Author comment in response to Anonymous Referee #1

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We thank the referee for the constructive assessment and for identifying where the physical interpretation can be made more informative. We have completed the requested limited F10.7 comparison and report its results below. Following the editorial instruction for this final-response phase, we have not prepared a revised manuscript. The textual and figure changes described below are proposed for a subsequent revision if invited by the editor.

R1.1. Physical interpretation of the orbit and IPP comparison

Referee comment

> *The discussion identifies plausible mechanisms for both the winter and summer enhancements, but in my opinion it does not fully exploit the data to constrain them. The GEO vs. IGSO/MEO comparison is the methodological strength of the paper and could be used more explicitly to favour or disfavour specific drivers. For the winter case, the near-identity across motion classes already argues against a stationary horizontal gradient; making this point explicit would strengthen the interpretation.*

Response

We agree that the comparison should lead directly to a physical interpretation. The winter afternoon enhancement appears along nearly repeated GEO viewing paths as well as moving paths. It remains present in both motion classes when elevation and azimuth are matched. This supports disturbances evolving within, or passing through, the repeatedly sampled region. Satellite motion through a stationary horizontal gradient alone is therefore an inadequate explanation for the observed winter pattern. This behavior is consistent with traveling or evolving daytime disturbances, including the regional winter daytime MSTID environment discussed in the manuscript.

The directional comparison also helps explain summer. The near-midnight increase is present in aggregate GEO observations, so a moving viewing path is not required to observe it. However, the enhancement differs among satellite paths, and the moving-path advantage found with elevation matching reverses when azimuth is also matched. A reasonable physical interpretation is a time-dependent nighttime enhancement with horizontal organization: different paths sample different parts or orientations of the disturbed ionosphere. The result does not support treating IPP speed itself as the cause of a stronger disturbance.

We would make these inferences explicit in Sect. 4.2 while stating their spatial meaning more precisely in Sect. 2.2. TEC is a path-integrated measurement, and the thin-shell IPP is a geometric representative of the path, not a point measurement of electron density. Accordingly, the comparison supports temporal variability along nearly repeated paths and directional differences, but cannot uniquely locate the structures or separate local development from propagation. Joint direction matching also reduces the sampled dates, so its effect cannot be assigned to azimuth alone. We would avoid describing the winter groups as statistically equivalent: their difference is unresolved in the direction-matched sample, which is not an equivalence test. The well-supported orbit comparison is principally GEO versus IGSO; the MEO subsets contain only 9 winter and 18 summer paired dates and are descriptive.

Evidence already supplied: main Table 1; Supplement Tables S16 and S18; satellite and omission results in Tables S19-S21. No new orbit experiment is needed for this clarification.

R1.2. High- and low-F10.7 comparison

Referee comment

> *Additionally, the six-year dataset spans a wide range of solar activity (F10.7 ~65-200 sfu). A simple split by high/low F10.7 would help clarify whether enhancement amplitude scales with background plasma density, which is relevant for distinguishing MSTID-like processes from other candidates.*

Response

We performed this comparison using the existing paired-date winter and summer samples, preserving the original processing, observation-night date assignment, and equal-width LST 13-14 and 23-00 sectors. Dates were divided at the median daily F10.7 within each season: 70.35 sfu in winter and 72.75 sfu in summer. Thus, “high” and “low” denote relative groups within the sampled season, not solar-maximum and solar-minimum conditions. The eligible winter dates span 65.9-129.5 sfu and the summer dates 67.2-111.5 sfu, narrower ranges than that of the complete record.

For clarity, enhancement is expressed positively in each season: afternoon minus near-midnight in winter, and near-midnight minus afternoon in summer. All entries below are medians of paired-date contrasts, not differences between separately pooled sector medians. Intervals are 95% date-bootstrap intervals from 10,000 resamples; high-minus-low differences were resampled independently within the two groups.

Season	Group	Dates	Median enhancement (TECU)	95% interval (TECU)
Winter	Low	226	0.03670	0.02816 to 0.04445
Winter	High	226	0.05151	0.03761 to 0.06287
Summer	Low	229	0.01238	0.00767 to 0.01907
Summer	High	229	0.01862	0.01208 to 0.02740

The high-minus-low difference is 0.01481 TECU in winter (95% interval -0.00124 to 0.02957) and 0.00624 TECU in summer (-0.00286 to 0.01643). Both seasonal enhancements are present in both groups. Their point estimates are higher in the high-F10.7 groups, but neither difference is resolved from zero by these intervals.

The comparison therefore shows persistence of the seasonal patterns across the two sampled activity subsets, while leaving the strength of solar-activity modulation uncertain. F10.7 is also not a direct measurement of local electron density. The groups differ in year composition, so this test cannot isolate density scaling from other interannual conditions. We would report the table and split definition in the Supplement and summarize this interpretation in the Discussion, without assigning a disturbance mechanism from the sign of the point estimates.

