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ADDRESSING QPE LIMITATIONS WITH SOLID STATE TRANSMITTER X-BAND RADAR

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INTRODUCTION

Radar-based quantitative precipitation estimation (QPE) improves rainfall forecasts and hydrological applications. This study evaluates X-band radar configurations in Lombardy (northern Italy), operated by ARPA Lombardy, to optimize radar-rainfall relationship and address limitations like attenuation and signal extinction during extreme events.

CASE STUDY

The case study examines the October 31, 2023, convective event in Milan's hydraulic node, where a maximum rainfall height of 80 mm of precipitation was recorded overnight, leading to the Seveso River flooding and disruptions to local residents (Figure 1)

Two X-band radars, located in Desio (25 km north of Milan) and Flero (75 km east of Milan), monitored the event. The Desio radar experienced severe attenuation due to wet radome conditions as the convective core passed directly overhead. In addition, even the Flero radar was unaffected by wet radome, its greater distance resulted in signal attenuation and, in some areas, complete extinction, leading to an underestimation of precipitation.

OBJECTIVES

- Define the optimal configurations for operational QPE.
- Evince radar limitations during extreme precipitation events and possible ways of addressing them.

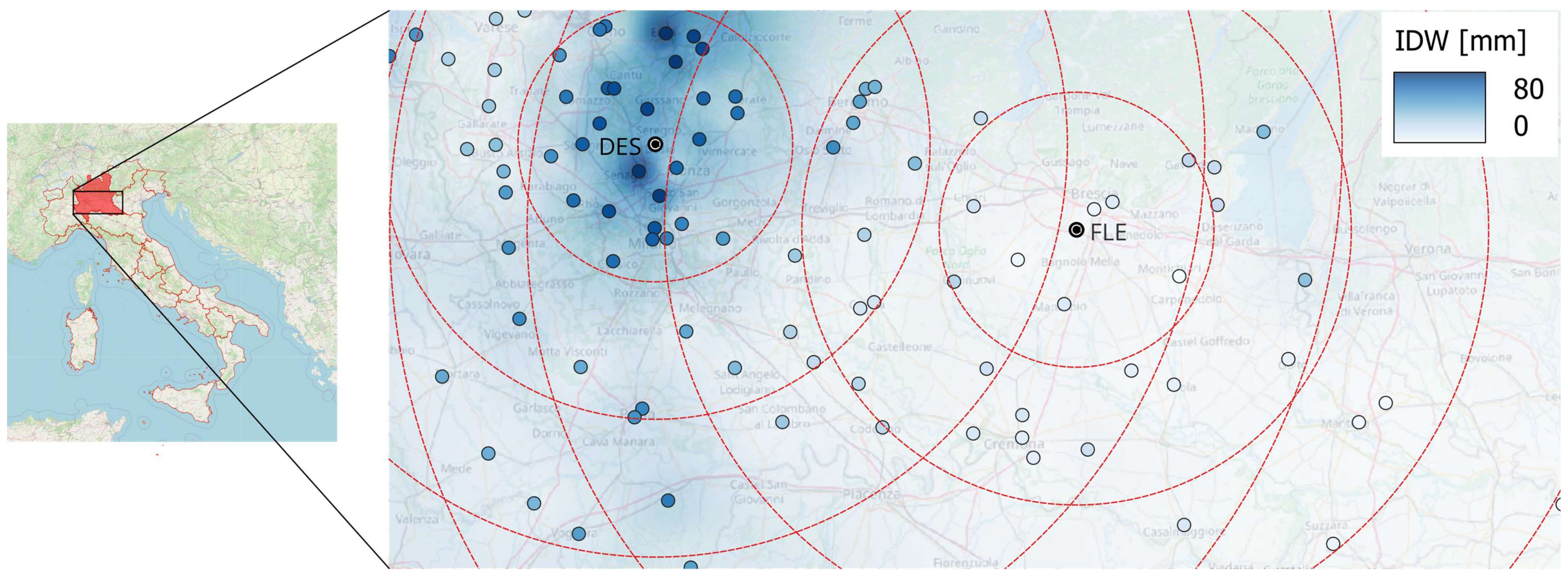

Figure 1. Accumulated precipitation field for the 2023-10-31 event

