Calibration and Validation of the SOLAR-1 Magnetometer

Konstantinos Horaites[1,2], Nathan Howard[1,2], Fadil Inceoglu[1,2], Juan V. Rodriguez[1,2], Michael Grotenhuis[3], Jeffrey Kronenwetter[3], Dimitrios Vassiliadis[4], Matthew Argall[5], Bernard Vasquez[5], Ivan Dors[5], Charles Smith[5], Roy Torbert[5,6]

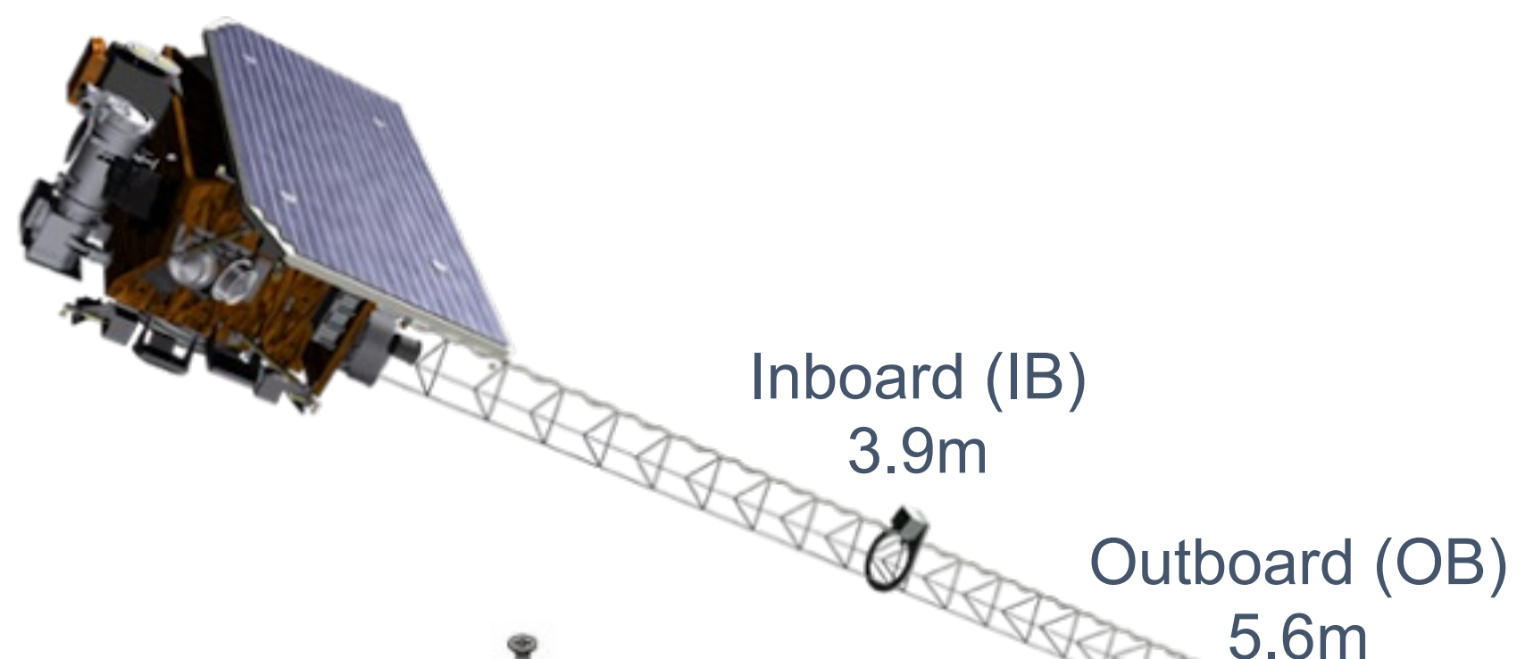
[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder; [2]NOAA National Centers for Environmental Information, [3]Chesapeake Aerospace at NASA, [4]National Oceanic and Atmospheric Administration, [5]University of New Hampshire, [6]Southwest Research Institute

