AGU ADVANCING EARTH AND SPACE SCIENCES

Space Weather

COMMENTARY
10.1029/2025SW004563

Key Points:
- Extreme geomagnetic field variation realized during the May 1921 storm disrupted telegraph and telephone systems across North America
- Long-line interference in the U.S. occurred during local nighttime and in the Midwest and East, where surface impedance is high
- Since the 1921 storm, communication systems (power systems) have become less (more) exposed to geoelectric hazards

Supporting Information:
Supporting Information may be found in the online version of this article.

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Citation:
Love, J. J., Lucas, G. M., Kelbert, A., Schnepf, N. R., Bedrosian, P. A., McBride, S. K., & Oughton, E. J. (2025). The Impact of the May 1921 superstorm on American telecommunication systems. *Space Weather*, *23*, e2025SW004563. https://doi.org/10.1029/2025SW004563

Received 2 JUN 2025
Accepted 11 JUN 2025

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The Impact of the May 1921 Superstorm on American Telecommunication Systems

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Abstract A compilation is presented of impacts (interference and damage) realized on long-line telegraph and telephone systems across North America during the 13–16 May 1921 magnetic storm. Impacts occurred primarily during local nighttime, after the third of four sudden commencements, and during the storm's most-prominent main phase. Impacts are attributed to rapid and high-amplitude geomagnetic field variation generated by substorms. This induced potential differences and between the grounding points of communication networks that were sufficient to cause system interference and damage. In the United States, impacts were concentrated in the Midwest and in the East, regions characterized by high electromagnetic surface impedance. Given technological changes, modern telecommunication systems are less exposed to storms like that of May 1921, while power-grid systems are now more exposed to them.

Plain Language Summary The magnetic storm of 13–16 May 1921 generated geopotentials (voltages) across the Earth's sufficient to cause significant operational interference and system damage to grounded long-wire telegraph and telephone systems in the United States and Canada. Widely reported in newspapers, these impacts occurred primarily during local nighttime and in the Midwest and the Eastern United States, regions with electrically resistive bedrock. New York City communication links were cut off. Today, communication systems are less dependent on long electrically conducting transmission lines, but electric-power-transmission systems are more dependent on them. Accordingly, the May 1921 storm serves as a harbinger of the threat that future magnetic storms represent for electric-power systems.

1. Introduction

The magnetic storm of 13–16 May 1921 was one of the greatest in the history of geomagnetic measurement. The storm induced aurorae in many nighttime skies, and it disrupted the operation of telegraph and telephone systems around the world (e.g., Hapgood, 2019; Kappenman, 2006). Such sights and impacts were spectacularly experienced in North America, where events were widely reported in local newspapers. In the state of North Dakota, for example, the Fargo Forum (1921) reported that, at times, communication was "paralyzed" as the storm seemed to work against battery currents needed to send telegraph signals. In some cases, engineers were able to partially work around these problems and restore some communication links by operating their lines without ground connections. In the Eastern United States, newspapers reported that the "sunspot aurora" put "virtually every telegraph wire" to and from New York City "out of commission" (Evening Public Ledger, 1921b; New York Times, 1921b; Sun, 1921). Excess electric currents were blamed for starting fires at communication depots (e.g., Brewster Standard, 1921; Telephone Review, 1921).

After the May 1921 storm had passed, comparisons were made with the Carrington storm of 2 September 1859 (e.g., Bauer, 1922). The two were of comparable geophysical strength (Cliver & Dietrich, 2013; Hayakawa et al., 2022; Love et al., 2019, 2024), and the Carrington storm, like the May 1921 storm, brought widespread disruption to telegraph systems (e.g., Boteler, 2006; Lanzerotti, 2017). Such impacts result from the induction of geoelectric potential differences across the Earth's surface. These can drive uncontrolled currents through the ground connections of long-line systems, causing operational interference and, even, damage. Recognizing that modern North American communication systems are, in comparison to those of 1921, less reliant on long grounded electrically conducting lines, results presented here inform projects for evaluating storm-induced

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geoelectric hazards and possible impacts on North American power systems, which are now reliant on long transmission lines (e.g., Abda et al., 2020; Boteler, 2003; Kappenman, 2004; Molinski, 2002; Pulkkinen et al., 2017).

