
Space Weather Technical Forecast

Issued on Thursday, 22 June 2023 at 13:15 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales <https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales>

Space Weather Forecast Headline: R1/R2 Radio Blackouts Likely throughout. Slight Chance of Minor Geomagnetic Storm G1 to end this UTC working week.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Moderate in the last 24 hours, with GOES16 recording an impulsive M1.1 flare at 21/1244UTC from AR3341, the same region that produced an X1 flare on 20 June. This was followed by an M1.0 at 21/1538UTC, originating from newly-numbered AR3337 near the north central meridian. Near the period's end, a third M-class flare peaked at M1.1 at 22/1121UTC, also from AR3341.

There are now up to fifteen sunspot regions on the disc, although this number has been relatively volatile in recent days.

The recent activity in AR3341 is perhaps somewhat surprising given its outward appearance in HMIIF, and it only presents as a stable (i.e. little growth) Dso/Beta, although it is resident in a large plage area that may yet reveal further spots given a better viewing angle. Also of note is the fact that a filament lies in very close proximity to its immediate east - this is something to be monitored. This being said, it appears that the late period M-class flare from the northern portion of AR3341 failed to dislodge this feature. AR3337 was numbered in the period and is currently a Dri/Beta-Gamma, having emerged from plage in the past 30 hours. This was not only responsible for the aforementioned M-class flare, but went on to produce occasional C-class activity for the remainder of the period.

The main trends in the remaining cohort of sunspots were: growth in the trailers of AR3340, a Csi/Beta in the northeast; also AR3339, a Dsi/Beta-Gamma in the southeast; with similar fading in the trailers of AR3335, a Cho/Beta in the southwest; also AR3333 a Cro/Beta in the southwest. Many of the remainder of spots were bipolar, but showed more stable tendencies.

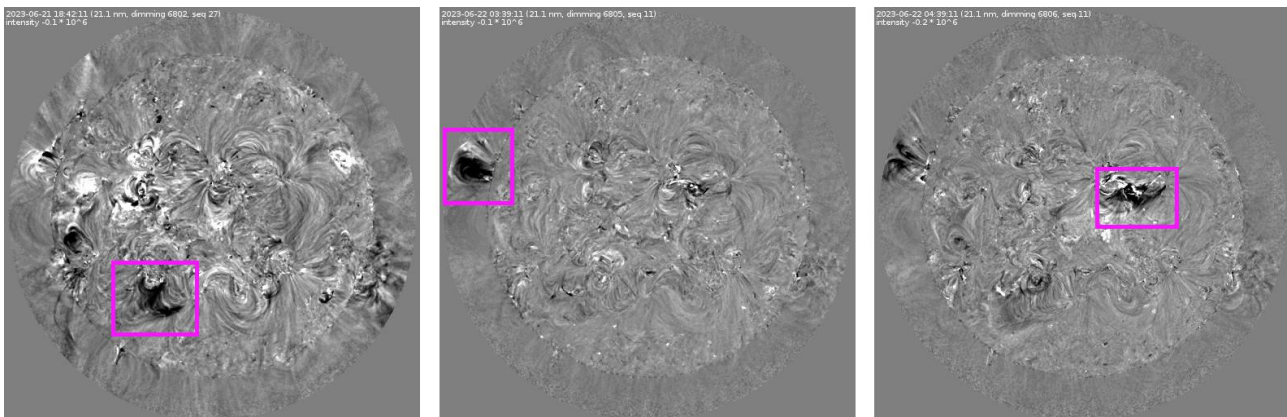


Figure 0: Rogue's gallery of three of the many candidates for CME-generating events of the period. These will be analysed very shortly for any Earth-bound components. Time-intergrated AIA211 dimming processing courtesy SIDC ROB.

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Regarding possible sources for Coronal Mass Ejection (CME) activity in the period, a possible arriving region in the northeast was responsible for a long-period C-class flare peaking around 22/0400UTC. This was tied to a CME seen heading east of the Sun-Earth line in subsequent coronagraph imagery. This has yet to be analysed. Also noted in the 24 hours was a disappearing filament in the southeast at both 22/1330UTC and again at 22/0500UTC, as well as a dimming around 21/1700UTC, all immediately east of AR3339. These will be analysed shortly. A northwestern solar quadrant filament became mobile from 22/0300UTC, appearing to migrate westward by 0500UTC, with some minor dimming visible on AIA211. Imagery is being monitored for any associated ejecta. Finally, a series of minor high latitude CMEs emanated from the northwest in the period. While these too have also yet to be analysed, there is no obvious front-sided source, and a far-sided solution seems more likely.

