EZIE-Mag

Explanation Guide

EZIE-Mag - short for EZIE Magnetometer - is an instrument that measures Earth's magnetic field, which is generated in the Earth's interior and extends into space, where it interacts with the solar wind coming from the Sun. The EZIE-Mag instrument is science-grade and allows you to detect changes in the magnetic field. EZIE-Mag is for educators, museums, libraries, and science centers and enables them to be citizen scientists.

Complete User Guide

EZIE-Mag Home Page

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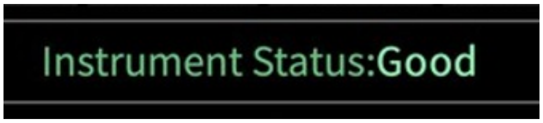
Introduction

The EZIE-Mag home page serves as the primary window into the operation of the EZIE-Mag magnetometer kit, displaying real-time magnetic field measurements, an instrument status indicator, and a sensor status indicator. This guide briefly explains every element on this page and how to interpret the information for effective scientific monitoring. If you have any issues, please contact us at EZIE-Mag-Support@jhuapl.edu!

Instrument Status Bar



The instrument status indicator, displayed as a colored banner, provides an immediate assessment of the overall health of the system. If any subsystem experiences issues, this status will change, indicating potential faults.

Station Information Panel

Identification Section

- The **ID Code** is a short, filesystem-safe string used for internal, system-local processes.
- The **Name** field becomes particularly useful in multi-station deployments. Descriptive names such as "Mountain Peak Observatory" or "Coastal Research Station" help operators and researchers quickly identify which physical installation generated specific datasets.
- The **Operator** field indicates the institution or individual responsible for this magnetometer station.
- The **Station Fingerprint** is a short unique identifier tied to the hardware/operating system. It allows unambiguous matching of files to a specific unit even if the human-readable name changes. The station fingerprint cannot be changed because it is generated based on hard-coded hardware parameters unique to a given system.

Station Information Panel *(continued)*

Location:

Latitude:	39.160 °
Longiude:	-76.899 °
Altitude:	156.100 meters

Location Section

The Location section displays the geographic coordinates of the station: latitude, longitude, and altitude. These values are captured by the GPS receiver when it attains a satellite fix.

Understanding your exact location is fundamental to geomagnetic measurements because the magnetic field of the Earth varies significantly with position.

IGRF Model Field:

North/South component X:	20877.58 nT	Horiontal component H:	21258.20 nT
East/West component Y:	-4004.70 nT	Total Field F:	50726.08 nT
Vertical component Z:	46056.75 nT		
Declination D:	-10.86 °		
Inclination I:	65.22 °		

IGRF Model Field Section

The International Geomagnetic Reference Field (IGRF) section displays the theoretical magnetic field that should exist at a location based on a mathematical model. This model represents the consensus of the global scientific community about Earth's main magnetic field.

The model field displays four key components:

- **North/South component (X):** The magnetic field strength in the geographic north direction. Positive values indicate northward field direction.
- **East/West component (Y):** The field strength in the eastern direction. Negative values indicate westward field direction.
- **Vertical component (Z):** The downward magnetic field strength. Positive values point down into Earth, while negative values point upward.
- **Total Field (F):** The total magnetic field intensity, calculated as the vector magnitude of all three components.

These model values serve as your baseline or "expected" field — that is, what measurements would be expected on a magnetically calm day with no space weather activity.

Station Information Panel *(continued)*

IGRF Model Field:

North/South component X:	20877.58 nT	Horiontal component H:	21258.20 nT
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IGRF Model Field Section *(continued)*

Any differences between measurements and model predictions could indicate several phenomena:

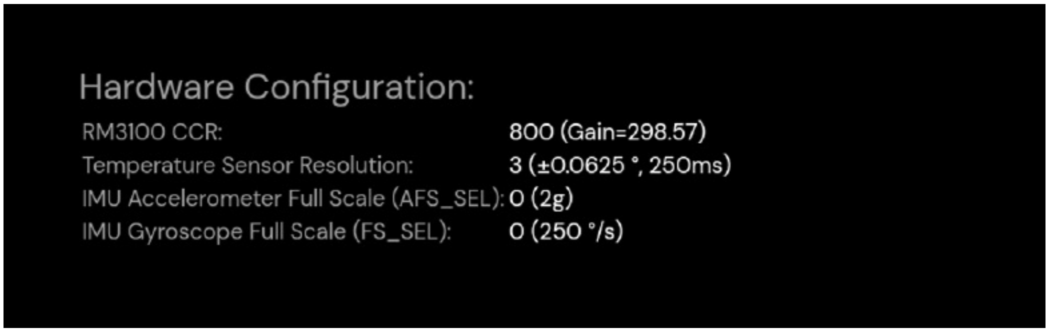
- **Local magnetic anomalies** (buried iron-ore deposits, human-made structures, etc.)
- **Magnetic storms** caused by solar activity, or
- The **electromagnetic fields generated by auroral currents** in the ionosphere.

