Effectiveness of super-hydrophobic radome coating

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4th WXRCalMon

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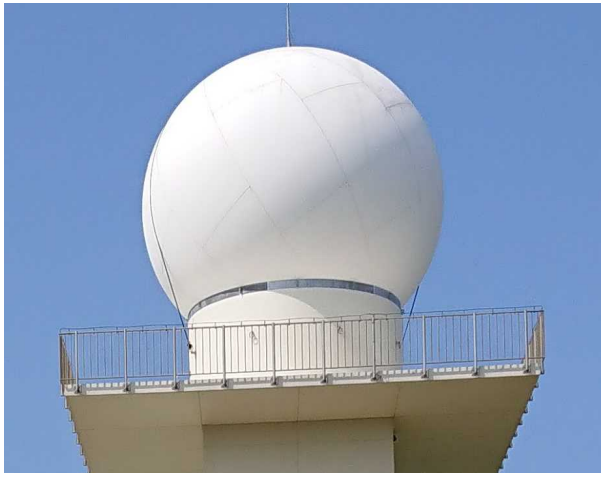
Contents

JMA Weather Radar Observation Network radomes

Tokyo (diameter 6.7m)
[FDS Italy]

Okinawa (diameter 7.0m)
[Japan Radio Co., Ltd.]

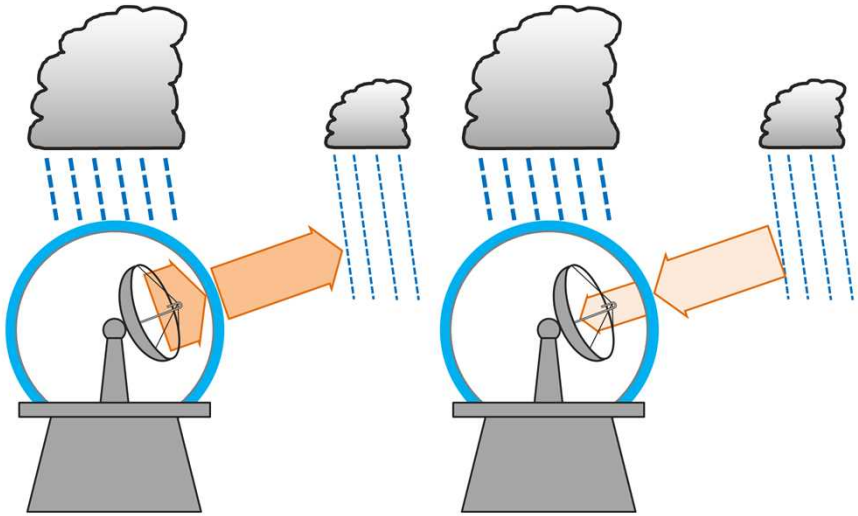


Naha Airport (diameter 11m)
[ESSCO]

Nagoya (diameter 6.7m)
[ESSCO]

Radome water repellency

Rain on radome surfaces causes significant attenuation of radio waves and underestimation of precipitation intensity.



Kurri and Huuskonen, 2008
Measurements of the Transmission Loss of a Radome at Different Rain Intensities

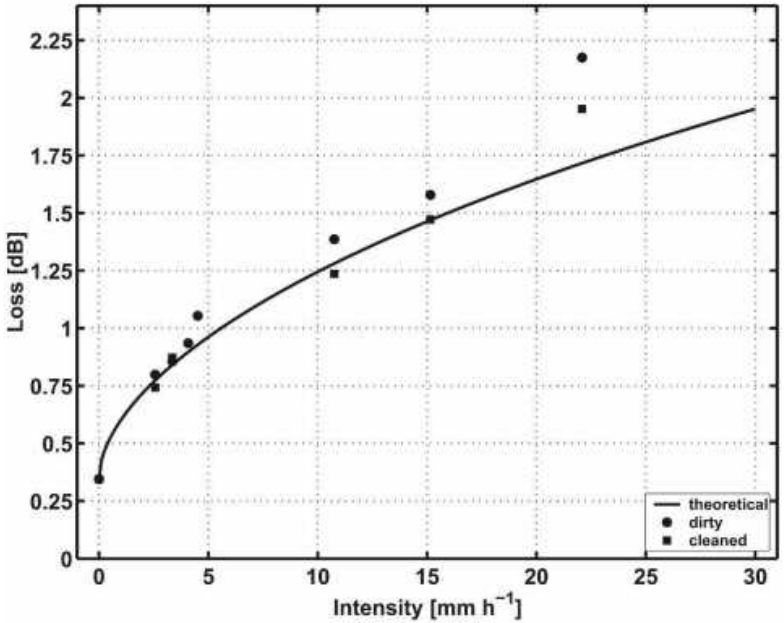
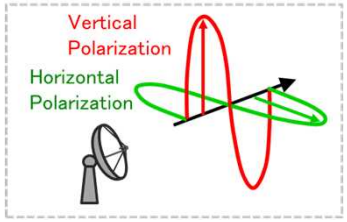


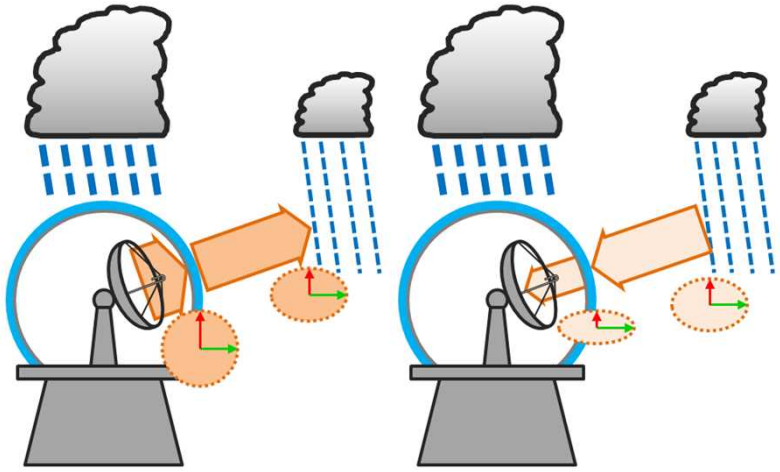
FIG. 7. Wet radome measurements performed with the dirty and cleaned radome scaled to be valid for a 6.7-m radome. The solid line presents the theoretical transmission loss based on Gibble's formula. Measurements and calculations are carried out at a water temperature of 30.5°C.

Radome water repellency

Levels of attenuation are more accentuated with vertical polarization because water flows downward. → **Z_{DR} positive bias**
This leads to mis-identification of precipitation particle shapes.

**WMO guidelines call for a difference of under 0.2 dB between polarizations.*





Frech, 2009
The effect of a wet radome on dualpol data quality

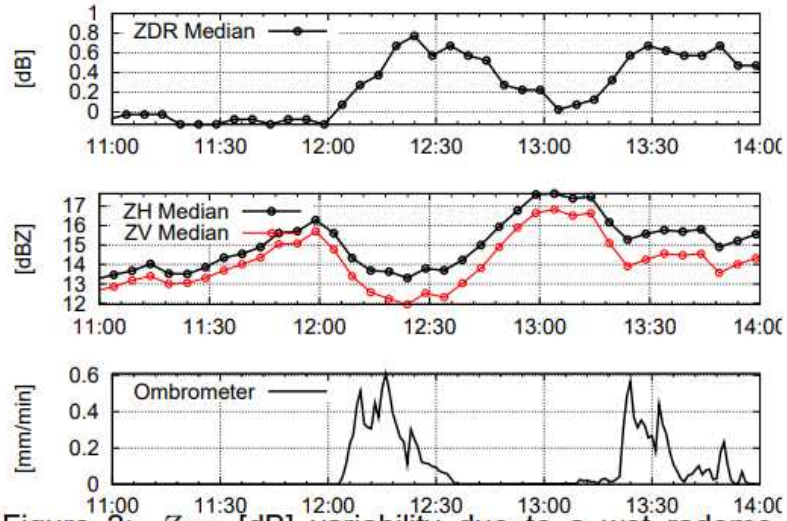
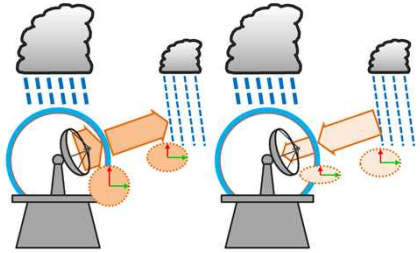


