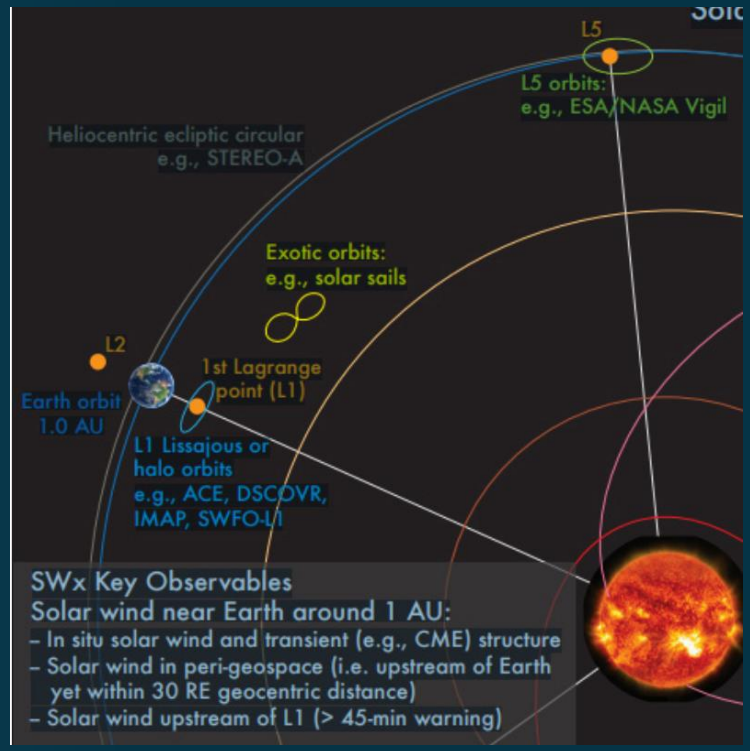
Science Highlights

Investigating Potential Benefits of Future Sub-L1 Missions With STEREO-A

E. Weiler, E. E. Davies, C. Möstl, N. Lugaz, A. Veronig, R. L. Bailey, M. A. Reiss
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Background

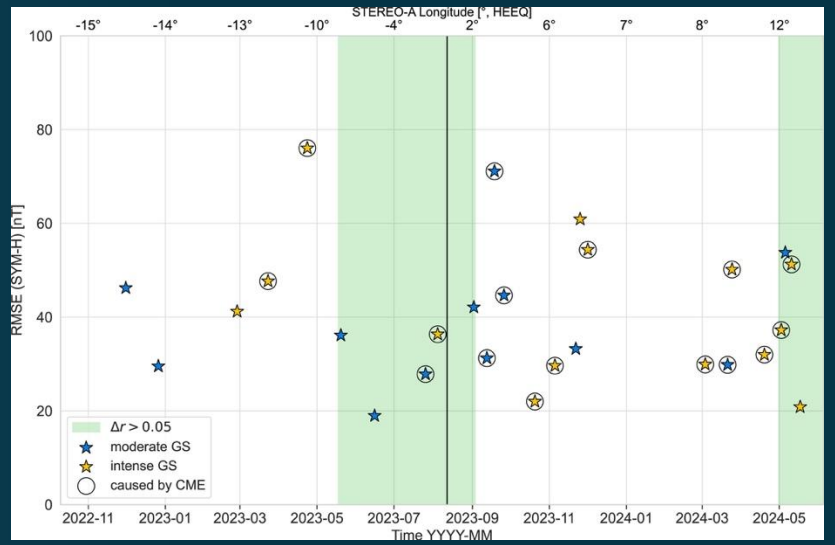
- Using solar wind measurements taken closer to the Sun than from the first Sun-Earth Lagrangian point (L1) for space weather forecasting had never been demonstrated quantitatively.
- L1 (0.01 AU from Earth) is the location of NASA's IMAP, Wind, ACE and NOAA's DSCOVR and SOLAR-1.
- To enable earlier warnings of the impact of solar storms, future mission concepts aim to place spacecraft closer to the Sun than L1.
- This is aligned with some of the recommendations of the 2024 Heliophysics Decadal survey (see Figure).
- STEREO-A crossed the Sun-Earth line on 2023 August 12, providing real-time measurements that can be used, for the first time, to quantify the improvement of such measurements.