2. Long-Line Networks

In the 1920s, most telegraph circuits (e.g., Lincoln Sunday Star, 1921) and some rural telephone circuits (e.g., Dresden Enterprise, 1921) consisted of single wires stretching from one communications depot to another. Ground connections at each depot provided for completion of the signal circuit through the Earth. Such simple systems provided generally reliable communication across short distances, but magnetic storms brought interference and even damage to long-line telecommunication systems (Telephone Review, 1921). This difference is related to the fact that storm-induced geoelectric fields at the Earth's surface are relatively feeble, usually just a few volts per kilometer. The integrated voltage along a given conducting line, from one ground point to another, does not add up to much on a short line, but it can add up to a lot if the line is long. For example, a geoelectric field of 5 V/km parallel to a line 100 km in length adds up to 500 V, enough to damage equipment or injure a person.

3. Impact Data

We examine two types of impact data: (a) the times of 35 impacts realized on telegraph and telephone systems, such as operational difficulty or loss of service, across the United States (U.S.) and Canada during the storm, (b) the locations of 38 cases of damage to telegraph and telephone infrastructure and 1 case of damage to a power-grid system, each described with specificity, and including fires, burned or melted fuses, coils, keys, wires, etc., attributed to the storm. In compiling impact times and locations, we have drawn upon reports in scientific and engineering journals, professional trade journals, and newspapers. Our compilation adds significantly to those of others (e.g., Hapgood, 2019; Odenwald, 2007; Silverman & Cliver, 2001); see Tables S1 and S2 in Supporting Information S1. Care needs to be taken in interpreting timestamps from 1921 (Hapgood, 2019). The U.S. did not have, in those days, a national convention for daylight-saving time, that is, the practice of moving clocks forward by 1 hour during the months of late spring to early fall. Some localities observed daylight savings, others did not. We use newspaper announcements to resolve this issue.

Newspaper headlines suggested that a fire that occurred on the morning of 15 May 1921 and which resulted in a shutdown of the signal and switching system of the Central Railroad in Manhattan, New York, might have been caused by the magnetic storm that was then ongoing (New York Times, 1921c). Hapgood (2019) notes that the fire occurred outside of peak levels of global geomagnetic disturbance, suggesting that the fire was possibly unrelated to the storm. And, indeed, the next day, the head of the electrical division of the Central Railroad was equivocal on the cause of the fire (New York Times, 1921a). Here, we simply note that the Central Railroad fire might have been caused by the storm. Another fire, one confidently attributed to the magnetic storm, occurred in the Union Railroad station in Albany, New York, causing significant damage to American Telephone & Telegraph (AT&T) lines. In nearby Brooklyn, New York, heat coils and arrestors were blown out on AT&T systems, again, as a result of the storm (Telephone Review, 1921).

4. Space-Weather Data

Magnetograms acquired during the May 1921 storm by the U.S. Coast and Geodetic Survey at the Cheltenham observatory in Maryland (e.g., Hazard, 1924) are, unfortunately, incomplete on account of the extreme amplitude of field variation (e.g., Hartnell, 1921). Two different geomagnetic indices are available for the May 1921 storm. *Dst* is a 1-hr resolution scalar index (Sugiura & Kamei, 1991) often interpreted as a measure of the strength of the westward-directed equatorial ring current in the magnetosphere (e.g., Daglis, 2006). We use the *Dst* sequence developed by Love et al. (2019) for the May 1921 storm. The *aa* index is a nominal measure of the range of geomagnetic vector variation at mid-latitudes over 3-hr time windows. We use a revised version of the *aa* index developed by Lockwood et al. (2018). We use a list of sudden commencement times available from the Observatori de l'Ebre (Curto et al., 2022). To our knowledge, the lowest-latitude report of discrete aurorae seen during the May 1921 storm at local zenith is from San Juan, Puerto Rico (Lyman, 1921). We assume that Puerto Rico was on Atlantic Standard Time (GMT-4).

