Solar activity and geospace environment previous to the Tenerife blackout

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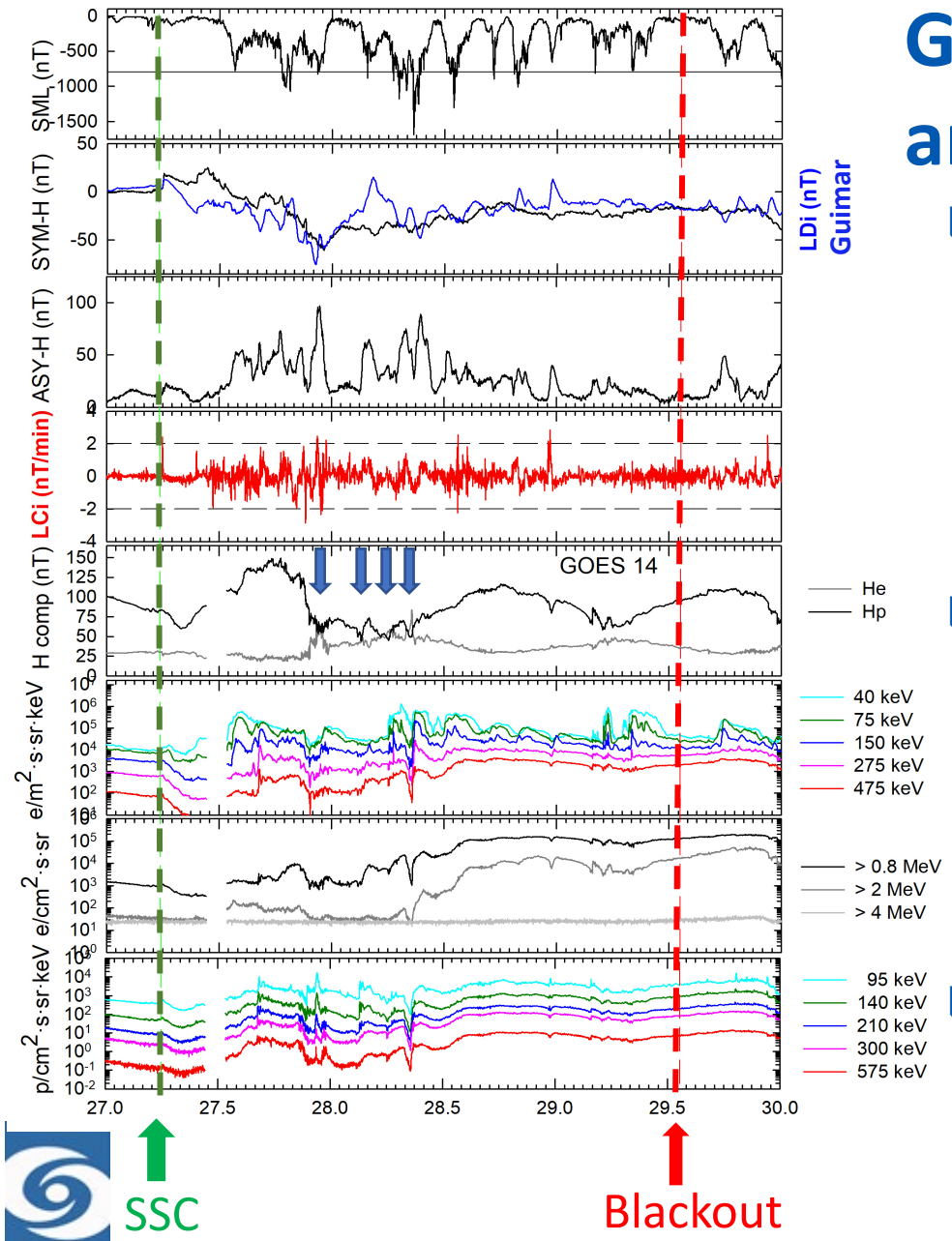
The 29th of September 2019 the Canary Island of Tenerife was hit by a major blackout. Not too high but continuous long duration local geomagnetic activity was recorded before the time of the blackout. GOES data show enhanced and injected particle fluxes indicating that the magnetosphere was disturbed by substorm activity. Interplanetary data evidence that this activity was triggered by a fast stream from a coronal hole. Nevertheless, solar wind measurements do not fit with typical ones during this type of streams. The combined analysis of coronagraph and AIA images reveals an ejection which was the clue to understand the interplanetary measurements and the hazardous Space Weather environment.

