

Responses to referee's comments:

We sincerely thank the referee for the careful review and constructive comments, which have helped us improve the manuscript. Our point-by-point responses are provided below in blue.

Referee #1:

Review of “Concurrent Heat and Intense UV Extremes in North America: Divergent Dynamical Drivers and Exacerbated Ozone Pollution” by Bao et al.

This manuscript examines the summer co-occurrence of heat and intense surface UV radiation over North America, identifies two regional hotspots, and explores the associated circulation patterns and surface ozone variations. The topic is relevant to compound climate–environmental risk and has potential merit. However, several aspects of the event definition and attribution require further clarification and strengthening. In particular, most composites, including the ozone analysis, appear to be conditioned on extreme heat years only; therefore, the respective contributions of concurrent UV extremes and heat require more careful quantification. In addition, the ozone analysis would benefit from a fuller consideration of precursor emissions, chemical sensitivity, and relevant meteorological and chemical processes. Addressing these issues would substantially strengthen the manuscript and support a more robust interpretation of the results.

We appreciate the positive evaluation from the reviewer and have made further modifications based on the valuable comments.

Major Comments:

1. The paper focuses on concurrent heat and intense UV extremes, whereas the monthly composites are currently selected using only a regional monthly temperature threshold. Since the UV condition is not included in the composite selection, and Figs. 2–6 are described as “during/associated with extreme heat events,” it would be helpful to clarify the extent to which the reported UV and ozone anomalies specifically reflect compound heat–UV conditions. I encourage the authors to consider defining the primary event using joint temperature and UV thresholds at a consistent temporal and spatial scale, and to report the corresponding event years/days and sample sizes for each month and region. Repeating key circulation, cloud, and ozone analyses for these joint events would strengthen the compound-event interpretation. If the joint sample is limited, the authors may also consider framing the results more explicitly as heat-event composites with concurrent UV anomalies.

We thank the referee for this constructive suggestion. We have introduced joint temperature and UV thresholds as the primary monthly event definition and repeated the circulation, cloud, and ozone analyses for the resulting compound samples. The event years and sample sizes are now reported for each region, month, and analysis period.

1. Consistent event definition and sampling

A compound heat–UV event is now defined at the monthly scale as a month in which the area-weighted regional mean of both T2m and UV exceeds its respective detrended climatological mean plus one standard deviation ($+1\sigma$). The temporal and spatial scales are consistent with those used in the original heat-event composites. Linear trends were removed immediately after data extraction as an initial preprocessing step, before threshold calculation and event selection, to reduce the influence of long-term background changes on event identification. Section 2.2 now makes the joint selection explicit, extending the heat–UV framework discussed by Xia et al. (2022).

Table R1 lists the four event categories over 1940–2022; Tables R3 and R4 report the independently identified ozone and SWC samples over 2003–2022 and 1950–2022. The updated compound composites are reproduced in Figs. R1–R6. The recomputed temperature-based reference maps are shown alongside this comparison in Figs. R7–R9. The event catalogues are also included as Tables S1–S3 in the manuscript Supplement.

2. Composite references and statistical comparisons

Composite anomalies retain the full-period calendar-month climatology after detrending as their reference. For the meteorological composite maps, two-sided Welch tests compare selected event years with the remaining non-target years for the same region, month, and analysis period. Compound maps use non-compound years as controls, while heat-event maps use non-heat years. Surface ozone composite maps display the anomaly fields without significance stippling or $\pm 1\sigma$ contours; regional ozone comparisons are presented under Major Comment 2.

Table R2 compares maximum anomalies within each study box for the recomputed temperature-based (heat-event) and compound composites. The heat-event reference includes all heat years, including compound years, and both sets use the revised detrending procedure. Joint selection yields larger T2m and UV maxima in both hotspots. Ozone maxima are higher in five of the six region–month comparisons and equal in Northern June. For example, the Northern August maximum increases from 4.57 to 10.47 ppbv and the Southern June maximum from 4.16 to 5.83 ppbv. The joint definition thus identifies months with more pronounced heat and UV anomalies and generally higher ozone maxima, extending the original temperature-based comparison to concurrent conditions. The complete within-box comparison is also retained as Table S10 in the manuscript Supplement.

3. Surface ozone data and period-specific categories

For the ozone analysis, temperature and UV thresholds were recalculated over 2003–2022 to match the CAMS EAC4 period. Table R3 provides the resulting event years and sample sizes for the four categories. Regional ozone comparisons against heat-only and UV-only events are presented in our response to Major Comment 2.

Table R1. Monthly event years by category, 1940–2022.

Region	Month	Compound years (n)	Heat-only years (n)	UV-only years (n)	Normal years (n)
Northern	Jun	1955, 1956, 1961, 1970, 1987, 1988, 2021 (7)	1941, 1995, 2006 (3)	1962, 1972, 1974, 1979, 1986 (5)	Remaining years (68)
Northern	Jul	1947, 1960, 1989, 2006, 2007, 2021 (6)	1941, 1964, 1975, 2002, 2012 (5)	1943, 1957, 1959, 1967, 2017 (5)	Remaining years (67)
Northern	Aug	1940, 1955, 1961, 1969, 1971, 1983, 1998, 2001, 2003 (9)	1949, 1973, 1981, 1984, 1991, 2022 (6)	1967, 1970, 1996, 2006, 2008, 2011, 2012 (7)	Remaining years (61)
Southern	Jun	1948, 1952, 1953, 1954, 1956, 1990, 1998, 2008, 2011, 2012 (10)	1958, 1980, 1994, 2010, 2018 (5)	1960, 1964, 1974, 2005, 2020 (5)	Remaining years (63)
Southern	Jul	1954, 1957, 1980, 2001, 2011, 2016, 2022 (7)	1951, 1953, 1963, 1964, 1966, 1969, 1998, 2020 (8)	1956, 1962, 1965, 1995, 2000, 2019 (6)	Remaining years (62)
Southern	Aug	1943, 1948, 1952, 1962, 2000, 2010, 2011, 2019, 2020 (9)	1944, 1951 (2)	1950, 1954, 1956, 1958, 2009, 2012, 2015 (7)	Remaining years (65)

Note: Parentheses give selected-year counts (n). Remaining years exceed neither threshold.

Following the CAMS guidance for surface values of three-dimensional variables, we have replaced the previous pressure-level field with the lowest model layer of CAMS EAC4 (model level 60). Ozone mass mixing ratios are converted from kg kg^{-1} to ppbv using $q \times 10^9 \times (28.97/48.00)$. All ozone composites, concentration distributions, regional comparisons and sensitivity analyses have been recomputed with this surface-layer field and the corrected conversion. The changed concentrations therefore reflect the corrected conversion, the surface-layer selection and the updated preprocessing. The surface, circulation and ozone descriptions have been updated using the recomputed results. The revised text distinguishes within-box maxima from regional mean ozone contrasts and describes the month- and region-dependent ozone distributions.

Table R2. Maximum composite anomalies within the study boxes.

Region / Variable	Jun	Jul	Aug
North T2m (heat-event, K)	2.99	2.55	2.79
North T2m (compound, K)	3.73	3.21	3.09
North UV (heat-event, W/m^2)	3.37	2.47	2.29
North UV (compound, W/m^2)	3.67	2.87	2.93
North O ₃ (heat-event, ppbv)	3.27	3.84	4.57
North O ₃ (compound, ppbv)	3.27	5.17	10.47
South T2m (heat-event, K)	2.50	2.22	2.53
South T2m (compound, K)	2.79	2.96	2.86
South UV (heat-event, W/m^2)	2.65	2.25	2.52
South UV (compound, W/m^2)	3.15	2.56	3.04
South O ₃ (heat-event, ppbv)	4.16	2.59	4.85
South O ₃ (compound, ppbv)	5.83	2.85	5.69

Note: Heat-event samples include compound years. T2m and UV use 1940–2022; CAMS EAC4 model level 60 O₃ uses 2003–2022. Bold values denote larger compound maxima.

Table R3. Event years for the CAMS EAC4 ozone analysis, 2003–2022.

Region	Month	Compound years (n)	Heat-only years (n)	UV-only years (n)	Normal years (n)
Northern	Jun	2006, 2021 (2)	None (0)	2003, 2015 (2)	Remaining years (16)
Northern	Jul	2006, 2007, 2021 (3)	2012 (1)	2017 (1)	Remaining years (15)
Northern	Aug	2003 (1)	2022 (1)	2006, 2008, 2011 (3)	Remaining years (15)
Southern	Jun	2011, 2012 (2)	2018 (1)	2005, 2008 (2)	Remaining years (15)
Southern	Jul	2011, 2016 (2)	2022 (1)	2003 (1)	Remaining years (16)
Southern	Aug	2011, 2020 (2)	2019 (1)	2009, 2010, 2015 (3)	Remaining years (14)

Note: Event categories are identified independently for 2003–2022. Parentheses give selected-year counts; Remaining years exceed neither threshold.

Table R4. Compound years for SWC composites, 1950–2022.

Region	Month	Compound event years	n
Northern	Jun	1956, 1961, 1987, 1988, 2021	5
Northern	Jul	1957, 1960, 1989, 2006, 2007, 2021	6
Northern	Aug	1955, 1961, 1969, 1971, 1983, 2001, 2003	7
Southern	Jun	1952, 1953, 1954, 1956, 1990, 1998, 2008, 2011, 2012	9
Southern	Jul	1954, 1957, 1980, 2001, 2011, 2016, 2022	7
Southern	Aug	1952, 1958, 1962, 2000, 2010, 2011, 2019, 2020	8

Note: Compound years are identified independently over 1950–2022; n gives selected-year counts.

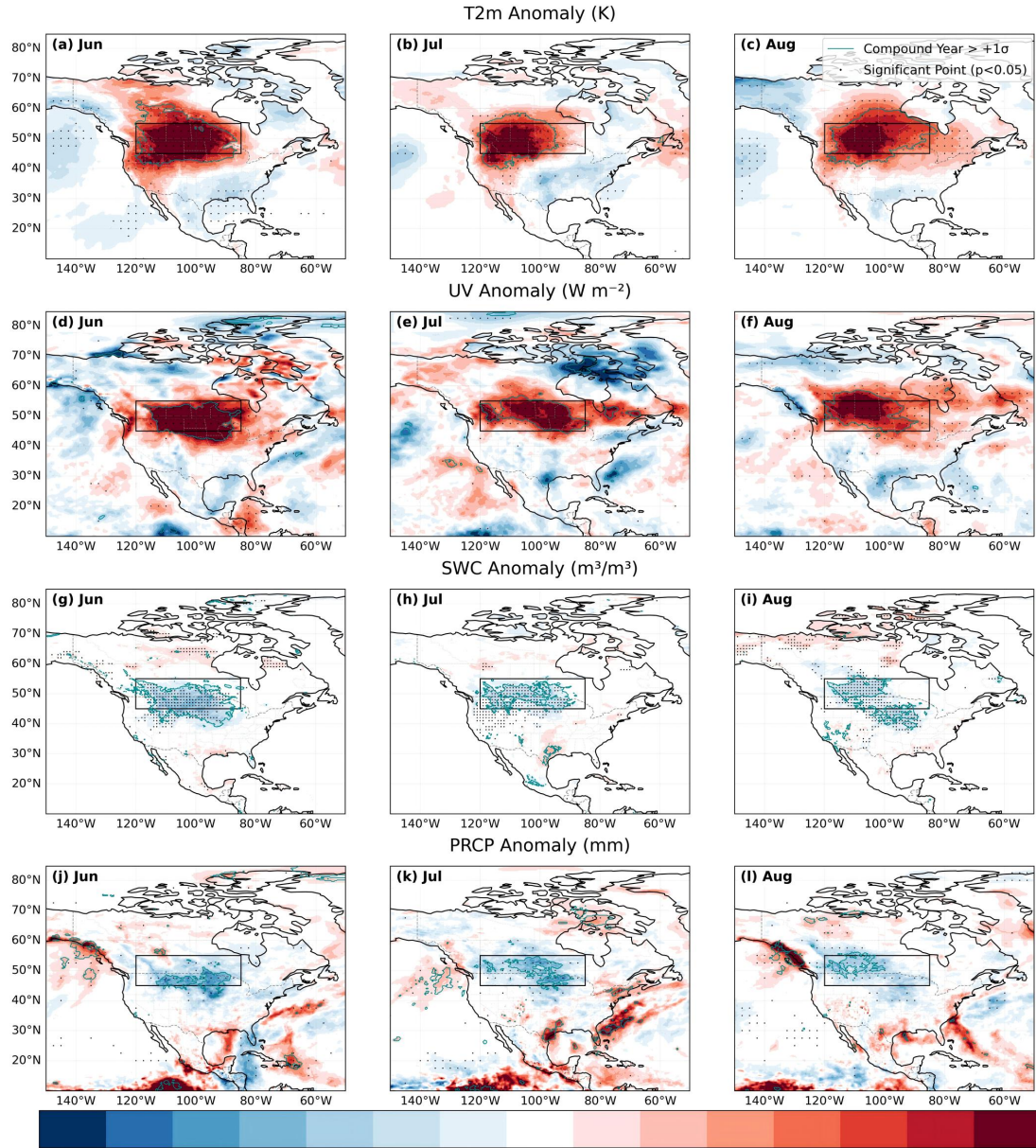


Figure R1. Updated replacement for original manuscript Fig. 2. Spatial distributions of composite anomalies during compound heat–UV months in the Northern Center for June–August. Colour scale ranges are ± 2.4 K for T2m (a–c), ± 2.4 W m⁻² for UV (d–f), ± 0.16 m³ m⁻³ for SWC (g–i), and ± 2.4 mm for precipitation (j–l). ERA5 fields cover 1940–2022 and SWC covers 1950–2022. Blue and red denote negative and positive anomalies; white denotes near-zero anomalies. Stippling marks $p < 0.05$; dark cyan contours outline anomalies exceeding one climatological standard deviation in magnitude.