Deviations of 50-100 nanoteslas (nT) or more from the model values often indicate the **onset of significant geomagnetic activity.**

Declination and Inclination

- The **Declination (D)** value represents the angular difference between magnetic north and geographic (true) north at the system location. This angle varies significantly across the surface of the Earth (near zero in some locations to more than 20° in others). It also changes slowly over time as a result of the movement of the magnetic poles of the Earth. A positive declination means magnetic north is east of true north. Negative values indicate that it is to the west.
- The **Inclination (I)** value indicates the "dip angle" — how steeply the magnetic field lines plunge into or emerge from the Earth at a location. As you move toward the magnetic poles, the field lines become increasingly vertical, from 0° inclination near the equator to 90° at the magnetic poles[1]

Station Information Panel *(continued)*



Hardware Configuration Section

Sensor Settings and IMU Configuration

- The **RM3100 CCR** (Cycle Count Register) controls the number of drive cycles per reading in the PNI RM3100 magnetometer. A higher CCR integrates longer, yielding lower noise and higher effective gain at the cost of update rate and power.
- The **Temperature Sensor Resolution** indicates the precision and sampling rate of the thermal monitoring system. The resolution value tells you the smallest temperature change the system can detect, typically in fractions of a degree Celsius.
- The **IMU Accelerometer Full Scale** setting defines the maximum acceleration the system can measure, typically expressed in units of Earth's gravity (g). Lower settings like ±2 g provide high sensitivity for detecting small vibrations and tilts, while higher settings like ±16 g can handle more vigorous motion without saturation.
- The **IMU Gyroscope Full Scale** setting configures the rotation sensor's maximum angular velocity detection range, typically expressed in degrees per second.

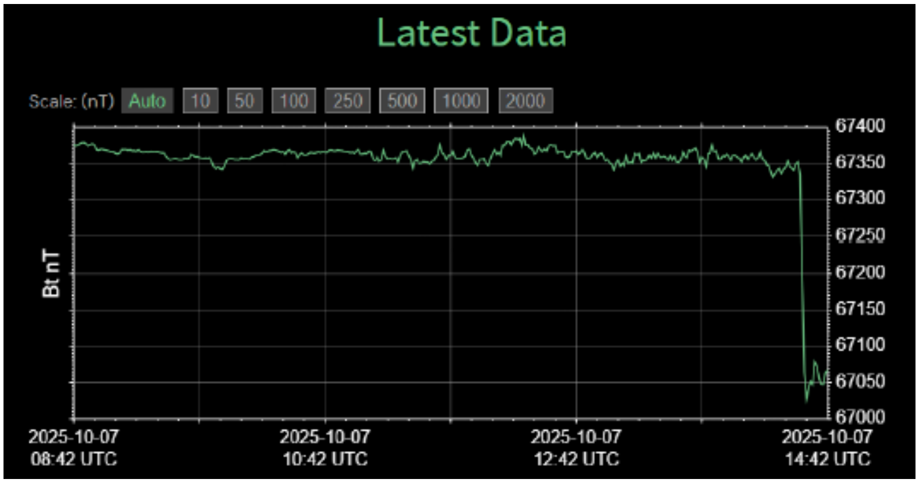
The measurements from these sensors are combined to calculate the orientation and state of the system. This is important because platform stability and orientation directly affect the quality and alignment of the measurements taken.

Data Visualization Section

Magnetic storms create sustained periods of enhanced variability, with the field strength potentially varying by hundreds or even thousands of nanoteslas over minutes to hours. The visualization helps operators immediately distinguish between normal daily patterns and unusual activity that indicates periods of interest.

