Comparative Observations of the 12 May 2021 Geomagnetic Event

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This report compares observations at three locations, two in Alaska and one in Scotland (table 1), of geomagnetic activity on 12 May 2021. One of the magnetometers in Alaska and the one in Scotland are SAM-III, whereas the other magnetometer in Alaska is a professional unit operated by University of Alaska Geophysical Institute {UAF-GI}. A solar flare on 9 May produced a coronal mass ejection (CME) that intercepted Earth on 12 May, producing interesting geomagnetic and radio phenomena. Our report focuses only on the geomagnetic observations and uses additional information from Space Weather Prediction Center (SWPC).

Table 1 ~ Magnetometer locations and types

Station	Geographic Coordinates	Geomagnetic Coordinates*	Type
Anchorage, Alaska USA	61.199° N; 149.957° W	61.72° N; 94.50° W	SAM-III fluxgate
Gakona, Alaska USA	62.407° N; 145.157° W	63.64° N; 90.73° W	Narod ring core fluxgate
Isle of Mull Scotland	56.380° N; 6.001° W	58.85° N; 80.86° E	SAM-III fluxgate

* Coordinate transformation for 2021 using IGRF {Kyoto}

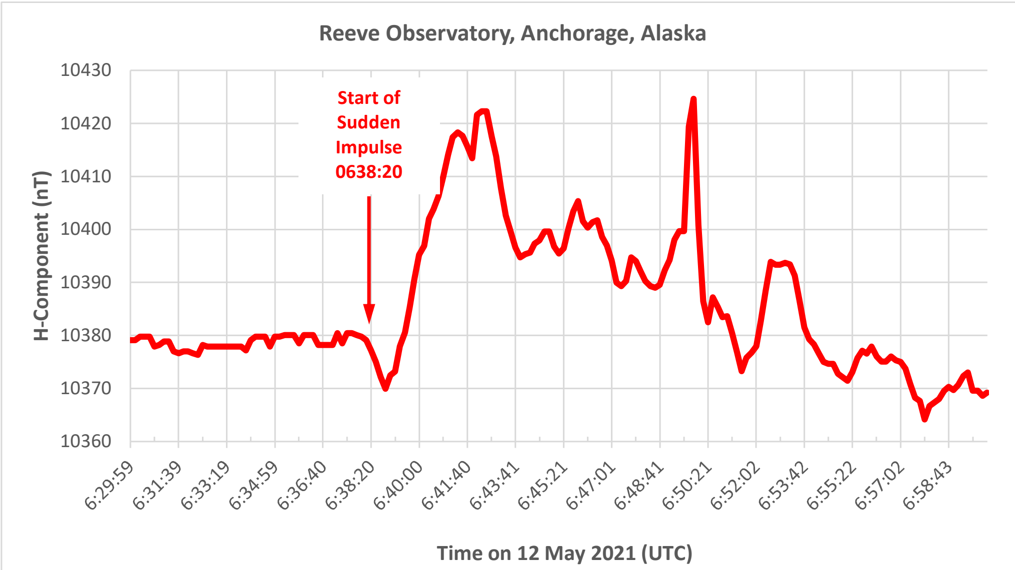
Event Description (based on SWPC *Forecast Discussions* {SWPC}): Solar active region 2822 produced a long duration C2/Sf flare at 1449 UTC on 9 May with an associated Type II radio sweep and a CME seen in STEREO A COR2 imagery beginning at 1538 UTC. An interplanetary (IP) shock was later observed at the DSCOVR spacecraft at 0547 UTC on 12 May. Solar wind speed at the spacecraft jumped from around 320 km s^{-1} to 450 km s^{-1} with similar jumps in density, temperature and magnetic field. The interplanetary magnetic field (IMF) associated with the CME showed only a short southward (negative) component immediately after shock arrival and was predominantly northward (positive) for the rest of the SWPC reporting period. Total IMF flux density reached 20 nT (the total magnetic flux density for background conditions is around 5 to 6 nT).

Ground magnetometers were quiet until the IP shock arrived at Earth's magnetosphere. SWPC reported the shock arrival as a sudden impulse (SI) at 0643 UTC with an amplitude of 51 nT based on data from the USGS Fredericksburg, Virginia USA magnetometer. SWPC also reported that by 0711 UTC on 12 May, geomagnetic field activity had risen to *active* levels (Kp-index = K4), reaching K7 by mid-day.