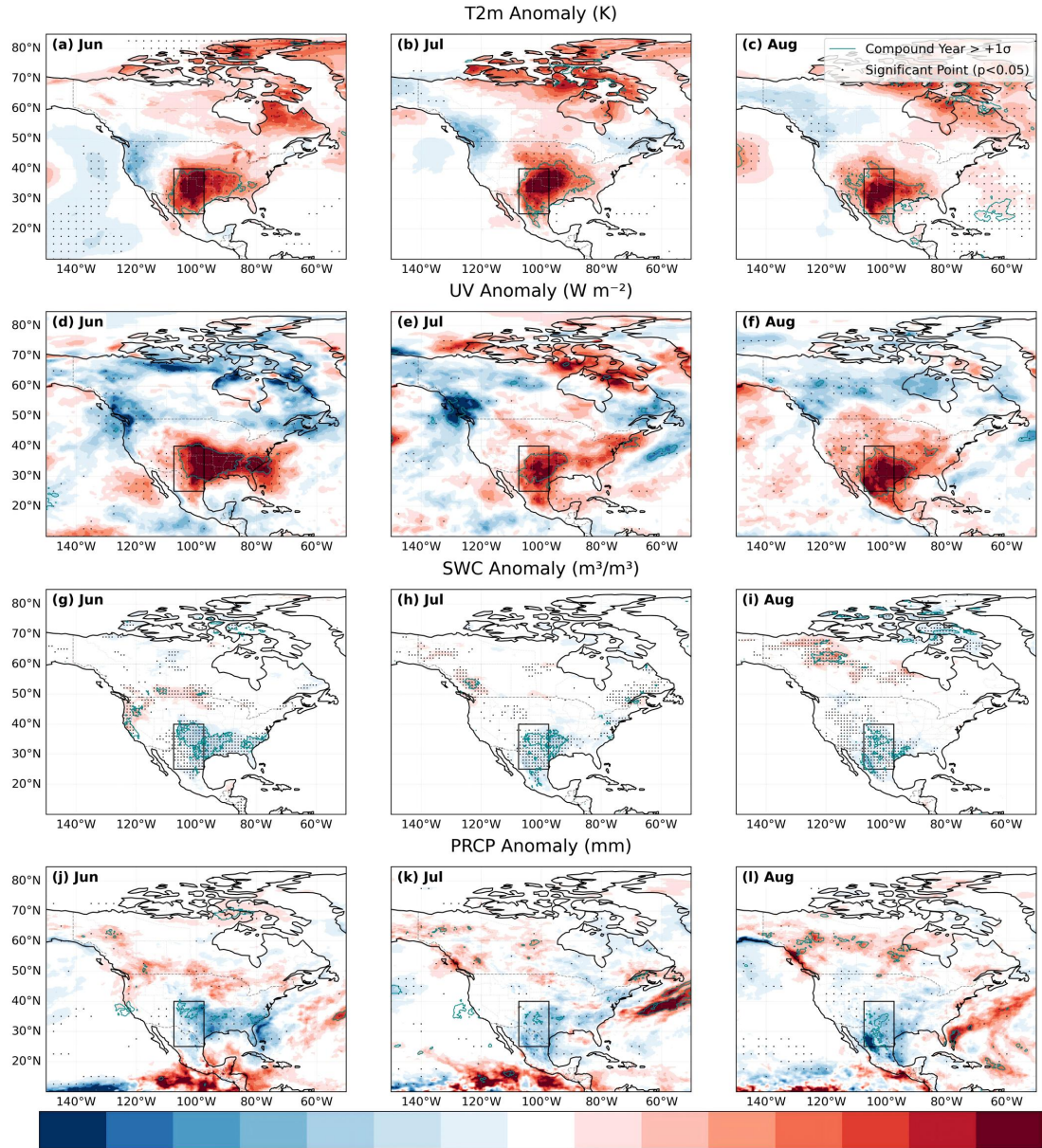


Figure R2. Updated replacement for original manuscript Fig. 3. Spatial distributions of composite anomalies during compound heat–UV months in the Southern Center for June–August. Colour scale ranges are ± 2.4 K for T2m (a–c), ± 2.4 W m^{-2} for UV (d–f), ± 0.16 $\text{m}^3 \text{m}^{-3}$ for SWC (g–i), and ± 2.4 mm for precipitation (j–l). ERA5 fields cover 1940–2022 and SWC covers 1950–2022. Blue and red denote negative and positive anomalies; white denotes near-zero anomalies. Stippling marks $p < 0.05$; dark cyan contours outline anomalies exceeding one climatological standard deviation in magnitude.

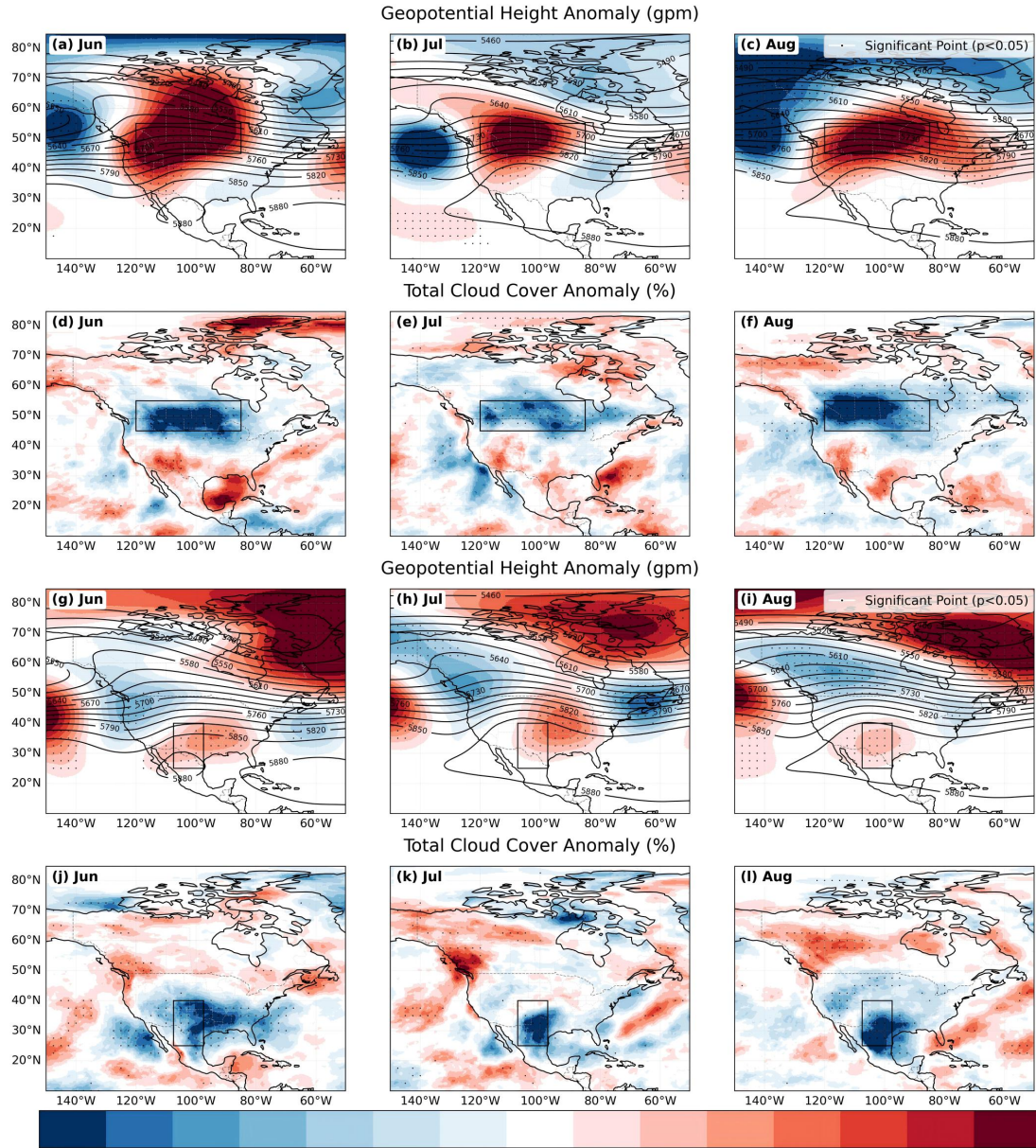


Figure R3. Updated replacement for original manuscript Fig. 4. Spatial distributions of Z500 and total-cloud anomalies during compound months in the Northern and Southern Centers for June–August 1940–2022. Panels (a–c) and (g–i) show Z500; (d–f) and (j–l) show total cloud cover. Colour scales are limited to ± 40 gpm for Z500 and ± 12 percentage points for total cloud cover; extrema reported in the text are calculated from the composite fields within the study boxes. Blue and red denote negative and positive anomalies; white denotes near-zero anomalies. Black contours show climatological Z500 from 5460 to 5880 gpm at 30-gpm intervals, Gaussian-smoothed with $\sigma = 1$ grid point. Stippling marks $p < 0.05$.

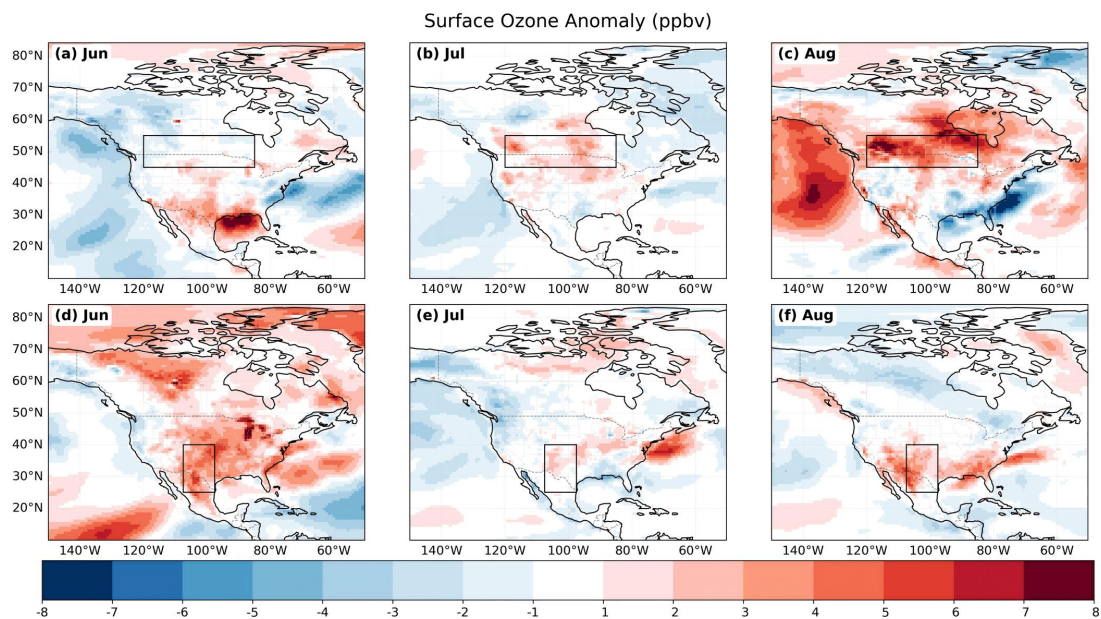


Figure R4. Updated replacement for original manuscript Fig. 5. Spatial distributions of monthly surface ozone composite anomalies (ppbv) during compound months in the Northern (a–c) and Southern (d–f) Centers for June–August 2003–2022, based on CAMS EAC4. Blue and red denote negative and positive anomalies; white denotes near-zero anomalies.

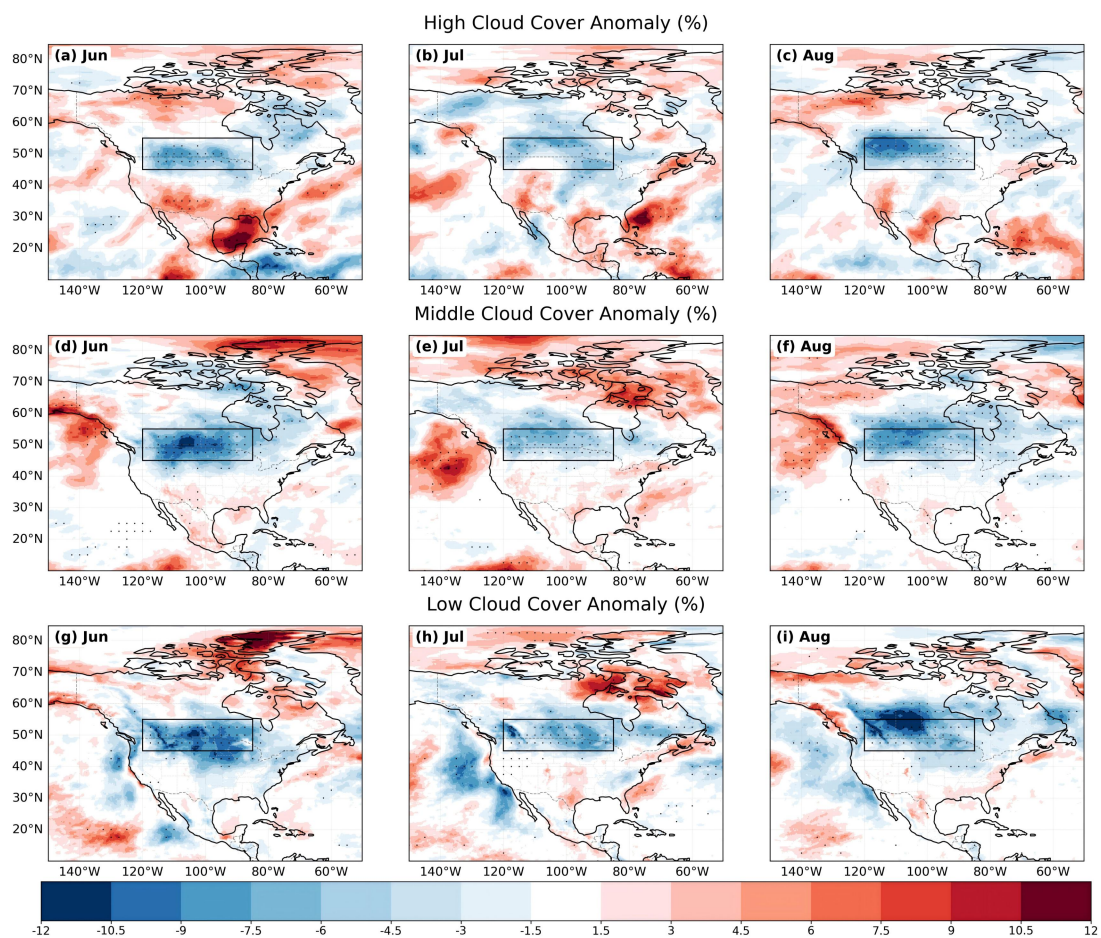


Figure R5. Updated replacement for original manuscript Supplement Fig. S4 (Northern Center). Northern compound-month cloud-cover anomalies (percentage points) during 1940–2022. Rows show high, middle, and low cloud cover; columns show June–August. Stippling marks pointwise $p < 0.05$.

