Basics of dual-polarization radar (2)
Quality Control (QC)

N. Nagumo, H. Inoue, and T. Sakai

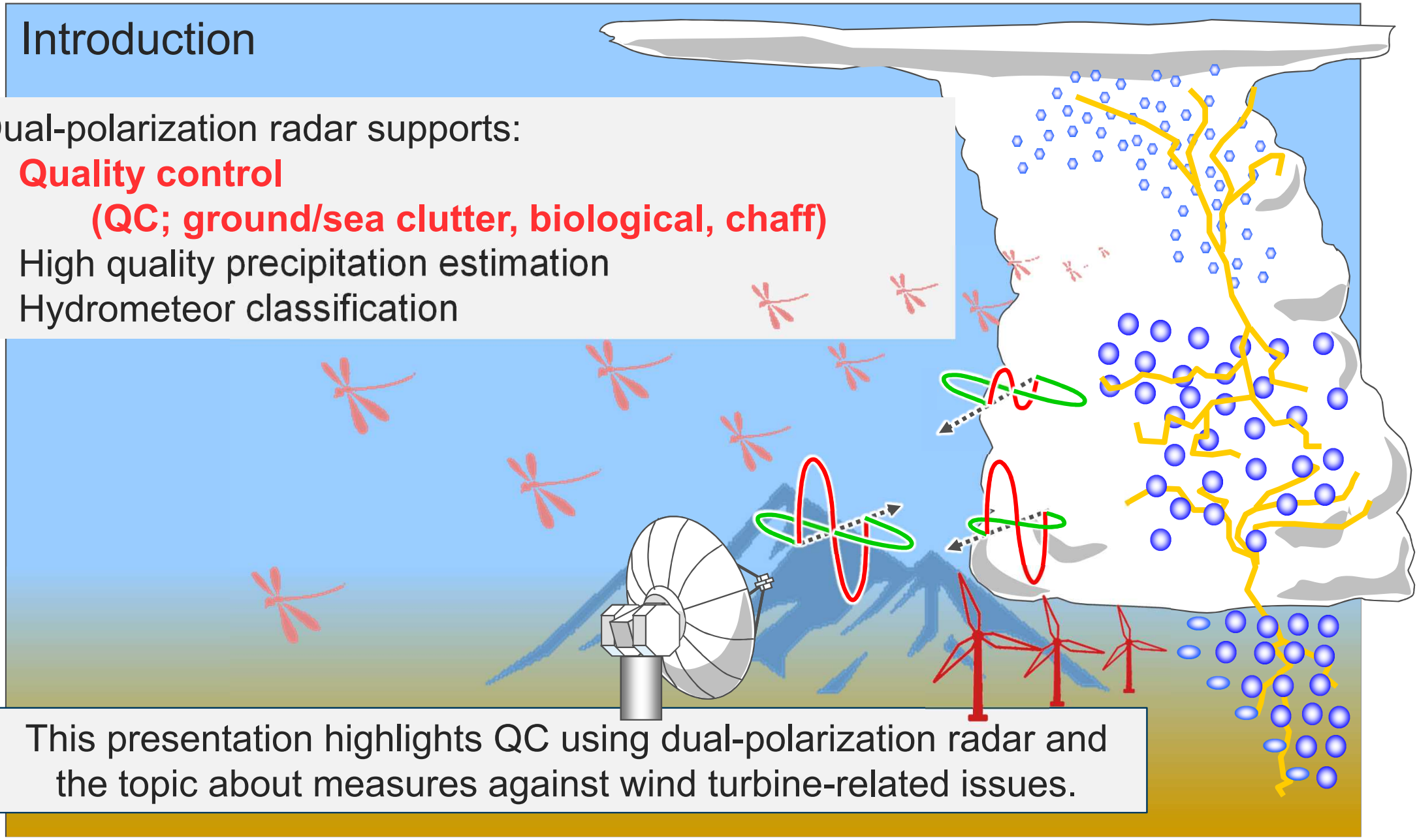
Office of Meteorological Analysis and Application Development
Administration Division, Atmosphere and Ocean Department, JMA

2 Basics of dual-polarization radar : Quality Control (QC)

Introduction

Dual-polarization radar supports:

- **Quality control**
  (QC; ground/sea clutter, biological, chaff)
- High quality precipitation estimation
- Hydrometeor classification



This presentation highlights QC using dual-polarization radar and the topic about measures against wind turbine-related issues.

2 Basics of dual-polarization radar : Quality Control (QC)

Contents

2.1 Control of non-meteorological echo

- Weather radar detects not only meteorological echoes but also other scatterers.
- Single polarization radar has difficulty distinguishing between these echoes.

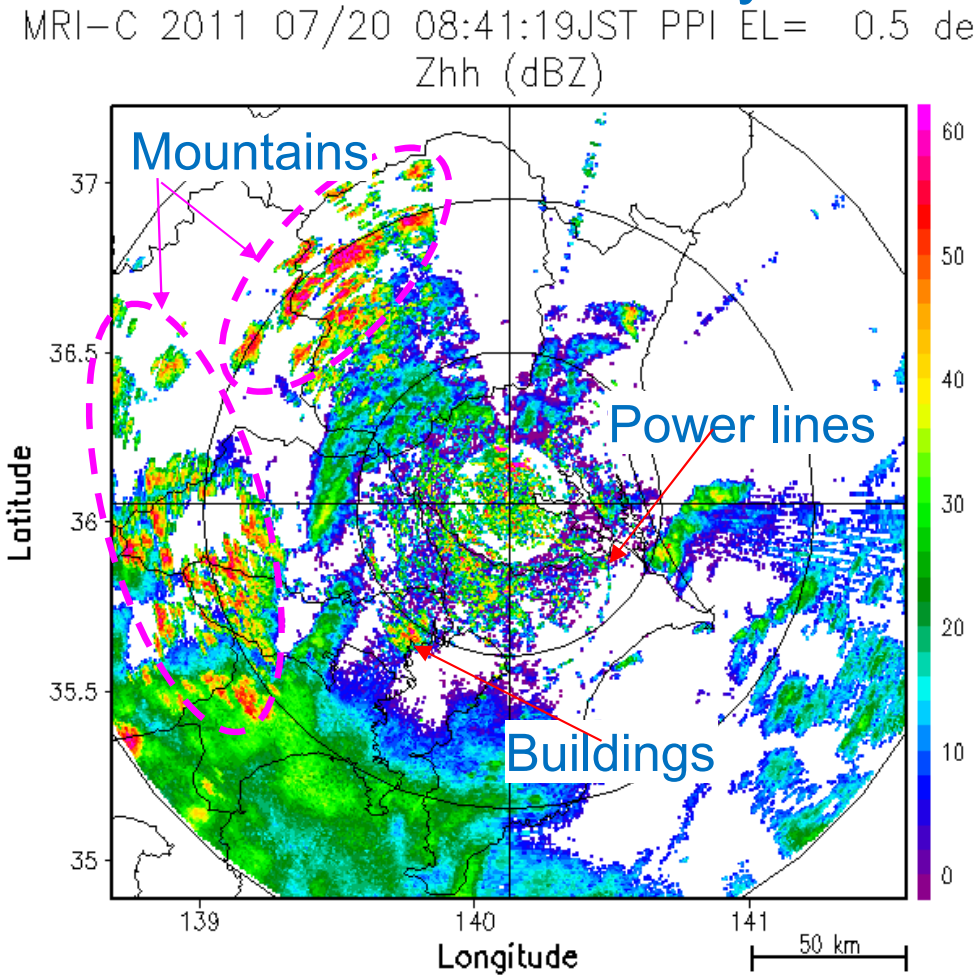
Examples of possible value ranges for dual-polarization variables

	Z_H (dBZ)	V (m s^{-1})	Z_{DR} (dB)	ρ_{HV}	$S(\Phi_{DP})$ (deg)
Meteorological echo	varies	varies	-2 to 7	0.85 <	< 10
Ground clutter	varies	near 0	varies	varies	30 <
Sea clutter	varies	varies	varies	< 0.7	30 <
Biological scatterers	varies	varies	7 <	< 0.7	10 <

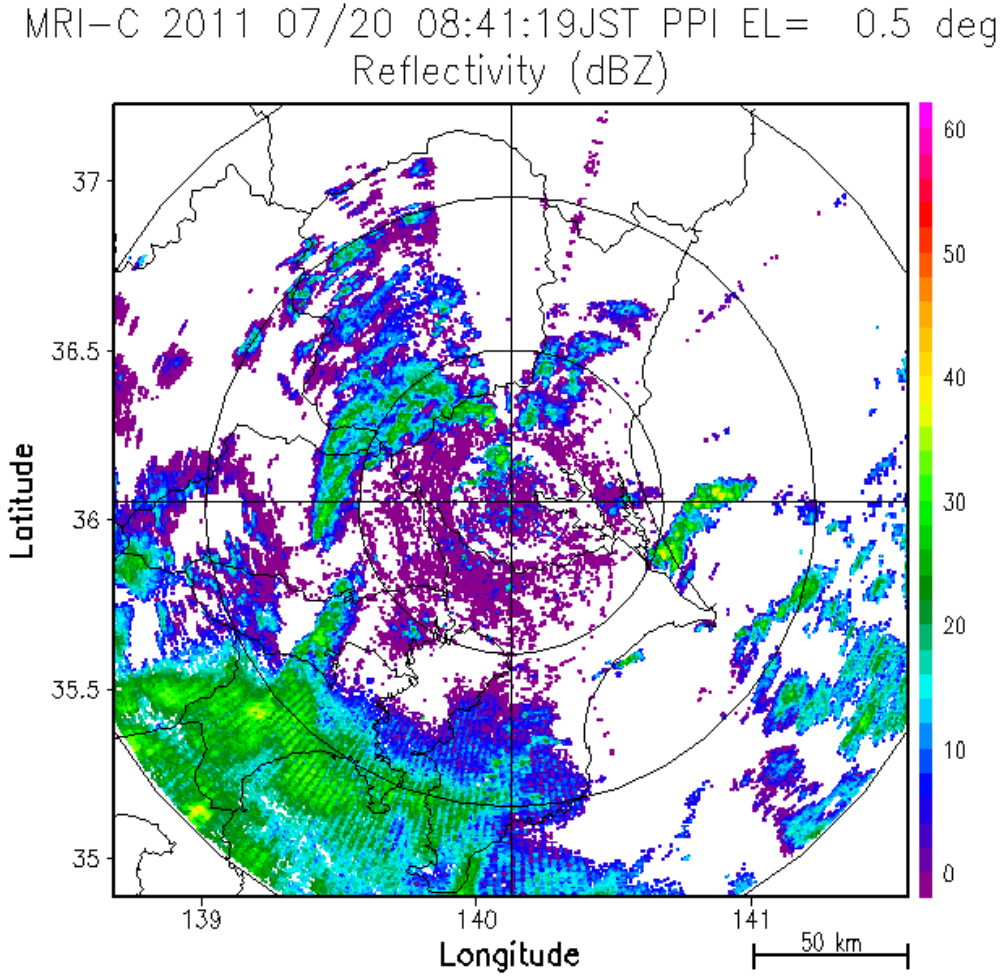
2.1 Control of non-meteorological echo (Ground clutter)

- Doppler filtering cannot fully remove ground clutter.
- Doppler filtering may degrade data.

