Dvorak Analysis Challenges during Rapid Intensification

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Introduction

The Joint Typhoon Warning Center (JTWC) provides tropical cyclone (TC) monitoring and forecasts to the Department of Defense. The Satellite Operations department (SATOPS) of JTWC places substantial emphasis on satellite data for TC analysis. To perform fixes of storm position and intensity, analysts employ the Dvorak technique, which is used worldwide by TC forecast centers[2,6]. This study aims to assess the challenges of the Dvorak technique during very rapidly intensifying (RI) TC's.

Motivation

The quality of TC analysis directly affects the input and output of numerical weather prediction models and the TC forecast. JTWC forecasters rely on Dvorak analysis from SATOPS due to a scarcity of in-situ meteorological observations and a lack of routine aerial reconnaissance. The considerable influence of the Dvorak technique on TC analysis at JTWC necessitates a robust understanding of the strengths and weaknesses of the method. The consensus is that technique performs best with average TC characteristics[3,6]. This study introduces rapid intensification cases to test the limits of the method, highlights challenges under these situations, and proposes solutions to mitigate the deficiencies.

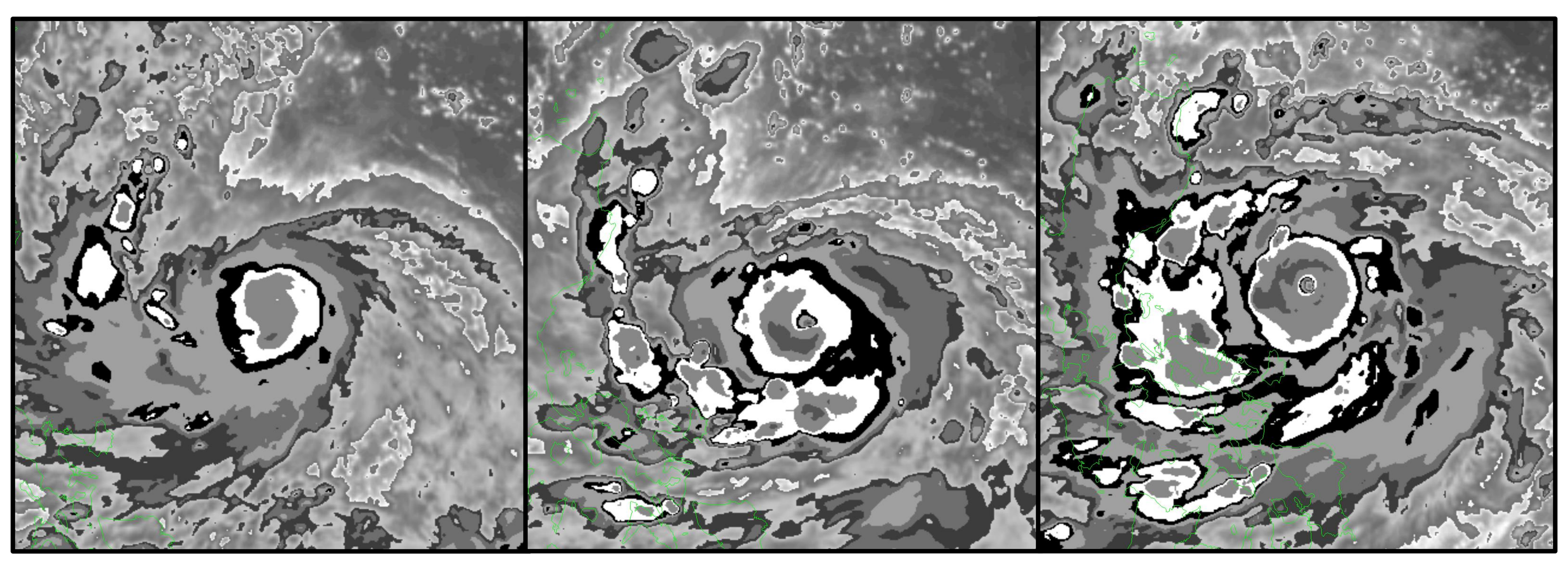

Figure 1. RI of Typhoon 18W on Sep 24, 2022 at 06Z (left), 12Z (middle), and 18Z (right).

Methods

Several TC's that underwent RI were examined. Two experienced JTWC satellite analysts performed independent, 6-hourly intensity estimates for the RI phase using the Dvorak technique.

