https://doi.org/10.5194/egusphere-2026-5
Preprint. Discussion started: 30 January 2026

"Corotating Interaction Region (CIR)", "Interaction Region", "Stream Interaction Region (SIR)", which term should be used?

Bruce T. Tsurutani[1], Rajkumar Hajra[2], Gurbax S. Lakhina[3]

[1]Retired, Pasadena, California 91208, USA
[2]School of Earth and Space Sciences, University of Science and Technology of China, Hefei 230026, China
[3]Retired, B-701, Neel Sidhi Towers, Plot no 195, Sector-12, Vashi, Navi Mumbai 400703, India

Correspondence to: Bruce T. Tsurutani (bruce.tsurutani@gmail.com)

Abstract. We discuss the history of quasiperiodic ~27-day recurrent geomagnetic activity and the origin of the names "interaction region", "corotating interaction region" and "stream interaction region". The latter three names have an identical meaning. We recommend the most commonly used name "corotating interaction region" or CIR for sole usage in the literature to avoid confusion.

1 Comment

Maunder (1904) was perhaps the first person to report the statistics of "magnetic disturbances of the solar rotation-period" (the phrase is taken from the title of the Maunder, 1905 paper). In the 1904 paper, Maunder used the Greenwich, England observations of "magnetic movements" for his study. In the study of data from 1886 to 1889 and 1895 to 1898, he found intervals where "there is a strong tendency for certain (solar) longitudes to recur". Maunder concluded: "Several important consequences follow from this relation. First, that our magnetic disturbances are directly due to some solar action. Next, that action must be located in certain restricted areas of the Sun's surface; it cannot be general to the surface as a whole, for it is precisely as certain meridians return to the centre of the disc, that we have the return of the disturbances. Thirdly, the mode of the transmission of this solar influence to the Earth, must be along definite lines; it cannot be of the nature of radiation, equal in all directions, as it is with light and heat. These are the most important conclusions to be drawn from the inspection of the catalogue."

It was not until Chree (1913), the director of The King's Observatory, Richmond, U.K., proved that Maunder's ~27-day quasiperiodic results were statistically significant, giving us the "Chree superposed epoch" statistical analyses, a method widely in use today. Although these periodic geomagnetic activities at Earth were substantiated by Chree, no identifiable optical features causing them were apparent on the Sun's visible disc.

While analyzing the data of terrestrial-magnetic activity for the years 1906-1931, Bartels (1932) similarly found strong ~27-day recurrences related to solar rotation. As he could not identify any visible signatures on the Sun that could cause ~27-day

https://doi.org/10.5194/egusphere-2026-5
Preprint. Discussion started: 30 January 2026

periodic geomagnetic activity at Earth, Bartels (1932, 1934) called these "magnetically active" or "M"-regions of the Sun. After 1934, the science community adopted the Bartels M-region terminology.

It was not until soft X-ray images of the Sun were available from the Skylab satellite that Krieger et al. (1973) "identified a magnetically open structure in the low corona……with density scale heights typically a factor of two less than that in the surrounding large scale magnetically closed region". Krieger et al. (1973) traced back a high velocity stream using "instantaneous ideal spirals" and found "a striking agreement between the Carrington longitude of the solar source of a recurrent high velocity solar wind stream with the position of the hole". Krieger et al. (1973) called these magnetically open structures "coronal holes".

However, it was postulated by later scientists that the coronal hole high-speed solar winds would not simply propagate unimpededly from the Sun to the Earth, but would interact with an upstream slow solar wind. Belcher and Davis (1971) showed this schematically as in Figure 1, and called this an "interaction region".