Normal reflectivity

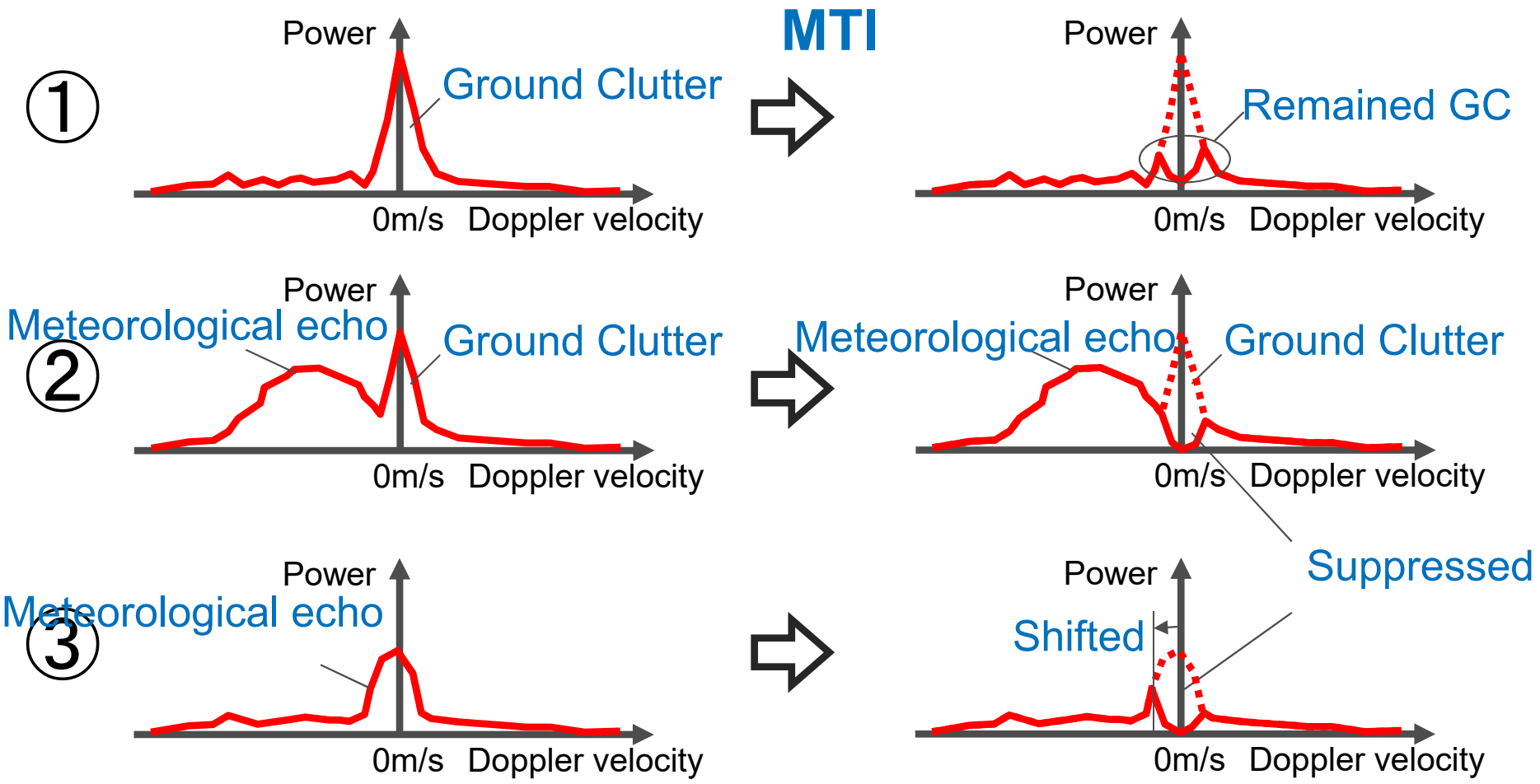


Doppler filtered reflectivity



2.1 Control of non-meteorological echo (Ground clutter)

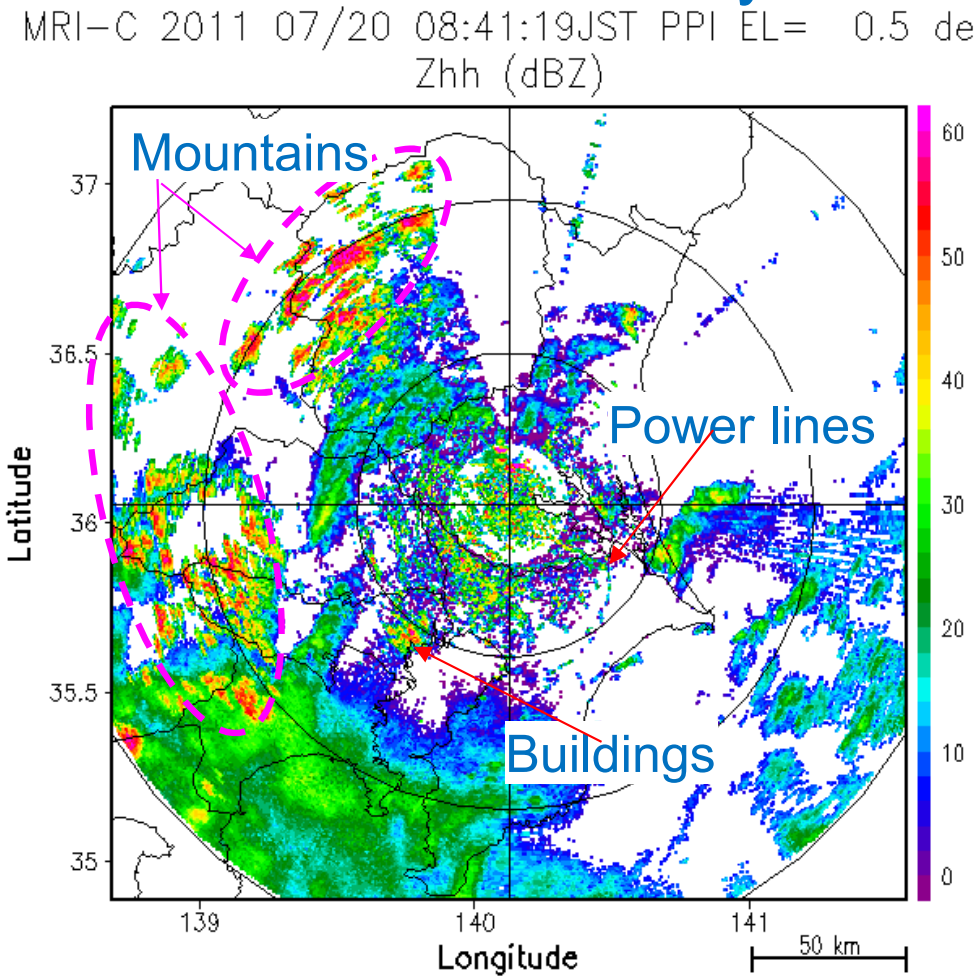
- Doppler filtering (MTI: Moving Target Indicator) removes and interpolates the power component around 0 m/s in power spectrum.
- It also removes some of meteorological echoes (side effect).



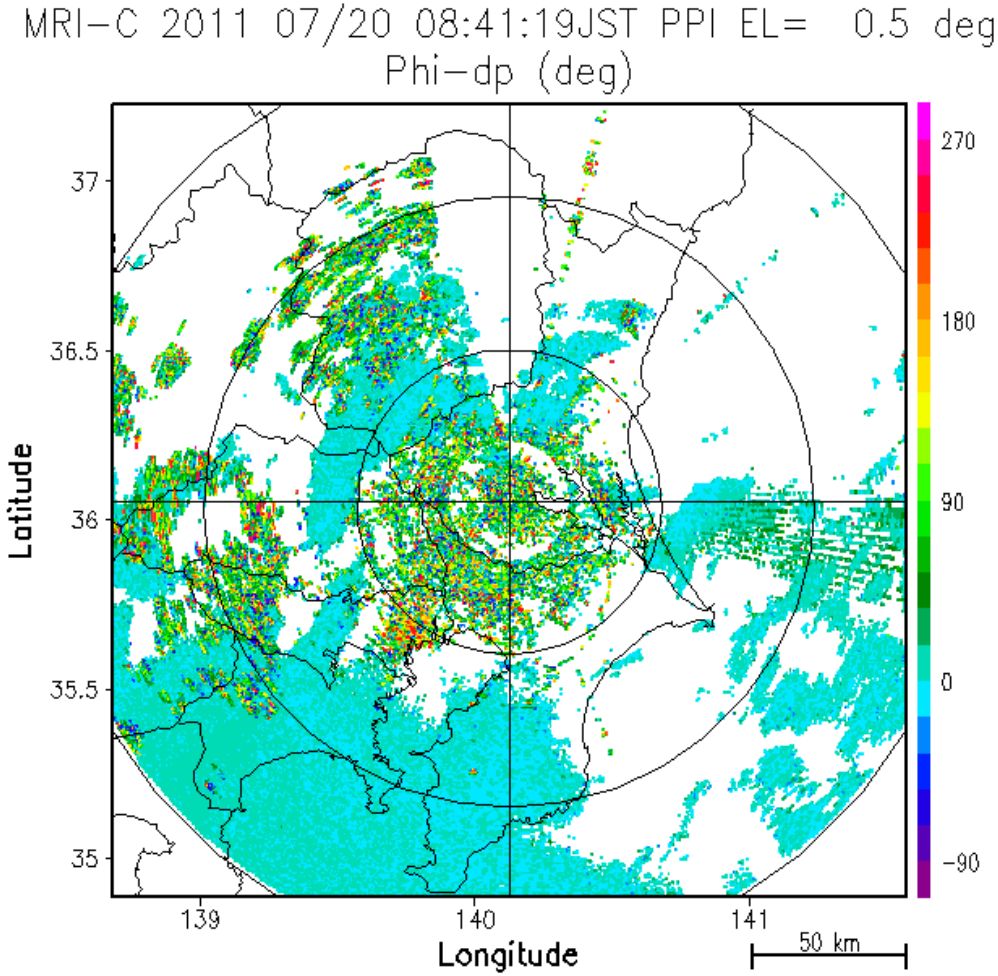
2.1 Control of non-meteorological echo (Ground clutter)

- Φ_{DP} is spatially fluctuating in ground clutter regions.
- Φ_{DP} is spatially smooth in precipitation echo.

Normal reflectivity

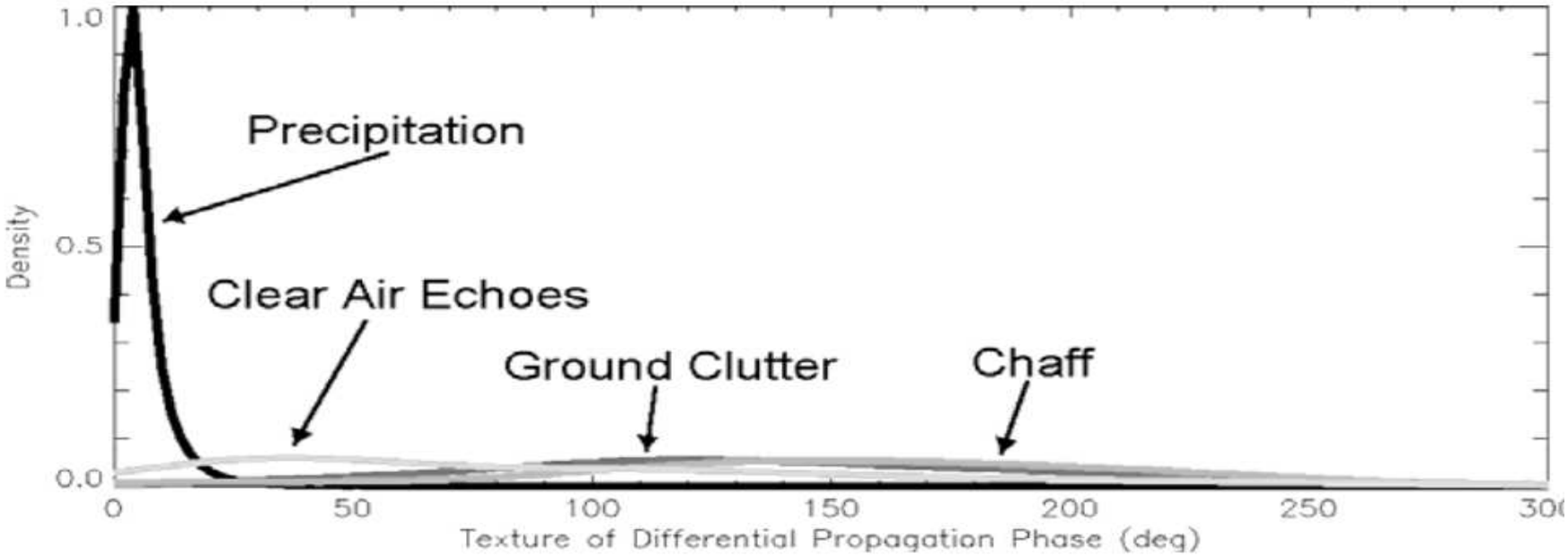


Φ_{DP}



2.1 Control of non-meteorological echo (Ground clutter)

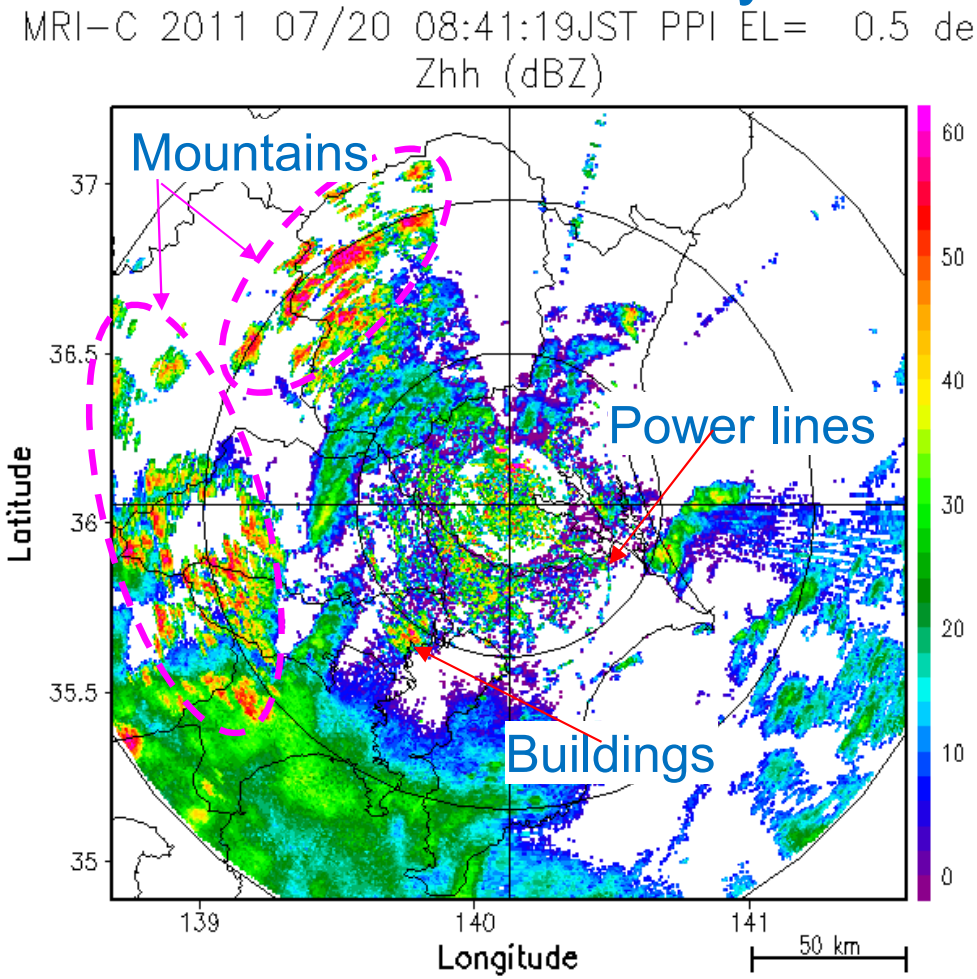
- $S(\Phi_{DP})$: Standard deviation of Φ_{DP}
  - Reflects sparseness or non-uniformity of scattering targets within sampling volume
  - Possible range of values : larger than 0
  - Can clearly indicates precipitation echo
  - Useful for hydrometeor classification and QC