Above: Solar wind measurements upstream of L1 were one of the key recommendations of the Space Weather panel of the 2024 Heliophysics Decadal Survey. *Credits: Top left corner of Figure 9b of the 2024 Heliophysics Decadal Survey*

Analysis

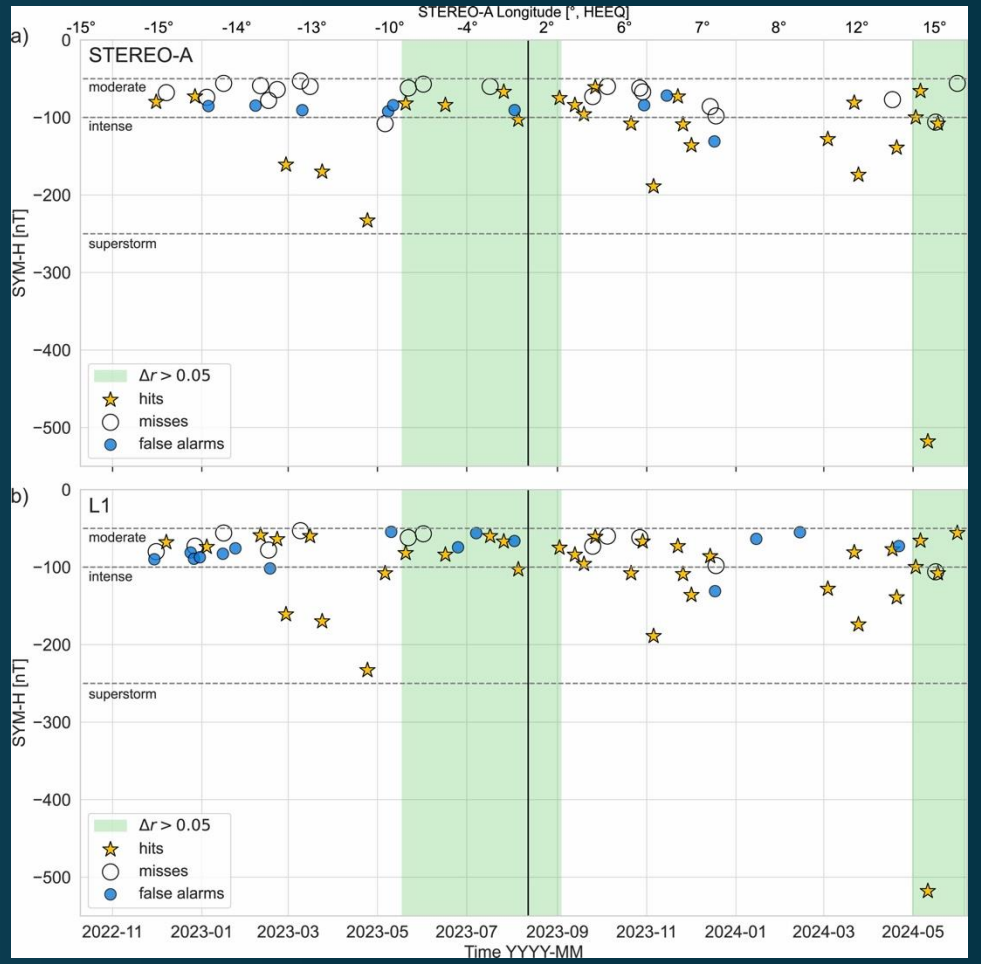
- Between November 2022 and June 2024, STEREO-A crossed the Sun–Earth line, covering longitudinal and radial separations of ±15° from the Sun–Earth line and 0.015–0.06 au from Earth orbit.
- 47 geomagnetic storms, at least of moderate level (Dst < -50 nT), occurred during this time.
- Using STEREO-A beacon (real-time) magnetic field and science plasma data, 26 would have been correctly forecasted, including the ten strongest geomagnetic storms.
- The accuracy was significantly higher for small longitudinal separations with the Sun-Earth line (12 out of 16 correctly forecasted storms for separations of ≤ 7° vs. 12 out of 23 for ≥10°) and when STEREO-A was east of the Sun-Earth line.
- STEREO-A measurements provide advanced warning of up to 6 hours relative to warning times provided by L1 measurements.



