WindRAD Scatterometer Quality Control in Rain

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- Why Quality Control (QC) in rain?
- QC algorithms (Rn, Joss, RnJ)
- QC for Ku-band-only wind retrieval
- QC for C&Ku band wind retrieval
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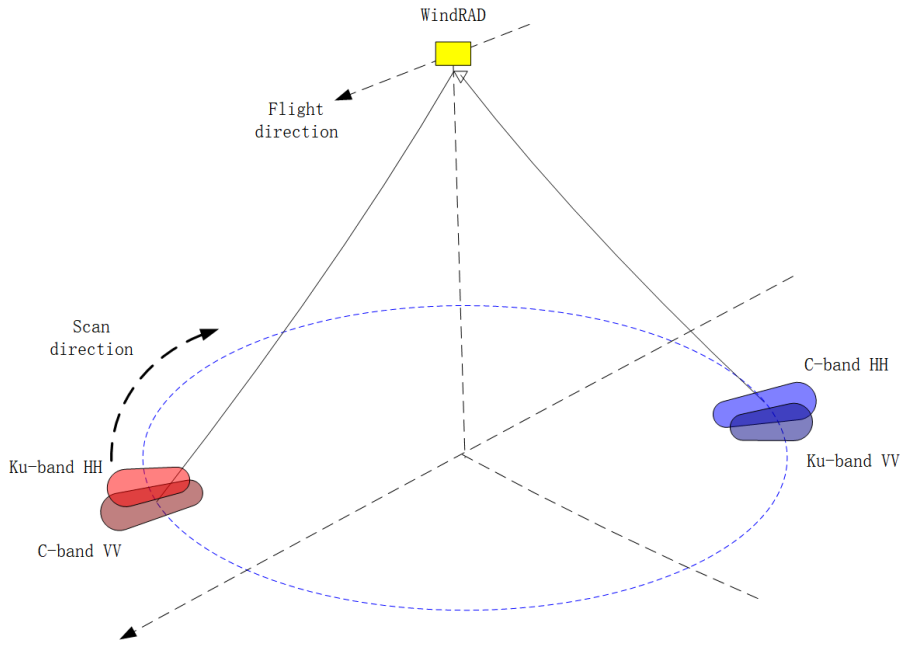
What is WindRAD?

WindRAD is a wind scatterometer onboard **FY-3E** satellite.

It was launched on 9th July 2021 by CMA (China Meteorological Administration).

WindRAD is a **dual** frequency **rotating fan-beam** scatterometer.



Why Quality Control (QC) in rain?

- Raindrops are relatively small compared to the radar wavelength, which can cause Rayleigh volume scattering in the atmosphere. Larger raindrops and smaller wavelengths lead to more intense Rayleigh scattering.
  Therefore, Ku-band observations are very sensitive to rain.

- C-band's wavelength is much longer than Ku-band, and C-band winds are much less affected by rain.

- Under rainy conditions, the Ku-band backscatter signal σ∘ is generally enhanced, and the rain enhancement effect disturbs Ku-band wind retrievals. The rain-induced backscatter is generally larger than the wind-induced backscatter, which leads to positively biased retrieved winds. WVCs with rain must be identified and flagged.

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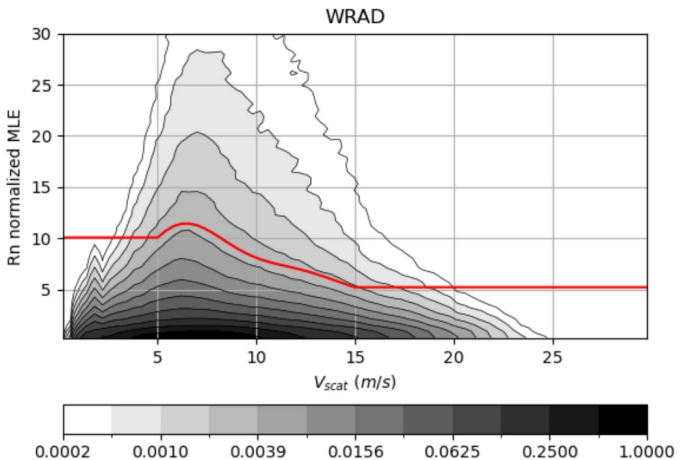
QC algorithms

(Rn, Joss, RnJ)

- Rn is normalized MLE residual, and it represents the distance between the measured σ◦s and the simulated σ◦s.