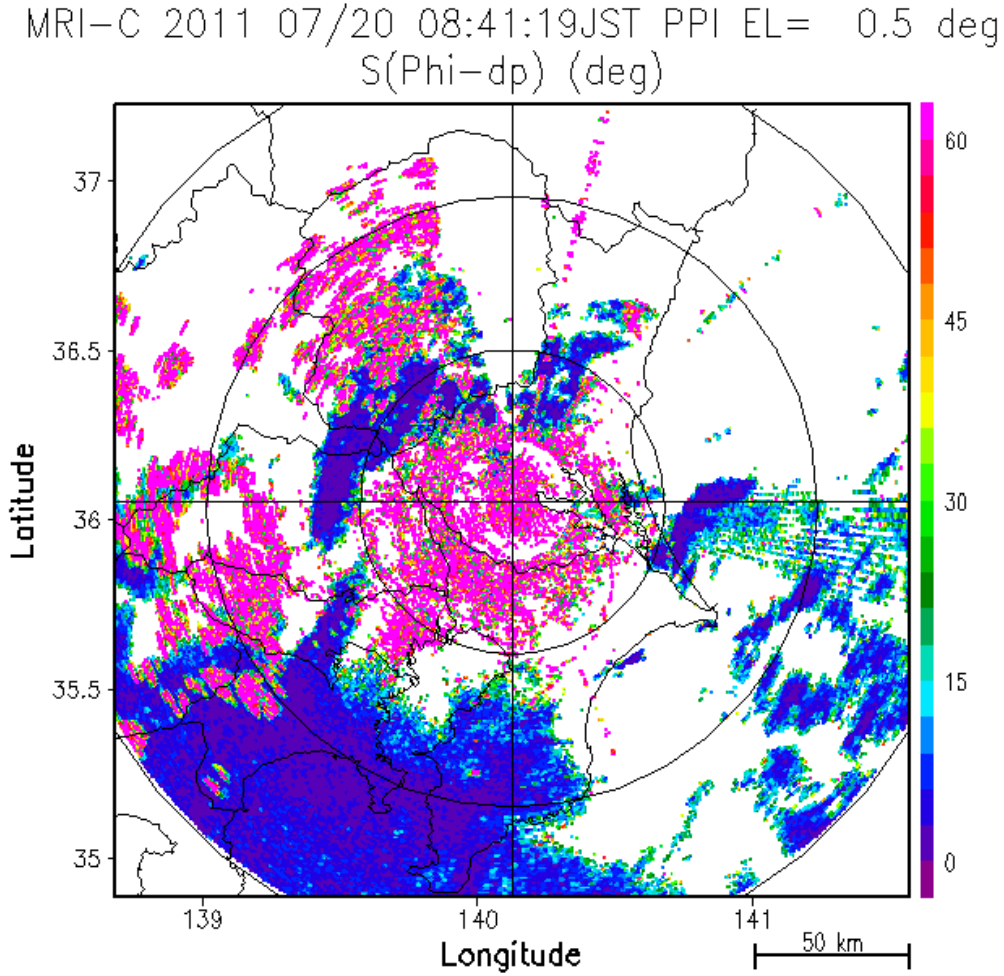
2.1 Control of non-meteorological echo (Ground clutter)

- Standard deviation of Φ_{DP} clearly shows ground clutter.

Normal reflectivity



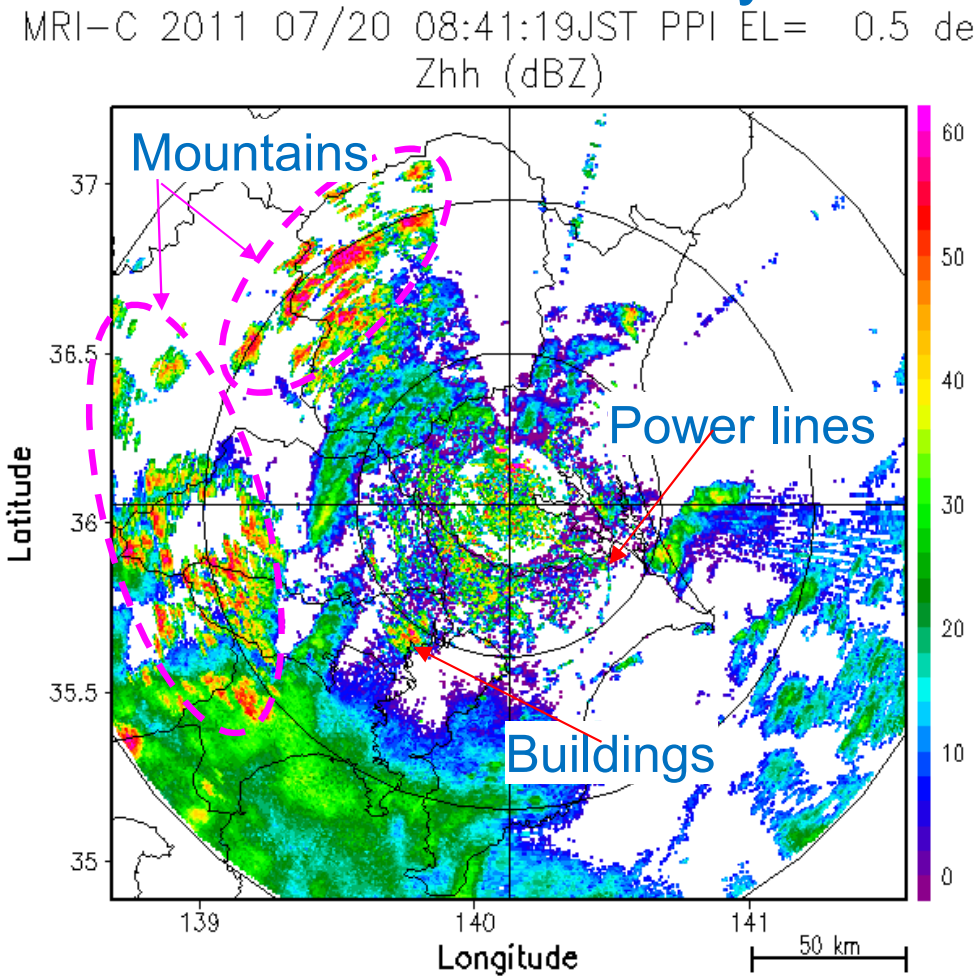
$S(\Phi_{DP})$



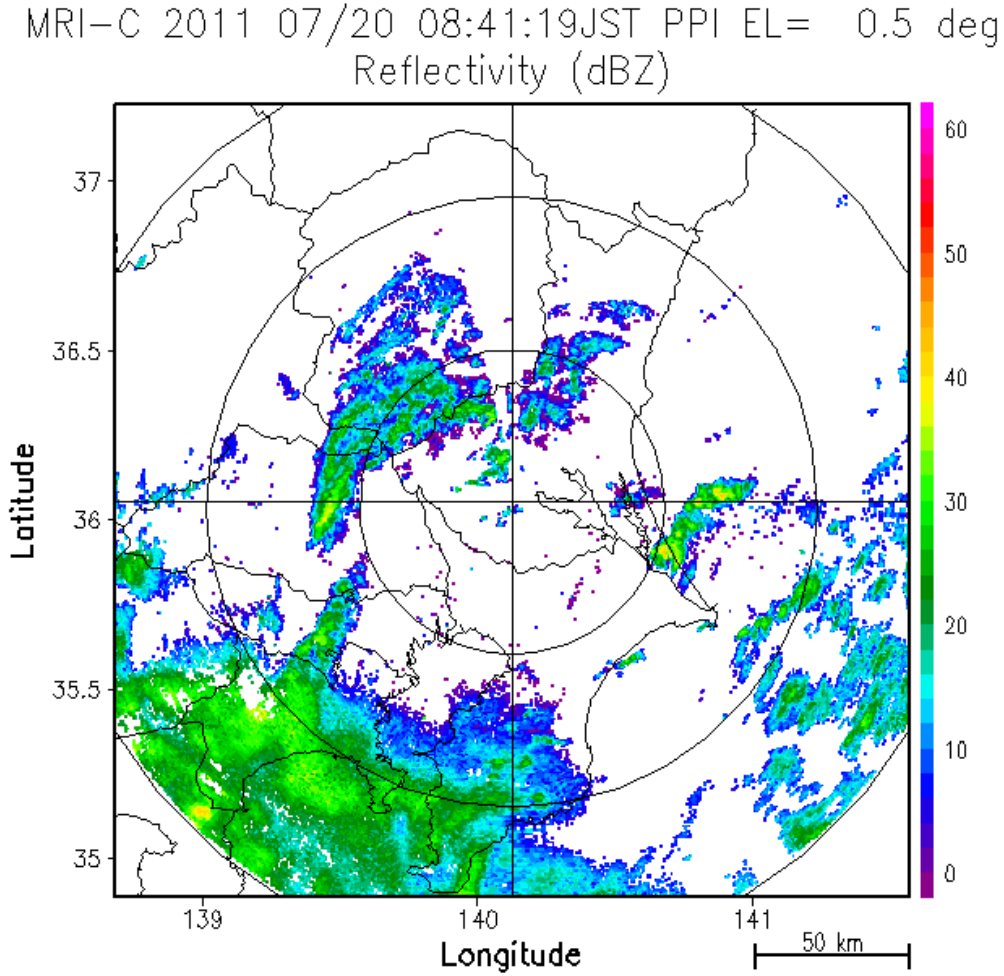
2.1 Control of non-meteorological echo (Ground clutter)

- Ground clutter can be efficiently removed using $S(\Phi_{DP})$.