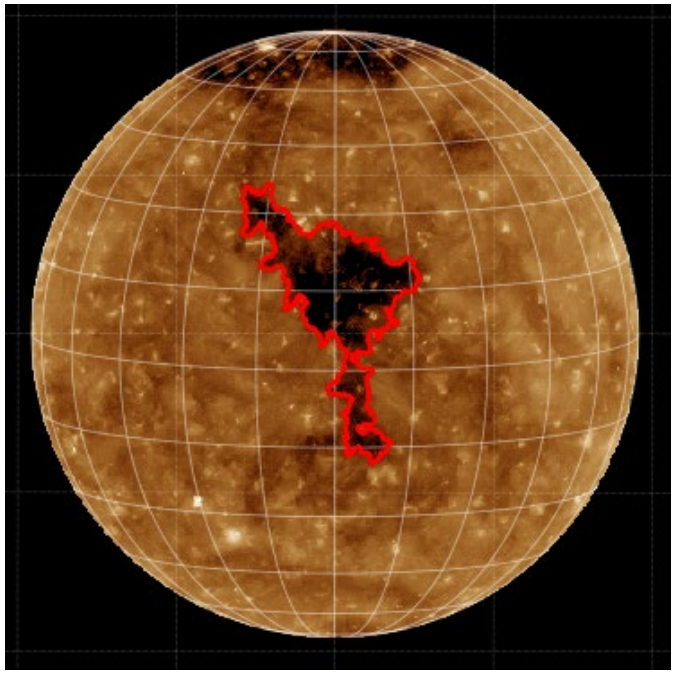
Geospace environmental conditions (ground and magnetosphere) close to the blackout



- On 27 September 2019 the storm sudden commencement (SSC) at 06 UT marks the beginning of a moderate geomagnetic storm (peak value -70 nT) according to the global SYM-H index, but intense and continuous auroral activity was recorded by the SML index up to 30 September. The local indices computed from Güimar-Tenerife geomagnetic data (LDi and LCi) better reflect that activity as larger magnetic disturbance fluctuations (and larger change rates) throughout the period
- Several dipolarizations in the magnetosphere were observed (blue arrows) at the geostationary orbit as seen by GOES satellites, with the corresponding particle injections from the magnetotail plasma sheet (both electrons and protons of low- and high- energy) widely spread in longitude. At those times Güimar was right located on nightside magnetosphere, especially exposed to the effect of enhanced particle flows
- The index LCi, which is related to GICs [*Cid et al., 2019*], shows moderate intensity but continuous and fluctuating disturbances for more than two previous days of the major blackout in Canary Island of Tenerife on 29 September at 12:11 UT