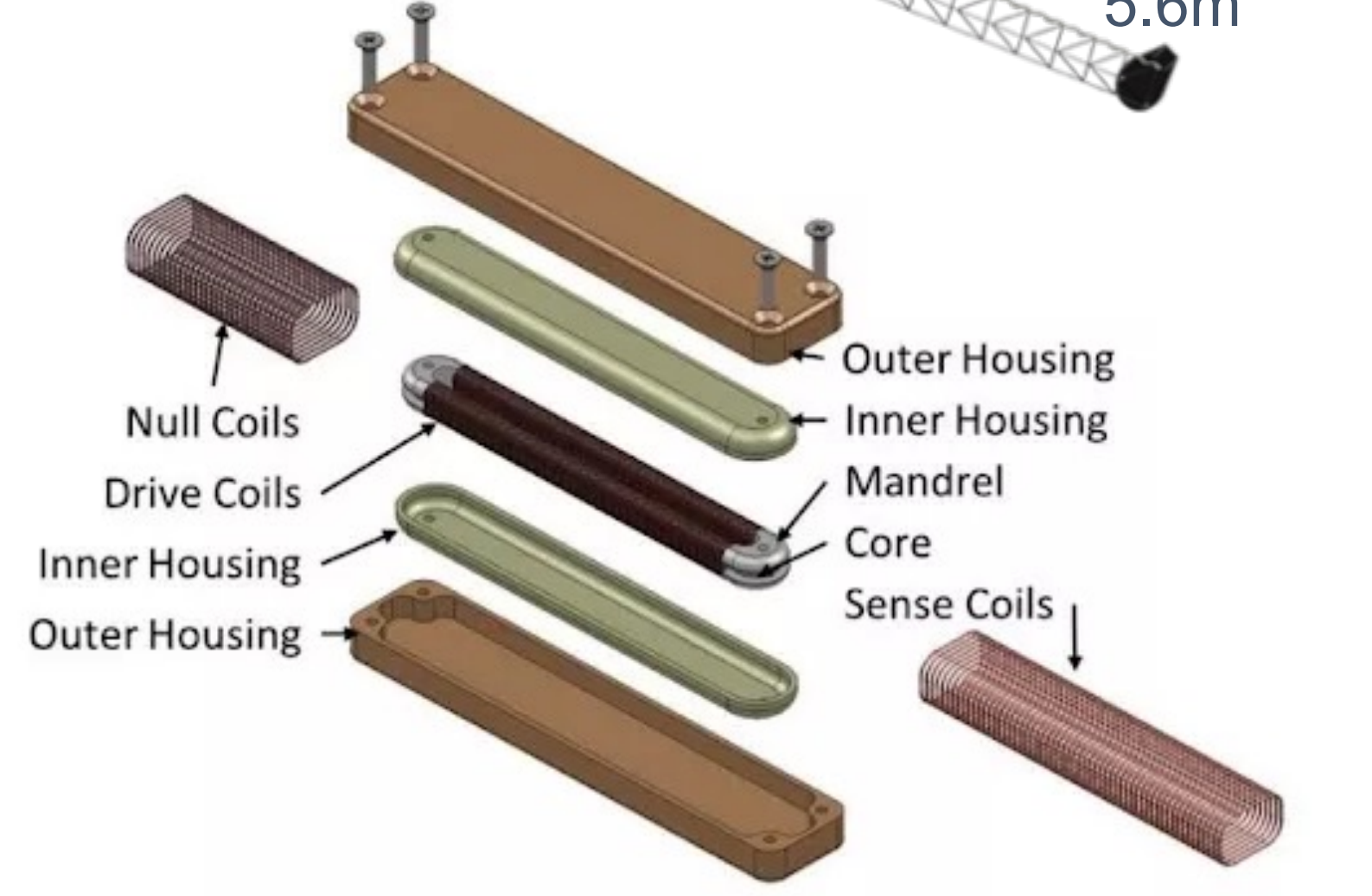
University of Colorado Boulder

Abstract

The Space Weather Observations at L1 to Advance Readiness - 1 (SOLAR-1, formerly SWFO-L1) NOAA mission was launched in September 2025, as a successor to the DSCOVR mission. The satellite will be used to observe incoming solar wind particles and fields before they reach Earth, and the in situ magnetic field will serve as a "key parameter" for operational prediction of space weather events. As the spacecraft journeyed to the L1 Lagrange point, our magnetometer team began the process of in-flight instrument commissioning. This entails calibration of the instrument and validation of its measurements, which is required before the release of data products. In collaboration with the Southwest Research Institute and the University of New Hampshire, NOAA has applied algorithms to calculate the instrumental offsets and other parameters that must be determined in-flight. We also identified the stray magnetic fields originating from the spacecraft (thrusters, reaction wheels, etc.) and quantified the magnitude of the noise. To help end-users remove spurious signals from their analyses, we generated quality flags that will be incorporated with the public data. Finally, we compared the spacecraft's inboard and outboard sensors with each other, and also compared the primary (outboard) magnetometer with similar instruments on other spacecraft orbiting the L1 Lagrange point. In this presentation, we show the outcomes of NOAA's commissioning efforts and discuss the state and quality of the magnetometer measurements, which will be of great value to the operational and scientific communities.

Instrument Description



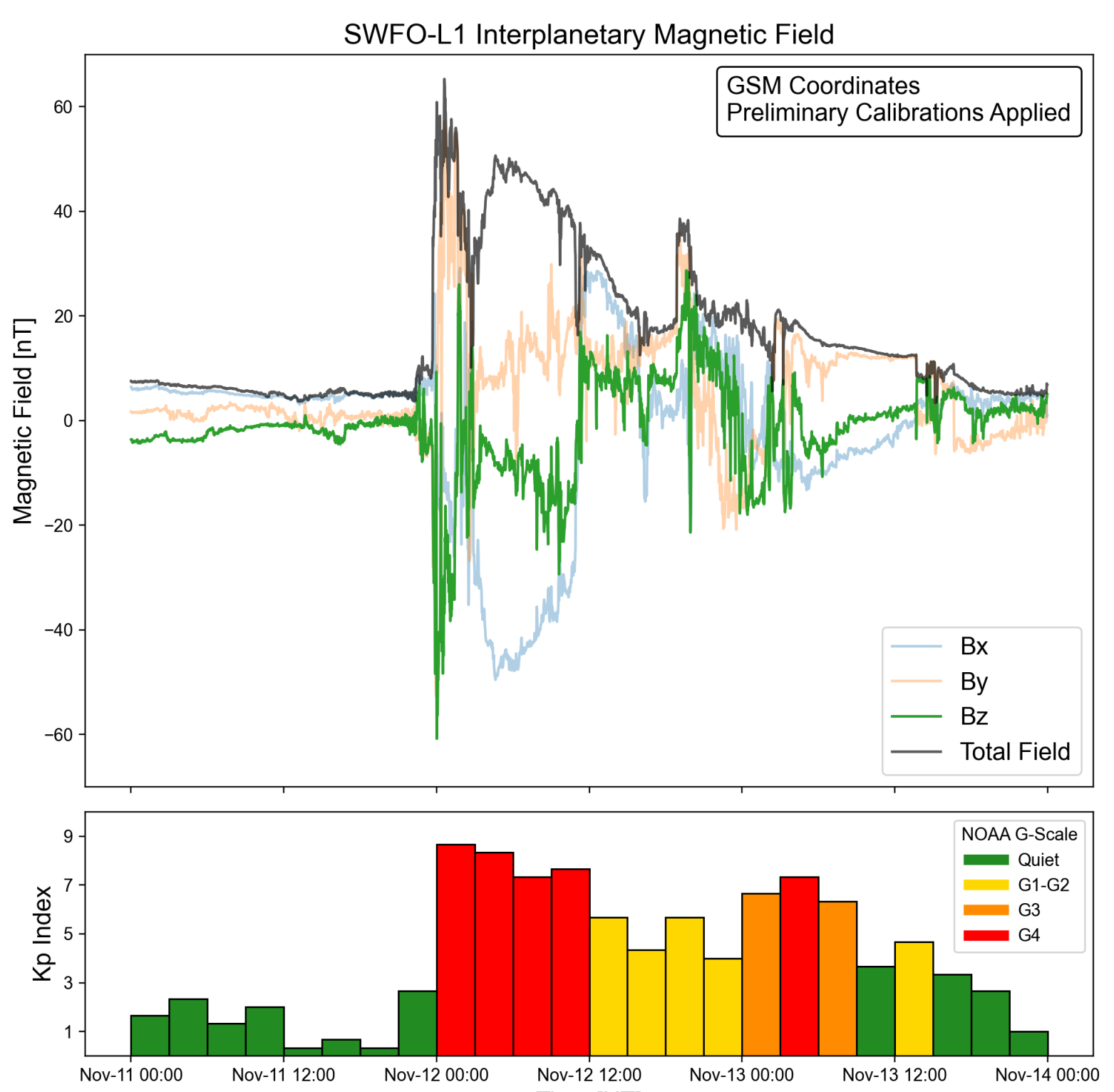


- •The Magnetometer (MAG) instrument measures the three IMF vector components
- •SOLAR-1 carries two, boom-mounted, three-axis fluxgate magnetometers with racetrack cores, which provide magnetic stability, low noise, and reliable manufacturing
- •Sources of measurement noise include magnetic fields generated by the spacecraft or electronics
- •Two magnetometers, Inboard (IB) and Outboard (OB), on a shared boom. Provides redundancy and capability to discriminate noise from SW fluctuations.
- •MAG instruments are provided by SwRI / UNH (Torbert et al. 2026)
- •SWPC algorithms provide the real-time data, while NCEI algorithms provide retrospective data