Normal reflectivity



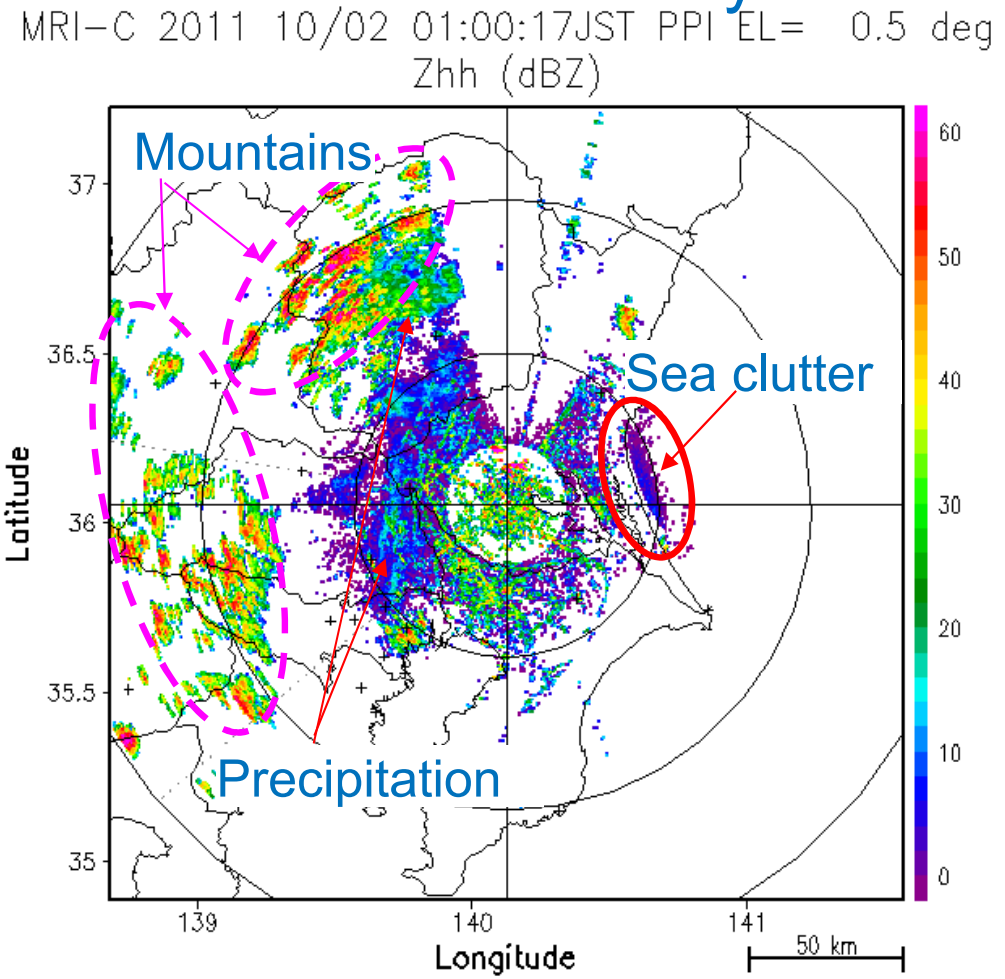
GCs are removed



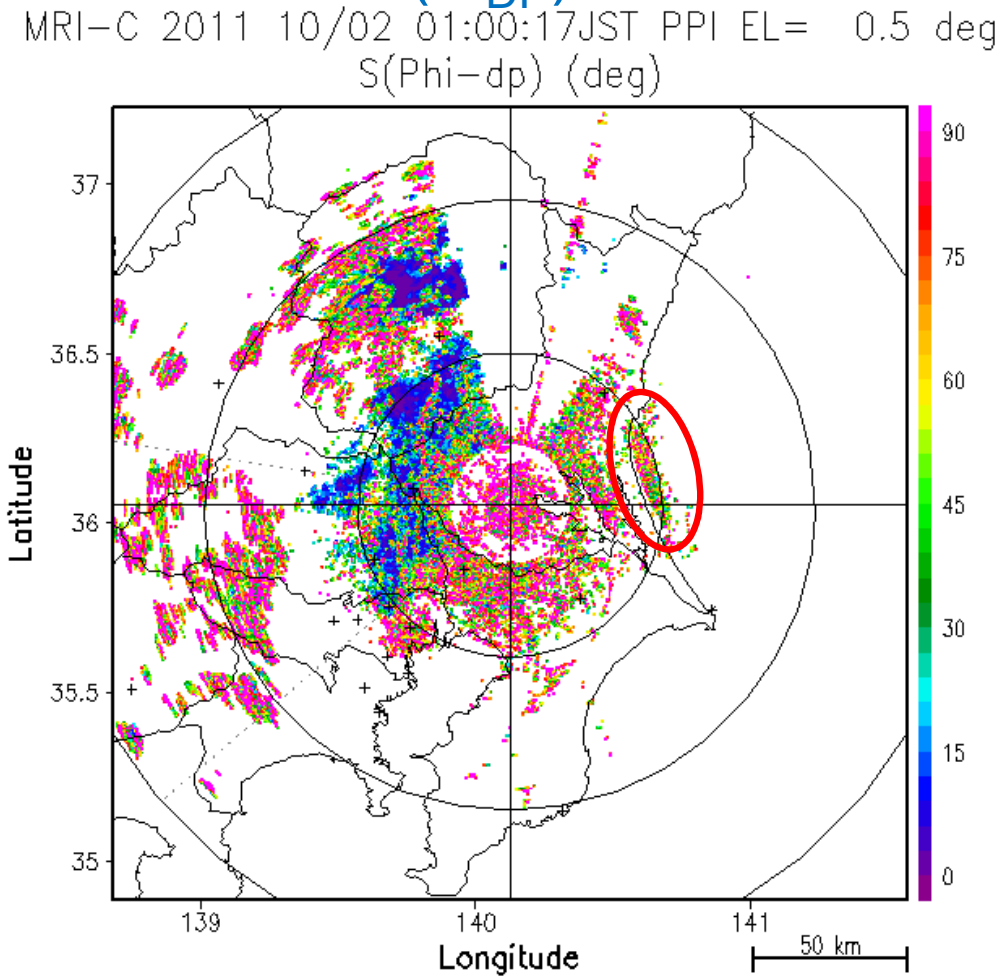
2.1 Control of non-meteorological echo (Sea clutter)

- Sea clutter can be efficiently identified using $S(\Phi_{DP})$.

Normal reflectivity



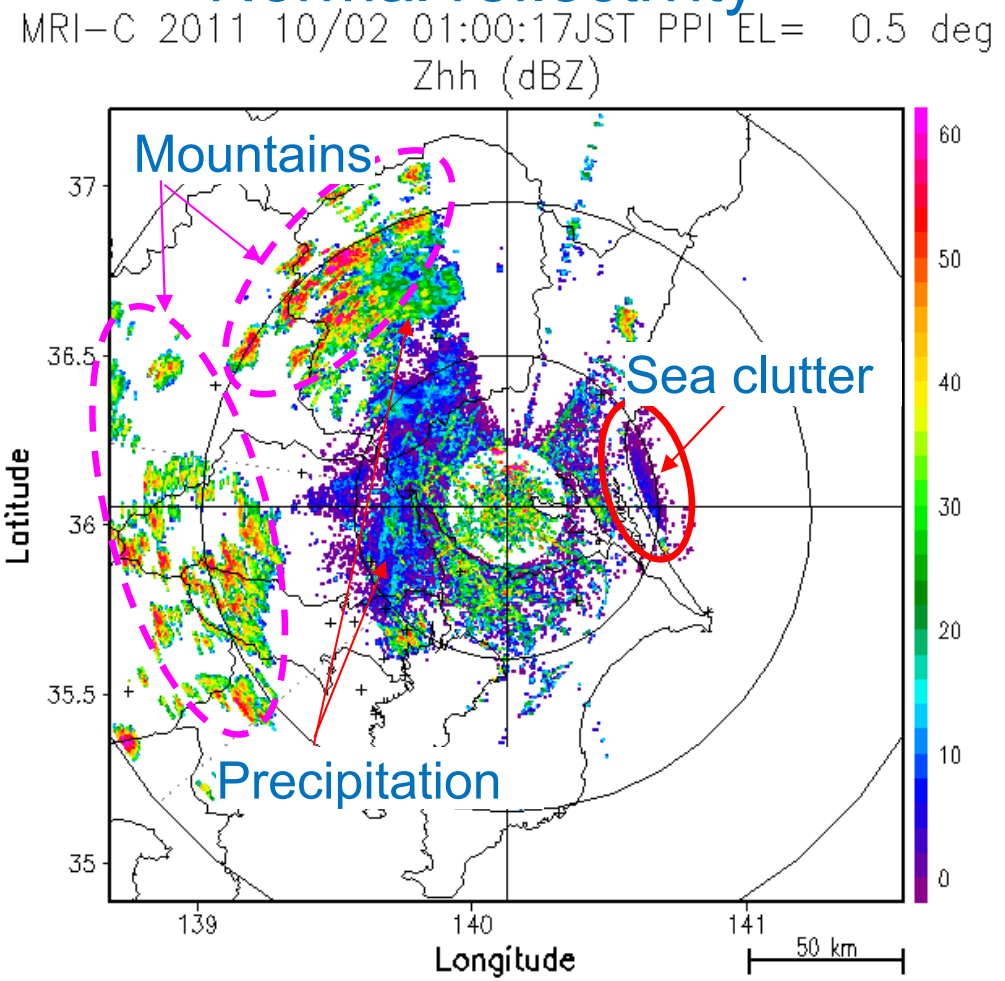
$S(\Phi_{DP})$



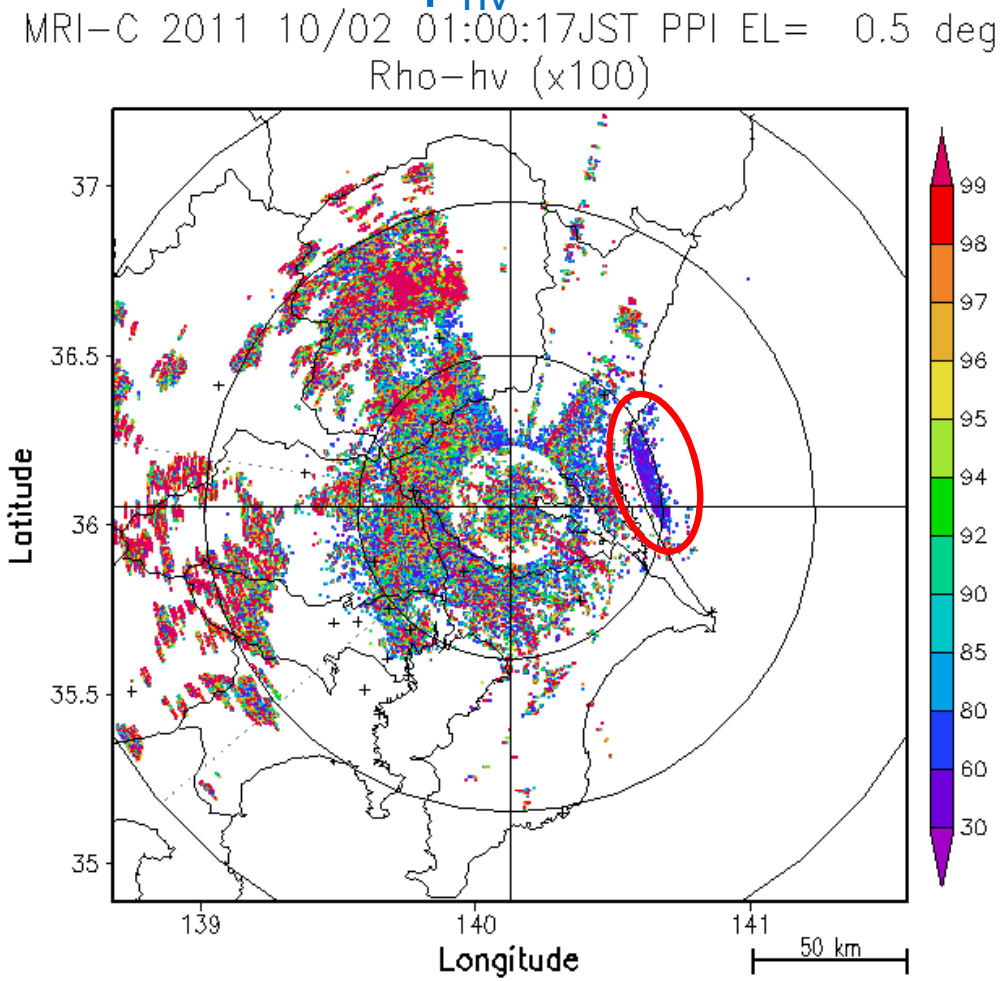
2.1 Control of non-meteorological echo (Sea clutter)

- Sea clutter can be also identified by ρ_{hv}.

