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A Climatology of 1995–2024 United States Warm-Season Derecho Events and Analysis of Potential Climate Forcing Associations

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ABSTRACT

We identified 147 contiguous United States warm-season (May, June, July, and August) derechos between 1995 and 2024. This results in an average of approximately five derechos each warm season. Using the compiled database, trends in derecho occurrence over the last 30 y were evaluated. The frequency of derecho-producing convection has increased over the past 30 y, most notably during the last 10 y, although the degree to which inconsistencies in storm reporting over the decades and multi-decadal climate variability contribute to this trend is unclear. The number of high-end derechos occurring every year has also increased with time. Spatiotemporal distributions and derecho series are identified, and distributions of severe wind reports across derecho events are presented for the 1995–2024 period. Spatial trends in derecho-path locations emulate the (warm) seasonal shift of mesoscale convective systems and elevated mixed layers across the US, with a poleward shift as the warm season progresses. In addition to the derecho-trend analysis, we also look at associations between annual and monthly derechos with seasonal and sub-seasonal climate-forcing mechanisms. The most notable association is Niño-4 sea-surface temperature anomalies with warming in the central Pacific.

1. Introduction

Derecho-producing mesoscale convective systems are an annual occurrence across the continental United States (CONUS) during the late spring and summer months (May, June, July, and August [MJJA]). A few derechos in recent history have produced multiple billions of dollars in damage, loss of property and major infrastructure, and even fatalities. Historic examples include the 29 June 2012 derecho (Bentley and Logsdon 2016; Law 2016; Shourd and Kaplan 2021) that impacted parts of the Midwest, Appalachia, and Mid-Atlantic, as well as the ≥$13 billion, 10 August 2020 "Corn Belt" derecho, which was the costliest single thunderstorm disaster in US history (Smith 2020; NWS 2024).

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Work to evaluate how derechos may evolve in the future, warmer climate is relatively new with only a handful of studies and varied findings. Using climate modeling, the consensus is that the spatial coverage of future derechos, mesoscale convective systems (MCS), and other convectively driven wind events (e.g., Prein et al. 2017; Schumacher and Rasmussen 2020; Lasher-Trapp et al. 2023; Prein 2023; Haberlie et al. 2024; Kaminski et al. 2024) and environments conducive to them (Singh et al. 2017; Diffenbaugh et al. 2013; and others) will increase in a warmer climate. In fact, increases in MCS and convective nontornadic winds have already been noted over the past few decades (Feng et al. 2016; Schumacher and Rasmussen 2020; Prein 2023; Haberlie et al. 2024). The major uncertainty in projected derecho activity lies in how the future intensity of such events may be impacted. On one hand, climate modeling has indicated that both singular MCSs and derecho-producing MCSs (DMCSs), as well as entire seasons, could increase in duration and intensity by the end of the century (Prein et al. 2017; Haberlie et al. 2024; Kaminski et al. 2024).

On the other hand, some modeling results indicate no trend in future (D)MCS intensity (Schumacher and Rasmussen 2020). A derecho that occurred over the Mediterranean in 2022 was found to be directly influenced and strengthened by anthropogenic climate change (González-Alemán et al. 2023), while modeling experiments of the 29 June 2012 Midwest and Mid-Atlantic derecho indicated that the same event in a warmer climate could be weakened (Li et al. 2023). Derechos are highly destructive events that have major impacts on infrastructure, agriculture, lives, and property (Squitieri et al. 2023a). Given the possibility for increased future derecho coverage, and perhaps strength, the need for improved and timelier derecho forecasting has never been more pressing.

Derecho forecasting has progressed over the last few decades, following advancements in convection-allowing numerical modeling. Despite this, even short-term (within 12 h of initiation) forecasting of derecho development and evolution is still difficult due to the large sensitivity of convection-allowing model forecasts in environments conducive to derecho-producing convection (Squitieri et al. 2023b). Along with the ability to forecast derechos hours or days ahead of time, the ability to forecast and anticipate high-end severe-weather outbreaks including derechos, as well as particularly active severe weather seasons, is also in high demand (Weaver et al. 2013; Gensini 2021).

An abundance of studies regarding the link between climate variability and specific types of severe convective storms (SCSs) towards this end is apparent over the past couple of decades, particularly with regards to potential El Niño-Southern Oscillation (ENSO) and Madden-Julian Oscillation (MJO) SCS connections, amongst others. Links between ENSO La Niña events and tornadoes have been identified throughout the literature (Allen et al. 2015; Lee et al. 2016; Corey and Senkbeil 2023), and the positive phase of the Trans-Niño Index (TNI) has also shown correlation to years with strong tornado outbreaks (Lee et al. 2013). Some skill has also been demonstrated in forecasting tornadoes using MJO active phases and evolution (Thompson and Roundy 2013; Tippett 2018; Moore and McGuire 2020; Miller et al. 2022), including forecasts at the sub-seasonal timescale (Baggett et al. 2018). Similar links have been made with La Niña events (Allen et al. 2015), as well as various phases of the MJO, and hail frequency and intensity (Barrett and Henley 2015; Baggett et al. 2018; Miller et al. 2022). The ENSO and MJO have also been found as useful indicators for general severe convection (Tippett et al. 2015; Zheng et al. 2018; McCormick et al. 2023) and even lightning (Abatzoglou and Brown 2009; Malloy et al. 2023).

The impacts of climate variability on warm-season temperature anomalies also have been explored (Loikith and Broccoli 2014; Luo and Lau 2020; Jong et al. 2020, 2021). With anomalous heating and elevated mixed layers (EML) and pressure ridges being strongly associated with derecho-producing convection (Banacos and Ekster 2010; Shourd and Kaplan 2021; Pryor and Demoz 2022; Squitieri et al. 2023b) and summertime MCSs in general (Feng et al. 2019), the influence of larger-scale background climate (i.e., climate indices) and climate change on EMLs are also relevant. To the authors' knowledge, no such studies exist examining the link between climate teleconnection indices and derecho occurrence. This is perhaps and partly because of no publicly available, comprehensive, and large-enough derecho database from which to conduct such a study (Squitieri et al. 2023a).

The purpose of this study is twofold. Because no climatologically appropriate (i.e., ≥30 y), publicly available database of derecho events exits, a database of 1995–2024 warm-season derechos was developed. First, we present an analysis of derecho events and trends over the last 30 y using the new climatology. Second, we examine potential associations between annual warm-season derecho occurrence and various climate signals which have been found to influence other types of SCSs including tornadoes, hail, and general severe convective wind events. The data and methods used to compile the derecho database used in this study and conduct statistical and qualitative analysis are described in section 2. Results are presented in section 3, and additional discussion and conclusions are in section 4.

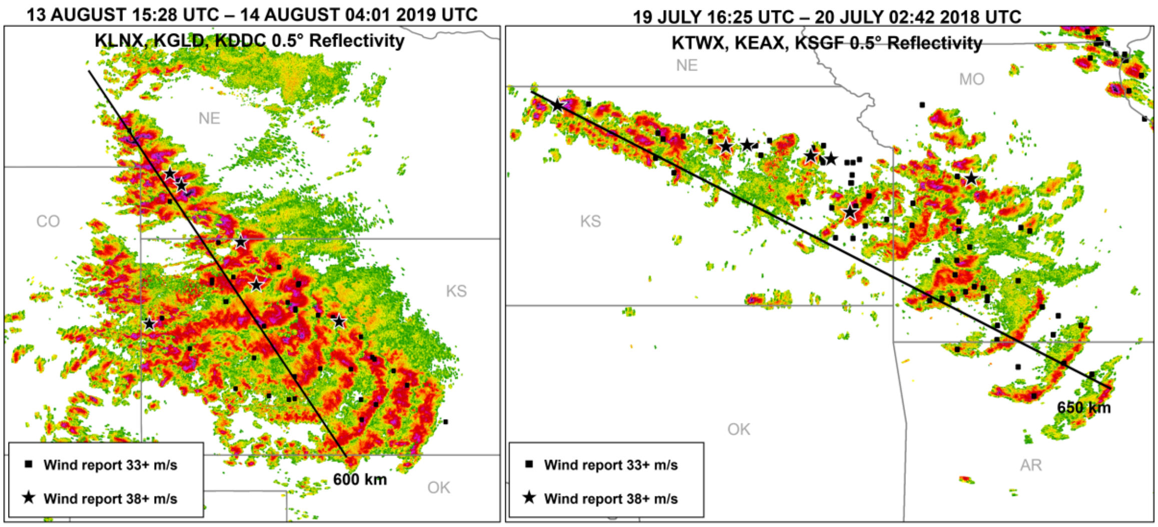

Figure 1: Left panel: 13 August 2019, and right panel: 19 July 2018 derecho NEXRAD base reflectivity (0.5°) composites, approximate derecho path centerline/major axis, and filtered SPC storm reports (black squares: severe wind ≥26 m s^{-1}, black stars: severe wind ≥38 m s^{-1}). The derecho approximate path centerlines and major axis lengths are annotated on the maps in black. NEXRAD on AWS was accessed from https://registry.opendata.aws/noaa-nexrad/ and processed using the Python ARM Radar Toolkit (Helmus and Collis 2016). "Filtered" storm reports were obtained from the SPC Severe Weather Events Archive (SPC 2024).

2. Data and methods

a. Derecho database

The numerous definitions of a derecho are well outlined in recent literature (Squitieri et al. 2023a; Kaminski et al. 2024; Squitieri et al. 2025a). The original Johns and Hirt (1987) definition (Table 1) was used operationally until circa 2019 when the American Meteorological Society (AMS) formally adopted proposed definition criteria from Corfidi et al. 2016. Previous (Johns and Hirt 1987; Bentley and Mote 1998; Bentley and Sparks 2003; Coniglio and Stensrud 2004; Ashley and Mote 2005) and recent (Guastini and Bosart 2016; Gatzen et al. 2020; Fery and Faranda 2024; Li et al. 2024; Squitieri et al. 2025a, 2025b) derecho climatologies all use varying definitions and identifying criteria for derechos, with most studies adhering to the definitions of either Johns and Hirt (1987) or Coniglio and Stensrud (2004), which are listed in Table 1.

Scientists (i.e., Corfidi et al. 2016 and Squitieri et al. 2025a,b) are converging on a more phenomenologically based definition of a derecho, as compared to previous decades which saw the use of a more generic definition for such a storm. The operational definition of a derecho at the time of this writing, according to the AMS, is "a widespread convectively induced straight-line windstorm" (AMS 2019). They note that derechos also have phenomenologically distinct features such as "sustained" bow echoes, book-end vortices, and rear-inflow jets. The impacted area must have a major axis length of ≥650 km and a minor (cross) axis width of ≥100 km or greater. An example of a derecho meeting these length and width criteria is shown in the right panel of Fig. 1. The 650-km operational length requirement was initially proposed by Corfidi et al. (2016) before being adopted by the AMS (2019). For reference, the Table Rock Lake derecho that occurred on 19 July 2018, a "significant" (NWS 2019) derecho that killed 17 people, had a path length of 650 km (Fig. 1, right panel). The previous derecho length requirement was 400 km, the same proposed in the seminal paper on derechos by Johns and Hirt (1987). The 400 km distance limit was reintroduced in the Squitieri et al. (2025a, 2025b) climatology. Corfidi et al. (2016) proposed to remove the Johns and Hirt (1987) requirement for several (i.e., three) significant (≥33 m s^{-1}) wind reports, while the most recent proposed definition (Squitieri et al. 2025a, 2025b) introduced a significant-wind report requirement of at least five gusts ≥33 m s^{-1}. These "hard" limitations to derecho path length and number of significant gust reports are all arbitrary and subjectively chosen by experts. The criteria used to identify derechos in this study (Table 1) are a synthesis of the Corfidi et al. (2016), Coniglio et al. (2004), and Johns and Hirt (1987) definitions.

Table 1: Various published criteria for identifying derechos which were used to inform the criteria in this study. The Johns and Hirt (1987), Coniglio and Stensrud (2004), and Corfidi et al. (2016) criteria are compared to those in the present study. Adapted from Table 1 in Coniglio and Stensrud (2004).