- Rain backscatter is isotropic and causes a deviation between the measured σ◦s and the simulated σ◦s (using the wind GMF).

$$MLE = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{\sigma^{\circ}_{mi} - \sigma^{\circ}_{si}}{K_p(\sigma^{\circ}_{mi})}\right)^2, \qquad R_n = MLE/\langle MLE\rangle$$



Note: The threshold is a trade-off between the data rejection of all rain-contaminated WVCs and the data rejection of good wind retrievals.

Joss*:

It uses the speed component of the observation cost function in the 2D variational ambiguity removal (2DVAR) step to reject additional WVCs which were not identified by the Rn method.

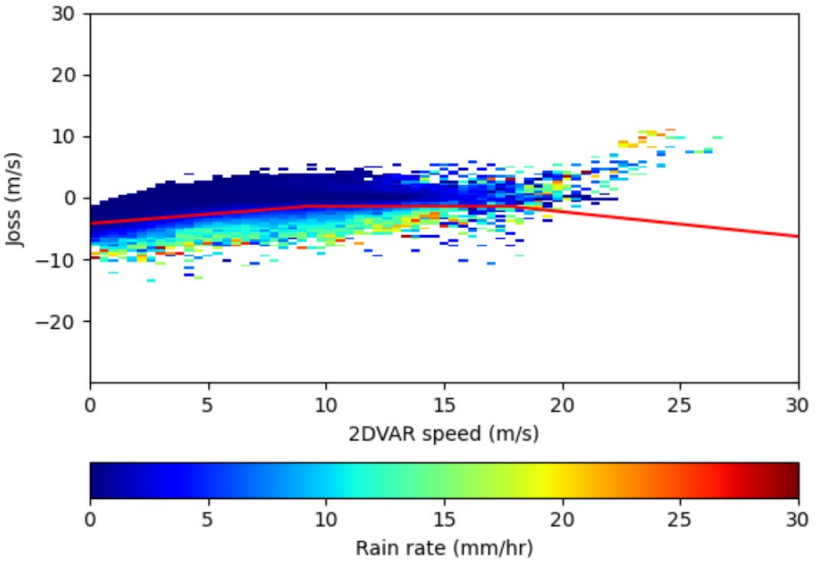
Joss is sensitive to the spatial consistency in the wind field and depending on the neighboring WVCs. Rn works locally in one WVC. It is useful to combine Joss and Rn to take both local WVC information and spatial consistency into account. Therefore, a combined QC method with Rn and Joss, called RnJ, is proposed.

*X. Xu and A. Stoffelen, "Improved Rain Screening for Ku-Band Wind Scatterometry," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 58, no. 4, pp. 2494-2503, April 2020, doi: 10.1109/TGRS.2019.2951726.

$J_{OSS} = f - fs$ ➡ It uses the speed component of the observation cost function in the 2D variational ambiguity removal (2DVAR) step to reject additional WVCs which were not identified with Rn method (RnJ method).

f is the analysis wind speed derived in 2DVAR, and *fs* is the selected retrieved wind speed.

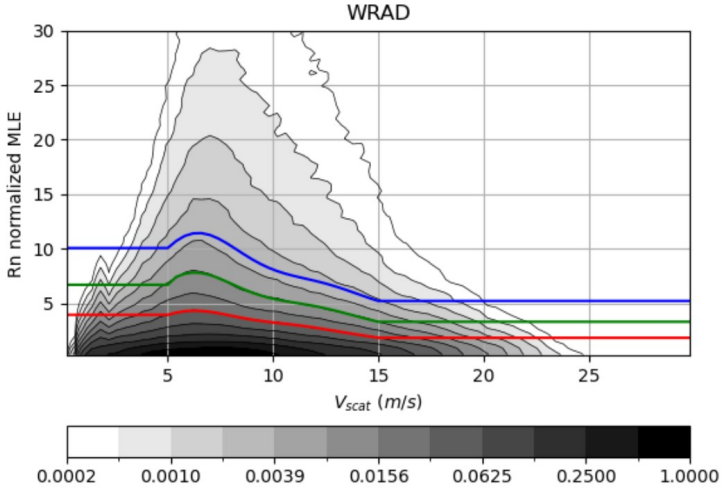
$$J_{OSS} = \begin{cases} 0.3 \times v - 4.2 & \text{if } v < 9 \text{ m/s} \\ -1.5 & \text{if } 9 \text{ m/s} \leq \text{v} < 18 \text{ m/s} \\ -0.4 \times v + 5.7 & \text{if } v > 18 \text{ m/s} \end{cases}$$