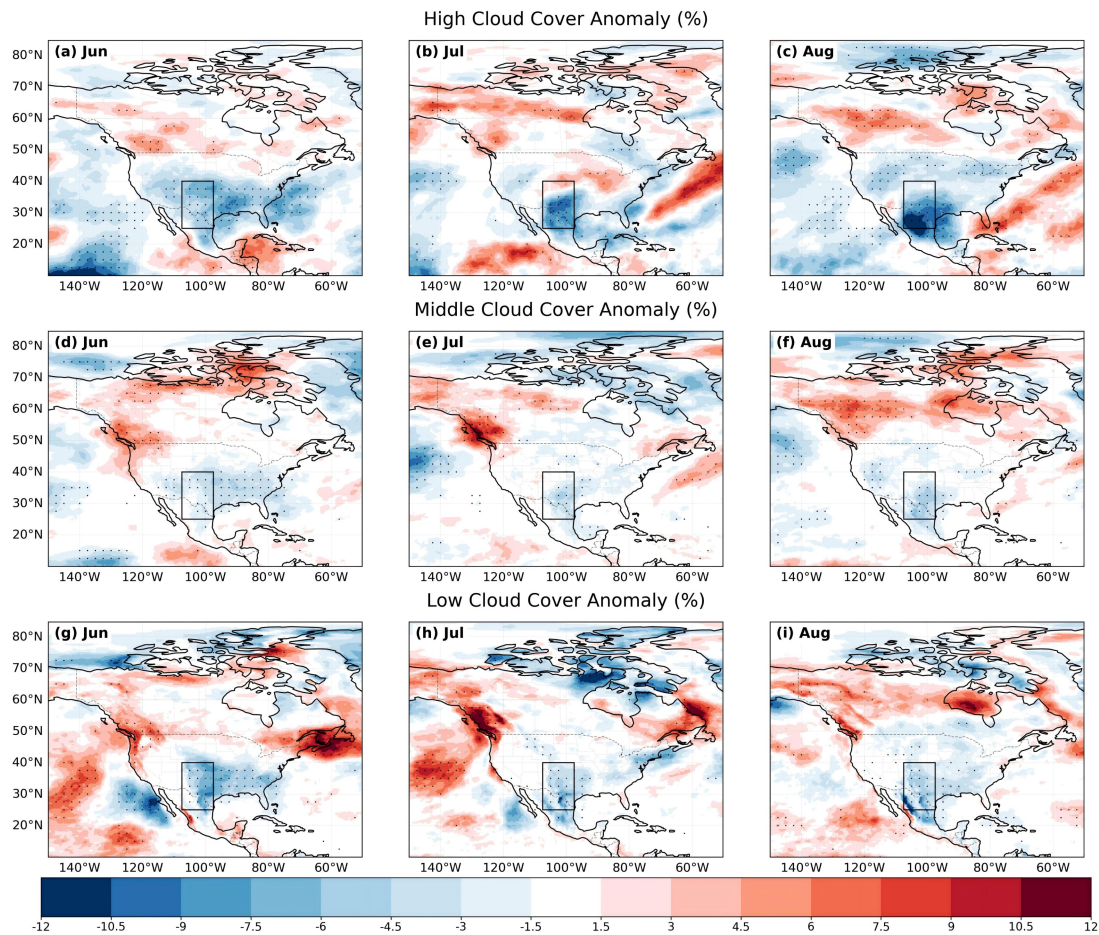


Figure R6. Updated replacement for original manuscript Supplement Fig. S3 (Southern Center). Southern compound-month cloud-cover anomalies (percentage points) during 1940–2022. Rows show high, middle, and low cloud cover; columns show June–August. Stippling marks pointwise $p < 0.05$.

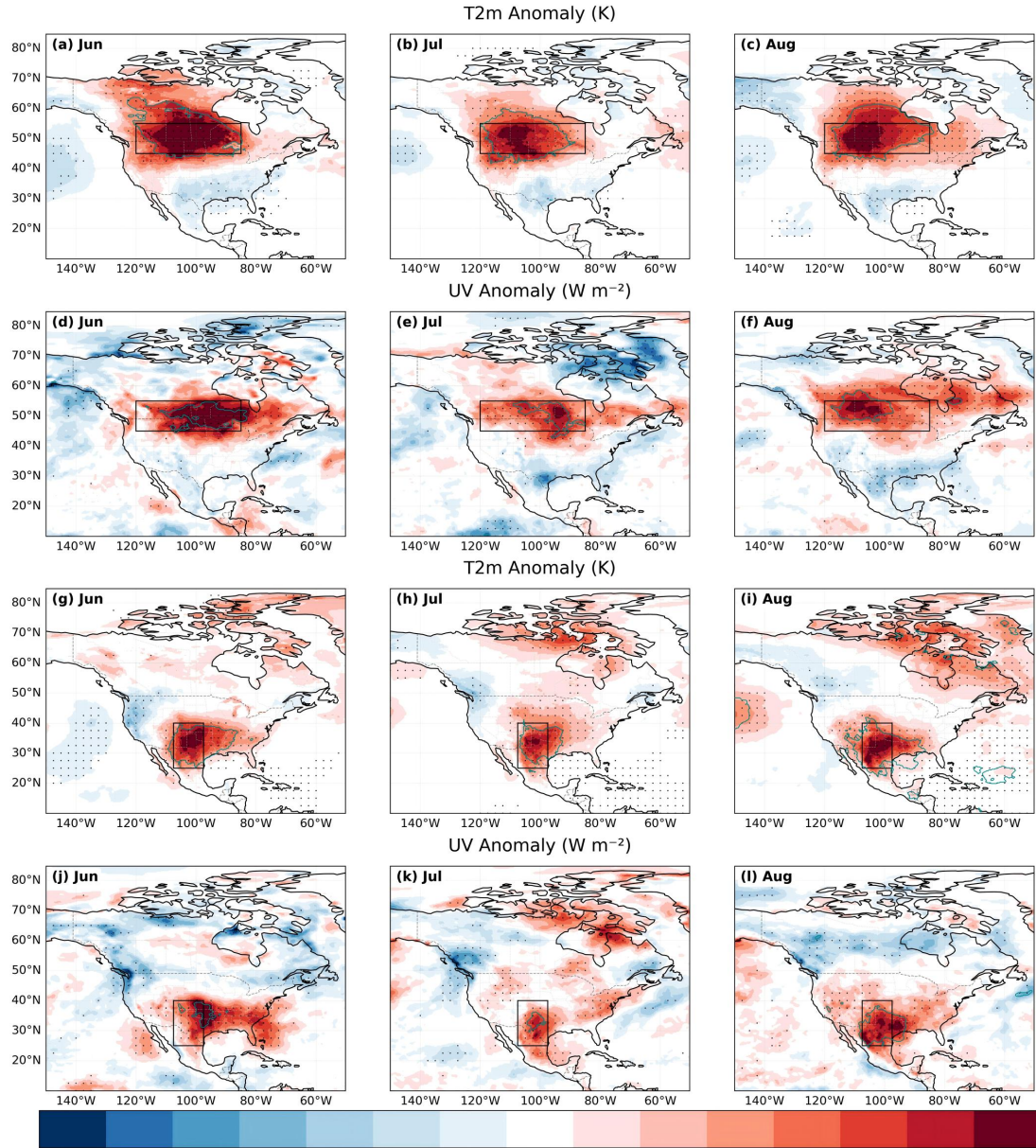


Figure R7. Temperature-based reference composites of T2m and UV over 1940–2022. Rows show Northern T2m (K), Northern UV (W m^{-2}), Southern T2m, and Southern UV; columns show June–August. Colour scales span ± 2.4 K for T2m and ± 2.4 W m^{-2} for UV. Heat-event samples include compound years. Stippling marks pointwise $p < 0.05$, and cyan contours identify anomalies exceeding one climatological standard deviation in magnitude.

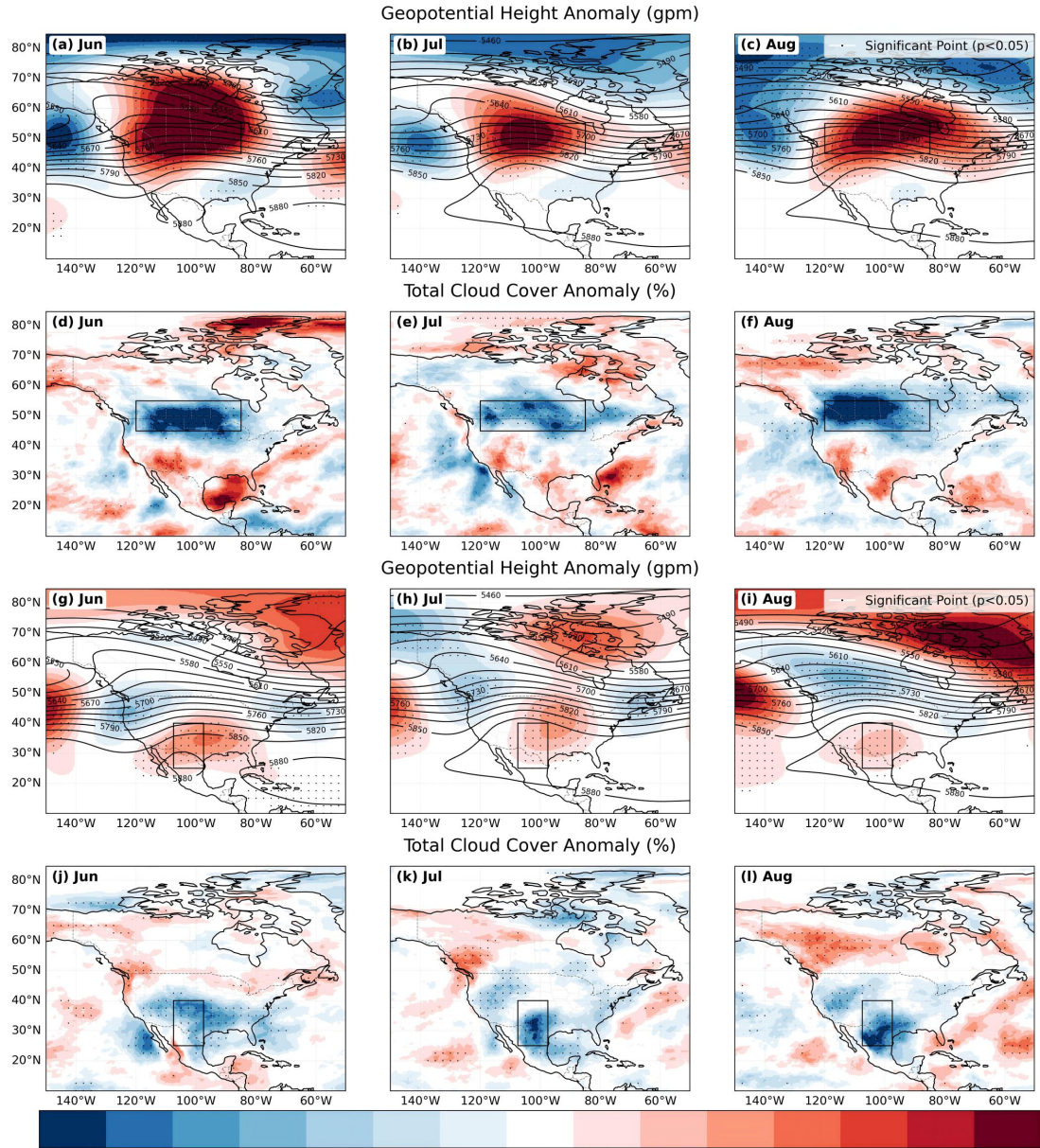


Figure R8. Temperature-based reference composites of Z500 (gpm) and total cloud cover anomalies (percentage points) during 1940–2022. Rows show Northern Z500, Northern cloud cover, Southern Z500, and Southern cloud cover. Colour scales span ± 40 gpm for Z500 and ± 12 percentage points for cloud cover. Stippling marks pointwise $p < 0.05$. Z500 climatological contours use Gaussian smoothing with $\sigma = 1$ grid point for display.

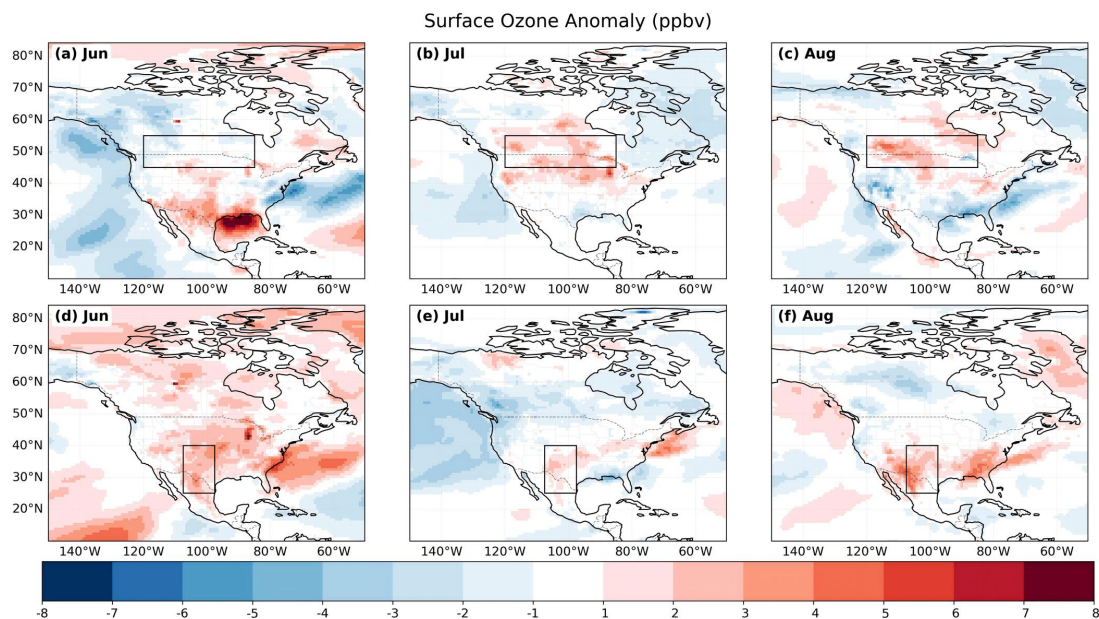


Figure R9. Ozone anomalies (ppbv) from CAMS EAC4 model level 60 for the temperature-based reference samples over 2003–2022. Rows show the Northern and Southern Centers; columns show June–August.

Changes in the manuscript:

We have revised Section 2.1.

Revised text: “To examine the association of concurrent extreme heat and intense ultraviolet radiation with surface ozone, monthly mean surface ozone from model level 60, the lowest model layer of the CAMS atmospheric composition reanalysis (EAC4), was used for the period 2003–2022 at a horizontal resolution of $0.75^\circ \times 0.75^\circ$.”

We have revised Section 2.2.