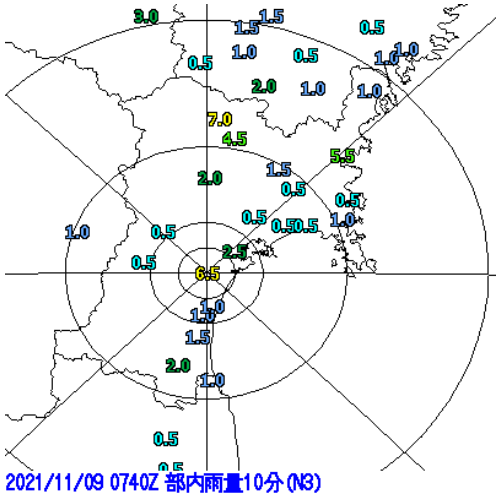
Figure 2: Z_{DR} [dB] variability due to a wet radome. Before the precipitation reaches the radar site, Z_{DR} is slightly negative. During the precipitation event Z_{DR} becomes positive ($Z_{DR} \approx 0.8$).

Rain-related Z_{DR} biases

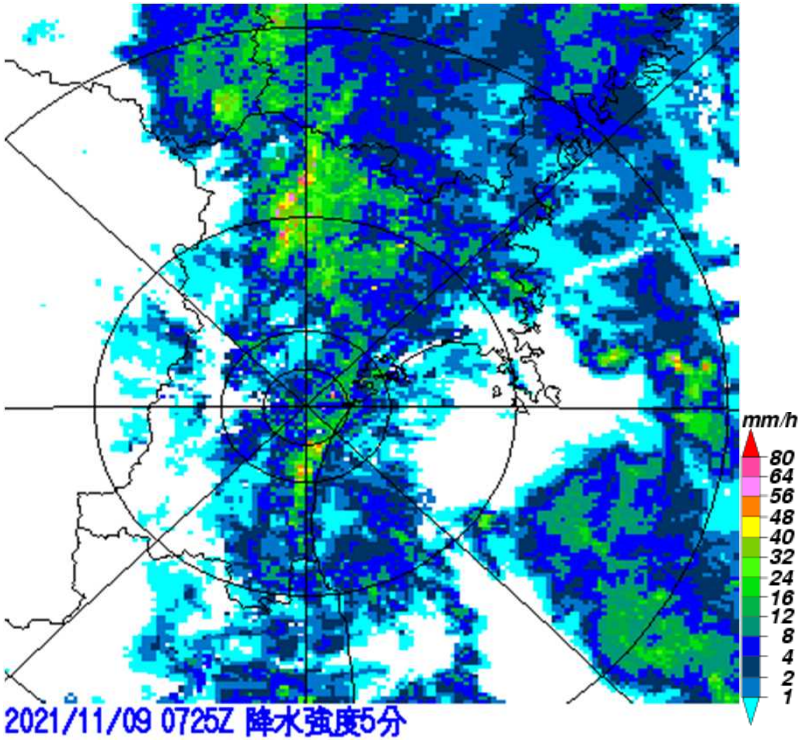
Positive Z_{DR} biases due to wetting from heavy rain



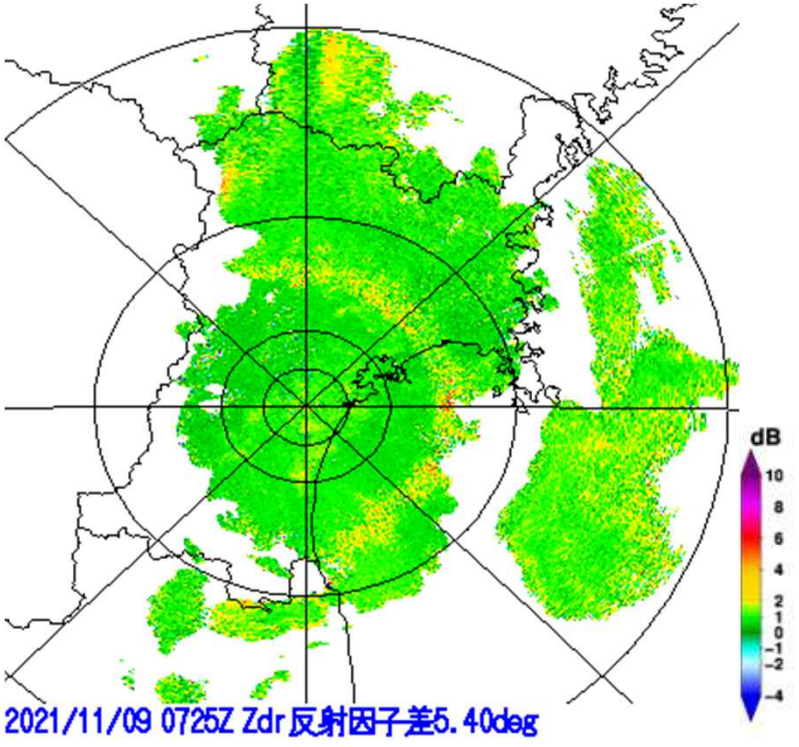
Raingauge 6.5mm/10min



Precipitation Intensity (radar composition)



【Sendai radar】Z_{DR}



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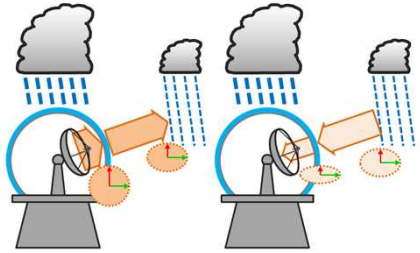

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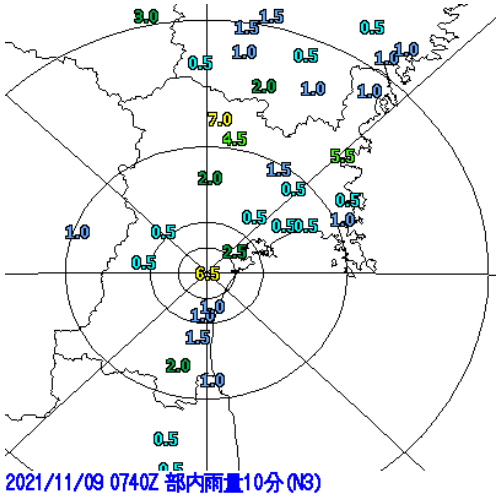

