

Results from a prototype for the GOES Particle Intersensor Analysis Toolkit

William Rowland^{1,2}, Robert Weigel³, Changyong Cao²

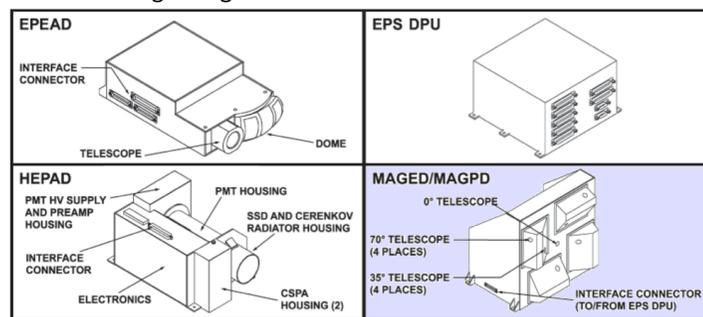
- 1) I.M. Systems Group; 3206 Tower Oaks Blvd. Suite 300 Rockville, MD 20852
- 2) NOAA/NESDIS/Center for Satellite Applications and Research (STAR); 5200 Auth Rd., Suite 701, Camp Springs, MD 20746
- 3) George Mason University; Department of Computational and Data Sciences, College of Science, George Mason University, 4400 University Dr., MSN 6A2, Fairfax, Virginia 22030

Introduction

This toolkit has been designed to intercalibrate identical particle telescopes which face in different directions aboard the same three-axis stabilized satellite. When implemented, it will permit both the scientists responsible for calibration and the users to monitor changes in sensor response over the lifetime of the instrument.

The instrument

Data from the GOES-13 Magnetospheric Electron Detector (MAGED) were used as a proxy for GOES-R data to test this toolkit. MAGED has 9 identical telescopes facing in different directions, each of which has 5 energy channels measuring energies between 30keV and 600keV.



Elements of the EPS: the EPEAD, EPS DPU, HEPAD and MAGED/MAGPD
Taken from http://www.gsfc.nasa.gov/GOES/GOES-NOP_Bookstore.pdf

Concept

Intercalibration of particle telescopes requires identifying time intervals where multiple telescopes should be measuring the same flux. Fluxes for these telescopes are calculated by multiplying the count rate by a constant. Count rates have been utilized here because relative differences are currently being examined, avoiding an extra multiplication. Particle distributions can be described by the number density of particles with a given velocity 3-vector at a given position 3-vector (a 6-d phase space). All 9 telescopes are on the same satellite, therefore, for this application the position portion is resolved. Each telescope also measures the same set of five particle energies.

The telescopes are pointing in different directions, and therefore accept particles with different velocity vectors. Finding integration periods where particles with different velocity vectors are in equivalent phase space regions is therefore the purpose of the tool. The first adiabatic invariant for particle physics is applicable under the conditions present, and is given by the following equation:

$$\frac{1}{2} m * v_{\perp}^2 / B = \frac{1}{2} m * (v * \sin \alpha)^2 / B = \mu$$

This means that the energy associated with a particle's motion perpendicular to the magnetic field has a constant ratio relative to the magnetic field magnitude. The perpendicular component of the motion can be calculated based on total velocity (constrained by particle energy) and pitch angle. Therefore, to first order, all particles with identical pitch angle and energy are confined to the same fixed region of the overall phase space. The pitch angles for particles accepted by each telescope are governed by the pointing of the telescope relative to the magnetic field.

The tool permits the user to identify and compare data for which the telescopes have the same pointing relative to the magnetic field.

Verification

To verify the calculations performed, proxy data were created. The magnetic fields used were in the following directions in the spacecraft reference frame: +X, +Y, +Z, -Z, then in the direction of each telescope (opposite that of the particles going into them), and finally going from 0 to 360 in X-Z Plane, then 0 to 360 in Y-Z Plane.

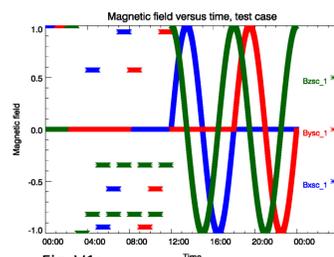


Fig. V1: Test case data giving X, Y, and Z components of magnetometer measurements. Coordinates shown in Fig. V3.

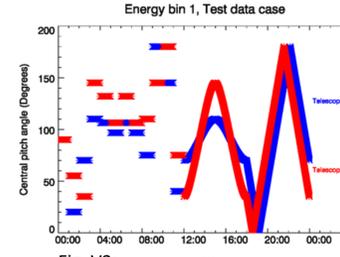


Fig. V2: The central pitch angle for the magnetic fields generated by the test case described above.

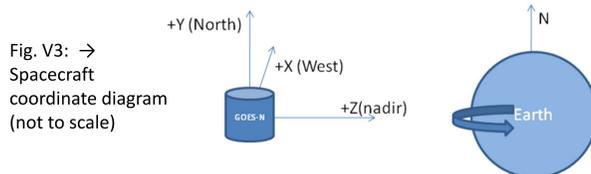


Fig. V3: → Spacecraft coordinate diagram (not to scale)

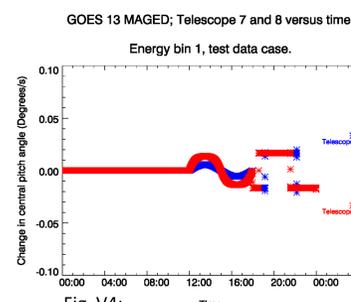


Fig. V4: The rate of change in the pitch angles calculated in Fig. V2. The user can screen out data if the rate of change is large.

