STEREO Science Highlight

Global insight into a complex-structured heliosphere based on the local multi-point analysis

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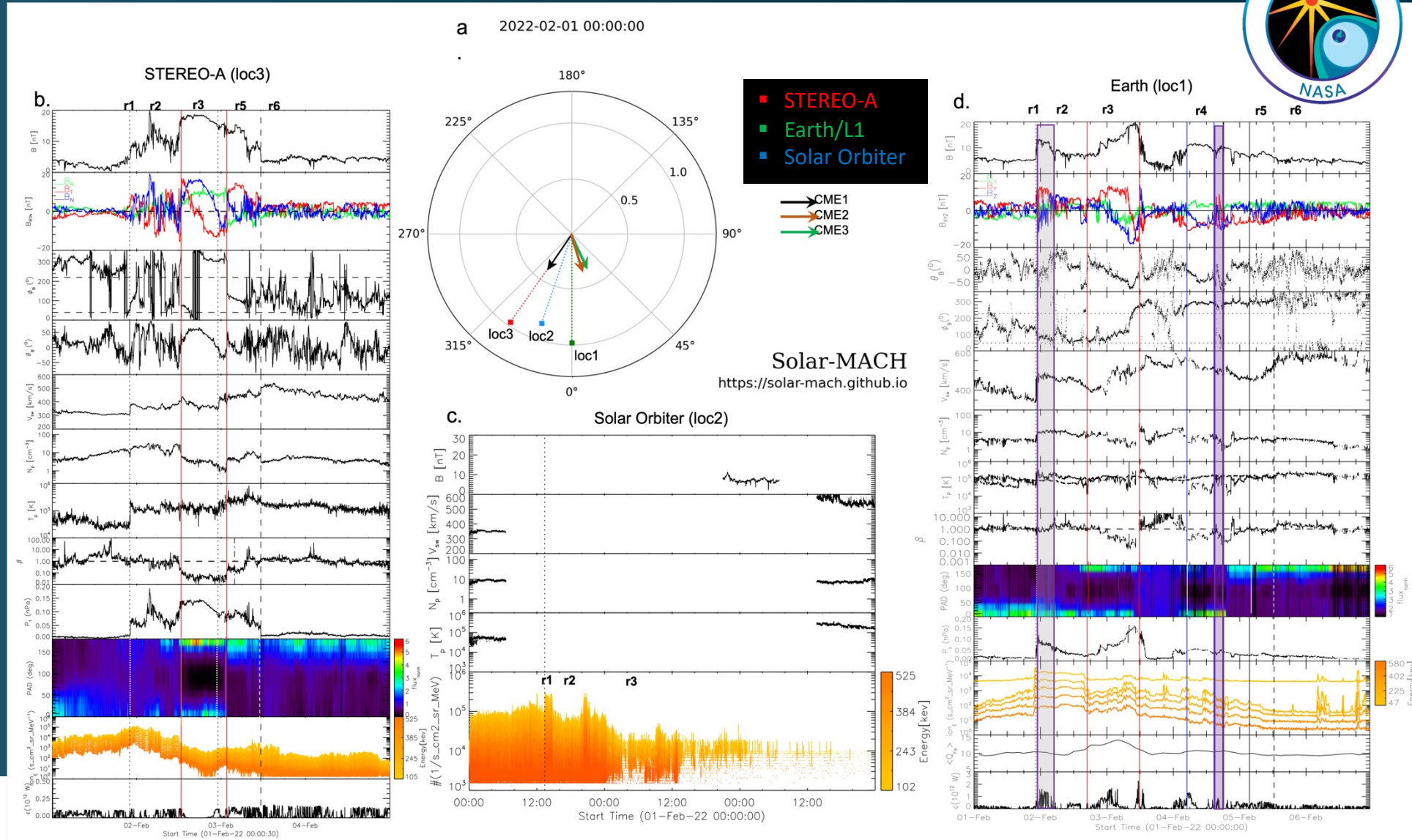
Background

- Objective: To better understand how the complex global structure of the heliosphere effects geomagnetic storms.
- Background: The heliosphere is shaped by different large-scale and small-scale structures originating from the Sun, including Coronal Mass Ejections (CMEs) and streams of solar wind plasma moving at different speeds. These structures may interact, creating complexity and resulting in significant space weather disturbances, which, in turn, can cause disruptions to human technology.
- Goal: To obtain a comprehensive understanding of the complex global heliosphere during the events studied in early February 2022, including the shapes, origins, and interactions of the various structures involved so that we could understand the space weather impacts of the events, which influenced the loss of Space-X Starlink satellites.
- *This was not possible with a single viewpoint – a multi-point analysis was needed.*