5. A Chronicle of Events

In Figure 1, we present a graphical representation of time-variable space-weather conditions and related impacts on telegraph and telephone systems across North America during the 13–16 May 1921 storm. This duration of time might be viewed as encompassing three separate storms related to four separate coronal-mass ejections. These ejections originated from an active sunspot group (e.g., Lundstedt et al., 2015), and they resulted in a series of sudden commencements at Earth (e.g., Hapgood, 2019, his Section 3). The first amounted to the beginning of the magnetic storm at 08:06 EST (13:06 Greenwich Mean Time, GMT) on Friday, 13 May. This is reflected in an increase in *aa* from 9 to 146 nT, and an increase in *Dst* from −24 nT to +36 nT. Two hours later, wire service "trouble" commenced in Illinois (Rock Island Argus, 1921). A second sudden commencement came at 14:24 EST 13 May, when *aa* attained the, still rather modest, value of 164 nT. This was followed by generally "disarranged" wire service in New York State (Buffalo Evening Times, 1921b), and, then, more specifically, the loss of the Associated Press wire service, also in New York State (Poughkeepsie Eagle-News, 1921a). Geomagnetic disturbance and impacts on communication systems then subsided until the (eastern local time) evening of 14 May.

A third sudden commencement, at 17:12 EST on 14 May, initiated one of the greatest magnetic storms of the 20th century. The responsible coronal-mass ejection was possibly a potent product of two interacting ejections (e.g., Hapgood, 2019, his Section 6). As the storm entered its main phase, the magnetospheric ring current gained strength, and *Dst* descended to a depth of −907 nT at 00:00-01:00 EST 15 May. In comparison, the storm of 13–14 March 1989 (e.g., Allen et al., 1989) attained a *Dst* of −594 nT. The 2 September 1859 Carrington storm (e.g., Boteler, 2006) is estimated to have attained a *Dst* of −964 nT (Hayakawa et al., 2022; Love et al., 2024). During the main phase of the May 1921 storm, *aa* recorded a corresponding increase in mid-latitude geomagnetic disturbance, attaining $aa = 832$ nT from 22:00 14 May EST to 01:00 15 May EST, the greatest amplitude attained by that index since its inception in 1868. At about the same time as the storm attained its deepest *Dst* and maximum *aa* values, aurorae were seen at zenith in San Juan, Puerto Rico (local midnight).

As seen in Figure 1, most telecommunication-system impacts listed in Table S1 in Supporting Information S1 occurred during the six-hour period from the time of the third sudden commencement to the time when aurorae were seen overhead in the Caribbean. In North Dakota, wire service was described as "paralyzed" (Fargo Forum, 1921). In Minnesota, wires were not only "paralyzed," but telegraph and telephone fuses were "burned out" (Sunday Journal, 1921). On a more regional scale, interference was experienced on Western Union (e.g., Omaha Daily Bee, 1921; Sunday State Journal, 1921) and Postal Telegraph systems (e.g., Sunday Journal, 1921). The telephone systems of the North Pacific Railroad and the Soo Railroad were out (e.g., Sunday Journal, 1921). In the Eastern U.S., a fire was started in the Brewster, New York, Central New England Railroad station, eventually causing it to burn down (Brewster Standard, 1921; Lyman, 1921); the Associated Press news-wire service was "out of commission" (News, 1921; Sun, 1921); the telephone service of the Boston and Albany Railroad was out and system cables, fuses, and keys were burned (Springfield Weekly Republican, 1921); communication links between various cities were out (e.g., Bath Daily Times, 1921b; Telephone Review, 1921). This remarkable record of impacts can be plausibly attributed to storm main-phase geomagnetic disturbance generated by substorms and induced ionospheric electrojet currents over nighttime North America (e.g., Hapgood, 2019, his Section 6).