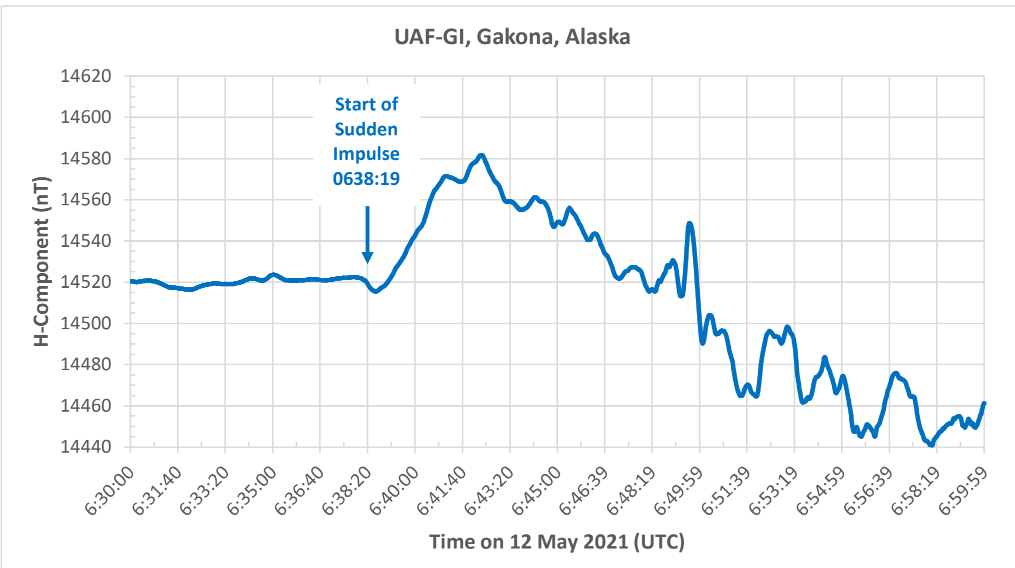
Observations: Slight differences in SI time and amplitude were recorded by the three magnetometer stations (table 2). The differences in time with respect to SWPC may be due to the way they interpret their data. They "look for 'a sudden perturbation, positive or negative, of several nT, in the H-component of the data' ... contained in an ASCII text list of the one-minute readings."[Reeve] The differences in amplitude are accounted for by the different locations of the magnetometer sensors and their sensitivities. The SAM-III magnetometer sensors are uncalibrated. Raw data produced by the three stations for the time period 0630 to 0700 UTC are plotted below.

Table 2 ~ Sudden impulse observations and magnetometer sample rates. Amplitudes are based on the H-component of the magnetic field (vector sum of local Bx and By measurements).

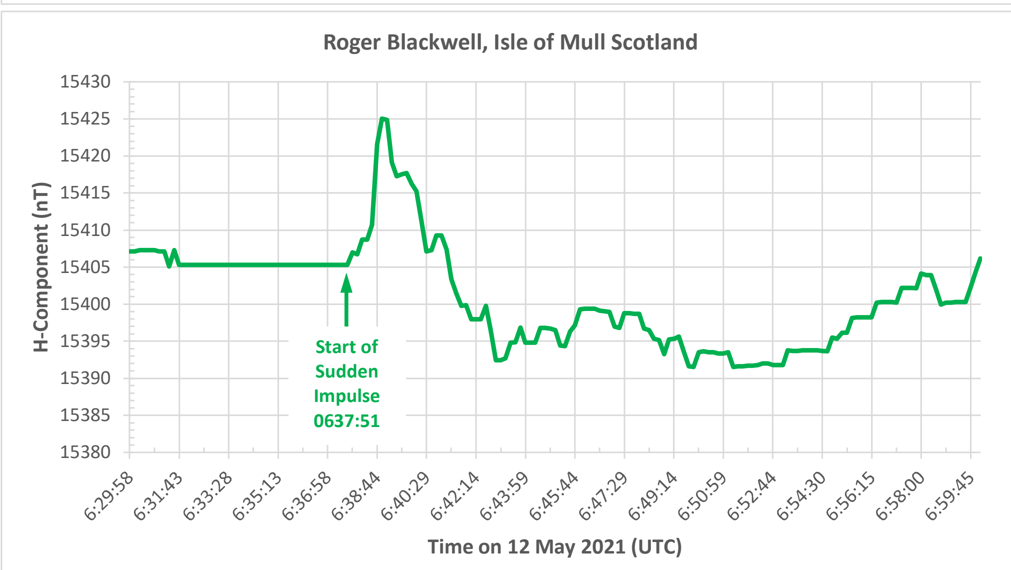
Station	SI time (UTC)	SI amplitude (nT)	Sample rate
Anchorage, Alaska USA	0638:20	52	0.1 Hz
Gakona, Alaska USA	0638:19	70	1.0 Hz
Isle of Mull Scotland	0637:51	20	0.1 Hz