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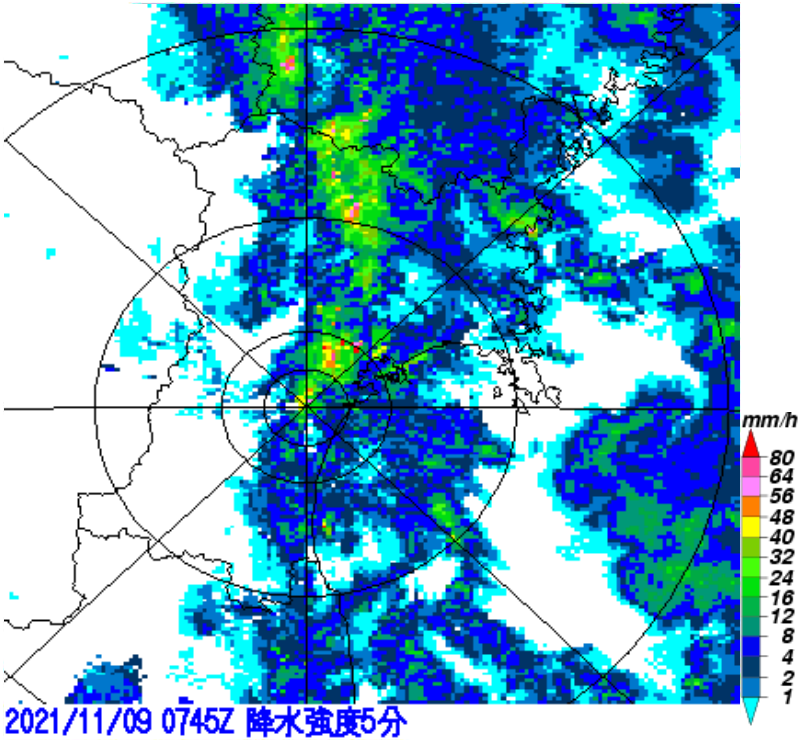
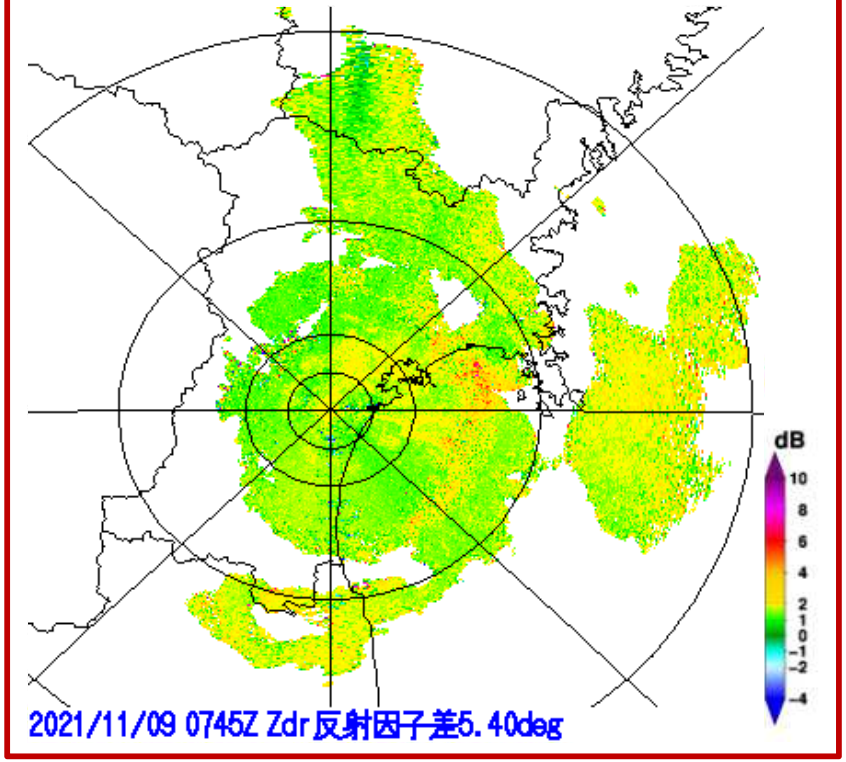


【Sendai radar】Z_{DR}



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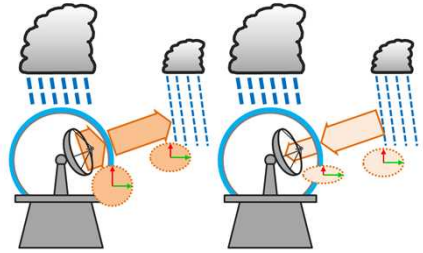
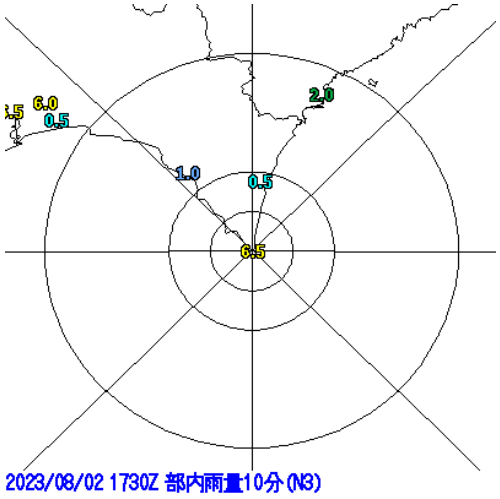
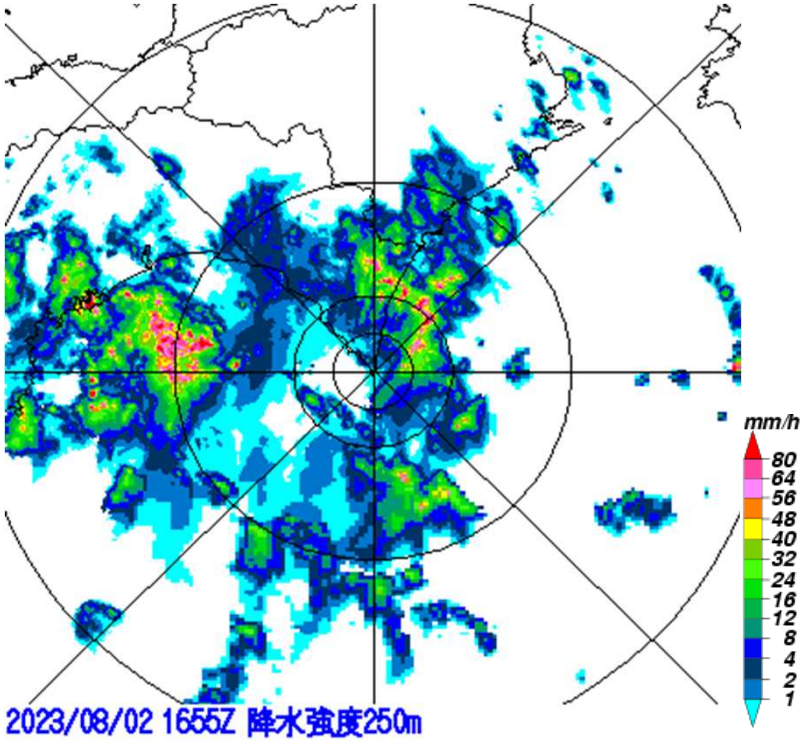


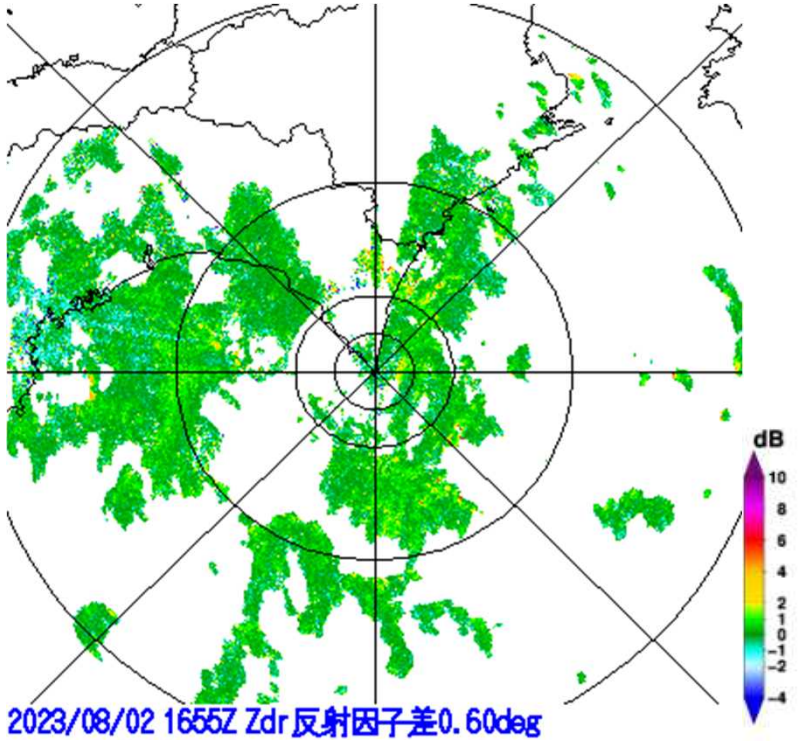
Raingauge 6.5mm/10min



Precipitation Intensity (radar composition)