- Use BD-enhanced, 10.3µm IR imagery to determine DT (*figure 1*).
- Apply constraints to DT to determine FT/CI[4].
- Convert CI to the equivalent sustained wind speed.
- Compute the difference between the converted CI and the best track intensity[1,5]. The original fix data was also compared (*figure 2*).

A subjective reanalysis of satellite data was conducted for the largest errors.

12W (2022)					
Date/Time	Best Track	Fix Intensity	Error	Unconstrained	Resulting Error
8/28 18Z	50kt	T3.0/45kt	-T0.3/-5kt	T3.0/45kt	-T0.3/-5kt
8/29 00Z	60kt	T3.5/55kt	-T0.3/-5kt	T3.5/55kt	-T0.3/-5kt
8/29 06Z	75kt	T4.0/65kt	-T0.4/-10kt	T4.0/65kt	-T0.4/-10kt
8/29 12Z	100kt	T5.0/90kt	-T0.4/-10kt	T5.5/102kt	+T0.1/+2kt
8/29 18Z	120kt	T5.5/102kt	-T0.7/-18kt	T6.0/115kt	-T0.2/-5kt
Mean Absolute Error			9.6kt	-	4.4kt
Root Mean Squared Error			10.7kt	-	5.9kt

Table 1. Intensity fix estimate difference from Typhoon 12W's best track intensity (2022).