Revised text: “Monthly event selection uses regional T2m and UV series after linear detrending, performed before threshold calculation. For each calendar month, a compound month occurs when both variables exceed their respective detrended climatological mean plus one standard deviation ($+1\sigma$). Heat-only and UV-only months exceed only their respective threshold; normal months exceed neither. The temperature-based reference includes all heat months, including compound months. Event catalogues are constructed independently for the main 1940–2022 analysis (Table S1), the 1950–2022 SWC composites (Table S2) and the 2003–2022 ozone analysis (Table S3), with thresholds estimated for each period.”

Revised text: “Composite anomalies are calculated relative to the full-period calendar-month climatology after detrending, using the available period for each variable. For meteorological composites, two-sided Welch tests compare event and non-target years: compound months against non-compound months, and heat months against non-heat months. Stippling denotes pointwise $p < 0.05$. The $\pm 1\sigma$ contours identify event-mean anomalies exceeding one full-period calendar-month climatological standard deviation in magnitude. Reported extrema are taken within the corresponding study box. Surface

ozone maps show the composite anomaly fields; quantitative ozone comparisons use the regional analysis described below.”

We have revised Section 3.2.

Revised text: “In the northern hotspot, extreme heat and enhanced UV radiation are strongly synchronized from June to August. Maximum 2 m air temperature anomalies (reaching 3.73 K, 3.21 K, and 3.09 K, respectively) geographically coincide with surface UV enhancements of 3.67 W m^{-2} , 2.87 W m^{-2} , and 2.93 W m^{-2} (Fig. 3a–f). Concurrently, this region suffers from pronounced hydroclimatic deficits. Maximum reductions in surface soil moisture reach -0.1448 , -0.1016 , and $-0.0929 \text{ m}^3 \text{ m}^{-3}$, alongside corresponding precipitation decreases of -2.56 , -2.02 , and -1.90 mm (Fig. 3g–i). These localized negative anomalies confirm pronounced dry conditions accompanying compound heat–UV extremes.”

Revised text: “The southern hotspot also displays a pronounced compound warm–dry signature. Temperature anomalies peak at 2.96 K in July, alongside UV radiation increases of up to 3.15 W m^{-2} in June (Fig. 4a–f). The southern region experiences severe soil moisture depletion, reaching $-0.1138 \text{ m}^3 \text{ m}^{-3}$ in August. This late-summer desiccation is accompanied by substantial precipitation deficits, reaching a maximum reduction of -4.11 mm in August (Fig. 4g–i). The concurrent warming, soil moisture depletion and precipitation deficits reveal coupled hot and dry conditions in this southern region. Joint selection yields larger T2m and UV maxima than the temperature-based reference in all six region–month comparisons (Table S10; Fig. S4).”

Revised text: “In the northern center, compound extreme events are accompanied by a mid-latitude high-pressure ridge consistent with meridional disturbances of the westerlies. During compound months, 500-hPa geopotential height exhibits pronounced positive anomalies (maximum increases of 59.26, 50.09, and 46.19 gpm from June to August; Fig. 5a–c).”

Revised text: “In contrast, compound events in the southern center are associated with westward-extending mid-tropospheric ridging. Positive 500-hPa anomalies reach 22.44 gpm within the study box and occur alongside broader ridging towards the western Atlantic (Fig. 5g–i).”

Revised text: “Maximum reductions in total cloud cover reach 18.02 percentage points in the north (Fig. 5d–f) and 16.47 percentage points in the south (Fig. 5j–l). Notably, the cloud-layer composites show pronounced reductions in low- and mid-level cloud cover, alongside changes in high clouds (Figs. S5–S6).”

We have revised Section 3.3.

Revised text: “During summer compound heat–UV months, surface ozone concentrations increase by up to 10.47 ppbv in the Northern Center and 5.83 ppbv in the Southern Center (Fig. 6), with the largest local enhancements occurring in Northern August and Southern June, respectively. The warm, reduced-cloud environment identified above provides a plausible setting for enhanced photochemical ozone production, helping connect these local ozone enhancements with the circulation and

surface conditions accompanying compound events. Compound maxima exceed the temperature-based reference in five of six comparisons and are equal in Northern June (Table S10; Fig. S14).”

Event catalogues, temperature-based reference composites and the within-box comparison are included in Supplement Tables S1–S3 and S10 and Figs. S4, S7 and S14. The updated cloud-layer composites are included as Supplement Figs. S5–S6.

2. Strong solar radiation commonly contributes directly to surface warming, while heat-associated anticyclones also reduce clouds and increase UV. The manuscript acknowledges this common pathway but does not demonstrate why treating heat and UV as a compound event adds information beyond high temperature or clear-sky conditions. Please quantify the frequency of heat-only, UV-only, and joint events. A map of joint-event frequency/dependence would be more informative than correlation alone. The manuscript should then test whether joint events produce ozone or exposure impacts significantly greater than heat-only and UV-only events.

We thank the referee for asking us to quantify the information provided by joint event selection. We have added regional event frequencies, spatial frequency maps, and separate ozone comparisons against heat-only and UV-only events. Together, these analyses characterize the geographical concentration of compound events and the ozone conditions associated with their occurrence.

1. Event frequency and spatial concentration

Using the area-weighted regional means and detrended $+1\sigma$ thresholds, compound events occur in 10/83 (12.0%), 7/83 (8.4%), and 9/83 (10.8%) of years for June–August in the Southern Center, and in 7/83 (8.4%), 6/83 (7.2%), and 9/83 (10.8%) in the Northern Center (Table R1). These frequencies correspond to long-term average return intervals of roughly 8–14 years for a given calendar month within each hotspot. Compound events are more frequent than heat-only or UV-only events in most months; for example, Southern June frequencies are 12.0%, 6.0%, and 6.0%, respectively.

The grid-point frequency maps apply the same joint definition to each grid point’s detrended series over 1940–2022 (Fig. R10). They show a greater concentration of compound events in and around the two hotspots, while single extremes occur more broadly across North America. We quantify this pattern using an enrichment ratio: the proportion of high-frequency land area within the two hotspot boxes combined, normalized by the boxes’ share of land area in the mapped domain (10–85°N, 210–310°E). Land cells are identified using the ERA5 land–sea mask (≥ 0.5), and both proportions use cosine-latitude area weights. At the 10% frequency threshold, the ratio is 1.41 for compound events, compared with 0.53 for heat-only and 0.60 for UV-only events (Table R5). Compound events are therefore approximately 2.4–2.7 times as concentrated in the hotspots by this measure. The 5% threshold gives the same ordering (1.26, 0.93, and 0.95, respectively). The enrichment definition and sensitivity to the frequency threshold are documented in manuscript Supplement Table S4. This

geographical concentration gives the joint-event analysis a distinct spatial focus and is consistent with regional circulation conditions favoring concurrent heat and intense UV.

2. Regional ozone contrasts

We compare regional monthly ozone anomalies among compound, heat-only, UV-only and normal conditions (Fig. R11). CAMS EAC4 model level 60 ozone is converted to ppbv and averaged using cosine-latitude weights. A linear trend is removed from the 60 JJA monthly values for 2003–2022, followed by subtraction of calendar-month means. Table R3 lists the event years, Table R7 distinguishes monthly observations from distinct years, and Tables R6 and R8 report the mean comparisons and their uncertainty.

For an exploratory permutation comparison, we enumerated all distinct allocations of pooled monthly observations to the compound and control groups, using the difference in group means. The null assumes exchangeable observations from a common distribution. The one-sided alternative is a higher compound mean; the two-sided comparison allows either direction. Monthly permutations do not preserve within-year dependence, so their p-values are reported as exploratory.

The compound-group mean ozone anomaly is 1.31 ppbv in the Northern Center and 2.04 ppbv in the Southern Center. Relative to heat-only and UV-only events, the mean differences are 1.47 and 0.85 ppbv in the Northern Center, and 0.91 and 1.08 ppbv in the Southern Center (Table R6). Both single-event comparisons therefore point to higher pooled JJA mean ozone anomalies under compound conditions.

3. Sampling uncertainty and sensitivity

We estimated uncertainty using 20,000 whole-year bootstrap draws (random seed 20261012), resampling each year's three JJA observations together. Event labels were held fixed, and the ozone trend and monthly means were refitted in each draw. The reported intervals are the 2.5th–97.5th percentiles of draws containing both comparison groups. This preserves the within-year grouping of months and provides an exploratory assessment suited to the limited event sample. The resampling assumes exchangeability between years and conditions on the identified event categories. Valid-draw counts are reported in Table R8. The corresponding preprocessing and resampling methods are now stated in Section 2.2, with uncertainty and sensitivity details in manuscript Supplement Tables S6–S8 and Fig. S15.

We assessed the influence of individual years by omitting each of the 20 calendar years in turn and refitting the ozone trend and monthly means, with event labels fixed (Fig. R13). All four contrasts against the separate single-event categories remain positive in all 20 analyses. Compound-minus-heat-only differences range from 0.04 to 3.08 ppbv in the Northern Center and from 0.33 to 1.31 ppbv in the Southern Center; compound-minus-UV-only ranges are 0.13–1.27 and 0.76–1.38 ppbv, respectively (Table R9). Their direction is consistent across these analyses, with the greatest variation in magnitude in the Northern heat-only comparison.

The positive mean contrasts in both hotspots and their persistence after individual-year removal suggest a tendency toward higher regional ozone anomalies under compound heat–UV conditions. The exploratory 95% bootstrap intervals span zero and the permutation p-values exceed 0.05 (Table R8); we therefore interpret the magnitude of this tendency in the context of the available event sample.

Figure R12 replaces original manuscript Fig. 6. The normal, pooled single-extreme and compound curves provide a calendar-month perspective alongside the regional mean comparisons.

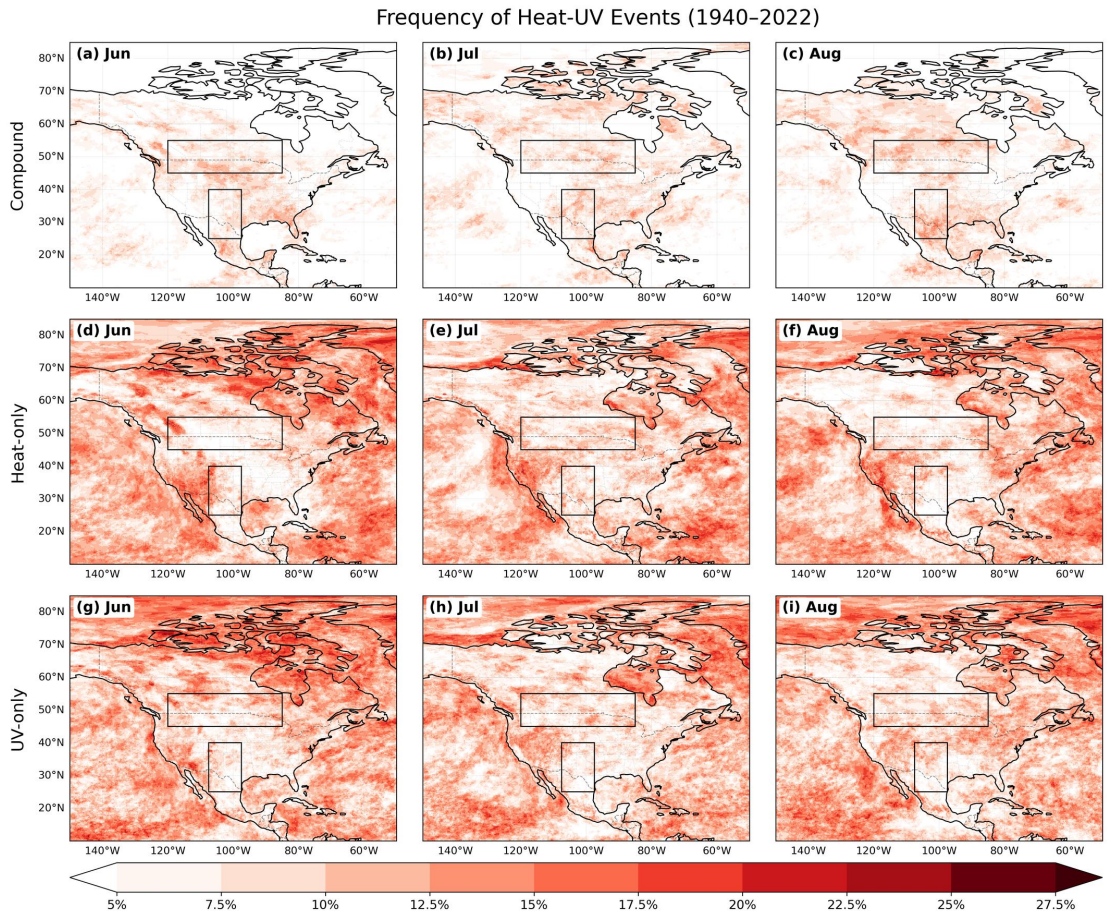


Figure R10. Grid-point frequencies of compound (top), heat-only (middle), and UV-only (bottom) months during 1940–2022. Columns show June–August. Frequency is the percentage of 83 years meeting the detrended threshold criteria at each grid point. Black boxes mark the study regions.

Table R5. Spatial enrichment of high-frequency events.

Frequency threshold	Compound	Heat-only	UV-only
> 5%	1.26	0.93	0.95
> 10%	1.41	0.53	0.60

Note: Both area fractions use cosine-latitude weights over land (land–sea mask ≥ 0.5) within 10–85° N, 210–310° E. The ratio measures the fraction of high-frequency land area inside the hotspot boxes relative to their share of domain land area.

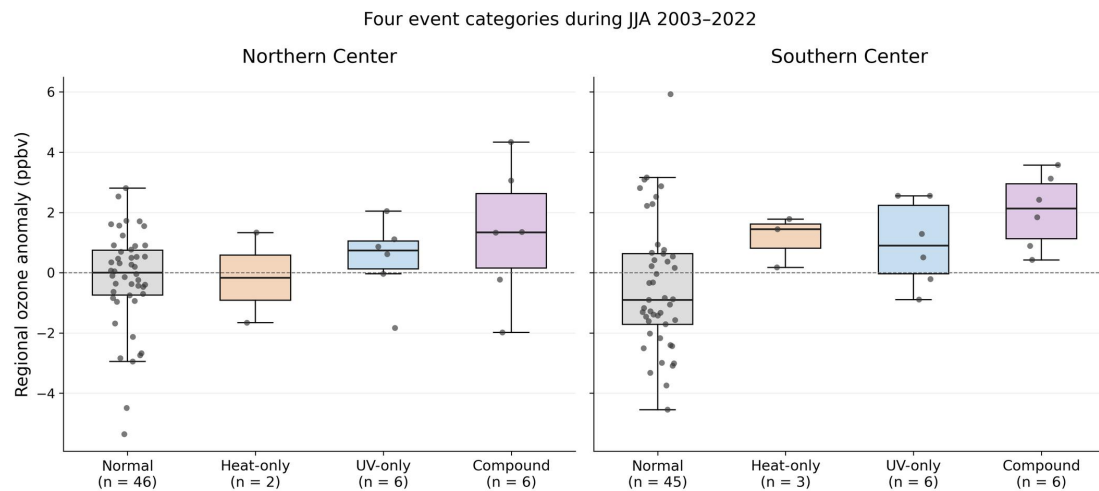


Figure R11. Regional monthly surface ozone anomalies (ppbv) during JJA 2003–2022 in the Northern (left) and Southern (right) Centers for four event categories. Boxes show the interquartile range and median; whiskers extend to observations within 1.5 times the interquartile range. Points show year–month observations, and n gives their count.