【Murotomisaki radar】Z_{DR}



Rain-related Z_{DR} biases

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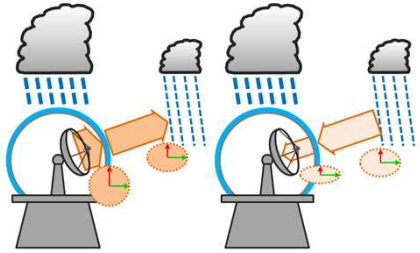

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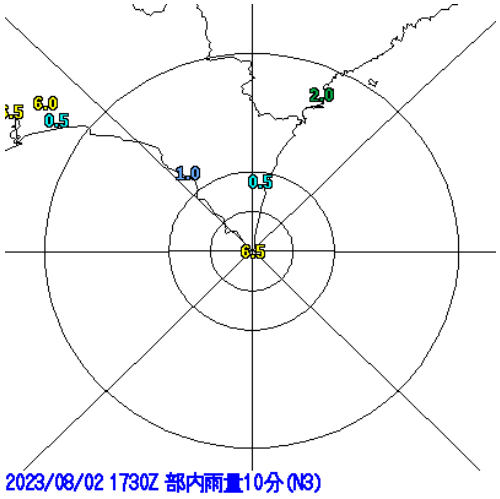

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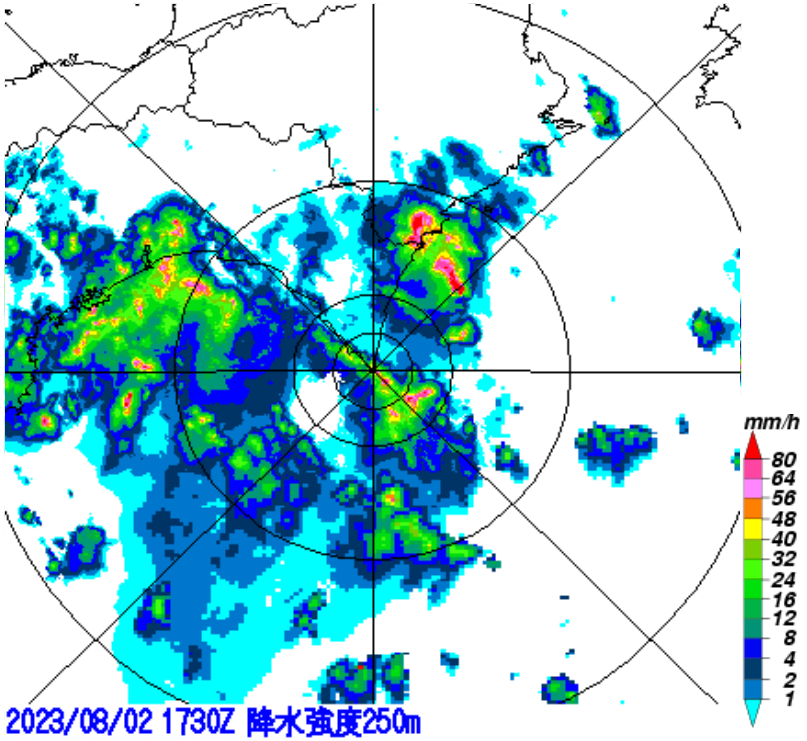
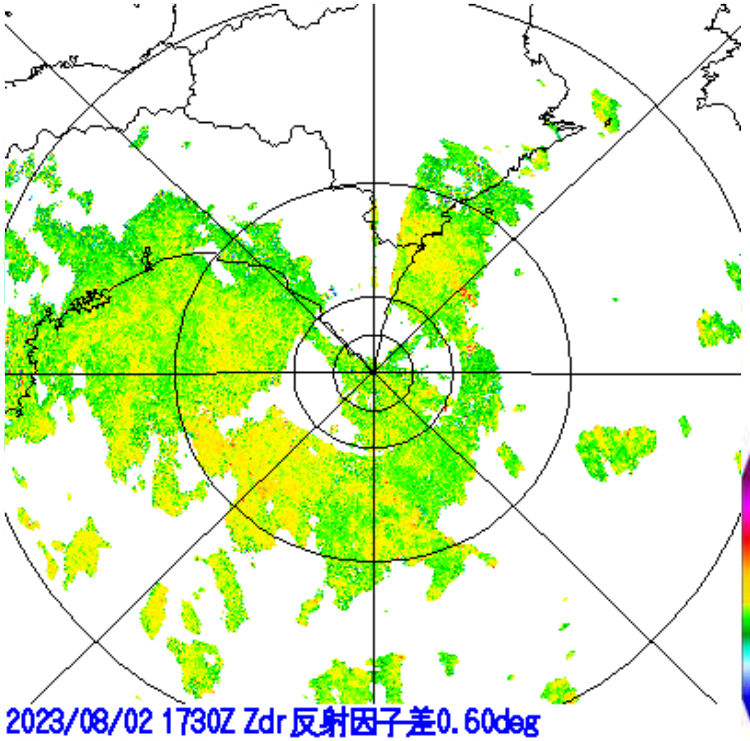


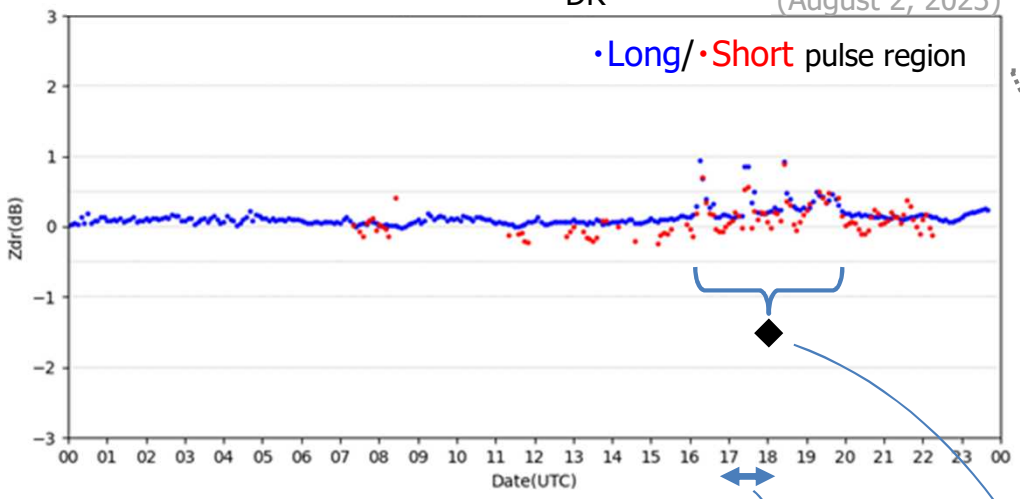
【Murotomisaki radar】Z_{DR}



Rain-related Z_{DR} biases

Positive Z_{DR} biases due to wetting from heavy rain

【Murotomisaki radar】Z_{DR} (August 2, 2023)



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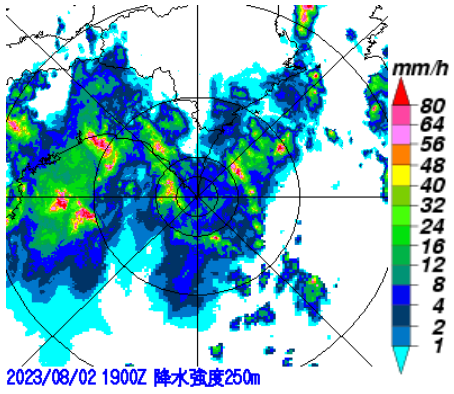
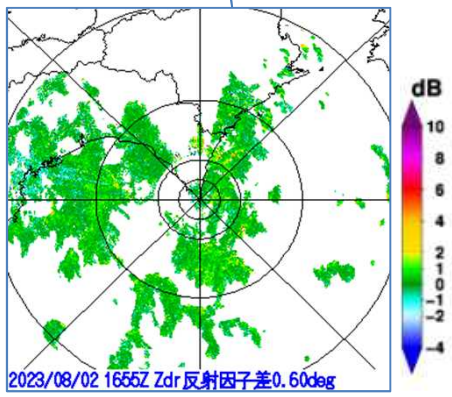


16:55~18:00



[Graph]
Z_{DR} bias monitoring tool design
(Hotta et al. 2nd WXRCalMon 2019)

Targeting weak precipitation, data meeting certain criteria from low elevation-angle observations performed every 5 minutes are averaged and displayed in time-series format.

data criteria
$\|Z_{DR}\| < 5.0$
$0.99 < \rho_{hv} \leq 1.0$
$10 < Z_H \leq 15$
$S(Z_{DR}) < 0.3$
$S(\rho_{hv}) < 0.01$

S(*) : Median Absolute Deviation for data within 2km square around the target bin

Data for individual regions are analyzed separately.