Normal reflectivity



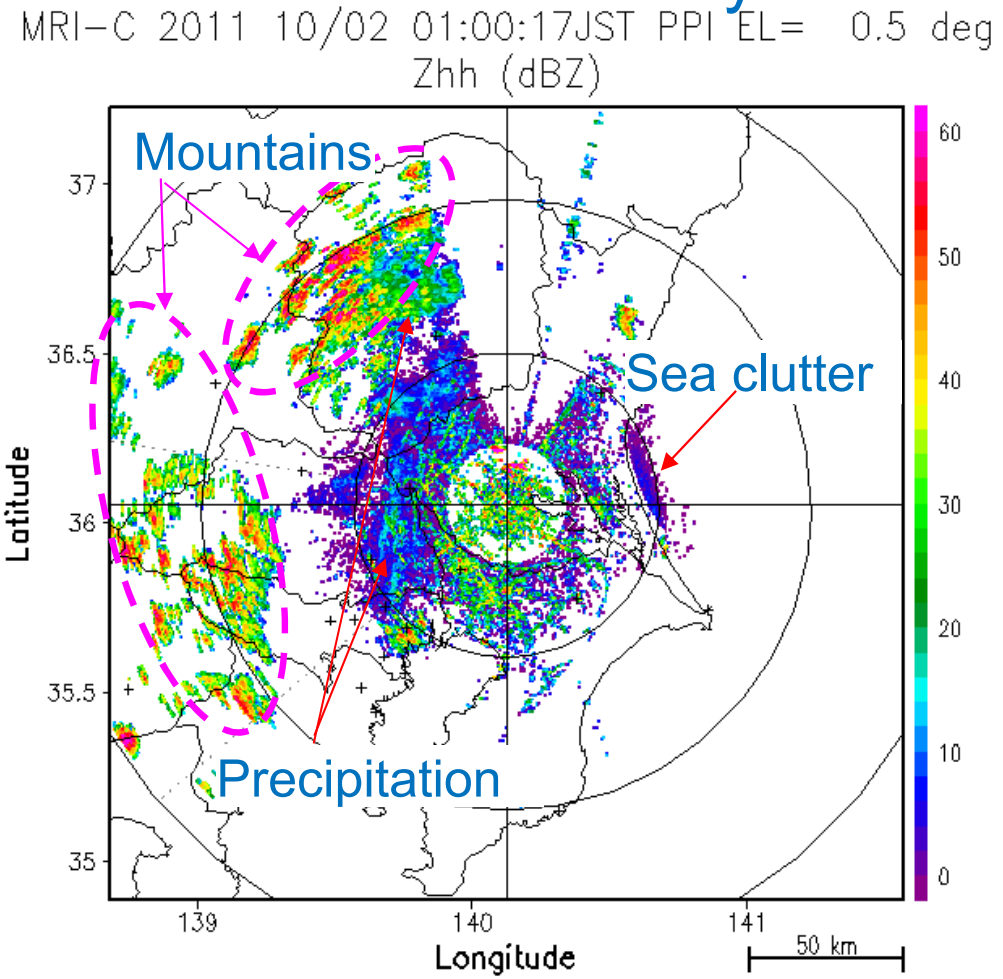
ρ_{hv}



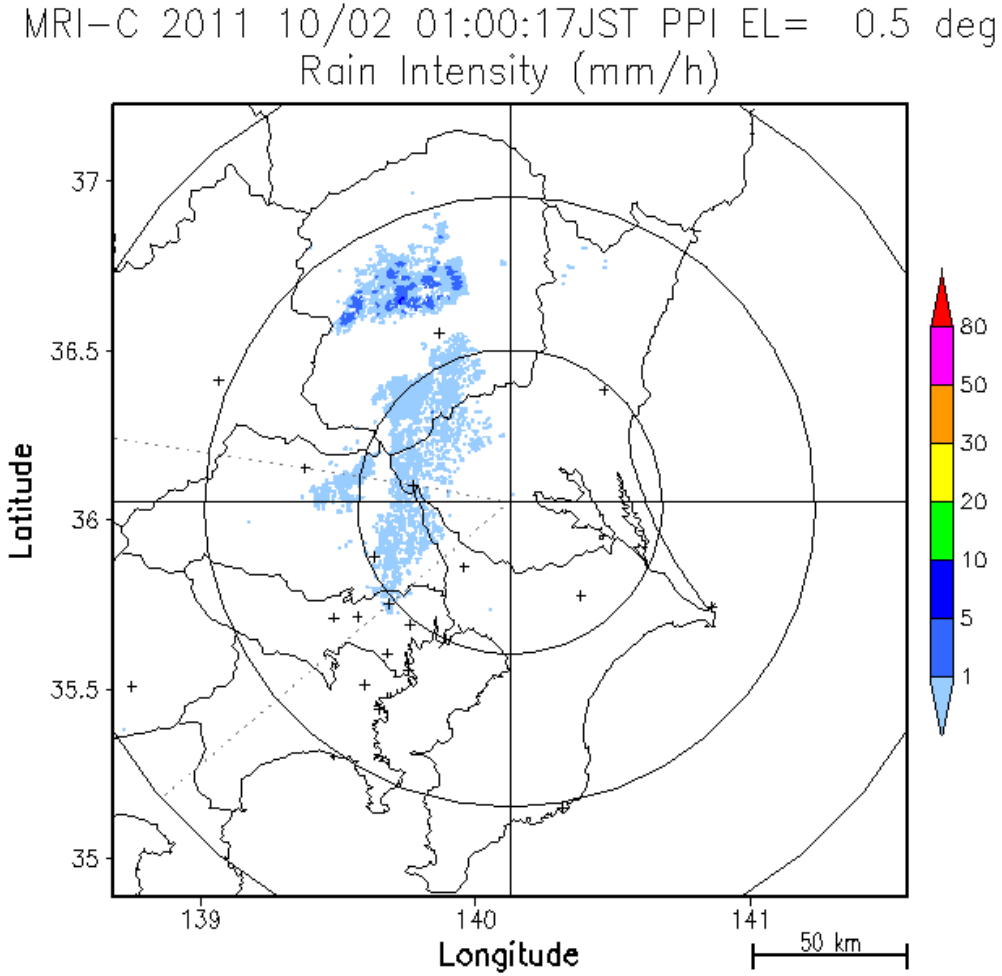
2.1 Control of non-meteorological echo (Sea clutter)

- Sea clutter can be efficiently removed.

Normal reflectivity



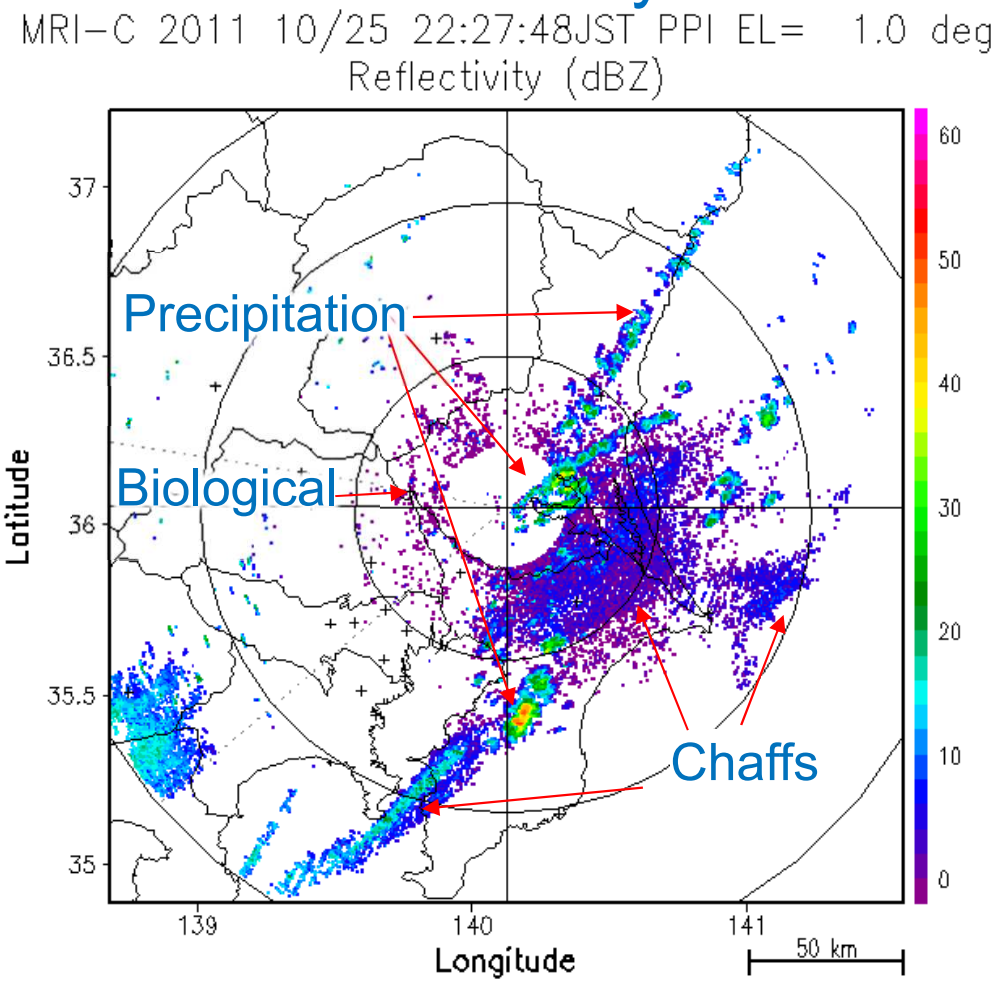
Rain rate



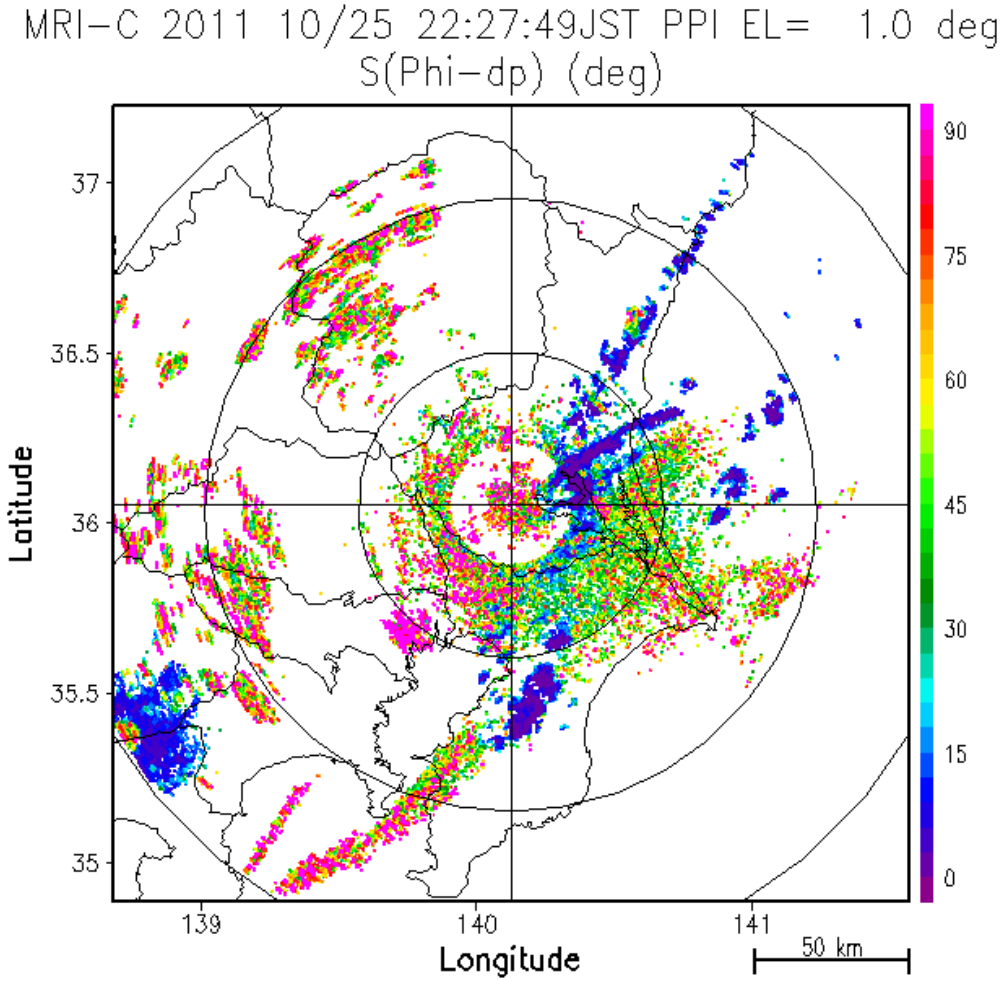
2.1 Control of non-meteorological echo (Biological echoes and chaffs)

- Biological echoes and chaffs can be efficiently identified using $S(\Phi_{DP})$.