No.	*Johns and Hirt 1987 (JH87)*	*Coniglio and Stensrud 2004 (CS04)*	*Corfidi et al. 2016 Proposed Definition*	*Present Study*
1	There must be a concentrated area of convectively induced wind gusts greater than 26 m s^{-1} that has a major axis length of 400 km or more	As in JH87	There must be a concentrated area of convectively induced wind gusts greater than 26 m s^{-1} that has a major axis length of 650 km or more and major axis width of 100 km or more	There must be a concentrated area of convectively induced wind gusts greater than 26 m s^{-1} that has a major axis length of 600 km or more and major axis width of 100 km or more
2	The wind reports must have a chronological progression	As in JH87	As in JH87	As in JH87
3	No more than 3 hours can elapse between successive wind reports	No more than 2.5 hours can elapse between successive wind reports	Not specified	As in CS04
4	There must be at least three reports of either F1 damage or wind gusts greater than 33 m s^{-1} separated by at least 64 km during the MCS stage of the event	Low end, not used; Moderate, as in JH87; High end, there must be at least three reports of either wind gusts greater than 38 m s^{-1} or comparable damage, at least two of which must occur during the MCS stage of the event	Not used	Moderate as in JH87, High-end as in CS04
5	The associated MCS must have spatial and temporal continuity	The associated MCS must have spatial and temporal continuity, and each report must be within 200 km of the other reports within a wind gust swath	As in JH87	As in JH87
6	Multiple swaths of damage must be part of the same MCS as indicated by the available radar data	As in JH87	As in JH87 and must include radar-observed features such as a bow echo(es) and rear inflow jet(s)	As in Corfidi et al. 2016

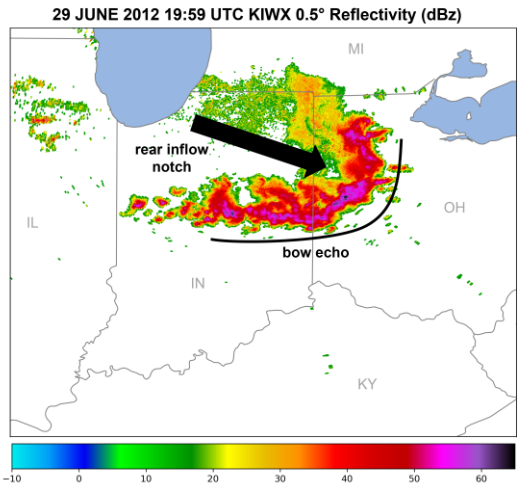

Figure 2: NEXRAD base (0.5°) reflectivity valid at 19:59 UTC 29 June 2012. Data sourced and processed as in Fig. 1.

The definition of a derecho employed herein is a concentrated area of convectively-induced gusts ≥26 m s^{-1} with ≥3 gusts ≥33 m s^{-1}. Each event must have a major axis length ≈600 km, and a minor axis width ≥100 km. Also, phenomenologically unique criteria such as sustained bow echoes and rear-inflow jets (Fig. 2), identifiable on radar, were also included to qualify derechos in the present study. The length requirement was reduced from 650 km (Corfidi et al. 2016) to 600 km to include five events the authors deemed derechos based on their physical properties. One of these sub-650 km derechos is shown in the left panel of Fig. 1 for reference. There are also two additional cases included in this study with sub-600 km path lengths. While the addition of the sub-600 km events is subjective, the authors consider both events to be derechos based on their physical characteristics and respective intensities. Each sub-600 km event had at least one gust >45 m s^{-1} (>100 mph). Derechos in this study were also classified as "high-end" using the same criteria as in Coniglio and Stensrud (2004, see Table 1) where, in addition to qualifying as a derecho, at least three gusts of ≥38 m s^{-1} must be reported or observed (Table 1), with ≥64 km between each report to address report clustering.

Derechos during the 1995–2004 warm seasons (MJJA) were identified manually using a combination of resources. First, the SPC Severe Weather Events Archive was consulted for events with storm report patterns indicative of a long-lived, bowing MCS during MJJA. The new climatology by Squitieri et al. (2025a, b) that spans from 2000–2022 validates the decision to only include MJJA events, as they only found two cold-season (non-MJJA) derechos during that time. For each of the identified events, storm reports from the SPC archive (filtered when available), the SPC National Severe Weather Database Browser (SPC 2024), and the NCEI Storm Events Database (NCEI 2024) were consulted to ensure the required number of gusts at specified intensities were present for each event. NEXRAD radar reflectivity data was simultaneously evaluated to verify that gusts were associated with a bowing MCS(s) and accompanied rear-inflow jet (s). Radar data were viewed using the SPC Severe Weather Events Archive (where available), Iowa State University Iowa Environmental Mesonet NEXRAD Mosaic app (Herzmann 2025) and RadarScope (DTN 2025a). Derecho-path start and end locations, used for calculating the estimated path (major axis) length, were approximated using storm reports and radar.

Across the literature, the guidance on how to discern when a storm or cluster of storms should be considered the start of a derecho is quite varied. The beginning of a derecho path in this study was chosen as the location where a convective cell(s) or a parent, non-derecho-producing MCS, begins its upscale growth into a progressive, bowing DMCS, or begins generating severe wind reports, a combination of the criteria used in Coniglio et al. (2004) and Corfidi et al. (2016). The end is where the last storm report(s) occur, as derecho remnants tend to keep their bowing shape even after winds are no longer severe, based on the observation and examination of thousands of bow-echo events by the authors during this study.

Datasets from previous derecho climatologies (Coniglio and Stensrud 2004; Guastini and Bosart 2016; Li et al. 2024) also were examined and informed the development of the database presented here. The Coniglio and Stensrud (2004) dataset spans from 1986–2001 with a total of 244 derechos. Their dataset covers the entire calendar year, as opposed to just MJJA as in the present study. Their derecho path-length requirement was the shorter 400-km distance, and some weaker bowing MCS were included in the Coniglio and Stensrud (2004) that do not meet the minimum of at least three well-spaced (i.e., >64 km) wind reports of 33 m s^{-1} or greater wind reports. When excluding cold-season and the "low-end" events from the Coniglio and Stensrud (2004) climatology, their total number of derechos in the 16-y period of study is reduced to 113 events. Due to the limited availability of consistent and quality data pre-2000, we relied more heavily on the Coniglio and Stensrud (2004) database for identifying and verifying derecho events between 1995–2000, but still consulted all other resources mentioned previously for the most informed derecho identification possible.

The Guastini and Bosart (2016) database spans the warm seasons (MJJA) from 1996–2013 and includes 256 derechos over the 18-y period of study. Their criteria also exclude the minimum ≥33 m s^{-1} gust requirement. Derechos are not broken out into categories such as low-end, moderate, and high-end, so it is unclear how many of the 256 events are low-end and would not be directly comparable with this study. The Li et al. (2024) derecho climatology contains 537 events from 2004–2021, many of which also would not be considered derechos in the present study or operationally. The criteria used in Li et al. (2024) are unique compared to other studies, due to their leveraging of machine-learning in the identification of DMCS. They use observational networks to find "wind swaths," but with much lower windspeed requirements than all other derecho studies (Li et al. 2024). As a result of identification by wind swath, many of the "derechos" in their database do not have all the phenomenological features required to be derechos. Consistent with Coniglio and Stensrud (2004) and Ashley et al. (2005), and as noted by Squitieri et al. (2023a), we found major differences between all datasets examined due to the variation in physical derecho criteria required (or not) and the quantitative (wind report) criteria used across studies.

b. Seasonal climate-index statistics

Derecho events from the resulting 1995–2024 database and nine climate indices from January through August of each year were analyzed statistically, using Pearson correlation coefficients and associated p-values, as well as Spearman rank correlation coefficients and their associated p-values. These statistics were computed using the statistical functions of the Python module SciPy (Virtanen et al. 2020). This type of significance testing is common throughout literature related to climate indices and teleconnections (e.g., Muñoz and Enfield 2011; Weaver et al. 2012; Lee et al. 2013; Tippett et al. 2014; Barrett and Henley 2015; Tippett et al. 2015; Corey and Senkbeil 2023,), and the Pearson correlation is favored amongst these studies. However, given the wide variability in annual derecho occurrence and resulting outlier years, the Spearman correlation is also considered here, as it is not as heavily influenced by outlier data.

Examining potential associations between derecho occurrence and various seasonal climate teleconnection signals represents a gap in literature. Results from this type of analysis have potential application to seasonal severe weather and derecho forecasting. The climate indices evaluated and a description of their associations with other SCSs and extreme warm-season temperatures and drought are described in the subsequent sections. All climate index data was obtained from The NOAA Physical Sciences Laboratory (PSL) El Niño Index Dashboard (NOAA PSL 2024a) unless noted otherwise.

i.) El Niño Southern Oscillation

ENSO is one of the main drivers of interannual climate variability (e.g., Tippett et al. 2015; Gensini 2021; Corey and Senkbeil 2023) and has an influence on the spatial distribution and frequency of various types of SCSs over North America. Studies have examined the potential links between ENSO and U.S. tornado activity, and have come to the consensus that La Niña winters lead to increased winter and spring tornado and hail activity over the continental U.S. (CONUS) (Lee et al. 2013; Allen et al. 2015; Lee et al. 2016; Cook et al. 2017; Moore et al. 2018; Mercer et al. 2024; Nouri et al. 2021).

On the other hand, tornado outbreaks (in general) are more likely during El Niño events (Mercer et al. 2024), thus highlighting the inherent complexity of the SCS and climate-teleconnection problem. Associations have also been made between ENSO, specifically La Niña events, and extreme temperatures and drought, key for the development of anomalous high pressure and EMLs across North America during the warm season (Hu and Feng 2012, Luo and Lau 2020, Jong et al. 2021). ENSO can be examined a variety of ways, including but not limited to the Oceanic Niño Index (ONI), Niño 1+2 region sea-surface temperature (SST) anomalies, Niño 3.4 SST anomalies, Niño 4 SST anomalies, and the TNI. All these ENSO indices and metrics were examined against annual derecho occurrence.

ii.) Pacific North American Oscillation

The Pacific North American (PNA) oscillation is a prominent mode of wintertime climate variability across North America (Liu et al. 2020) but has been found to impact warm-season weather patterns too (Harding and Snyder 2015; Corey and Senkbeil 2023). While typically not seen as a major driver of severe convection over the CONUS, some associations have been made between the PNA and U.S. cold season and warm-season tornadoes (Corey and Senkbeil 2023; Kim et al. 2024; Mercer et al. 2024). The PNA can also be more influential on extreme temperatures across the CONUS than ENSO (Loikith and Broccoli 2014), with positive PNA resulting in drier/warmer conditions and increased periods of drought over the central and western CONUS (Justino et al. 2022), key EML development regions. The findings of Liu et al. (2020) indicate that there will be significant increases in extreme PNA events (both positive and negative) and, as such, extreme weather and climate across the CONUS in a warmer climate (RCP 8.5), with a tendency towards more positive PNA events.

iii.) Pacific Decadal Oscillation

The Pacific Decadal Oscillation (PDO) is an atmospheric and SST oscillation akin to ENSO, though on a much longer timescale (multi-decadal, Mills and Walsh 2013). As the PDO is generally considered to mostly influence the weather during boreal winter, not much work has been done on the effects of PDO on SCSs or during the warm season.

iv.) North Atlantic Oscillation

The North Atlantic Oscillation (NAO) differs from the previously described climate indices in that it is based on surface sea-level pressure differences across the Atlantic Ocean rather than the Pacific Ocean. The NAO is examined less often with regards to SCSs, perhaps because it is downstream rather than upstream with respect to the CONUS. Though previously found to have no impact on tornado or SCS occurrence (Lee et al. 2013), recently Corey and Senkbeil (2023) suggested that the NAO does have some regional influence on tornado activity.

v.) Madden-Julian Oscillation

The MJO is a prominent driver of intraannual climate variability rather than interannual variability (Tippett et al. 2015; Gensini 2021). To evaluate the MJO, both the real-time multivariate MJO (RMM) index (Wheeler and Hendon 2004; Gottschalck et al. 2010; Zhang 2013) and univariate outgoing longwave radiation (OLR)-based MJO index (OMI, Kiladis et al. 2014; Stachnik and Chrisler 2020) were compared with derecho occurrence. While the RMM has been traditionally favored for evaluating SCS and climate relations, the RMM can dampen or lose the MJO signal during the boreal summers (Kiladis et al. 2014; Tippett 2018; McCormick et al. 2023). Because of this, OMI was also evaluated. MJO RMM values were acquired from the Commonwealth of Australia Bureau of Meteorology (2024), while ECMWF Reanalysis v5 (ERA5) OMI values were obtained from the NOAA PSL website (NOAA PSL 2024b). Because OMI data were only available through 2023, only 142 derechos (1995–2023) instead of the full 147 were evaluated against the MJO.