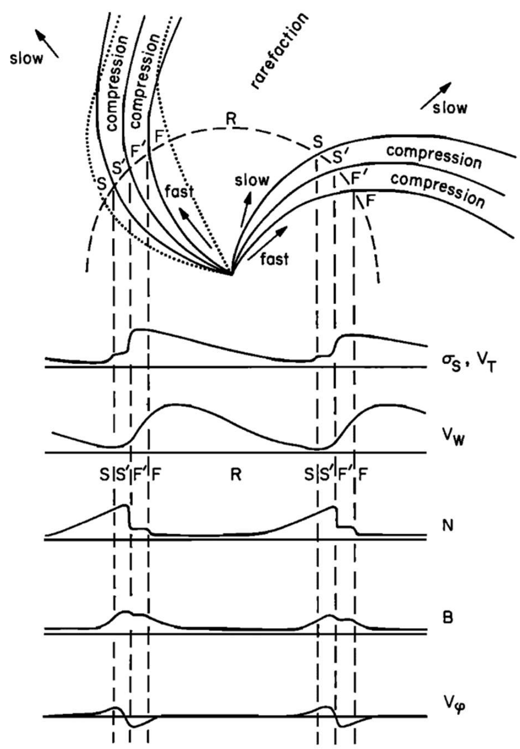

Figure 1: Top: schematic of two high-speed streams and adjacent slow stream corotating with the Sun. The regions indicated are: the unperturbed slow solar wind (S), compressed, accelerated slow solar wind (S'), compressed, decelerated fast solar wind (F'), unperturbed fast solar wind (F), and a rarefaction (R). S' and F' form the interaction region, and the stream interface is at the S'–

https://doi.org/10.5194/egusphere-2026-5
Preprint. Discussion started: 30 January 2026

F/ boundary. Dotted lines indicate magnetic field lines in the slow and fast solar wind which thread into the interaction region beyond 1 AU. Bottom: curves showing as functions of time the changes in solar wind parameters that will be observed by a spacecraft as the streaming pattern sweeps past at 1 AU. Various plasma parameters: proton thermal speed (V_T), magnetic field fluctuation level (σ_s), solar wind speed (V_W), density (N), magnetic field intensity (B), and transverse component of the solar wind velocity (V_φ). The figure is taken from Belcher and Davis (1971).

Belcher and Davis (1971) postulated that the "interaction region" was not corotating in a physical sense, but was shaped like an Archimedean spiral. They stated: "It is instructive to consider this steady state flow in a rotating coordinate system. The structure in the upper half of their Fig. 13 (Figure 1 in this article) now does not rotate; instead, the spacecraft moves clockwise in a circle and makes observations that, when plotted as functions of time, yield the idealized curves shown in the bottom half of the figure. In this corotating frame, the velocity is everywhere parallel to the smoothed magnetic field lines, and hence the flow is in a spiral whose pitch changes as it passes into the regions of compression because of the pressure gradient (or discontinuity) across the transition. The deflection provides a natural explanation for the observation."

Belcher and Davis (1971) were later challenged by Burlaga (1974) and Hundhausen and Burlaga (1975) concerning a sharp transition between slow and fast flows (the formation of a tangential discontinuity as stated by Belcher and Davis, 1971) separating the two flows and plasma and magnetic field regions (see Richardson, 2018 for further discussion). However, the tangential discontinuity was later found and is now referred to as a "stream interface", or SI (Gosling et al., 1978).

Smith and Wolfe (1976) performed the first high spatial resolution examination of these "interaction regions" using Pioneer 10 and 11 magnetometer and plasma data. They called these regions "Corotating Interaction Regions" or CIRs. Smith and Wolfe (1976) showed the presence of shocks at the leading and trailing edges of the CIRs at large distances from the Sun and the general lack of shocks closer to the Earth, advancing the knowledge of Belcher and Davis (1971) on this topic. An example of a shock pair associated with the slow and fast stream interaction region is shown schematically in Figure 2.

https://doi.org/10.5194/egusphere-2026-5
Preprint. Discussion started: 30 January 2026

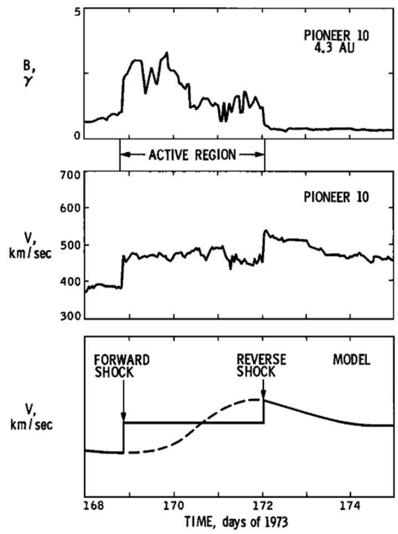

Figure 2: Pioneer 10 Plasma and Field Observations. Top panel: hourly averages of the field magnitude. The space between an abrupt onset and an equally abrupt termination defines the "interaction region". Central panel: hourly values of the solar wind velocity with abrupt jumps at the beginning and end of the "interaction region". Bottom panel: a qualitative diagram showing how the positive gradient associated with a fast stream at 1 AU (dashed) is replaced at large distances by a region of essentially zero gradient bounded by a forward and a reverse shock. The figure is taken from Smith and Wolfe (1976).

