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** / 2024-06

THE UPPER ATMOSPHERE OVER PERU

JUNE 2024

IGP

In June 2024, the occurrence of F region irregularities was minimal due to high solar activity and seasonal conditions. Out of 23 nights of measurements, ionospheric irregularities were observed on only one night, as shown in Figure 1. A G3-class geomagnetic storm occurred on 28 June 2024, causing disturbances in the horizontal component of the Earth's magnetic field (H) at the Jicamarca station (see Figure 5). The ISR observed vertical plasma drift and 150 km echoes also experienced modifications (see Figure 6).

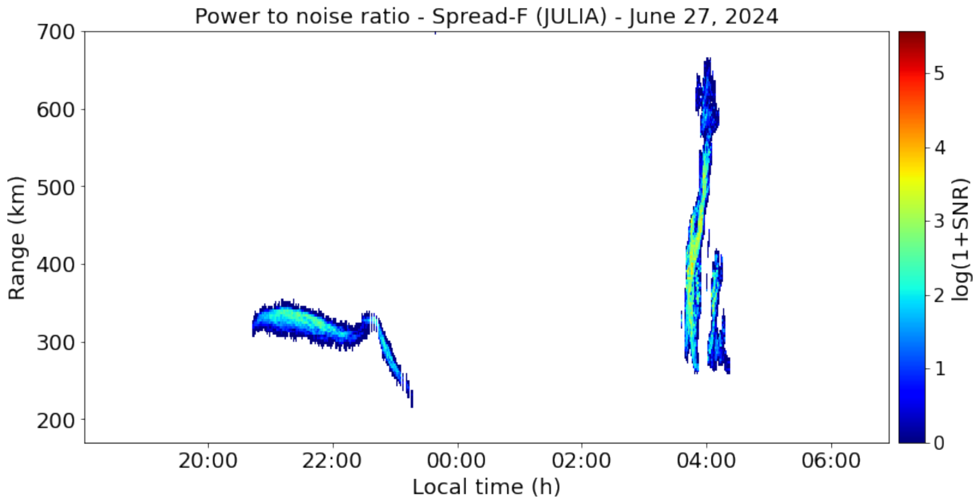

Figure 1. Signal-to-noise ratio of the Spread-F event on June 27th, 2024 as detected by the JULIA-MP mode.

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

Average winds MLT at 90 km [m/s]	
Meridional	Zonal
Min: 58.2 S Max: 24.9 N	Min: 8.3 O Max: 40.4 E

Maximum diurnal variation of the horizontal component of the geomagnetic field (H)[nT]	
LIM:120	AQP:64
HYO: 125	NZC: 69
PIU: 65	

Average vertical plasma drifts (300 km- 400 km) [m/s]	
Min.	Max.
-25	17

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

DID YOU KNOW THAT?

Effective solar radiation ionizes the Earth's upper atmosphere, leading to the formation of the ionosphere and associated irregularities. This ionization process creates plasma regions that can become unstable under certain conditions, resulting in phenomena such as scintillations and disruptions in radio wave propagation. Several factors influence ionospheric ionization, including local time, geographic location, seasons, and the solar zenith angle. Equatorial Spread F (ESF) refers to irregularities in the F region of the ionosphere that result in plasma density depletion. This phenomenon commonly occurs at nearly all longitudes during the equinox following sunset. However, the conditions leading to these irregularities are less favorable during the June solstice. The irregularities vary in size from tens to hundreds of kilometers in the magnetic zonal direction and are present at different latitudes and altitudes. They are thought to originate from the Generalized Rayleigh-Taylor Instability (GRTI), which involves the interaction of fluids with different densities. More recently, the "Electrostatic Shear Instability" (Kelvin-Helmholtz instability), which pertains to the interaction of various fluid layers moving at different speeds, has been proposed as a contributing factor to the origin and dynamics of ESF. One of the most important parameters for the linear growth of the GRTI is the vertical velocity of the equatorial plasma in the F region. This velocity increases due to the zonal electric field at the magnetic equator, which enhances the Pre-Reversal Enhancement (PRE) around sunset. This explains the high occurrence of the ESF after sunset and during the equinox months (see Figure 2). On the other hand, studies have shown that ESF events can occur during the June solstice, particularly under conditions of low solar flux. Gaining a better understanding of the processes that contribute to irregularities during the June solstice is an ongoing area of interest and research.

