Dear Referee #2,

Thank you very much for your thoughtful review and constructive comment. Following your earlier comment on the red-aurora issue, we still lack the observations required for a definitive analysis, and the TIE-GCM-based estimate indeed has uncertainty. At this stage, we are unable to resolve this issue. Through our discussions with you, we realized that relying solely on qualitative pattern recognition to emphasize scattering while overlooking other mechanisms was premature. Accordingly, we have extensively revised the Introduction and Discussion to (1) remove the previous qualitative inference in the Introduction, emphasize that scattering is only one of several possible causes of the wind differences, and clearly state our current limitations, (2) add relevant background and discussion on red aurora and (3) remove the incomplete assessment of scattering's impact on wind observations from the Discussion. Thank you for your insightful comments. It has led us to conduct more comprehensive and rigorous consideration and discussion. The following is our thinking and modification.

Our research is based on the spatially uneven airglow. At mid-latitudes, the main factor significantly causing uneven red-line airglow is the red aurora. Airglow and aurora form differently, but their emission bands and height profiles are so alike that ground optical instruments record them as one. Red aurora, mainly from <80 eV electrons, produces 630.0 nm stable auroral red arc (SAR) in mid-latitudes during storm recovery (Upadhyay et al., 2025) and has also been observed in the main phase (Shiokawa et al., 2013). Red aurora is thought to inject less energy and to spread over a broader region than auroras at other wavelengths (Rees and Luckey, 1974; Gabrielse et al., 2021). Kataoka et al. simulated red-line profiles for comparison between May 9th and May 11th (Kataoka et al., 2024). They found that the red aurora lifted the emission peak above 300 km and markedly increased the intensity above the peak. Consequently, when the interferometer faces the aurora, it may sample winds from higher and farther away than the usual 250 km height. We agree that such errors could exist, and the significant deviations in the northward observations and scattering models seem to point to this as well.

In our last response, TIE-GCM was taken as a large-scale storm-time wind field for reference. We used it to estimate that the wind difference caused by the interferometer's shifted sight would probably be smaller than what we observed. About the TIE-GCM simulation, we agree that its spatial resolution and empirical convection pattern could not accurately catch small-scale aurora (Matsuo and Richmond, 2008). It primarily simulates large-scale Joule heating processes in the polar region and the resulting thermospheric surge. Using the TIE-GCM to address this issue is indeed likely to introduce considerable uncertainty. At present, we lack additional thermospheric-wind or auroral instruments poleward of our station, so the true value of both the red aurora and the neutral wind remains unknown, and the possible influence of red aurora cannot yet be ruled out.

In the original Introduction, we relied on a qualitative assessment of the observed pattern and ascribed the wind bias primarily to scattering. We now realize that this conclusion was premature. It could mislead readers into ignoring other possible causes. Therefore, we have carefully revised the Introduction to clarify that, among dynamical processes, red-aurora effects, scattering, and other factors, only the scattering can be evaluated with our model, whereas the others cannot yet be ruled out. We have removed the assessment of scattering's impact on wind observations from the Discussion (Section 4.3), since we overestimated the scattering impact on red-line wind measurements in the previous manuscript. Our observations likely contain complex contributions from aurora and dynamics that, as noted, cannot yet be quantitatively separated. Section 4.3 has therefore been removed to prevent an incomplete assessment. We have also revised several related yet overly assertive statements elsewhere in the manuscript. In addition, we have added brief context on the aurora effects in the Introduction and expanded the Discussion to address non-scattering influences in greater detail. Below, we attach the key revisions. All corresponding revisions in the manuscript are highlighted in purple. Thank you again for this valuable suggestion.

The key revisions are:

(1) Add a paragraph on aurora and other potential influences at L59 of the Introduction.