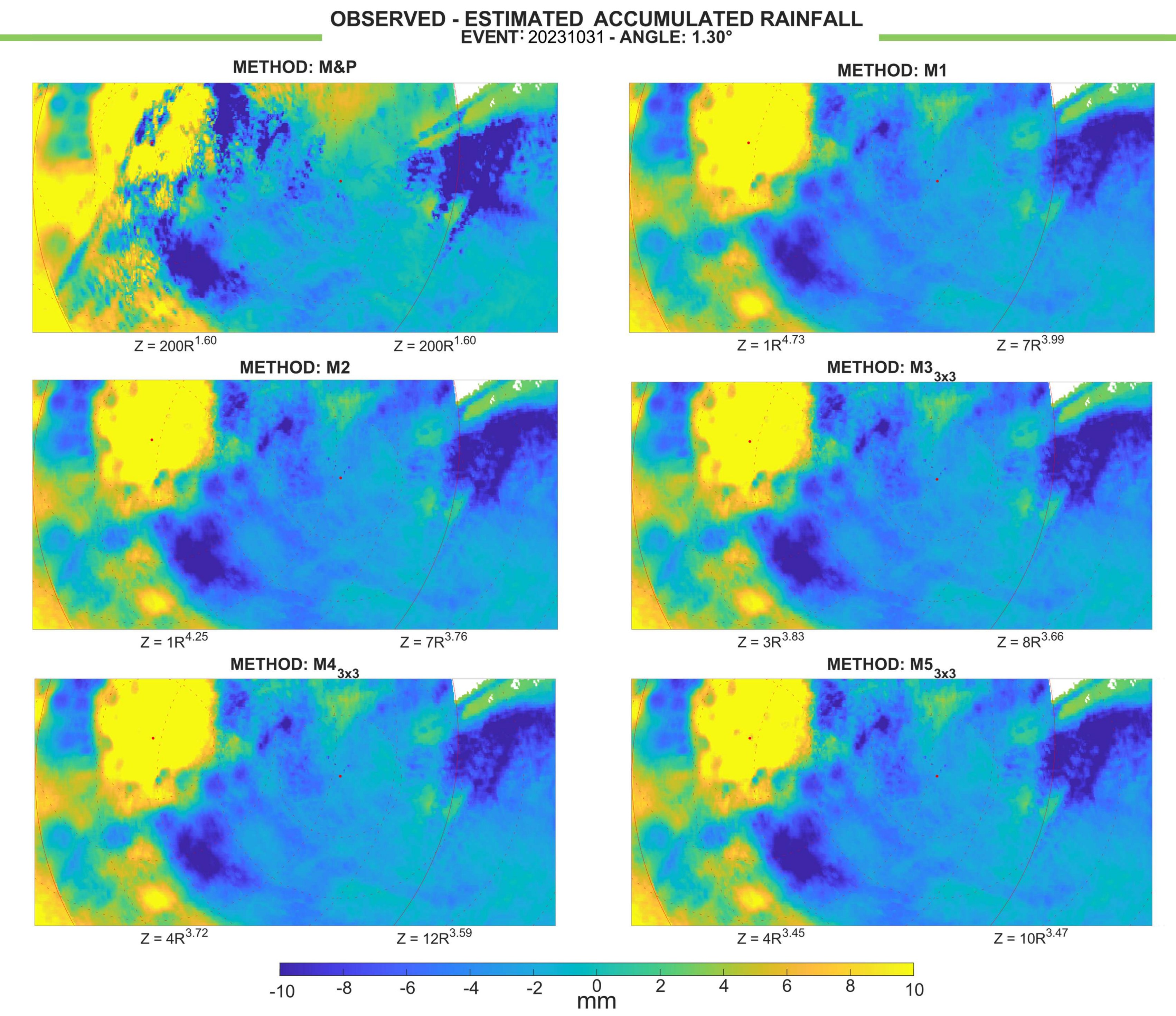

Figure 2. Observed – Estimated accumulated precipitation maps for calibrated R(Z) relations

METHODOLOGY

Step 1: Calibration of R(Z) Relations

- Three elevation angles: 0.70°, 1.30°, 3.00°.
- Rainfall intensities from ARPA rain gauge network.
- 5 methodologies including spatial windowing methods for R-Z dataset creation [1].
- Standard Marshall & Palmer relation.
- R(Kdp) as first approach of using polarimetric information in the present study.

Step 2:

- Attenuation correction of the radar reflectivity factor field through specific differential phase information [2].
- Re-calibration of R(Z) relations to observe how the precipitation field changes.

To evaluate performance, estimated precipitation was compared with the Inverse Distance Weighting (IDW) interpolation of rain gauge observations. Accumulated precipitation difference maps (observed minus estimated) were generated to visualize over- and underestimations (Figure 2).

Additionally, boxplots summarizing the precipitation difference for all the evaluated radar-rainfall relations were obtained considering all points within an area of 50 km around each radar (Figure 3). This helped identify systematic over or underestimation patterns across the study area.

Finally, scatterplots comparing radar estimates vs. rain gauge observations were created to analyze how different methodologies and elevation angles influence overall precipitation estimation accuracy (not shown here).

