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*Enabling Intelligent Data Downlink Prioritization of In-Situ Observations through Generalizable and Computationally Inexpensive Anomaly Detection*

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# Generalizable anomaly detection enables rapid data prioritization of in-situ spacecraft observations for subsequent downlink.

**BACKGROUND:**

Time-series observations of magnetic fields and plasma moments are critical to our study and understanding of the various phenomena that couple mass, momentum, and energy throughout near-Earth space. Recently, our desire to study specific phenomena such as magnetic reconnection have driven us to take these measurements at higher rates, greatly increasing the quantity of raw data onboard spacecraft, only of which a small percentage can be telemetered to Earth at full cadence. This work presents a computationally simple and generalizable technique for the prioritization of onboard data, enabling greater scientific return across a wide range of spacecraft and observations.

**METHOD:**

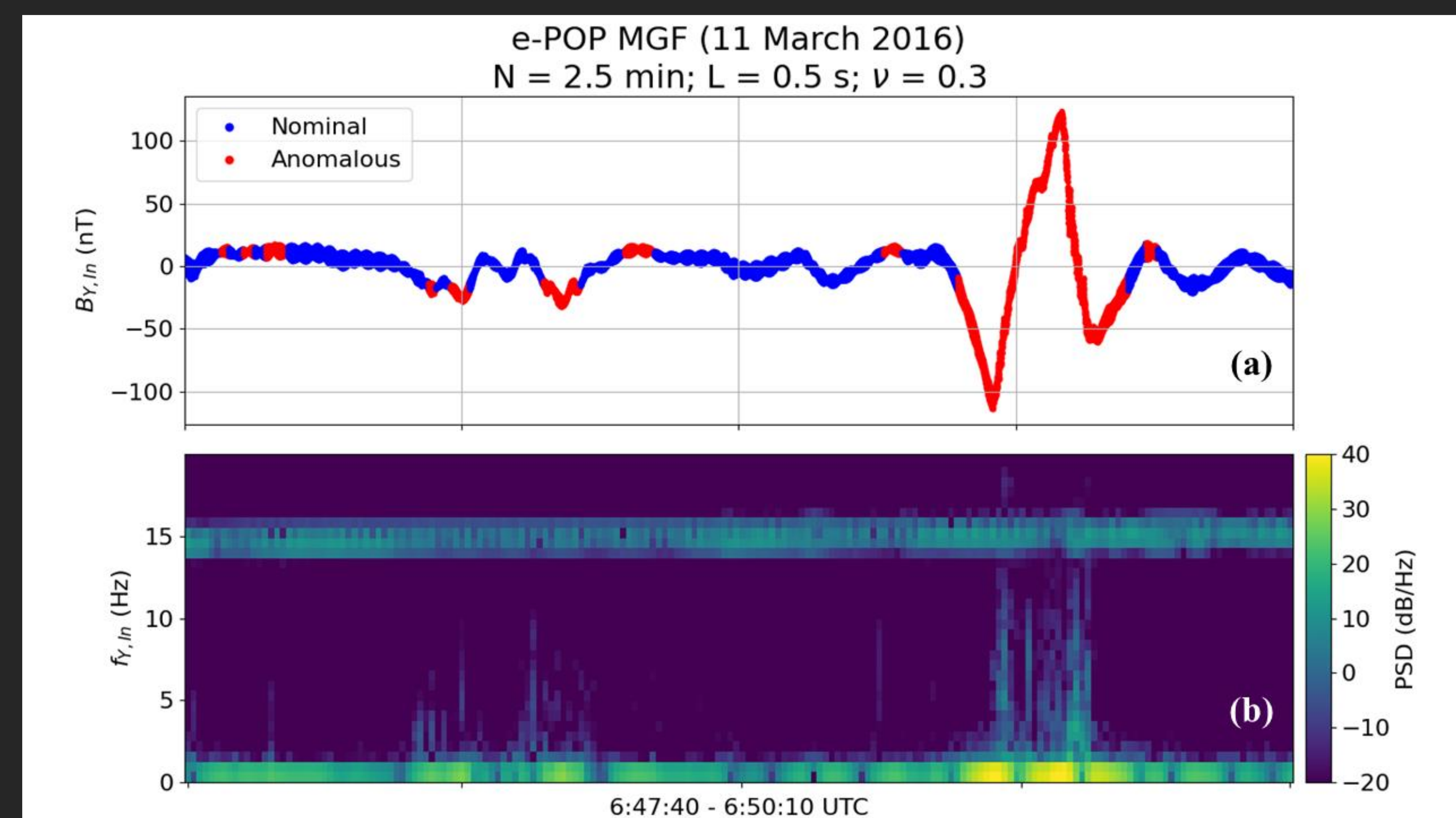
1. Time-series measurements are used to generate a reduced trajectory matrix by concatenating delayed intervals into a single matrix, enabling a higher-dimension feature space to represent the temporal variation within the signal.
2. The reduced trajectory matrix, fed into traditional Principal Components Analysis (PCA), reduces the dimension of the feature space based on its variance.
3. A One-Class Support Vector Machine (OC-SVM) is used to cluster the reduced feature space based on a nonlinear Gaussian kernel.
4. Nominal and anomalous points in the reduced feature space can be inverted into nominal and anomalous intervals within the original signal.