"Scattering-induced biases are more pronounced during spatially uneven airglow brightness, such as during auroras (Harding et al., 2017a). Uneven airglow brightness refers specifically to inhomogeneous red-line emissions. At mid-latitudes, marked uneven red-line airglow usually comes from red aurora. Despite their distinct origins, the spectral and altitudinal overlap of airglow and aurora will let ground-based optical instruments conflate the two. **For red-line observations, the aurora itself may also bias the derived winds.** Aurora could elevate the red-line emission profile (Kataoka et al., 2024b), so the interferometer samples winds that are both higher and farther away. This makes the northward view sense winds deviate from the expected thermospheric wind at 250 km altitude when looking toward the aurora. Additionally, spectral contamination from precipitating energetic ions could also bias interferometers (Makela et al., 2014). They suggested that the enhanced downwelling at mid-latitudes during storms might result from the contamination of the spectral profile by fast O atoms associated with the influx of low-energy O^+ ions."

(2) We have revised the end of the Introduction to remove any assertive qualitative analysis and to state the objectives of our study more clearly.

"During two geomagnetic storms on May 10th and October 10th, 2024, …… These atypical winds at SIZW only occurred with auroras statistically and significantly deviated from the regional climatological norms over the China region (Jiang et al., 2018; Yang et al., 2020). This raises the question of whether the atypical winds arise from dynamical processes, are influenced by red aurora, or stem from scattering-induced biases and other measurement-related factors. Unfortunately, most of these mechanisms could amplify the wind-speed contrast between opposite cardinal directions, rendering them difficult to disentangle (Harding et al., 2017a). ~~However, the simultaneous variations in vertical winds, horizontal differences, and red-line brightness show no phase lag, thus not providing evidence for the energy conversion process (Ishii et al., 1999). Instead, these variations resemble a systematic error, as they all involve negative LOS speeds. This suggests that scattering impact may be more significant than dynamic mechanisms in these cases.~~ **Given the scarcity of additional thermospheric-wind or auroral instruments, we remain unable to quantify every potential mechanism. Motivated by the observed phenomena, this study attempts to estimate how scattering modulates the atypical winds in these storms.** While prior studies focus on vertical wind biases of Fabry-Perot interferometers under auroral conditions (Harding et al., 2017a; Harding et al., 2017b), we will analyze the formation and patterns of horizontal differences caused by scattering. We will also incorporate Doppler Asymmetric Spatial Heterodyne (DASH) interferometer data to compare scattering impact across different interferometer types. As red auroras now regularly appear at the low magnetic latitudes of Japan and China during elevated solar activity (Kataoka et al., 2024a; Kataoka et al., 2024b; Ma et al., 2024), a deeper understanding of scattering-induced biases is essential for the proper use of interferometer data collected in these regions. In the following text, a scattering radiative transfer model is used to simulate interferometer observations in two cases with visible aurora. The presence and patterns of scattering-induced biases are analyzed by comparing simulations with observations."

(3) We have revised L405–412 of the Discussion to expand the auroral influences.

"Furthermore, these bright region observations do not necessarily reflect the usual 250 km thermospheric wind. In Fig. 3 and Fig. 5, the north-looking wind observations show unusually high wind speeds, which are significantly different from the simulations. In particular, on October 10th, the north-looking wind speed varied dramatically with the intensity of the northern aurora. During the two auroral peaks, the north-looking wind direction also reversed. This indicates that the interferometer receives an additional effect when it looks toward the aurora. **This indicates that the interferometer receives an additional effect when it looks toward the aurora.** Kataoka et al. showed that red aurora lifted the red-line emission profile, raising its peak above 300 km and brightening the upper part on May 11th (Kataoka et al., 2024b). Consequently, the interferometer can sample winds that are higher and more poleward. Because storm-time surges propagate from the polar region to the equator, these higher, poleward regions are likely to carry stronger equatorward winds. The interferometer may record a larger wind speed toward the aurora. Additionally, spectral contamination from precipitating energetic ions can also bias interferometers (Makela et al., 2014). In other words, the interferometer is partly sensing the speed of non-neutral species, boosting the observed wind. These issues lie beyond what scattering models can reproduce. From the observed pattern, we infer the presence of non-scattering effects, especially in the poleward view. Due to the absence of nearby higher-latitude neutral-wind observations relative to SIZW, quantifying their respective contributions remains challenging."

(4) Section 4.3 has been removed from the discussion since we overestimated the scattering impact on red-line wind measurements in the previous manuscript.

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