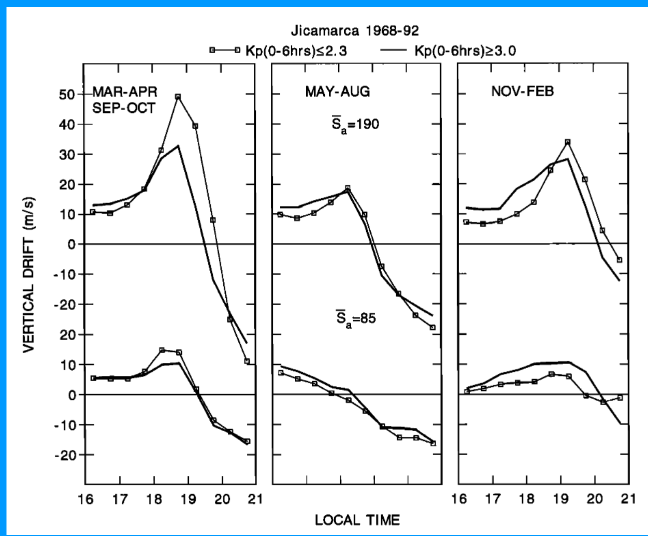

Figure 2. Variation of the vertical drift velocity for periods of low (bottom panels) and high solar flux (upper panels) in geomagnetic quiet (lines with squares) and perturbed conditions (continuous lines) for different seasons[[1]]. Note that for the June solstice (center panel), the vertical velocity does not reach values that could produce the ionosphere instability that causes the spread-F phenomenon. Figure adapted from[1].

1. Climatology

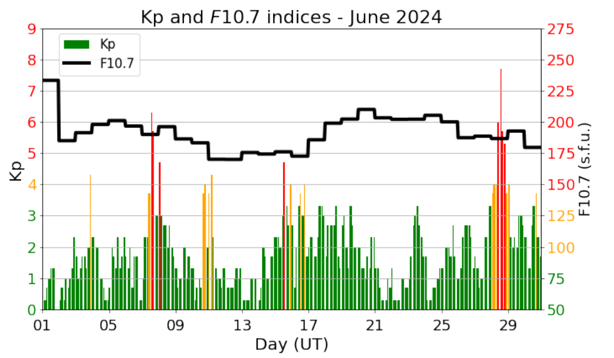

Figure 3. Kp and F10.7 cm (u.f.s. $= 10^{-22} W m^{-2} Hz^{-1}$) values for May, retrieved from OMNIWeb [2].

Geomagnetic activity, as indicated by the Kp[3] index, was generally quiet 90% of the time, moderate 6% of the time, and strong 4% of the time. In contrast, solar activity, represented by the F10.7[4] index, was consistently high throughout the period (see Figure 3 and Table 1). Previous studies have identified a significant relationship between daily and seasonal variations in the horizontal component of the geomagnetic field (H)[5], which we validated with our measurements.

Spread-F occurrences are expected to be the minimum in the months close to the June solstice (May, June, and July), with strong or moderate solar activity. The presence of plasma bubbles may appear between 200 and 400 km before midnight, and between 200 and 600 km after midnight. Previous observations and climatology showed good agreement[6]. In addition, the June climatology for high solar activity (provided by the Scherliess-Fejer model) shows that the height average (300-400 km) of vertical plasma drifts 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 start increasing due to the pre-reversal enhancement[7] phenomena, reaching 17 m/s at 17:00 LT before decreasing to -27 m/s before midnight. Except for the hours closest to the pre-reversal and after midnight, the values estimated by climatology and our measurements show moderate consistency.

Climatological studies[8] show that during the months near the June solstice, 150 km echoes appear around 09:00 LT, fade after 15:30 LT, and are detectable between 135 and 165 km. During this period, we observed that the minimum height of appearance aligns with expectations, and the maximum altitude is consistent with climatological data. Additionally, the time of appearance of the irregularities matches climatological expectations, but the time of disappearance occurs an hour earlier.

2. Geomagnetic storms

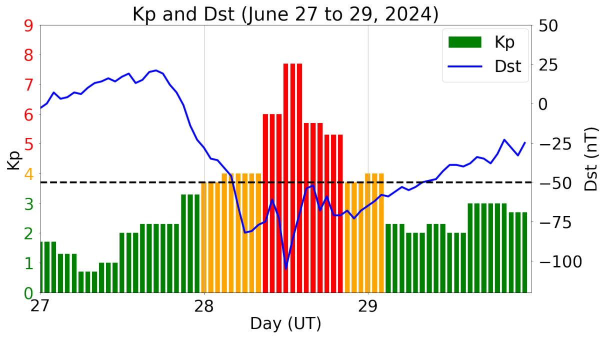

Figure 4. Kp and Dst indexes for June 27-29, 2024. The horizontal black line indicates a value of -50 nT. Values less than or equal to this threshold are termed geomagnetic storms.