3. Results

a. 1995–2024 warm-season derechos

i.) Spatiotemporal trends

Thirty warm seasons from 1995–2024 were evaluated for SCS events qualifying as derechos. Of those, 147 derechos (Fig. 3) were identified, for an average of five per warm season (Table 2). Large interannual variability of derecho events is immediately apparent (Figs. 3, 4, and 5) consistent with the findings of Squitieri et al. (2025b). Most derechos occur in June (34.0%) and July (36.7%) with an average of nearly two per season for each month (Table 2). The average number of derechos *per year* increased over the period of study, with approximately three from 1995–2004, four from 2005–2014, and more than seven from 2015–2024 (Fig. 4).

Consistent with Squitieri et al. 2025b, derecho occurrence has large interannual variability, with some years having few or no derechos and others having >10 events. The annual average number of derechos identified by this study is lower than that of previous climatologies that found averages from about seven derechos per warm season (Coniglio et al.

2004) up to 14 (Guastini and Bosart 2016) or more (Li et al. 2024). This is higher than the results of Squitieri et al. (2025b), who found an average of just three derechos a year. Differences across climatologies are largely due to differences in wind-report requirements, path-length restrictions, and the inclusion of certain physical characteristics.

Of the 147 derechos classified, 46 are high-end using the Coniglio and Stensrud (2004) criteria discussed in section 2a. These 46 events make up just under ⅓ of derechos (31.3%). The average number of high-end events has also increased over the last 30 y. From 1995–2004 an average of <1 high-end derecho occurred per year. This number increased to >1 per year from 2005–2014, then to ≈3 each year from 2015–2024. Since 2013 there have been ≥5 derechos per year, and ≥1 high-end event each year. This trend has been identified in MCS climatologies, with MCSs occurring more frequently and becoming more intense (Feng et al. 2016; Schumacher and Rasmussen 2020; Haberlie et al. 2024). The increased frequency, spatial coverage, and intensity of MCSs (particularly long-lived MCSs) may continue in a future warmer climate over the next century (Prein et al. 2017; Schumacher and Rasmussen 2020; Haberlie et al. 2024).

During May and June, derechos occur over much of the eastern half of the CONUS. In May the derecho paths are quite varied, with the three main corridors of derecho activity (Johns and Hirt 1987, Coniglio and Stensrud 2004, Guastini and Bosart 2016, Wade et al. 2024) not emerging until June (Fig. 5, top panels). The three main regions where derechos are most frequent include the Northern Plains and Upper Midwest, the "Corn Belt" and Midwest, and the southeastern Great Plains (outlined in Fig. 3, left panel). During July and August, derechos are almost exclusively confined to these three main derecho corridors. The two most prominent derecho-producing regions are the Corn Belt/Midwest and the Northern Plains into the Upper Midwest corridors. The results for derechos in this climatology are consistent with those of Johns and Hirt (1987), Coniglio and Stensrud (2004), and Guastini and Bosart (2016), and Squitieri et al. (2025b), with any differences largely being driven by variability across identification criteria, including storm-report requirements and minimum path length.

A poleward shift in derecho activity occurs as the warm season progresses, with almost no derechos occurring in the Deep South during July and August (Fig. 5, bottom panels), a consistent trend across derecho climatologies (Coniglio and Stensrud 2004; Coniglio et al. 2004; Guastini and Bosart 2016; Squitieri et al. 2025b). This trend is also seen in the seasonal movement of general MCS activity (Feng et al. 2019), the EML (Andrews et al. 2024) and northwest-flow outbreaks and the polar jet stream (Johns 1982, Johns and Hirt 1987, Wang et al. 2009), a possible connection that should be evaluated explicitly in future research.

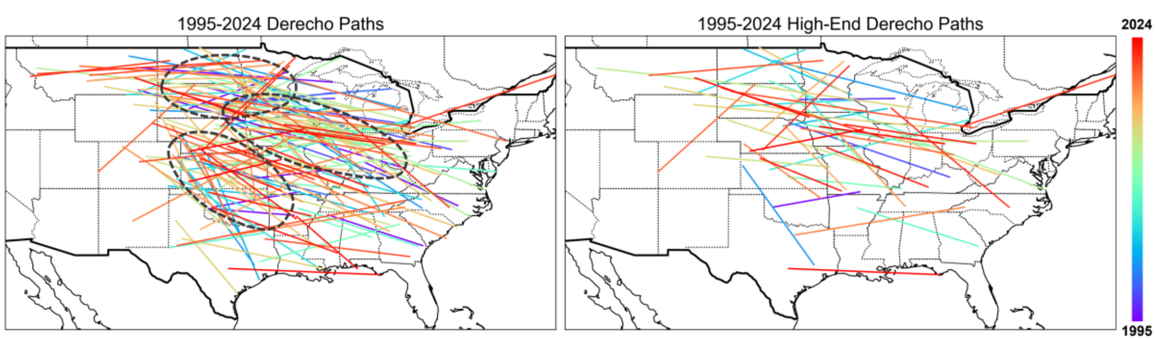

Figure 3: Left panel: 1995–2024 warm season (May, June, July, August) and right panel: 1995–2024 high-end derecho approximate path centerlines colored by year of occurrence. 30 warm seasons from 1995 through 2024 were evaluated for SCS events qualifying as derechos. Of the 30 warm seasons evaluated, 147 derecho events were identified, 46 of which are high-end.

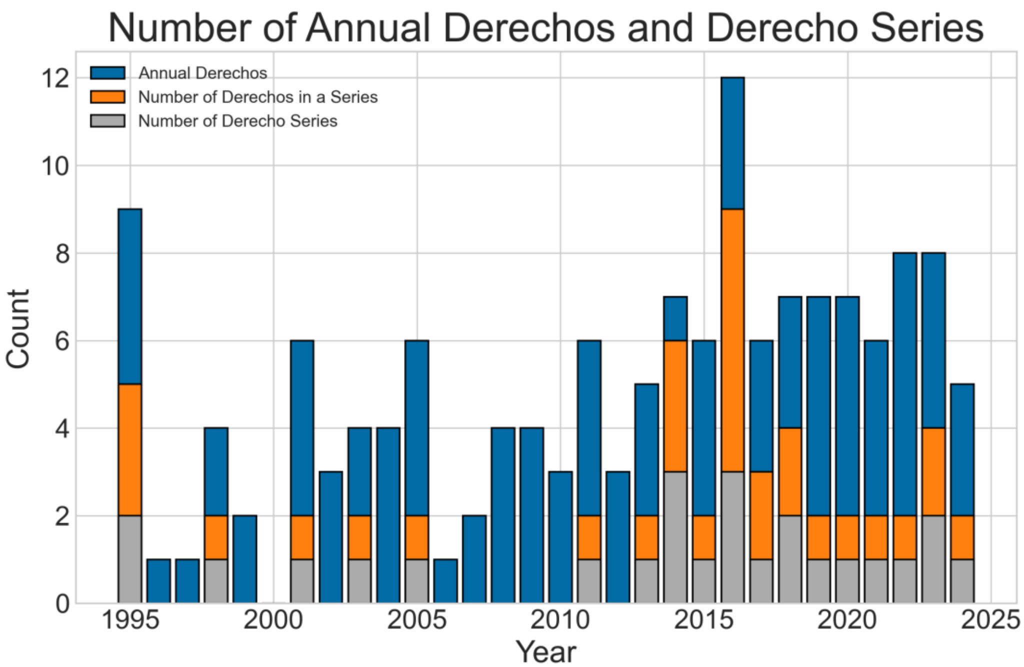

Figure 4: Time series of 1995–2024 annual derechos (blue), annual derecho events attributable to a series (orange), and annual count of derecho series (grey).

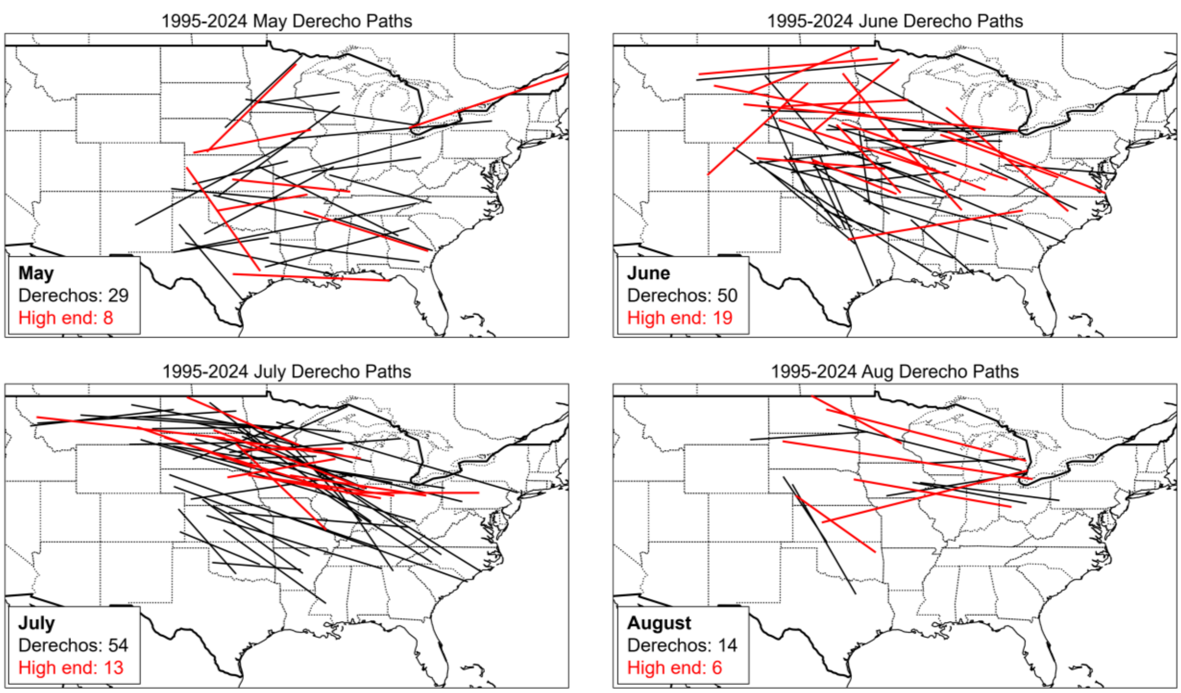

Figure 5: 1995–2024 warm season derecho approximate path centerlines by warm season month: May (top left), June (top right), July (bottom left), and August (bottom right).

Table 2: Summary table of the 1995–2024 derecho database developed for this manuscript. Includes a breakdown of derechos by annual (total and high-end) and monthly occurrence.

YEAR	TOTAL DERECHOS	HIGH END DERECHOS	DERECHOS BY MONTH			
			May	*June*	*July*	*August*
1995	9	1	2	2	5	0
1996	1	0	1	0	0	0
1997	1	1	0	0	1	0
1998	4	1	1	1	2	0
1999	2	0	0	1	1	0
2000	0	0	0	0	0	0
2001	6	2	1	2	2	1
2002	3	0	0	1	1	1
2003	4	2	1	0	3	0
2004	4	0	1	1	2	0
2005	6	3	0	4	2	0
2006	1	1	0	0	0	1
2007	2	0	1	0	0	1
2008	4	3	1	1	2	0
2009	4	1	2	1	1	0
2010	3	1	0	1	2	0
2011	6	0	2	1	3	0
2012	3	1	0	1	1	1
2013	5	2	1	1	2	1
2014	7	2	0	7	0	0
2015	6	3	2	2	2	0
2016	12	2	0	3	7	2
2017	6	2	2	3	1	0
2018	7	1	0	5	1	1
2019	7	2	2	2	1	2
2020	7	2	0	2	4	1
2021	6	2	2	2	0	2
2022	8	4	3	2	3	0
2023	8	3	1	4	3	0
2024	5	4	3	0	2	0
TOTALS	147	46	29	50	54	14
AVERAGE	4.9	1.5	1.0	1.7	1.8	0.5
MAX/YEAR	12	4	3	7	7	2

Table 3: Summary table of derecho series events. A derecho series is defined as at least two derecho events occurring within 72 h. The dates, derecho counts, and number of high-end derechos are included.

