PERÚ | Ministerio del Ambiente | Instituto Geofísico del Perú

"Decenio de la Igualdad de oportunidades para mujeres y hombres "
"Año del Bicentenario, de la consolidación de nuestra Independencia, y de la conmemoración de las heroicas batallas de Junín y Ayacucho"

BULLETIN

IGP / **ROJ** / 2024-05

THE UPPER ATMOSPHERE OVER PERU

MAY 2024

IGP

During May 2024, we witnessed several geomagnetic storms. The most intense one (G5) occurred on May 10th and 11th, with a Dst's minimum of -412 nT. A storm of this magnitude had not happened in 20 years. The effects of the storm disturbed the ISR vertical drifts (Figure 1) with values that reach up to 100 m/s on May 10th(blue curve), while on May 11th (green curve) the measured drifts were negative after dawn.

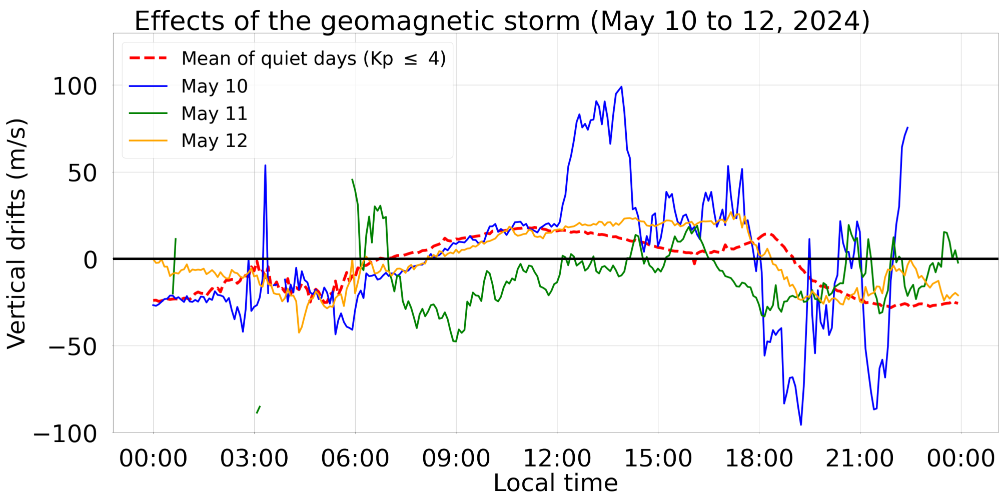

Figure 1. The effects of the geomagnetic storm that occurred between May 10th and 12th of 2024, above the average of the heights between 300 and 400 km of the ISR vertical drifts.

Table 1. Summary of monthly measurements on some ionospheric parameters and space weather predominant conditions. May 2024.

Average winds MLT at 90 km [m/s]		**Maximum diurnal variation of the horizontal component of the geomagnetic field (H) [nT]**		**Average vertical plasma drifts (300 km - 400 km [m/s]**	
Meridional	Zonal	LIM:138	AQP:74	Min.	Max.
Min: 67.5 S Max: 31.0 N	Min: 14.3 O Max: 23.9 E	HYO: 140	NZC: 84	-26	17
		PIU: 72			