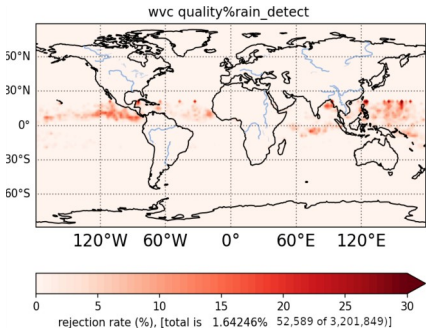
QC for Ku-band-only wind retrieval

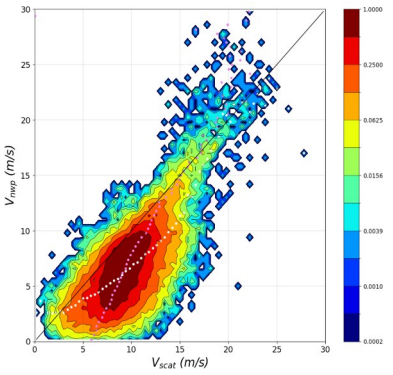
QC for Ku-band-only wind retrieval

Find the appropriate threshold

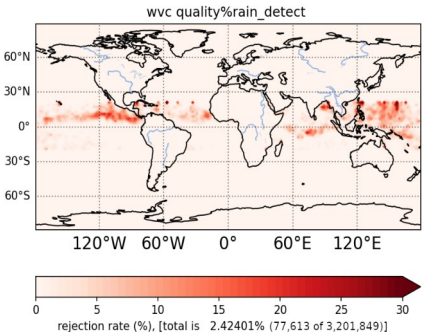


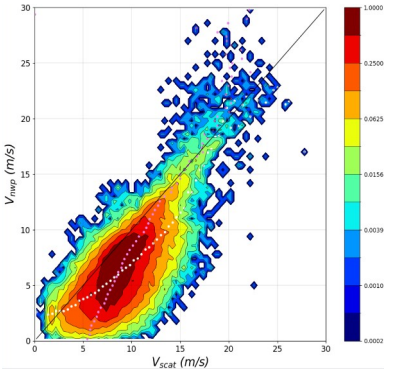
Blue



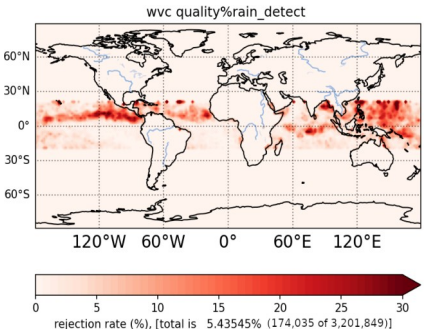


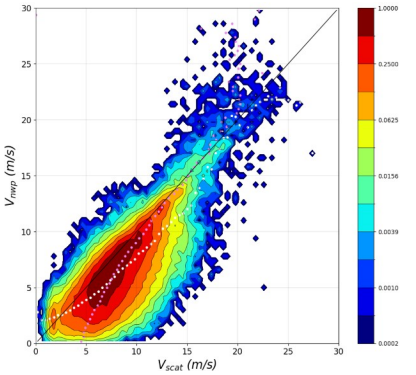
Green





Red





Too many rejections

Rejected winds:

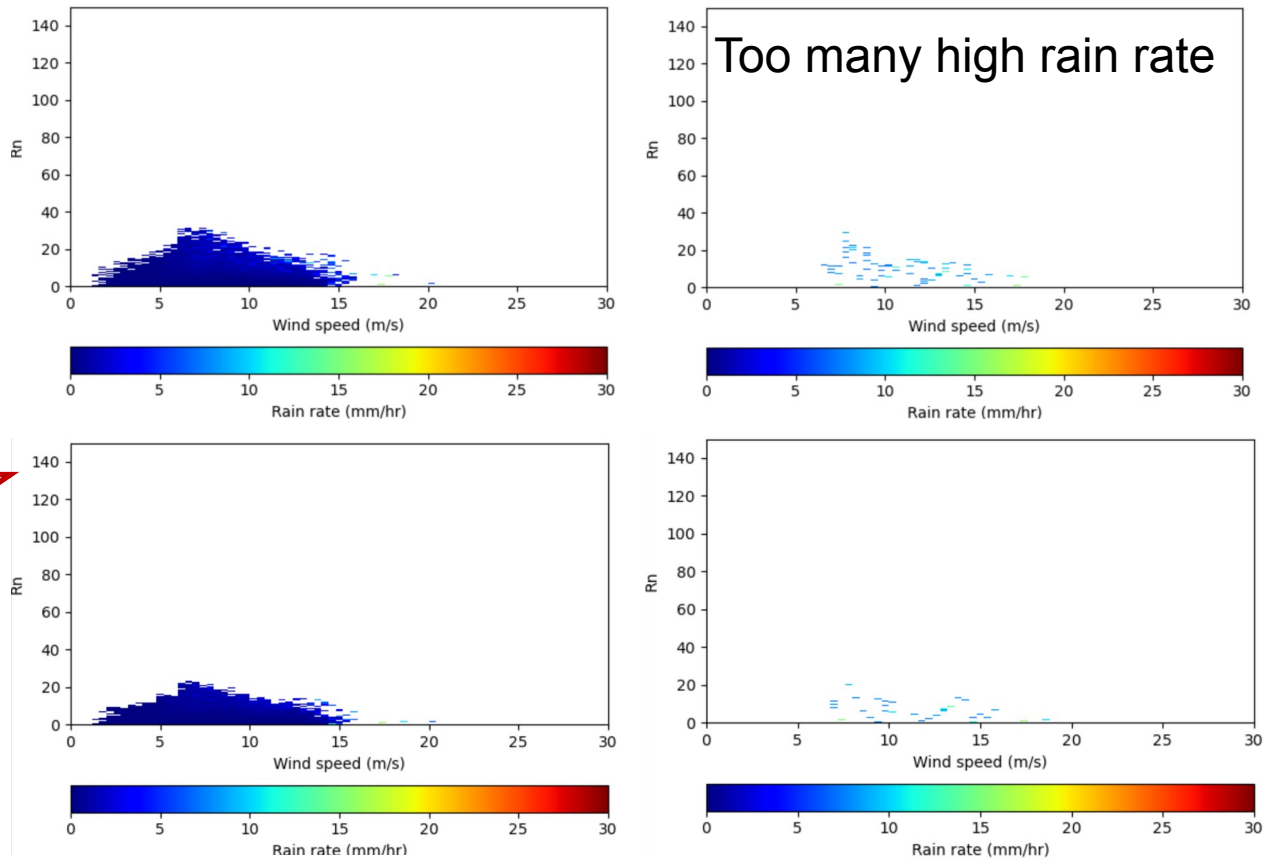
- Upper panel: rejection rate
- Lower panel: rejected winds vs NWP winds

Rn of the **accepted winds** collocated with rain:

- Left panel: all the accepted winds
- Right panel: only with the rain rate > 7 mm/hr

Blue

Green



RnJ (combine Joss with Rn)

An additional 0.41% of all WVCs are rejected by RnJ as compared to Rn.
Compare the wind statistics against NWP winds:

Table 1. Ku-band wind statistics comparison of R_n and R_nJ against NWP winds, with tropical region latitude $[-20°, 20°]$, using data from August 2023 to March 2024.