Space Weather Events

Nov 12-13, 2025

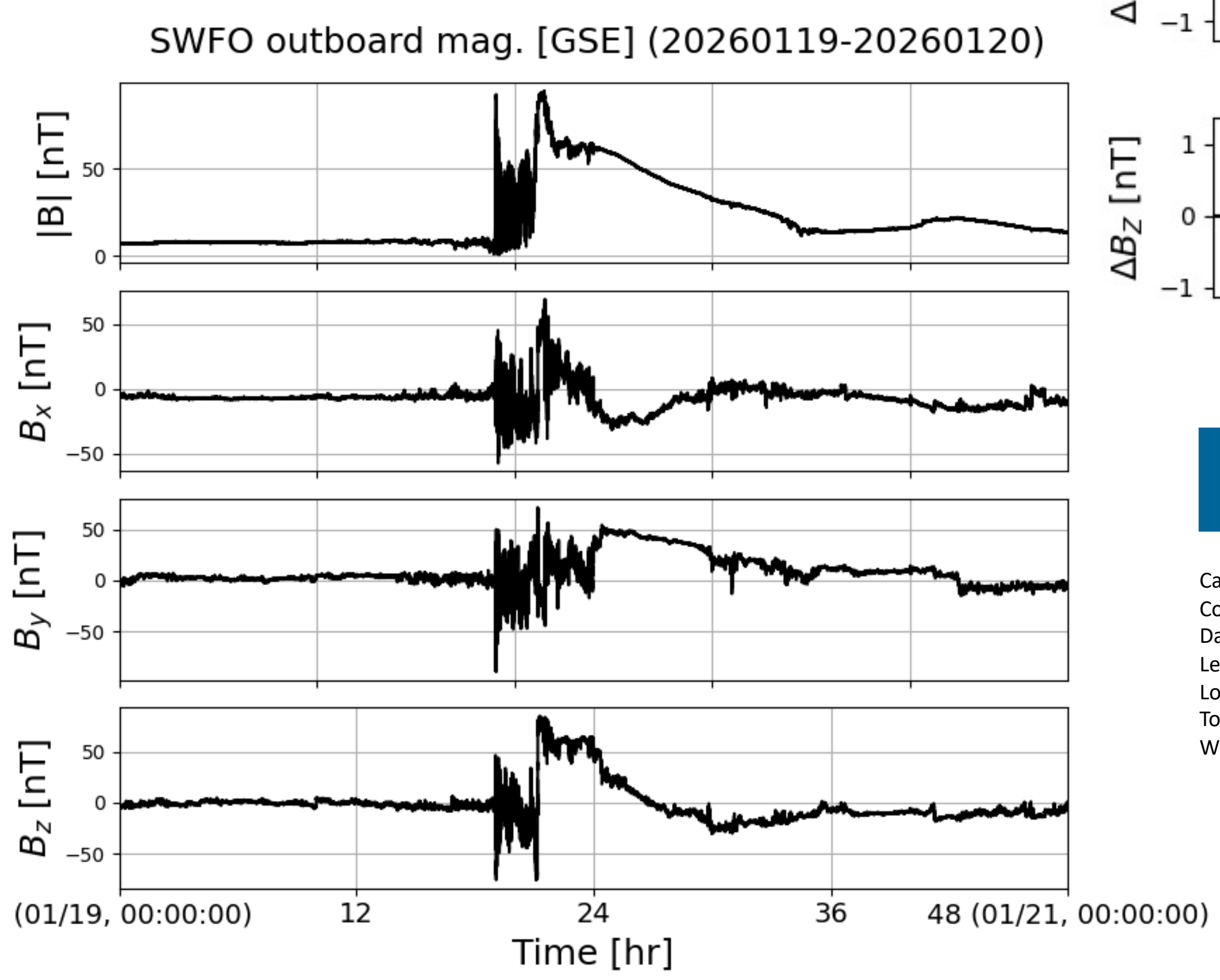
- Triggered G4 geomagnetic storm



See MAG "First Light" announcement: https://www.nesdis.noaa.gov/news/noaa-shares-first-space-weather-data-swfo-l1s-magnetometer

Jan 19-20, 2026

- max(|**B**|)=94.4 nT, among largest at ~1 AU



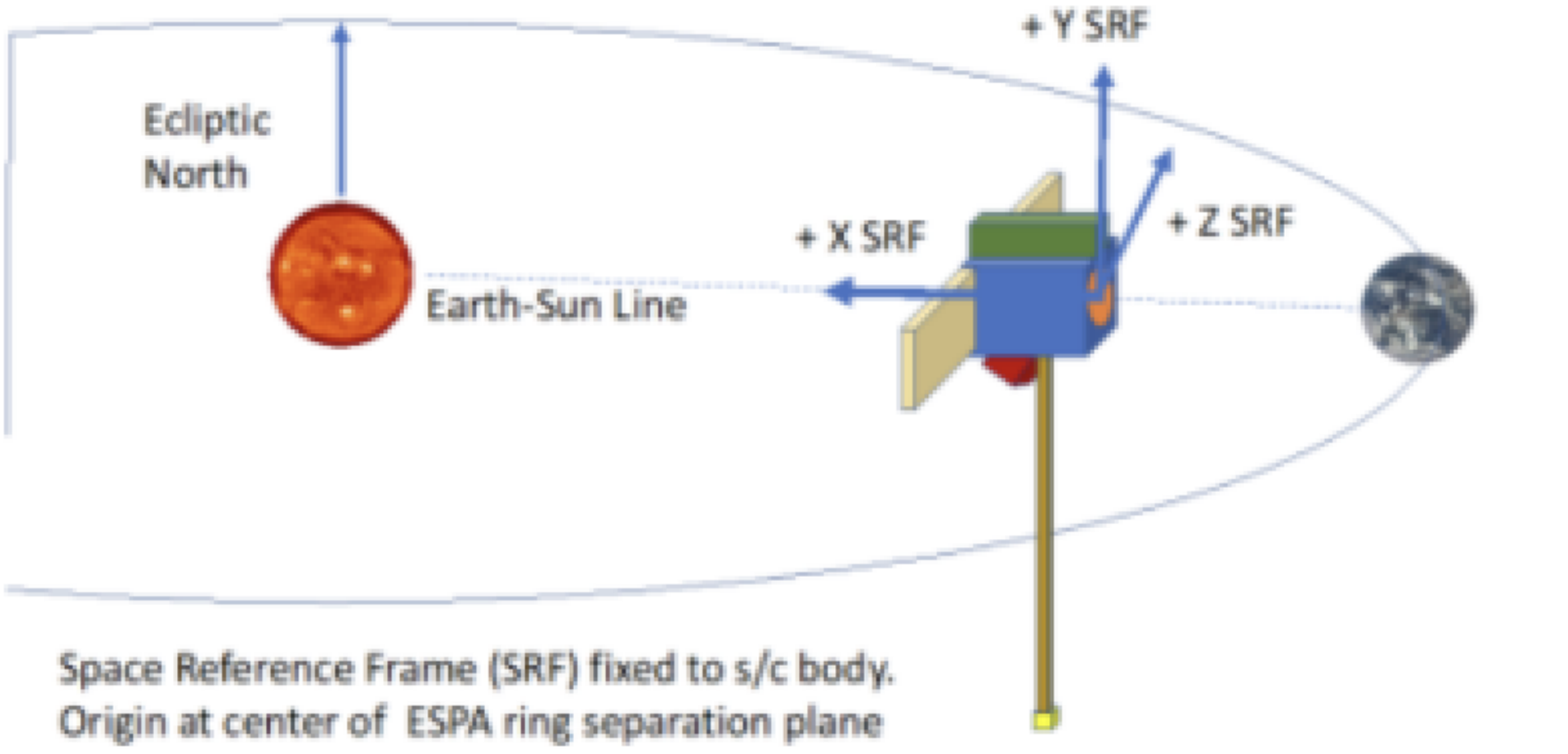
Calibration

Maneuver method

(Connerney et al. 2017; Califf et al. 2023, Loto'aniu et al. 2023)

Perform a rotation

Rotations around 2 orthogonal axes are sufficient to determine the sensor's 3 independent vector offsets