Event Number	Year	Dates	Derecho Count	High End Derechos
1	1995	7 and 8 June	2	0
2	1995	11, 12, and 14 July	3	1
3	1998	20 and 21 July	2	0
4	2001	9 and 11 June	2	0
5	2003	2 and 3 July	2	2
6	2005	2 and 3 July	2	0
7	2011	10 July	2	0
8	2013	8 and 10 July	2	2
9	2014	3 and 4 June	2	1
10	2014	14 and 16 June	2	1
11	2014	30 June	2	0
12	2015	19 and 21 June	2	2
13	2016	28 and 29 June	2	0
14	2016	5 and 6 July	2	0
15	2016	9, 10, 13, 14, and 16 July	5	0
16	2017	13, 15, and 16 June	3	2
17	2018	22 and 24 June	2	0
18	2018	28 June	2	1
19	2019	19 and 21 June	2	1
20	2020	7 and 8 July	2	0
21	2021	3 and 4 May	2	0
22	2022	8 and 9 July	2	0
23	2023	15 and 17 June	2	1
24	2023	28 and 29 July	2	1
25	2024	13 and 15 July	2	2
Sum			55	17

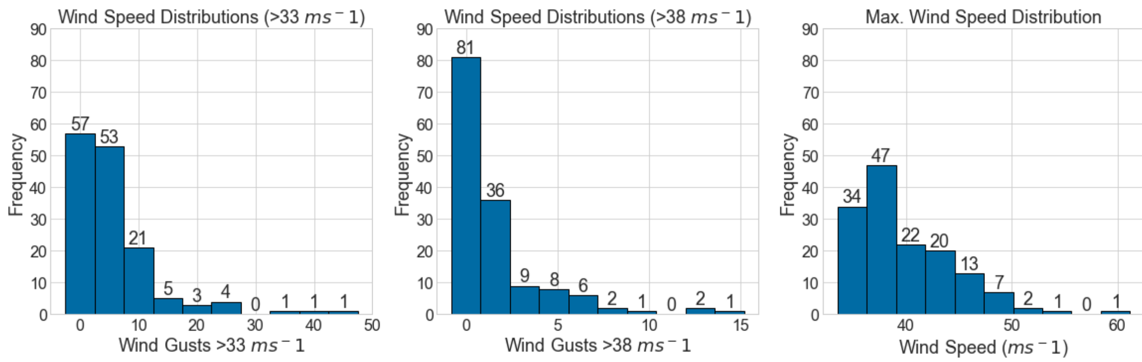

Figure 6: Distributions of derecho gust speed occurrence per event: ≥33 m s^{-1} (left), 38 m s^{-1} (middle), and maximum gust speeds for all events (right).

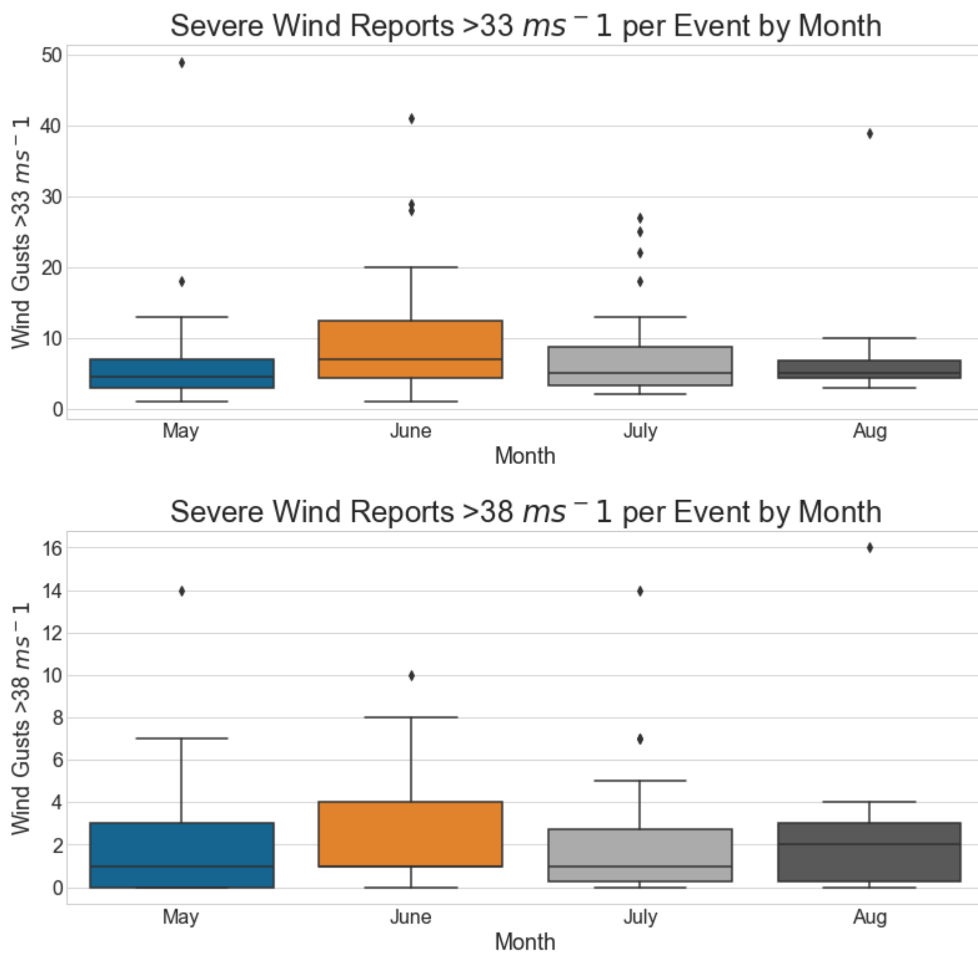

Figure 7: Derecho storm-report counts by month of the season. The top panel shows the distribution of 33+ m s^{-1} gusts per event per month, and the bottom panel shows the same for ≥38 m s^{-1} gusts. Black diamonds indicate outlier events. The colored rectangles encompass results from the first quartile through the third quartile. The lines within the colored rectangles show the median monthly wind report count per derecho, while the whiskers extend to 1.5 × the interquartile range.

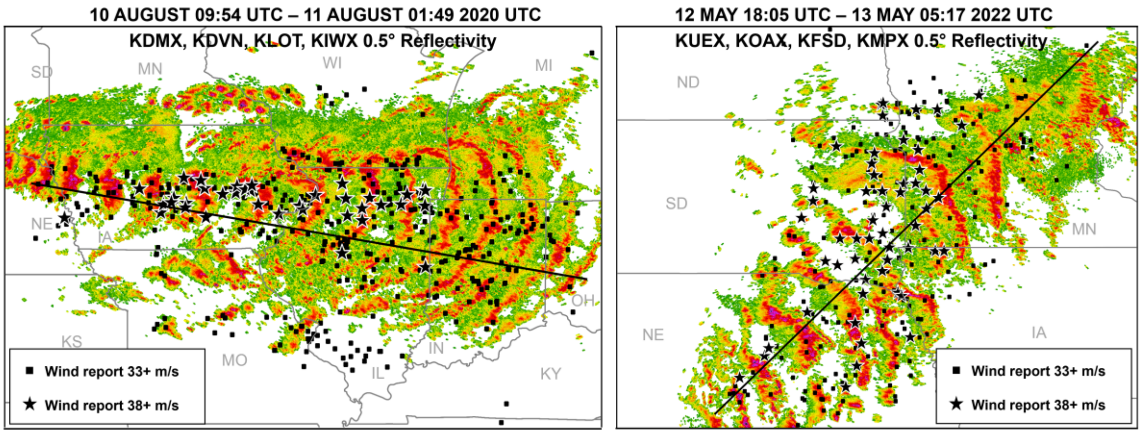

Figure 8: Left panel: 10 August 2020, and right panel: 12 May 2022 derecho NEXRAD base reflectivity (0.5°) composites, approximate derecho path centerline, and filtered SPC storm reports (black squares = severe wind >26 m s^{-1}, black stars = significant wind >38 m s^{-1}). The derecho approximate path centerlines and major axis lengths are annotated on the maps in black. Radar data obtained and processed as in Fig. 1. "Filtered" storm reports were obtained from the SPC Severe Weather Events Archive (https://www.spc.noaa.gov/exper/archive/events/).

i.) Derecho series

A derecho series is defined in the literature as a period with more than one derecho occurring within 72 h or any sequence of derechos with <72 h between each event (Ashley et al. 2005). From 1995–2024, a total of 25 derecho series occurred (Table 3). The results here are different from those of Ashley et al. (2005), who found that derecho series from 1994–2003 averaged two to three derechos per event, with numerous series consisting of four or more events. Ashley et al. (2005) also found that over 62% of derechos are part of a larger series, whereas we found that only 37.4% of derechos belonged to a series. These differences are most likely due to the more stringent gust-report requirement in the present study. Despite these differences, cold-pool-driven MCSs and DMCSs regularly occur in series or episodes.

ii.). Wind reports

Most of the derecho events identified in this study (60.5%) had ≥5 gust reports ≥33 m s^{-1}, while only 20 derecho events had five or more reports ≥38 m s^{-1} (Fig. 6, left and center panels). Only four derechos had ≥10 reported gusts ≥38 m s^{-1} (Fig. 6 and Fig. 7). Almost all derechos (95.9%) during the period of study had a maximum gust of 36 m s^{-1} or greater. Most derechos (76.9%) had a maximum reported gust ≥38 m s^{-1}, while just over a quarter of derechos (25.9%) had a maximum gust ≥45 m s^{-1}. Only four derechos (2.7%) had a maximum gust ≥51 m s^{-1} (Fig. 6, right panel). The average number of significant high-wind reports ≥33 m s^{-1} per derecho is eight, and the average number of high-end high-wind reports (≥38 m s^{-1}) is about two. As for high-end derechos, the average number of ≥33-m s^{-1} gusts are nearly doubled to over 14 per event, and ≥38-m s^{-1} gusts average over five per event (Fig. 7). The derecho with the highest count of ≥33-m s^{-1} gusts occurred on 12 May 2022 with 49 reports, 14 of which were ≥38-m s^{-1} gusts. The event with the highest count of ≥38-m s^{-1} gust reports was the 10 August 2020 Corn Belt derecho, with 16 (out of 39 total significant ≥33-m s^{-1} gusts). Summaries of both particularly high-end events are shown in Fig. 8. Another derecho of note occurred on 6 June 2020 from Utah and Colorado northeast through the Dakotas. This event saw the most significant (≥33 m s^{-1}) gust reports in any single day since 2004 (NWS 2025).

While severe-wind reports have increased over the last 10–15 y (Squitieri et al. 2025a,b), the extent to which this may have influenced the number of recorded derecho events each year is unknown. Derechos in the presented database increased nearly twofold after 2013, while reports per event have increased <1.2× over the same period. When generally comparing our results to Fig. 8 of Squitieri et al. (2025b), derechos in the past 10–15 y occurred across regions where the number of estimated and measured gust reports per event have both increased and decreased over the decades. The authors are of the opinion that the large spatial coverage of derecho events, inclusion of both estimated and measured reports, report spacing in consideration of possible report clustering, and the inclusion of phenomenologically specific physical characteristics, should largely cushion the impacts of regional increases in storm reporting on increases in derecho events across the climatology. That said, additional decades of derecho data are needed before this can be confirmed.

b. Derechos and monthly climate indices

i.) Annual derecho occurrence and climate

As discussed in section 2, various climate indices were evaluated against annual warm-season derecho occurrence to evaluate potential elements for longer-term derecho forecasting. Results from both the Pearson correlation coefficient (Table 4) and Spearman rank correlation (Table 5) statistical tests are presented here. Additionally, multiple significance levels are called out as recommended by Nicholls (2001) to relieve some of the "arbitrariness" of choosing which significance level to use.