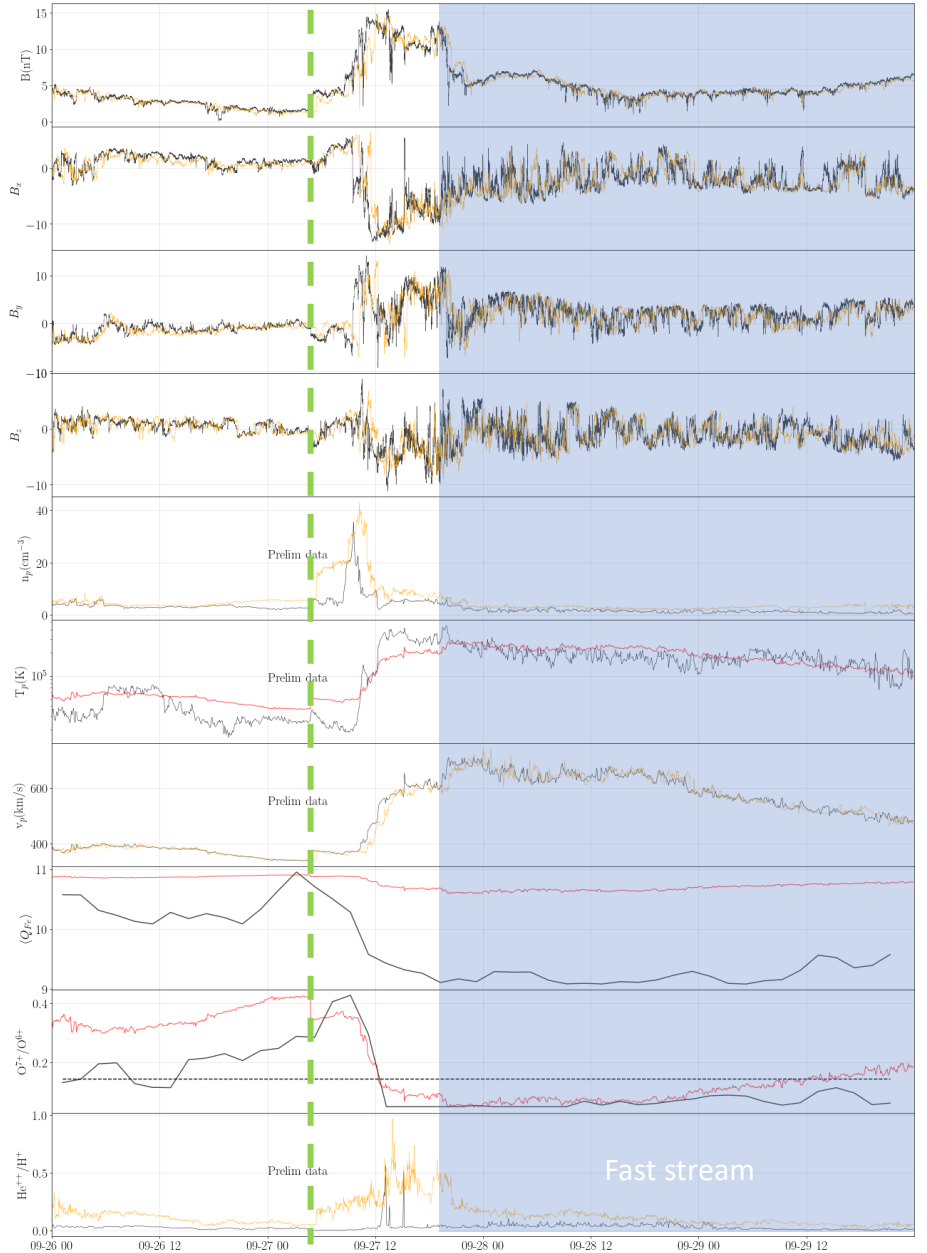
The triggers of the storm

- The main trigger of the storm is the interaction region between the fast wind from a coronal hole and the (quiet) slow wind ahead
- A huge coronal hole close to the solar equator appears in AIA/SDO 193 nm at the right position for the fast stream reaching the Earth on Sep 27 about 12 UT



A huge solar coronal hole close to the solar equator is present in the AIA/SDO Fe XII image

- An interplanetary shock can be noticed in ACE and WIND data on Sep 27 at 5:35 UT. The density enhancement is larger than usual in interaction regions
- When checking solar wind composition some signatures of the presence of the counterpart of a CME appear: enhancement of He^{++}/H^{+}, O^{7+}/O^{6+} and $<Q_{Fe}>$

