Dear Editor,

we sincerely thank the Reviewer #2 for recommending acceptance of our paper and we warmly thank the Associate Editor for the careful reading of the revised manuscript and for the constructive comments. Below we provide a point-by-point reply to all comments we carefully addressed in the revised version of the manuscript. We also highlighted all changes in the track-changes version.

Sincerely,

Tommaso Alberti

(on behalf of all the authors)

Associate Editor Comments

I believe that one of the main criticisms raised by Referee#1 was not completely understood and addressed. In your methodology, you start from extracting intense turbulence events from measurements and then you identify the large-scale circulation (Z500) associated with them. Addressing the Referee comment, in the revised manuscript, lines 149-151 say "It is important to emphasize that similarity in Z500 does not imply identical turbulence-generation mechanisms or identical atmospheric states. Instead, it identifies comparable large-scale circulation configurations suitable for circulation-conditioned attribution." That's clear now, but I believe that the doubt of the referee was about the fact that when you look for analogues large-scale field in the past, you find days where synoptic conditions are very close, but you are not sure that the days you have identified are characterized by any turbulence, isn't it? If this is the case, you are comparing a turbulence-prone environment in present climate, against an environment in the past which is similar in the synoptic scale, but that did not produce any turbulence. In this condition, the comparison may be tricky, and the conclusions may be misleading.

Since this point is not fully clear neither for me, I would strongly suggest the authors to clarify in the paper or provide an answer/explanation if this is just a further misunderstanding. In any case, this point deserves to be clarified.

We thank the Editor for raising this point, which allows us to clarify an important aspect of the methodology that was not sufficiently explicit in the manuscript. The Editor is correct that we cannot verify whether turbulence occurred on the individual analogue days: automated EDR reports are not available for most of the 1950–2023 period. However, the comparison underlying the attribution is not between the observed (turbulent) 2024 event and past (possibly non-turbulent) days. The observed event is used only to define the target circulation pattern. Analogues are then searched for in both the historical (1950–1986) and the present-day (1987–2023) periods using exactly the same criterion (Z500 similarity), and neither population is selected on the basis of observed turbulence. The present-day analogues are therefore no more "turbulence-guaranteed" than the historical ones: both are populations of ERA5 days of the same kind, sharing a synoptic configuration similar to that of the observed event.

Conditioning on the large-scale circulation is precisely the core of conditional, circulation-based attribution (Yiou et al., 2017; Jézéquel et al., 2018; Faranda et al., 2023): the question addressed is how the same dynamical configuration translates into different outcomes in a different climate. In this framework, finding higher turbulence diagnostics under the same circulation pattern is itself the relevant information, since it shows that the change cannot be explained by a change in the frequency of the synoptic configuration, but rather by a change in the environment in which that configuration develops.

The attribution compares these two analogue populations in terms of the turbulence diagnostics (VWS, DEF and TI1) computed from ERA5. The attributed quantity is thus the change in the turbulence-favourable environment under comparable large-scale circulation, i.e., whether the same synoptic configuration is now associated with higher turbulence potential than in the past, rather than the occurrence of turbulence on individual analogue days. In this sense, the approach is consistent with reanalysis-based studies of long-term changes in clear-air turbulence (e.g., Prosser et al., 2023; Foudad et al., 2024), which also rely on turbulence diagnostics rather than direct observations, with the additional constraint of conditioning on the large-scale circulation. Furthermore, the composites of the turbulence diagnostics computed over the analogue populations of both periods display enhanced VWS and TI1 in the same regions where they are enhanced during the observed event. Hence, the selected analogues are not merely similar in terms of Z500, but are also turbulence-favourable days in a diagnostic sense, with turbulence-prone regions consistent with those of the event. The observed EDR reports serve to identify the events of interest and to verify that the diagnosed turbulence fields are spatially consistent with where turbulence was actually encountered (Figs. 2, 6, 10 and 14, panels c–d, compared with Figs. 1, 5, 9 and 13).

To make this explicit, we have added to the "Analogue Identification" step (Sect. 2.2) a statement that the observed event only defines the target circulation, that neither analogue population is selected on the basis of observed turbulence, and that turbulence occurrence on analogue days cannot be verified. We also added to the "Climate Attribution" step a statement clarifying that the comparison is between two analogue populations of the same kind, that the attributed quantity is the change in the turbulence-favourable environment rather than turbulence occurrence, that conditioning on the circulation is the essence of conditional attribution, and that the composites of the turbulence diagnostics over the analogues are consistent with the turbulence-prone regions of the observed event. We added to the limitations paragraph of the Conclusions that turbulence encounters on analogue days cannot be verified, and that, as the EDR archive lengthens, a natural extension will be to verify whether present-day analogues are also associated with a higher frequency of observed MOG turbulence.

That said, here are some minor issues to correct in the revised version of the paper.

line 14: what does “stronger turbulence diagnostic” mean? Isn’t it just “stronger turbulence”?

The distinction is intentional and is directly related to the main comment: we diagnose turbulence potential through TI1 and its components, not observed turbulence intensity. To

avoid ambiguity, the sentence now reads "higher values of the turbulence diagnostics, i.e., more turbulence-favourable environments".

line 37 and line 94: citation missing, I read just (, ICAO)

This was a formatting issue in the bibliography entry, where the corporate author was not protected by braces. The entry has been corrected and the citation now reads correctly.

Some acronyms are defined more than once. e.g. lines 92, 135 EDR - eddy dissipation rate has been already defined at line 84; lines 156-157: TCWV, CAPE, CIN, SST already defined. Please, check acronyms across the whole paper.

We have checked all acronyms. Each is now defined once in the abstract and once at first use in the main text (EDR, PIREPs, MOG, Z500, TCWV, CAPE, CIN, SST, t2m, CONUS); subsequent redefinitions have been removed. Definitions are retained in figure captions so that captions remain self-contained.

lines 136-137 “EDR provides … in aviation” Repetition, already written in lines 92-93

Removed

line 361: remove comma “(Fig. 14e),.”

Corrected

Figures 2, 6, 10 and 14: panel (a): is it geopotential or a geopotential anomaly? The scale on the right is between -200 and 200 m. What is it? In the caption you should describe the first row of these figures, I guess it is the standard output of Turbometer.

Panel (a) shows the Z500 anomaly with respect to the 1950–2023 daily climatology, as in the standard ClimaMeter output. The captions now describe the first row (attribution and rarity gauges, defined in Sect. 2.2), specify the variable and unit of each panel (a–d), and state that panel (e) shows differences in m while panels (f–h) show relative differences in %. All figures have been regenerated with the units shown on all panels, and the unit of the VWS colour bar has been corrected (s^{-1}).

Figures 3, 7, 11 and 15: panels a-d: unit of measure is missing. As for the point above, is it Z500 or an anomaly? panels e-h: unit of measure is missing. panels i-l: why is in km/h? Should be in m/s. You may consider to add this info in the caption.

Panels (a–d) show Z500 anomalies with respect to the 1950–2023 daily climatology; this is now stated in the captions. The figures have been regenerated with units on all panels, wind speed has been converted to m s^{-1}, and SST is now shown in °C for consistency with the text. While

revising these captions, we also noticed and corrected an error in the caption of Fig. 15 (CONUS), where panels (e–h) show 2-m temperature and panels (i–l) SST.

Figures 4, 8, 12, and 16: missing unit of measure in all panels. You may consider to add this info in the caption.

The figures have been regenerated with units on all panels, which are also given in the captions (CAPE and CIN in J kg^{-1}, TCWV in kg m^{-2}).