At present then, there are no new confirmed Earth-directed CMEs.

Solar Wind / Geomagnetic Activity: The solar wind, as measured by DSCOVR and ACE at L1, showed an ongoing weak connection to a negative polarity coronal hole high speed stream. The precise source is not certain, but is either the diffuse tail of CH15/-, or perhaps more likely the more pole-ward CH13/-. The phi angle was accordingly mainly negative (towards the Sun).

Solar wind speeds have been Slightly Elevated over the past 24 hours, generally residing within the mid-400s of km/s between 475 and 425, with an overall declining trend. The density was within single figures ppcc over the same interval on a level trend, as was the IMF, with a peak of 7nT and a north-south variation of +/-7nT. The Bz component was mainly co-aligned with Earth's until 1900 and after 0700UTC, else being more anti-aligned.

The net result of the above solar wind measures was for Quiet to Unsettled geomagnetic activity, with a provisional peak Kp of '3o' in the 21-24UTC interval.

Energetic Particles / Solar Radiation: High energy proton flux (greater than 10MeV), as observed by GOES16, was at Background levels.

High energy electron flux (greater than 2MeV), as observed by GOES16, remained at mainly Moderate levels, narrowly approaching the High level during the diurnal peak. The associated 24-hour fluence fell at first, but later recovered this lost ground. The observed fluence at 22/0001UTC was 3.58e7 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity is Likely to be Moderate, with isolated or occasional M-class flares and a Slight Chance of X-class flares.

Solar Wind / Geomagnetic Activity: The end of the current UTC week carries greater than average uncertainty. No definitively Earth-directed CMEs feature, and the magnitude of initial fast winds is expected to be modest. A gradual descent to Background speeds is expected into the UTC weekend.

There is a Slight Chance of a G1/Minor Storm interval on Days one and two (22 and 23 June), should any resurgent fast wind combine with a glance from a CME, however perhaps the more likely state of affairs is Unsettled geomagnetic activity transitioning to Quiet over the four days.

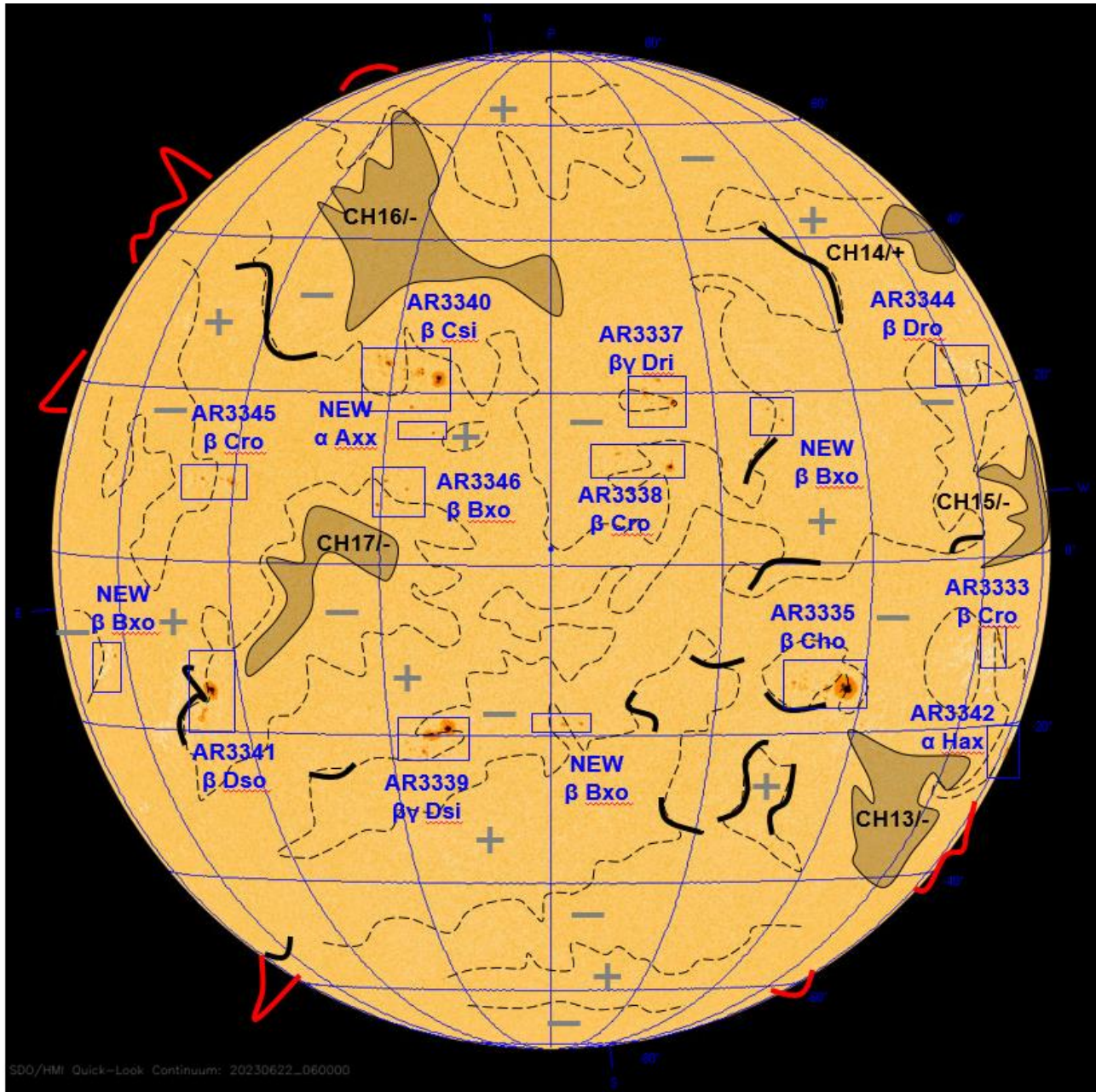
Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux is expected to remain at Background levels, with a slowly increasing daily Slight Chance of S1 or greater.