Reflectivity

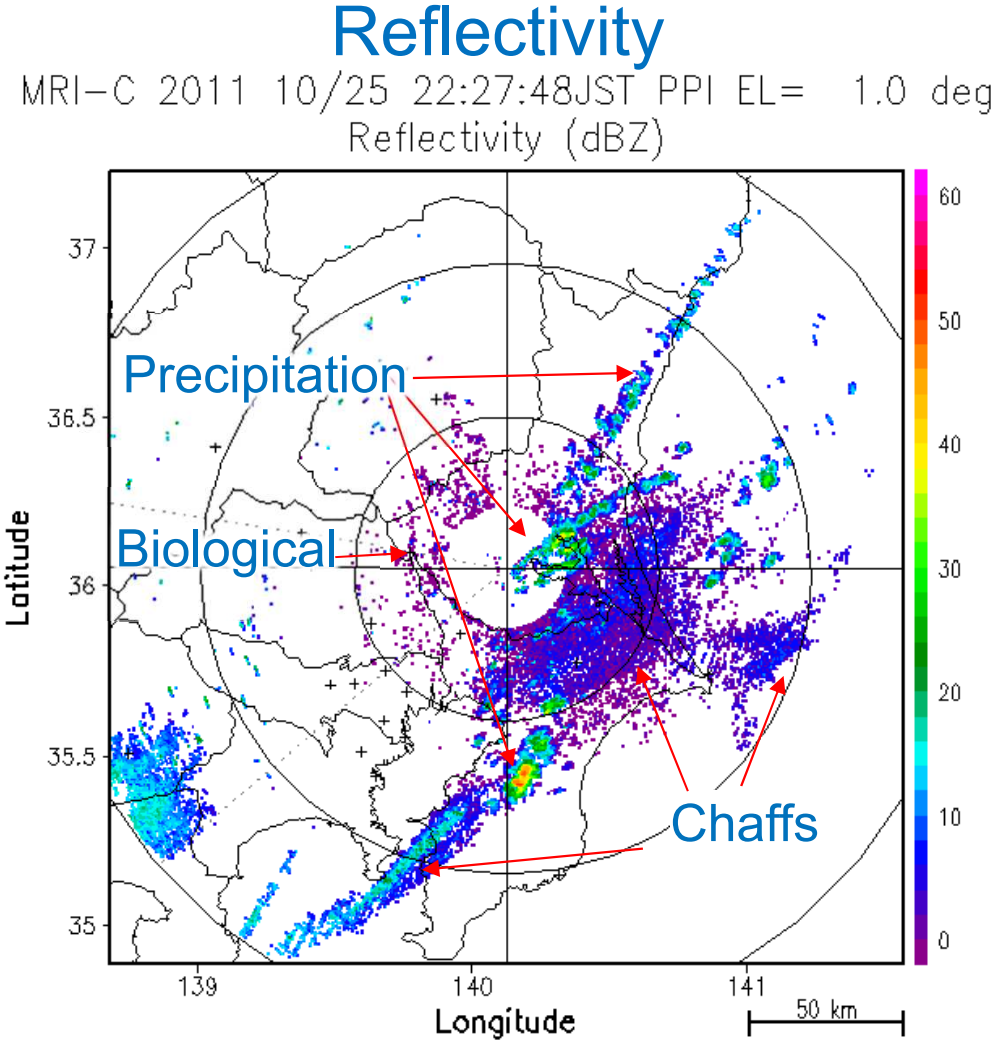


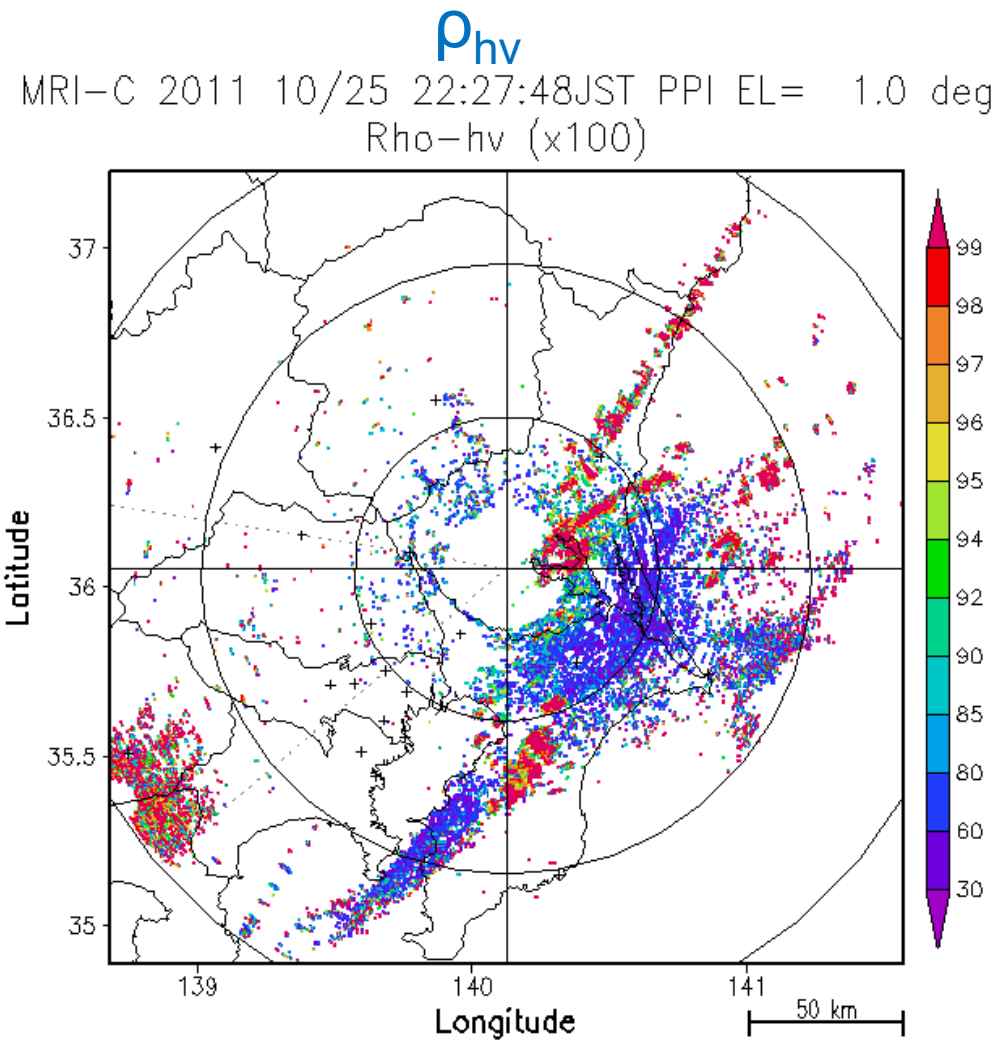
$S(\Phi_{DP})$



2.1 Control of non-meteorological echo (Biological echoes and chaffs)

- Biological echoes and chaffs can be efficiently identified using ρ_{hv}.

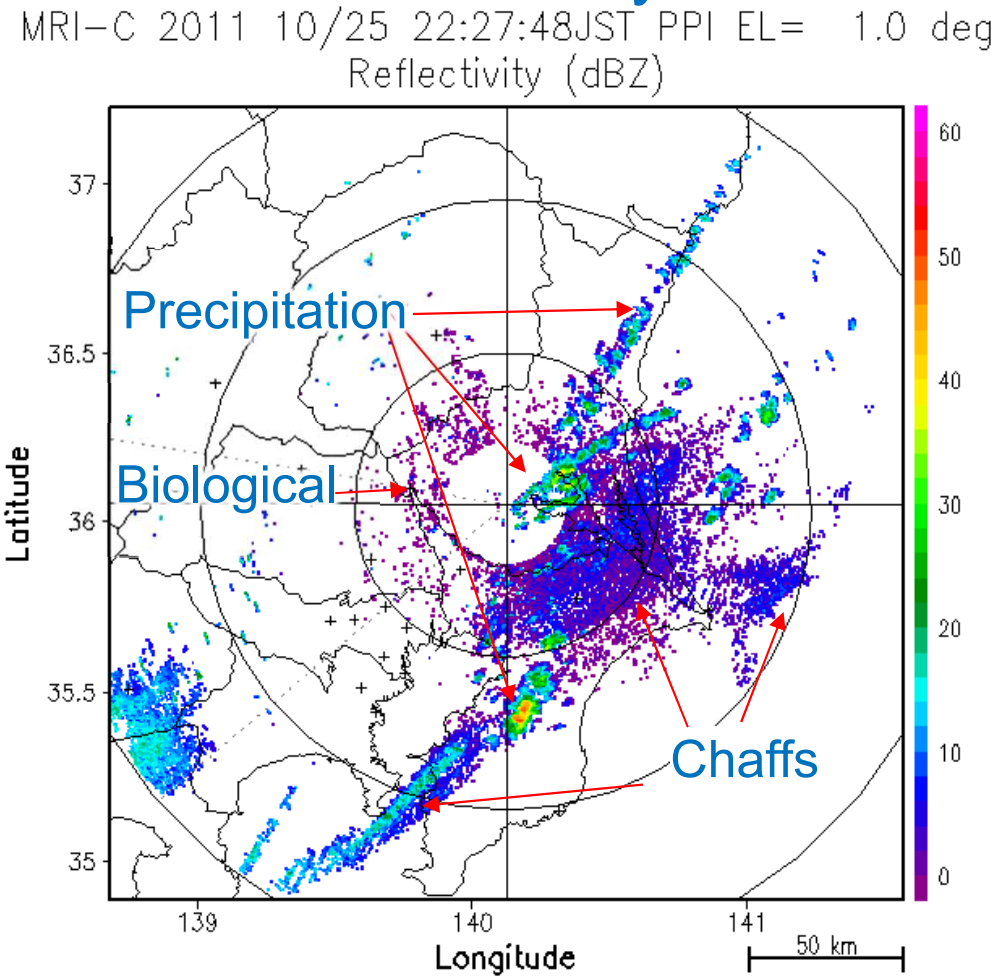




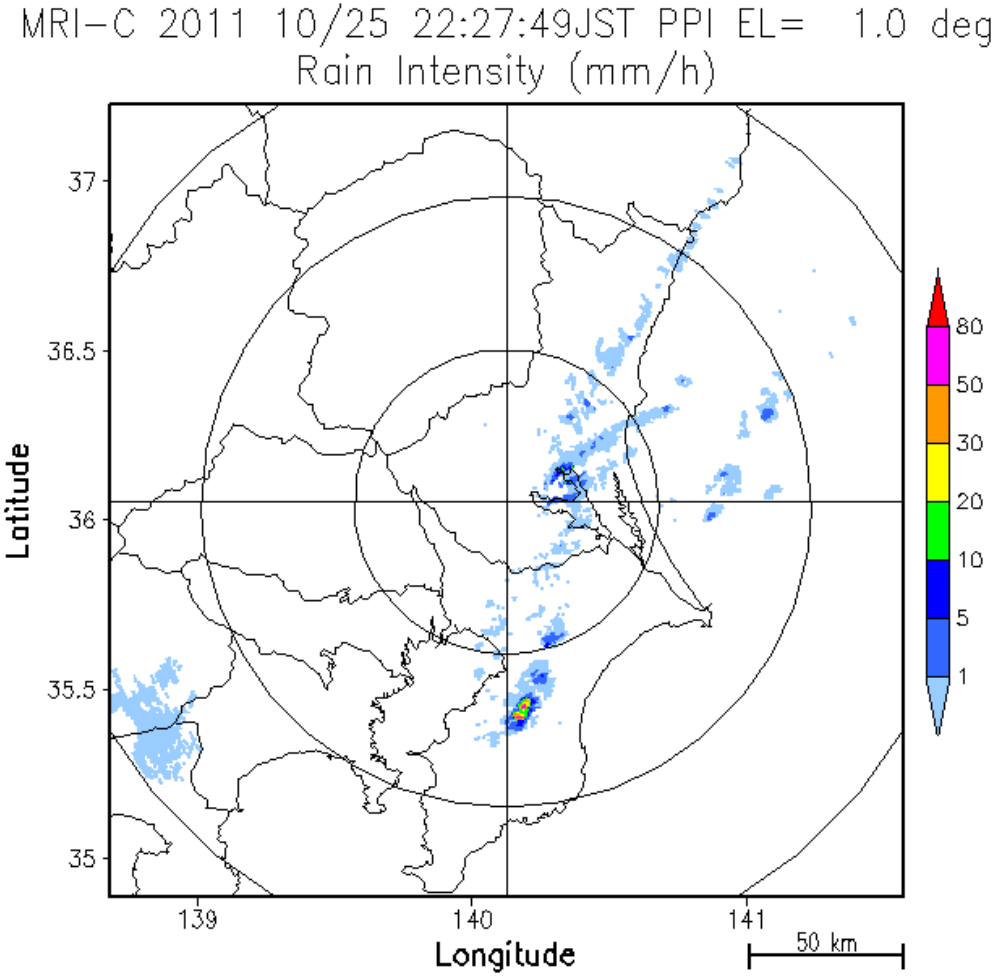
2.1 Control of non-meteorological echo (Biological echoes and chaffs)

- Biological echoes and chaffs can be discriminated using $S(\Phi_{DP})$, ρ_{hv}, and Z_{DR}.

Reflectivity



Rain rate

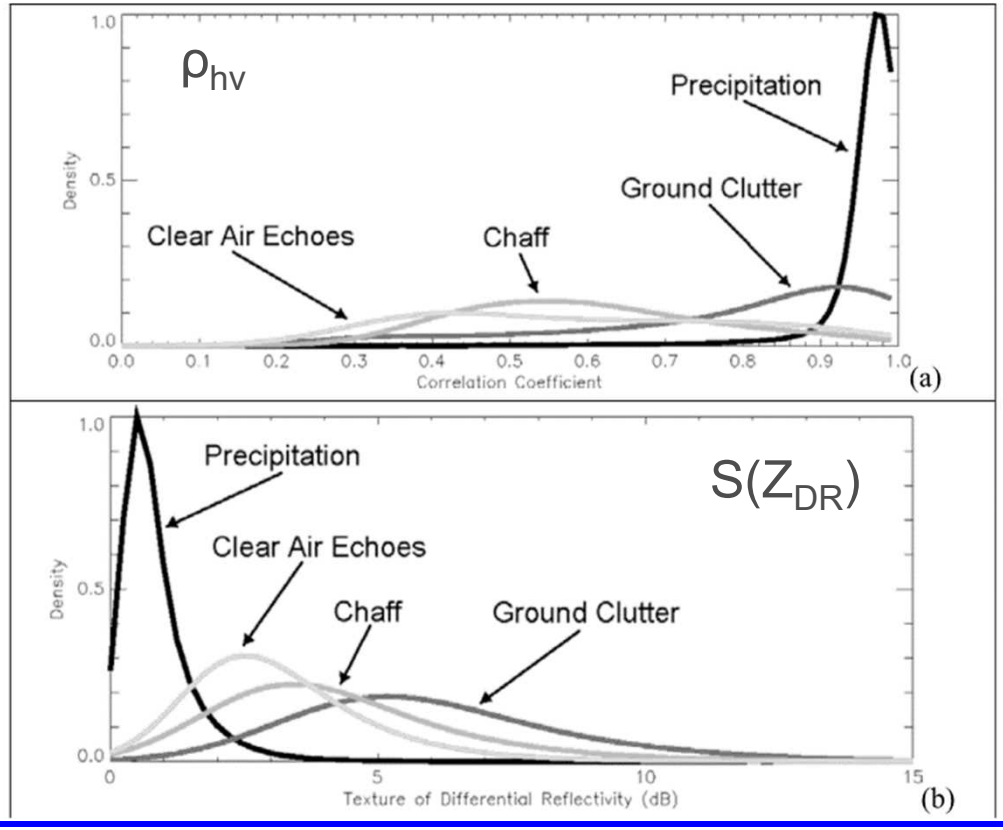


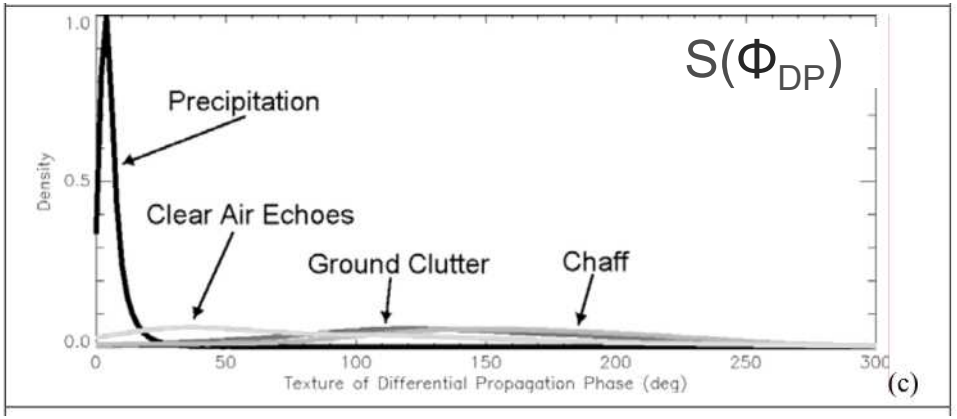
2.2 Non-meteorological echo removal

Non-meteorological echoes can be effectively removed with a combination of particular variables in following separate processes;

(1) Ground clutter, sea clutter and chaff are removed via selective filtering in each radar site system.