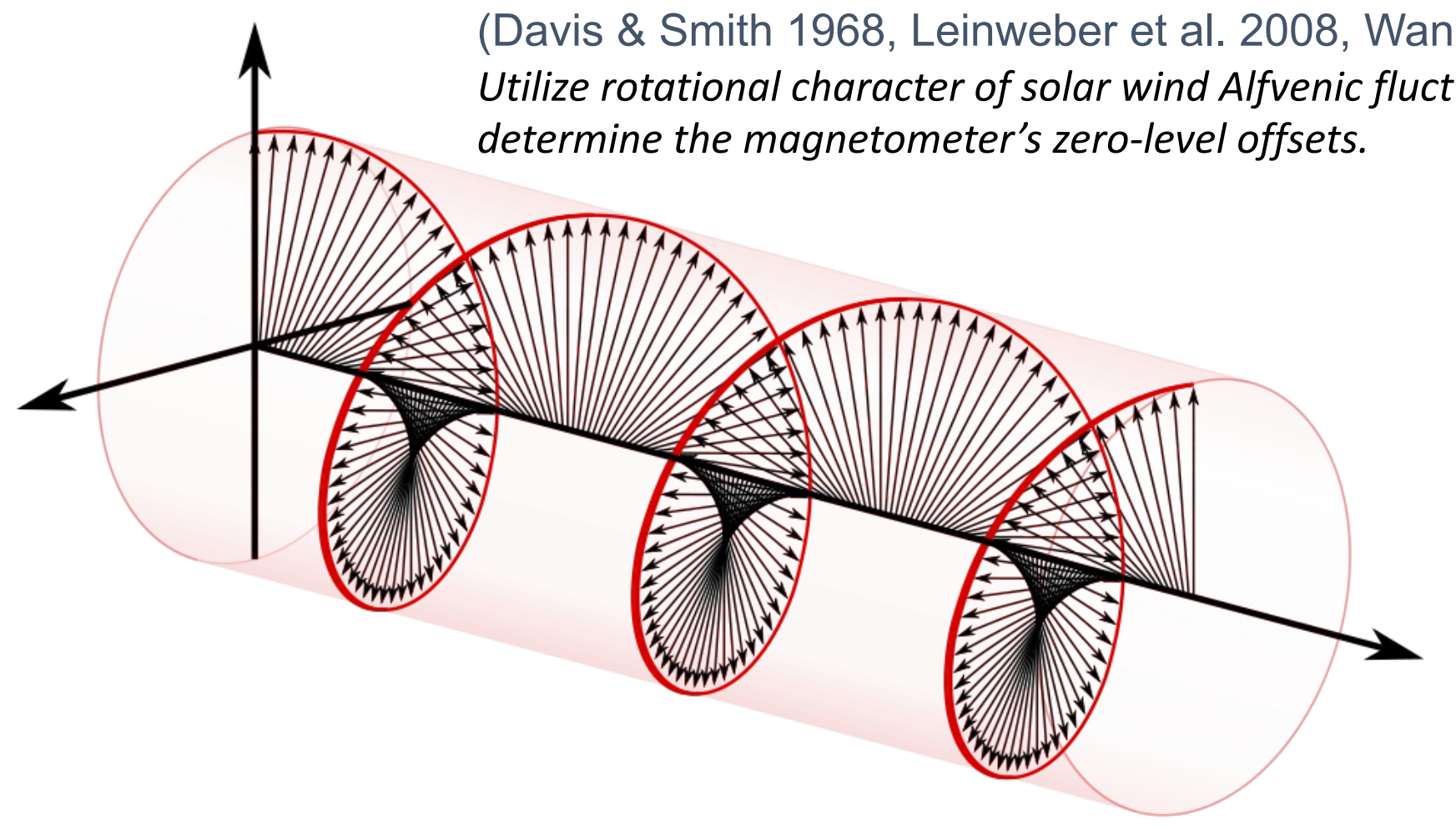


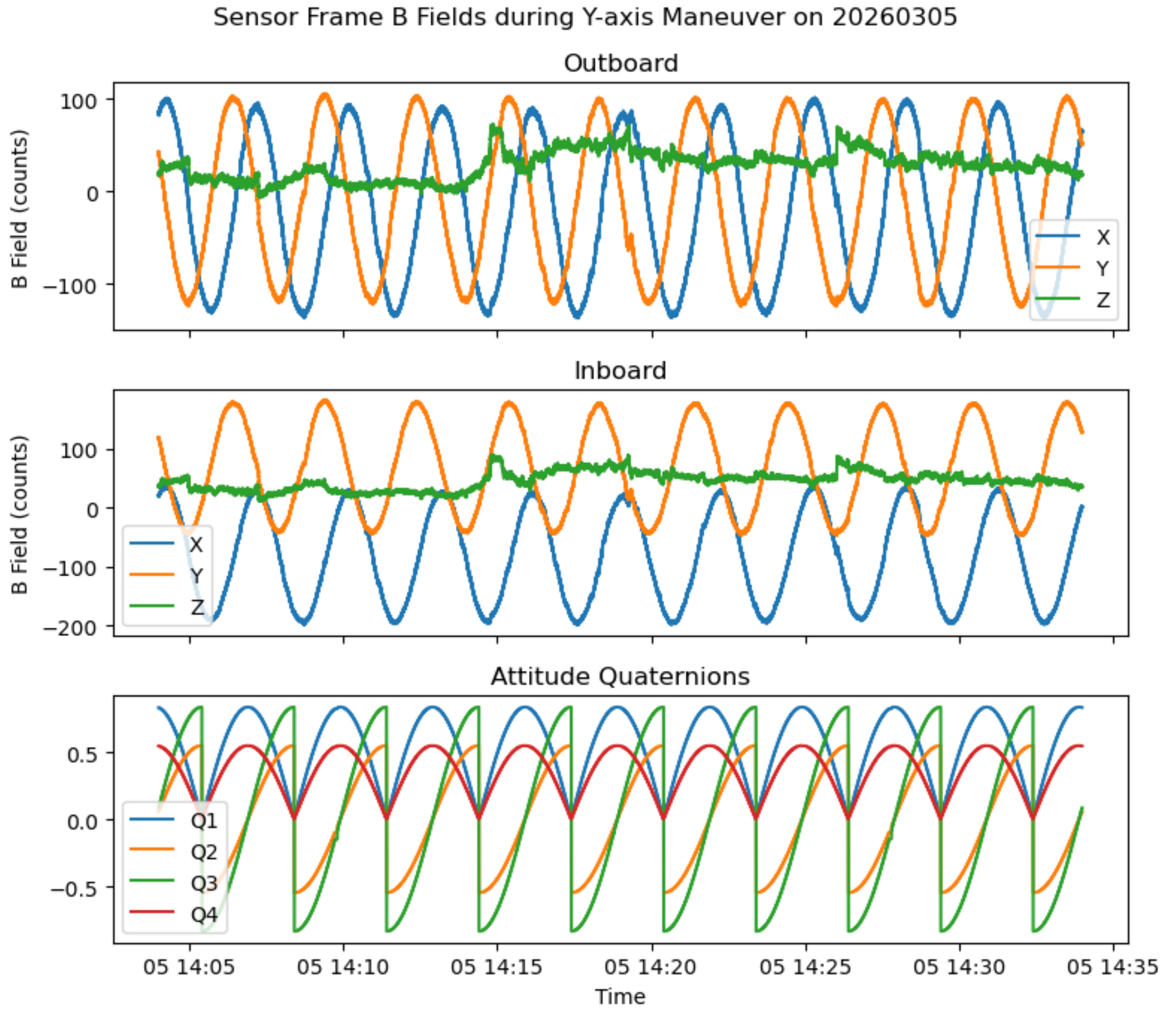
$$B = B_{raw} - B_{offset}$$

Davis-Smith method

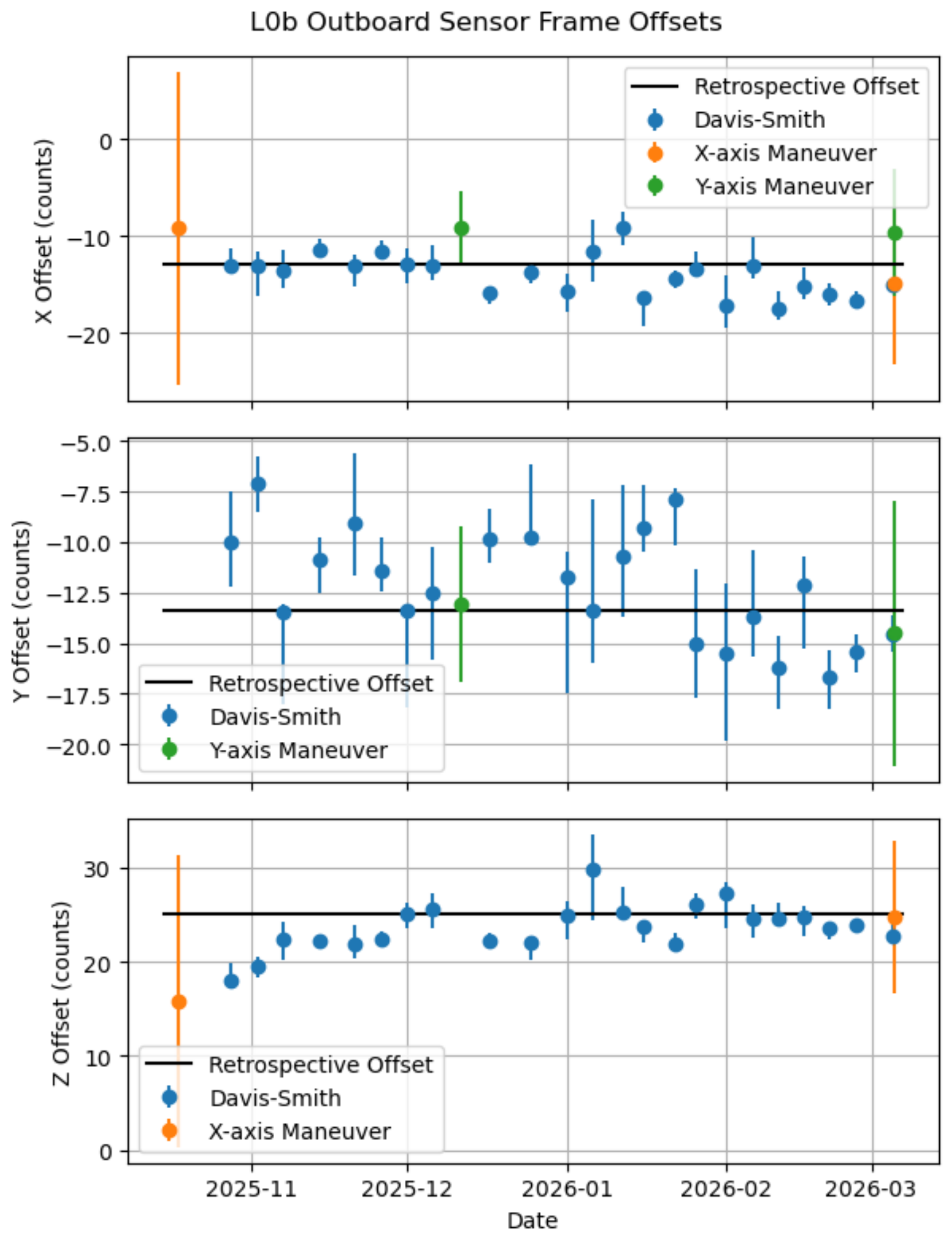
(Davis & Smith 1968, Leinweber et al. 2008, Wang 2022)

Utilize rotational character of solar wind Alfvenic fluctuations to determine the magnetometer's zero-level offsets.





- During rotational maneuvers, a constant offset in the sensor frame manifests as a **sinusoidal signal** in the stable frame
- Method determines offsets that **minimize the sinusoid's amplitude**



Maneuver method (orange & green) offsets are consistent with Davis-Smith!