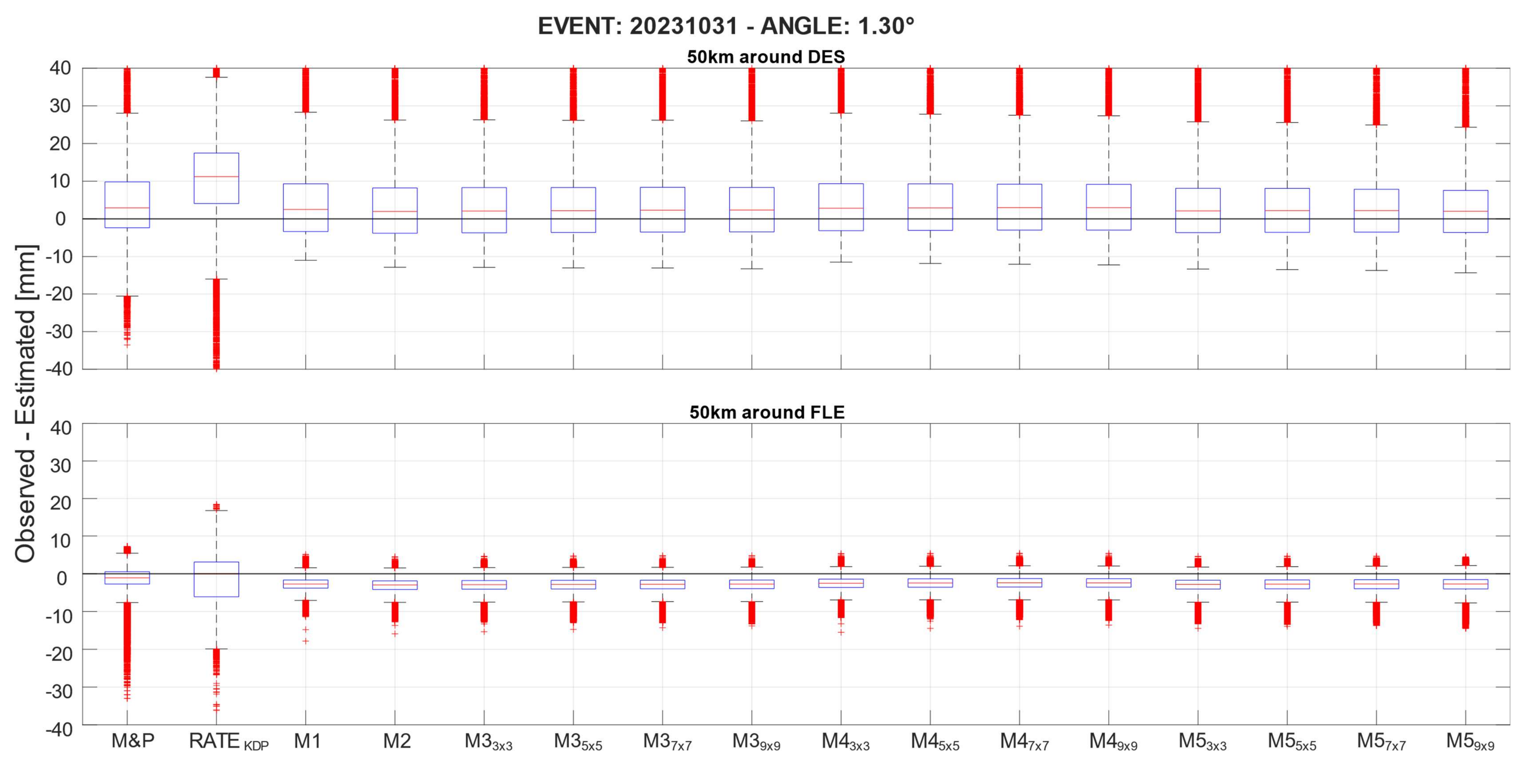

Figure 3. Observed – Estimated accumulated precipitation boxplots for calibrated R(Z) relations

RESULTS & CONCLUSIONS

- Accumulated precipitation near Desio shows a wider range of over- and underestimation, with M1 to M5 methodologies exhibiting a right-skewed distribution (tail in underestimation).
- Flero shows less variability and a more symmetrical distribution of differences. M1 to M5 tend to overestimate precipitation in this area.
- The 1.30° elevation angle provides better precipitation estimates, as it yields a narrower data range compared to 0.70° and 3.00°.
- The use of R(Kdp) requires further investigation, as it exhibits higher variability, though values remain close to zero for the Flero radar.
- Attenuation correction led to moderate improvements, but its impact was limited due to event-specific challenges such as wet radome effects and, more critically, signal extinction.
- A key observation is the variability in R(Z) coefficients and exponents across different radars, even when using the same regression method.