The leading association between annual derechos and climate teleconnections, according to the Pearson statistical test, is with ENSO. Of note is that the year with most derechos—2016 with twelve—was preceded by a very (≥2.0°C SSTA) strong El Niño winter. Since the ONI is based on Niño 3.4 region SSTAs, both Niño 4 and Niño 3.4 winter and spring SSTAs also show significant associations with derecho occurrence at both the 90% and 95% significance levels. Niño-3 SSTAs are significant only at the 90% level. In addition to ENSO, February NAO is associated with annual derechos at the 95% significance level and the PNA is significantly correlated during January (95%) and June (90%). Spearman rank correlation coefficient statistical testing was also done (Table 5), as Spearman rank is far less influenced by outlier years such as 2016. Niño-4 SSTAs during the preceding winter and spring and present warm season are still significantly correlated with annual derechos, while the ONI and Niño 3.4 SSTAs are no longer statistically significant (95%). Perhaps more interesting are the consistencies between the two statistical tests with respect to June PNA and February NAO values, being statistically significant at the 95% level. February NAO is also statistically significant at the 95% level, while April TNI remains significant at 90%.

To attribute physical reasoning to the correlations discussed above, statistically significant (95% via both statistical tests) climate teleconnections with annual derecho occurrence were qualitatively evaluated and include: Niño-4 SSTAs, NAO, PNA, and, to a lesser extent (i.e., significant only at the 90% level), Niño-3 SSTAs and the TNI. Specifically, we looked at the top eight derecho-producing years (all years with ≥7 annual DMCS), as well as the bottom four derecho-producing years (all with ≤1 annual derecho). The top eight derecho-producing years are 2016 (12 derechos), 1995 (nine), 2022 & 2023 (eight each), and 2014, 2018, 2019, & 2020 (seven each). The four years with the least number of derechos were 2000 with none, and 1996, 1997, and 2006, all with one each.

Table 4: Pearson correlation coefficients calculated using the Python module SciPy (Virtanen et al. 2020). Values in bold indicate correlation coefficients with p-values above 90% significance ($p \leq 0.10$), and underlined values denote correlation coefficients above the 95% significance level ($p \leq 0.05$).

Index	*January*	*February*	*March*	*April*	*May*	*June*	*July*	*August*
ONI	**0.348**	**<u>0.371</u>**	**<u>0.387</u>**	**<u>0.392</u>**	**0.332**	0.233	0.108	0.005
TNI	–0.276	–0.291	**–0.319**	**–0.318**	–0.267	–0.214	–0.194	–0.180
Niño 1+2	0.239	0.088	0.090	0.128	0.053	0.050	–0.017	–0.024
Niño 3	**0.340**	**0.311**	**0.325**	0.259	0.085	0.063	–0.006	–0.093
Niño 3.4	**<u>0.375</u>**	**<u>0.387</u>**	**<u>0.403</u>**	**<u>0.376</u>**	0.246	0.174	0.036	–0.089
Niño 4	**0.322**	**<u>0.379</u>**	**<u>0.418</u>**	**<u>0.400</u>**	**<u>0.405</u>**	**<u>0.410</u>**	0.267	0.151
PNA	**<u>0.454</u>**	–0.068	–0.075	–0.178	–0.085	**0.363**	0.180	0.123
PDO	–0.020	0.020	0.093	0.039	0.078	–0.026	0.005	–0.078
NAO	0.195	**<u>0.376</u>**	0.013	0.044	–0.152	0.058	–0.239	–0.100

Table 5: Spearman rank correlation coefficients calculated using the Python module SciPy (Virtanen et al. 2020). Values in bold indicate correlation coefficients with p-values above 90% significance (p≤0.05), and underlined values denote correlation coefficients above the 95% significance level.

Index	*January*	*February*	*March*	*April*	*May*	*June*	*July*	*August*
ONI	0.248	0.272	0.280	0.293	0.267	0.244	0.189	0.062
TNI	−0.273	−0.290	−0.291	**−0.312**	−0.208	−0.180	−0.127	−0.156
Niño 1+2	0.206	−0.006	−0.055	0.086	0.040	0.031	−0.038	0.017
Niño 3	0.262	0.206	0.231	0.281	0.117	0.121	0.092	−0.102
Niño 3.4	0.262	0.293	0.301	**0.313**	0.235	0.256	0.101	−0.074
Niño 4	0.297	**0.332**	**0.361**	**0.353**	<u>**0.393**</u>	<u>**0.425**</u>	0.231	0.176
PNA	0.308	−0.142	−0.023	−0.297	−0.113	<u>**0.423**</u>	0.099	0.199
PDO	−0.082	−0.125	−0.020	−0.021	0.045	−0.030	−0.048	−0.018
NAO	0.264	<u>**0.392**</u>	0.026	0.016	−0.109	0.014	−0.205	−0.073

Across all tests there is a strong (90 to >95%) correlation between February through June Niño-4 SST anomalies. While Niño-4 SSTs do influence the operational El Niño indicators (Niño-3.4 SSTs and ONI) and the TNI, those indicators are much less correlated with derecho occurrence, if at all, compared to Niño-4 SSTs. Seven of the eight top derecho-producing years had positively neutral (0<SSTAs<0.5) to weakly positive (0.5<SSTAs<1) Niño-4 SST anomalies during the months of May and June, with 2022 being the exception (both weakly negative). Three of the four lowest derecho-producing years, all with one or less derecho each, had negative May/June Niño-4 SSTs to varying degrees. Regarding monthly correlated ENSO indicators, in all instances (Niño-3, Niño-3.4, and Niño-4 SSTAs), June derechos are correlated with real-time SSTAs, while July derechos are correlated with SSTAs from the winter season prior.

The TNI was developed to identify various "flavors" of ENSO events (Trenberth and Stepaniak 2001), though these flavors do not include El Niño Modoki events, which are a more recently identified relative of the traditional ENSO (Ashok et al. 2007). The El Niño Modoki occurs when the central equatorial Pacific is warm, flanked by two cool regions to the east and west. Given that the TNI is expressed by the SSTA difference between the Niño-1+2 and Niño-4 regions, it can identify central Pacific warm ENSO events (i.e. Modoki) when the index is negative and vice versa. However, the TNI lacks the western-most El Niño Modoki tripole that helps identify all El Niño Modoki events, which may explain the general lack of significant correlation between derecho occurrence and TNI, but presence of a strong correlation with Niño-4 SSTAs. El Niño Modoki events are known to suppress precipitation in the western U.S., rather than increase it as with the traditional El Niño (Ashok et al. 2007; Liang et al. 2021). Suppressed precipitation allows for warmer temperatures and stronger anomalous high-pressure domes to form over the elevated western U.S. While by no means the sole ingredient in derecho-production, EMLs play particularly important role for the northwest-flow/ridging and zonal synoptic modes of derecho development, as derechos often develop and propagate around the edges of EMLs, earning them the moniker "ridge rollers." Future work may want to examine possible links between ENSO Modoki event teleconnections with derechos and other SCSs. Possible links with ENSO Modoki were not considered here due to the unavailability of public Modoki indices.

While the NAO is typically discussed as a wintertime phenomenon and is one of the major drivers of wintertime climate in the Northern Hemisphere, the NAO does also have impacts during the warm season (Ogi et al. 2003; Feldstein 2007). Specifically, positive winter NAO values are associated with increased "circumpolar" temperatures during the following summer. The summer atmospheric circulation in the Northern Hemisphere is also more prone to double jet structure of the subtropical jet and blocking patterns, which are also conducive to heating and drying near ridges. Positive February NAO values correlated with annual derecho occurrence at the 95% significance level, using both Pearson and Spearman rank correlation coefficients. All eight of the top derecho-producing years took place after positive NAO Februarys.

Table 6: Results for Spearman rank correlation coefficients between monthly derecho events and monthly climate indices. Bold values are significant at the 90% significance level or greater (p ≤ 0.10). Underlined values are significant at the 95% significance level or greater (p ≤ 0.05).

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*
Oceanic Niño Index								
May Derechos	−0.022	−0.025	−0.028	−0.026	−0.056	−0.067	0.030	0.032
June Derechos	0.122	0.168	0.183	0.217	0.262	**0.325**	0.298	0.136
July Derechos	**0.385**	**0.388**	**0.428**	**0.413**	**0.333**	0.128	−0.043	−0.095
August Derechos	0.101	0.104	0.105	0.080	0.010	−0.008	−0.001	0.039
Trans-Niño Index								
May Derechos	0.142	0.133	0.043	−0.055	−0.023	−0.110	−0.102	−0.058
June Derechos	−0.214	−0.221	−0.180	−0.169	−0.064	−0.071	−0.060	−0.157
July Derechos	−0.273	−0.264	−0.281	−0.217	−0.114	−0.031	0.053	0.106
August Derechos	−0.168	−0.186	−0.142	−0.247	**−0.364**	**−0.386**	**−0.441**	**−0.438**
Niño 1+2 SST Anomalies								
May Derechos	0.139	−0.030	−0.170	−0.069	−0.234	−0.171	−0.094	−0.074
June Derechos	0.132	−0.089	0.007	0.214	0.217	0.165	0.109	0.078
July Derechos	0.226	0.188	0.113	0.147	0.032	−0.018	−0.123	0.018
August Derechos	−0.052	0.120	0.052	−0.084	−0.146	−0.115	−0.180	−0.270
Niño 3 SST Anomalies								
May Derechos	0.060	0.065	−0.083	−0.124	−0.099	−0.046	0.027	−0.077
June Derechos	0.192	0.097	0.211	**0.371**	**0.319**	0.278	0.200	0.022
July Derechos	0.304	**0.390**	**0.382**	0.267	−0.054	−0.092	−0.035	−0.120
August Derechos	0.142	0.143	0.095	0.038	−0.063	−0.053	−0.169	−0.117
Niño 3.4 SST Anomalies								
May Derechos	0.038	−0.049	−0.041	−0.065	−0.037	0.041	0.089	−0.083
June Derechos	0.170	0.191	0.235	0.291	**0.367**	**0.375**	0.155	0.035
July Derechos	**0.376**	**0.433**	**0.422**	**0.336**	0.018	−0.068	−0.034	−0.173
August Derechos	0.090	0.111	0.104	0.043	−0.004	0.114	0.031	0.019
Niño 4 SST Anomalies								
May Derechos	−0.091	−0.063	−0.070	−0.113	−0.069	0.012	0.077	0.010
June Derechos	0.211	0.226	0.287	**0.311**	**0.451**	**0.476**	0.254	0.242
July Derechos	**0.374**	**0.404**	**0.348**	0.297	0.117	0.060	−0.024	−0.104
August Derechos	0.133	0.106	0.106	0.113	0.131	0.204	0.187	0.188
Pacific North American oscillation								
May Derechos	0.243	−0.145	−0.018	−0.251	0.009	0.306	0.195	0.066
June Derechos	0.076	−0.246	−0.008	−0.172	−0.087	**0.446**	0.011	0.269
July Derechos	**0.342**	**0.350**	0.178	−0.137	0.002	0.254	0.056	−0.019
August Derechos	0.063	−0.182	−0.170	−0.302	−0.180	−0.018	0.031	0.037
Pacific Decadal Oscillation								
May Derechos	−0.138	−0.143	−0.103	−0.078	−0.116	−0.042	−0.065	−0.012
June Derechos	−0.016	−0.097	0.000	−0.032	0.029	−0.062	−0.094	−0.015
July Derechos	−0.039	−0.005	0.077	−0.019	−0.006	−0.100	−0.157	−0.189
August Derechos	0.069	−0.085	−0.245	−0.121	−0.094	−0.093	0.042	−0.005

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*
North American Oscillation								
May Derechos	−0.146	−0.068	0.189	0.027	−0.059	−0.088	−0.145	0.023
June Derechos	0.373	**0.360**	−0.086	0.055	−0.145	0.118	−0.112	−0.100
July Derechos	0.133	0.208	−0.045	−0.165	−0.024	−0.174	**−0.327**	0.044
August Derechos	0.027	−0.102	−0.013	0.228	−0.058	0.155	0.028	−0.073