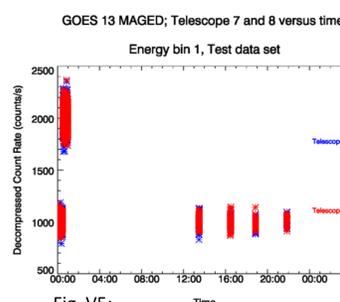


Fig. V5: The count rate for each telescope where the angles showing in V2 match to better than 1 degree. Real data meeting these criteria permit direct comparison between the telescopes.

References and Acknowledgements

Osager, T.: Geostationary Operational Environmental Satellite (GOES) Program, 2006: GOES-13 Contingency Operational Readiness Review (CORR) Instrument Performance Assessment, August 28, 2006, 95pp.

Thanks to Juan Rodriguez and Janet Green of SWPC for helpful conversations concerning the topic, and for providing the initial test data used to prototype the program.

Thanks to Dan Wilkinson and William Denig from the NGDC for stewardship of and access to the data used to baseline this version of the program.

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Results

These are results for telescopes 2 and 4 of GOES-13 using data from the summer of 2010. The algorithm can easily incorporate additional data.

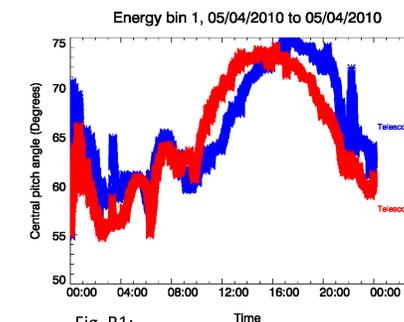


Fig. R1: The central pitch angle for particles measured by two telescopes. This was calculated using data from the GOES-13 Magnetometer.

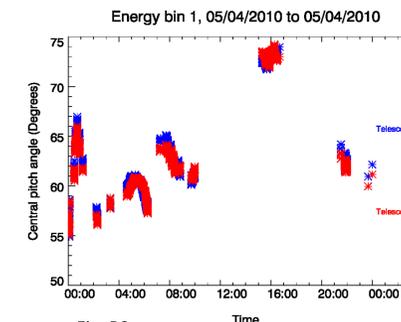


Fig. R2: The subset of data from Fig. R1 flagged as matching to within 1 degree. These data can be used for intracalibration.

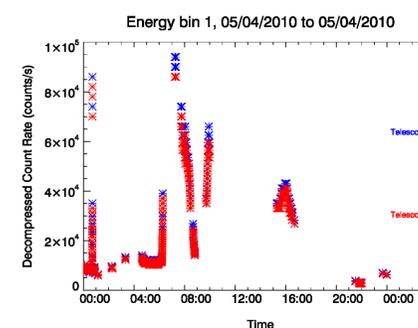


Fig. R3: The decompressed count rates corresponding to the matching data. "Decompressed" count rates are the count rates after data compression has been taken into account.

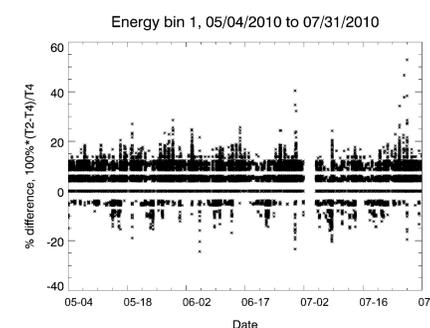
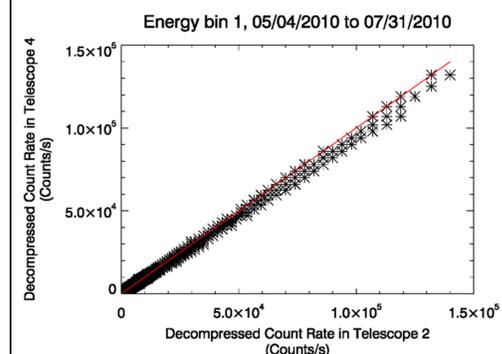


Fig. R4: The % difference between Telescope 2 and Telescope 4 for three months of 2010. The banding effect is caused by the data compression algorithm used for the GOES-NOP series and will not be present for the GOES-R series. Notice that Telescope 2 generally has a higher count rate even when viewing the same distribution of particles than Telescope 4. A minimum threshold of 1000 counts per integration cycle was selected.

GOES 13 MAGED; Telescope 4 versus Telescope 2



← Fig. R5: The decompressed count rate of T4 against that of T2 for the matches identified above. Again, T2 generally has a higher count rate than T4.

Conclusions and Future Work

The technique provides useful data comparing the responses for various telescopes, and will be equally applicable to the GOES-R MPS-Lo and MPS-Hi.

The software will be automated to run new data as they become available. After that, the next step will be to fold in analysis routines permitting determination of appropriate adjustments to the calibration coefficients of the instrument. Extension of the toolkit to work with MAGPD data is also necessary, and should be achievable in a reasonable timeframe either before or after the items just mentioned.