6. Geography of Impacts

In Figure 2, we show a map of the locations of damage to telegraph and telephone infrastructure realized during the May 1921 storm. Damage was concentrated in the Midwest and in the Eastern U.S.; two instances of damage were in Eastern Canada. As noted by Love et al. (2022, 2023), the geographic organization of impacts on long-line systems across North America, as realized during several historical magnetic storms, has been primarily due to the geographic expression of Earth-surface impedance (e.g., Bedrosian & Love, 2015; Kelbert, 2020)—high-amplitude geoelectric fields are induced in electrically resistive crust. As a result, the geographic organization of impacts, mostly in the Midwest and East, is a pattern that holds from one storm to another. Its validity is reinforced with the inclusion, here, of impact data for the May 1921 storm.

On that theme, consider the locations of damage described as "fires." There are seven in our compilation, two on switchboards in St. Paul (Evening Tribune, 1921) and in Minneapolis (Sunday Journal, 1921), neighboring cities in the Midwest state of Minnesota. Three fires occurred in the Hudson Valley Region of New York State: in

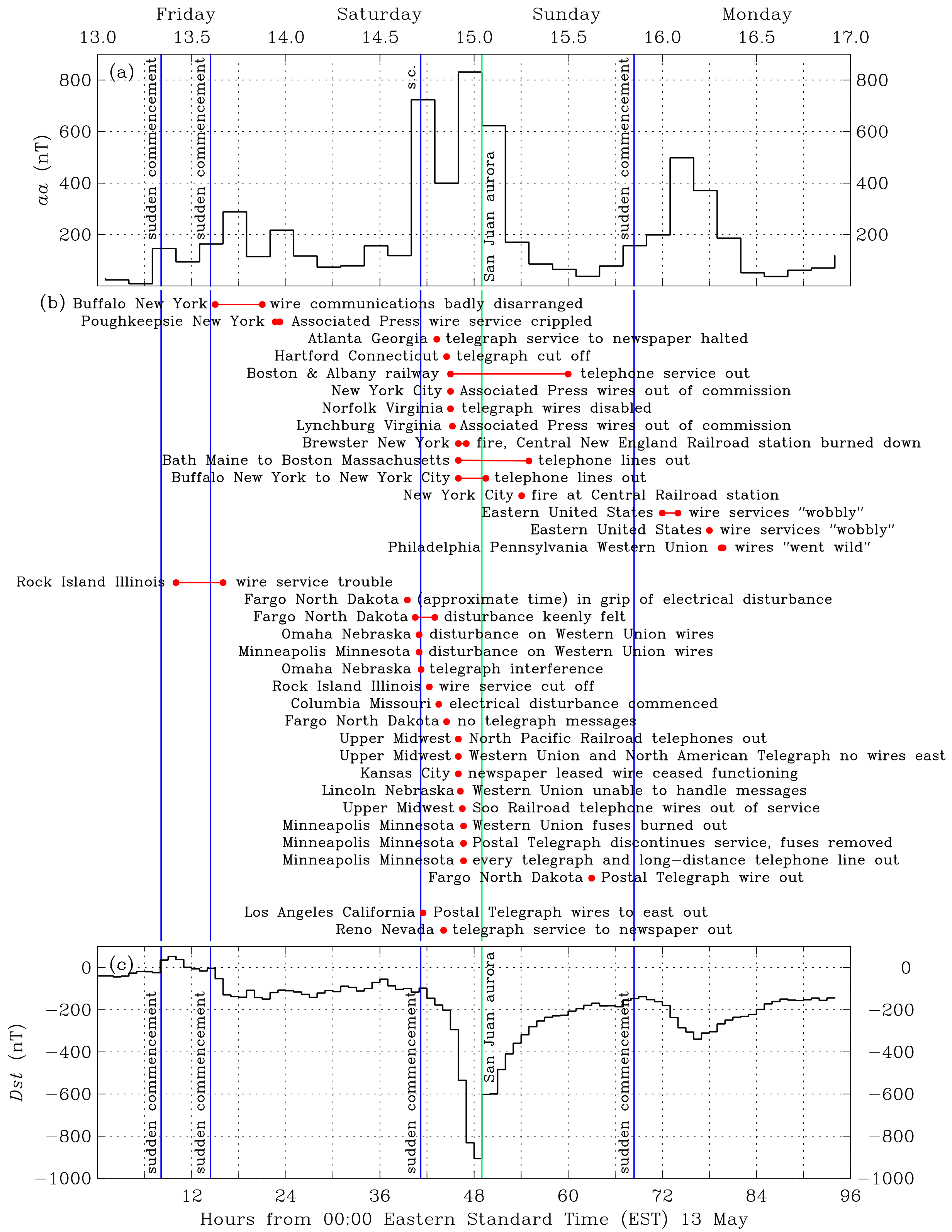

Figure 1. A timeline of events for the May 1921 storm from 00:00 13 May EST, to 00:00 17 May EST: (a) the 3-hr *aa* index; (b) start and (when available) end times of interference experienced on North American telecommunication systems, grouped into eastern, midwestern, and western regions; (c) the 1-hr *Dst* index. Also shown are the times of sudden commencements and the time of aurorae seen at local zenith in San Juan, Puerto Rico.

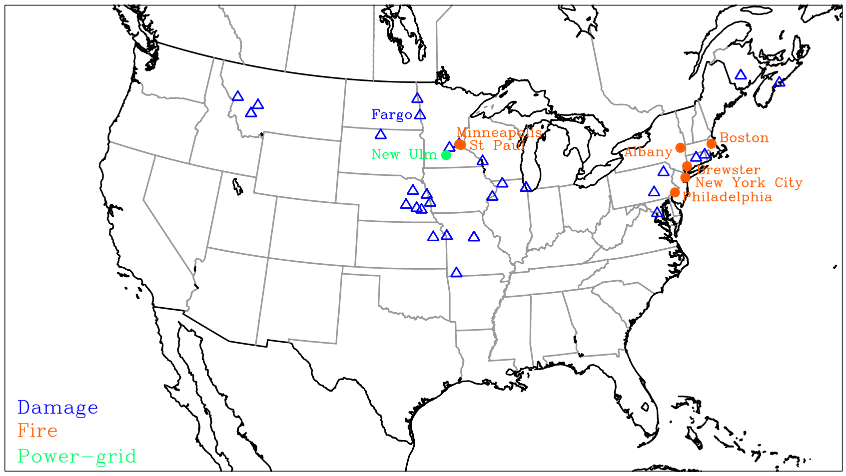

Figure 2. Locations of communication-system damage (blue triangles), fire (orange dots), and one case of power-grid damage (green dot) realized across North America during the May 1921 magnetic storm.