◆An upward spike of approximately 0.5 dB is seen at around 19:00 UTC
◆Spike-like rise toward 1 dB (approx.. 16:30, 17:30, 18:30)
→ Apparent positive Z_{DR} bias due to wetting

Snow

Radio wave attenuation due to snow and ice accumulation on radars on high mountains in northern Japan is observed.
Around 2004, Hakodate radar observations were affected by snow.

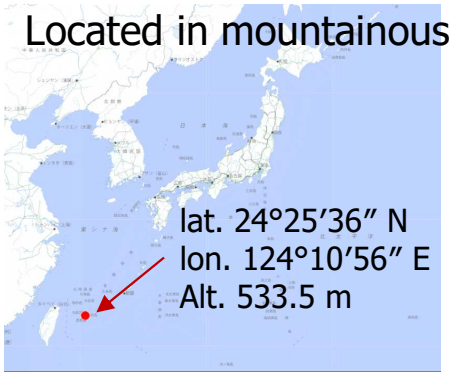
Hakodate radar (2004)

Greenish residue on Ishigakijima radome surface

April 2011 → June 2012

This may be aerial algae or lichen.

Located in mountainous terrain on a remote island



The radar requires regular cleaning.

Radome coating requirements

- Radio wave transparency

JMA radar specifications state that radome horizontal and vertical polarization should average 90% or more, and that the difference between the two should be under 0.1 dB.

- Water repellency

Enough to suppress the effects of wetting, snow accretion and other influences

- Weather resistance (UV rays and other influences)

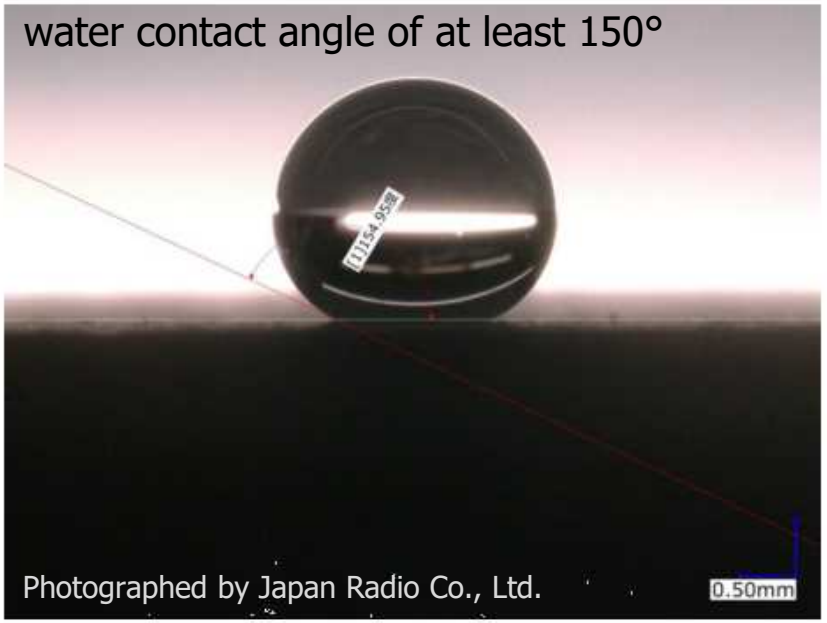
No need for recoating beyond the radar's service life of around 15 years. Radomes may be cleaned every 7 to 8 years.

- Algae resistance

This reduces the need for cleaning at specific radar sites.

Super-hydrophobic radome coating from 2023

Photographed by NIHON TOKUSHU TORYO CO., LTD.



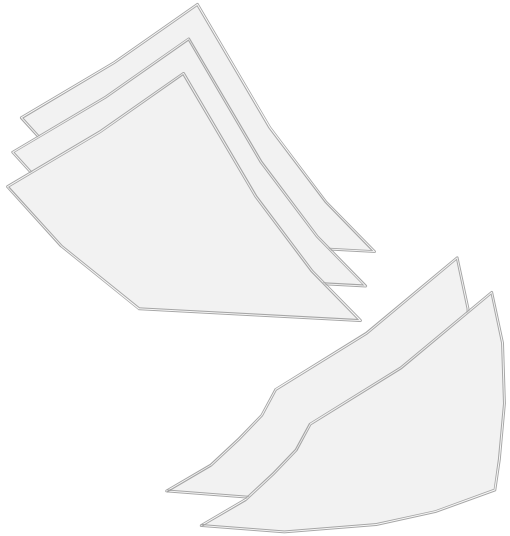
SKY-HULLO HAS (developed by SUBARU CORPORATION and NIHON TOKUSHU TORYO CO., LTD.)

- ✓ **Super-hydrophobic**: produces a water contact angle of at least 150°
- ✓ **Highly durable**: the hardest super-hydrophobic coating available (designed for aircraft). Resistant to UV rays.
- ✓ **Recoating possible**
- ✓ **Addition of anti-algae agent possible**

*Negligible radio wave attenuation

Super-hydrophobic radome coating applied to Okinawa radar equipment

Radome panel coating → Radome assembly → Spraying to check water repellency

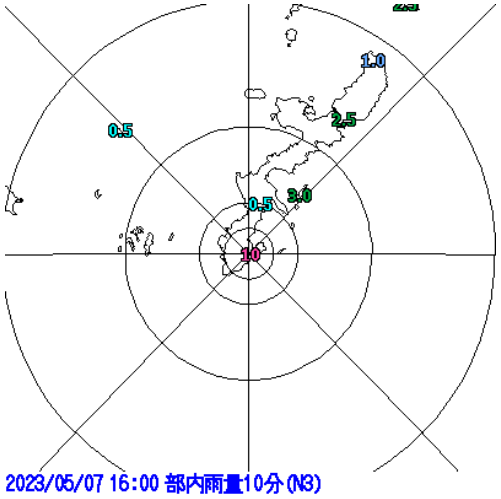


Photographed by Japan Radio Co., Ltd.

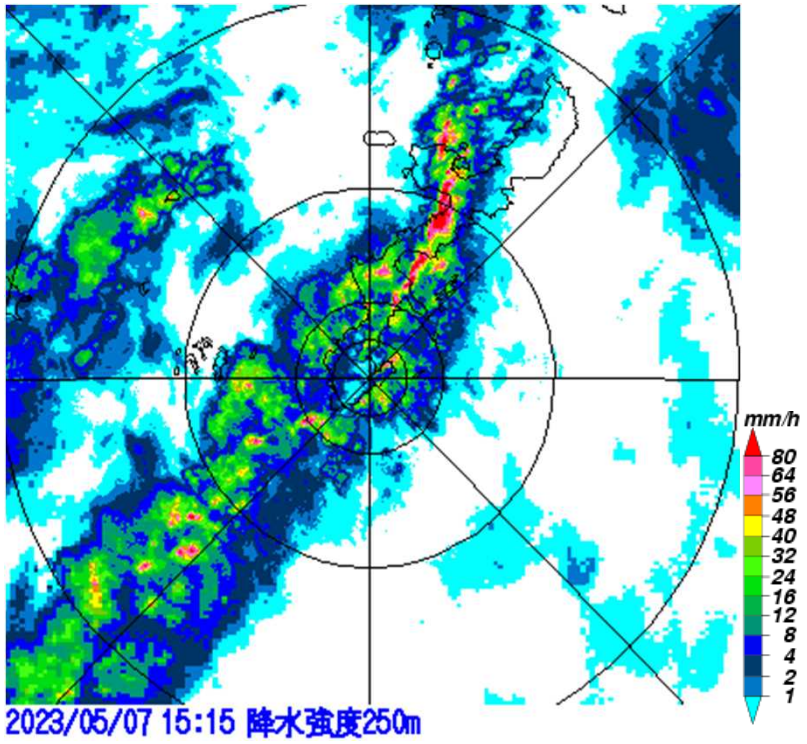
Radar observation with super-hydrophobic radome coating

No positive Z_{DR} bias was observed in association with heavy rain.