Validation

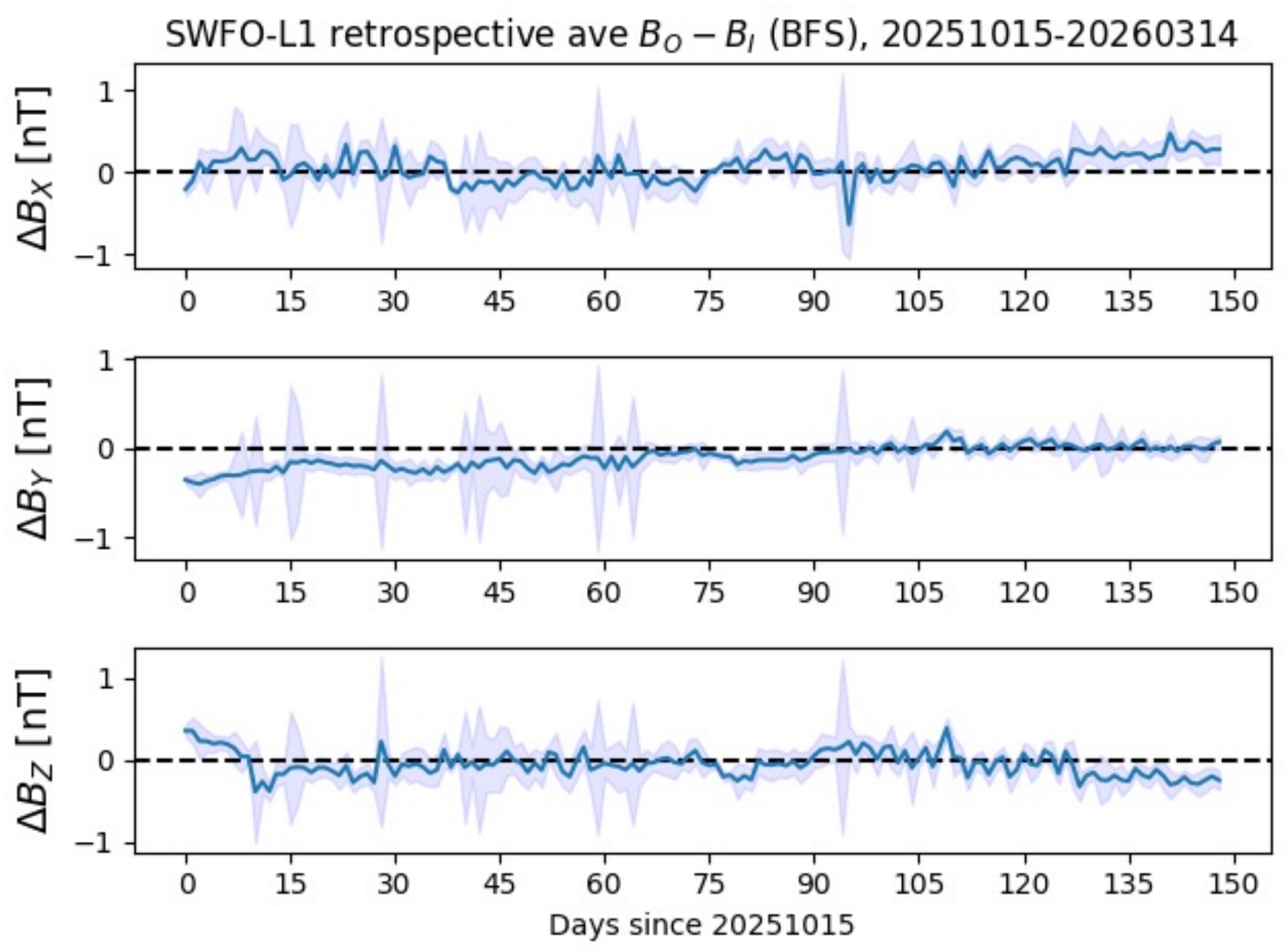
Sensor comparisons

Subtract the offset-corrected data from outboard (B_O) and inboard (B_I) mags

$$\Delta B = B_O - B_I \quad \text{(target: } \Delta B = 0\text{)}$$

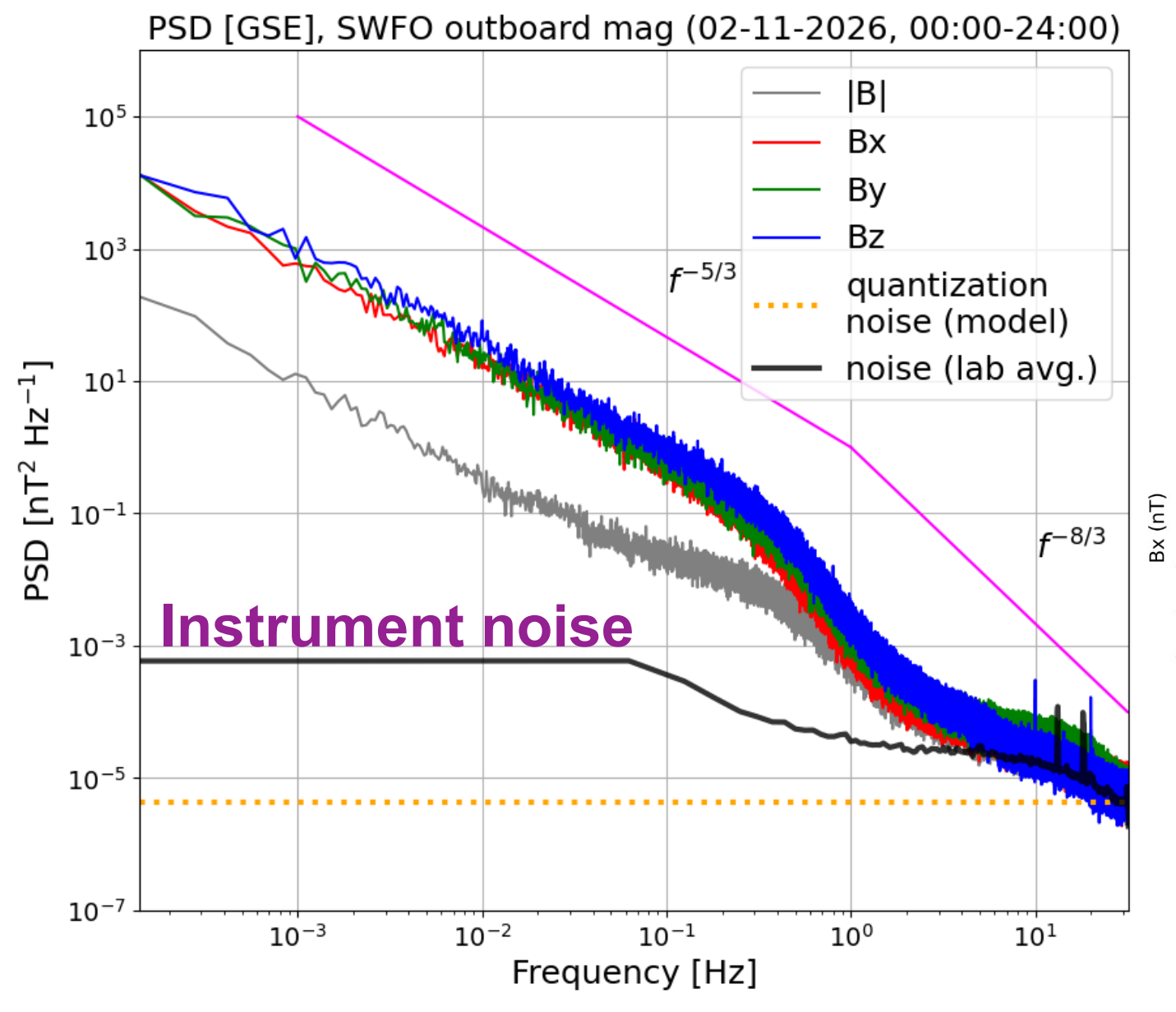