Albany, New York, where a railroad station caught fire (Telephone Review, 1921); south of that, in Brewster, New York, where, as already noted, a railroad station burned down (Brewster Standard, 1921); and south of that, the (possibly relevant) fire at the railroad station in New York City (New York Times, 1921c). Fires were reported on telephone switchboards in nearby Boston (Boston Daily Globe, 1921) and Philadelphia (Gray, 1930).

In addition to the numerous reports of damage on telecommunication systems during the May 1921 storm, we also found one report of damage, in the New Ulm Review (1921) of Minnesota, to an American electric-power-grid system. This report, though isolated, is of historical interest because it has been said that the March 1940 was the first storm to have an impact on power-grid systems (e.g., Barnes et al., 1991; Boteler, 2015; Kappenman, 2010; McNish, 1940). In subsequent decades, telecommunication and power-transmission would follow different trajectories of technological development. Communication systems would become less dependent on long lines, and power transmission would become more dependent on long lines. As a result, communication systems would become less exposed to storm-induced geoelectric fields, and power systems would become more exposed to them.

Data Availability Statement

We consulted the following archives: The International Service on Rapid Magnetic Variations (https://www.obsebre.es/en/variations/rapid), The New York Times (https://timesmachine.nytimes.com), Newspapers.com (https://newspapers.com), NewspaperArchive (https://newspaperarchive.com), New York State Historic Newspapers (https://nyshistoricnewspapers.org).

Acknowledgments
We thank R. D. Gold, K. A. Lewis, E. J. Rigler, and B. R. Shiro for reviewing a draft manuscript. We thank A. N. Davis for help with preparing figures. This work was supported by the Geomagnetism Program of the U.S. Geological Survey. E. J. Oughton was funded via National Science Foundation RAPID Award 2434136 and the NSF NCAR Early Career Innovator Award 1852977. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. government.

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