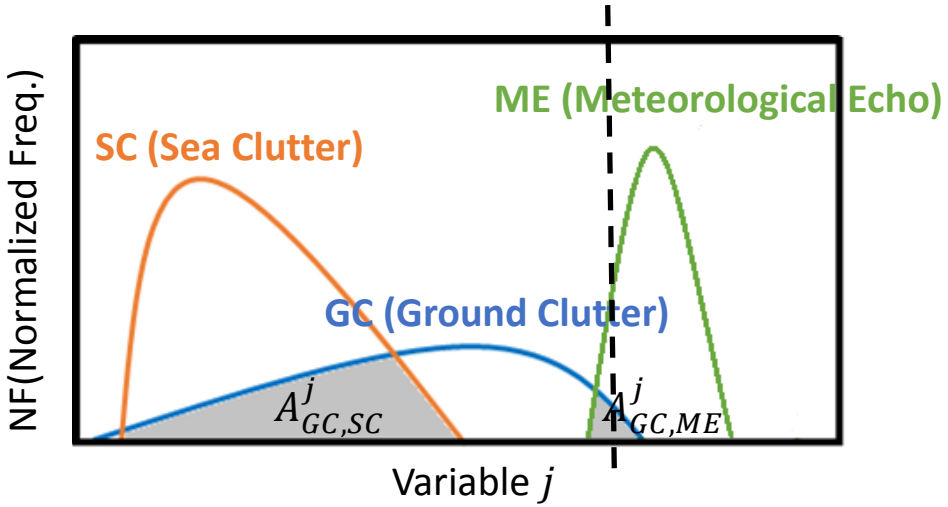
✓ **averaging the MFs representing non-meteorological signal (Gourley et al. 2007)**

Larger overlapping area is, less distinct two categories are.

Methodology – Fuzzy Logic Method

Weighting

$$score(category) = \sum_{var=1}^{var=10} MF_{category}^{var} \times W_{category,x}^{var}$$



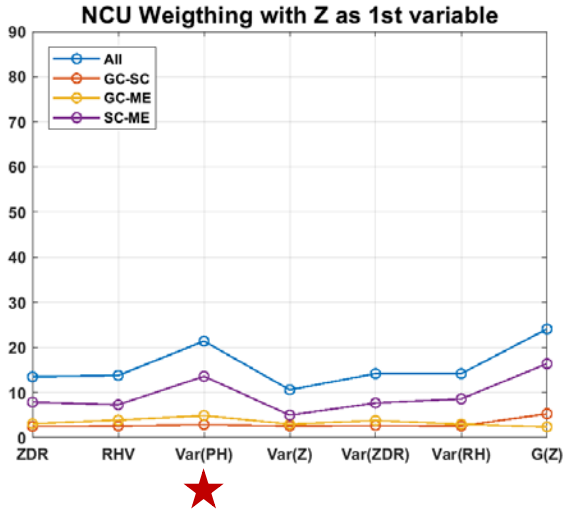
Weighting Set	Formula
No Weighting	$W^j = 1$
1D Weighting	$W^j = \frac{1}{A^j}$, where $A^j = A^j_{GC,SC} + A^j_{GC,ME} + A^j_{SC,ME} \ldots$
Array Weighting	$W^j_{GC,SC} = \frac{1}{A^j_{GC,SC}}$; $W^j_{GC,ME} = \frac{1}{A^j_{GC,ME}}$; $W^j_{SC,ME} = \frac{1}{A^j_{SC,ME}} \ldots$

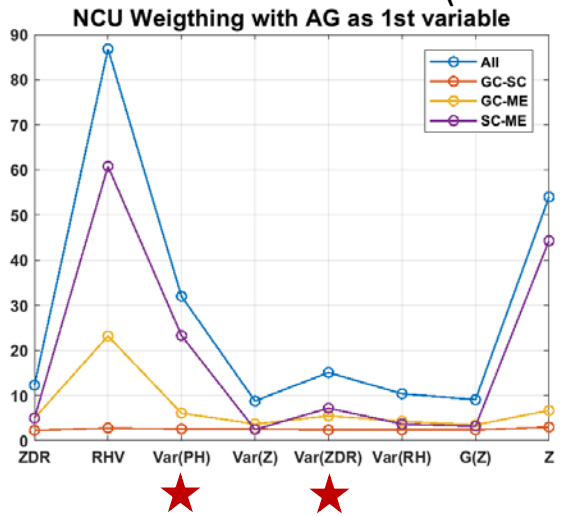
A = Overlapping Area ; j= Nth Variable ; Subscript = category (GC, SC, ME…)