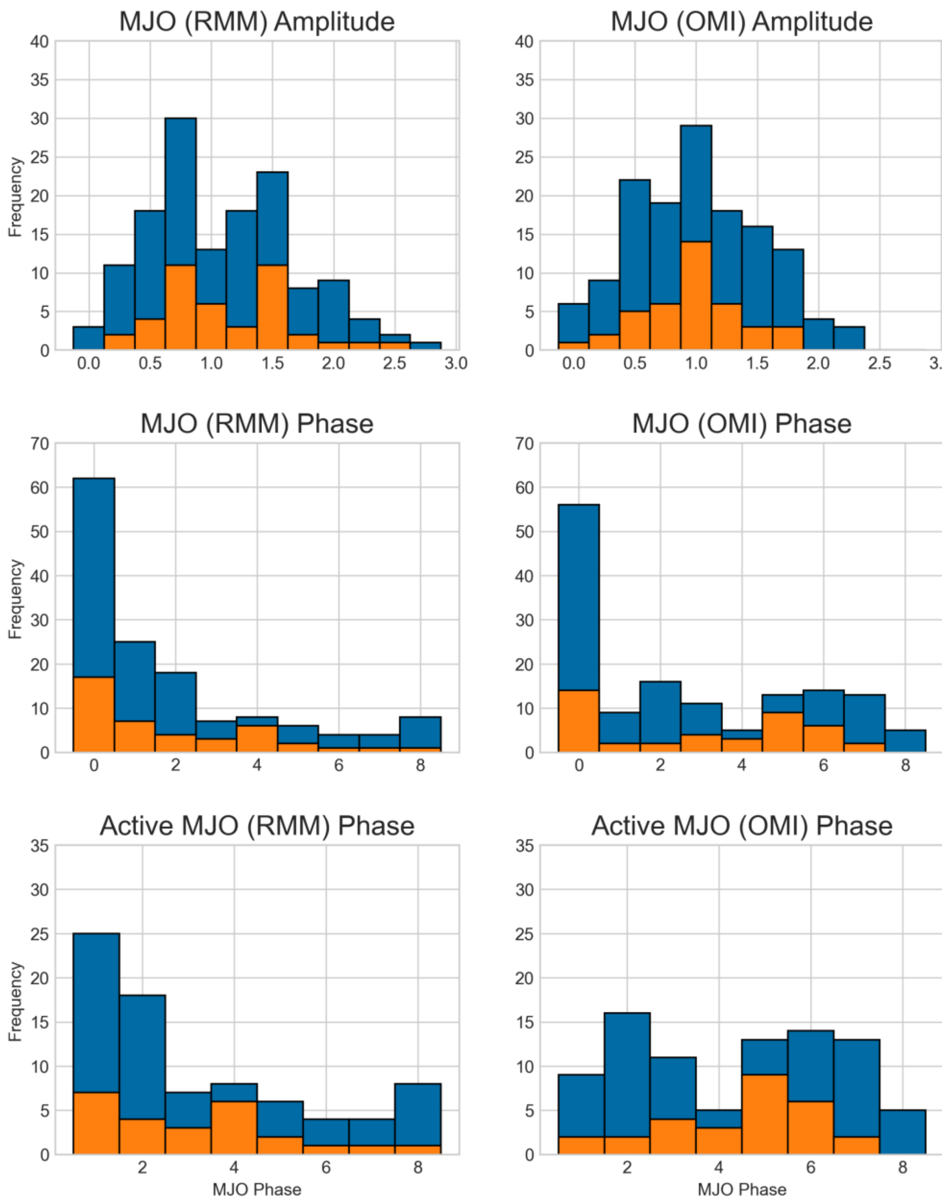

Figure 9: Distribution of derecho event Madden-Julian Oscillation (MJO) amplitudes (top panels), phases (non-active MJO is phase 0, center panels), and active-only MJO phases (bottom) using both the real-time multivariate MJO (RMM) index (left panels) and outgoing longwave radiation (OLR)-based MJO index (right panels). Blue bars indicate the distributions of all derecho events. Orange bars represent high-end events.

Both the Pearson correlation and Spearman rank statistical tests also identified positive June PNA values as correlated to annual derecho occurrence at varying significance levels. The PNA is generally regarded as a wintertime phenomenon. June PNA values for the top eight derecho-producing years were examined to verify the robustness of the significance. Four of the eight years had weakly positive ($0.5 \leq$ PNA ≤ 1.0) PNA values during the month of June, and one year had a weakly positive neutral ($0.0 \leq$ PNA ≤ 0.5) PNA value during June. Additionally, the bottom four derecho-producing years (all years with one or less derechos) had negative PNA values. Positive PNA values lead to increased levels of drought over the central and western regions of the U.S. (Justino et al. 2022).

i.) Monthly derecho occurrence and climate

Monthly derecho occurrence was also evaluated against monthly climate statistics. For the monthly analysis, only the Spearman rank correlation coefficients were evaluated (Table 6). While no significant correlations were found between May derecho occurrence and any of the analyzed climate indices, this was not the case for other months. June events are strongly correlated (95% significance) with real-time or near (within two months) real-time Niño 3 (April), Niño 3.4 (May, June), and Niño 4 (May, June) SST anomalies as well as the June PNA. More robust correlations are found for July derechos, especially with the ENSO indicators ONI, Niño 4 SSTAs, and Niño 3 SSTAs, though some correlation was also found with PNA and NAO. An interesting result emerged for August derecho occurrence with a strong negative correlation (>98% significance) between August derechos and TNI. This is one of the strongest correlations across the dataset. Every August with at least one derecho event was during the negative TNI phase.

ii.) Madden-Julian Oscillation and derecho occurrence

Looking at derecho occurrence and MJO events using RMM data (Fig. 9, left panel), 56.3% of derechos occur during active MJO events, the remainder when the MJO is inactive. When evaluating MJO with the OMI (Fig. 9, right panel), 60.6% of derechos occurred during active MJO events, the remainder in inactive periods. The percentage of derechos occurring during active MJO events increases when examining only high-end derechos (not shown). There is a tendency across both indices towards earlier MJO phases during derecho occurrence. The earlier MJO phases tend to result in dry anomalies over much of the western half of the U.S., including the Great Basin, Intermountain West, and Desert Southwest, all of which act as source regions for summer high-pressure domes and EMLs (DTN 2025b).

4. Discussion and conclusions

This study provides a detailed look into derecho trends and spatiotemporal distributions over the past 30 y. The spatial and temporal distributions of derechos are largely consistent with other derecho climatologies, despite differences across identification criteria. The main derecho corridors are identified: the Northern Plains and Upper Midwest, the Corn Belt region and, to a slightly lesser extent, the Southern Great Plains. As the warm season progresses, derecho occurrence takes a poleward shift, and events become confined to the three main corridors. The vast majority of, if not all, derechos outside of the main derecho corridors occur in May and June. By August, the main focal regions for derecho development are the Northern Plains/Upper Midwest and Corn Belt.

Observed derecho occurrence and intensity increased over the period of study, most notably over the past 10 y, although it is unclear how much this is influenced by changes in storm reporting and multi-year variability. According to the World Meteorological Organization, the ten warmest years on the planet on record occurred from 2015–2024. 2024 was the warmest year on record and the first to exceed warming by >1.5°C above pre-industrial levels (WMO 2025). An increase in MCS activity over the past decade has already been observed (Feng et al. 2016; Schumacher and Rasmussen 2020) and is expected to continue in a future, warmer climate (e.g., Prein et al. 2017; Schumacher and Rasmussen 2020; Haberlie et al. 2024).

An increase in the frequency and spatial coverage of derecho occurrence may also be possible in a warmer climate (Lasher-Trapp et al. 2023; Kaminksi et al. 2024), along with convective nontornadic winds in general (Prein 2023). The literature surrounding future MCS and wind potential lends credibility to the idea that increasing derecho activity in a warming climate may be a meteorological trend and not just a result of increases in storm reporting over the decades.

Many more years of derecho data and additional convection-permitting regional climate modeling are necessary to evaluate these trends further.

Another finding of this study is a strong correlation with annual derecho occurrence and Niño-4 SSTAs. This is an interesting teleconnection in that Niño-3.4 SSTAs, nor the TNI, are not also significantly correlated with derecho occurrence, suggesting that classical ENSO events are not a driver of derecho activity, but that conditions in the central Pacific may be. Future derecho teleconnection research for seasonal forecasting may examine the correlations with ENSO Modoki modes (Ashok et al. 2007) and derechos, since ENSO Modoki is a result of warming in the central Pacific, consistent with the results presented here.

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REVIEWER COMMENTS

[Authors' responses in *blue italics.*]

REVIEWER A (Brian J. Squitieri):

Initial Review:

Recommendation: Accept with major revisions.

Overall Comments: The authors have submitted a revised manuscript that provides a new climatology on derechos employing a phenomenally distinct definition, which also investigates potential correlations between derecho frequencies and larger-scale seasonal planetary patterns. This submission is improved upon the earlier submission and is (in my mind) much closer to publication. However, beyond several minor points/corrections that I feel need to be made, there are a couple of major points that I strongly urge the authors to consider before publication, so I recommend major revisions for this submission. Below, I begin with the strongest points of consideration, followed by more minor considerations. I have also attached a copy of the author's submission where I have addressed grammar issues and sentence restructuring. Track changes are included, so the authors and the Editor can see what changes were proposed.

Largest point of concern: The authors imply their increase in derechos over the past decade or so as possibly being driven by climatological processes, also suggested as a future possibility by Prein (2023), Kaminski et al. (2024), among others. The authors did credit that there could be paralleling/competing factors such as an increase in wind reports due to greater observational capabilities over the last several years. However, I think the one major issue in this manuscript is that the authors severely underestimate how significant of a competing factor report-increases really are to their implications that derechos are on the increase due to climatological factors.

At SPC, we are currently formulating a comprehensive archive on derechos spanning back to the 1950s. While such a task can be done, we find that the only feasible methods we can implement prior to the mid-1980s are quite crude, partly due to the severe lack of wind reports, which have always been an issue. Looking at the Squitieri et al. (2025b) Fig. 8 (attached), there have been major increases in wind reports from the 1990s into the 2000s. However, even though the overall rate of report increases has leveled off a bit into the 2010s, report trends in the last decade alone have shown a sharp increase in measured severe (including significant-severe) gusts across the Plains states (Fig. 8h,j). In tandem with this, our derecho climatology (albeit with stricter report requirements) shows that derecho frequency has increased considerably across the Plains (e.g. Fig. 7b, also attached). This could be because of all the mesonets (and other observational networks) that have been established or have expanded in this time frame. For example, one can see in the third attached figure that one of the higher density increases in measured gusts (regardless of magnitude) over the past decade is in southern Nebraska, where there also happens to be a concentration of mesonet stations via the Nebraska Mesonet (green ellipses).

One way to test for the possibility of derecho inflation driven by report inflation is to plot the author's derechos with respect to time (e.g. like Fig. 7b in Squitieri et al. 2025b). The authors simply could perform this task by replotting Fig. 5, but with a temporal coloring scheme. I would be very curious to see if much of the increase in derechos since 2010 is in the Plains. If so, then I strongly request that the authors hold derecho increases driven by increased observation densities with equal weight to all other possible mechanisms for increased derecho frequencies. Intuitively, an increased frequency in observing the EML may drive greater MCS/wind/derecho frequencies in the Plains, since the Plains are the closest downstream region to the EML source. Nonetheless, one cannot ignore how an increase in wind report measurements over the last decade cuts off so neatly around the SD/MN, NE/IA, and KS/MO areas, with IA (a derecho hotspot) seeing a measured report decrease.

To test for the increase in derecho activity as a result of substantially increased storm reporting over the last decade, derecho paths were plotted with respect to time as in Squitieri et al. 2025b (Fig. 7b) as suggested. The same was also done for high-end events. This new 2-panel plot now serves as Fig. 3. While the trend towards more derechos in the northern Plains is quite marked in the Squitieri et al. (2025b, Fig. 7b) climatology, that signal does not seem quite so prevalent here. While a number of these events do initiate within and traverse the Plains, many of them also continue into regions with demonstrated decreases in storm reporting (Squitieri et al. 2025b, Fig. 8) over the past decade.