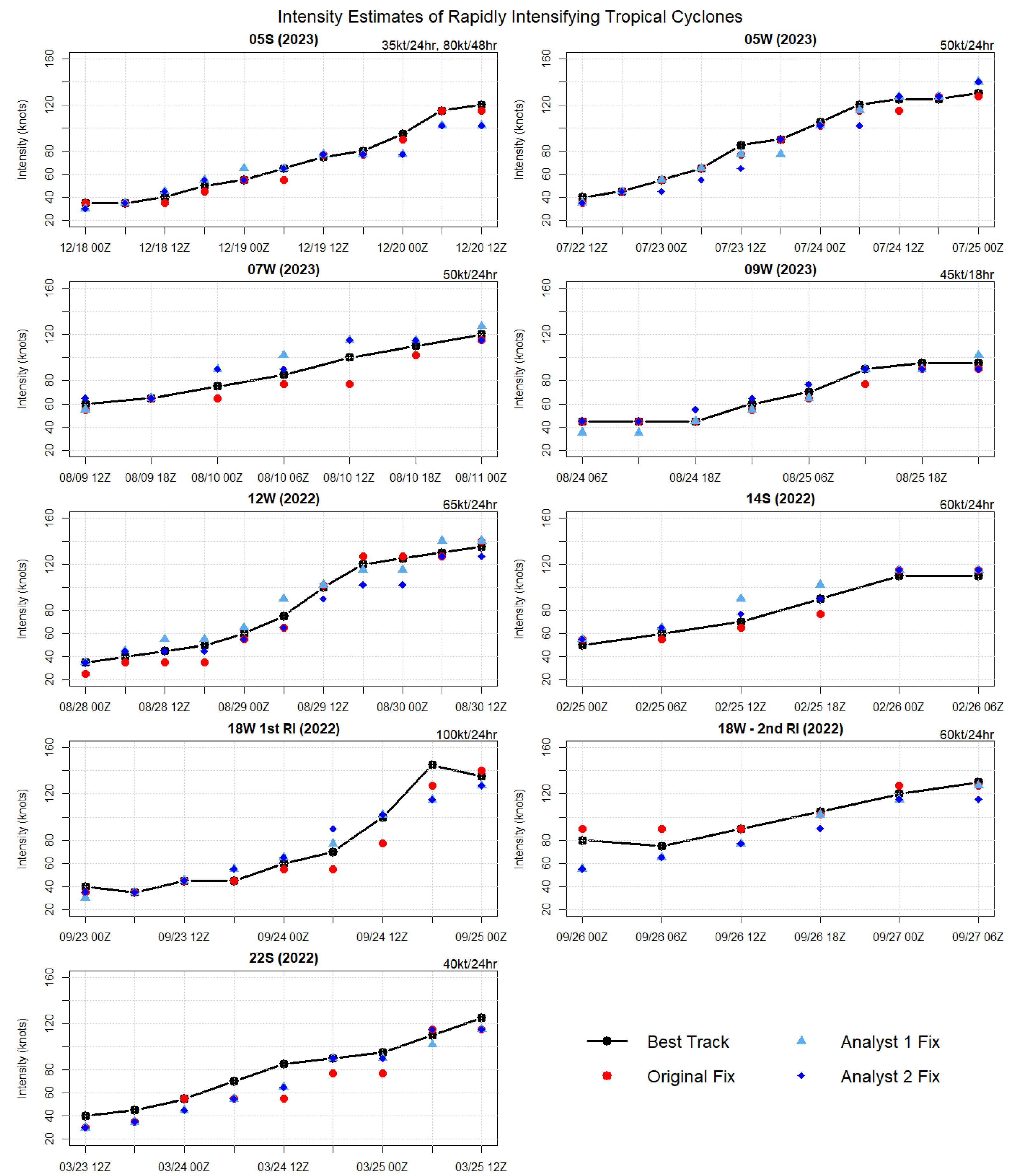

Figure 2. Intensity estimate scatterplots of selected RI cases compared to the best track.

Analysis

The distribution of errors were similar across the board, which tend to have larger, longer left tails (*figure 4*). Linear regressions performed on the Mean Absolute Error (MAE) and Root-Mean-Square Error (RMSE) yielded insufficient evidence of a relationship between more extreme RI and larger errors. Several sources of errors were identified for these RI cases:

1. The combination of a pinhole eye feature and a large scan angle can lead to cooler eye temperatures and an erroneously low intensity estimate.
2. Once intensity estimates fall behind, the errors can grow with time when constraints are applied (*table 1*).
3. The embedded center method is susceptible to error even if the center position fix was assessed to be accurate based on available data (*figure 3*).

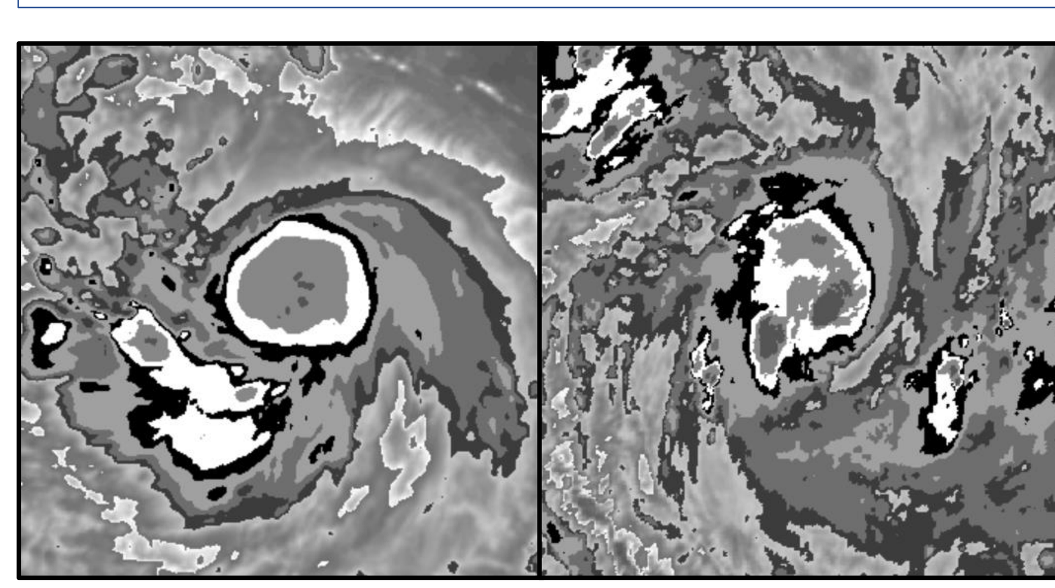

Figure 3. Embedded center patterns in 2022 from: (Left) Typhoon 18W estimated at 60kt. (Right) Tropical Cyclone 22S estimated at 85kt. Applying the method yields DT=4.0, or 65kt, for both cases.