Increasing solar activity led to a G3-class geomagnetic storm on June 28th, 2024 (Figure 4). The storm reached a minimum Dst value of -105 nT and was triggered by a Coronal Mass Ejection (CME) that occurred on June 25, 2024[9], following a solar filament eruption[10].

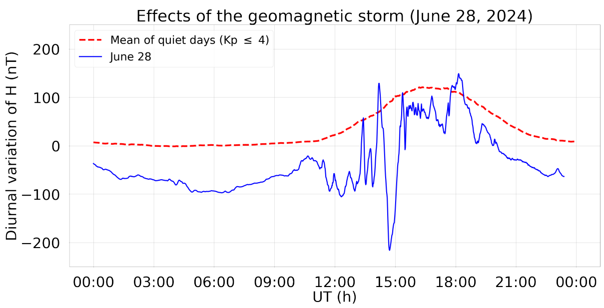

Figure 5. Effects of the geomagnetic storm on the diurnal variation of the horizontal component of Earth's magnetic field at the Jicamarca station on June 28, 2024.

This storm affected magnetometer observations at the Jicamarca Station and the diurnal variation of the horizontal component of the Earth's magnetic field (H) (Figure 5). Additionally, the storm had a significant impact on the ISR vertical drift measurements obtained with the Instituto Geofísico del Perú's Jicamarca Radio Observatory (IGP-JRO) main radar, as illustrated in Figure 6. On the day of the storm, the drifts were negative after sunrise and continued until 08:00 LT. At 10:00 LT, the drifts shifted from positive (upward) to negative (downward), a change from the drift average observed during geomagnetic quiet times. Moreover, the vertical drifts of the 150 km echoes also showed alterations (see Figure 6), following the same pattern observed in the ISR measurements.

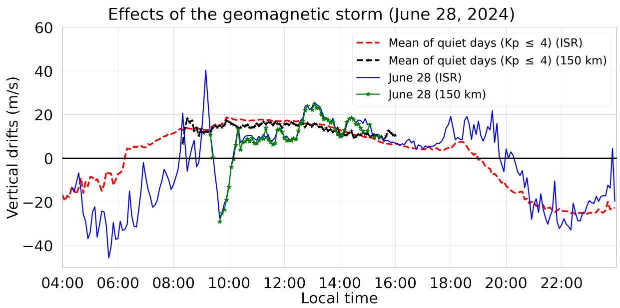

Figure 6. Variations in average vertical plasma drift at altitudes of 300 to 400 km (red) and 150 km echoes (black), along with the mean variation during quiet times. The blue and green lines represent the ISR vertical plasma drift and 150 km echoes, respectively.

3. Radar observations on the upper atmosphere

The vertical plasma drift of the 150 km echoes in the transition region between the E and F layers was monitored for 17 days using the IGP-JRO main radar in JULIA-MP mode. The echoes begin after 08:00 LT and disappear by 16:00 LT, occurring between altitudes of 135 and 150 km (see Figure 7). These findings are generally consistent with climatological expectations, with the notable exception of the maximum height, which is 15 kilometers higher than anticipated.

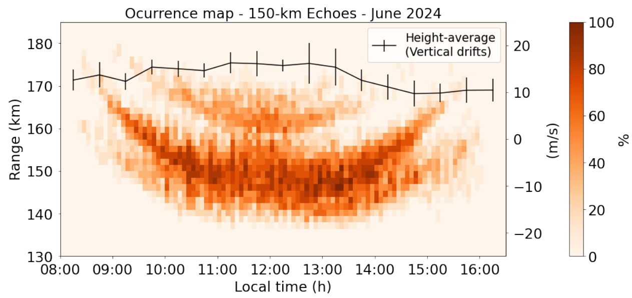

Figure 7. Map of occurrences of the 150 km echoes and the average height of their vertical drifts.

The vertical plasma drift was monitored for 27 days between 300 and 400 km using the IGP-JRO main radar with the JULIA-MP mode, as shown in Figure 8. These measurements reveal that the average vertical plasma drift is approximately -16 m/s (downward) after midnight and gradually increases until it reverses direction (upward) around 06:00 LT, reaching a velocity of 17 m/s by 11:00 LT. After this peak, the vertical plasma drift decreases until a sharp increase occurs around 18:00 LT, known as pre-reversal enhancement[7], with values approaching 5 m/s. Our observed values show moderate agreement with the Scherliess-Fejer model values, with the most significant discrepancy being 12 m/s at 17:30 LT.