Smith and Wolfe (1976), like Belcher and Davis (1971), also realized that the structures did not corotate, but had a profile in space like water streaming from a rotating water sprinkler head. They stated: "As the solar wind expands beyond 1 AU, this stream interaction becomes more pronounced (Collard and Wolfe, 1974). Compression of the plasma and magnetic field within the interaction region leads to stresses which accelerate the preceding slow plasma and decelerate the trailing fast plasma. According to theory, these interaction regions trace out a spiral which corotates with the sun (Siscoe, 1972)."

Tsurutani et al. (1995b) and Tsurutani et al. (2006) demonstrated that it was amplification of interplanetary Alfvén waves within the two compressed regions of the "interaction region" that caused enhanced geomagnetic activity at the Earth. Tsurutani et al. (1995b) followed the Smith and Wolfe (1976) title and called the interaction regions CIRs. Intense, compressed interplanetary magnetic field (IMF) B_z southward components of the Alfvén waves within the CIRs, through magnetic reconnection with the Earth's magnetopause magnetic fields (Tsurutani and Meng, 1972), could cause geomagnetic storms (SYM-H < –50 nT). However, because of the high level of IMF B_z fluctuations (fluctuating in both the northward and southward directions) found within CIRs (Tsurutani et al., 1995a), the storm intensities rarely exceed SYM-H < –100 nT (Tsurutani et al., 2024). It was also noted that CIRs would sometimes contain primarily IMF B_z northward components and thus, little or no geomagnetic activity would result. These latter phenomena explain the statistical nature of the Maunder

https://doi.org/10.5194/egusphere-2026-5
Preprint. Discussion started: 30 January 2026

(1904, 1905) and Bartels (1932) results. Sometimes there would be geomagnetic activity in the next 27 days and sometimes not.

The physical situation is even more complicated than what Maunder (1904, 1905) and Bartels (1932, 1934) had imagined or what was discussed in Belcher and Davis (1971) and Smith and Wolfe (1976). Besides the "interaction region"/"Corotating Interaction Region", there is a trailing high-speed solar wind which could impact the Earth's magnetosphere for days to weeks, depending on the size of the coronal hole (Tsurutani and Gonzalez, 1987; Tsurutani et al., 1995a, 2006; Hajra et al., 2013). The pure high-speed solar wind stream following the CIR contain nonlinear Alfvén waves which could cause long durations of low-level geomagnetic activity. The authors explained that this geomagnetic activity was not a CIR storm "recovery phase", but was fresh solar wind energy input into the magnetosphere through magnetic reconnection. Tsurutani and Gonzalez (1987) named these geomagnetically active intervals "High Intensity, Long-Duration, Continuous AE Activity" or HILDCAAs. See also Hajra et al. (Hajra et al., 2013, 2014a, b, c, 2015a, b).

Between 1976 and 2006 the "interaction regions" of Belcher and Davis (1971) were called CIRs in the literature following Smith and Wolfe (1976). However, in 2006, Jian et al. (2006) called the "interaction regions" inside 1 AU, "stream interaction regions" or SIRs. Jian et al. (2006) wrote: "A stream interaction region (SIR) forms when a fast solar stream overtakes a slow stream, leading to structure that evolves as an SIR moves away from the Sun." They conducted "a separate assessment of the longer-lasting corotating interaction regions (CIRs) that recur on more than one solar rotation." Jian et al. (2006) thus made a distinction between when an "interaction region" recurred 27 days later from those that did not.

Richardson (2018) has written a review of "stream interaction regions" throughout the heliosphere. In the abstract, he writes: "This paper focuses on the interactions between the fast solar wind from coronal holes and the intervening slower solar wind, leading to the creation of stream interaction regions that corotate with the Sun and may persist for many solar rotations." The above description of an SIR is the same as described by Belcher and Davis (1971) and Smith and Wolfe (1976) but now Richardson (2018) is renaming multiple 27 day rotating events as SIRs and not CIRs.