Data Visualization Section *(continued)*

Latest Data Time Series Plot

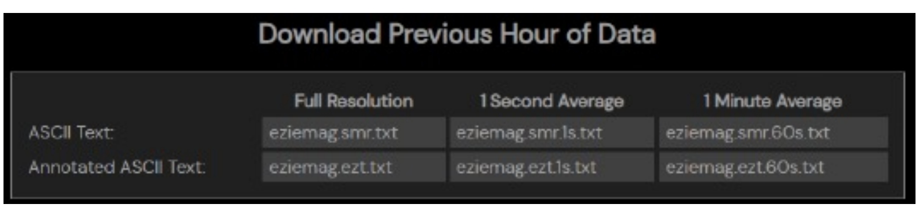


The upper graph displays a rolling window of recent magnetic field measurements as a continuous time series.

- The **horizontal axis** shows UTC **timestamps**, using UTC (Coordinated Universal Time), rather than local time, to ensure consistency across the global magnetometer network. When a magnetic storm occurs, all stations record it at the same UTC time regardless of their time zones, facilitating correlation of observations.
- The **vertical axis** shows **magnetic field strength** in nanoteslas (nT), the standard unit for geomagnetic measurements. One nanotesla is one billionth of a tesla. For reference, the strength of the magnetic field of the Earth typically ranges from about 25,000 nT at the equator to 65,000 nT at the poles.

The trace represents the total magnetic field intensity or individual components, depending on the display mode. During magnetically quiet periods, smoother variations will be observed, including the solar quiet (Sq) daily variation — a predictable pattern caused by electric currents in the ionosphere driven by solar heating. This creates a gentle rise and fall in the field strength that peaks around local noon.[2]

Download Previous Hour of Data

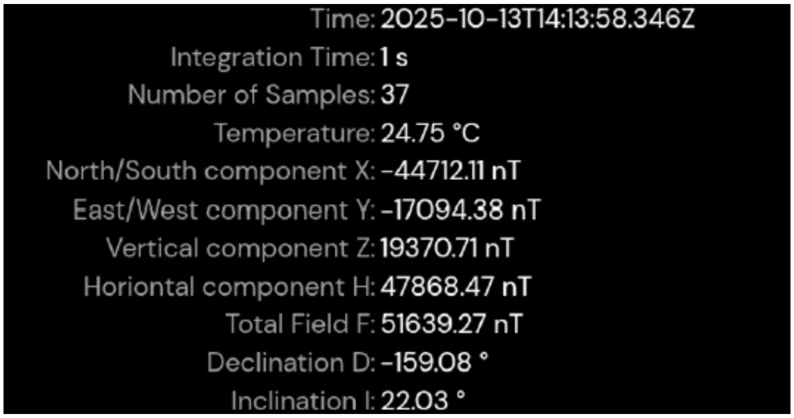


Download Previous Hour of Data

	Full Resolution	1 Second Average	1 Minute Average
ASCII Text:	eziemag.smr.txt	eziemag.smr.1s.txt	eziemag.smr.60s.txt
Annotated ASCII Text:	eziemag.ezt.txt	eziemag.ezt.1s.txt	eziemag.ezt.60s.txt

The data download section provides access to recent measurements in various formats and time resolutions. The data can be downloaded at multiple levels of averaging. **Full Resolution** provides the raw data measured from the station with no averaging, while the one-second and one-minute averaging options average the data collected over the respective time periods.

Current Measurement Values



The Real-Time Data section updates continuously with the latest measurement from the magnetometer.

The **Integration Time** field indicates how long the magnetometer averages its internal high-rate samples to produce each output value. A one-second integration time means each displayed measurement represents the average of many individual samples, which serves to reduce random noise.

The **Number of Samples** counter indicates how many integration periods have been completed since the last system restart or data reset. This monotonically increasing counter helps verify continuous operation.

Magnetic Field Components

The real-time magnetic field measurements are presented in a geographic coordinate system aligned with Earth's rotation axis, not magnetic poles. This standardization allows direct comparison between stations worldwide:

- **North/South component (X)** points toward geographic north (positive direction). This component is typically strongest at low magnetic latitudes and decreases toward the poles where field lines are more vertical. Changes in this component often indicate east-west flowing ionospheric currents.
- **East/West component (Y)** points toward geographic east (positive direction). Variations in this component can indicate north-south current flows or the passage of traveling ionospheric disturbances. At mid-latitudes, this is often the smallest component.
- **Vertical component (Z)** points perpendicular to Earth's surface (positive downward). This is typically the largest component at high latitudes where field lines are steep. Changes in the vertical component can indicate overhead current systems or approaching magnetic storm fronts.
- **Horizontal component (H)** represents the combined horizontal field strength, calculated as the vector sum of X and Y components. This parameter is particularly useful for studying equatorial phenomena where the field is predominantly horizontal.
- **Total field (F)** combines the X, Y, and Z components of the measured magnetic field into a single value representing the total magnetic field strength. This parameter is most stable and least affected by sensor orientation errors, making it valuable for long-term monitoring of field strength.