Analysis

- A complexly structured heliosphere was analyzed in-situ using multiple probes e.g., STEREO-A (loc3), Solar Orbiter (loc2) and Wind & ACE (loc1), and remotely by STEREO-A and SDO (loc 1)
- Heliospheric disturbances caused G1-class storms at the Earth and influenced the loss of 38 Starlink satellites.
- There were multiple structures: CMEs and their resulting sub-structures (magnetic flux rope (FR) shock, sheath), a high-speed stream (HSS), and stream interaction region (SIR).

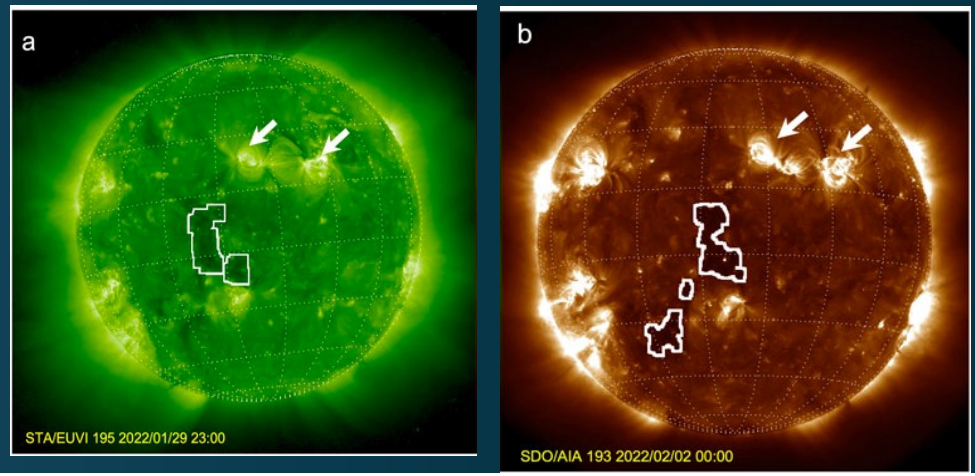


r1: Shock
r2: Sheath
r3: CME1 FR
r4: CME2+CME3 FR
r5: SIR
r6: HSS

In situ observations of the complex structured heliosphere (regions between r1-r6) by multiple probes (b, c, d) and the location of the probes during the observations (a). (Pal et al. 2023)

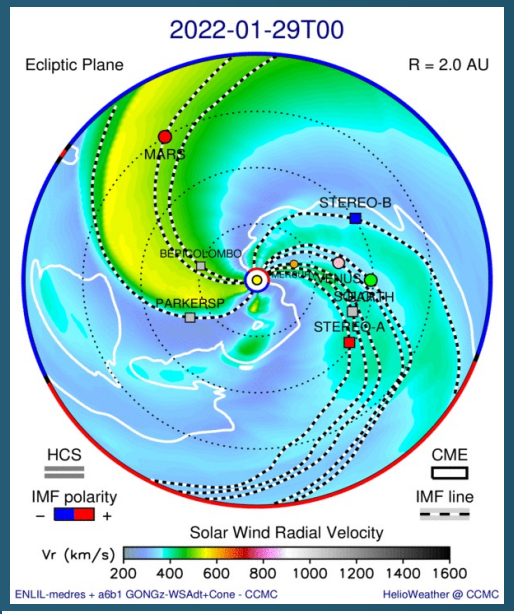
Analysis and Findings

- Applying forward modeling (Thernisien et al. 2006) and harmonic mean (Lugaz et al. 2009) techniques to the remote observations it is evident that there were three consecutive CMEs -- two of them merged (CME2+CME3) and the other (CME1) was significantly distorted by high-speed stream from a neighboring coronal hole.