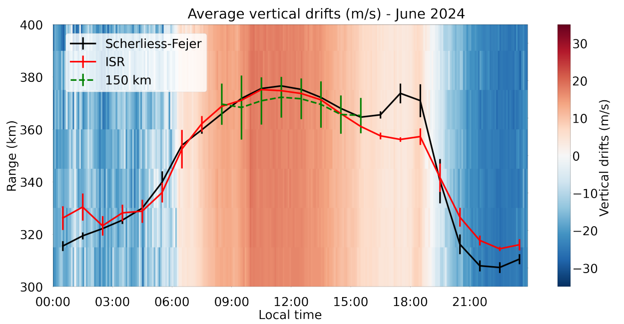

Figure 8. ISR monthly average vertical drifts for the June geomagnetic quiet days. The red curve represents the height average between 300 and 400 km and the black curve, the predicted values by the Scherliess-Fejer model. The green curve shows the height average value of 150 km echoes.

Furthermore, during 17 nights of measurements with the AMISR-14 radar system determined that there were no irregularities on the F layer for that period. These observations moderately agree with the climatology (radar in JULIA mode)[6]. Moreover, the JULIA-MP mode was operational for 23 nights, with irregularities detected on only one of those nights. The first irregularity was of the bottom type, occurring between 200 km and 350 km, while the other was of the post-midnight type, occurring between 250 km and 670 km (see Figure 1). These observations are consistent with the climatological data.

The time and height averages of the zonal and meridional winds in the Mesosphere Lower Thermosphere (MLT) region for June 2024 (refer to Figure 9) indicate that the predominant periods are 24 hours (diurnal solar tide). The average zonal wind at the mesopause (∼90 km) ranged from +40.4 m/s at 12:00 LT to -8.3 m/s at 02:00 LT. The maximum average meridional wind speed was +24.9 m/s at 19:00 LT, while the minimum was -58.2 m/s at 05:00 LT. The maximum zonal wind was +84.2 m/s at 14:15 LT on June 30th, and the minimum was -76.7 m/s at 01:15 LT on June 28th. Meanwhile, the maximum meridional wind was +95.3 m/s at 18:45 LT on June 22nd, and the minimum was -118.3 m/s at 03:45 LT on June 26th.

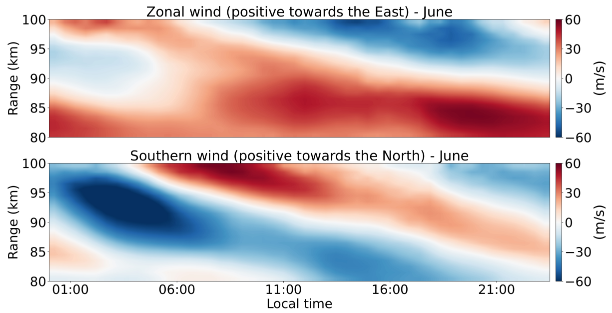

Figure 9. Monthly average of zonal and meridional winds during June 2024.

4. LISN instruments observations

Measurements of the horizontal component (H) of the geomagnetic field at the IGP-JRO magnetic stations during geomagnetic quiet days are shown in Figure 10. The average values of the Jicamarca and Huancayo stations were significantly higher than those of the other sites because they are located on the geomagnetic equator, where the Equatorial Electrojet (EEJ) contributes to increase. Additionally, there was notable daily variability, especially around 11:00 LT (16:00 hours UTC). The maximum variations of the monthly average values for June were recorded as follows: Piura (65 nT), Huancayo (125 nT), Jicamarca (120 nT), Arequipa (64 nT), and Nazca (69 nT).

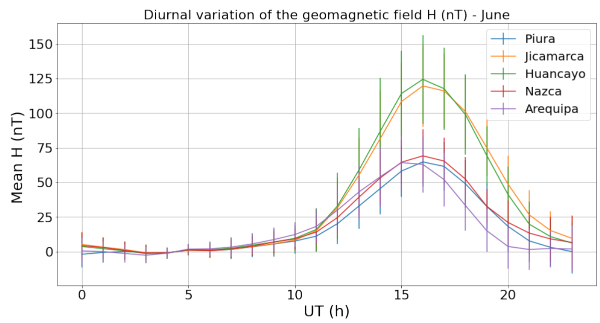

Figure 10. Average values of the diurnal variation of H components for all the geomagnetic stations that operated during June 2024.

5. Conclusions

- A G3 class intensity geomagnetic storm with a Dst value of -150 nT occurred on June 28th, 2024. This geomagnetic storm generated disturbances in the horizontal (H) component of the Earth's magnetic field over the Peruvian longitudes.

- This same storm disturbed the ISR and 150 km Echo vertical drifts, where unusual negative values were recorded until 10:00 LT.
- Solar activity, as measured by the F10.7 index, was high 100% of the time this month. This is the first month to record this level of activity, in contrast to last month, where it was high only 94% of the time. This suggests we are approaching the solar maximum predicted for July 2025.

6. References

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