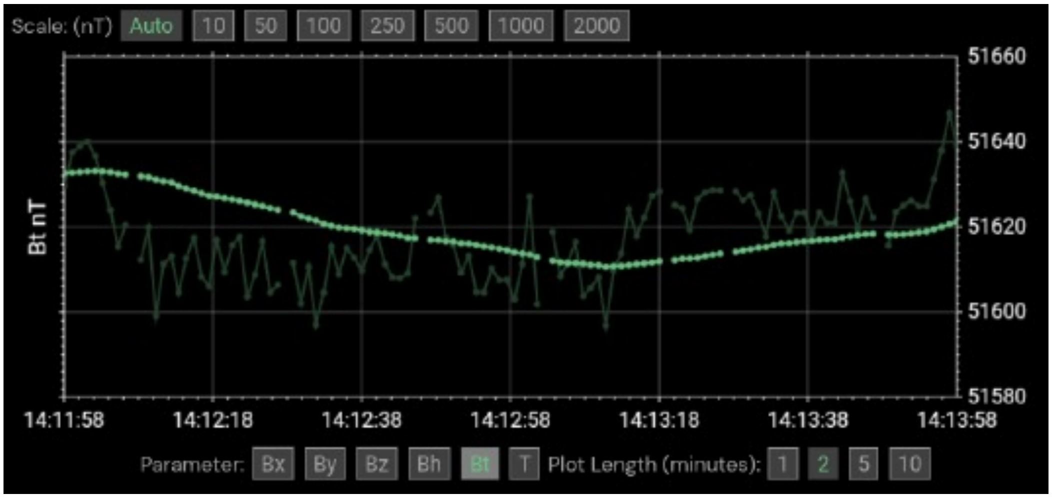
The displayed **Declination (D)** and **Inclination (I)** values are derived from the real-time component measurements.[3]

Current Measurement Values *(continued)*

Temperature Monitoring

The temperature reading comes from a dedicated temperature sensor, as well as a temperature sensor that is integrated with the magnetometer. The EZIE-Mag system uses this temperature data to implement correction algorithms.[4]

Real-Time Data Display

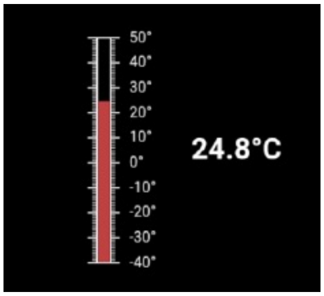


The lower graph provides a high-resolution view of immediate magnetic field activity. The horizontal axis spans a compressed time frame, allowing operators to observe rapid field changes and transient phenomena that might be smoothed out in longer-term displays.[5]

Sensor Status Displays

Compass Display

The circular compass shows the magnetic field direction parallel to the ground. The display shows where the horizontal component of the magnetic field vector points, similar to how a traditional compass needle points toward magnetic north.



Temperature Gauge

The vertical temperature gauge displays the current station temperature. Both rapid temperature changes and extreme temperatures are problematic because they can induce transient errors that take time to settle.

Sensor Status Displays (continued)

IMU Orientation

The pitch and roll measurements provide a picture of the orientation of the magnetometer in three-dimensional space. These inertial measurement unit (IMU) readings enable precise coordinate transformation from the sensor reference frame to the geographic reference frame. **These measurements are critical for data quality** because any tilt in the magnetometer platform affects how the three-axis sensors align with the geographic coordinate system. As such, any pitch or roll must be compensated for with the measurements taken to ensure that the measured magnetic field components accurately represent the north, east, and vertical directions.

These gauges can be used to level the sensor platform as precisely as possible during installation, minimizing the correction factors needed and optimizing measurement accuracy.