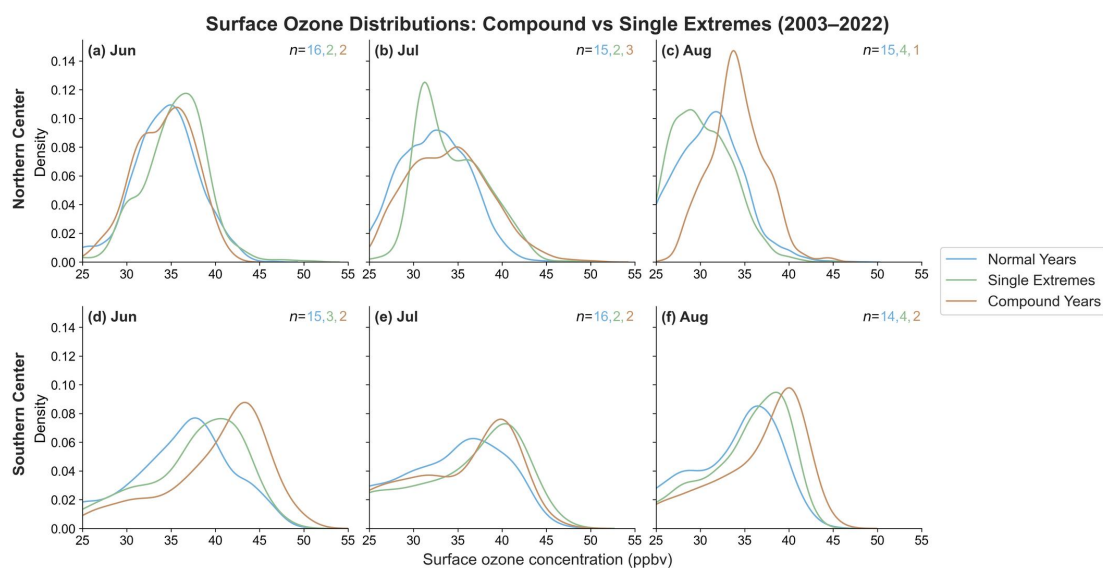


Figure R12. Updated replacement for original manuscript Fig. 6. Monthly surface ozone concentration distributions (ppbv) during June–August 2003–2022 in the Northern (a–c) and Southern (d–f) Centers. Blue, green and orange curves denote normal, pooled single-extreme and compound years, respectively. Single extremes combine heat-only and UV-only years; panel n values give selected-year counts.

Table R6. Regional mean ozone contrasts and permutation comparisons.

Region	Control	$\Delta\text{O}_3(\text{ppbv})$	p(one-sided)	p(two-sided)
Northern	Heat-only	1.47	0.286	0.571
Northern	UV-only	0.85	0.223	0.446
Northern	Single (pooled)	1.01	0.163	0.326
Southern	Heat-only	0.91	0.143	0.286
Southern	UV-only	1.08	0.093	0.186
Southern	Single (pooled)	1.02	0.067	0.133

Note: ΔO_3 is the compound-minus-control mean (ppbv); Single (pooled) combines heat-only and UV-only observations. Exact monthly-label permutation p-values are exploratory because allocations do not preserve within-year dependence. The one-sided alternative is a higher compound mean.

Table R7. Regional ozone anomaly summaries, JJA 2003–2022.

Region	Category	Year–month observations	Distinct years	Mean(ppbv)	SD(ppbv)
Northern	Normal	46	19	−0.22	1.66
Northern	Heat-only	2	2	−0.17	2.12
Northern	UV-only	6	6	0.46	1.31
Northern	Compound	6	4	1.31	2.26
Southern	Normal	45	19	−0.48	2.16
Southern	Heat-only	3	3	1.13	0.85
Southern	UV-only	6	6	0.96	1.43
Southern	Compound	6	4	2.04	1.24

Note: Counts distinguish year–month observations from distinct years; a year can contribute to multiple categories when its monthly labels differ.

Table R8. Ozone mean contrasts and exploratory uncertainty intervals.

Region	Control	$\Delta\text{O}_3(\text{ppbv})$	95 % bootstrap interval (ppbv)	p(two-sided)	Valid draws
Northern	Heat-only	1.47	[−1.02, 4.30]	0.571	17217
Northern	UV-only	0.85	[−1.07, 3.18]	0.446	19753
Northern	Single extremes (pooled)	1.01	[−0.83, 3.25]	0.326	19764
Southern	Heat-only	0.91	[−1.02, 2.48]	0.286	18982
Southern	UV-only	1.08	[−0.63, 2.52]	0.186	19738
Southern	Single extremes (pooled)	1.02	[−0.52, 2.31]	0.133	19758

Note: Intervals are exploratory 95% whole-year bootstrap percentiles; valid draws are out of 20,000. The two-sided monthly-label permutation p-values are exploratory because monthly allocations do not retain within-year dependence. Pooled single extremes combine heat-only and UV-only observations.

Table R9. Sensitivity of ozone contrasts to individual-year removal.

Region	Control	Minimum(ppbv)	Maximum(ppbv)	Positive analyses
Northern	Heat-only	0.04	3.08	20/20
Northern	UV-only	0.13	1.27	20/20
Southern	Heat-only	0.33	1.31	20/20
Southern	UV-only	0.76	1.38	20/20

Note: Each analysis excludes all JJA observations from one year and refits the ozone trend and calendar-month means, with event labels fixed.

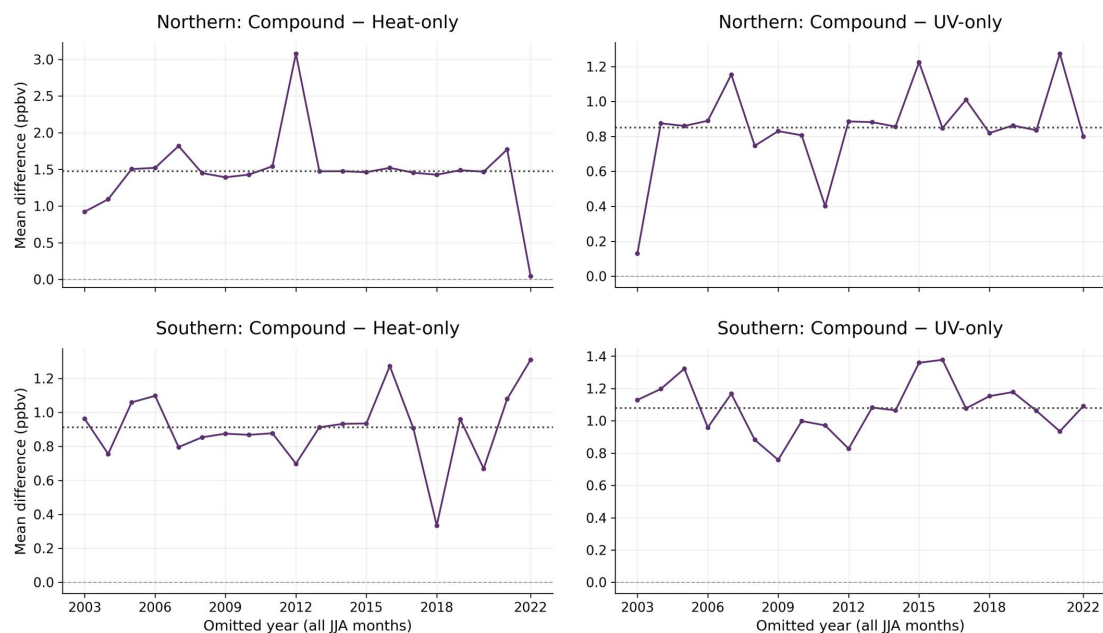


Figure R13. Leave-one-year-out sensitivity of regional ozone mean contrasts during JJA 2003–2022. Rows show the Northern and Southern Centers; columns compare compound with heat-only and UV-only events. Each point excludes all JJA observations from the indicated year. Dotted lines show full-sample contrasts and dashed lines mark zero. Panel vertical scales differ.

Changes in the manuscript:

We have revised Section 3.1.

Revised text: “Compound months are concentrated around the two hotspots, whereas heat-only and UV-only months have broader spatial distributions (Fig. 2). Based on the regional series, compound months occur in 7, 6 and 9 of 83 years in the Northern Center for June, July and August, respectively, corresponding to frequencies of 8.4 %, 7.2 % and 10.8 %. Southern frequencies are 12.0 %, 8.4 % and 10.8 %, based on 10, 7 and 9 years (Table S1).”

Revised text: “The JJA-mean enrichment ratio at the 10 % grid-point frequency threshold is 1.41 for compound events, compared with 0.53 for heat-only and 0.60 for UV-only events. The same ordering holds at 5 %, with ratios of 1.26, 0.93 and 0.95, respectively (Table S4). Thus, by this area-based measure, compound events are more strongly concentrated within the selected hotspots than either single-event category.”

We have revised Section 2.2.

Revised text: “Separately, regional monthly ozone anomalies are calculated from area-weighted CAMS EAC4 surface ozone after removing a linear trend from the 60 JJA monthly values for 2003–2022 and subtracting calendar-month means. Four-category comparisons use the 2003–2022 event catalogue. Compound-minus-control mean contrasts are assessed using exploratory monthly-label permutation comparisons. Uncertainty and sensitivity are evaluated using whole-year bootstrap and leave-one-year-out analyses, retaining each year’s three JJA observations together when

resampling or omitting years. Permutation comparisons, category summaries, bootstrap intervals and individual-year sensitivity are reported in Tables S5, S6, S7 and S8, respectively.”

We have revised Section 3.3.

Revised text: “Compound months have mean regional ozone anomalies of 1.31 ppbv in the Northern Center and 2.04 ppbv in the Southern Center (Fig. 8). The higher Southern mean reflects positive regional compound anomalies in all three summer months, while the Northern enhancement is concentrated in July and August. Compound-minus-heat-only and compound-minus-UV-only differences are +1.47 and +0.85 ppbv in the north and +0.91 and +1.08 ppbv in the south. These positive contrasts are consistent with temperature-sensitive chemistry and enhanced photolysis acting together in the warm, high-radiation environment of compound events (Jacob and Winner, 2009; Madronich et al., 2023). Category means and the distinction between year–month observations and distinct years are reported in Table S6.”

Revised text: “All four contrasts remain positive in all 20 individual-year removal analyses (Fig. S15; Table S8), showing that the higher regional mean ozone under compound conditions persists after omitting any single year. Exploratory 95 % whole-year bootstrap intervals span zero, and monthly-label permutation p-values exceed 0.05 (Tables S5 and S7). Together, the monthly concentration shifts and regional mean comparisons identify elevated ozone accompanying compound heat–UV conditions in both hotspots.”

Revised text: “Probability density function (PDF) analysis further reveals month-dependent shifts towards higher surface ozone concentrations during compound conditions, particularly in Southern June and August and Northern August (Fig. 7). In the Southern Center, the dominant concentration peak shifts from approximately 38 to 43 ppbv in June and from 36 to 40 ppbv in August. These rightward shifts indicate that higher ozone concentrations become more characteristic of compound conditions, extending the ozone association beyond a change in the regional mean alone. Northern August likewise shows a compound peak near 34 ppbv, compared with approximately 32 ppbv in normal years, highlighting a late-summer ozone response in this region.”

The enrichment definition, sample summaries, permutation comparisons and uncertainty and sensitivity details are included in Supplement Tables S4–S8 and Fig. S15.

3. Surface ozone is influenced by precursor emissions and their trends (NO_x, VOCs, and CO), chemical regime, transport and ventilation, boundary-layer dynamics, stagnation, deposition, biomass burning, aerosol–radiation interactions, and stratospheric influence, in addition to temperature and radiation. The stronger southern response is attributed to dense anthropogenic precursors and enhanced photochemistry; however, the manuscript does not currently provide corresponding precursor data, sensitivity diagnostics, or chemical-model results. I encourage the authors to provide additional quantitative evidence, where feasible, such as precursor and meteorological controls or chemical-sensitivity diagnostics. Alternatively, the interpretation could be moderated to describe the observed co-variation in EAC4 more cautiously, while acknowledging that the relative contributions of UV, temperature, emissions, and transport cannot be fully separated by the present analysis.

We thank the referee for this helpful suggestion. We have reorganized the ozone discussion around the quantified CAMS EAC4 contrasts and the accompanying meteorological conditions. Compound samples have higher pooled mean ozone anomalies than both single-event categories in the two hotspots, and all four contrasts remain positive after individual-year removal. The revised interpretation connects this observed tendency with the regional circulation and cloud patterns, while considering precursor availability, chemical sensitivity, and transport as potential contributors to regional ozone variations. The quantitative comparisons and their uncertainty are presented under Major Comment 2.

Sections 3.2–3.4 are retitled “Regional circulation and land surface conditions associated with compound heat–UV events,” “Surface ozone variations associated with compound heat–UV events,” and “Trends in the frequency of compound days,” respectively. The revised research aims in Section 1 use the same observational and diagnostic scope.

We have revised original manuscript Fig. 8 to bring the circulation, land surface, ozone and trend results together in a conceptual schematic, reproduced here as Fig. R14. Its title highlights regional mechanisms, frequency trends and associated surface ozone anomalies. Wave-related mid-latitude ridging in the north and an inferred westward extension pathway in the south summarize interpretations of the mid-tropospheric composite patterns, alongside cloud–radiation effects and coupled heat–drought feedback. The separate 850-hPa NASH diagnostic adds a month-dependent low-level perspective, reported under Minor Comment 1 and in the circulation diagnostics of the manuscript Supplement.

The revised schematic replaces “Dominant Descending Branch” with “Positive ω Anomaly” and “Severe Surface Ozone Surge” with “Elevated Surface Ozone.” The heat–drought feedback label retains “Coupled,” with the intensity qualifier removed. Trend annotations now give +0.72 and +1.29 days per decade for the Northern and Southern Centers, respectively. The revised caption explains the physical interpretations and the qualitative ozone symbols and inset distribution curves.