High energy electron flux (greater than 2MeV) is affected by the initial lack of certainty stemming

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from the geomagnetic forecast. This said, it is otherwise most likely to remain near current Moderate-peaking diurnal levels, and the 24-hour integrated fluence to most likely remain under the Active threshold.

Figure 1. Solar Analysis Valid 22/0600UTC.



Key: Filament ____, Prominence ____, Magnetic Field Line - - -, Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

Geomagnetic Storms:

No definitively Earth-directed CMEs feature in this forecast, however it remains the case that flanking incidence is possible from CMEs emitted east of the Sun-Earth line earlier this week - as shown by a minority of MOSWOC Enlil ensemble members. It remains true that this is not the favoured forecast, and the deterministic unperturbed run is preferred.

Earth is otherwise currently under the influence of a modest negative polarity fast wind. The source is either the diffuse tail of the western limb-located CH15/-, or else the lower-latitude CH13/-. The lack of certainty should only have minor impacts on the forecast - 'minor' due to being near the semi-annual minimum potency of coronal holes, and 'uncertain' in that any CIR leading CH13 may be yet to occur.

All considered, the geomagnetic forecast carries low confidence for the remainder of the UTC working week, rising for the weekend in the wake of any outstanding CMEs and with the uncertainty about any CIR between fast winds passed by this stage.

There is a vestigial Slight Chance of G1 should any CME glance combine with any CIR and initial stages of CH13, but this is both a low risk and should lessen with time, certainly by the UTC weekend.

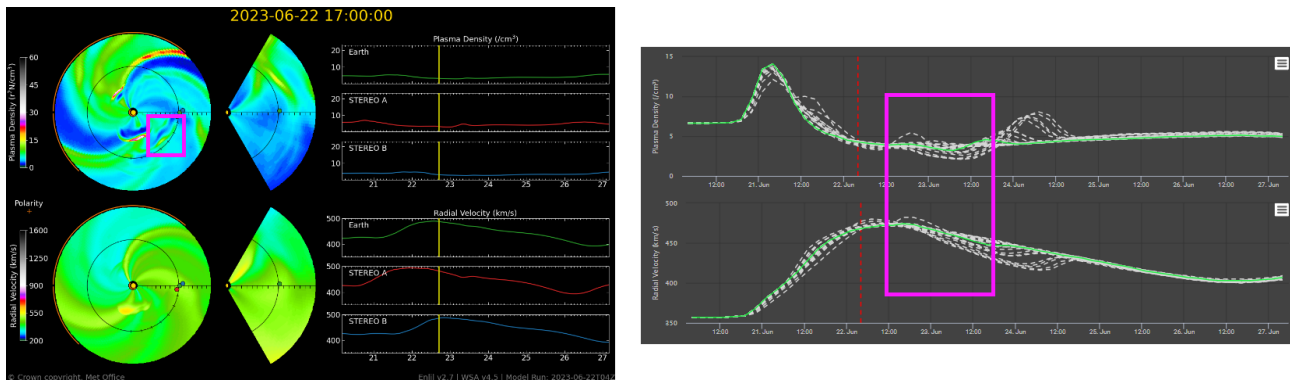
Solar winds are expected to be Slightly Elevated or perhaps briefly Elevated (500km/s) on Days one and two, followed by a gradual descent to Background speeds into the UTC weekend. There is a Slight Chance of a G1/Minor Storm interval on Days one and two (22 and 23 June), should any resurgent fast wind combine with a glance from a CME, however perhaps the more likely state of affairs is Unsettled geomagnetic activity transitioning to Quiet over the four days.