Above: Difference (root mean square error) between observed and modeled geomagnetic SYM-H indices for the 26 geomagnetic storm (GS) events. Blue stars indicate geomagnetic storms of observed moderate strength, yellow stars storms of at least intense strength. *Credit: Weiler et al., 2026*

Findings

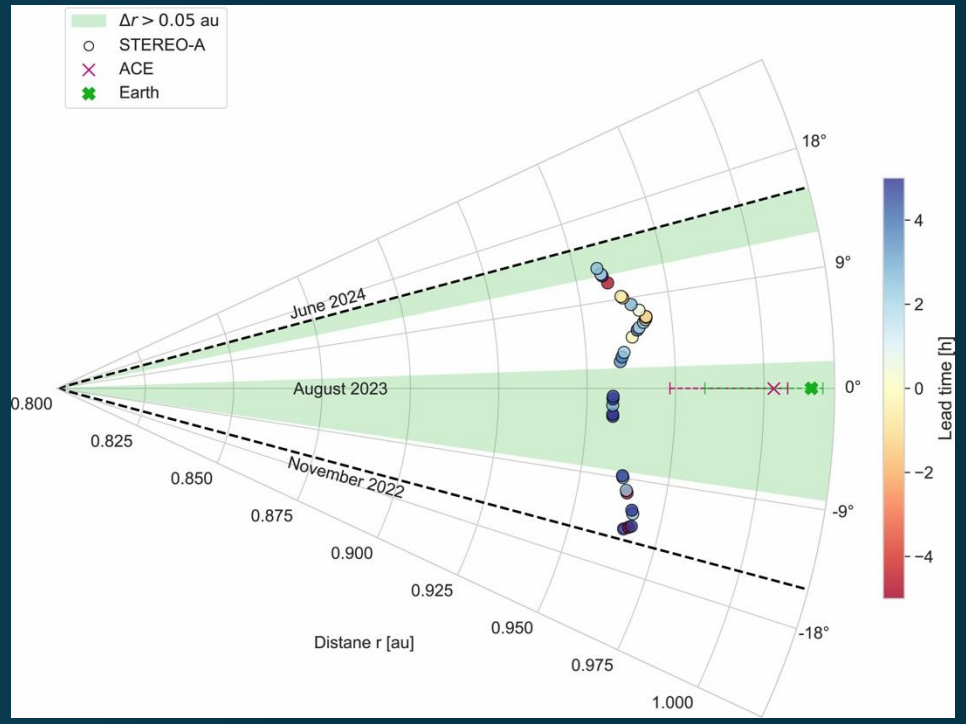
- Solar wind measurements sunward of L1 can provide accurate space weather forecasts if the spacecraft is close to Sun-Earth line (<10° separation).
- The lead time shows a clear dependence on the east vs. west location of STEREO-A with respect to the Sun-Earth line which may indicate CME deformation or deflection due to the Parker spiral.



Above: Overview of hits, misses, and false alarms when using STEREO-A data (top) vs. L1 data (bottom) to model the geomagnetic SYM-H index for the 47 storms.
Credits: Weiler et al., 2026

Impacts

- Solar wind measurements sunward of L1 are now proven to improve the lead time of space weather forecasting and to result in only a small decrease in the accuracy of predicted geomagnetic indices.
- Operational missions should be placed sunward of 0.95 au to ensure that there is a gain in lead time for measurements slightly off the Sun-Earth line.
- Operational missions should stay within ±10° from the Sun-Earth line to minimize false alarms and misses.
- This might be achieved with a constellation of spacecraft in distant retrograde orbits (DROs)
- Increased warning time for CME impacts would lead to more planning time and potential actionable mitigation strategies for effects to systems affected by space weather, including power, communications, and aviation.



Above: Visualization of the 32 CMEs observed by STEREO-A and L1 from Nov. 2022 to June 2024 color-coded with the gain/loss in lead time. The shaded green areas are regions where STEREO-A was > 0.05 au from Earth in heliocentric distance. *Credit: Weiler et al., 2026*

Additional Info

- Publication information

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  E. Weiler[1,2], E. E. Davies[1], C. Möstl[1], N. Lugaz[3], A. Veronig[2,4], R. L. Bailey[5], M. A. Reiss[6,7]

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  - Institutions: [1]Austrian Space Weather Office, [2]University of Graz, Austria, [3]University of New Hampshire, [4]Kanzelhöhe Observatory, [5]Conrad Observatory, Austria [6]NASA GSFC, [7]USRA
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