An additional 13 derechos from 2023 and 2024 are included in our analysis, only one of which does not meet the 5+ significant-severe reporting criteria in Squitieri et al. 2025b (measured versus estimated gusts not considered). Seven of the 13events were high end events, all of which contained at least one 100+ mph gust. There was an average of 17 significant gust reports per event across the seven high end events. As can be seen in the updated plots, these events cover a wide area including those regions with decreased wind reporting per Squitieri et al. 2025b (their Fig 7). The 6 June 2020 derecho from UT/CO northeast through the Dakotas saw the most significant (75+ mph) wind gust reports in any day since 2004 (NWS 2025), despite being a region with minimal reporting increases and even decreases. Three high-end events have impacted the state of Iowa since the 10 August 2020 derecho super-high-end event, despite the storm reporting decreases per Fig. 7 in Squitieri et al. 2025b. We do see an increase in the number of reports per event, but the phenomenological and length criteria required for derecho identification should largely cushion the increase in derechos as a result of increased storm reporting. Additional discussion surrounding this was added to the Wind Reports section 3.a.III. A breakdown of storm-report increases per event versus derecho events per year is provided below for your reference.

Period	Avg >74mph reps	Avg 85+ mph reps	% increase	Avg Annual Derechos	% increase
1995-2004	4.9	1.6	-	3.4	-
2005-2014	8.4	2.3	**171%**	4.1	121%
2015-2024	9.7	2.6	116%	7.2	**176%**
Period					
2003-2012	7.3	2.24	-	3.7	-
2013-2022	8.6	2.16	119%	7.1	192%

Major Comments: An explanation of the climate indices is helpful. However, section b goes into a lot of detail about these indices and highlights their potential relationship with tornado events. It would benefit the paper to chop down this section, discussing only the basics of each index, and why they might be important to derechos.

The discussion related to climate indices has been reduced and possible relations to derecho environments have been added.

It would strengthen your work to point out that Squitieri et al. (2025b) found monthly derecho distributions like this study (i.e. compare their Fig. 7a with your Fig. 5). Note how May tends to have the Plains states SW–NE tracks. Such cases are the warm-season trough events pointed out by Andy Wade's recent work (feel free to cite his AMS presentations). I think it is important to keep in mind the different synoptic patterns when trying to consider planetary/climate scale connections to derecho activity. Warm-season troughing patterns can be quite different from zonal/northwest flow (ridge-riding events), so maybe this may explain some difficulties in (statistically) making planetary-scale connections with derecho activity in the broader sense?

Discussion has been added regarding the monthly spatial distribution of derechos and associated synoptic patterns.

With the rapid increase in reports we are seeing over the decades, there is great potential for report clustering (observed or estimated). As such, how is clustering taken into account? Report clustering must be addressed somehow. Like other studies, I recommend evaluating reports based on either densities or number of reports separated by a given distance. If this makes things too complex for this research, I would at least add discussion about the potential for report clustering to influence these results up front.

Report clustering was handled as it was in Johns and Hirt (1987) with the three 33-m s^{-1} gusts separated by at least 64 km. Explicit discussion of this outside of Table 2 is now included.

[Minor comments omitted…]

Second Review:

Recommendation: Accept with minor revisions.

Overall Comments: The authors have submitted a revised manuscript that provides an interpretation of the seasonal occurrence of U.S. derechos based on a phenomenological derecho definition. The authors have also used this formulated database to explain large spatial/temporal scale planetary atmospheric patterns with derecho seasonal occurrence, with some physical explanation of the results. Overall, I think this manuscript has improved and is about ready for publication. I do have some minor points and a couple of grammar items I would like to point out for the authors to consider. As such, I recommend minor revisions.

[Minor comments omitted…]

REVIEWER B (Kristie Kaminski):

Initial Review:

Recommendation: Accept with major revisions.

Summary: This research provides a modern, warm-season derecho climatology and is one of the first (to my knowledge) to investigate potential relationships between oscillations and seasonal and sub-seasonal derecho activity. The results are worthy of publication and would provide a good reference for future research on proposed derecho definitions and favorable derecho environments/climate forcings. With this said, I think major revision is necessary and I hope the authors find the below comments helpful. Many of the comments are related to one of the EJSSM criteria for reviewers: quality of presentation. I believe the authors could leverage previous work more effectively (i.e., tell the reader why a mentioned paper matters for the sake of this research) and include more explanation of figures. I have also included comments related to figures I feel are “missing”, but I understand producing these may not be possible. Again, I hope you find the below helpful and I am glad to see someone doing this work!

Substantive Comments (Major Comments): My main comment is related to the quality of presentation. There are some instances in the text in which the writing could be more scientific. Also, in the introduction and background sections, the authors do not use the science to tell their story but list the results of several studies in succession, without connecting back to the point they are trying to make. It is my opinion that the manuscript could be much stronger if the authors tried to parenthetically reference the studies in some of these sections. Additionally, revisions to some of the presented maps could make interpretation of the results easier.

Examples (writing), language throughout the manuscript: I would suggest casual phrases like "also important to consider", "there is much work to be done", "for a long time", "it is well established", "seems", "apparently", etc. be eliminated or interchanged for stronger language.

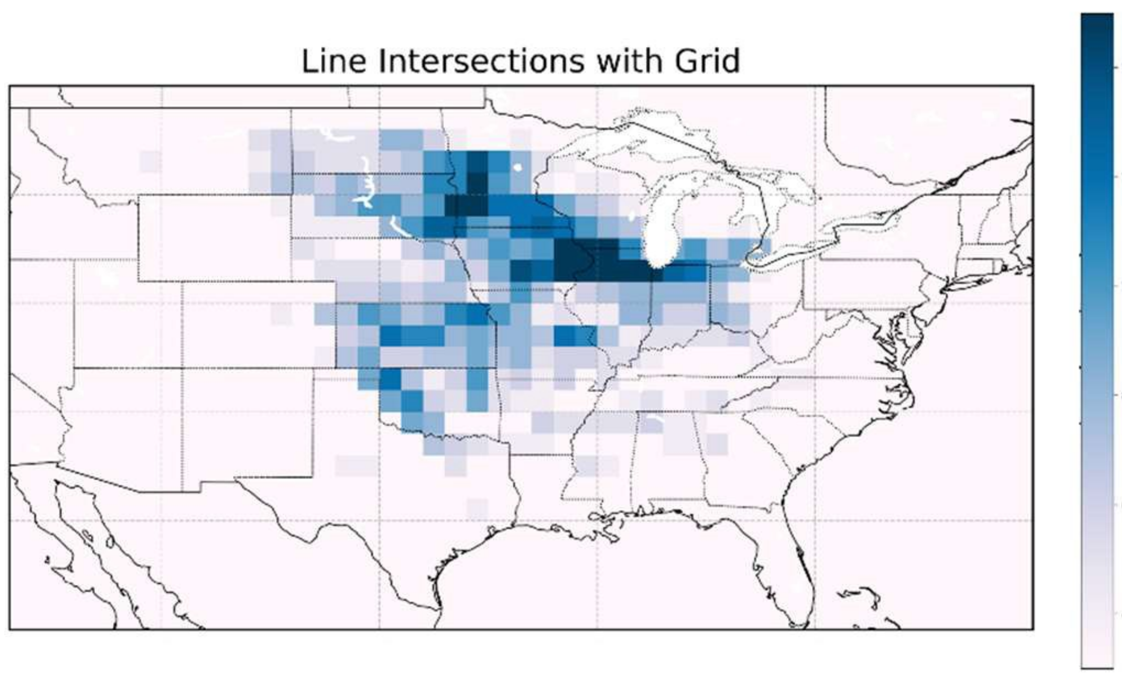
Introduction: Can you discuss the state of research on derechos and anthropogenic climate change, the importance of severe convective storm (SCS) forecasting, and advancements in SCS subseasonal forecasting without using the actual study as the subject in your sentences?

Data and methods—seasonal climate index statistics: Same concern as above, particularly in the sections separately discussing each oscillation. If you are going to discuss the results of individual studies, be clear on how they link to each other, how they link back to the main idea of the paragraph, and why this background is relevant for derechos.

Much (hopefully all?) of the casual language throughout the manuscript was updated or removed. Points of concern regarding sentence structure when citing or discussing sources also have been addressed.

Examples (figures): I understand this may be a huge ask, but a heatmap (or some sort of density/contour map) alongside Figs. 3 and 5 is necessary. I cannot easily discern what region has the highest frequency from looking at this figure as it exists. I have never seen a derecho climatology without this type of spatial frequency map. I would emphasize that your climatology is the only modern climatology that most closely follows the current SPC criteria and many stakeholders outside of the academic community would find a typical spatial frequency map *extremely* useful.

Figures 3 and 5 have been updated per the recommendation of another reviewer. Regarding the heatmap, I am unfortunately unable to create one of these without some very time-consuming data management, reformatting, and GIS-gymnastics. The most feasible plot would be akin to the heatmap shown in Guastini and Bosart (2016), where the number of derechos to pass through a given grid point is counted. However, I do not currently have the necessary storm report data: a) for all events, and b) in consistent file formats. I am unfamiliar with the practically perfect hindcast (PPH) grids and methods used to produce them (kernel density estimates, etc.) in Squitieri et al. (2025 a,b), and I also have concerns using report densities versus singular derecho occurrence. An approximate plot could be created using a 100-km (diameter) buffer around the derecho centerlines and then counting instances across grid points, but this would not be a fully accurate plot.



By plotting **only** the centerlines crossing through 1° × 1° grids, I generated a quick estimate heat map for you, shown above. It is certainly not viable for inclusion in the manuscript. I would be happy to provide my dataset to anyone who might be willing to take on this actual task. As a compromise for this manuscript, I have added discussion about the regions with the most derechos and annotated Fig. 3 with the three main derecho producing regions.

In your introduction, you specify that one purpose of this study is to serve as a derecho climatology. However, there is very limited discussion of spatial trends, and you do not state which region, or state, has experienced the most derecho activity over the last 30 y or how this varies over the course of the warm season.

Discussion on the special trends has been added in the results section (3.a.I).

If possible, it would also be nice to have some visualization or discussion on how high-end events differ spatially from your broader dataset.

Figures 3 and 5 have been updated to include the spatial distribution of high-end events only, both on a yearly (Fig. 3, right panel) and monthly (Fig. 5, red centerlines) basis per your review and others.

Further, more linking to prior work is needed for the first focus (climatology) of the study. You do this for the derecho-series section, please extend that to your discussion of temporal and spatial frequency. I recognize this will not be a one-to-one comparison given definition choices, but even general agreement should be stated. Does your climatology broadly echo what has been presented in the past?

Discussion related to the temporal and spatial frequency as it relates to other derecho climatologies is now included.

Your presentation of results and associated discussion for the seasonal and sub-seasonal relationships, while organized, is very detailed. Where possible, I would recommend omitting some detail (refer the reader to your tables) so the reader can focus on the main results you want to present. The monthly section was a little hard to follow, as most paragraphs hit all the assessed relationships. Be sure to emphasize what you want your reader to take away from each paragraph. Further, in this part of the manuscript there are references to “loose”, “strong”, and “significant” correlation. Please define what these mean, especially since correlation values are not included in the main text.

This section has been reworked entirely per your recommendation and others.

This may be a focus of future work, but I wonder if classifying your derechos based on their formation environment (similar to the approach in Guastini and Bosart 2016) would yield additional insight when assessing oscillation relationships. For example, May sees derecho activity across most of the central CONUS (likely associated with different formation regimes), while July sees most activity across the Midwest and Ohio Valley (likely associated with northwest flow).

While this was not done in the present study, some discussion of this has been added, as similar spatial distributions to the Squitieri et al. (2025a,b) climatology were found between Wade et al. (2024) and this manuscript.

[Minor comments omitted…]

Second Review:

Recommendation: Accept with minor revision.

Overview: Thank you to the authors for their effort and thoroughness in addressing my comments and those of the other reviewers. I believe the manuscript has been significantly improved, particularly the sections related to the teleconnections. I have a few suggestions below for the authors to consider, mainly regarding the "quality of presentation". As I mentioned in my last review, I hope the authors find these comments helpful.

My only remaining "major" concern pertains to the observed increases in wind reporting over time and how this might influence derecho identification. I appreciate the authors' discussion and their careful selection of criteria to mitigate the potential influence, and I agree that disentangling this influence is quite challenging. I suggest that the authors briefly mention this as a potential limitation of the study or note that this should be kept in mind when interpreting results. While it is touched upon in the conclusion of the manuscript, it is not directly stated as a potential limitation.

Additional discussion surrounding the limitations of using storm reports has been added in various places throughout the manuscript.

[Minor comments omitted...]