Pitch Gauge

The **bottom-left circular gauge** displays the platform's **pitch angle**, measuring the forward/backward tilt of the magnetometer sensor package. Values near zero indicate the platform is level in the north-south direction (or whichever axis is defined as forward/back for the installation). Positive values typically indicate forward tilt, while negative values show backward tilt, measured in degrees.

Roll Gauge

The **bottom-right circular gauge** shows the platform's **roll angle**, measuring the side-to-side tilt of the magnetometer sensor package. This represents rotation about the longitudinal axis (whether the platform is leaning left or right). Like pitch, values near zero indicate a level installation, while positive and negative values show the direction and magnitude of tilt in degrees.

Summary and Scientific Context

The EZIE-Mag home page brings together all of these elements to provide a comprehensive view of the status of the system and the magnetic environment it is measuring. This ground-based magnetometer works in concert with the broader EZIE mission. While the satellites are able to observe the large-scale current patterns from above, each ground station measures the magnetic field changes that these currents produce at the surface of the Earth. Together, they provide a complete picture of how energy from the solar wind flows through Earth's magnetosphere, couples to the ionosphere, and dissipates in the upper atmosphere.

Summary and Scientific Context *(continued)*

Understanding these measurements helps scientists predict the effects of space weather events on technological systems. GPS positioning errors, satellite drag variations, induced currents in power grids, and disruption of radio communications all correlate with the magnetic variations each station measures. By maintaining continuous, high-quality observations, each magnetometer station serves as an important node in Earth's space weather monitoring infrastructure, contributing to both scientific research and practical applications that protect critical technology systems!

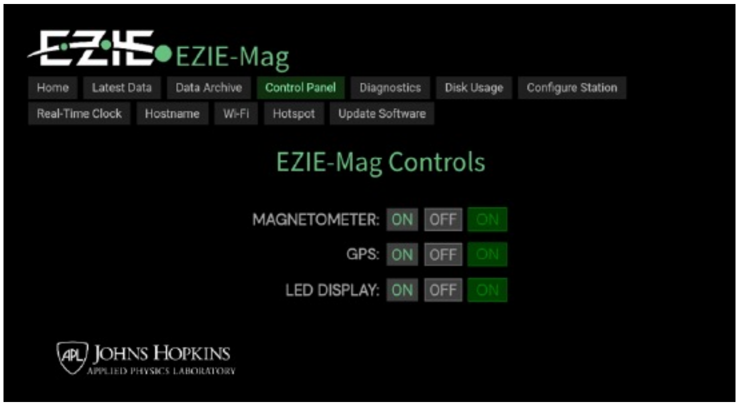
Latest Data

Provides an interface to download the last 24 hours of data from the system.

Data Archive

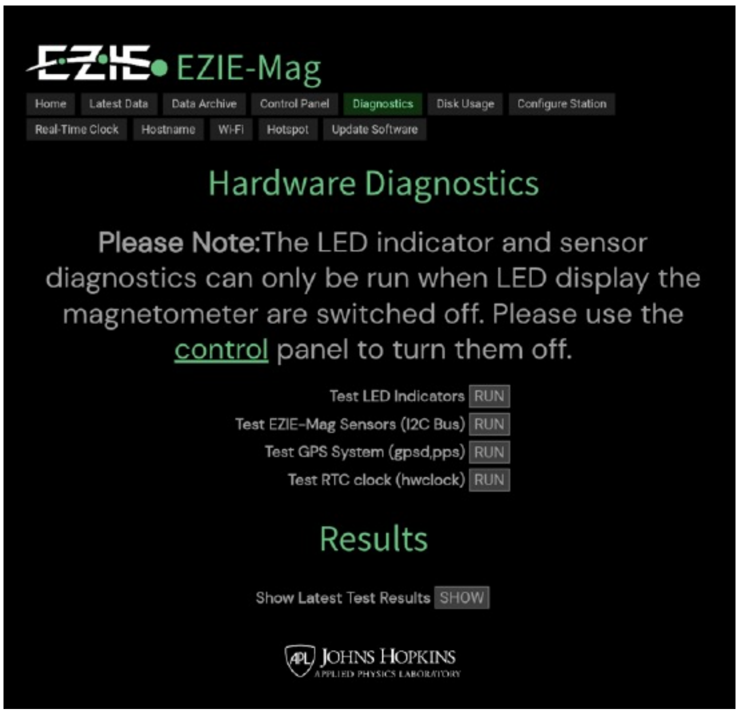
Provides an interface to download an archive of the previous day and previous week of data.

