In-Situ Calibration of the Swarm-Echo Magnetometers

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This paper describes an in-flight calibration method for the CASSIOPE/e-POP, now known as Swarm-Echo, satellite that was launched in 2013 and included two fluxgate magnetometers on a shared boom. Several issues with the attitude determination system, failure of reaction wheels over time, and the natural drift of off-set and gains of the fluxgates contributed to the magnetometer data becoming less reliable. The paper describes applying a method to use the Earth's model geomagnetic field during quiet times and some rules on when to trust or discard attitude determination estimates to create a new “clean” magnetometer data set.

This is a useful paper describing the new calibration methodology and will enable expanded scientific use of the SWARM-ECHO magnetic data set.

Specific and General Questions interspersed below.

- Line 11: “calibration performed on data from January 3, 2014, to January 30, 2021”
- What is the length of the boom and the distance to the two magnetometers?
- Line 20, for comparison – what is the orbital altitude of e-POP compared to the other SWARM spacecraft? Are there any “conjunctions” that can be used to calibrate magnitude (and with field-line tracing) the direction of the field between the SWARM spacecraft?
- Line 34: Suggest breaking last clause into separate sentence...“attitude. However that time interval is beyond the scope of this manuscript.”
- Line 65, 125: “data have...”
- Line 135: What is SQUAD/SLERP?
- Line 151: Is “&” used intentionally instead of “and”?
- Line 164: “metadata are...”; Line 165: “and are included”
- A lot of the work is attempting to get a good handle on the attitude of the spacecraft despite the loss of sensitivity of the star trackers and other ADS efforts. Is there housekeeping information that tells you when different subsystems are on or off to attempt to assess the magnitude of the spacecraft noise? What is the relative magnitude of the residual pointing accuracy error on the final data product compared to your estimate of the spacecraft noise?
- Line 192: “...important than the quantity” (than instead of that)
- Line 208: What is the effect of saturation of the sensor heads in terms of calibration? Was this a big effect initially (compared to the ground-calibration values), but once sensors were repeatedly permed up on orbit, minimal effect? (From Table 1 there seems to be essentially no impact on Gain.).
- Table 1: Though having a large stray field from the boom makes sense since the large X offset is seen in the outboard sensor and not the inboard, what is the boom made from that could give such a large field? It would be of interest to see the pre-flight offset values to get a sense of the combination of the spacecraft fields and off-set drift combined.
- Line 250: “taken”
- Figure 5. Is this “all” the data or only Kp<3 and small change in Dst “quiet” data?
- Line 279: “...in in-situ...”
- Was the inboard and outboard sensor used in a “Ness”-type gradiometer way to remove any spacecraft noise? If not, why not?
- Figure 6. What are the red and blue traces in panel b?
- A wild idea not necessarily to pursue for this study (following on the “conjunction” idea in a statistical sense given above), is to use the other SWARM satellites to determine the magnetic equator (when the field is horizontal) and compare locations of Echo with the other SWARM for different 7 day intervals. The poles do shift and move over months/years, but the equator should be pretty “fixed” over multiple 7 day intervals allowing for Echo to pass over the same longitude sector. The offset in location potentially can be used to estimate “off-set” in angle using the CHAOS field line mapping.