REVIEWER C (Michael C. Coniglio):

Initial Review:

Recommendation: Accept with major revisions.

Overview: This study presents an analysis of a comprehensive database of U.S. derechos with a focus on identifying linkages to climate indices. I appreciate the authors' efforts here as I know generating a large derecho database requires a lot of work. While other efforts to update derecho databases and definitions with the inclusion of more cases has occurred recently (e.g. the Squitieri et al. papers), these efforts were done in parallel and those papers shouldn't impede the publication of the present work. This work stands on its own and should eventually be published in *EJSSM*.

The analysis is interesting and relevant to the broader goal of understanding how climate change is impacting extreme weather events. The supporting material discussed in the introduction seemed appropriate and comprehensive, although I admit I'm much more qualified to speak on the past work on derecho climatologies than literature on climate indices. The presentation and was generally good with clear and concise figures. However, I found the writing and syntheses of the results could be improved. It's always a challenge to discuss specific quantitative results from your analyses while not clouding the primary, robust, and most interesting findings and their connection to the broader goal. To this day I still struggle to find the right balance! In this paper, I found it to be a slog to get through the text that describes the statistical results. I feel like more focus could be placed on the most robust results with more connections to the possible physical reasons for the correlations. In the specific comments below, I provide several examples and suggestions for how you can shorten and improve the narrative to help highlight your main points (but I haven't specified all of them).

Per your recommendations and others, much of the paper has been reworked for clarity. A lot of additional discussion is included relating to the use of storm reports for identifying derechos. Comparisons across other studies have also been explicitly stated.

In addition to my concerns on the writing, I'm a little skeptical of the conclusion that derecho frequency is increasing, most notably in the last 10 years. The connection to the possible increase in EML days over a similar period is intriguing and provides a potential physical explanation for the derecho trend. However, as you're aware, steep mid-level lapse rates associated with the EML is only one factor in producing derechos. A reservoir of high low-level humidity to support large conditional (and potential) instability is a key factor, as is the presence of some vertical wind shear for MCS organization. Convective inhibition, locations/timing of mesoscale lifting, and how "pristine" the warm sector is ahead of the developing system also are factors. Any of these factors could temper any long-term association between the EML and derechos. There's currently no discussion of these finer points that likely play a substantial role in the ability to relate derecho occurrences to global-scale signals.

Furthermore, as I'm sure you're also aware (and as you do indicate in the paper), the severe-wind-report database is fraught with nonmeteorological problems. These issues have prevented most authors from prescribing any physical meaning to having more derecho events in later years in their databases. That said, maybe the gust report/observation quality has been good enough and stable enough to do that now, but I'm not sure you've justified that sufficiently. Given the potential attention that might come with proclaiming an increase in derecho frequency over the last 30 y, I feel like more care is needed to demonstrate that this signal is not dominated by nonmeteorological factors. Beyond just stating an increase in derecho frequency, your analysis of climate indices relating to derecho frequency and intensity also hinges on having a relatively accurate and stable database, heightening the importance of addressing the nonmeteorological factors. I like that you cite recent work that provides more evidence that leans in that direction, but I admit I'm not familiar with that work and the specific analyses that led to those conclusions. At the very least, I'd like to see more specific reasoning based on more specifics of this past work (Schumacher and Rasmussen 2020, Lasher-Trapp et al. 2023, Prein et al. 2023, Kaminski et al. 2024) and how your results may be more specifically linked to them. In other words, I'd like to see more discussion of how those studies came to their conclusions. I presume they used simulations, but what proxies were used to determine derecho frequency? Do you also see those same trends in their proxies over your dataset? I feel like some analysis along these lines would help readers gain confidence in your claims.

To test for the increase in derecho activity as a result of substantially increased storm reporting over the last decade, derecho paths were plotted with respect to time as in Squitieri et al. 2025b (Fig. 7b) as suggested by another reviewer. The same was also done for high-end events. This new 2-panel plot now serves as Fig. 3 and is shown below for your reference. While the trend towards more derechos in the northern Plains, possibly because of increases in storm reporting there, is quite marked in the Squitieri et al. (2025b, Fig. 7b) climatology, that signal does not seem so prevalent here. While a number of these events do initiate within and traverse the Plains, many of them also continue into regions with demonstrated decreases in storm reporting (Squitieri et al. 2025b, Fig. 8) over the past decade.

During 2023 and 2024 we identified 13 derecho events, only one of which doesnot meet the 5+ significant severe reporting criteria in Squitieri et al. 2025b (measured versus estimated gusts not considered). Seven of the 13 events were high end events, all of which contained at least one 100+ mph gust. There was an average of 17 significant wind gust reports per event across the seven high end events. As can be seen in the updated plots, these events cover a wide area including those regions with decreased wind reporting per Squitieri et al. 2025b (their Fig 7). The 6 June 2020 derecho from UT/CO northeast through the Dakotas saw the most significant (75+ mph) wind gust reports in any day since 2004 (NWS 2025), despite being a region with minimal reporting increases and even decreases. Three high-end events have impacted the state of Iowa since the 10 August 2020 derecho super high-end event, despite the storm reporting decreases per Fig. 7 in Squitieri et al. (2025b). We do see an increase in the number of reports per event, but the phenomenological and length criteria required for derecho identification should largely cushion the increase in annual derechos as a whole as a result of increased storm reporting. Additional discussion surrounding this was added to the Wind Reports section 3.a.III. A breakdown of storm-report increases per event versus derecho events per year is provided [as a table, in the response to reviewer A].

My final general comment and suggestion is that once the revisions are made, the authors should go through the manuscript carefully to tighten the writing and fix grammatical errors (the occurrences of the latter increased as the paper went on; I refrained from pointing them out in the current round but will do so in the next round). To do this, I find it helps to put the paper aside for several days before going through it one more time prior to hitting the submit button. It's amazing what putting it out of your mind for a period of time will do for helping to improve the writing and finding mistakes!

In addition to the more general concerns, I provide more specific comments below…

[Minor comments omitted…]

Second Review:

Recommendation: Accept pending major revisions.

General Comments: I appreciate the authors' consideration of my concerns and the additional analysis done to attempt to support their arguments. I also appreciate the care taken in tightening up the sections discussing derecho occurrence and climate indices. I think that part of the paper reads better and is in a pretty good place (with some additional minor suggestions given below). There are some interesting results here that I think are starting to be identified regarding climate teleconnections that could be useful to S2S-type forecasting.

However, my main and largest concern remains on the authors' claims on the causes of the increasing trend in derecho occurrence and intensity. I appreciate the additional analysis showing the derecho tracks by year and the linkages to Squitieri et al. (2025b) Figs. 7 and 8. However, I'm still skeptical that these tests are sufficient to convince readers that the increase in storm reports is not the leading cause of this trend. First, the authors argue that derechos continue into areas where reports, both estimated and measured, have decreased on average (based on Squitieri et al 2025b figure 8), and therefore reporting isn't contributing much to the trend. However, the vast majority of the events initiate and go through their early evolution in the regions with a rather large increase in the number of estimated and measured reports, so that argument goes both ways. Plausibly, events in earlier years weren't identified as derechos because their first halves were underreported compared to today. I see that the authors have acknowledged this in their response, but I still don't think this is given enough consideration.

Second, in their response the authors cite only 2 y of recent cases (2023 and 2024), along with a single recent high-end event in the mountainous areas of the west to contribute to their argument that reporting trends are not a large influence here. They also further argue that Iowa experienced three high-end events since 2020 despite what they claim are storm-reporting decreases. However, on average there doesn't really seem to be significant decreases in reporting overall in Iowa when averaged over the whole state (again, Squitieri et al. 2025b, Fig. 8). But more importantly, just a few recent active years really can't be used to independently support the long-term climate trend being claimed here.

Third, the authors present an interesting analysis of the number of reports per event broken down by 10-y blocks. They show that the average number of reports per event haven't risen nearly as much percentage-wise as the number of events themselves. They argue that this shows a limited influence of reporting. However, would we necessarily expect the same percentage increase in the number/density of reports per event as the number of events themselves? Filtering methods of the reports possibly have changed over the years as they've become more widespread, so that the final records now are removing many more "duplicate" reports than before (Roger may be able to speak more about this). *[Editor's note: SPC filtering of reports is done only on the preliminary daily reports maps. Final* Storm Data *wind reports, which are transferred intact to the SPC wind dataset, aren't filtered after being provided to NCEI by NWS, or at SPC later.]* Also, this feels like a bit of an apples-to-oranges comparison since the count of derechos is a yes/no determination (binary and categorical), whereas the count of reports is more of a continuous measure. I think you'd need to look at the trends for derechos that occurred entirely (formed and dissipated) in areas where reporting hasn't changed much to really make this argument. But then you likely wouldn't have enough cases to say anything definitive. Some information might be gleaned from additional analysis along these lines, but I don't think what the authors have presented goes far enough or is strong enough to make this argument.

Fourth, a 30-y period, even if there was no influence from non-meteorological factors, is not long enough to identify any multi-year or decadal variability influences on the trends. There does appear to have been some shifting of the derecho hot spots over the years, with the early 1980s being prolific in the northern plains into the Midwest (John and Hirt 1987), the 2000s being more prolific in the southern Plains (Bentley and Mote climatologies), with a return to more prolific activity over the northern plains/Midwest in more recent years (Squitieri climatology). Multi-year/decadal temporal fluctuations are possible along with those geographical fluctuations. There isn't any mention or consideration given to that possibility.

All that said, I do see the merits in the arguments that the wind report database may have just enough fidelity to *start* uncovering the meteorological and climatological influences on derecho characteristics. The strongest part of this argument is the linkages to the trends in the parent convective systems themselves, which can be better identified with decades of consistent radar and satellite observations. I presume that's what the recent studies that you've cited to support your arguments have done, so I think this linkage could be emphasized even more.

Overall, without stronger analysis that demonstrates the changes in reporting are not the leading cause for the trends, I think there's a fair amount of work still to be done to the narrative to soften the stated linkages to the warming climate. That said, ***I think this can largely be addressed by softening the wording and adding qualifiers in the appropriate places***. I provide these instances below with suggestions for how I would do this.

I conclude with a handful of additional minor comments that include additional suggestions for tightening the narrative and some other minor concerns.

Specific Substantive Comments: I think the abstract needs a sentence or statement saying it's still unclear how much influence the reporting database or multi-year variability is having on the identified trends in derecho occurrence and intensity. It reads too definitive that there's a real trend there. After "most notably during the last 10 years", I'd add, "although the degree to which the reporting database or multi-year variability is contributing to this trend is still not clear."

A qualifier was added to the abstract as recommended.

The last paragraph of the "WIND REPORTS" section is the one I'm most concerned about and my thoughts are mostly summarized above. I'd replace this paragraph with "Overall, severe wind reports have increased over the 30-year period covered by this climatology, most notably in the central U.S. and plains (see Fig. 8 in Squitieri et al. 2025b) where the majority of derecho events form and mature. This suggests that changes in reporting are likely influencing the trend. Overall, this study takes the viewpoint that the large spatial coverage of derechos, inclusion of both estimated and measured wind reports, report spacing in consideration of possible report clustering, and the inclusion of phenomenologically specific physical characteristics may cushion the impacts of storm report increases on increases in derecho events across the climatology. However, while the large increase in identified events the last 10 years is intriguing, we recognize that the relative influences of these factors remain unknown and will await more years of events and a longer period of standardized reporting practices."

This entire section has been reworked based on your recommendations and those of another reviewer.

The second and third sentences starting off section 4 are too definitive. I'd replace them with: "One trend identified is an increase in derechos and intensity over the period of study, most notably over the past ten years, although it's not clear how much changes in reporting or multi-year variability are influencing this trend. In support of this being a meteorological trend, recent literature (Prein et al. 2017; Schumacher and Rasmussen 2020; Lasher-Trapp et al. 2023; Haberlie et al. 2024; Kaminski et al. 2024; etc.) suggests that this is consistent with identified trends in severe convection and their environments overall *[note: you may need to tweak this wording based on what these papers are showing more specifically]*, and so this may be a trend we can expect for the rest of the 21st century under global warming. However, additional analysis is needed to identify the relative influence of the possible factors."

The entirety of section 4 has been reworked and reorganized per your recommendations and those of another reviewer.

[Minor comments omitted…]