(2) Clear-air echoes (representing useful information on air flows) are discriminated in the central processing system.

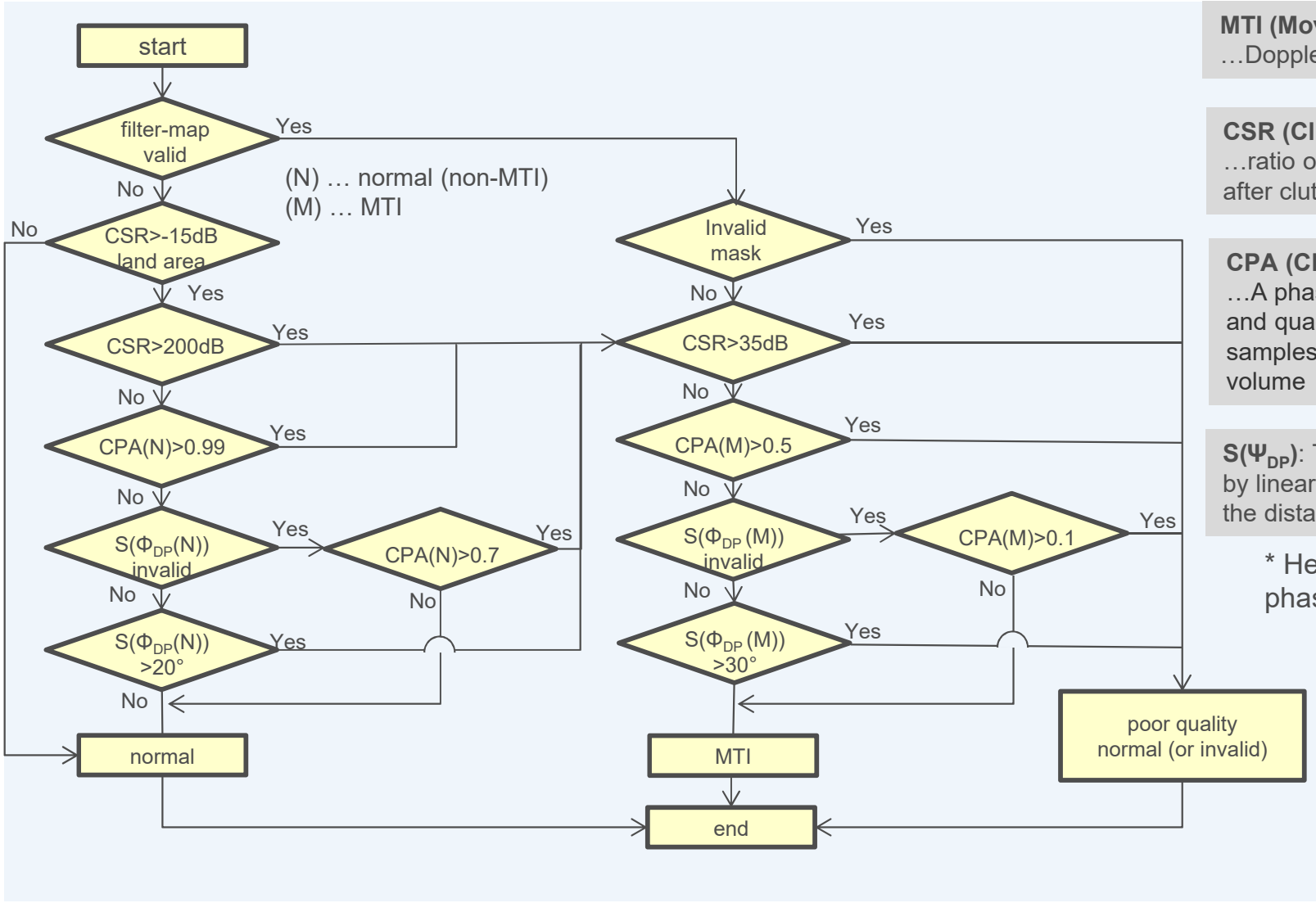




Sugier & Tabary(2006): EVALUATION OF DUAL-POLARISATION TECHNOLOGY AT C-BAND FOR OPERATIONAL WEATHER RADAR NETWORK

2.2 Non-meteorological echo removal

Selective filtering developed by MRI (JMA) for ground/sea clutter removal



MTI (Moving Target Indicator)
…Doppler filtering

CSR (Clutter Suppression Ratio)
…ratio of received power before and after clutter filtering

CPA (Clutter Phase Alignment)
…A phase variability of the in-phase and quadrature-phase time series samples for a given radar resolution volume

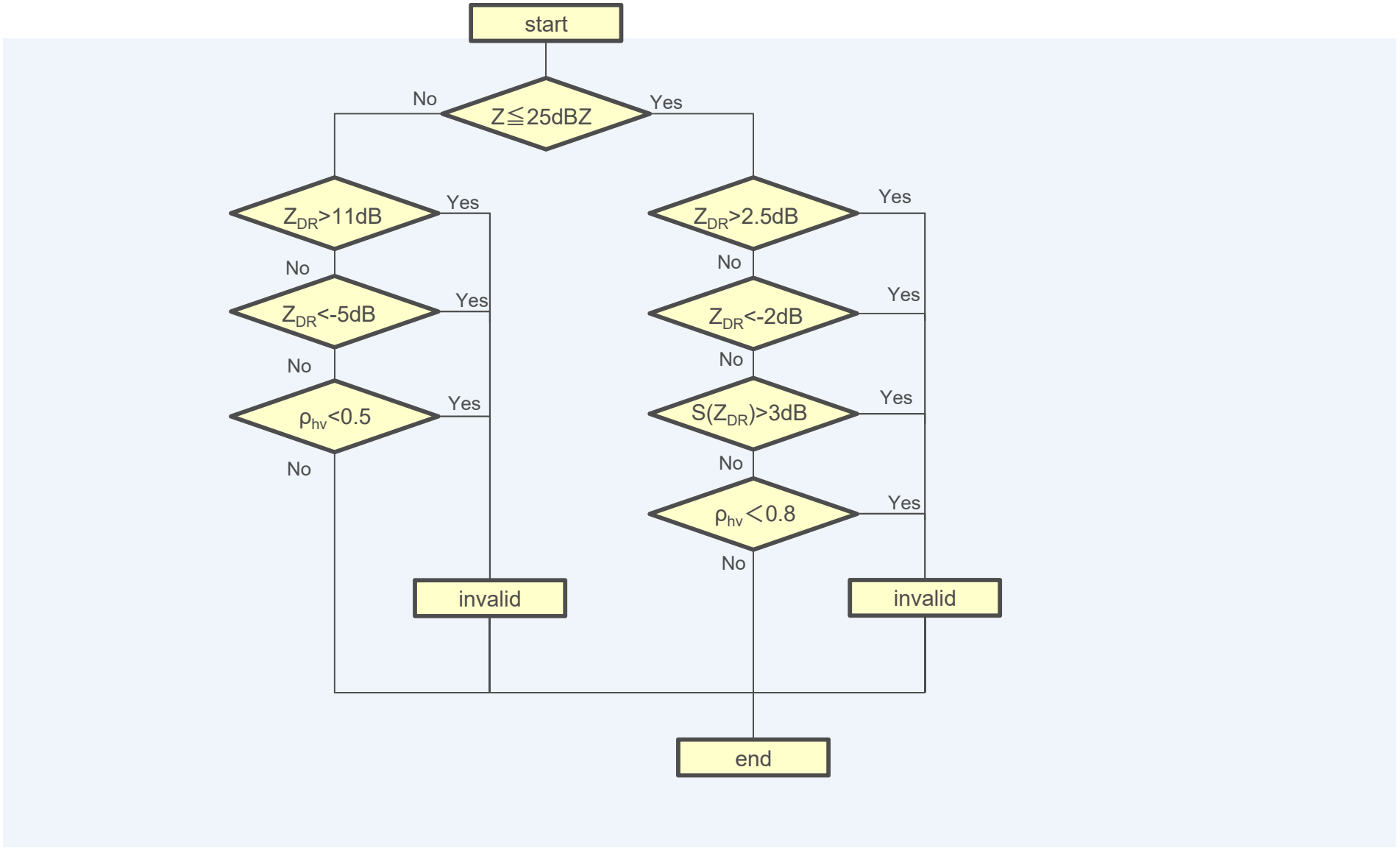
$S(\Psi_{DP})$: The standard error obtained by linearly approximating the Ψ_{DP} in the distance direction.

* Here, Φ_{DP} indicates measured phase difference Ψ_{DP}.

* Designs differ slightly with the progress of development and cumulative expertise.

2.2 Non-meteorological echo removal

Clear-air echo discrimination developed by JMA for QPE

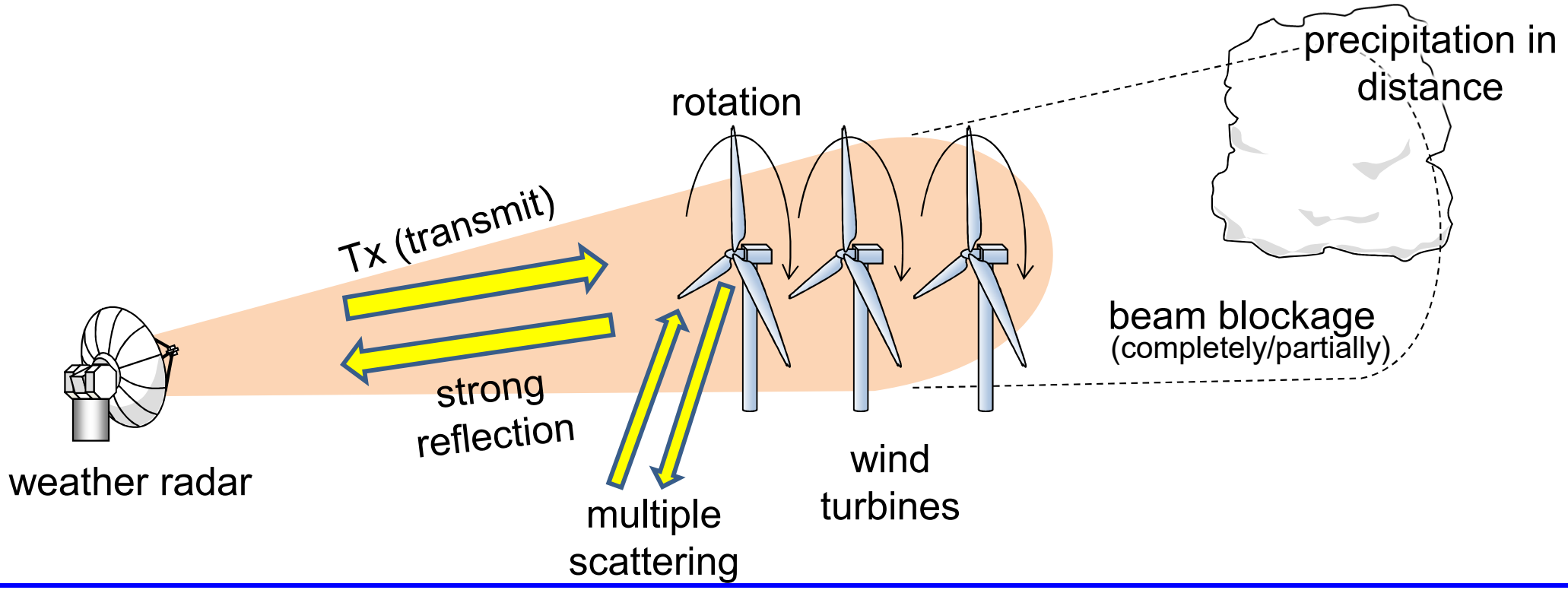


* Designs differ slightly with the progress of development and cumulative expertise.