Methodology – Fuzzy Logic Method

(Above Ground height)

NCU

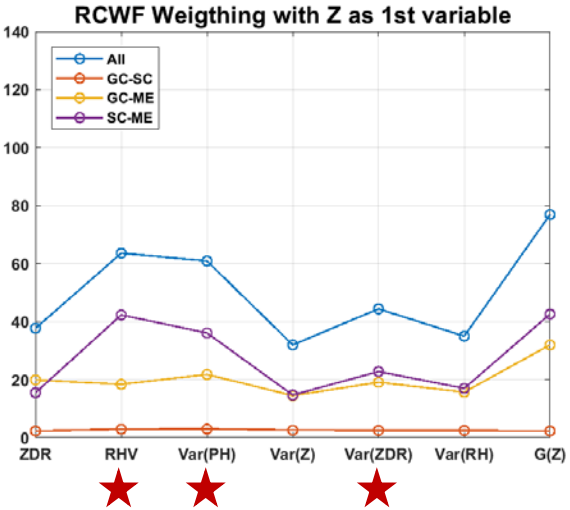


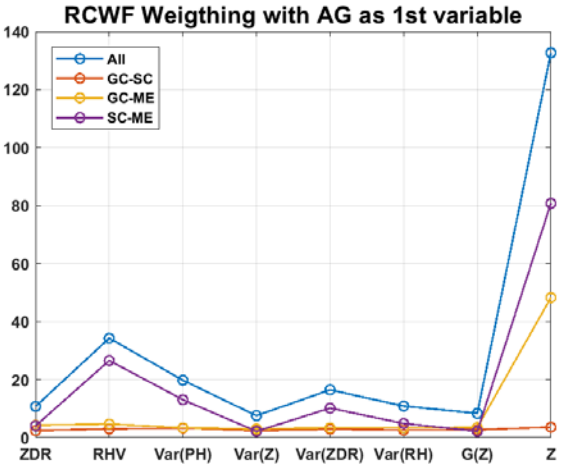


AZ as 1st variable

NCU	AZ-AG
All	40.8
GC-SC	9.1
GC-ME	9.9
SC-ME	21.8

RCWF





AZ as 1st variable

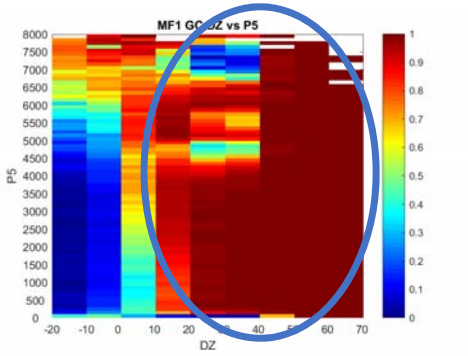
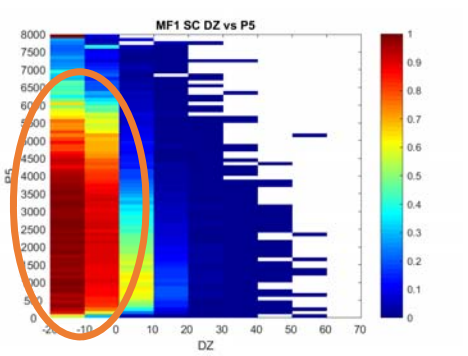
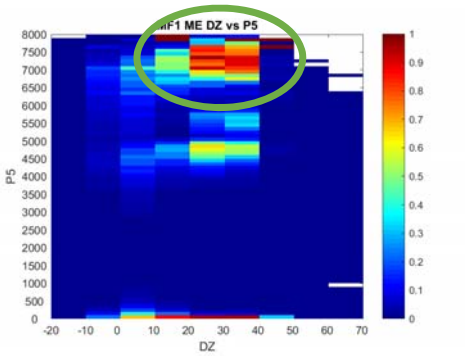
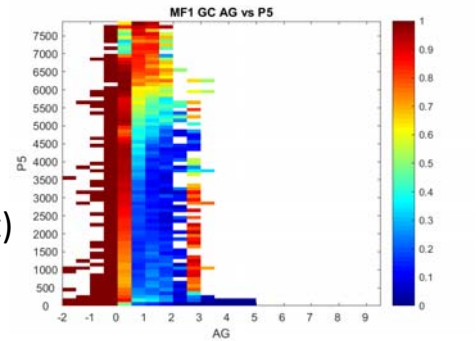