Jian et al. (2006) also mentioned that they used the term "stream interaction regions (SIRs)" "following the suggestion of Gosling et al. (2001)" to include "transient and possibly localized stream interactions" "with poor recurrence." However, what are these "transient stream interactions" and how would one distinguish them from observations of regular interaction regions? If they have "poor recurrence" or poor occurrence, is it necessary to give them a new name?

https://doi.org/10.5194/egusphere-2026-5
Preprint. Discussion started: 30 January 2026

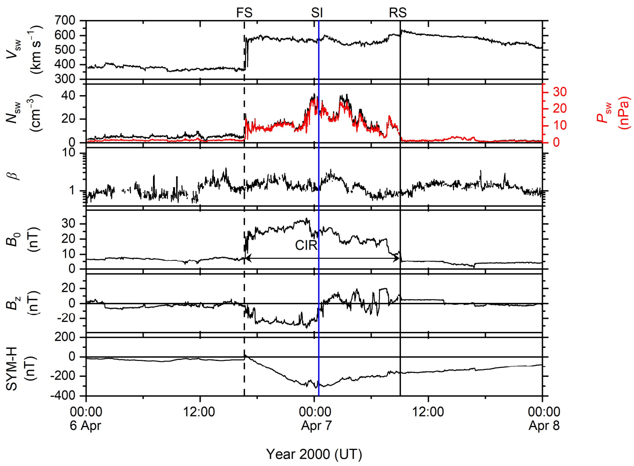

Figure 3: An unusual CIR detected at 1 AU. From top to bottom, panels show variations of the solar wind plasma speed V_{sw}, density N_{sw} (black, legend on the left) and ram pressure P_{sw} (red, legend on the right) in the same panel, plasma-β, IMF magnitude B_0, B_z-component, and ring current index SYM-H during 6–7 April 2000. Vertical lines indicate a fast forward shock (FS, black dashed line), a stream interface (SI, blue solid line), and a reverse shock (RS, black solid line). The CIR, bounded by the fast forward and reverse shocks, caused a magnetic storm of peak SYM-H intensity = –319 nT. The figure is updated from Tsurutani et al. (2024).

The event on 6 to 7 April 2000 shown in Figure 3 was originally misidentified by several authors as an interplanetary coronal mass ejection, and was recently reanalyzed as a highly unusual CIR (Tsurutani et al., 2024). The interplanetary structure was bounded by both forward and reverse fast shocks and caused an unusually strong magnetic storm of peak SYM-H intensity = –319 nT. Tsurutani et al. (2024) stated: "A plasma region between a tangential discontinuity and the stream interface had a scale size of ~0.096 AU. We hypothesize that this is the first detection of a coronal jet at 1 AU. The jet/Gold magnetic tongue (1959, https://doi.org/10.1029/JZ064i011p01665) was embedded within the CIR, contained the southward B_z and caused the magnetic storm. We hypothesize that a shrinking coronal hole and magnetic reconnection caused the formation and release of the jet."

This interplanetary event can be thought of an ejecta event, which would not recur 27 days later. Note that the boxcar like profile is essentially identical to the schematic of Figure 2 shown in Smith and Wolfe (1976). The only difference would be the lack of Alfvénic B_z fluctuations in the first half of the magnetic structure. Tsurutani et al. (2024) did not give this a new name but called it a CIR.

https://doi.org/10.5194/egusphere-2026-5
Preprint. Discussion started: 30 January 2026

2 Conclusions

We find the term SIR to not indicate anything different from Belcher and Davis (1971) and Smith and Wolfe (1976) concerning the physical nature of the "interaction region" close to the Sun, at 1 AU or distances beyond 1 AU. It should be noted that neither Belcher and Davis (1971) nor Smith and Wolfe (1976) required their "interaction regions" to recur 27 days later.

To compound matters, other scientists have misinterpreted the tangential discontinuity, which has aptly been called the "stream interface" or SI with an SIR.

In our opinion, we think that the most common term of "Corotating Interaction Region" or CIR should be used in the future.

Data availability. Figure 1 is taken from Belcher and Davis (1971). Figure 2 is taken from Smith and Wolfe (1976). In Figure 3, solar wind plasma and magnetic field data are obtained from NASA's OMNIWeb Plus (https://omniweb.gsfc.nasa.gov/; King and Papitashvili, 2020), and the geomagnetic SYM-H index is obtained from the World Data Center for Geomagnetism, Kyoto, Japan (https://wdc.kugi.kyoto-u.ac.jp/).