Averaged across **all** regularized-cadence 8 S/s measurements: ΔB_{ave}

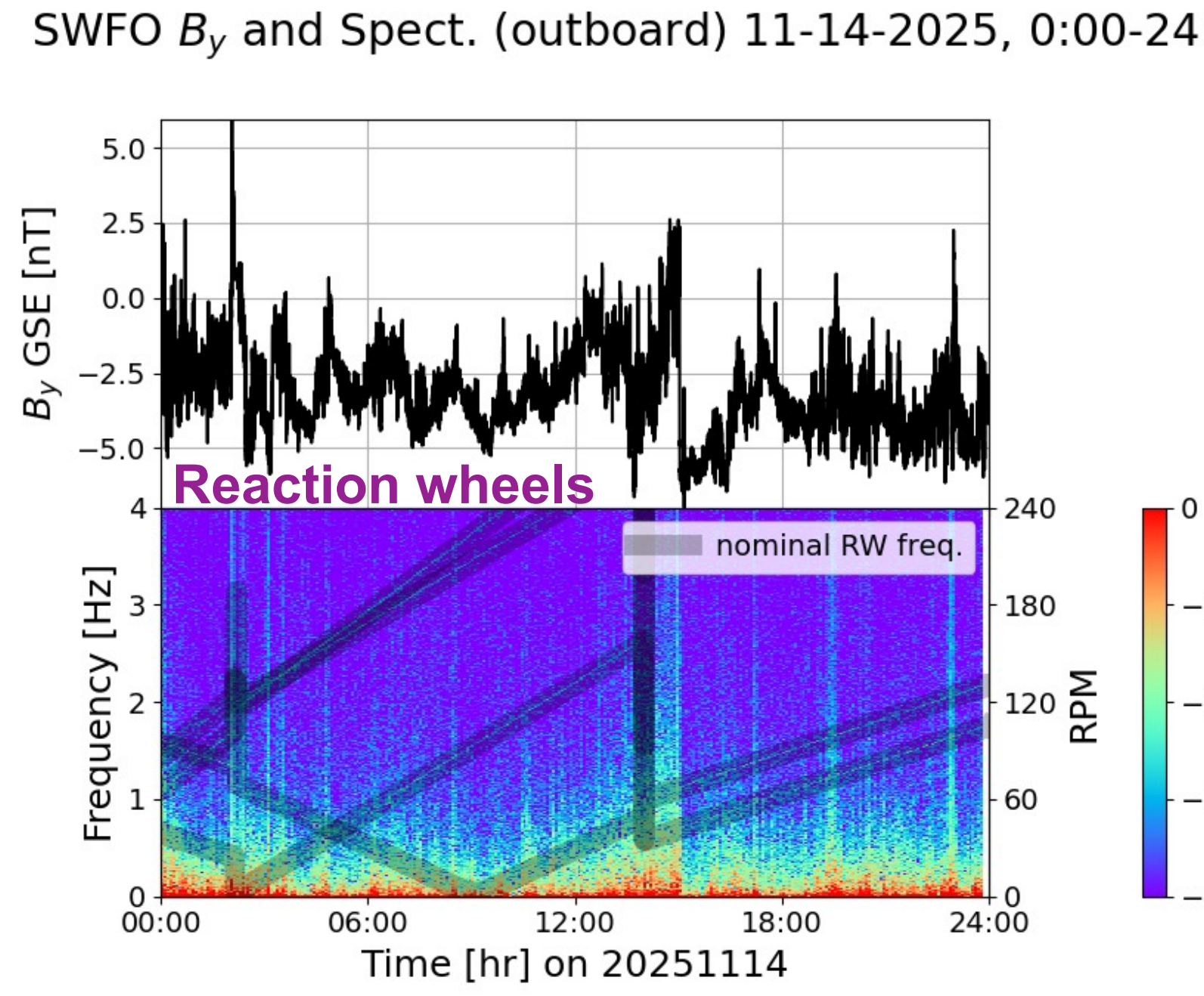
$\Delta B_{ave,X}$ = 0.09 ± 0.30 nT (mean ± 1-σ err.)
$\Delta B_{ave,Y}$ = -0.08 ± 0.25 nT
$\Delta B_{ave,Z}$ = -0.04 ± 0.29 nT