Geo-Magnetic Storm	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Minor or Moderate	G1 to G2	No	10	10	1	1
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Nil.

Figure 2: Latest MOSWOC Enlil and ensemble, showing continued slight perturbations possible early in the four days from passing eastern hemisphere CMEs – with one such feature highlighted in magenta. The risk of this occurring ought to have largely passed by the upcoming UTC weekend, whereupon a weak fast wind signature should already be fading, as shown.



Radio Blackouts - X-Ray Flares:

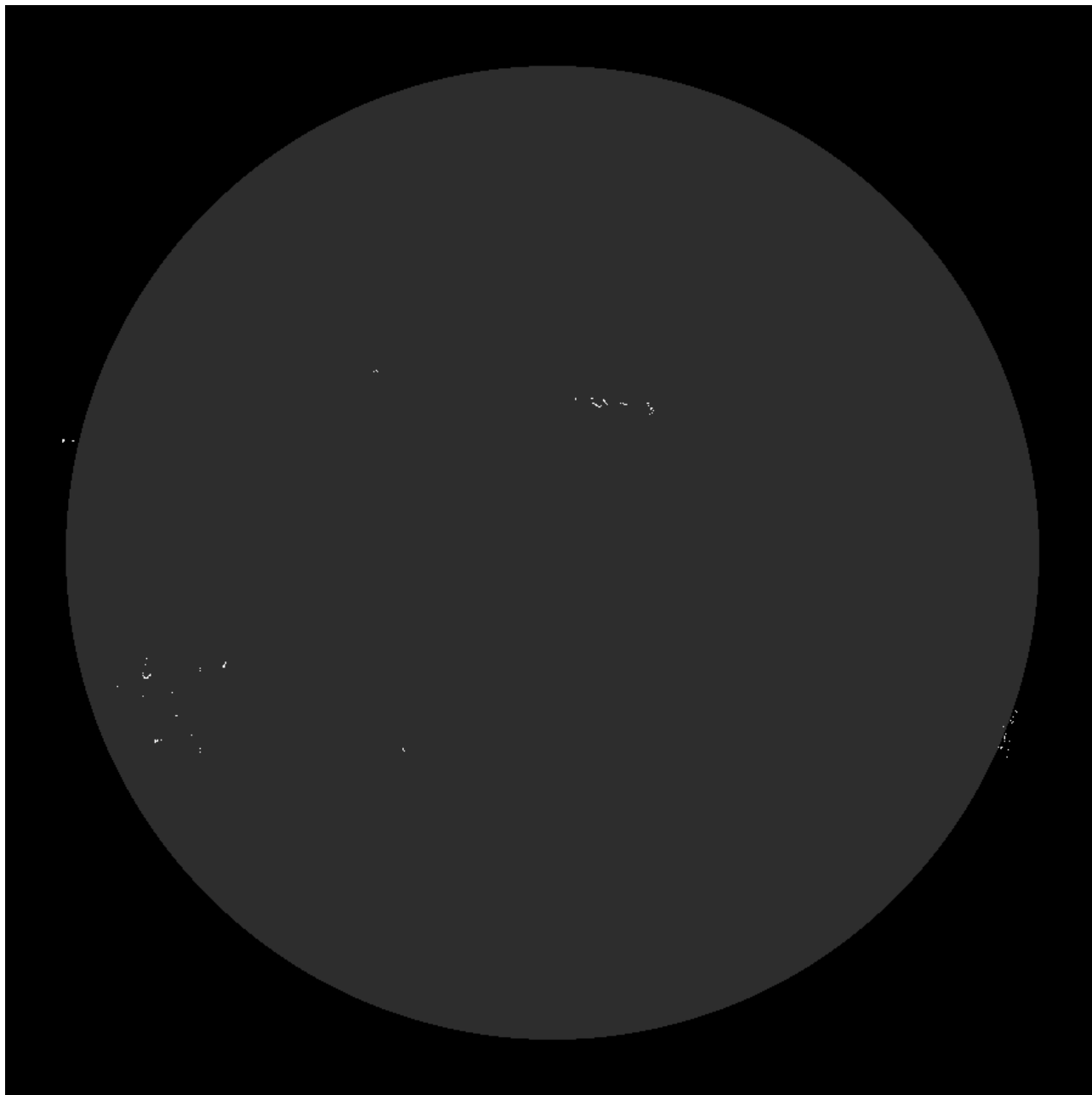
There are now up to fifteen sunspot regions on the disc. The Pentiction 10.7cm flux value has reduced slightly from its 180sfu peak on 20 June - the day of AR3241's X-class flare. The most recent observed value is 176 on 21 June, although this is still very near its 27-day peak (on 20 June).