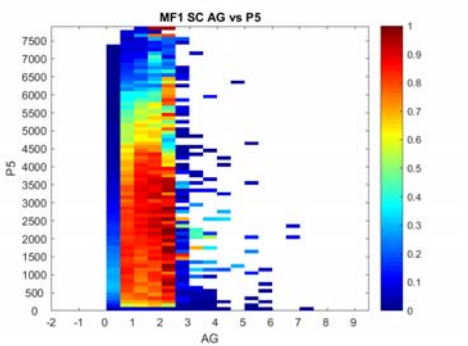
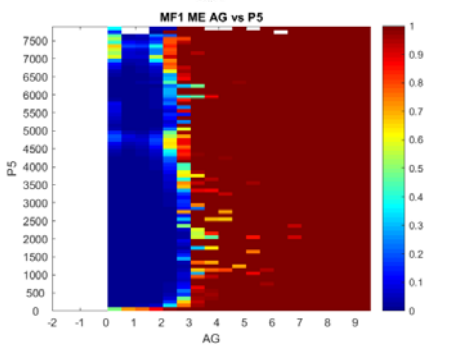
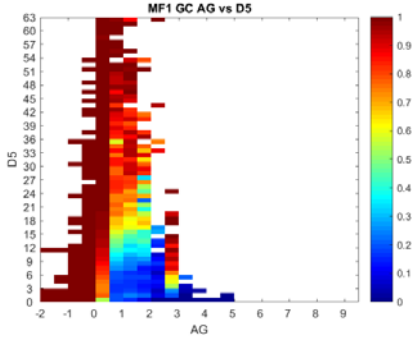
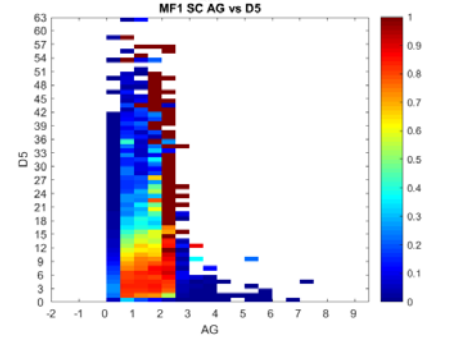
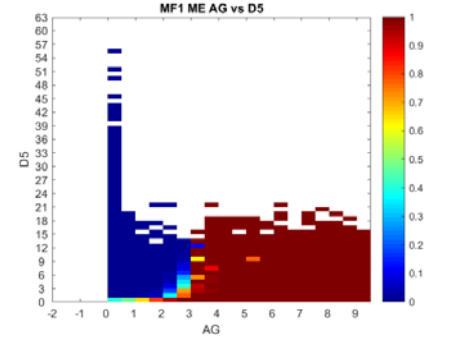
RCWF	AZ-AG
All	18.5
GC-SC	4.1
GC-ME	6.3
SC-ME	8.1

Methodology – Fuzzy Logic Method

$MF_i=NF_i/sum(NF_{i=1,3})$
where i is GC, SC and ME

NF (Normalized Freq.) → 2D MF (Membership Function)