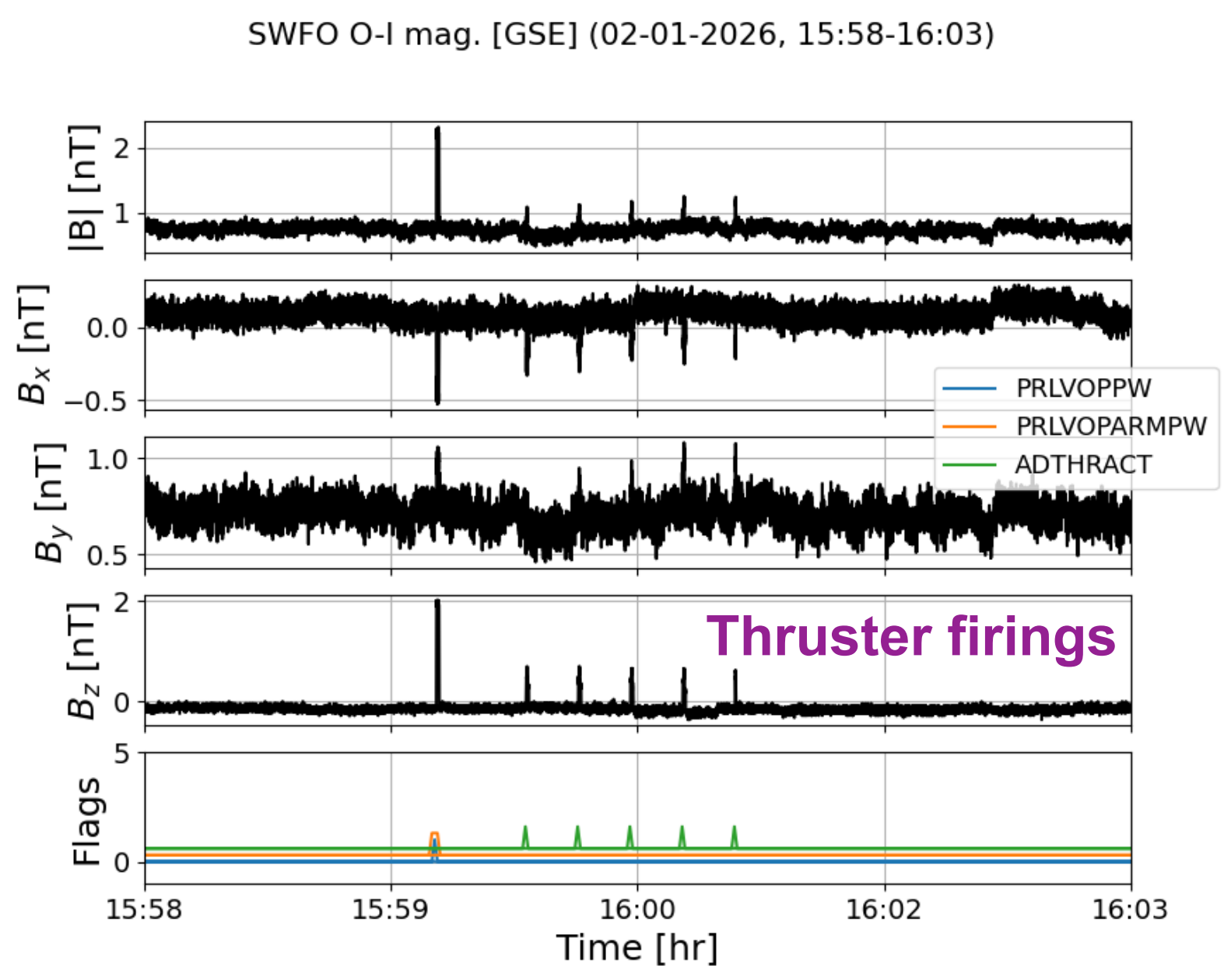


Product Level Noise

- Lower limit to on-orbit **noise floor** has been shown to correspond to lab-measured sensor noise floor
- **Reaction wheel** signatures have been shown to correspond to speeds recorded in telemetry up to 32 Hz
- Instrument noise and/or reaction wheels relevant at **frequencies > 1 Hz**
- A new flag has been implemented to flag **thruster**-related signatures