Control Panel



Contains three toggle controls (Magnetometer, GPS, LED Display) as well as current state indicators for each sensor/system. These devices/can be enabled or disabled from this window in order to help with debugging and diagnosis of the system, should the need arise. This page is password-protected to prevent unauthorized access.

Diagnostics

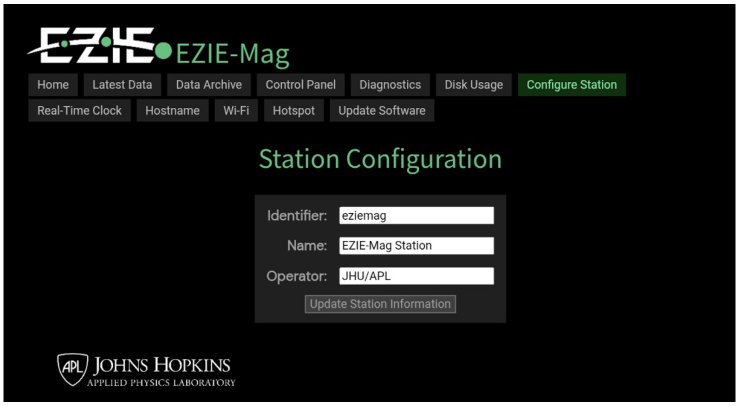


Contains diagnostic tests for each subsystem (LED Indicators, EZIE-Mag Sensors, GPS, RTC clock) as well as a "Show Latest Test Results" button. These tests can be run to help with system debugging and diagnosis, should the need arise. This page is password-protected to prevent unauthorized access.

Disk Usage

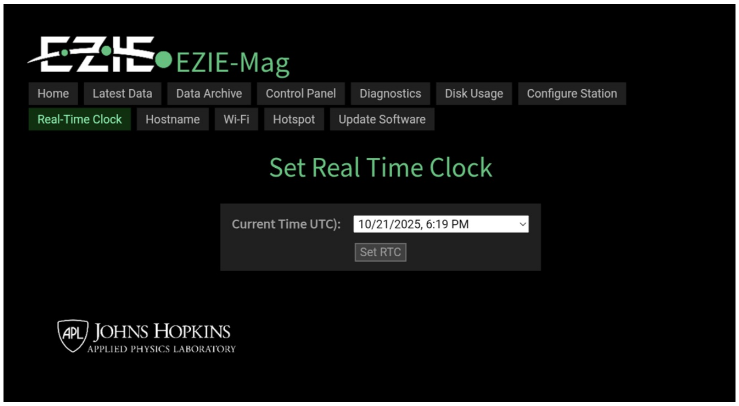
Contains a single button that shows the total remaining system memory, useful for debugging or diagnosis of the system in the case of (missing) data issues due to the disk being full.

Configure Station



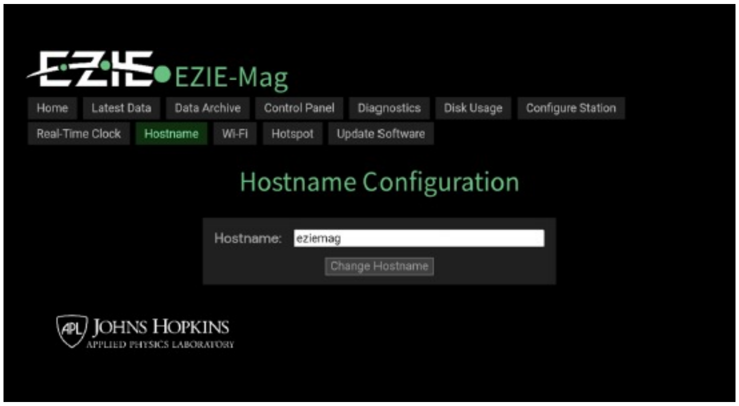
Provides the ability to modify the system metadata (identifier, user name, system operator). This information is included with the data collected by the station and is used to identify the station in the larger multisystem network, making it possible to determine which station particular data came from. This page is password-protected to prevent unauthorized access.