NCU

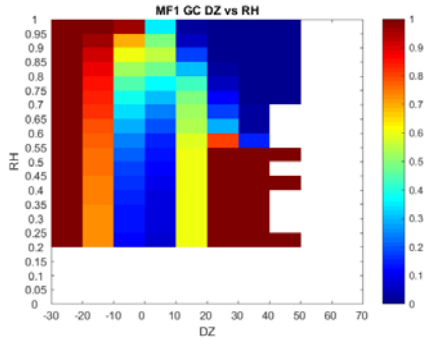
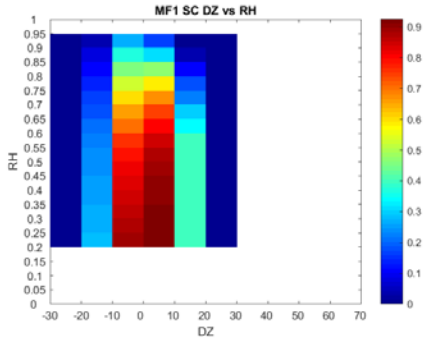
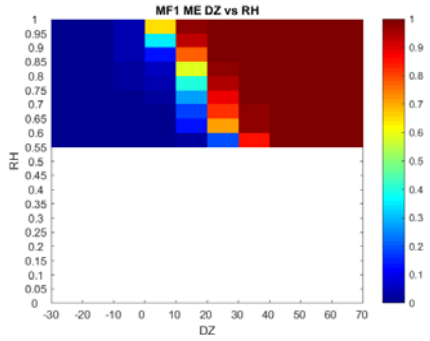
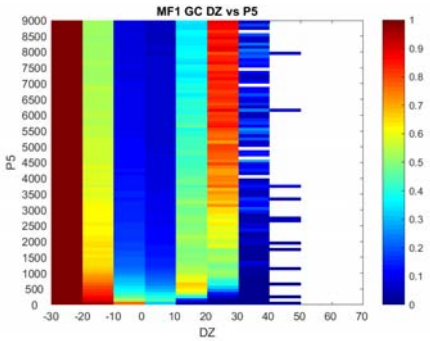
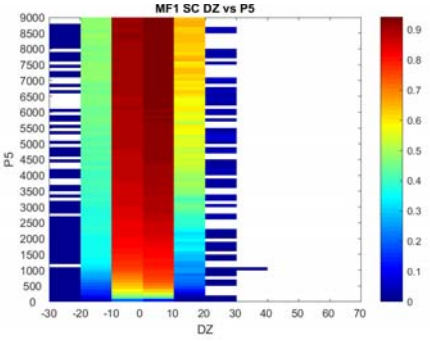
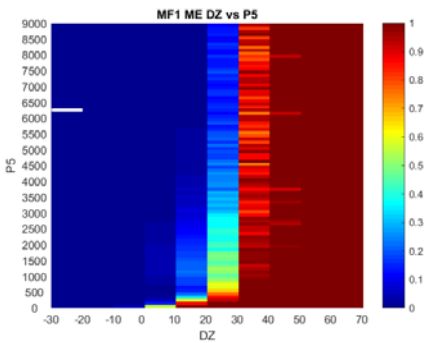
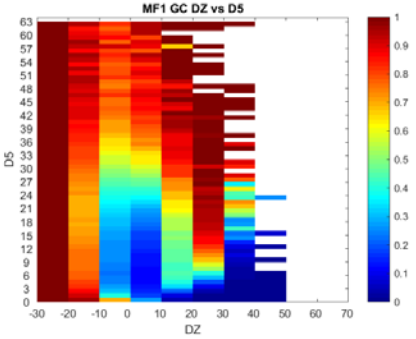
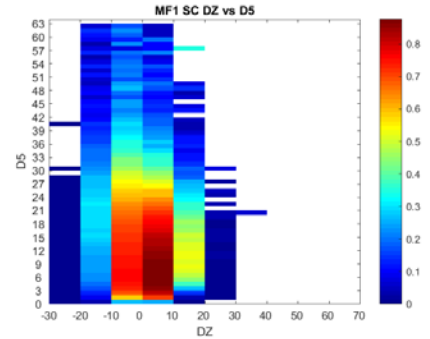
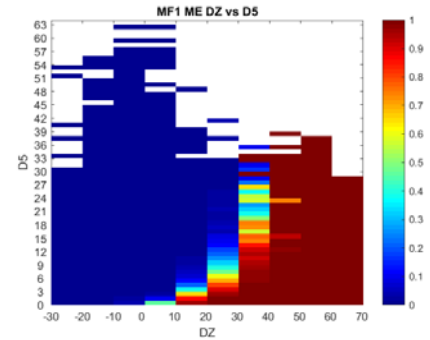
	GC (Ground Clutter)	SC (Sea Clutter)	ME (Meteorological Echo)
Z - Var(PH)			
AG - Var(PH) (Above Ground height)			
AG - Var(ZDR)			