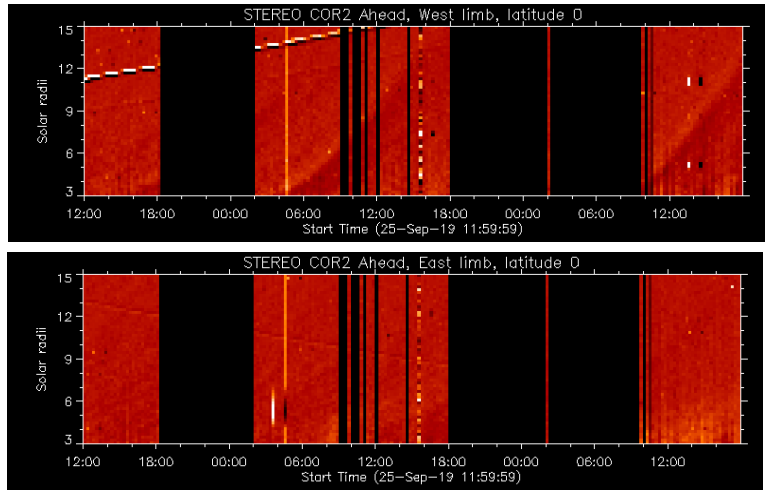


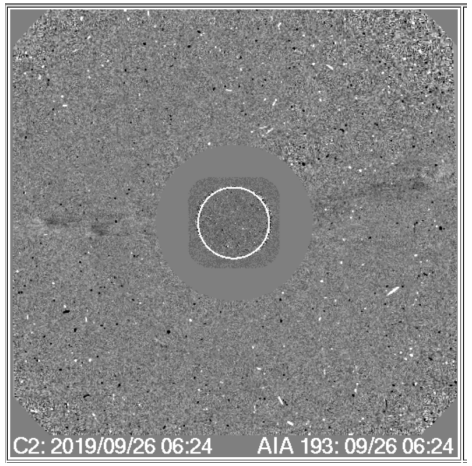
Solar wind data from ACE (black) and WIND (orange) spacecrafts. Note that some data from ACE are preliminary. Theoretical expectations for some parameters appear in red

IP Shock

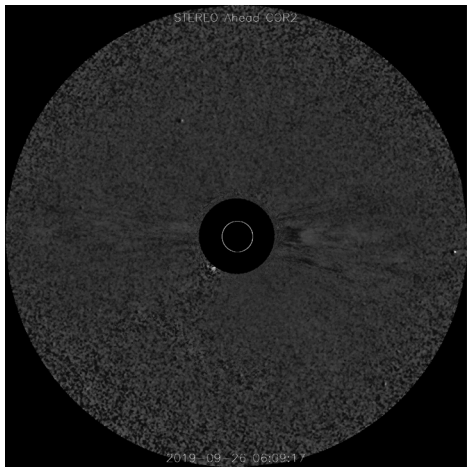
Looking for any solar ejection

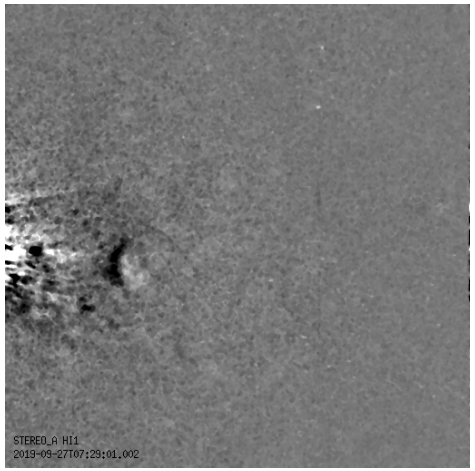
A slow CME (≈200 km/s) first appears on Sep 26 at 05:24 UT in COR2/STEREO A FOV, but only on the Earth-oriented West limb. It is a poor event and missed by automatic systems



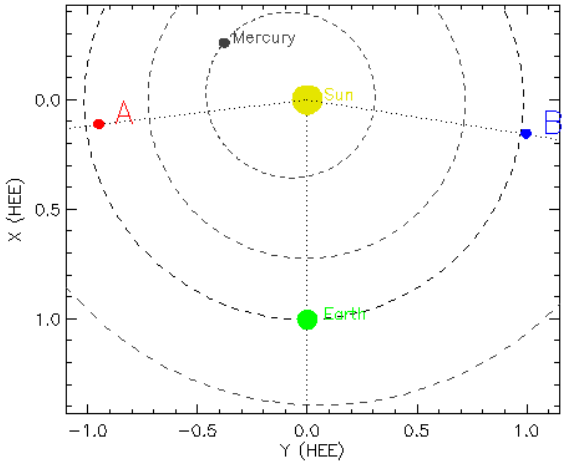


At 05:24 UT on Sep 26 a CME with a speed of 280 km/s first appears in the field of view of C2/LASCO SOHO. It shows brightness in West and East limbs and is also a poor event missed by automatic systems