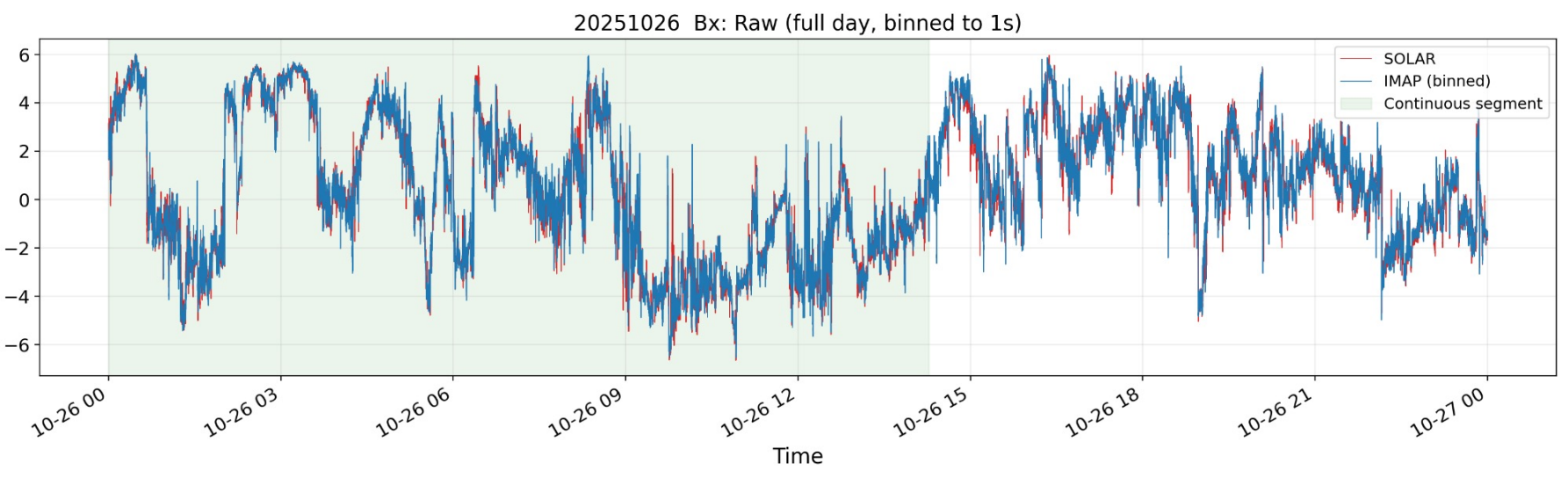


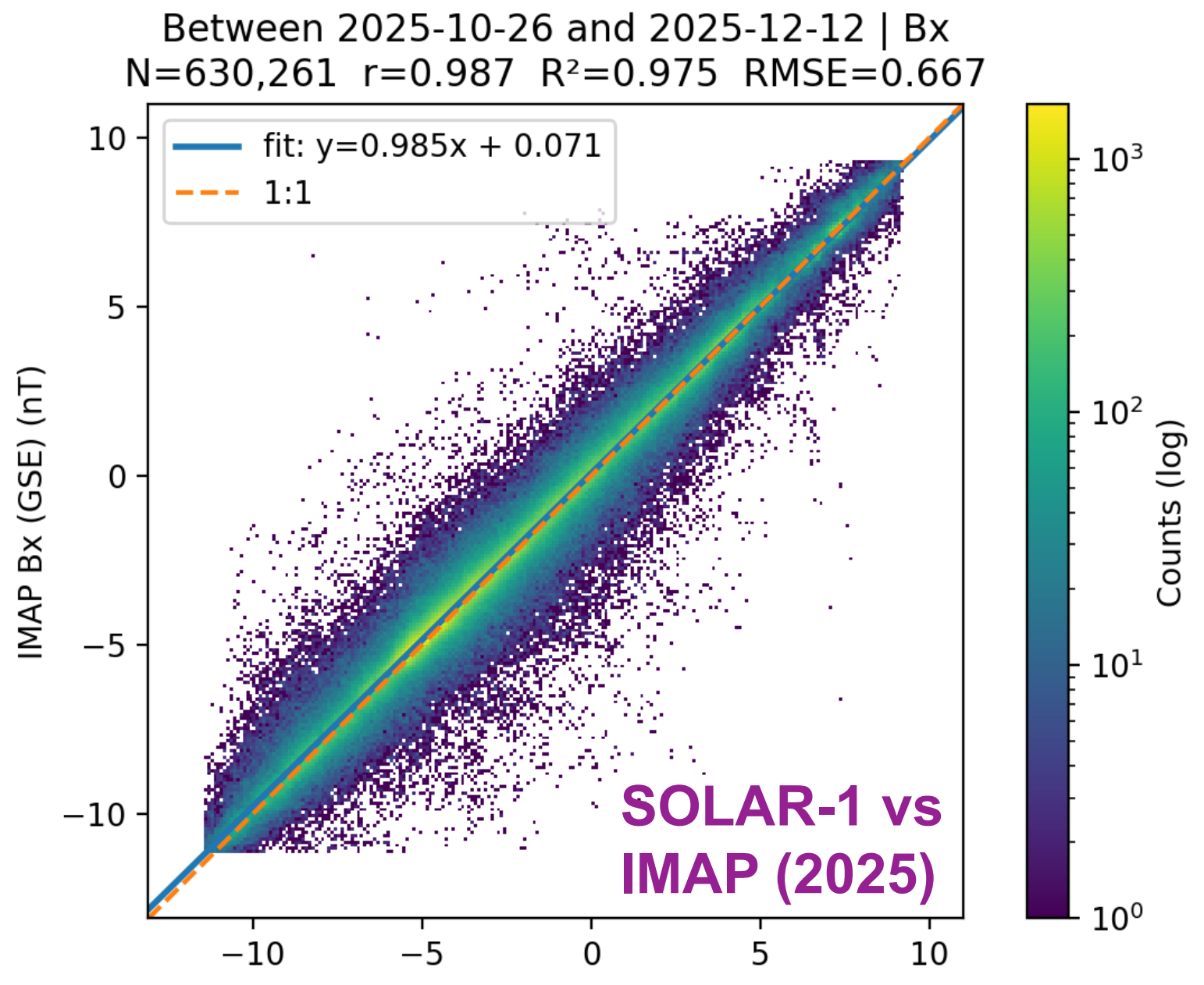




Inter-satellite Comparisons

- Correlate satellites' vector **B** time series
- Correct for time lag between signals
- **High SOLAR-1/IMAP* correlations (nearly 1:1) !**
- Good agreement with Wind, ACE, DSCOVR
  - More distant: ~40-170 R_E





GSE Frame	X	Y	Z	Av. Dist and Range (R_E)
SOLAR-1 vs IMAP (2025) **Cross-calibration opportunity**				
Linear Fit	y=0.985x + 0.071	y=0.974x + 0.019	y=0.993x + 0.178	**0.50** (0.43 - 0.57)
Correlation	0.987	0.990	0.985	

*preliminary IMAP data, used with instrument team permission

References

Califf, S., Rich, F. J., Loto'aniu, T. M., Singer, H. J., & Redmon, R. J. (2023). Long-term bias stability of the GOES-NOP magnetometers. Earth and Space Science, 10(11),.
Connerney, J. E. P., et al. (2017). The Juno magnetic field investigation. Space Science Reviews 213.1, 39-138.
Davis, L., Smith, E.J. (1968). In-Flight Determination of Spacecraft Magnetic Field Zeros. EOS Trans. AGU 49, 257
Leinweber, H. K., Russell, C. T., Torkar, K., Zhang, T. L., & Angelopoulos, V. (2008). An advanced approach to finding magnetometer zero levels in the interplanetary magnetic field. Measurement Science and Technology, 19(5), 055104.
Loto'aniu, P. T. M., Davis, A., Jarvis, A., Grotenhuis, M., Rich, F. J., Califf, S., Inceoglu, F., Pacini, A., & Singer, H. J. (2023). Initial on-orbit results from the GOES-18 spacecraft science magnetometer. Space Science Reviews, 219, 84.
Torbert, R.B., Dors, I., Argall, M.R., Smith, C., Fischer, D., Magnes, W., Vaith, H., Abel, D., Cardarelli, G., Frost, C., Vasquez, B., Marhefka, F., Valavanoglou, A. (2026). The magnetometer on SWFO-L1. Space Science Reviews. In review.
Wang, G. Q. (2022). In-flight calibration of the spaceborne fluxgate magnetometer in the Martian magnetosheath. Earth and Planetary Physics, 6(6), 592–600.

SPOT SPACE WEATHER PORTAL

Download the MAG data from the SPOT Space Weather Portal: **https://www.ncei.noaa.gov/cloud-access/space-weather-portal**

Acknowledgments

This research was supported by the NOAA cooperative agreement NA22OAR4320151.

The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of NOAA or the U.S. Department of Commerce.

We thank the IMAP magnetometer team for sharing the preliminary data shown here, which was used for comparison with SOLAR-1 MAG during post-launch commissioning.