Real-Time Clock



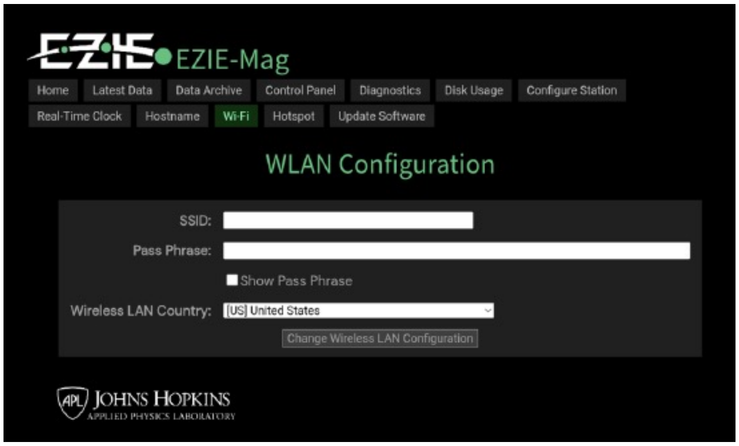
Provides the ability to set the time on the real-time clock, if needed.

Hostname



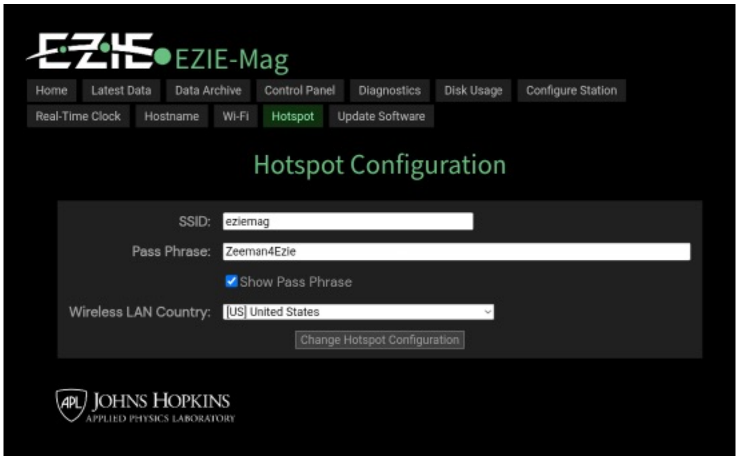
Provides the ability to change the hostname of the system. The name provided here is used as the local name of the system on the connected network (hotspot or connected Wi-Fi network). The address to reach the eziemag dashboard will be **<name in field>.local** (eziemag by default).

Wi-Fi



Provides the ability to connect the EZIE-Mag kit to an existing Wi-Fi network.

Hotspot



Allows the modification of hotspot parameters, namely network name (SSID), password, and region. Changing these settings will reboot the system. Modification of these settings is necessary when multiple EZIE-Mag systems are operated in close proximity to each other, providing the only way to differentiate and selectively connect to the kits locally.

Update Software

Provides a simple interface with which to update the software running on the system. This is useful for when there are modifications made to the software that affect the performance of the system, such as when the IGRF model is updated (every 5 years).

Footnotes

1. This parameter strongly influences how the station responds to space weather events. Stations at high magnetic latitudes (steep inclination) are more sensitive to auroral zone disturbances, while those near the magnetic equator respond more strongly to equatorial electrojet currents. Footnote in text
2. When geomagnetic activity increases, the trace becomes more varied. Sudden impulses appear as sharp steps in the data, caused by the arrival of solar wind shocks at Earth's magnetosphere. Footnote in text
3. The declination and inclination values displayed in the Data Visualization section are derived using trigonometric relationships. These angular parameters often show the first signs of developing geomagnetic disturbances, because changing current systems alter the field direction before significantly affecting the total intensity. Footnote in text
4. Temperature affects magnetometer measurements through several mechanisms. The magnetometers themselves exhibit thermal drift as the magnetic properties of the cores of the sensing elements change with temperature. The electronics also have temperature-dependent characteristics that can introduce measurement errors if not accounted for. Footnote in text
5. This real-time trace reveals the "texture" of the magnetic field that gets averaged out in longer-term plots. During quiet conditions, you can observe continuous pulsations (Pc waves) — naturally occurring ultralow-frequency waves in Earth's magnetosphere. These waves provide information about magnetospheric dynamics and solar wind coupling.

   During active periods, sudden impulses that may appear as simple steps in the daily plot reveal themselves as complex waveforms, and multistep structures become visible. Substorm onsets become visible as rapid-fire fluctuations that can change the field by tens of nanoteslas per second. Footnote in text

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