Methodology – Fuzzy Logic Method

$MF_i=NF_i/sum(NF_{i=1,3})$
where i is GC, SC and ME

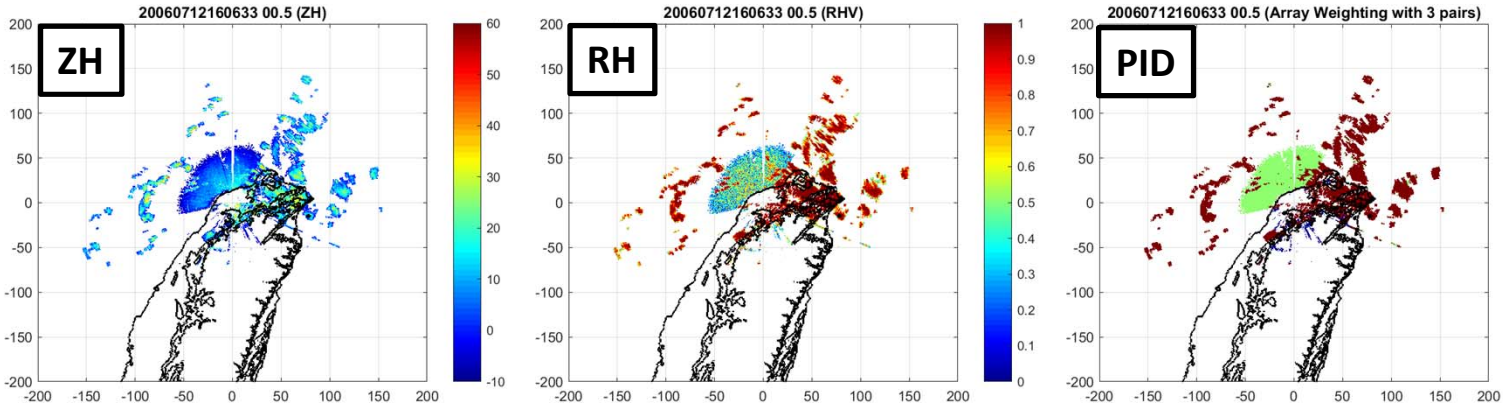
NF (Normalized Freq.) → 2D MF (Membership Function)

RCWF

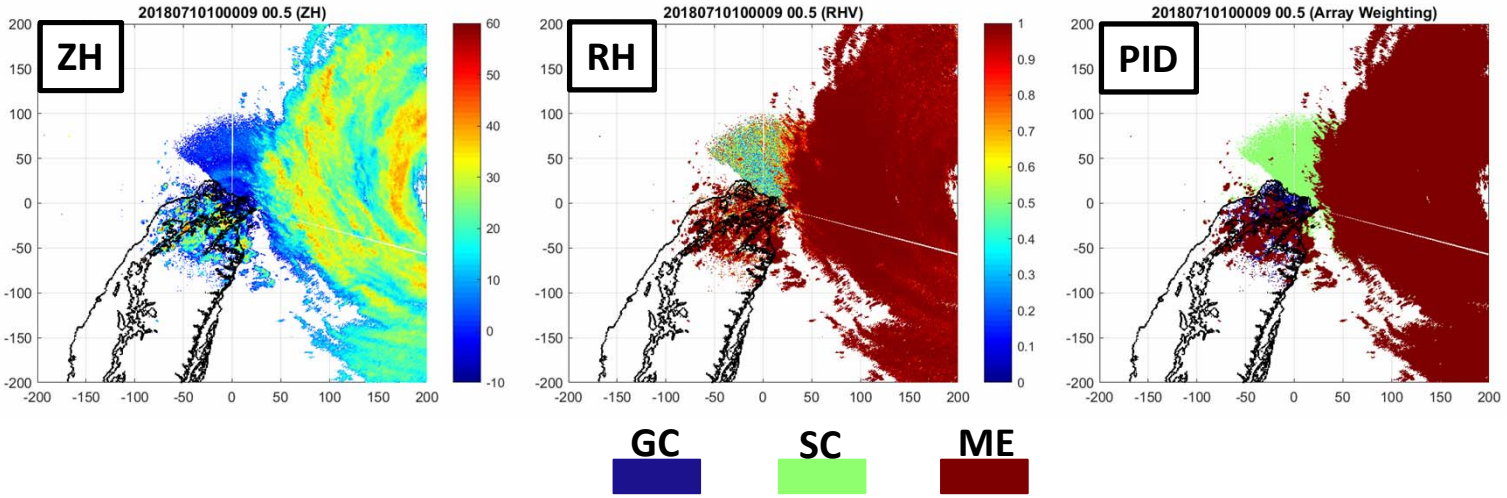
	GC (Ground Clutter)	SC (Sea Clutter)	ME (Meteorological Echo)
Z - RH			
Z - Var(PH)			
Z - Var(ZDR)			