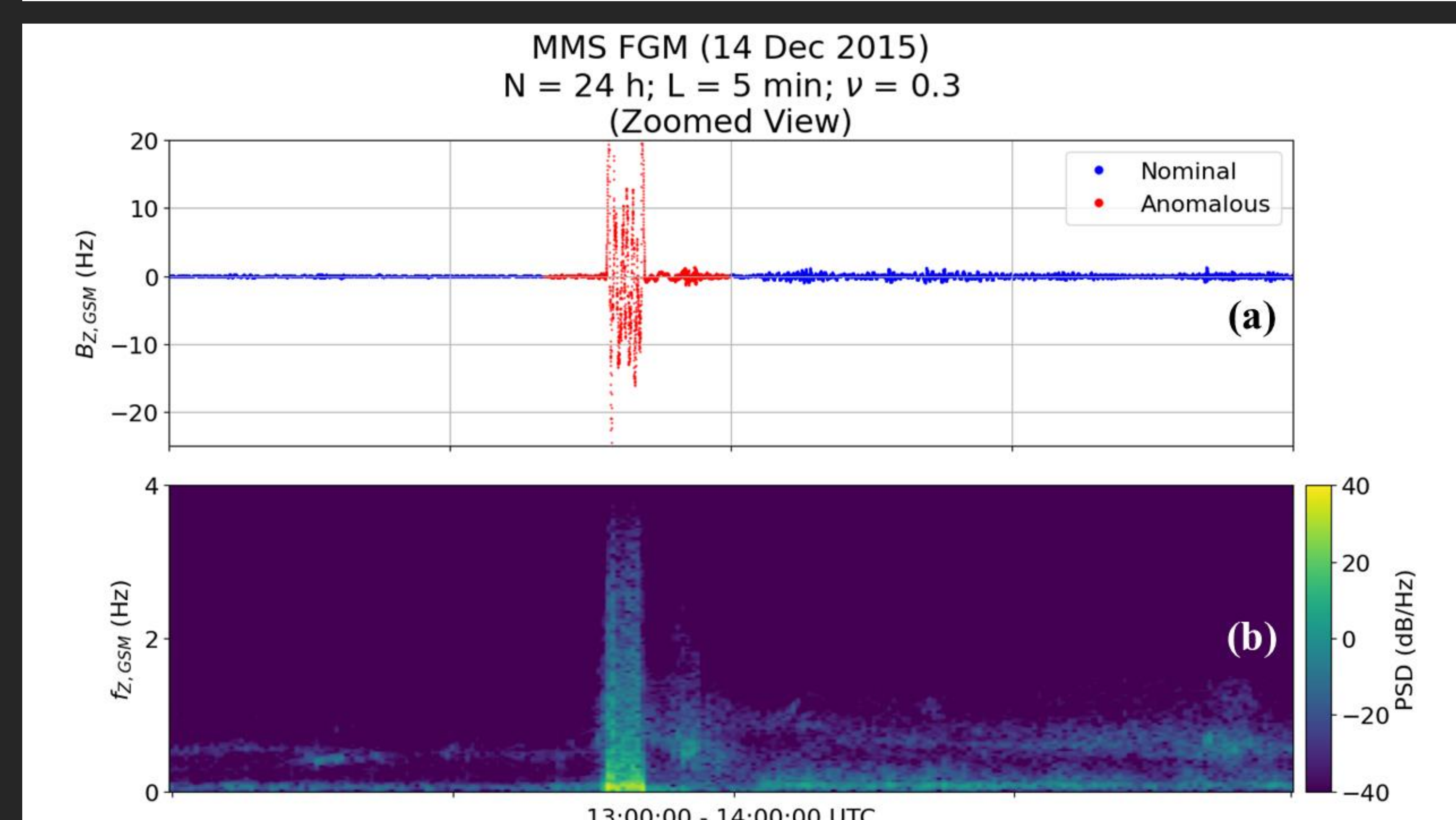
**PRELIMINARY RESULTS:**

- Application to magnetic fields measurements from CASSIOPE MGF and MMS FGM instruments.
- Successfully identified anomalous regions containing previously identified scientific phenomena such as Alfvén waves and EMIC waves.
- Application to plasma moments from MMS FPI enables data prioritization from multiple observations.

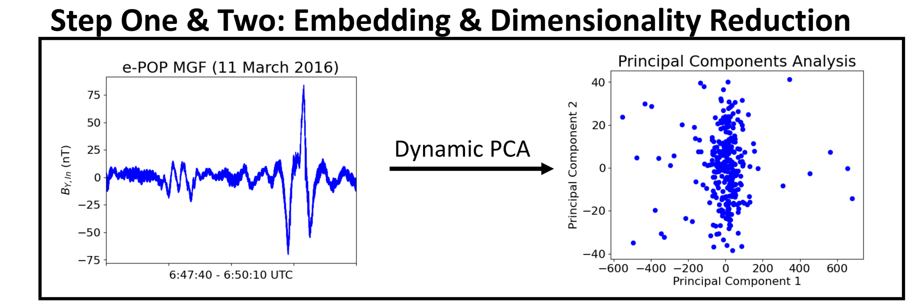
**ONGOING WORK:**

- Manuscript currently in-progress.
- Automated characterization of identified anomalies.