GEOMAGNETIC ACTIVITY: **QUIET**	SOLAR ACTIVITY: **HIGH**

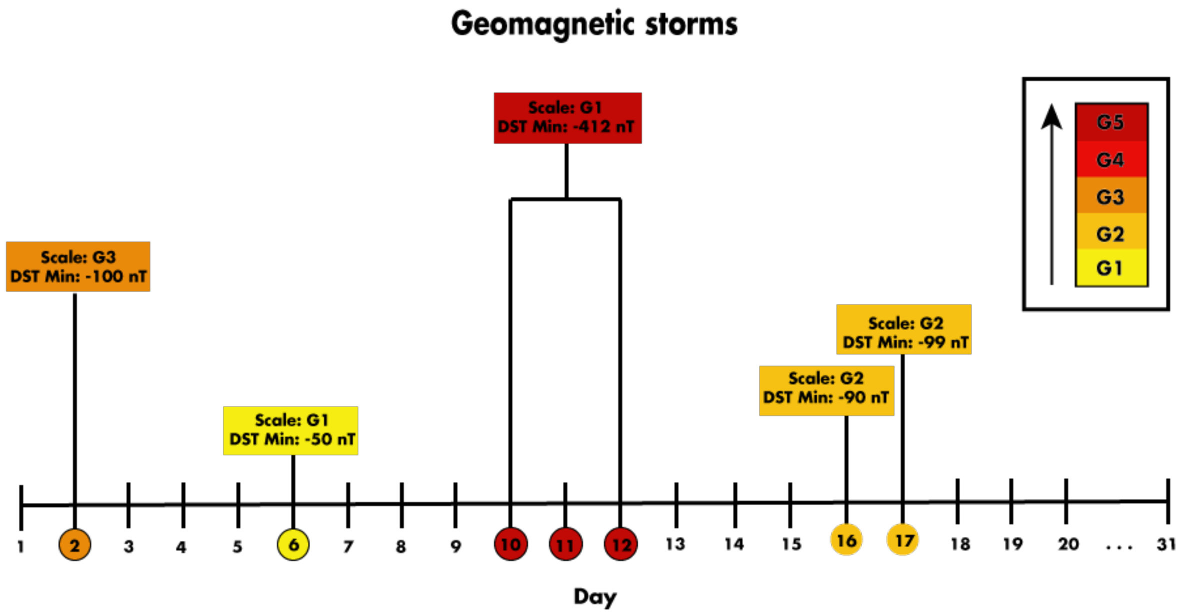

Figure 2. Geomagnetic storms intensity of May and their associated Dst index value.

DID YOU KNOW THAT?

Polar auroras are luminous phenomena usually observed around the geomagnetic poles. They occur when charged particles impact high atmosphere gasses and when solar winds (produced by intense solar storms) transport magnetic fields. The geomagnetic storm between the 10th and 12th of May 2024 (class G5) was the strongest of the last two decades. It produced one of the most intense auroras of the last 500 years, generating aurora borealis and australis that could even be observed in latitudes far from the poles, like in Spain or Mexico (northern hemisphere) or Uruguay, Argentina, and Chile (southern hemisphere). These events happened because of the considerable solar eruptions and coronal mass ejections (CME) that bombarded the Earth with clouds of charged particles and magnetic fields.

On the other hand, Earth's atmosphere is approximately composed of 78% nitrogen and 21% oxygen, among other gasses like carbon dioxide. The concentration of each element depends on the altitude. Thus, each region will have a color depending on the excited atom species and the received energy. In altitudes with low nitrogen concentrations (<100 km), auroras are blue or violet, and the molecular oxygen (100-300 km) produces green auroras. In higher altitudes the mix of components may produce pink or yellowish auroras. For altitudes beyond 300 km, the atomic oxygen produces red or pink auroras (see Figure 3). That is because as the atomic oxygen has less concentration, it needs to be excited by highly energetic particles that originate from very intense solar storms[1].

Figure 3. Boreal aurora observed in Madrid, Spain (40° North latitude), on May 10 of 2024[2]. The pink and red colors predominance indicate an intense magnetic storm that interacts with the oxygen atoms at altitudes beyond 300 km.

1. Climatology

Geomagnetic activity (Kp[3]index) was generally quiet 85% of the time, moderate 5%, and strong 10%; however, solar activity (F10.7[4]index) was high 94% of the time and moderate 6% of the time (refer to Figure 4 and Table 1). Previous studies have found a significant relationship between daily and seasonal variations in the horizontal component of the geomagnetic field (H)[5], which we replicated with our measurements.

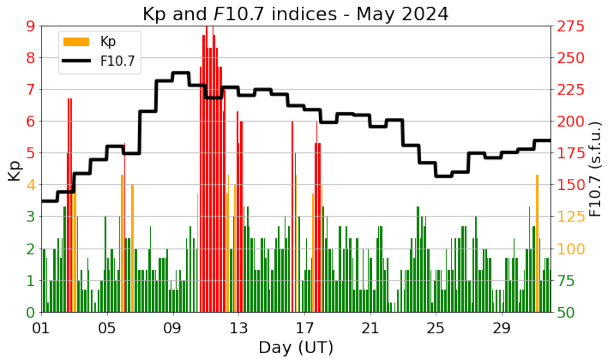

Figure 4. Kp and F10.7 cm (u.f.s. $= 10^{-22} W m^{-2} Hz^{-1}$) values for May, retrieved from OMNIWeb.