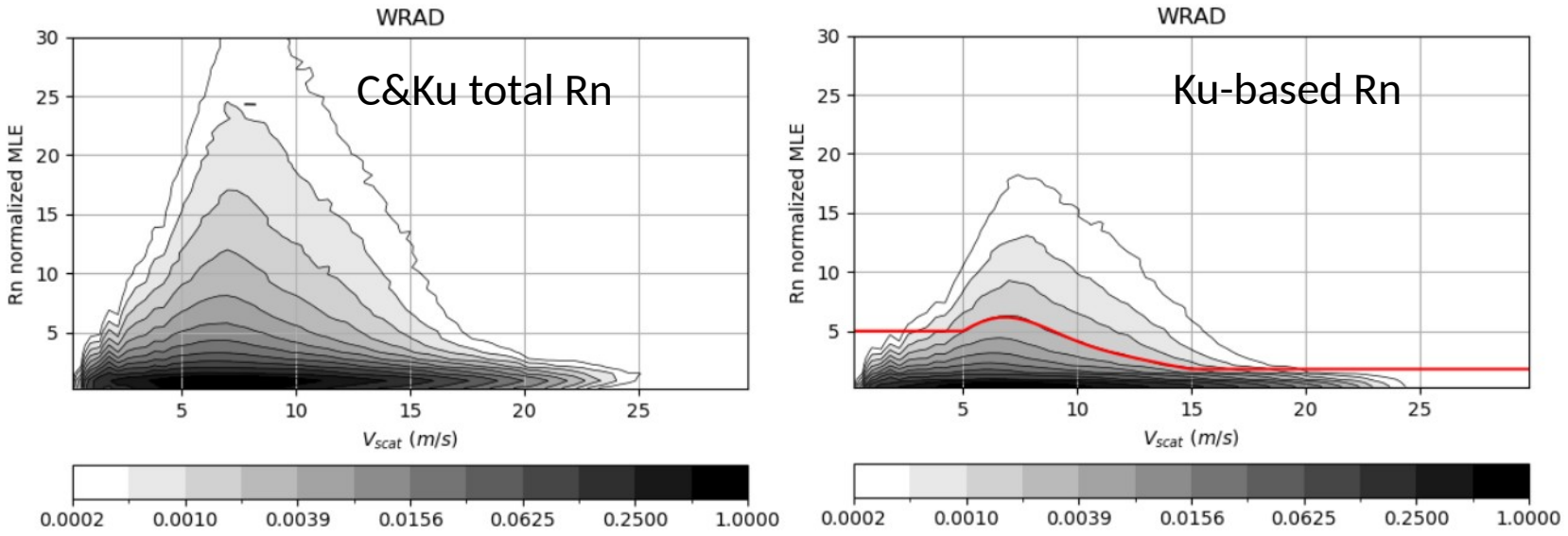
	QC Method	Speed Bias (m/s)	SDD of u (m/s)	SDD of v (m/s)
Rejected winds	R_n	2.312	2.34	2.38
	R_nJ	2.491	2.39	2.44
Accepted Winds	R_n	0.113	1.15	1.19
	R_nJ	0.096	1.13	1.17

Additionally, RnJ accepts only 0.007% of the winds with a rain rate above 7 mm/h; this is half the amount that is accepted by Rn (0.014%).

QC for C&Ku combined wind retrieval

Which Rn distribution should be used?

Rn distribution differences due to C-band



Note: the Ku-based Rn distribution is normalized by the total number of views in a WVC for the convenience of calculation, which is about double compared to the Ku only views. Thus, its distribution is about half of the C&Ku total Rn distribution.