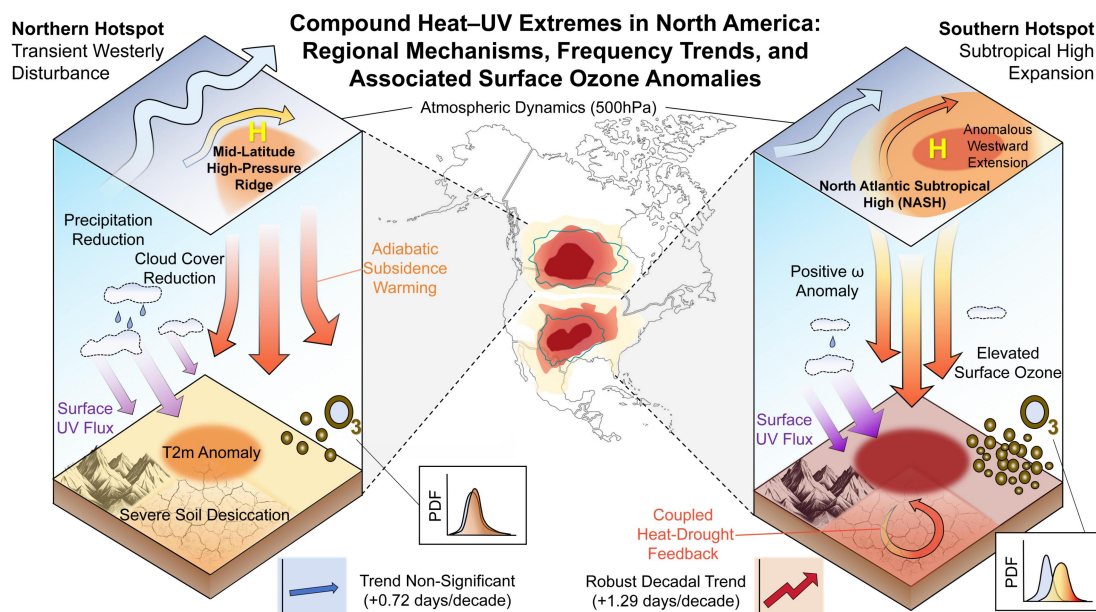


Figure R14. Updated replacement for original manuscript Fig. 8. Conceptual synthesis of regional circulation, land surface conditions, frequency trends and associated surface ozone during compound heat–UV extremes. Circulation pathways represent physical interpretations of the composite patterns; the southern westward-extension label refers to the 500-hPa ridge pattern. Ozone symbols and inset density curves are qualitative. Trend labels show changes in annual JJA compound-day counts during 1980–2022.

Changes in the manuscript:

We have revised the abstract.

Revised text: “The co-occurrence of extreme heat and intense ultraviolet (UV) radiation poses severe yet insufficiently understood threats to terrestrial ecosystems and public health. Using reanalysis datasets from 1940 to 2022, we reveal the spatiotemporal characteristics and circulation conditions associated with compound summer heat–UV events across North America, identified using joint detrended temperature and UV thresholds. We identify two primary hotspots: the southwestern United States to northern Mexico, and central-western Canada to the northwestern United States. These events are accompanied by regional mid-tropospheric ridging, dry land surface conditions and reduced cloud cover. An additional 850-hPa diagnostic shows month-dependent estimates of the North Atlantic subtropical high western-ridge position alongside the local 500-hPa ridge patterns. CAMS EAC4 model-level-60 ozone during 2003–2022 shows positive compound-minus-single-event regional mean contrasts of 0.85–1.47 ppbv. Their direction persists after individual-year removal, while exploratory 95 % bootstrap intervals span zero. Since 1980, the frequency of compound days has increased significantly by 1.29 days per decade in the Southern Center. This upward trend highlights an intensifying climate–environmental hazard, underscoring the value of considering combined heat, UV and ozone conditions in regional risk assessments.”

We have revised Section 1.

Revised text: “Based on the above considerations, this study aims to: (a) identify the spatiotemporal characteristics of compound heat–UV events in North America; (b) examine their associated atmospheric circulation patterns; (c) evaluate their associations with surface ozone; (d) analyze their long-term trends.”

We have revised Section 4.

Revised text: “The positive regional ozone contrasts in both hotspots, together with their persistence after individual-year removal, identify an air quality dimension of compound heat–UV conditions. Temperature and radiation, together with precursor availability, chemical sensitivity, and transport, may shape the associated ozone variations. However, the present analysis cannot fully separate the relative contributions of UV radiation, temperature, precursor emissions, and atmospheric transport to the ozone variations identified in CAMS EAC4.”

Revised text: “This circulation–cloud pathway complements the heat–UV analysis of Xia et al. (2022) and connects the compound extremes with established land–atmosphere and cloud–radiation relationships.”

Revised text: “Compound months also have higher pooled mean ozone anomalies than both single-event categories in both hotspots, with positive contrasts retained after individual-year removal. Since 1980, the Southern Center has experienced a statistically significant increase in compound-day frequency of 1.29 days per decade; the Northern Center exhibits a positive tendency amid pronounced interannual variability.”

The schematic has been updated; its revised caption is reproduced with Fig. R14 above.

Minor Comments:

1. The discussion of circulation mechanisms could be phrased more cautiously. The composite patterns are consistent with ridging, subsidence, reduced cloud cover, and warming; however, additional circulation diagnostics (e.g., NASH position/index, wave-activity or blocking metrics, and vertical velocity) would help support the proposed dynamical interpretations. Likewise, total-column ozone anomalies alone may not be sufficient to diagnose tropopause-lifting or stratosphere–troposphere exchange.

We thank the referee for this suggestion. We have added 500-hPa pressure velocity composites (Fig. R15), an area-weighted regional Z500 diagnostic (Fig. R16), and an 850-hPa NASH western-ridge analysis (Fig. R17 and Table R10). Figure R18 summarizes the NASH coordinate contrasts. These diagnostics quantify local mid-tropospheric ridging, vertical motion anomalies and the month-dependent low-level ridge geometry; the requested diagnostics are included as Figs. S8–S11 and Table S9 in the manuscript Supplement.

1. Mid-tropospheric ridging and vertical motion

The updated 500-hPa pressure velocity maps show positive anomalies over parts of both hotspots (Fig. R15), indicating enhanced descent or weakened ascent relative to the calendar-month background. Together with reduced cloud cover and positive Z500 anomalies, these patterns help characterize the circulation environment accompanying concurrent heat and intense UV conditions.

For Fig. R16, the regional Z500 series were calculated using weights proportional to the cosine of latitude and detrended separately by calendar month over 1940–2022. We compared compound years with all non-compound years, comprising heat-only, UV-only, and normal years, using two-sided Welch tests. Compound/non-compound sample sizes are 7/76, 6/77, and 9/74 for June–August in the Northern Center, and 10/73, 7/76, and 9/74 in the Southern Center.

Regional mean Z500 anomalies during compound years are +45.93, +32.34, and +36.18 gpm for June–August in the Northern Center, and +11.85, +10.16, and +9.75 gpm in the Southern Center. All six region–month comparisons against non-compound years are significant at $p < 0.01$ (Fig. R16). This provides quantitative support for regional mid-tropospheric ridging as a circulation feature accompanying compound events in both hotspots.

2. Low-level NASH position

The 850-hPa NASH western ridge is defined as the western intersection of the Atlantic-connected 1560-gpm boundary with $u = 0$, retaining northward-increasing zonal wind (Li et al., 2012). Absolute monthly fields define the geometry, and the extracted longitude and latitude indices are detrended separately by calendar month over 1940–2022 before comparison of compound and non-compound years. Annual intersections provide the samples; group-composite contours in Fig. R17 visualize the circulation setting. The longitude differences are -2.68° , $+2.14^\circ$ and $+6.37^\circ$ for June–August, respectively, with the largest estimated eastward position difference in August ($p = 0.070$). The 95% intervals include zero (Table R10; manuscript Supplement Table S9). Local 500-hPa ridge enhancement can therefore coexist with a relatively eastward low-level western ridge, adding a vertical and month-dependent perspective to the Southern circulation pattern.

The Northern positive Z500 anomalies support mid-latitude ridging, with previous studies providing context for possible Rossby wave influences (Teng et al., 2013; Teng and Branstator, 2017). The revised circulation interpretation distinguishes this mid-tropospheric pattern from the independently diagnosed low-level NASH position.

3. Total column ozone

The updated total column ozone composites are reproduced in Fig. R19 as updated replacements for original manuscript Supplement Figs. S5–S6. Monthly within-box

minima range from -14.65 to -11.98 DU in the Northern Center, compared with -3.10 to -2.09 DU in the Southern Center. Section 3.2 discusses ridge-related tropopause elevation and horizontal ozone redistribution as a plausible explanation for the stronger Northern column response, drawing on the broader circulation–transport context provided by Neu et al. (2014).

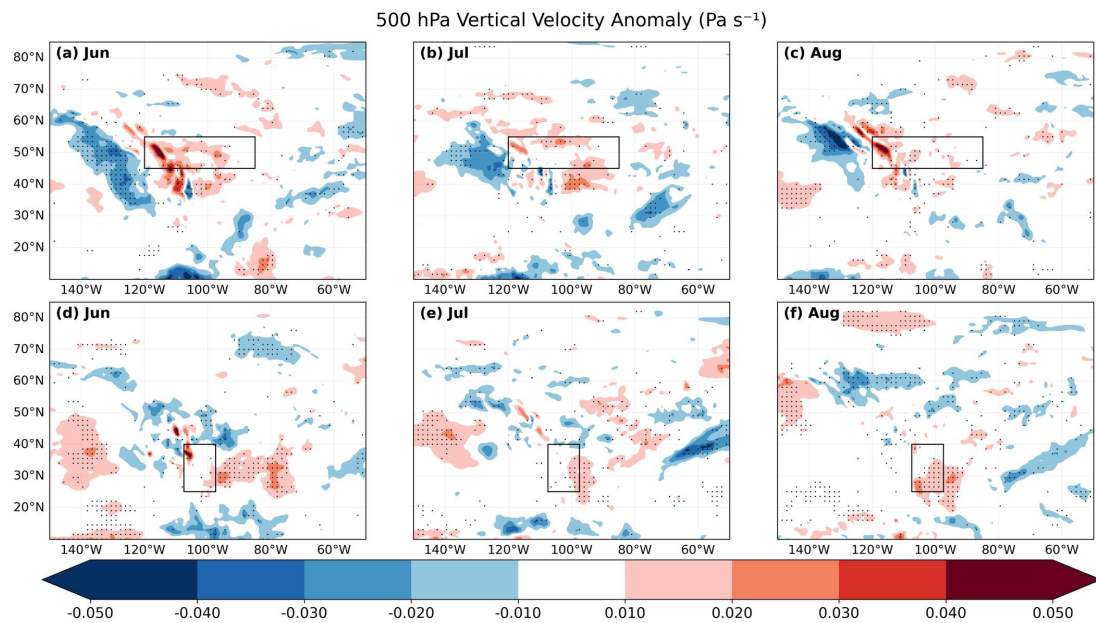


Figure R15. ERA5 500-hPa pressure velocity anomalies (ω , Pa s^{-1}) during compound months over 1940–2022. Rows show the Northern and Southern Centers; columns show June–August. Positive anomalies denote enhanced descent or weakened ascent. Stippling marks pointwise $p < 0.05$. Boxes mark the study regions.

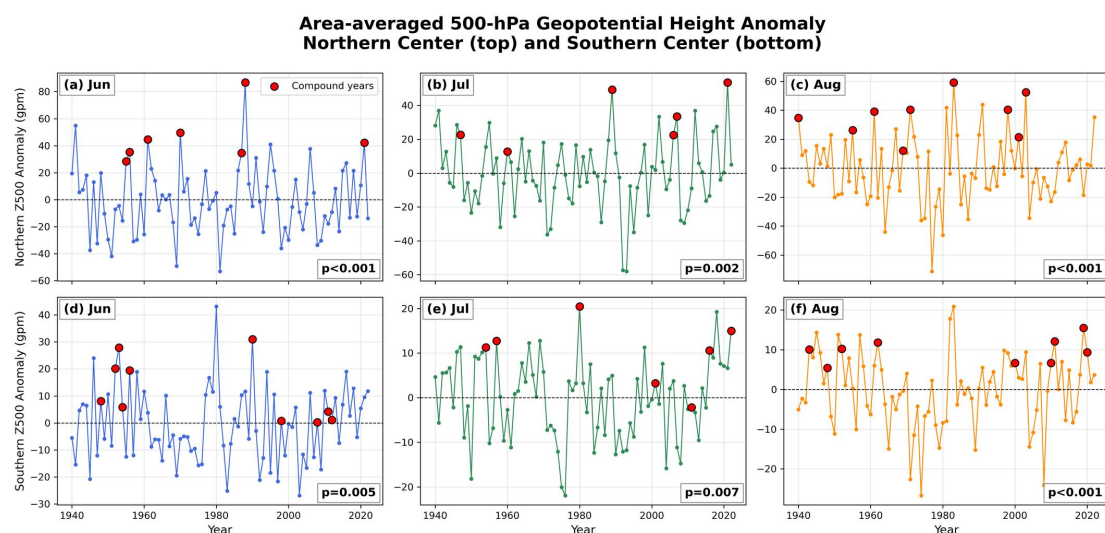


Figure R16. Area-weighted regional Z500 anomalies (gpm) during JJA 1940–2022. Rows show the Northern and Southern Centers. Red circles mark compound years. Panel p-values compare compound with non-compound years using two-sided Welch tests.

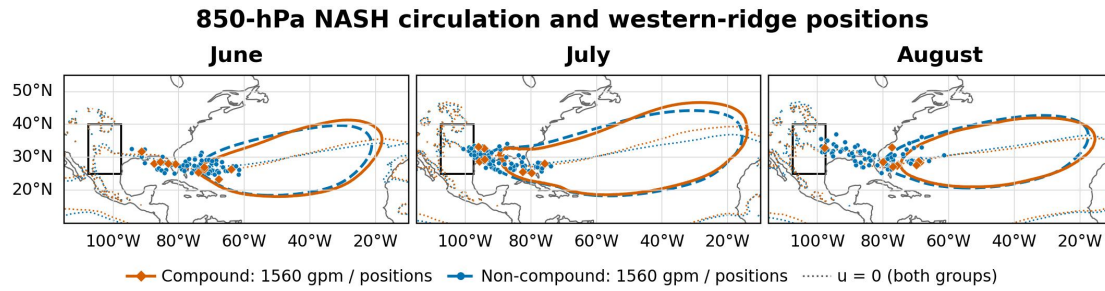


Figure R17. Monthly 850-hPa NASH geometry during 1940–2022. Orange and blue denote Southern compound and non-compound years. Solid or dashed boundaries show the 1560-gpm contours of group-composite absolute heights; dotted curves show $u = 0$. Diamonds and circles show individual annual western-ridge positions. The black box marks the Southern Center. Annual intersections, rather than intersections of the group-composite curves, supply the statistical samples.