Result

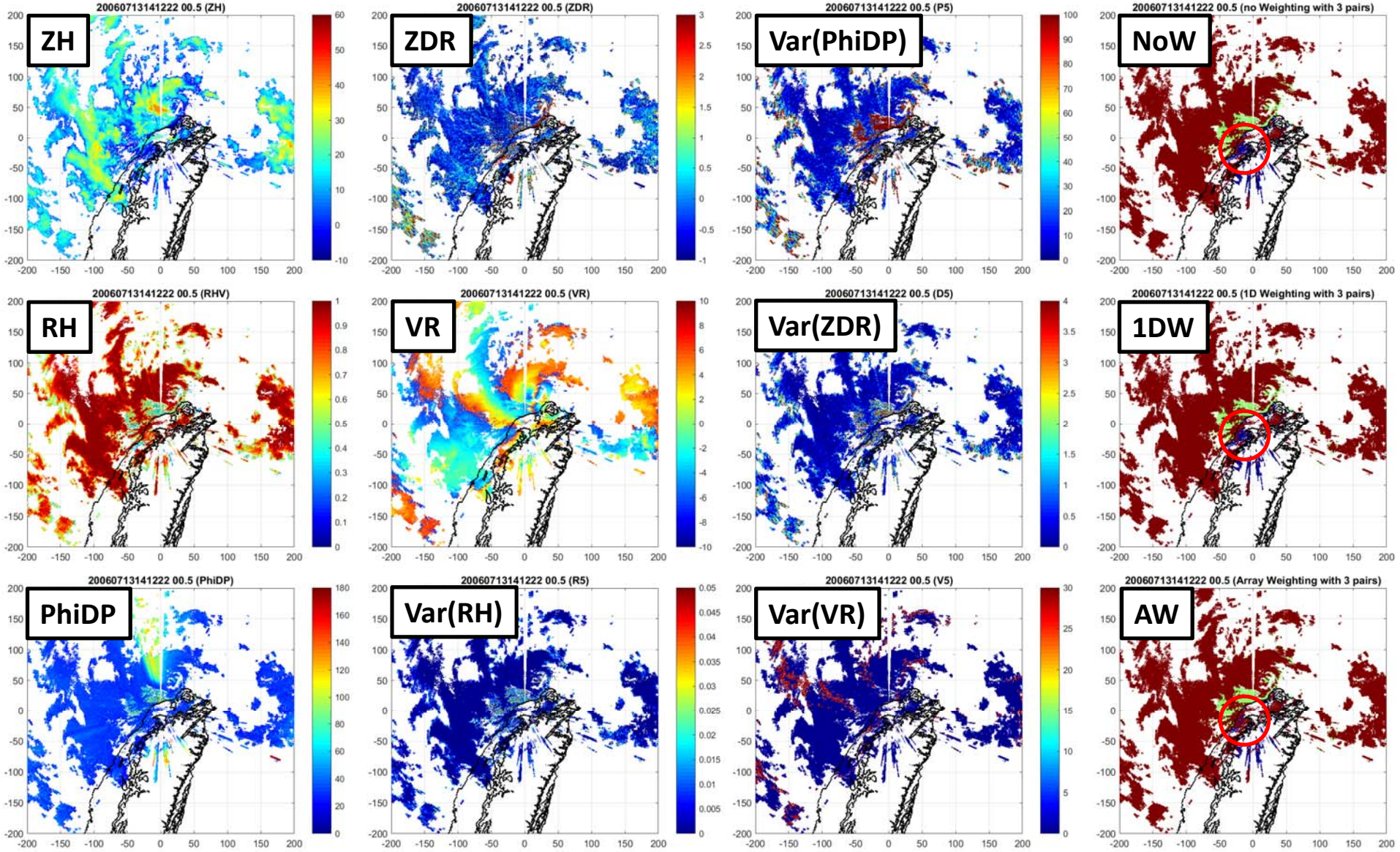
NCU 2006 Bilis typhoon



RCWF 2018 Maria typhoon



Result – NCU

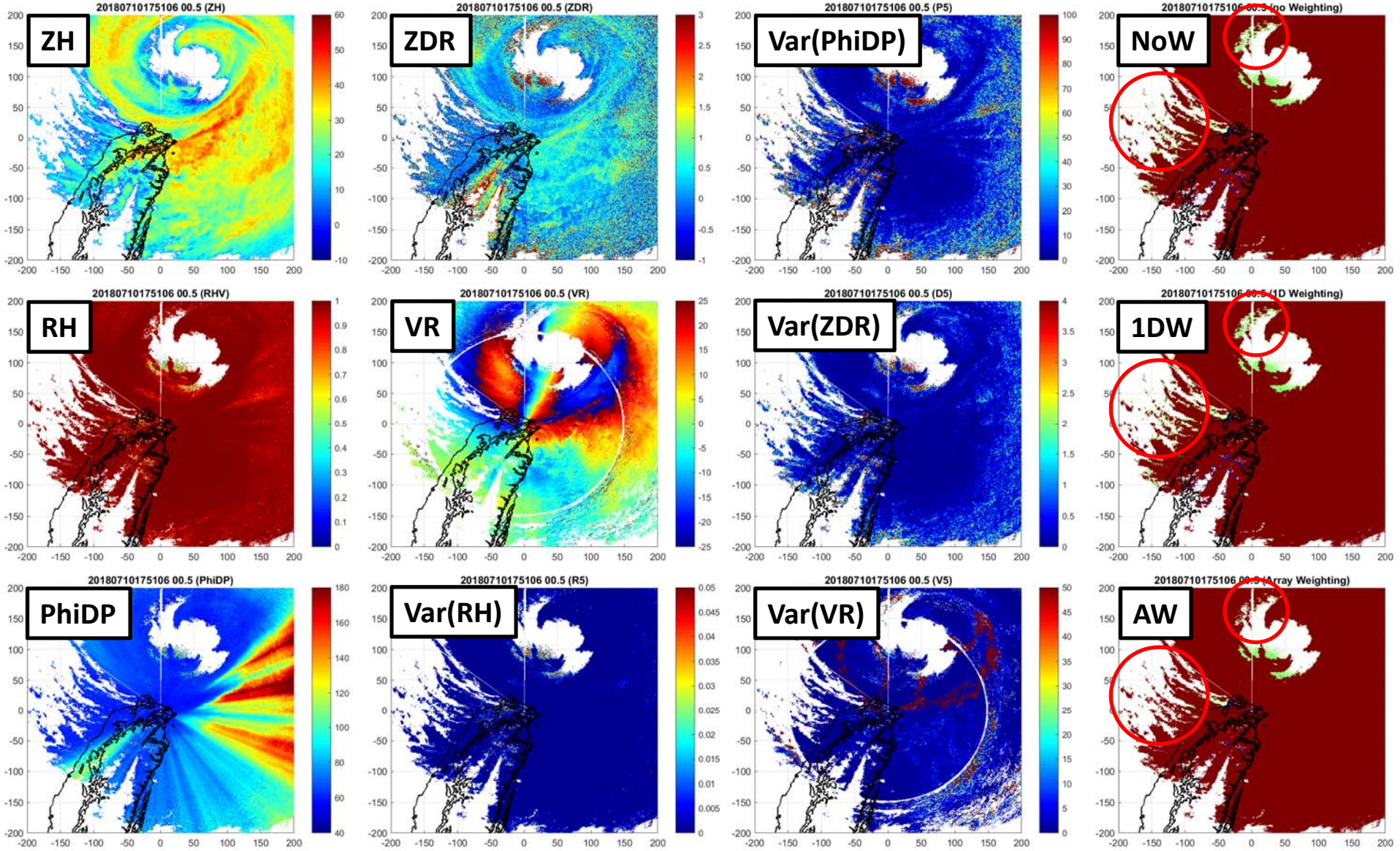


GC

SC

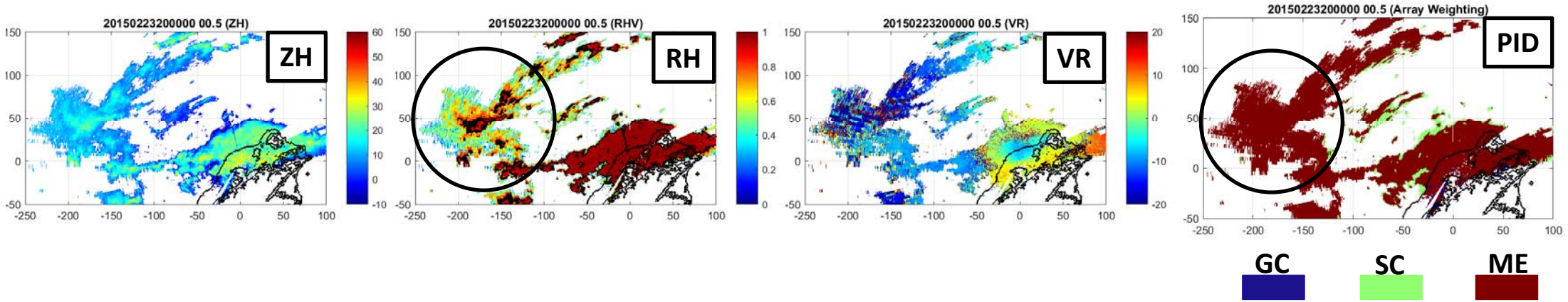
ME

Result – RCWF


ZH
ZDR
Var(PhiDP)
NoW
RH
VR
Var(ZDR)
1DW
PhiDP
Var(RH)
Var(VR)
AW
GC
SC
ME

Result

NCU – Low RH



Weighting Set	Missing low RH %		Missing weak Z %		Incorrect categorized %	
	NCU	RCWF	NCU	RCWF	NCU	RCWF
No Weighting	44.47	13.82	9.55	20.28	3.87	6.15
1D Weighting	44.95	13.67	8.58	21.22	3.69	6.45
Array Weighting	48.38	18.02			3.11	5.58

- ✓ Keep more data where RH is relatively low, especially for NCU radar.