2.3 Measures against wind turbine-related issues

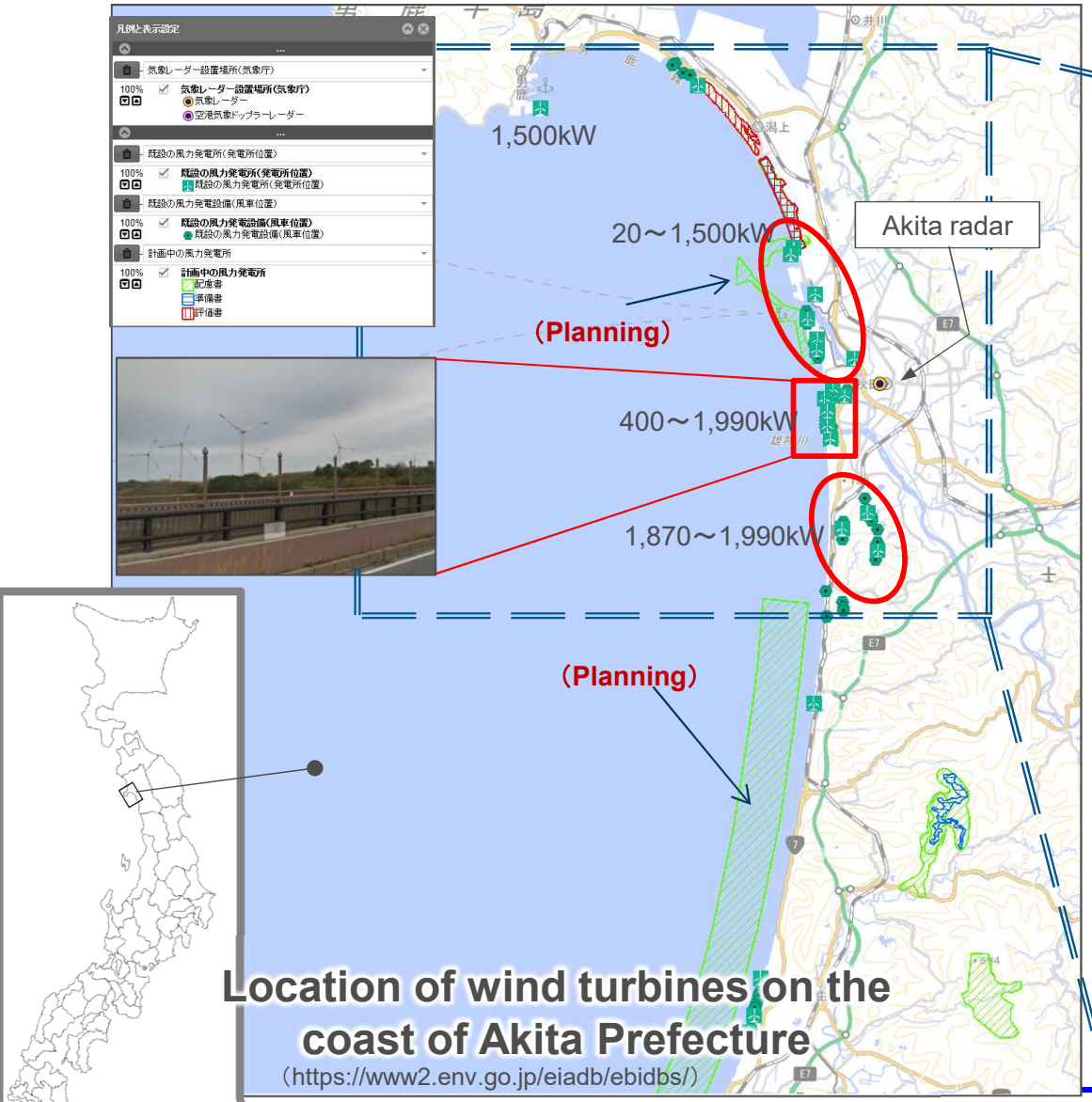
Potential effects of wind turbines on weather radar waves

- Radar beam blockage by turbines ⇒ Distant observation impractical
- False echoes caused by multiple scattering⇒ Incorrect precipitation data
- Effects on Doppler velocity observation ⇒ Inaccurate wind speed data/tornado detection
- Receiver damage due to strong reflection ⇒ Observation system breakdown

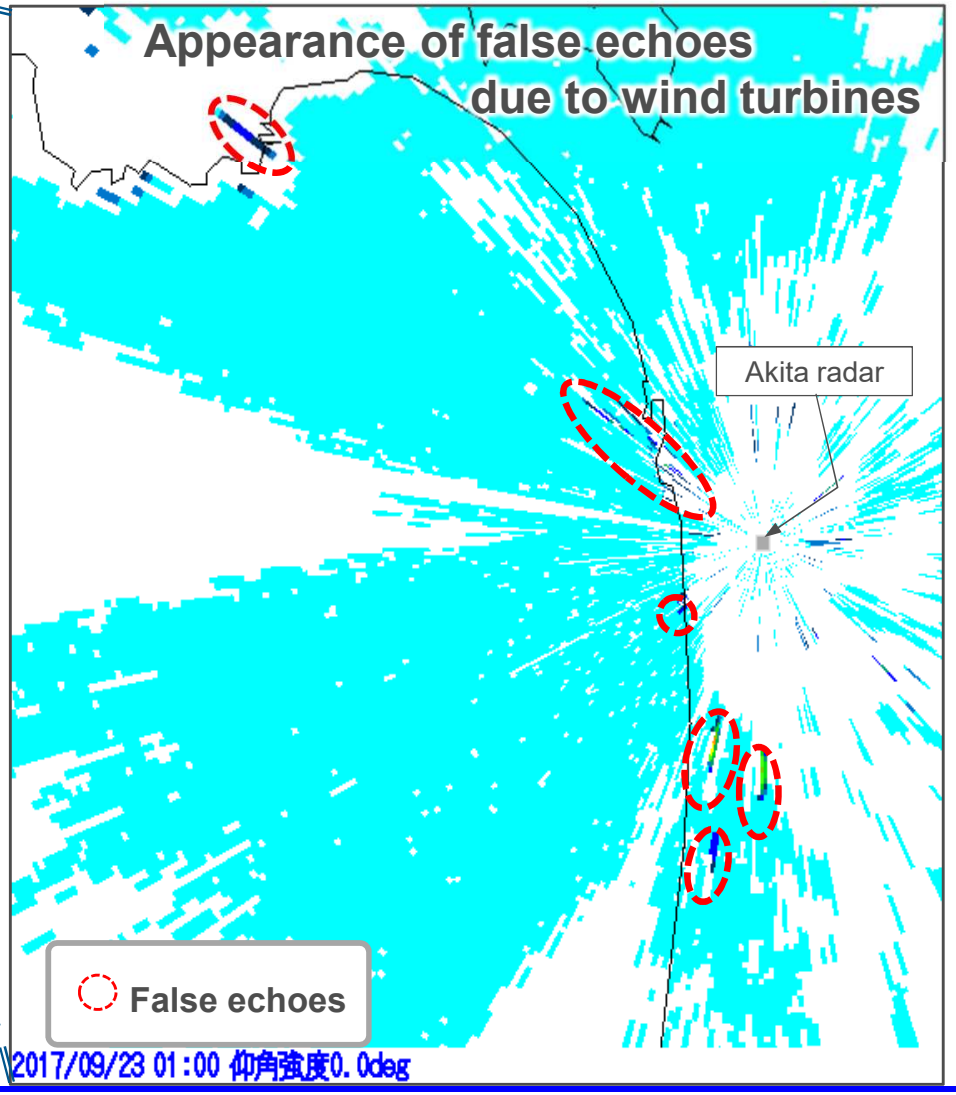


2.3 Measures against wind turbine-related issues

Japan's northwest coast is one of the places with the most wind turbines. Their false echoes have been reported. Further wind power projects are also planned.



Location of wind turbines on the coast of Akita Prefecture
(https://www2.env.go.jp/eiadb/ebidbs/)



2.3 Measures against wind turbine-related issues

Dual-polarization application is expected to allow discrimination of meteorological and non-meteorological radar echoes. Wind turbine clutter can be partially removed.

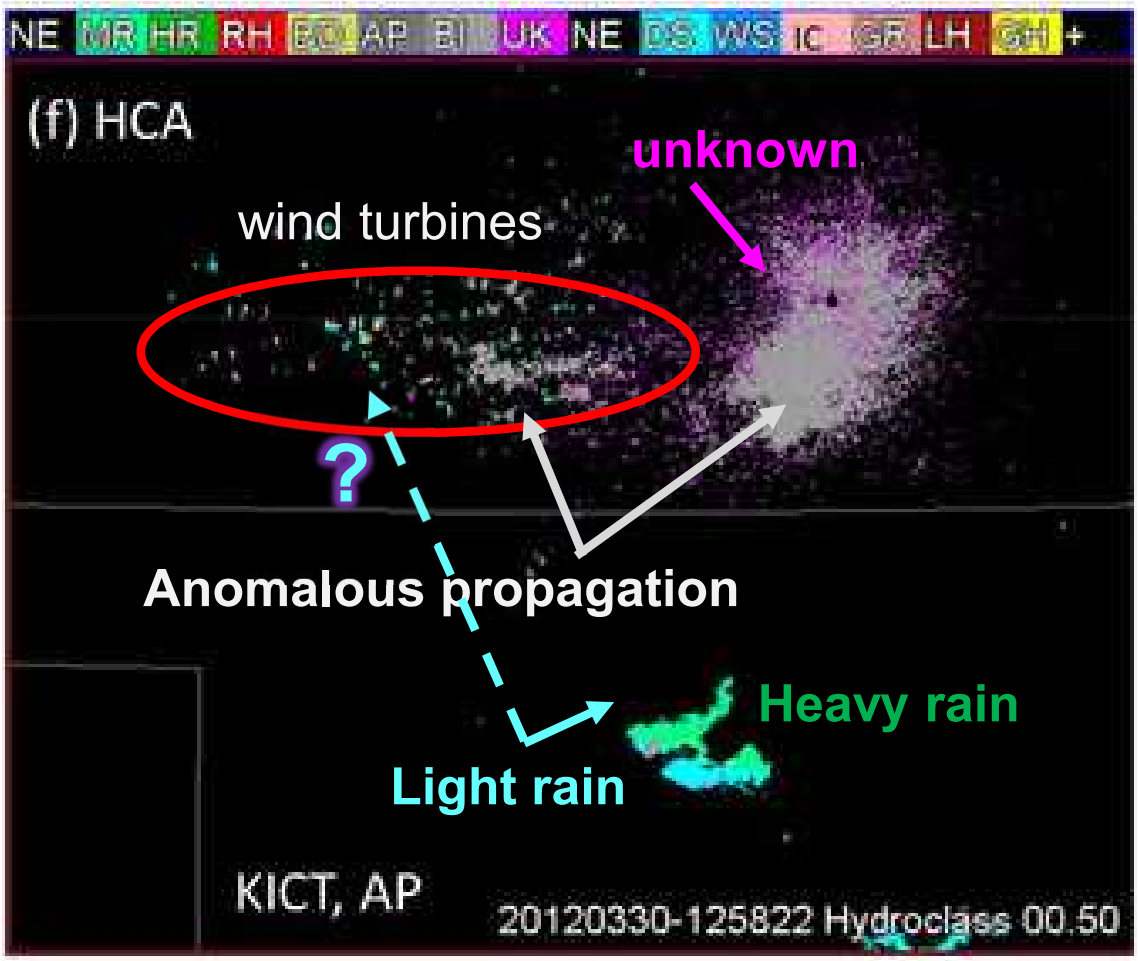


Fig. 5 (f) in Krause (2016)
HCA for KICT at 1247 UTC 30 Mar 2012 with strong AP and wind turbine clutter.

Krause (2016) demonstrated a simple classification algorithm by which some wind turbines are discriminated as exhibiting abnormal propagation, while others are identified as light rain.

It is also important to consider wind-turbine location may result in radar impairment.

2.3 Measures against wind turbine-related issues

- Wind turbine effects on weather radar vary with distance.
- The World Meteorological Organization (WMO) has guidelines on weather radar and wind turbine siting.
- In Japan, wind turbine operators are advised to liaise with JMA regarding plans to install wind turbines within 45 km of JMA's radars.

Range	Potential Impact	Guidelines
0 – 5 km	The wind turbine may completely or partially block the radar and can result in significant loss of data that cannot be recovered.	**Definite impact zone:** **should not be installed in this zone**.
5 – 20 km	Multiple reflection and multipath scattering can create false echoes and multiple elevations. Doppler velocity measurements may be compromised by rotating blades.	**Moderate impact zone:** Terrain effects will be a factor. Analysis and consultation is recommended. Reorientation or resiting of individual turbines may reduce or mitigate the impact.
20 – 45 km	Generally visible on the lowest elevation scan; groundlike echoes will be observed in reflectivity; Doppler velocities may be compromised by rotating blades.	Low impact zone: Notification is recommended.
> 45 km	Generally not observed in the data but can be visible due to propagation conditions.	Intermittent impact zone: Notification is recommended.

citation : WMO guidance statement on weather radar/wind turbine siting. The CIMO Guide, 2014

2.4 Summary

- Dual-polarization data contributes to efficient quality control for ground/sea clutter, clear-air echoes, chaff removal.
- JMA introduces selective filtering and clear-air echo removal algorithms which is the combined use of dual-polarization variables and remove non-meteorological echo efficiently at radar site system and central processing system, depending on the purposes.
- Dual-polarization radar may decrease the effects of wind turbine-issues, but it is important to follow WMO guidelines to avoid negative effects.

Thank you for attention