Author contributions. BTT had the original idea and prepared the first draft. RH and GSL participated in the development, revision of the article and approved the final draft.

Competing interests. The author declares that there is no conflict of interest.

Financial support. The work of RH is funded by the "Hundred Talents Program" of the Chinese Academy of Sciences (CAS) and the "Excellent Young Scientists Fund Program (Overseas)" of the National Natural Science Foundation of China (NSFC).

References

Bartels, J.: Terrestrial-magnetic activity and its relations to solar phenomena, Terr Magneti and Atmo Electr, 37, 1–52, https://doi.org/10.1029/TE037i001p00001, 1932.

Bartels, J.: Twenty-seven day recurrences in terrestrial-magnetic and solar activity, 1923–1933, Terr Magneti and Atmo Electr, 39, 201, https://doi.org/10.1029/TE039i003p00201, 1934.

Belcher, J. W. and Davis, L.: Large-amplitude Alfvén waves in the interplanetary medium, 2, J. Geophys. Res., 76, 3534–3563, https://doi.org/10.1029/JA076i016p03534, 1971.

Burlaga, L. F.: Interplanetary stream interfaces, J. Geophys. Res., 79, 3717–3725, https://doi.org/10.1029/JA079i025p03717, 1974.

Chree, C.: III. Some phenomena of sunspots and of terrestrial magnetism at Kew Observatory, Phil. Trans. R. Soc. Lond. A, 212, 75–116, https://doi.org/10.1098/rsta.1913.0003, 1913.

Collard, H. R. and Wolfe, J. H.: Radial gradient of solar wind velocity from 1 to 5 AU, Solar wind three; Third Conference, Pacific Grove, CA, 1974.

Gold, T.: Plasma and magnetic fields in the solar system, J. Geophys. Res., 64, 1665–1674, https://doi.org/10.1029/JZ064i011p01665, 1959.

Gosling, J. T., Asbridge, J. R., Bame, S. J., and Feldman, W. C.: Solar wind stream interfaces, J. Geophys. Res., 83, 1401–1412, https://doi.org/10.1029/JA083iA04p01401, 1978.

Gosling, J. T., McComas, D. J., Skoug, R. M., and Forsyth, R. J.: Stream Interaction Regions at High Heliographic Latitudes During Ulysses12/22/2004 6:25PM Second Polar Orbit, Space Science Reviews, 97, 189–192, https://doi.org/10.1023/A:1011871421324, 2001.

Hajra, R., Echer, E., Tsurutani, B. T., and Gonzalez, W. D.: Solar cycle dependence of High-Intensity Long-Duration Continuous AE Activity (HILDCAA) events, relativistic electron predictors?, JGR Space Physics, 118, 5626–5638, https://doi.org/10.1002/jgra.50530, 2013.

Hajra, R., Tsurutani, B. T., Echer, E., and Gonzalez, W. D.: Relativistic electron acceleration during high-intensity, long-duration, continuous *AE* activity (HILDCAA) events: Solar cycle phase dependences: Relativistic electrons during HILDCAAs, Geophys. Res. Lett., 41, 1876–1881, https://doi.org/10.1002/2014GL059383, 2014a.

Hajra, R., Echer, E., Tsurutani, B. T., and Gonzalez, W. D.: Solar wind-magnetosphere energy coupling efficiency and partitioning: HILDCAAs and preceding CIR storms during solar cycle 23, JGR Space Physics, 119, 2675–2690, https://doi.org/10.1002/2013JA019646, 2014b.

Hajra, R., Echer, E., Tsurutani, B. T., and Gonzalez, W. D.: Superposed epoch analyses of HILDCAAs and their interplanetary drivers: Solar cycle and seasonal dependences, Journal of Atmospheric and Solar-Terrestrial Physics, 121, 24–31, https://doi.org/10.1016/j.jastp.2014.09.012, 2014c.

Hajra, R., Tsurutani, B. T., Echer, E., Gonzalez, W. D., and Santolik, O.: RELATIVISTIC ($E > 0.6$, > 2.0, AND > 4.0 MeV) ELECTRON ACCELERATION AT GEOSYNCHRONOUS ORBIT DURING HIGH-INTENSITY, LONG-DURATION, CONTINUOUS AE ACTIVITY (HILDCAA) EVENTS, ApJ, 799, 39, https://doi.org/10.1088/0004-637X/799/1/39, 2015a.