Spread-F occurrence is expected to be low in months close to the June solstice (May, June, and July), with high or moderate solar activity. The presence of bubbles might occur between 200 and 400 km. There is good agreement between observations and climatology[6].

Furthermore, the May climatology for high solar activity (given by the Scherliess-Fejer model) indicates that the height average (300-400 km) of vertical plasma drifts is approximately -24 m/s after midnight, increasing to 19 m/s at 11:00 LT. Following that, these values decrease up to 10 m/s at 15:00 LT, when they begin to increase due to the pre-reversal enhancement[7] phenomenon, up to 16 m/s at 18:00 LT, finally decreasing to -30 m/s before midnight. The values estimated by the climatology show moderate agreement with the measurements except for hours before dawn.

Climatological studies[8] point out that for months near the June solstice, the 150 km echoes appear around 09:00 LT, disappear after 15:30 LT, and are detected between 135 and 165 km. During this period, we found that the minimum altitude of appearance of these echoes was less than 5 km, and the maximum altitude agrees with the climatology. Moreover, the time of appearance of the irregularities agrees with the climatology, whereas the time of disappearance accounts for an hour less.

2. Geomagnetic storms

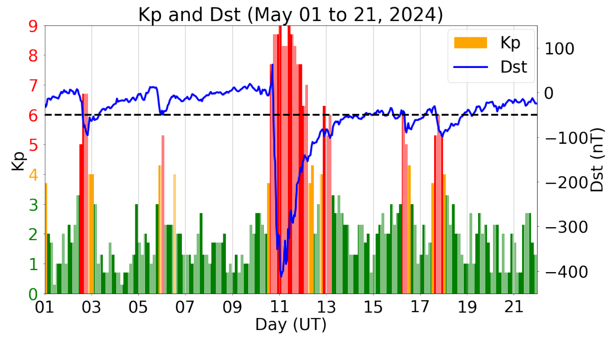

Figure 5. Kp and Dst indices from May 01-21, 2024. The horizontal black line represents the value of -50 nT. Values less or equal than this value are considered geomagnetic storms.

The increasing solar activity resulted in 5 geomagnetic storms (Figure 5). The first one with intensity G5 occurred on May 10th and 11th and lasted until the end of the 12th LT. The associated Dst value of the storm reached a minimum of -412 nT on the 11th. A storm of this magnitude had not happened in the last 20 years, when the 2003 Halloween storm yielded Dst values of -383 nT. Thus, the present year storm was even more intense[9].

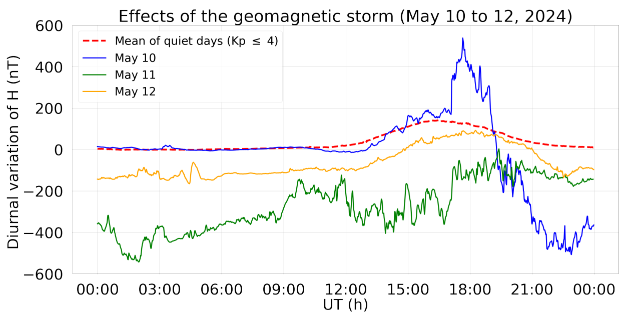

Figure 6. Effects of the geomagnetic storm occurred between May 10 and 12 of 2024 over the diurnal H variation of the geomagnetic Jicamarca station.

