Comments on **Principal Component Gradiometer technique for removal of spacecraft-generated disturbances from magnetic field data** by Ovidiu Dragos Constantinescu, Hans-Ulrich Auster, Magda Delva, Olaf Hillenmaier, Werner Magnes, and Ferdinand Plaschke.

The article presents an approach for correcting boom satellite magnetometer data by using reference magnetometers mounted within the satellite or on the boom closer to the satellite. The authors present the PiCoG algorithm (Principal Component Gradiometer algorithm). The idea is to identify the stray magnetic satellite field using a multitude of magnetometers and to remove it from the data.

The difference between measurements of different magnetometers show just the disturbing fields. The correction to be done depend linear on the measured differences. A Matrix **A** giving this linear dependence is to be determined and uploaded to the satellite for on board processing.

In **Section 2.1** the dipole field formula is used to show that a known dipole stray magnetic field at one magnetometer position, can be used to calculate the stray field at another magnetometer if positions of both magnetometers and of the disturbing dipole is known. The dipole moment is not needed. The same is done for a quadruple stray source.

In **Section 2.2** the situation with several sources is discussed: The contributions from more than one simultaneously active, arbitrary placed source with arbitrary time dependence cannot be separated from the ambient field in a simple way. At least two magnetometers are needed. Sources whose distance is small compared to the distance of the magnetometer act like a single multipole. It is stated: “For the procedure to work, the quadrupole contribution must be much weaker than the dipole contribution at both sensors.”

Configurations are discussed that may simplify the evaluation: One sensor is placed close to a disturber allows eliminating this disturber. Three mutually orthogonal sources can be separated using two (three axe) Sensors by principal component analysis. If more than three sources are present more than two sensors are required.

In **Section 3** the PiCoG cleaning algorithm is illuminated. While the ambient magnet field is the same at all sensors, the disturbance is not and can therefore be removed. The difference of two sensors is independent of the ambient field (Eq. 9). The disturbance at a given sensor is related to the differences to all other sensors by a Matrix A. The correction matrix A is to be computed directly from the measurements.

In **Section 3.1** it is assumed, that the disturbance to one sensor is much larger than to the others and an iterative procedure is proposed, dealing with one disturber first. To determine the direction of the stray field at each sensor, it is assumed that changes in the stray field are large compared to changes in the surrounding field values. The authors look at the variance of the measurements, identify the stray field variations and call the stray field direction at each sensor the “x-direction of a VPS (variance principal system)”. The stray field measured at one sensor can be used to correct measurements at another sensor. The correction to the VPS-x direction of the i-the sensor is proportional to difference between measurements of j-th and i-th sensor. Constant of proportionality is the square of the quotient of variance of the disturbance to the i-sensor by the variance of the difference. This procedure is summed up in the Matrix **A** and gives the first estimate of **A** in the iterative process.

In **Section 3.1.1** the case of two sensors and the disturbing dipole being lined up is discussed.

In **Section 3.2** the successive use of further disturbers is formalized.

In **Section 4** an application to data of spacecraft GK2A is presented. Two magnetometers on a boom and two magnetometers at the platform are available.

What exactly has been done is illuminated in **Section 4.1 .** One of the platform magnetometers is not used due to noise considerations. The other platform magnetometer is used to remove disturbance at both boom magnetometers. A time period with a prominent disturbance is used to determine the respective correction matrices. The direction of the disturbing signal in the boom magnetometer system is determined by calculation the variance on a 1°x1° grid. A second-order correction using platform magnetometers was not done, once more for reasons of noise consideration.

Remark:

The presented method needs the disturbing sources to change with time (variance analysis). In spacecraft magnetical cleanliness DC magnetic disturbers play a big role. On the other hand the offset drift of fluxgate magnetometer is a known problem. Is the method valid for DC calibration? Otherwise write “AC disturbance” in line 5 (Abstract) and in line 496 (Summary and Conclusion).