The raw probability for significant flares now stands at 70% for M and 10% for X, with the sheer number of regions contributing meaning that individual departures over the western limb will have less impact than usual. Both of the recent most active groups (AR3337 and AR3341) are expected to remain on the Earth-facing disc throughout.

Regarding arrivals, the signal from far-side soundings is weakest for the immediate oncoming and off-going limb regions, however the limited extra view that STEREO A affords suggests that there is a potentially significant arriving region in the northeast, and there was a CME from this location through the early hours UTC of the current UTC day. It is accounting for this feature that the flare risk is raised slightly relative to recent guidance but then held at this higher level on all days.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	75	75	75	75
Very Active	R3 to R5 X Class	No	10	10	10	10

Figure 3: SIDC ROB-generated map of solar flare locations in excess of C-class activity, showing AR3337 (upper-centre); AR3341 (well-dispersed lower left); and AR3342 (lower right) as being the main sources of activity. The well-dispersed nature of the flare sources in AR3341 may go some way toward explaining its potency despite its visible appearance (i.e. there is some 'sub-surface' structure beyond the visible spots).



Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux, as observed by GOES16, is at Background levels and expected to remain so throughout the period.

There remains a daily Slight Chance of reaching the S1/Minor Storm threshold given the sheer number of (bipolar) regions and complexity of the current front-side. On balance the risk is also felt to rise slightly, as fewer large sunspots are moving away from the western limb (on the far side) than are moving towards it (on the front side), leading to a gradual increase in risk,

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although it remains the case that no recent even very modest proton-generating events have been observed (at GOES or on ACE EPAM LEMS).

Radiation Storms	Level ($\text{cm}^{-2} \text{sr}^{-1} \text{s}^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	$\geq \text{S1}$	No	10	10	15	15
Very Active	$\geq \text{S3}$ *	No	1	1	1	1
* S3 $\geq 10 \text{ MeV} \geq 1000 \text{ pfu}$ and / or $\geq 50 \text{ MeV} \geq 10 \text{ pfu}$. (pfu = $\text{cm}^{-2}\text{sr}^{-1}\text{s}^{-1}$)						

High Energy Electrons Event ($\geq 2\text{MeV}$):

High energy electrons appear to have reached a steady state through midweek, with diurnal peaks now confined to within Moderate flux. There is currently some uncertainty, discussed in the 'Geomagnetic Activity' section surrounding which coronal hole is responsible for the current fast wind, as well as a small risk of passing CMEs in the immediate term.

Even with these factored in, any near-term day-on-day increase in electron flux ought to be very modest, with CH13's expected magnitude being similar to current solar wind conditions (and this might be the feature responsible), which have thus far proved incapable of generating Active 24-hour fluence.

MOSWOC REFM is currently offering a forecast significantly below persistence levels, which is considered good guidance, although there is the caveat that any outstanding CMEs obviously do not feature, and the geometry of the disc is different to last pass. The current most likely forecast is that an initial Chance of Active fluence should lessen slightly with time.

GEO Electron Environment	Level ($\text{cm}^{-2} \text{sr}^{-1} \text{day}^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	$\geq 2 \text{ MeV}$ $\geq 1 \times 10^8$	No	30	20	20	20
Very Active	$\geq 2 \text{ MeV}$ $\geq 1 \times 10^9$	No	1	1	1	1

Figure 4: Last seven days in L1 solar wind speed (top), and resulting GOES16 high energy electrons (middle). The current diurnal oscillation within Moderate flux is now most likely to continue, with the MOSWOC REFM forecast considered reasonable guidance in tracking below persistence (below), even though this does not account for any peripheral CME activity.