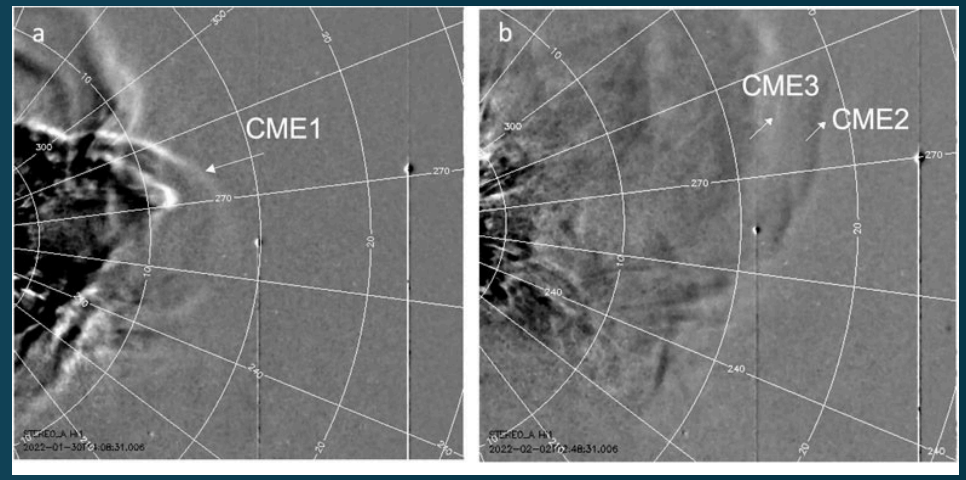


Extreme ultraviolet images from (a) STEREO-A/EUVI and (b) SDO/AIA showing coronal holes and active regions, the solar origins of heliospheric features (Pal et al. 2023)

- We ran a WSA-ENLIL+Cone model simulation (Arge & Pizzo 2000, Odstrčil et al. 1996, Zhao et al. 2002) available at NASA-CCMC to simulate the propagation of the complex structured heliosphere (shown left)



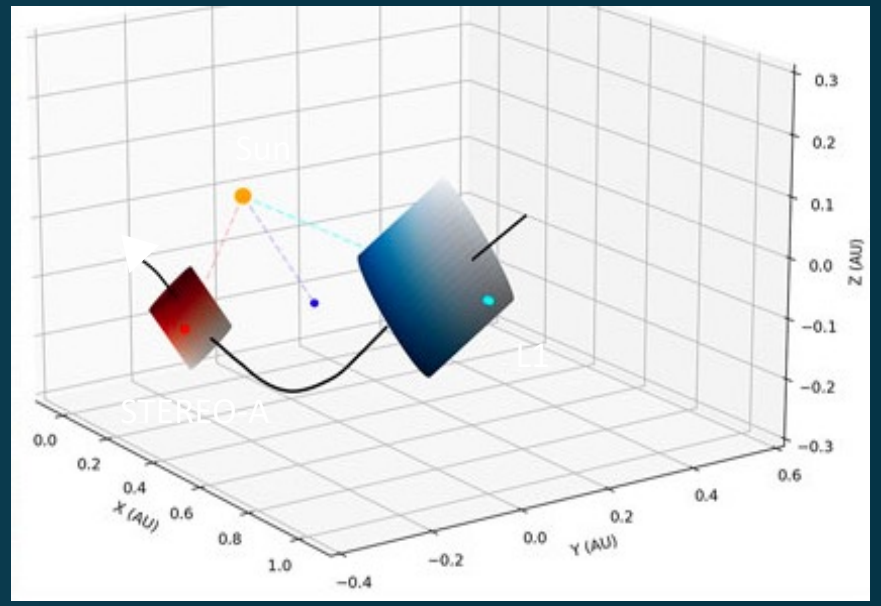
WSA-ENLIL Simulation of the structured heliosphere. Credit: CCMC & Pal et al. 2023



STEREO-A heliospheric images that made it possible to analyze the merging process of the CMEs (Pal et al. 2023)

Impacts

- This work demonstrates that evolution and interaction of solar events can regulate their space weather impact - the merged CMEs followed by the high-speed stream influenced CME1's local structure and amplified its geo-effectiveness.
- Multipoint analysis can allow us to obtain global insight into heliospheric structure including interacting geo-effective solar events.
- This work helps us understand the space weather influencing the loss of multiple Starlink satellites launched by Space-X in early February 2022.



Above: CME1's distorted global structure obtained using multipoint analysis. (Pal et al. 2023)

References

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Publication Information

"Global insight into a complex-structured heliosphere based on the local multi-point analysis"

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