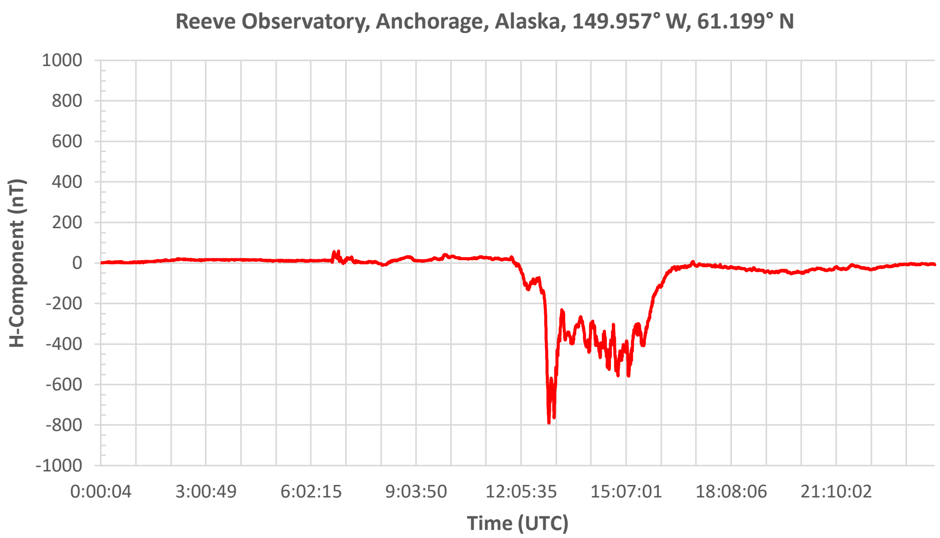
Reeve Observatory, Anchorage, Alaska
Start of Sudden Impulse 0638:20
H-Component (nT)
10430
10420
10410
10400
10390
10380
10370
10360
6:29:59
6:31:39
6:33:19
6:34:59
6:36:40
6:38:20
6:40:00
6:41:40
6:43:41
6:45:21
6:47:01
6:48:41
6:50:21
6:52:02
6:53:42
6:55:22
6:57:02
6:58:43
Time on 12 May 2021 (UTC)

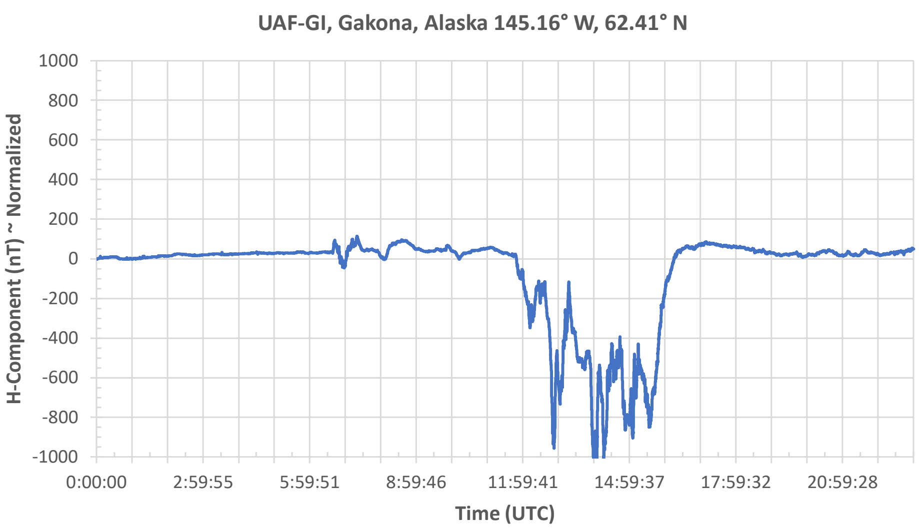


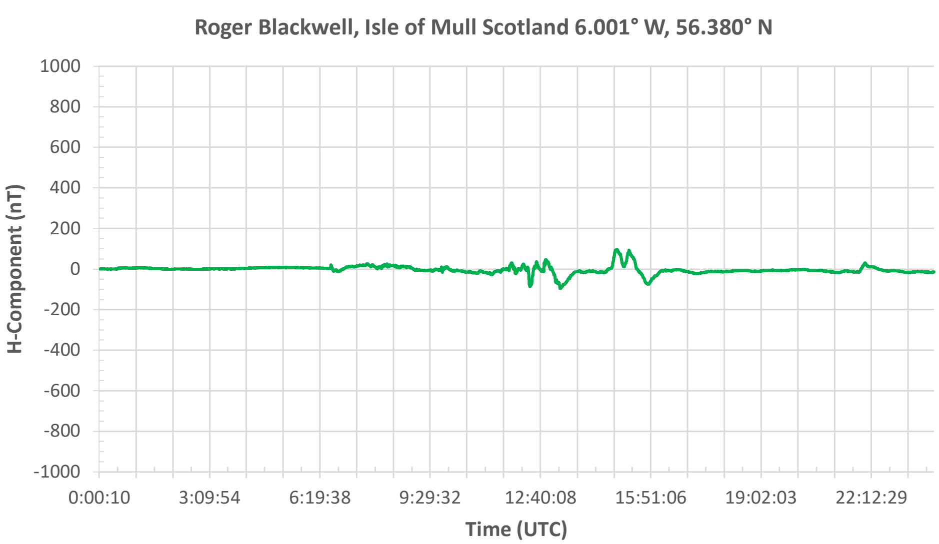
UAF-GI, Gakona, Alaska
Start of Sudden Impulse 0638:19
H-Component (nT)
14620
14600
14580
14560
14540
14520
14500
14480
14460
14440
6:30:00
6:31:40
6:33:20
6:35:00
6:36:40
6:38:20
6:40:00
6:41:40
6:43:20
6:45:00
6:46:39
6:48:19
6:49:59
6:51:39
6:53:19
6:54:59
6:56:39
6:58:19
6:59:59
Time on 12 May 2021 (UTC)