The G5 storm measurements showed a perturbation of the diurnal variation of the horizontal component of the magnetic Earth field (H) at the Jicamarca Station (see Figure 6). Moreover, the storm significantly impacted the ISR vertical drift measurements registered with the main radar of the Instituto Geofísico del Perú's Jicamarca Radio Observatory (IGP-JRO) (see Figure 1). On the 10th, the drifts reached values of 100 m/s, whereas on the 11th, the drifts were negative after sunrise and up to noon. On May 12th, after noon, the drift values increased up to the 17:00 LT in contrast to the drifts average values during the quiet geomagnetic days. On the other hand, the vertical drifts of the 150 km echoes were also affected (see Figure 7), keeping the same trend as the daytime ISR measurements.

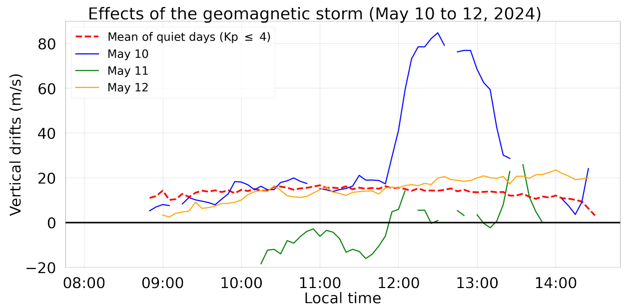

Figure 7. Effects of the geomagnetic storm occurred between May 10 and 12 of 2024 over the average of the vertical drifts of the 150 km echoes.

3. Radar observations on the upper atmosphere

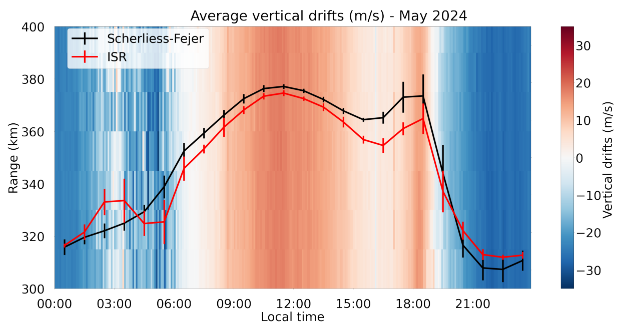

Figure 8. ISR monthly average vertical drifts for the May geomagnetic quiet days. The red curve represents the height average between 300 and 400 km and the black curve, the predicted values by the Scherliess-Fejer model.

The vertical plasma drift was monitored between 300 and 400 km using the IGP-JRO main radar with the JULIA-MP mode, as shown in Figure 8. During the monthly averaged quiet geomagnetic days, these measurements show that the height average vertical drift began around -24 m/s (downward) after midnight and gradually increased until it changed direction (upward) around 07:00 LT. It reached a velocity of 17 m/s at 11:00 LT. Following this, the vertical drift reduced until a sharp rise around 18:00 LT, known as pre-reversal enhancement[7], with values approaching 11 m/s. Our observed values exhibit moderate agreement with the Scherliess-Fejer model values, where the most notable difference was 9 m/s at 05:30 LT.

In contrast, 11 days of measurements were conducted for the 150 km echo drift to better examine the transition zone between the E and F layers. The echoes begin slightly before 09:00 LT, disappear at about 14:30 LT, and continue between 130 km and 165 km altitude as presented in Figure 9, which is moderately consistent with the climatology.

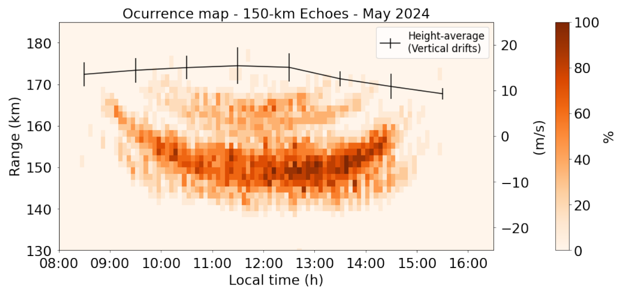

Figure 9. Vertical drifts average for the 150 km echoes during the geomagnetic quiet days.

Additionally, the radar system operated in JULIA-MP mode for 16 geomagnetic quiet nights. During that period, only three irregularities were detected in the 200–400 km range. The only observed morphology was the Bottom-Type (see Figure 10). These observations agree with the values expected from the climatology[10].