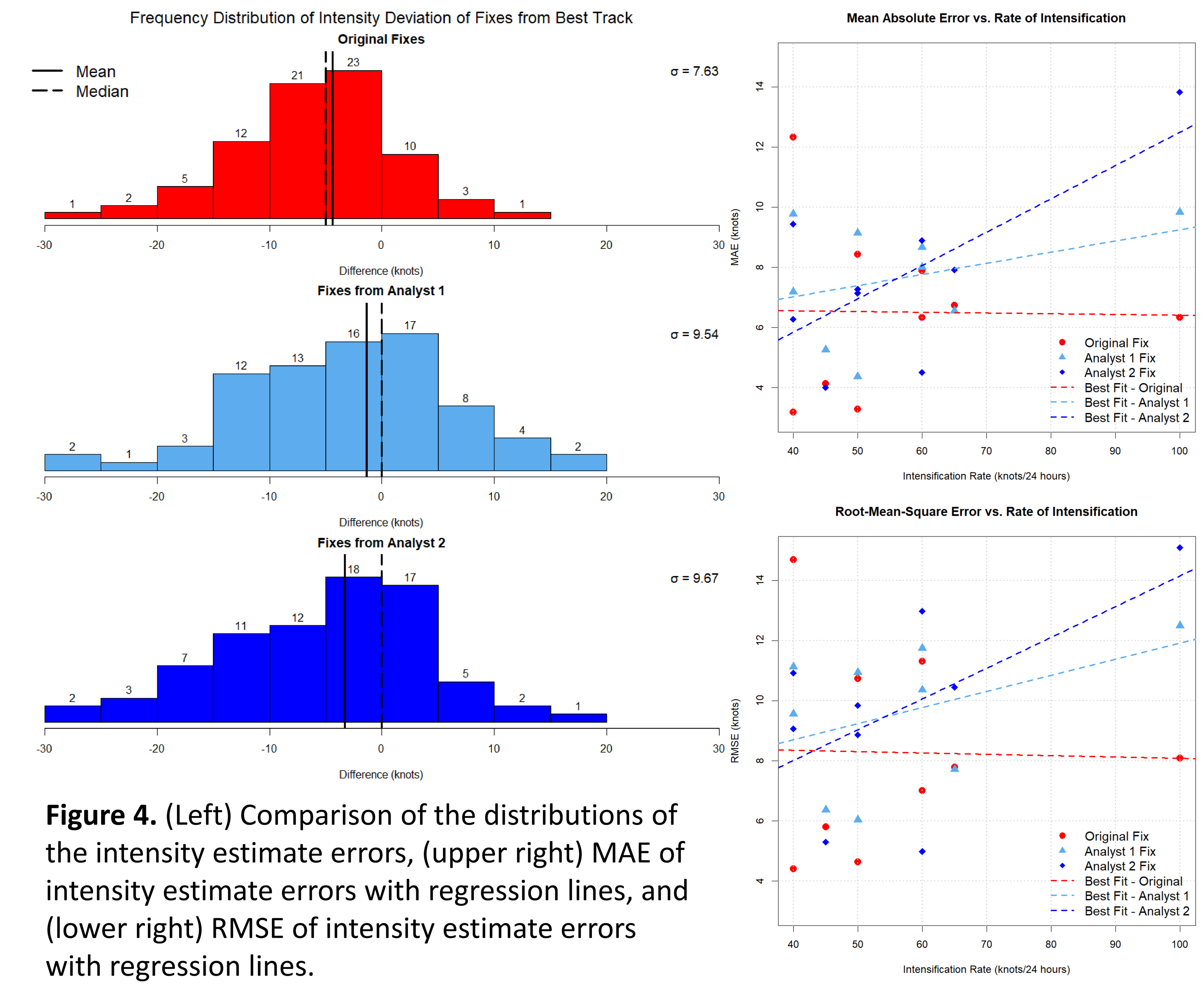

Figure 4. (Left) Comparison of the distributions of the intensity estimate errors, (upper right) MAE of intensity estimate errors with regression lines, and (lower right) RMSE of intensity estimate errors with regression lines.

Conclusion

These "errors" represent a difference from the best track, which can be biased towards Dvorak estimates, especially in the absence of weather observations. Nevertheless, the results of the subjective analysis agree with those of similar studies. Though this study did not establish a statistically significant relationship between error means and RI rate, it confirmed during subjective reanalysis some of the known biases of the Dvorak technique, which appear to be amplified during RI. The study proposes several mitigating solutions:

1. Assume the WMG gray shade for eye temperature in pinhole eyes.
2. Evaluate the need to loosen constraints based on NHC studies[1,5].
3. Modify the embedded center technique to consider storm size.

References

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