Roger Blackwell, Isle of Mull Scotland
Start of Sudden Impulse 0637:51
H-Component (nT)
15430
15425
15420
15415
15410
15405
15400
15395
15390
15385
15380
6:29:58
6:31:43
6:33:28
6:35:13
6:36:58
6:38:44
6:40:29
6:42:14
6:43:59
6:45:44
6:47:29
6:49:14
6:50:59
6:52:44
6:54:30
6:56:15
6:58:00
6:59:45
Time on 12 May 2021 (UTC)







24-h data: Plots of the data produced by the two SAM-III magnetometers and the UAF-GI Gakona magnetometer for 12 May are shown above. These plots show only the H-component of the magnetic field. The SAM-III magnetometers produce Bx-, By- and Bz-components (geographic coordinate system), so the H-component is derived by calculating the vector sum of Bx and By. The data posted by UAF-GI already includes the H-component {UAF-GI}. The H-component is then normalized to its value at the beginning of the UTC day. The vertical scales in the three plots are set to the same value of ±1000 nT. This setting compresses the Isle of Mull data so that many features seen in the Alaskan magnetograms are not obvious in the Isle of Mull magnetogram. The disturbance between 1200 and 1700 UTC measured at Isle of Mull had peak values of +98 and –95 nT, whereas the peak values for Anchorage were +59 and –789 nT and for Gakona were +114 and –1081 nT.

Discussion: The data produced by the two SAM-III magnetometers are time-stamped by the PCs that collect the data, and both PCs are synchronized by the Network Time Protocol (NTP) with GNSS-traceable time references. The Gakona magnetometer also uses a GNSS for time-stamping. Thus, it is believed that all data times are accurate to better than 20 ms. The slight differences in the times shown in the horizontal scale labels are due to missing data, but data timing errors are small compared to the overall time characteristics of the event.

There are two additional aspects of these observations that we mention. First, the 30-min plot for the sudden impulse from the relatively inexpensive SAM-III magnetometer in Anchorage compares very well to the far more expensive professional Narod magnetometer in Gakona. Many features in the 24-h data also are very similar. The stations are about 290 km apart and differ by 1° geographic latitude and 2° geomagnetic latitude. Some differences are expected simply because the magnetometers are in different magnetic environments but, in this case, they are relatively small.

Second, the data from Scotland shows similar feature timing aspects but much lower magnetic amplitudes, not only in the sudden impulse but also in the follow-on magnetically active conditions between 1200 and 1700. The time of the sudden impulse at 0638 corresponds to 10:38 pm local time at Anchorage (nightside) and 7:38 am at Isle of Mull (dayside). The great circle distance between the two stations is 6585 km and they differ by 5° in geographic latitude and 3° in geomagnetic latitude. Because of the different times, distance and geomagnetic latitude, it is expected that the current systems in the magnetosphere that produce varying magnetic fields on the ground, as well as the widely different ground magnetic environments, would lead to significantly different measurements. This appears to be the case with our observations. In particular, the Anchorage and Gakona stations are closer in latitude to the auroral electrojet than Isle of Mull and, thus, the former stations are more heavily influenced by geomagnetic variations produced by the electrojet current. Also, the shock occurred about 2.5 h after local sunrise at Isle of Mull, which explains why the shock was detected slightly earlier there than in Alaska.

Weblinks & References:

{Kyoto} http://wdc.kugi.kyoto-u.ac.jp/igrf/gggm/index.html

{SWPC} ftp://ftp.swpc.noaa.gov/pub/forecasts/discussion/

{UAF-GI} https://www.gi.alaska.edu/monitors/magnetometer : Magnetometer data, Geophysical Institute, UAF 2021. Retrieved from Research Computing Systems 12 May 2021.

[Reeve] Personal communications with Space Weather Prediction Center Product Subscription Service (PSS) Help, 3 June 2013