Table R10. NASH western-ridge coordinate contrasts, 1940–2022.

Month	Index	N compound/ control	Δ (°)	95% Welch interval (°)	p(two- sided)
June	Longitude	10/73	−2.68	[−9.47, 4.11]	0.402
June	Latitude	10/73	−0.17	[−1.75, 1.41]	0.815
July	Longitude	7/76	2.14	[−5.85, 10.12]	0.545
July	Latitude	7/76	−0.18	[−3.05, 2.70]	0.887
August	Longitude	9/74	6.37	[−0.63, 13.37]	0.070
August	Latitude	9/74	−1.19	[−2.99, 0.62]	0.174

Note: Differences and unadjusted 95% Welch intervals are in degrees. Negative longitude indicates westward displacement and negative latitude southward displacement. p-values are two-sided.

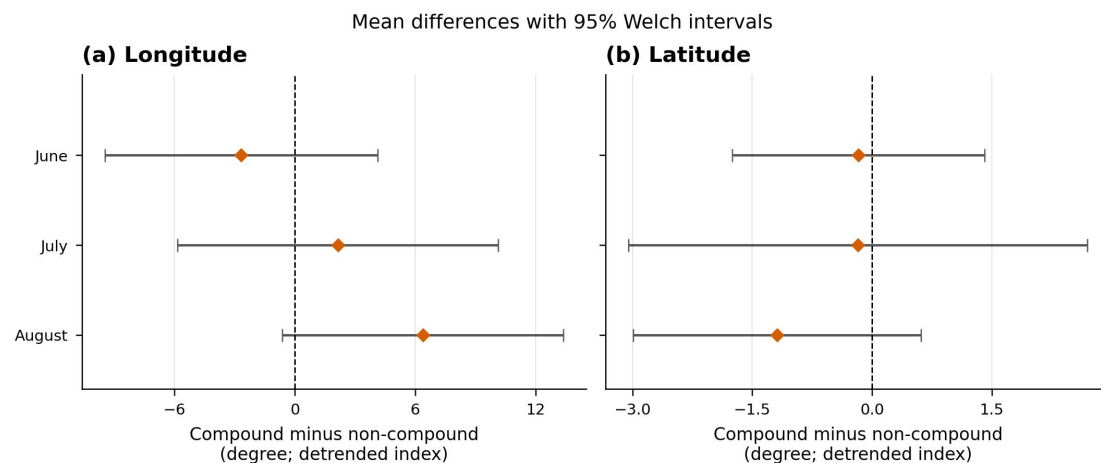


Figure R18. Compound-minus-non-compound differences in detrended annual NASH longitude and latitude indices for the Southern Center during 1940–2022. Bars show unadjusted 95 % Welch intervals. Negative longitude differences indicate westward displacement; positive latitude differences indicate northward displacement.

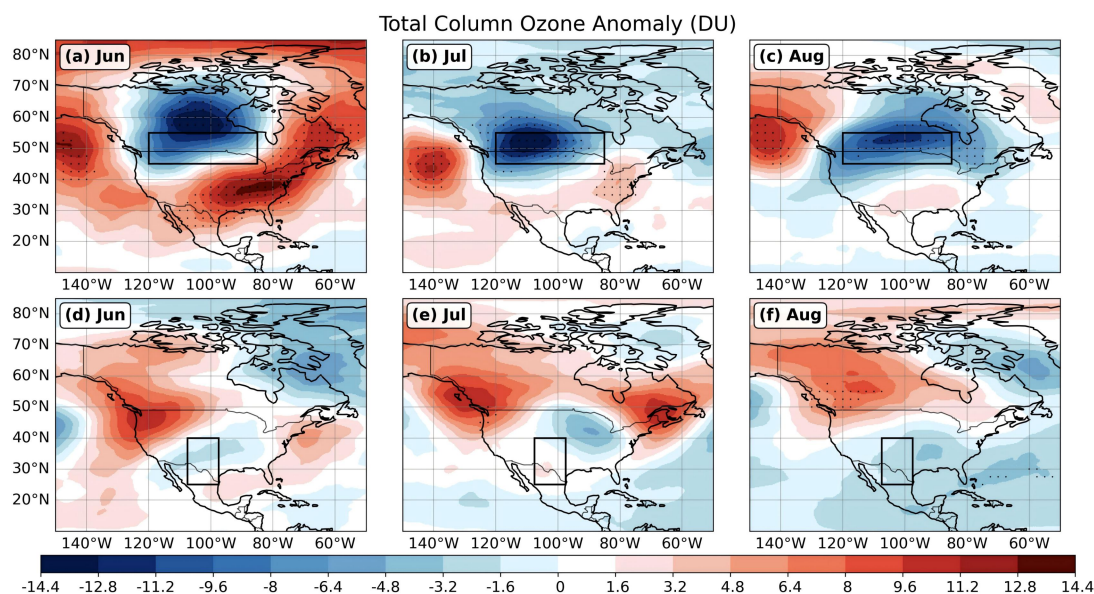


Figure R19. Updated replacements for original manuscript Supplement Figs. S5–S6. ERA5 total column ozone anomalies (DU) during compound months over 1940–2022. The Northern Center is shown above and the Southern Center below; columns show June–August. Stippling marks pointwise $p < 0.05$. Boxes mark the corresponding study regions.

Changes in the manuscript:

We have revised Section 2.2.

Revised text: “The 850-hPa NASH western ridge is defined by the western intersection of the Atlantic-connected 1560-gpm contour and $u = 0$, retaining northward-increasing zonal wind (Li et al., 2012). Positions are extracted from absolute monthly fields. The resulting annual longitude and latitude indices are detrended by calendar month over 1940–2022 before compound and non-compound years are compared using two-sided Welch tests.”

We have revised Section 3.2.

Revised text: “Regional mean Z500 anomalies are positive during compound months in both hotspots, with all six comparisons against non-compound years significant at $p < 0.01$ (Fig. S8). Positive 500-hPa pressure velocity anomalies over parts of the hotspots indicate enhanced descent or weakened ascent (Fig. S9). Together with the reduced cloud cover and positive Z500 anomalies, these diagnostics strengthen the physical interpretation of regional ridging as a circulation environment favoring simultaneous warming and enhanced surface UV.”

Revised text: “In the Southern Center, this mid-tropospheric ridge enhancement coexists with month-dependent differences in the low-level NASH western-ridge position. At 850 hPa, compound-minus-non-compound western-ridge longitude differences are -2.68° , $+2.14^\circ$ and $+6.37^\circ$ for June–August, with the largest estimated eastward displacement in August ($p = 0.070$; Fig. S10; Table S9). Such a vertical configuration may combine local ridge-induced warming with NASH-related modulation of moisture supply, influencing whether heat coincides with sufficiently clear skies for intense UV. The coordinate contrasts and their 95 % intervals are summarized in Fig. S11.”

Revised text: “The Northern ridge is also accompanied by pronounced negative total column ozone anomalies, with monthly minima ranging from -14.65 to -11.98 DU, compared with -3.10 to -2.09 DU in the Southern Center (Figs. S12–S13). One plausible explanation is that the amplified Northern ridge favors tropopause elevation together with horizontal redistribution of ozone, producing a stronger column response. Stratospheric circulation can influence tropospheric ozone through transport (Neu et al., 2014), providing a broader dynamical context for interpreting these column anomalies. The contrasting column responses are therefore consistent with differences in the upper-level structure and ozone transport associated with the two regional ridge configurations.”

We have revised Section 4.

Revised text: “The additional NASH analysis adds a vertical and monthly perspective to this circulation setting. Local mid-tropospheric ridging coexists with month-dependent low-level western-ridge position estimates, including a relatively eastward estimate in August. Low-level modulation of moisture transport from the Gulf of Mexico is a possible additional influence on whether hot conditions coincide with intense UV. The established role of the NASH in regional summer precipitation provides context for this hypothesis (Li et al., 2012).”

Diagnostic definitions, annual sampling and full comparisons are provided in Supplement Table S9 and Figs. S8–S11. The updated total column ozone composites are included as Supplement Figs. S12–S13.

2. Throughout the manuscript, consider moderating causal expressions such as “exacerbated ozone pollution” and “substantially accelerates” unless additional attribution analyses are provided.

We thank the referee for this suggestion. We have revised the title and replaced causal ozone wording with descriptions of the quantified associations:
“Concurrent Heat and Intense UV Extremes in North America: Regional Circulation Patterns and Surface Ozone Associations”

The revised title highlights the circulation patterns and surface ozone associations examined in the study. The Abstract, Section 3.3, Discussion, and conclusion now

connect the positive ozone contrasts with their meteorological context, using the quantitative evidence described under Major Comment 3.

Changes in the manuscript:

We have revised the title.

Revised text: “Concurrent Heat and Intense UV Extremes in North America: Regional Circulation Patterns and Surface Ozone Associations”

Causal ozone expressions have been revised consistently in the Abstract and Sections 3.3–4, as shown in the passages under Major Comment 3.

3. Please clarify how the detrended series, climatology, and mean ± 1 SD thresholds are used to identify hot years. Providing the selected event years and sample sizes in a supplementary table would improve transparency.

We thank the referee for this suggestion. Section 2.2 now specifies that the climatological mean and standard deviation are calculated from each region’s detrended calendar-month series, with extremes exceeding mean $+1\sigma$. Compound events exceed both temperature and UV thresholds. Event years and sample sizes are reported in Table R1 for 1940–2022, Table R3 for ozone over 2003–2022, and Table R4 for SWC over 1950–2022. Thresholds and events are identified independently for each analysis period. The catalogues are also retained as Tables S1–S3 in the manuscript Supplement. The updated T2m and newly added UV time series illustrate the joint monthly thresholds (Figs. R20–R21 below; Supplement Figs. S1–S2).

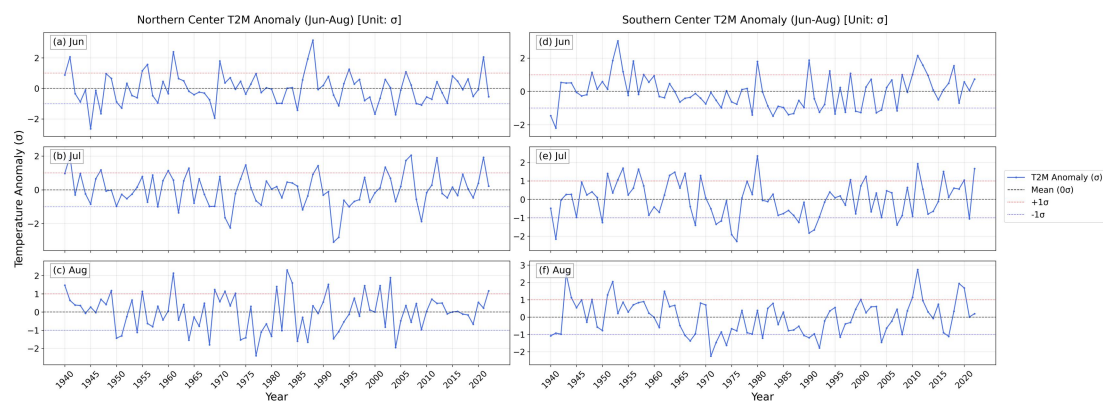


Figure R20. Time series of standardized monthly T2m anomalies during 1940–2022 in the Northern Center (a–c) and Southern Center (d–f), based on ERA5. Rows show June–August. Black dashed lines denote the climatological means; red and blue dotted lines mark $+1$ and -1 standard deviation, respectively. Series are linearly detrended before standardization. Event categories use the joint T2m and UV criteria in Table S1.

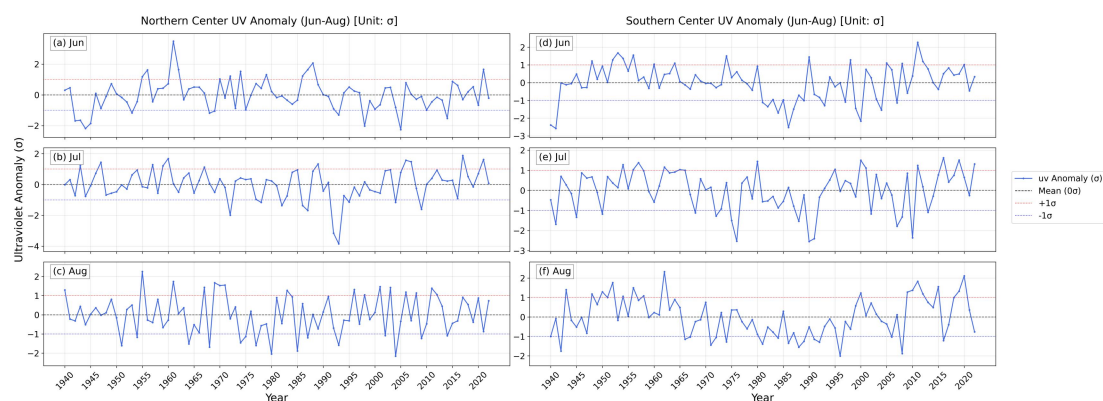


Figure R21. Time series of standardized monthly UV anomalies during 1940–2022 in the Northern Center (a–c) and Southern Center (d–f), based on ERA5. Rows show June–August. Black dashed lines denote the climatological means; red and blue dotted lines mark +1 and –1 standard deviation, respectively. Series are linearly detrended before standardization. Event categories use the joint T2m and UV criteria in Table S1.

Changes in the manuscript:

We have revised Section 2.2.

Revised text: “The standardized T2m and UV series illustrate the joint thresholds separately in Figs. S1–S2.”

The independently identified event years and sample sizes are listed in Supplement Tables S1–S3. The updated T2m and newly added UV time series are provided separately in Supplement Figs. S1–S2.

4. In the Fig. 1 caption, please check the panel reference “(g–h),” which appears to refer to panels g–i. The UV terminology should also be consistent: the stated 200–440 nm range is broader than UVB alone.

We thank the referee for identifying these issues. The panel reference for temperature–precipitation correlations in Fig. 1 is corrected to “(g–i).” The ERA5 variable is surface downward ultraviolet radiation (short name *uvb*, parameter 57), covering 200–440 nm. We therefore use “surface solar ultraviolet radiation (UV)” consistently, reserving *uvb* for the dataset identifier. Section 2.1 now identifies this variable and spectral range explicitly.