Hajra, R., Tsurutani, B. T., Echer, E., Gonzalez, W. D., Brum, C. G. M., Vieira, L. E. A., and Santolik, O.: Relativistic electron acceleration during HILDCAA events: are precursor CIR magnetic storms important?, Earth Planet Sp, 67, 109, https://doi.org/10.1186/s40623-015-0280-5, 2015b.

Hundhausen, A. J. and Burlaga, L. F.: A model for the origin of solar wind stream interfaces, J. Geophys. Res., 80, 1845–1848, https://doi.org/10.1029/JA080i013p01845, 1975.

Jian, L., Russell, C. T., Luhmann, J. G., and Skoug, R. M.: Properties of Stream Interactions at One AU During 1995 – 2004, Sol Phys, 239, 337–392, https://doi.org/10.1007/s11207-006-0132-3, 2006.

King, J. H. and Papitashvili, N. E.: OMNI 1-min Data Set, https://doi.org/10.48322/45BB-8792, 2020.

Krieger, A. S., Timothy, A. F., and Roelof, E. C.: A coronal hole and its identification as the source of a high velocity solar wind stream, Sol Phys, 29, 505–525, https://doi.org/10.1007/BF00150828, 1973.

Maunder, E. W.: Demonstration of the Solar Origin of the Magnetic Disturbances, Monthly Notices of the Royal Astronomical Society, 65, 18–34, https://doi.org/10.1093/mnras/65.1.18, 1904.

Maunder, E. W.: Early suggestions of the indication by magnetic disturbances of the solar rotation-period, The Observatory, 28, 100–104, 1905.

Richardson, I. G.: Solar wind stream interaction regions throughout the heliosphere, Living Rev Sol Phys, 15, 1, https://doi.org/10.1007/s41116-017-0011-z, 2018.

Siscoe, G. L.: Structure and orientations of solar-wind interaction fronts: Pioneer 6, J. Geophys. Res., 77, 27–34, https://doi.org/10.1029/JA077i001p00027, 1972.

Smith, E. J. and Wolfe, J. H.: Observations of interaction regions and corotating shocks between one and five AU: Pioneers 10 and 11, Geophysical Research Letters, 3, 137–140, https://doi.org/10.1029/GL003i003p00137, 1976.

Tsurutani, B. T. and Gonzalez, W. D.: The cause of high-intensity long-duration continuous AE activity (HILDCAAs): Interplanetary Alfvén wave trains, Planetary and Space Science, 35, 405–412, https://doi.org/10.1016/0032-0633(87)90097-3, 1987.

Tsurutani, B. T. and Meng, C. I.: Interplanetary magnetic-field variations and substorm activity, J. Geophys. Res., 77, 2964–2970, https://doi.org/10.1029/JA077i016p02964, 1972.

Tsurutani, B. T., Gonzalez, W. D., Gonzalez, A. L. C., Tang, F., Arballo, J. K., and Okada, M.: Interplanetary origin of geomagnetic activity in the declining phase of the solar cycle, J. Geophys. Res., 100, 21717–21733, https://doi.org/10.1029/95JA01476, 1995a.

Tsurutani, B. T., Ho, C. M., Arballo, J. K., Goldstein, B. E., and Balogh, A.: Large amplitude IMF fluctuations in corotating interaction regions: Ulysses at midlatitudes, Geophysical Research Letters, 22, 3397–3400, https://doi.org/10.1029/95GL03179, 1995b.

Tsurutani, B. T., Gonzalez, W. D., Gonzalez, A. L. C., Guarnieri, F. L., Gopalswamy, N., Grande, M., Kamide, Y., Kasahara, Y., Lu, G., Mann, I., McPherron, R., Soraas, F., and Vasyliunas, V.: Corotating solar wind streams and recurrent geomagnetic activity: A review, J. Geophys. Res., 111, 2005JA011273, https://doi.org/10.1029/2005JA011273, 2006.

Tsurutani, B. T., Hajra, R., Lakhina, G. S., and Meng, X.: Revisiting the Superstorm on 6–7 April 2000 Caused by an Extraordinary Corotating Interaction Region (With an Embedded Coronal Jet?), JGR Space Physics, 129, e2024JA032989, https://doi.org/10.1029/2024JA032989, 2024.