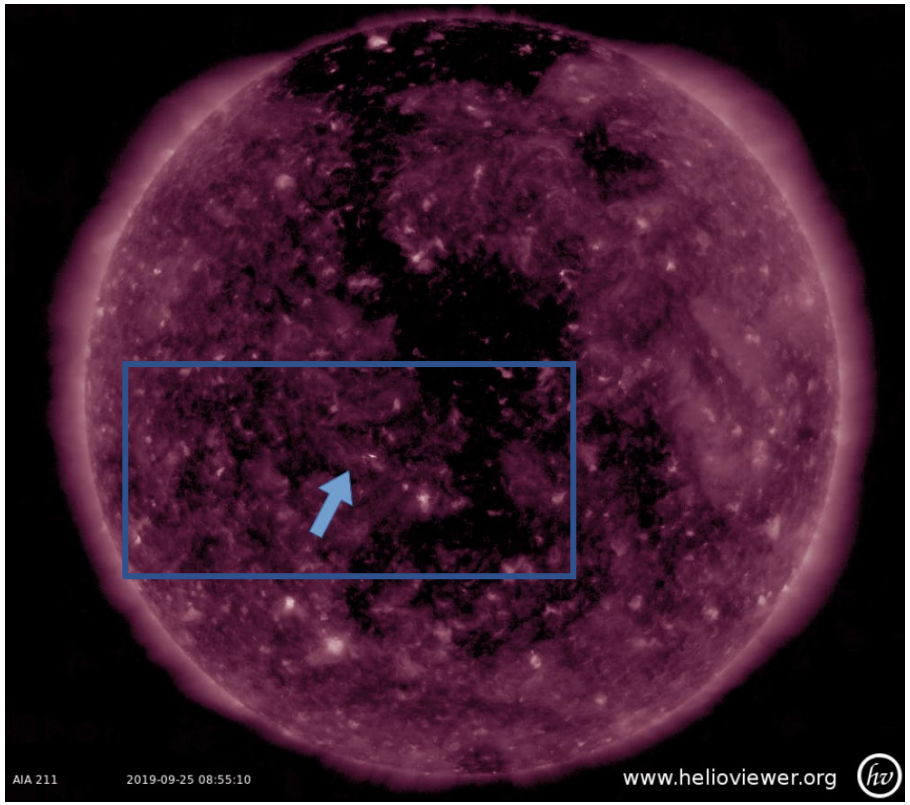


The CME makes its first appearance at HI1/STEREO FOV on Sep 26 at 16:49 UT. Nothing appears in HI2/STEREO



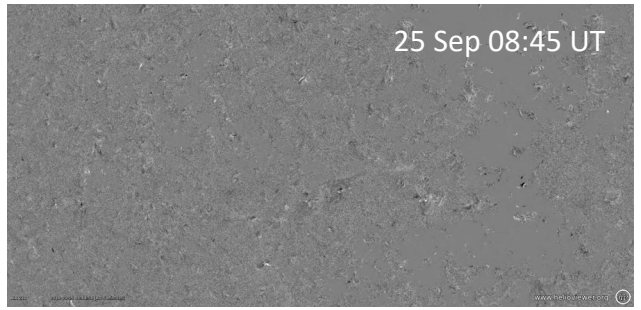
The relative position of the Sun, the Earth, Stereo A and B and SOHO on Sep 26 indicated that the CME on Sep 26 at 05:24 UT seen by both spacecraft was Earth directed

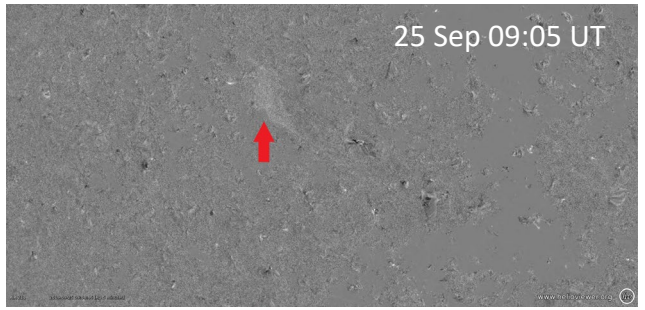
What about the solar disk?