For the daily indicators in Fig. R24, we use the average of 18:00, 19:00 and 20:00 UTC during JJA 1980–2022. Cosine-latitude regional averaging precedes estimation of a fixed 90th-percentile threshold from all JJA daily values pooled over that period. Daily values are not detrended. A compound day strictly exceeds both thresholds on the same date; each qualifying date counts once, and heat and UV counts include compound days.

Changes in the manuscript:

We have revised Section 2.1.

Revised text: “In the ERA5 dataset, solar ultraviolet radiation (short name uvb, parameter 57) is defined as radiation within the wavelength range of 200–440 nm and is termed UV throughout this study.”

Revised text: “In addition, daily daytime averages (18:00, 19:00 and 20:00 UTC) of 2 m air temperature and surface solar ultraviolet radiation from the ERA5 reanalysis were used for the period 1980–2022 to analyze the long-term variability of extreme weather events during June–August (JJA).”

We have revised Section 2.2.

Revised text: “Daily indicators are regional averages of the three sampled UTC hours. For each variable and region, a fixed 90th percentile is calculated from all undetrended JJA daily values pooled over 1980–2022. Compound days strictly exceed both thresholds on the same date; each qualifying date counts once, and heat and UV counts include compound days.”

The Fig. 1 panel reference is corrected to (g–i); UV terminology and the daily-count units are consistent throughout the text and figures.

5. For the correlation maps in Fig. 1, please clarify whether the monthly time series were detrended before calculating correlations. Because both temperature and UV radiation may contain long-term trends, it would be useful to distinguish interannual co-variability from correlation induced by a common trend.

We thank the referee for this clarification. For each grid point and calendar month, we removed linear trends from the paired series before calculating correlations, focusing the analysis on interannual covariability (Fig. R22). T2m–UV and T2m–precipitation correlations use 1940–2022; T2m–SWC uses the common 1950–2022 period, with both series detrended after SWC is matched to the ERA5 grid. The generally negative T2m–precipitation correlations provide a hydroclimatic context for the warm and dry composite conditions. The updated early- and late-period T2m–UV comparisons are reproduced below and replace original manuscript Supplement Fig. S2.

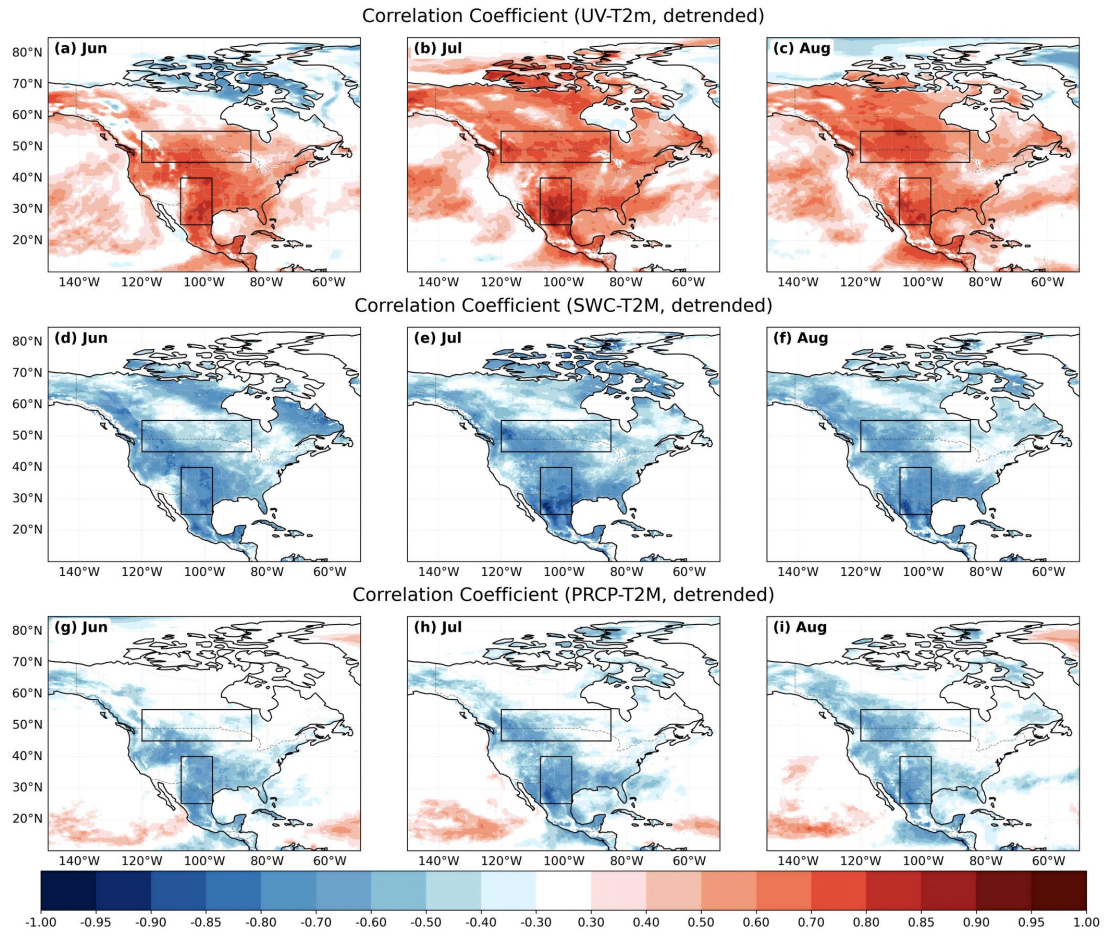


Figure R22. Updated replacement for manuscript Fig. 1. Spatial correlations of T2m with UV (a–c), SWC (d–f) and precipitation (g–i) for June–August. T2m–UV and T2m–precipitation cover 1940–2022; T2m–SWC covers 1950–2022. Red and blue indicate positive and negative correlations, respectively. Black boxes mark the two study regions.

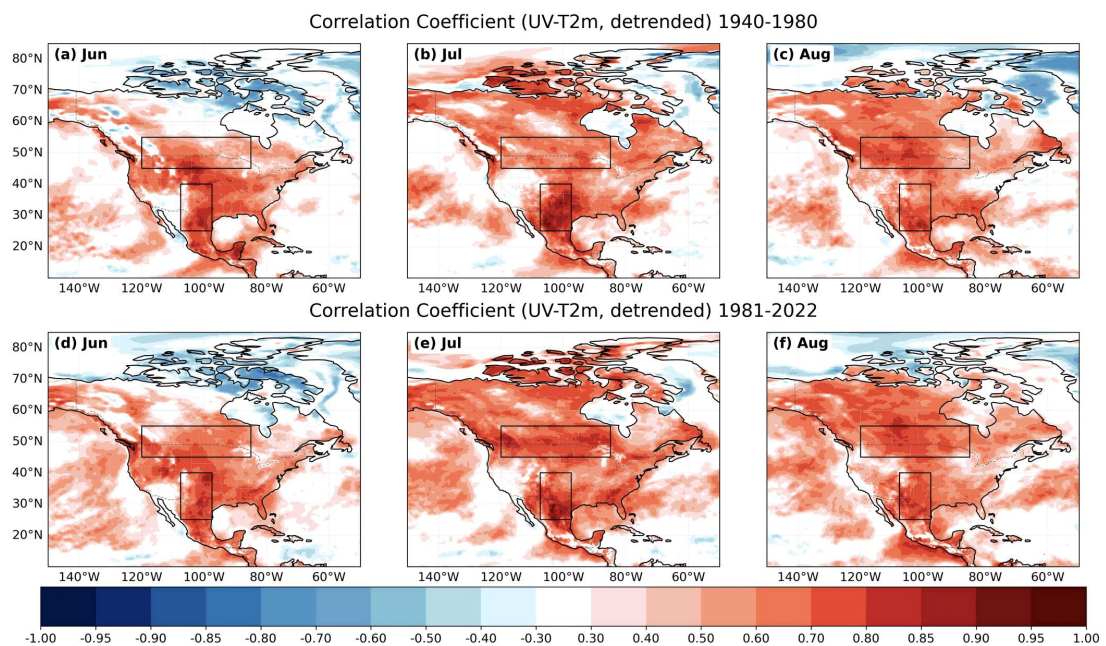


Figure R23. Updated replacement for original manuscript Supplement Fig. S2. Detrended T2m–UV correlations during 1940–1980 (top) and 1981–2022 (bottom). Columns show June–August. Boxes mark the study regions. These maps provide the subperiod comparison accompanying Fig. 1.

Changes in the manuscript:

We have revised Section 2.2.

Revised text: “Calendar-month correlations are calculated after linear detrending at each grid point. T2m–UV and T2m–precipitation correlations use 1940–2022; T2m–SWC uses 1950–2022. For the T2m–UV subperiod comparisons, trends are removed separately within 1940–1980 and 1981–2022.”

We have revised Section 3.1.

Revised text: “Spatial correlation analysis between summer 2 m air temperature and surface solar UV radiation during 1940–2022 reveals widespread positive correlations across most of North America (Fig. 1). Based on these spatial patterns, two primary hotspot regions characterized by concurrent extreme heat and intense UV radiation are identified. The maximum positive correlation coefficients reach 0.87 in June (Fig. 1a), 0.92 in July (Fig. 1b), and 0.88 in August (Fig. 1c). Furthermore, a comparison of these detrended correlations across two distinct periods (1940–1980 and 1981–2022) confirms that these two strong positive correlation centers (highlighted by black boxes) remain remarkably stable over the long term (Fig. S3).”

Revised text: “Similarly, temperature is strongly anti-correlated with total precipitation, exhibiting the strongest negative correlations of -0.81 in June (Fig. 1g), -0.89 in July (Fig. 1h), and -0.90 in August (Fig. 1i).”

The updated Fig. 1 shows detrended T2m correlations with UV, SWC and precipitation. Supplement Fig. S3 shows the detrended T2m–UV correlations for the two subperiods.

6. The trend values reported in Section 3.4 appear not to match those shown in the Fig. 7 legends. For example, the text reports northern trends of 1.60, 1.16, and 0.72 events per decade, whereas the figure labels appear to show 0.79, 0.91, and 0.39.

We thank the referee for identifying the mismatch. The corrected figure is reproduced as Fig. R24 (replacing original manuscript Fig. 7). Trends in annual JJA counts are: Northern Center, heat 1.60 days per decade ($p = 0.052$), UV 1.16 ($p = 0.057$), and compound 0.72 ($p = 0.068$); Southern Center, heat 3.35 days per decade ($p = 0.008$), UV 2.23 ($p = 0.001$), and compound 1.29 ($p = 0.022$). All estimates are positive, with statistically significant increases in the Southern Center. The figure and text consistently use days per decade for the annual counts of qualifying dates.

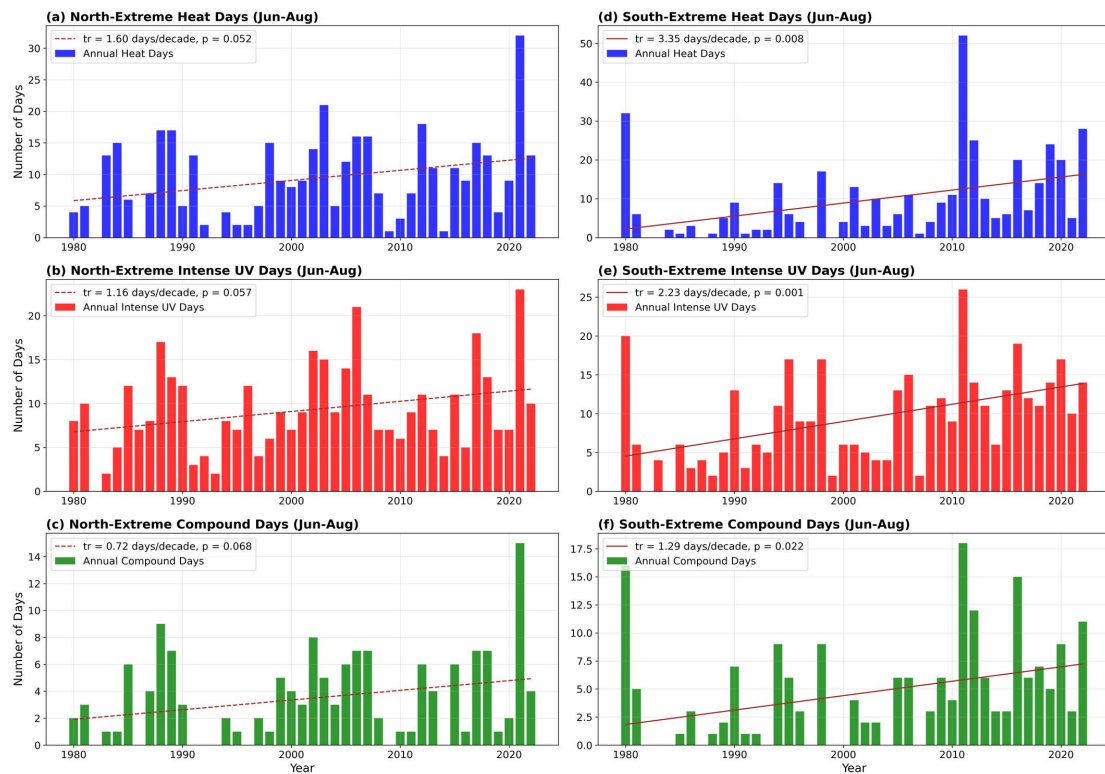


Figure R24. Updated replacement for original manuscript Fig. 7. Annual JJA counts of heat, intense UV, and compound days during 1980–2022 in the Northern Center (left) and Southern Center (right). Heat and UV counts include compound days. tr is the linear trend in days per decade. Two-sided p -values test a zero slope; solid and dashed trend lines denote $p < 0.05$ and $p \geq 0.05$, respectively.

Changes in the manuscript:

We have revised Section 3.4.

Revised text: “In the southern center, the escalation of extremes is stark and statistically robust ($p < 0.05$). Extreme heat and intense UV days increase at rates of 3.35 and 2.23 days per decade, with $p = 0.008$ and 0.001, respectively (Fig. 9d–e). The frequency of their concurrence increases by 1.29 days per decade ($p = 0.022$; Fig. 9f).”

Revised text: “Conversely, while the northern center exhibits upward tendencies, none of these trends achieve statistical significance at the 95 % confidence level (Fig. 9a–c). The rates of increase are substantially flatter (1.60, 1.16, and 0.72 days per decade for heat, UV, and compound days, respectively), with $p = 0.052$, 0.057, and 0.068. In this region, pronounced interannual fluctuations overshadow the long-term decadal signal.”

The same trend values and units are used in the Abstract, Section 4 and the captions and labels of the annual-count figure and conceptual schematic.

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