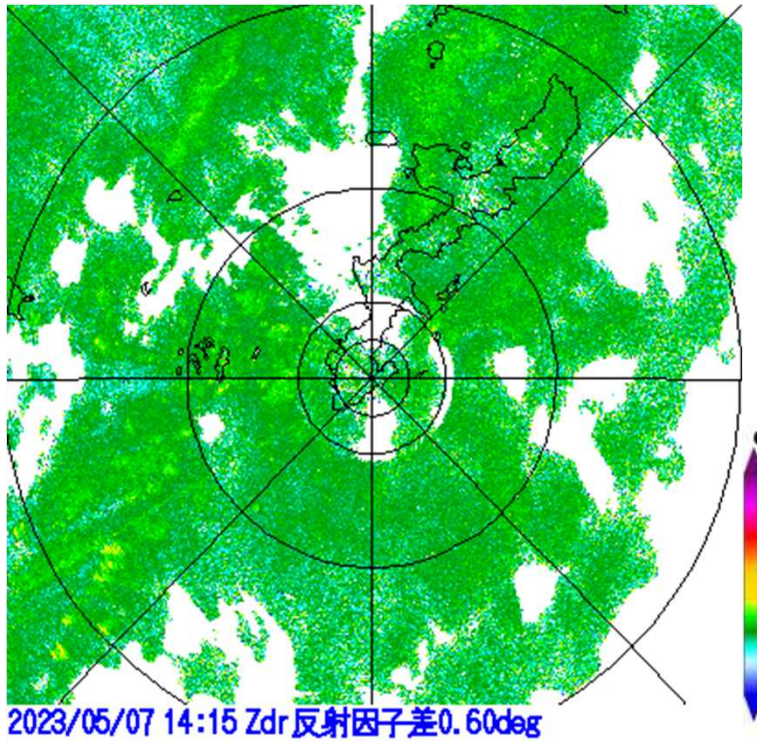
Raingauge 10mm/10min



Precipitation Intensity (radar composition)



【Okinawa radar】Z_{DR}

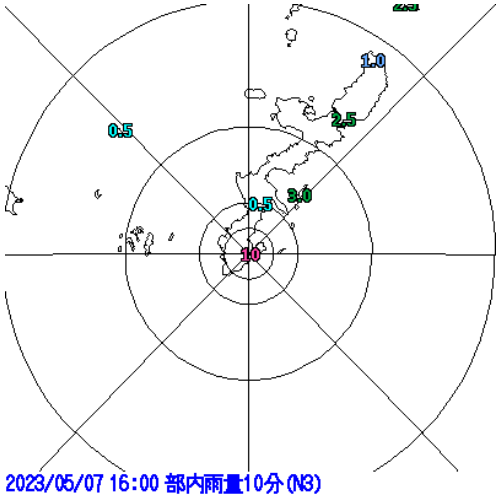


*As these data are pre-correction for attenuation due to rain echoes, negative Z_{DR} is seen behind the rain area.

Radar observation with super-hydrophobic radome coating

No positive Z_{DR} bias was observed in association with heavy rain.

Raingauge 10mm/10min



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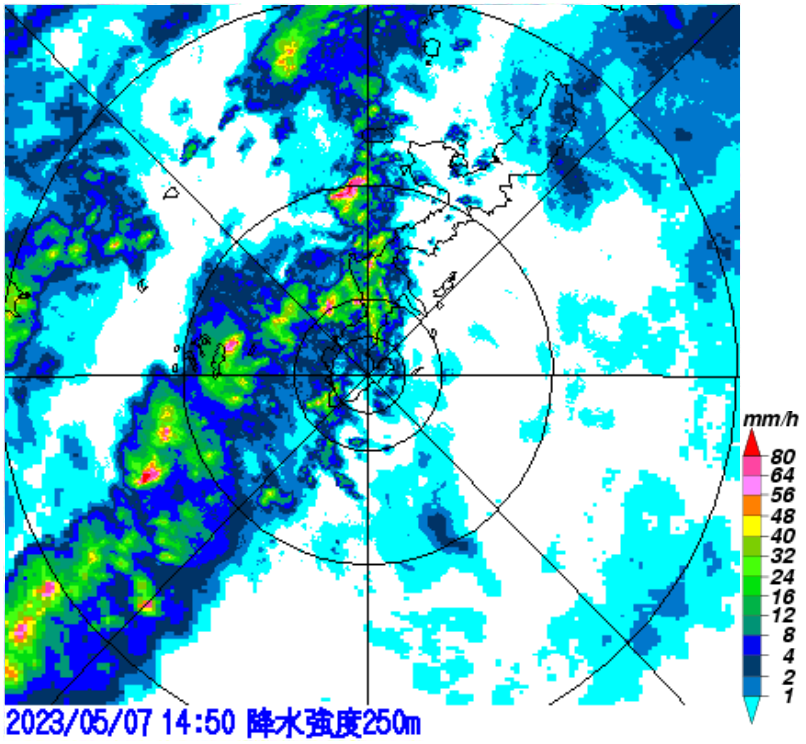
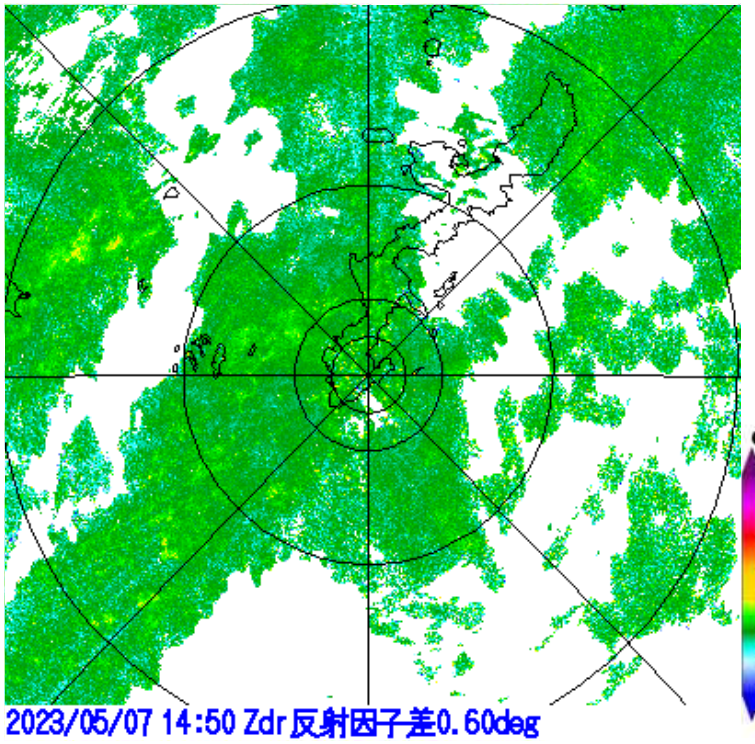


【Okinawa radar】Z_{DR}

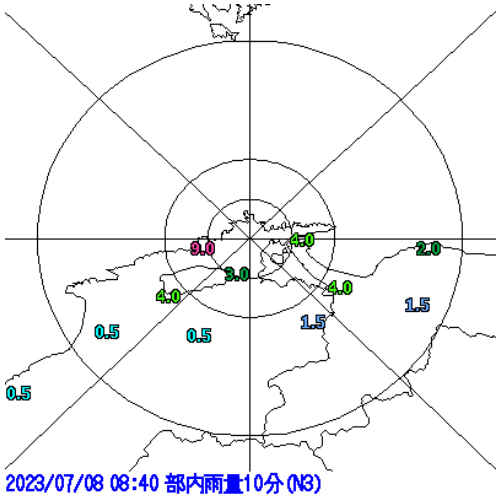


*As these data are pre-correction for attenuation due to rain echoes, negative Z_{DR} is seen behind the rain area.