R1.3. Comparison with regional disturbance climatologies

Referee comment

> *On a related note, the paper cites MSTID, spread-F, and plasma-bubble literature for the summer near-midnight enhancement, but does not directly compare the observed seasonal timing and amplitude with the occurrence statistics reported in those works. Discussing whether the observations are consistent or not with the known regional climatology of these phenomena would make the physical interpretation more grounded.*

Response

We agree and propose to make the agreement and the differences explicit, rather than listing these processes together as interchangeable explanations.

Over Taiwan, Cheng et al. (2021) reported summer southward MSTIDs mainly during 21:00-03:00 LT, with spring and winter daytime populations. Their study also resolved propagation direction, including a northward nighttime population in part of spring. Over Hong Kong, Le et al. (2024) found summer nighttime MSTIDs during 22:00-02:00 LT and winter daytime activity. The Hainan winter-afternoon and summer near-midnight patterns are compatible with this regional timing. The comparison would retain the source studies' time labels and season definitions: for example, Le et al. use May-July for summer, whereas we use June-August. We would not claim a minute-scale timing difference from these differently defined climatologies.

The Hainan spread-F literature provides a more discriminating comparison. Wang et al. (2010) found summer mixed spread F preferentially near or after midnight, whereas strong range spread F favored equinoxes and peaked before midnight. Shi et al. (2011) likewise found equinoctial maxima in strong range spread F and L-band scintillation. Our summer near-midnight maximum is consequently more compatible in timing with the late-night summer populations than with a simple interpretation in terms of the strongest equinoctial scintillation-associated events. This is a constraint on candidate populations, not a classification of the present TEC windows.

Amplitude requires a separate comparison. Le et al. selected coherent, propagating events with DTEC amplitude exceeding 0.5 TECU after Savitzky-Golay detrending. Our 0.01536 TECU summer value is a median night-minus-afternoon difference of running-median-based RMS, including weak and unclassified observations. It is neither an individual wave amplitude nor an occurrence rate. A numerical ratio between those quantities would not measure a physical difference in disturbance strength. We would state this distinction explicitly, so that the regional comparison informs possible processes without equating unlike observables.

These additions are proposed for Sect. 4.1, with a short link to the candidate explanations in Sect. 4.2. The cited studies are already in the manuscript bibliography.

R1.4. Interpretation of the VTEC-dTEC relationship

Referee comment

> *Finally, the non-linear dependence of dTEC RMS on background VTEC shown in Figure 1e is relevant to whether the enhancement is driven by a density-dependent process, as MSTIDs generally are. A brief interpretive remark on this would be welcome.*

Response

We agree that the background relationship matters. The relevant panel is Fig. 1d in the submitted version. It contains 276 matched month-local-time climatological cells, not individual disturbance events. Its broad, non-monotonic scatter shows that the short-timescale amplitude is not described by a simple increase with background VTEC across these cells. Different local-time and seasonal conditions are combined in that plot.

The physical implication is that background electron content alone does not describe the observed amplitude distribution; the occurrence, strength, motion, and viewing geometry of shorter-lived structures also matter. The plot does not isolate a nonlinear response law or establish that the underlying processes are independent of density. The F10.7 comparison above likewise leaves the strength of solar modulation uncertain. We would replace the submitted wording about large plasma content being “neither necessary nor sufficient” with this more direct interpretation in Sects. 3.3 and 4.1.

R1.5. Organization of Figure 1

Referee comment

> *Figure 1 combines coverage maps, activity index time series, and a diagnostic result in a single figure. Moving the methodological panels to the supplement, where similar material already appears, would improve readability.*

Response

We agree. In a subsequent revision, we propose to move the coverage, year-weighting, and activity-composition panels (submitted Fig. 1a-c) to the Supplement, with a short reference from the data and methods section. The VTEC-dTEC comparison (submitted Fig. 1d) would remain in the main Results next to its interpretation. The figure numbering and all cross-references would then be updated together. These changes have not been implemented during the present final-response phase.

References cited in this response

Cheng et al. (2021), Statistical study of medium-scale traveling ionospheric disturbances in low-latitude ionosphere using an automatic algorithm. https://doi.org/10.1186/s40623-021-01432-1

Le et al. (2024), Occurrence and characteristics of medium-scale traveling ionospheric disturbances observed by BeiDou GEO satellites over Hong Kong. https://doi.org/10.1029/2024JA032510

Wang et al. (2010), The statistical properties of spread F observed at Hainan station during the declining period of the 23rd solar cycle. https://doi.org/10.5194/angeo-28-1263-2010

Shi et al. (2011), Relationship between strong range spread F and ionospheric scintillations observed in Hainan from 2003 to 2007. https://doi.org/10.1029/2011JA016806