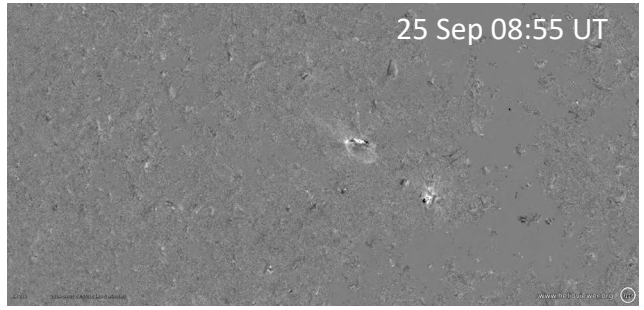


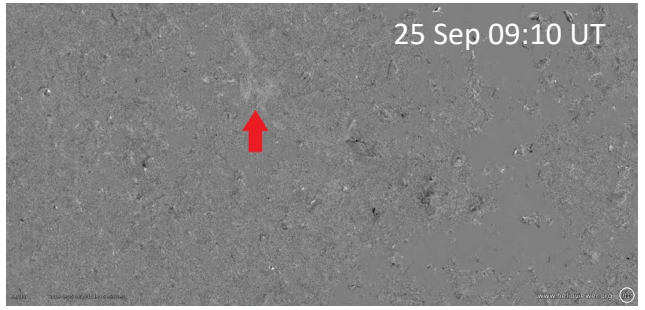
The arrow indicates the region where the filament erupts. It is close enough to the coronal hole to allow interaction between the two flows

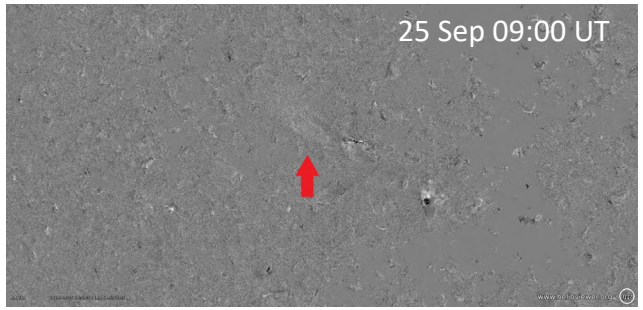
5-minute cadence AIA/SDO images at 211 nm reveal a filament slowing rising, which disappears on Sep 25 at 09:15 UT

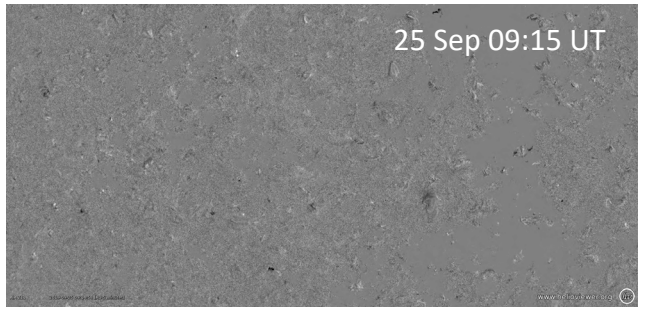












CONCLUSIONS

- The blackout in Tenerife took place when the Earth was hit by a moderate geomagnetic storm
- Not too high but continuous long duration geomagnetic activity was recorded for two days before the time of the blackout as it appears in the inner magnetosphere and local indices obtained from ground-based magnetometer records
- Solar wind data show an interplanetary shock at the time of the first disturbance at GUI, followed by a fast stream from a coronal hole. The large value of proton density, joint to the spikes in alpha-to-proton ratio and other compositional anomalies, suggest the possibility of a CME involved in the phenomenon
- Detailed analysis of solar images reveals an Earth directed CME most probably coming from a filament eruption without associated flaring activity. This CME was missed by all automatic methods
- Our results indicate that the storm was triggered by the interaction between the interplanetary counterpart of the CME and the fast stream from the solar coronal hole, which accelerated the CME at the interplanetary medium, leaving the geospace environment in a risky situation
- Even if we demonstrate that the terrestrial environment was hazardous during the Tenerife blackout, the influence of the storm in the blackout is out of the scope of this work

Acknowledgements. *This work is being supported by MINECO project AYA2016-80881-P (including AEI/FEDER funds, EU). We acknowledge the use of data products from AIA/SDO, LASCO/SOHO, COR2/STEREO, HI/STEREO, MAG/ACE, SWEPAM/ACE, SWICS/ACE, GOES, and Kyoto WDC and Guimar-Tenerife magnetometer and also, Intermagnet and CDAWeb for providing the access to some of the dataset.*