Radar observation with super-hydrophobic radome coating

No positive Z_{DR} bias was observed in association with heavy rain.

Raingauge 9.0mm/10min



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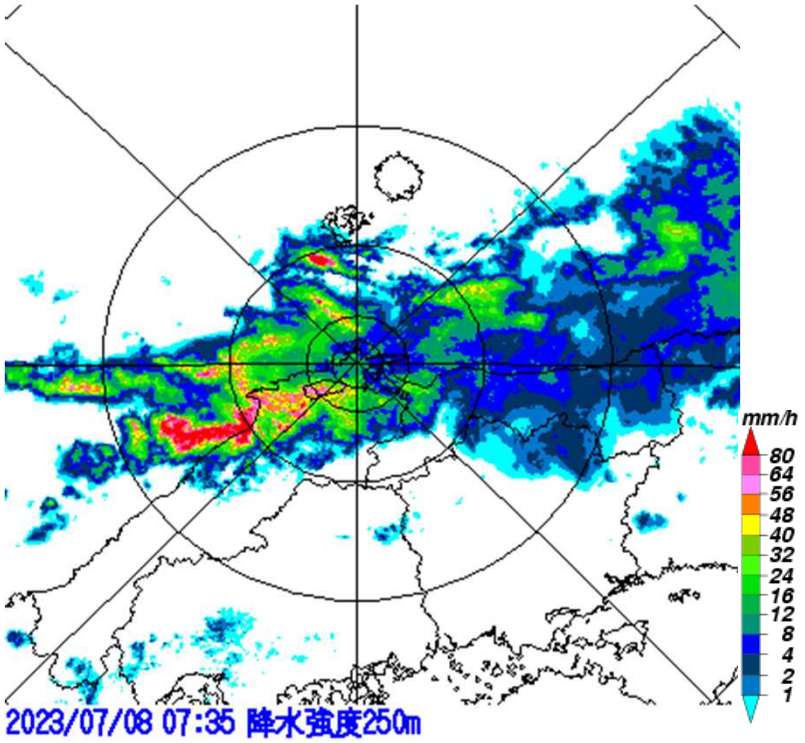
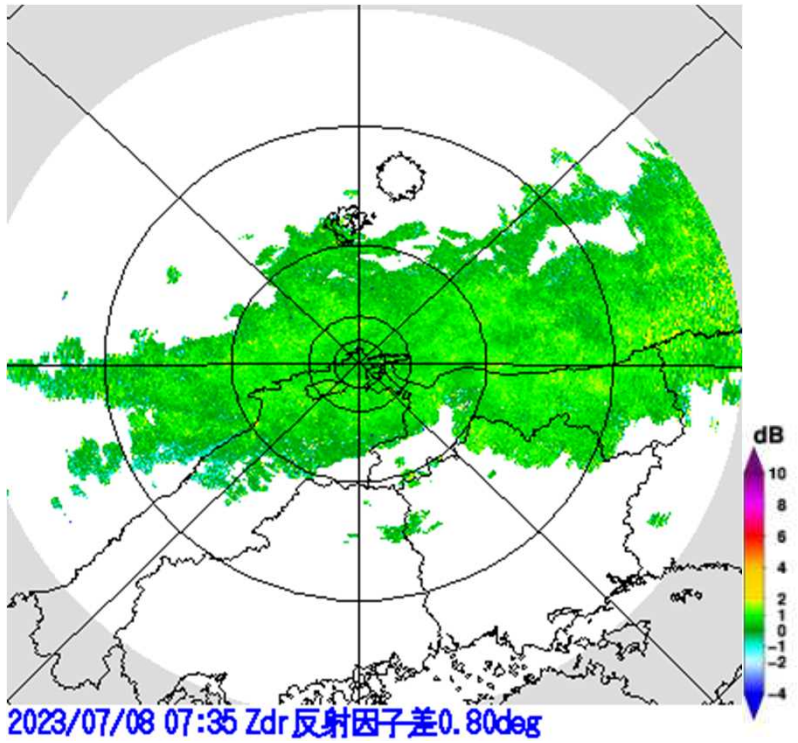


【Matsue radar】Z_{DR}

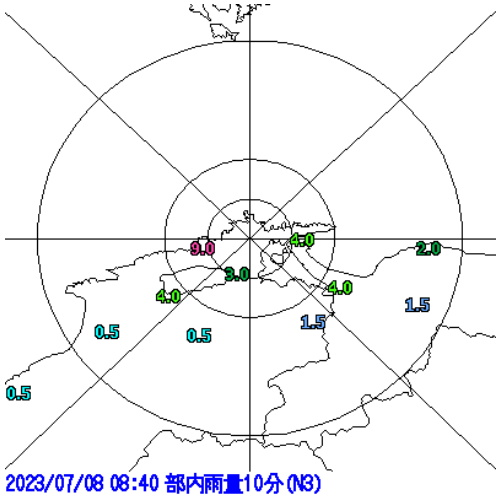


*As these data are pre-correction for attenuation due to rain echoes, negative Z_{DR} is seen behind the rain area.

Radar observation with super-hydrophobic radome coating

No positive Z_{DR} bias was observed in association with heavy rain.

Raingauge 9.0mm/10min



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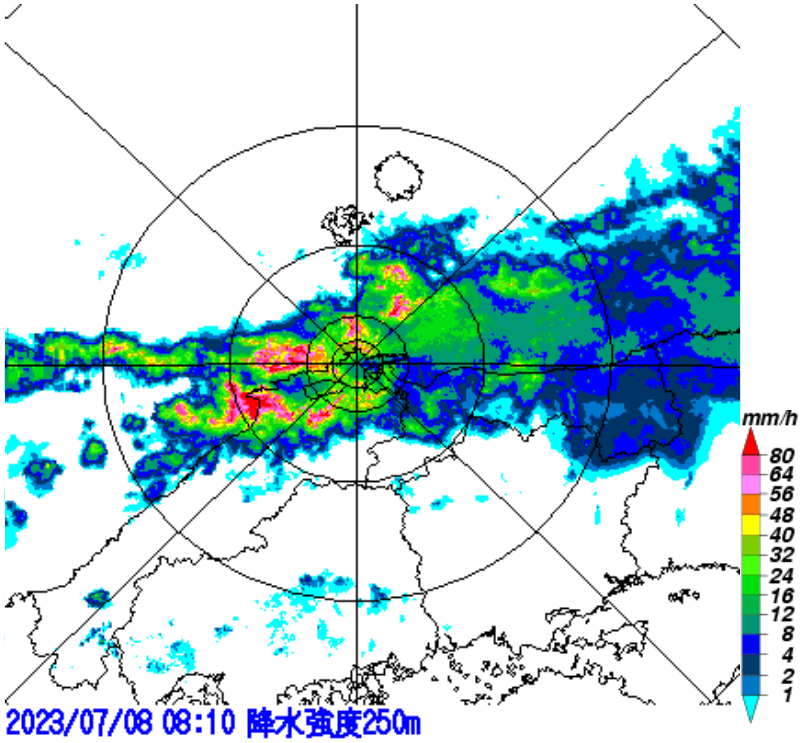
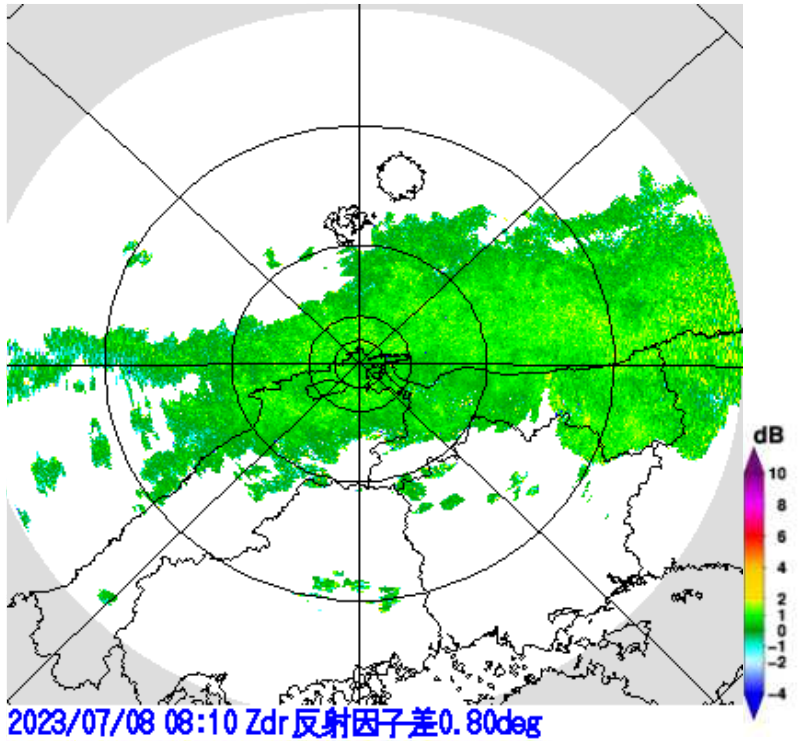