- ✓ Array weighing algorithm results in better performance in low RH or weak Z (<10dBZ) area.
  → save more information such as VR for data assimilation.

Result – QPE

Selected Case -

[yy/mm/dd/(h)]	Rain type	Max. Hourly / Accum. R
140605 (5h)	Mei-Yu	46 / 126.5
140819 (3h)	Convection	71.5 / 92.5
150224 (4h)	Front	29.5 / 58.5

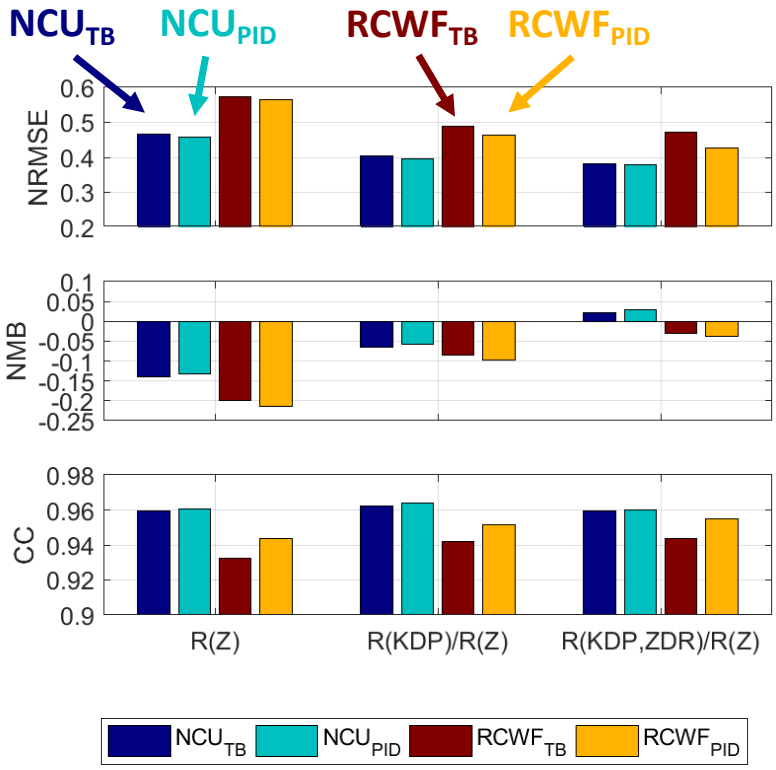
QC -

- ✓ Non-meteorological echo removal (**PID** / **T**hreshold-**b**ased method)
- ✓ Attenuation correction
- ✓ Wet radome correction

Corresponding rain-type rain rate algorithm -

- ✓ R(Z)
- ✓ R(KDP)/R(Z)
- ✓ R(KDP,ZDR)/R(Z)

QPE from **PID** or **T**hreshold-**b**ased (RHV) QC



comparable performance or even slightly better in NRMSE and CC.

Summary and Future work

Summary

- Each radar's MFs are trained to represent their own characteristics of different categorized signal.
- Compared to traditional threshold-based method, fuzzy logic algorithm with array weighting keeps more meteorological information and improves missing low RH % with respect to 1D and no weighting.
- QPE results by PID QC method show comparable performance to those by threshold-based (fine-tune) one.

Future work

- Variable pairs used in algorithm should be chosen in an objective way.
- More cases are needed to test the algorithm.

-- Thanks for your attention --