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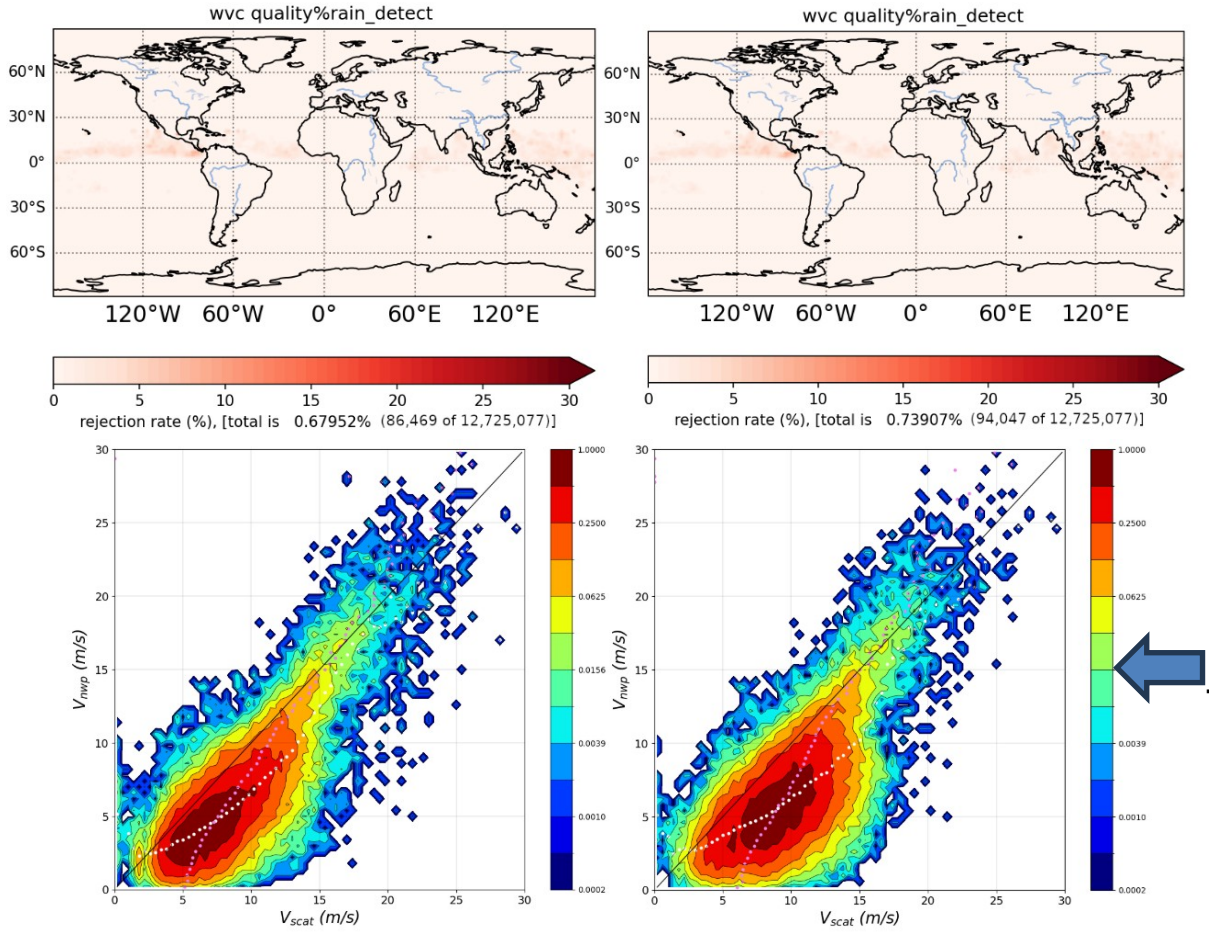
A similar number of rejected winds is required to equally compare the rejected wind statistics between the use of total Rn and the Ku-based Rn.

Total Rn



Ku-based Rn

Deviate more from the diagonal

Compare C&Ku and Ku-band-only with Rn QC

- The rejection rate with Rn C&Ku:1.11% vs. Ku-band-only 2.46%.
- Less winds are rejected with C&Ku compared to Ku-band-only.
- The wind statistics do not have large differences.

The percentage of accepted winds with a rain rate above 7 mm/h:

- C&Ku: 0.041%
- Ku-band-only: 0.014%
- The high rain rate in some WVCs is suppressed and those winds are accepted.

By adding C-band measurements to the wind retrieval, the rain effect is suppressed, and some of the WVCs rejected by the Ku-band Rn are now accepted by C&Ku. Thus, the C&Ku wind retrieval can achieve similar QC results in terms of rejected and accepted wind statistics and still reject fewer WVCs. Hence, the C-band has clear added value in rainy conditions, allowing us to obtain improved vector winds.

