CLUSTER and MMS missions : Estimation of the gradient of a field with a flattening tetrahedron

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The ESA mission CLUSTER, successfully launched in 2000 has been the first one to involve four identical spacecraft orbiting simultaneously around the Earth in order to provide a three dimensional view of plasma processes with inter-spacecraft distances varying from a few tens to a few thousands of kilometers. CLUSTER is going on and has already demonstrated the impressive benefit of simultaneous multipoint observations; its success has triggered new projects like the NASA MMS mission, launched in 2014, which is currently investing shorter scales than CLUSTER. For not too large inter-spacecraft distances, multi-spacecraft data analysis methods have been developed to estimate gradients of fields : see the detailed presentations in two ISSI books [1,2]. It has been demonstrated by Chanteur [3] that estimated gradients are spoiled by large errors when the tetrahedron of spacecraft flattens, which occurs twice per orbit and sometimes during “interesting” time intervals. Shen et al. [4] proposed to estimate gradients under such difficult configurations by making use of the principal axes of the inertia tensor of the configuration of the cluster : that solves the problem only partially, but the divergence remains along the normal to the plane of the singular “flat” tetrahedron. We have designed a rigorous analysis of the flattening tetrahedron by making use of a frame of reference attached to the tetrahedron which allows to estimate all components of the gradient, avoiding any divergence but nonetheless the estimated gradient is affected by the geometrical amplification of errors due to the flattening.

References

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