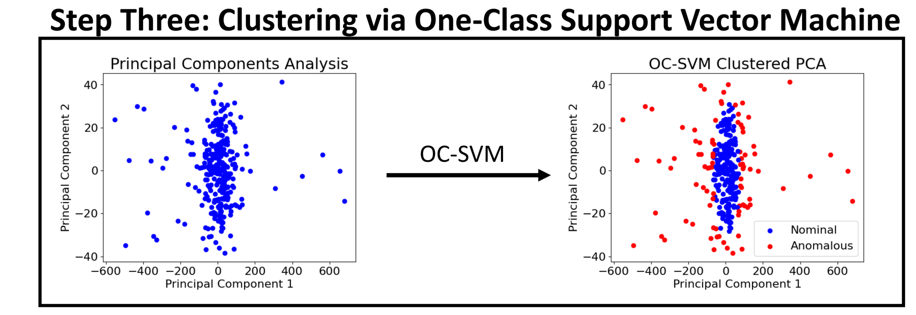



**Step One & Two: Embedding & Dimensionality Reduction**




**Step Three: Clustering via One-Class Support Vector Machine**




**Step Four: Inversion**

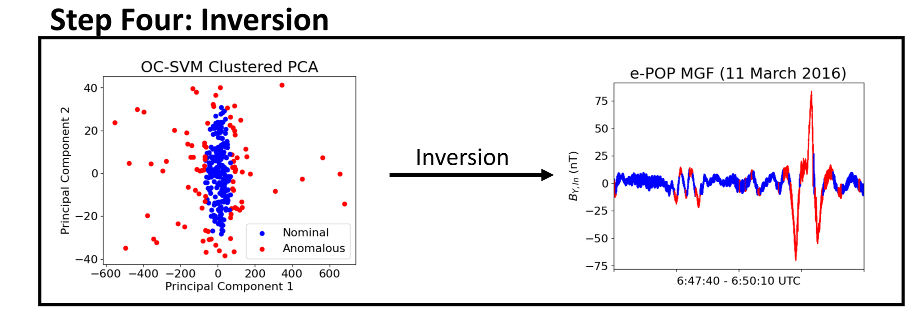
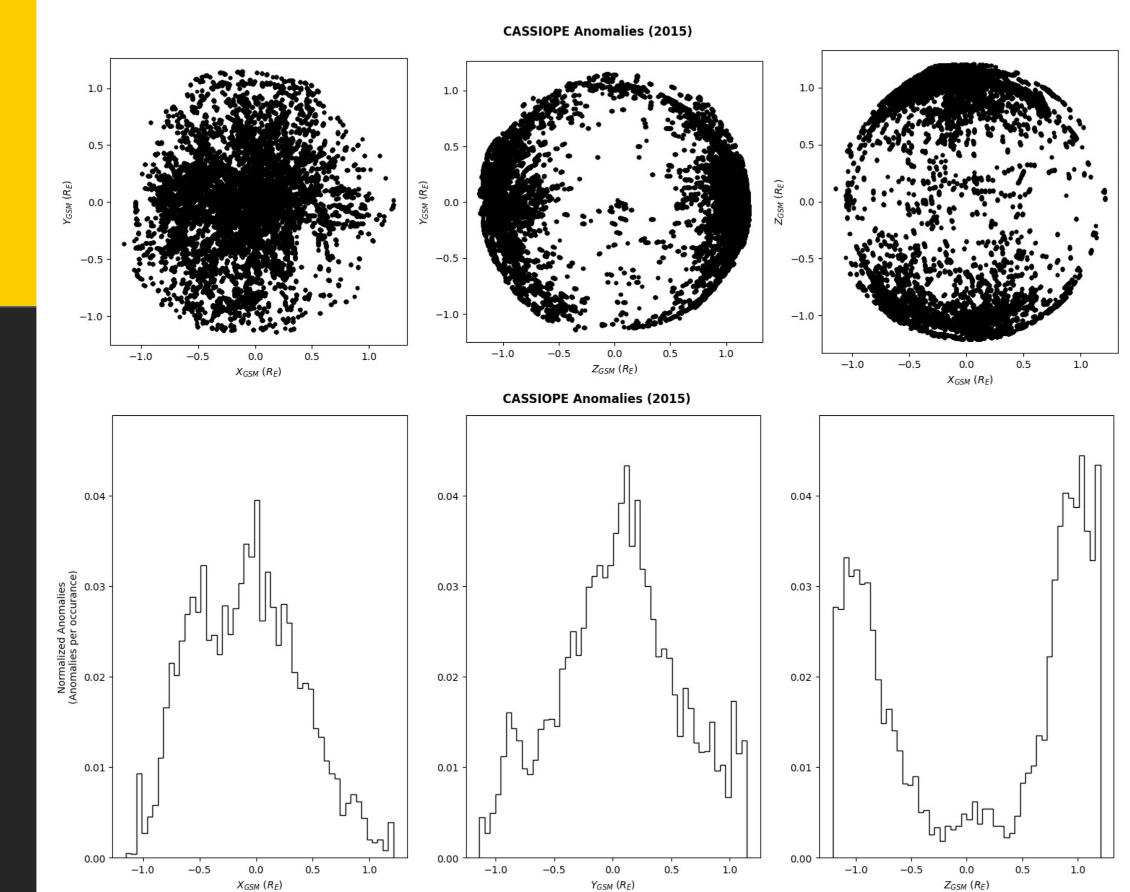
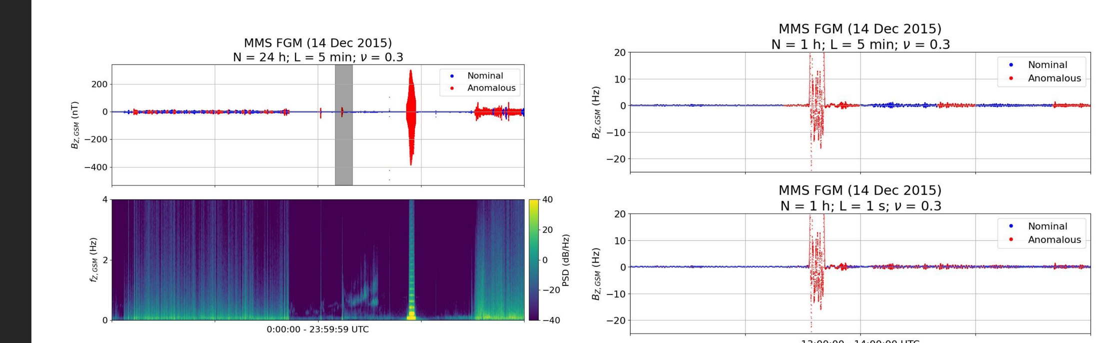