Critics on the method:

The authors report on their approach to correct measured magnetic data of the SOSMAG satellite. This is very interesting to coworkers on interpreting SOSMAG data. As reviewer I have to ask myself though, if the paper provides information useful beyond the SOSMAG satellite for a reader, who has the task of cleaning up magnetometer data. The authors call their method to deal with the SOSMAG data “PiCoG algorithm”. It is more of a methodology than an algorithm that could be coded as is.

In chapter 2.1 interesting formulas are deduced for dipole and quadruple fields. They are used to show, that the magnetic field of a low frequency source can be factorized in a time-dependant and a geometry part. But is not that clear anyway for quasi DC magnetic sources? Do the formulas for the geometry factors enter the evaluation?

In chapter 3.1. it is assumed, that one of the magnetometers is very close to a disturber. Does the method also work, if that is not the case?

Unfortunately none of modern methods for analysis of multivariate time series is used. Principal component analysis is one of them. It uses spectral analysis of the cross-covariance matrix of all additional measured magnetometer components with respect to the reference magnetometer. The components of the first eigenvector (largest eigenvalue) directly delivers the set of direction consinus deduced in chapter 3.1 to define the “x-direction of the VPS” for each additional magnetometer. Of course a paper could be interesting if it goes beyond standard methods. But it should than be clear that it surpasses their results in a certain respect. The results of sec. 2.1, that means the known geometry factors, add information not been used in standard methods. Using for example the geometry factors for better identifying disturbing time series in the data, or for better determining the distribution of disturbing signal to the different magnetometers would render this paper interesting to a broader public.

The time dependence of the disturbing signal is not at all used in chapter 3, where the PiCoG Algorithme is defined. Nevertheless during the actual data evaluation the authors implicitly use the time dependence by looking at different time periods, with different sources active. Fig. 2 shows the distribution of directions on a sliding window. Later on, in chapter 4. ramps and spikes are used to validate the result. These tricks should be included in the PiCoG algorithm.

The variance of measured date is used. That means field sources (ambient andmdisturbing fields) are understood as random processes. The motivation is not clear. In chapter 4.1 ramps and spikes in the measured time series are identified and used for validating the PiCoG results. The step amplitudes in all components could directly be used to deduce the geometry factors (Component of Matrix A in formula 10) between different magnetometers.

Fig. 4. Shows magnetometer values in the coordinate system orientated along the main axes of the data variances ellipsoid (VPS system). The figure shows, that the spike signal is still present in the z- and in the y-direction. Accordingly the VPS x-direction does not point along the spike disturbance.

Further remarks or questions:

L39: The PiCoG Process also is not running on the SC.

L48: This is the case if only variances are looked at. But the authors look later at ramps and spikes. They can even be identified, if they point along the ambient field.

L48: The term “principal component” is misleading. It usually refers to direction of a main axe of the stray ellipse in a multivariate random process.

L107: Perhaps better: “a collection of dipoles will in general generate multipole moments”

L 151: Which term is much larger? Would a strong disturber really make only one term large?

L137 this sentence would be more readable, if the summation symbol was omitted.

L157: Do you mean: “disturbing magnetic moments are fixed in direction with moments changing with time”?

L158: The stray field of one disturber has a constant direction in the magnetometer system. No need for a new coordinate system.

L166: Using this VPS suggests, that the disturber itself is a multivariate random process. But that is not the case. The VPS-x direction can be calculated by correlating the disturbing field strength with the measured x-, y- ,z- components. The term “variance principle system” is misleading. The reader could get the impression, that principal component analysis was done.

L167: Are the alpha i,j in Eq. 13a the same as the A i,j in Eq. 10? Than please use the same denomination.

L191: It is not clear to me if the b’s are known at this point and if yes, where they are calculated.

L211: Do you mean “if stray fields of different disturbers are not coincident at the magnetometer location”?

I quit following the text here because the authors use a matrix notation, where I guess vectors of stray fields are sufficient.

Conclusion: The paper is an excellent report on how the authors achieved to clean and calibrate SOSMAG data. However the term “principal component technique” in the title is misleading. The authors should revise the method and try to use or at least refer to standard methods for multivariate data analysis and, if possible, expand them to produce a paper of more general interest.