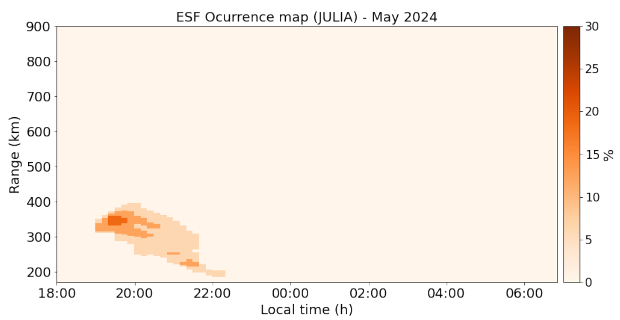

Figure 10. Map of occurrences of the Spread-F using the JULIA MP system for the geomagnetic quiet days of the month.

The time and height average of the zonal and meridional winds in the Mesosphere Lower Thermosphere (MLT) region for May 2024 (see Figure 11) exhibit predominant periods of 24 hours (diurnal solar tide). In the mesopause (~90 km), we observed that the maximum value of the average zonal wind was +23.9 m/s at 08:30 LT, and the minimum average value was -14.3 m/s at 23:30 LT. The maximum average of meridional wind was +31.0 m/s at 18:30 LT, and the minimum average was -67.5 m/s at 03:00 LT. The maximum zonal wind was +80.0 m/s at 00:15 hours on May 1st, and the maximum meridional wind was +105.7 m/s at 09:15 LT on May 4th, and the minimum -116.5 m/s at 03:15 LT on May 10th.

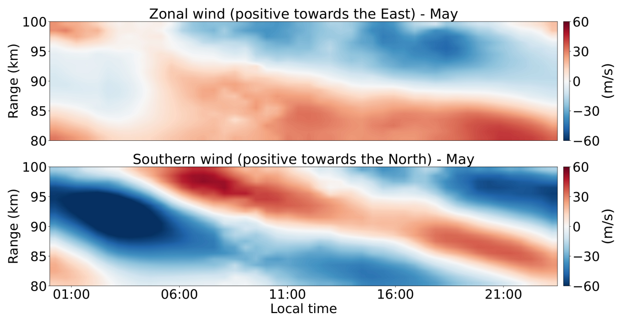

Figure 11. Monthly average zonal and meridional winds during May 2024.

4. LISN instruments observations

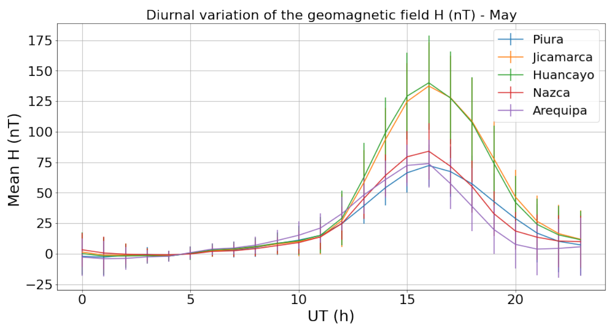

Figure 12. Monthly average values of the diurnal variation of H components for all the geomagnetic stations for the quiet days of May 2024.

Measurements of the horizontal component H of the geomagnetic field at the IGP-JRO magnetic stations are shown in Figure 12. The average values of the Jicamarca and Huancayo stations were higher than those of the other sites because they are located on the geomagnetic equator, and the Equatorial Electrojet (EEJ) adds to an increase in their values. Furthermore, there was significant daily variability, particularly around 11:00 LT (16:00 hours UTC). The maximum variations of the monthly average values for May were recorded for each station: Piura (72 nT), Huancayo (140 nT), Jicamarca (138 nT), Arequipa (74 nT), and Nazca (84 nT).

5. Conclusions

- The geomagnetic storm from the 10 to the 12 of May (class G5) reached a minimum Dst value of -412 nT. This event perturbed the diurnal variation of the horizontal component of the geomagnetic field H.

- The same storm, with the highest intensity over the last 20 years, perturbed the ISR and 150km Echoes vertical drifts, whose values reached 100 m/s and 85 m/s respectively.

6. References

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