【Matsue radar】Z_{DR}

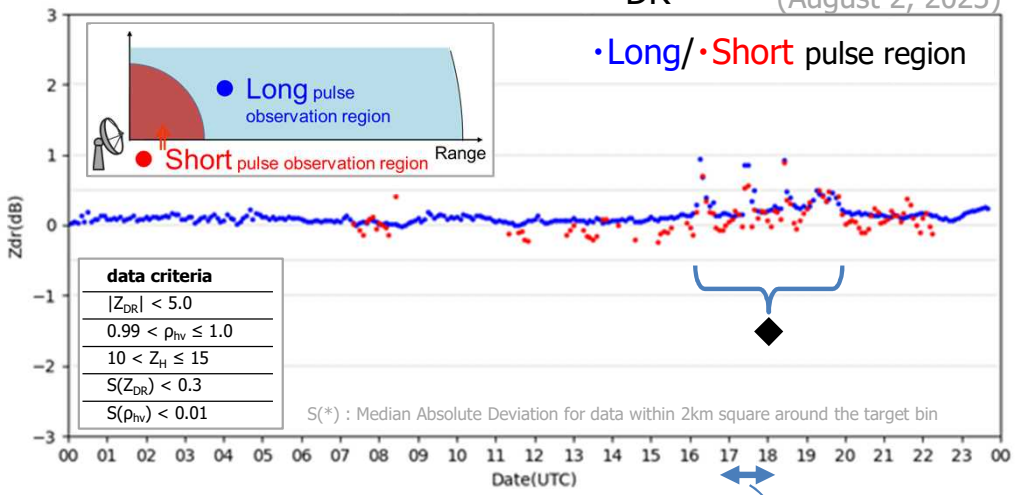


*As these data are pre-correction for attenuation due to rain echoes, negative Z_{DR} is seen behind the rain area.

Comparison of regular and super-hydrophobic radome coating – Z_{DR} time series

Regular radome coating

【Murotomisaki radar】Z_{DR} (August 2, 2023)



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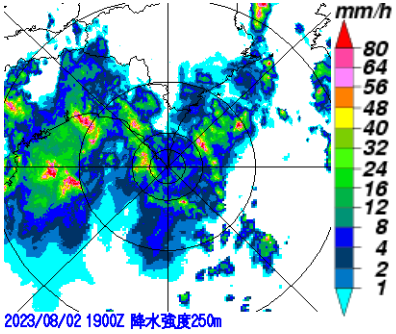
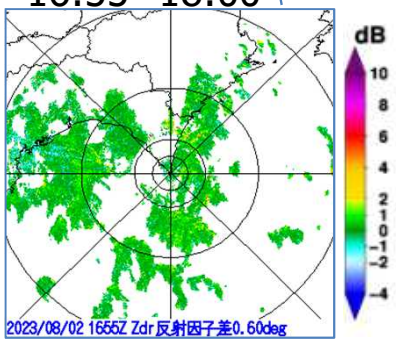


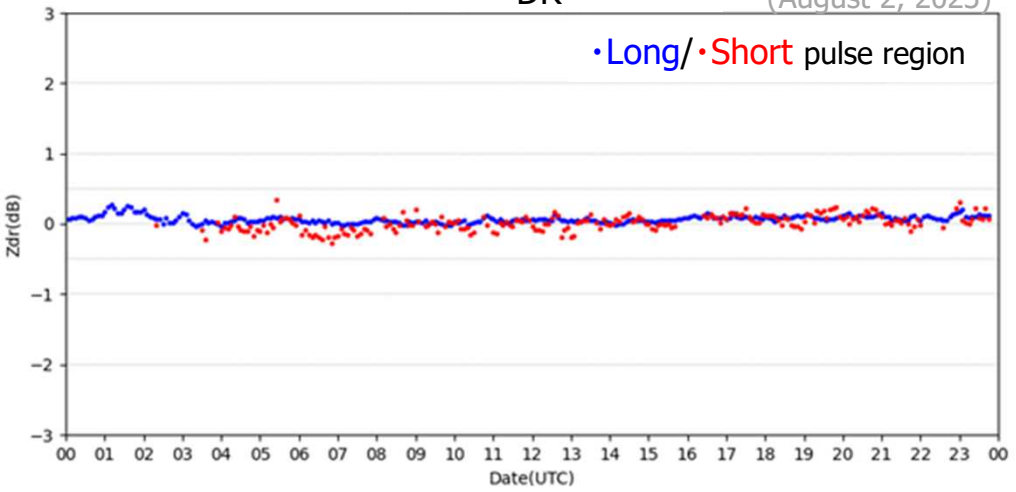
16:55~18:00



- ◆ An upward spike of approximately 0.5 dB is seen at around 19:00 UTC
- ◆ Spike-like rise toward 1 dB (approx.. 16:30, 17:30, 18:30)
  → Apparent positive Z_{DR} bias due to wetting

Super-hydrophobic radome coating

【Okinawa radar】Z_{DR} (August 2, 2023)



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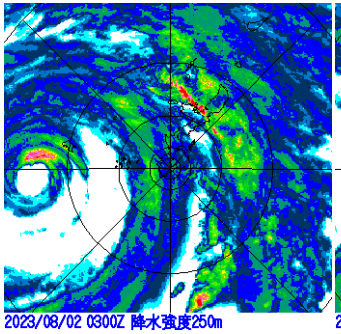

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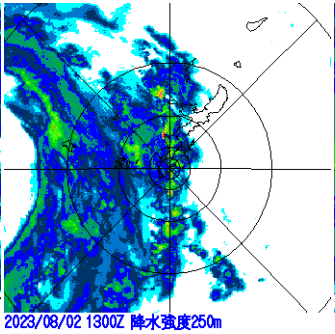

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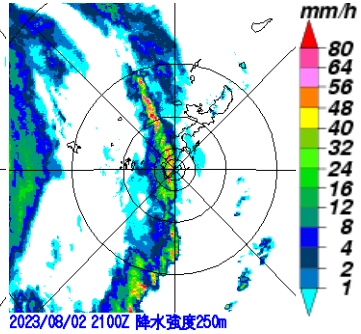
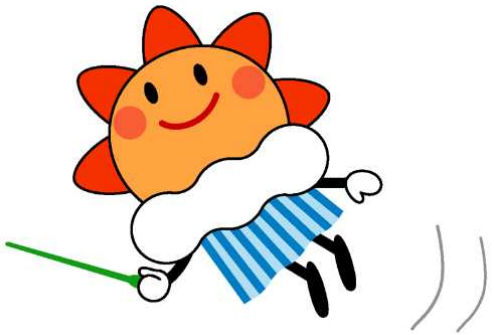


<u>No major effects on Z_{DR} are observed</u> despite heavy rain and strong wind throughout the day. Probably attributable to the super-hydrophobic radome coating.

Summary

- Wet radome surfaces cause Z_{DR} bias due to radio wave attenuation. Coverage with snow and other matter (e.g., dirt, lichen) also affects observation.
- Super-hydrophobic coating applied to updated radome equipment in 2023 eliminated Z_{DR} bias even in heavy rain.
- Effectiveness will continue to be monitored for reference in future JMA radar updates.

Thank you for your attention !



JMA's mascot, "Harerun"