*Calculated with data from August 2023 to March 2024 in the tropical region

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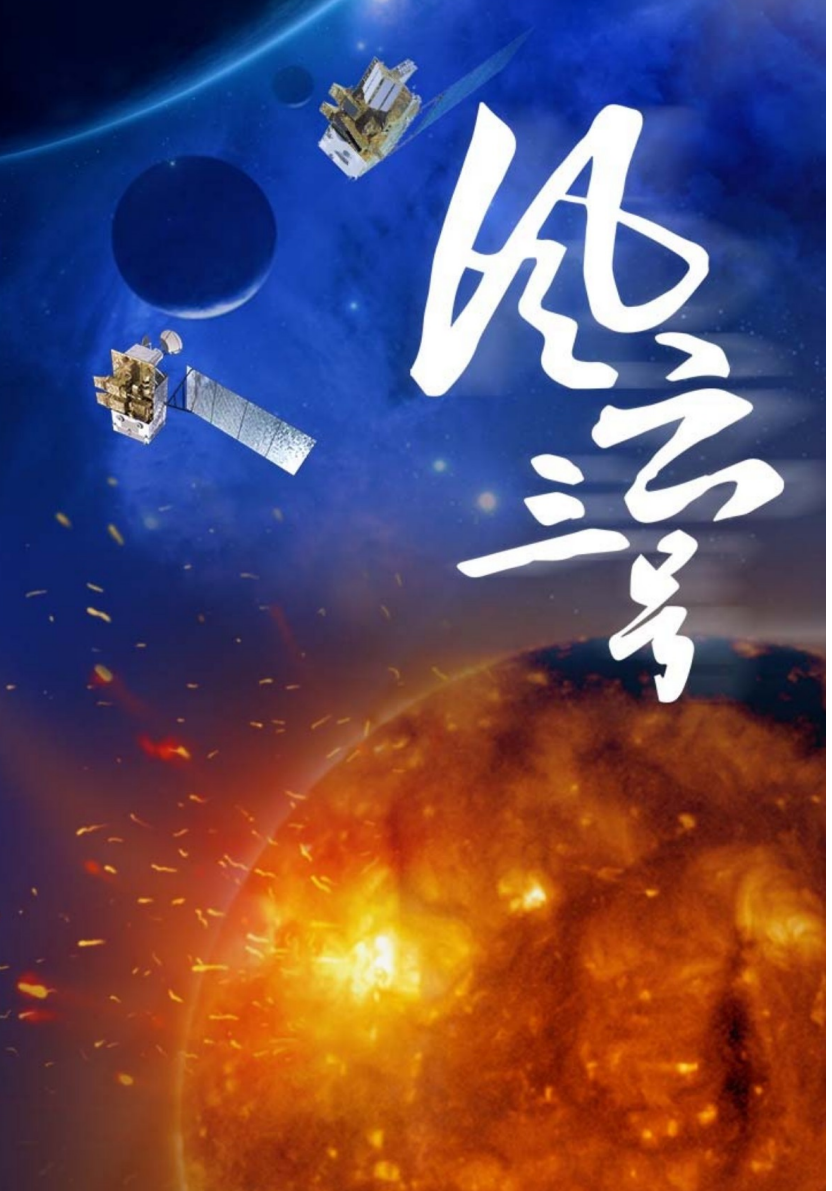
Summary

- Rn QC algorithm has been adapted to WindRAD.
- RnJ (the combination of Rn and Joss) is shown to be the optimal QC algorithm for Ku only and C&Ku wind retrievals.
- Ku-based Rn QC is introduced for C&Ku wind retrieval, which is more effective than the total Rn QC.
- By adding C-band observations to the wind retrieval suppresses the rain effect, and the same QC capabilities can be achieved with fewer rejected WVCs.

* Li, Z.; Verhoef, A.; Stoffelen, A.WindRAD Scatterometer Quality Control in Rain. Remote Sens. 2025, 17, 560. https://doi.org/10.3390/ rs17030560



Thank you for listening, questions?

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