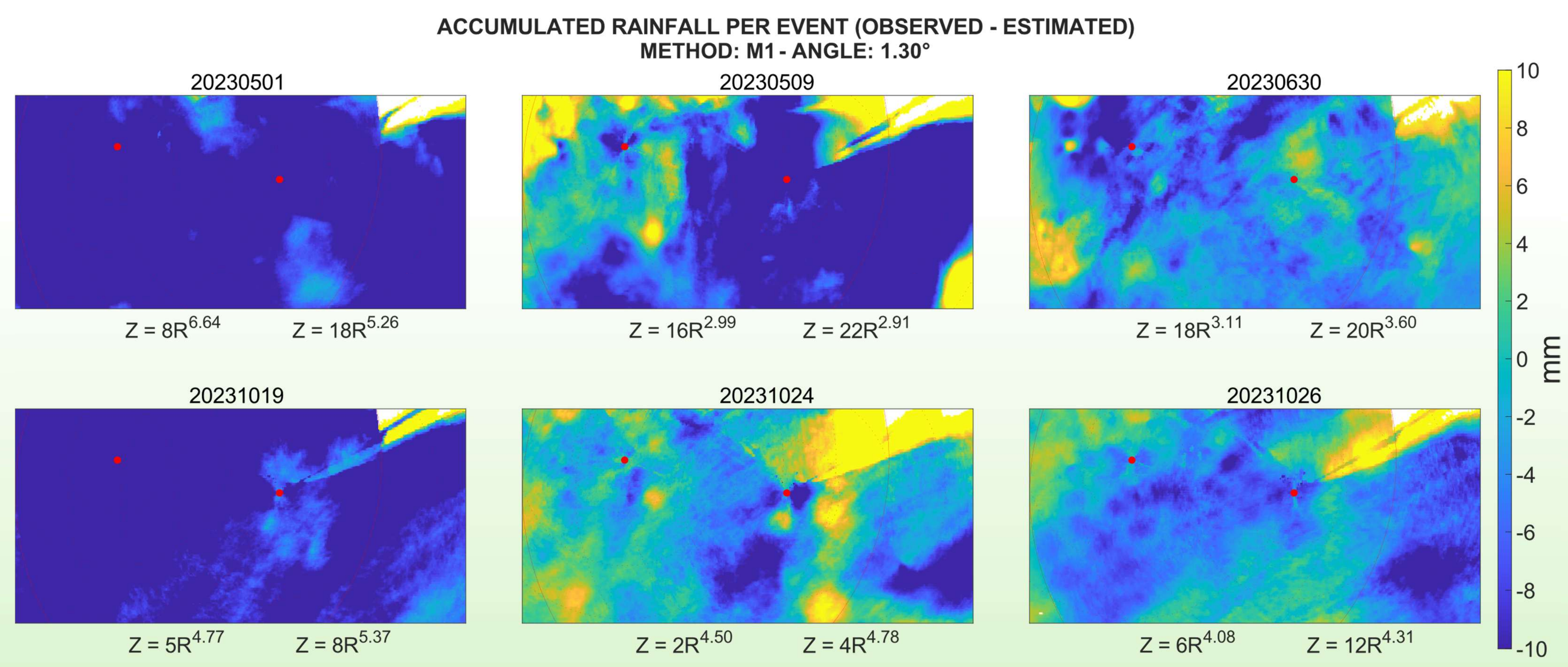

Figure 4. Observed – Estimated accumulated precipitation maps for stratiform events

LIMITATIONS & FURTHER DEVELOPMENTS

This study primarily focused on the relationship between radar reflectivity factor (Z) and rainfall intensity (R). The use of specific differential phase (Kdp) was limited to applying standard coefficients from the literature, without an in-depth analysis. A more detailed study is needed to fully leverage the polarimetric capabilities of the radars.

Additionally, signal extinction remains a critical challenge for extreme events. Future research should explore methods to mitigate this issue, potentially by integrating third-party data sources to enhance precipitation estimates.

Regarding the variability of the coefficients and exponents in the R(Z) relations obtained from the regressions, this highlights the need for further analysis under less extreme conditions. As shown in Figure 4, which compares six maps of differences for stratiform events (using a specific elevation angle and the M1 methodology), an event-dependent variation in the R(Z) estimation coefficients is observed. However, within each event, the variability between radars is lower.

REFERENCES

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[2] Bringi, V. N., & Chandrasekar, V. (2001). Polarimetric Doppler Weather Radar: Principles and applications. Cambridge University Press.

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