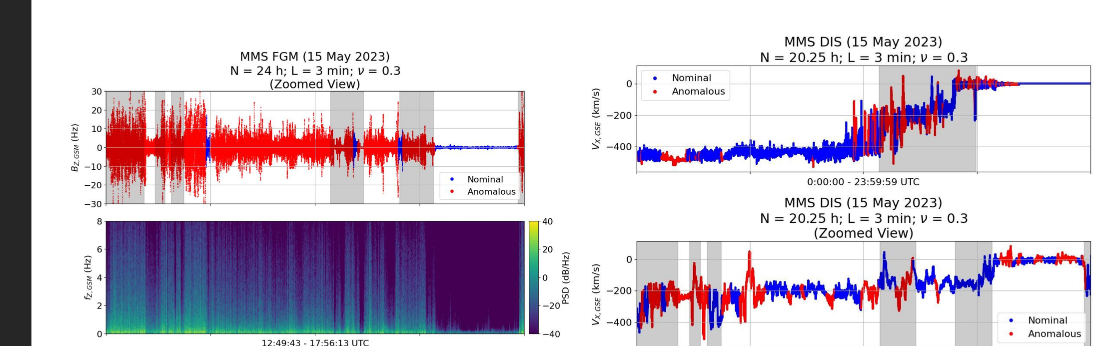

Illustration of the various steps of the proposed anomaly detection technique, applied to a 2.5-minute interval of magnetometer measurements captured by the CASSIOPE e-POP magnetic field instrument (MGF).




Anomalies identified using the proposed technique when applied to a full year of valid data from the CASSIOPE e-POP MGF; activity is notably clustered over the poles, as expected.



Anomalies identified using the proposed technique when applied to a 24-hour period of Magnetospheric Multiscale Mission (MMS) magnetometer measurements containing previously identified EMIC activity (left); Illustration of parameter changes on the proposed technique using only the one-hour period containing EMIC activity (right).



Anomalies identified using the proposed technique when applied to a 24-hour period of Magnetospheric Multiscale Mission (MMS) magnetometer measurements containing SITL-identified phenomena including magnetopause crossings (left); The proposed anomaly detection technique applied to the ion velocity measured by MMS during the same interval when valid data was available (right).

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References:
Engebretson et al., 2018. DOI: https://doi.org/10.1029/2018JA025984
Miles et al., 2018. DOI: https://doi.org/10.1002/2017GL076051

For related work, see:
**SH11G-03:** *A Dynamic PCA and Machine Learning Tool for Automated Identification of Solar Wind Disturbances Impacting Earth's Magnetosphere* (M. Martinez-Ledesma et al.)