Characterization of lightning with ISUAL data in order to identify the Transient Luminous Events of the TARANIS mission

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The main objective of the TARANIS (Tool for the Analysis of RAdiation from lightNing and Sprites) satellite is to understand transient energetic event mechanisms that generate transient luminous emissions (TLEs) and emitted gamma ray flashes (TGFs) in atmosphere above thunderstorm areas. These emissions highlight the coupling between atmosphere, ionosphere and magnetosphere. TARANIS microsatellite will observe from nadir. TLEs identification is impossible using images on board because TLEs and lightning are superposed. On board triggering using photometers is set up to further TLEs recording. It is necessary to take into account the temporal and spectral characteristics of lightning and TLEs. For this purpose, a dataset from a previous space mission called ISUAL is used. The main objective of the presented work is to show a new approach for a better knowledge about lightning and TLEs recognition.

1. Introduction

TLEs were discovered in the early 1990s. These events appear above thunderstorm areas all around the Earth [1, and all references there in]. Previous observations have shown that these emissions covered a broadband spectrum including radio wave, infrared (IR), far ultraviolet (FUV) [1]. The TARANIS mission will attempt among others to better understand the physical mechanisms at the origin of TLEs [2]. Their mechanisms are as diverse as the emissions are different from each other [1].

The new feature of the Micro Camera and Photometers instrument (MCP) aboard TARANIS is the spectral differentiation of light emissions produced by lightning and TLEs from nadir viewing. However, lightning and TLEs signals are superposed in this observation direction. Consequently, the identification is complex [2,3]. These, it is essential to characterize better lightning signal to make easier recognition with TLEs. For this purpose, we used a dataset from a previous space mission.

2. ISUAL's dataset

The ISUAL (Imager of Sprites and Upper Atmospheric Lightning) experiment on the FORMOSAT-2 satellite has recorded over 90000 events between 2004 and 2010. This mission has found nearly 7000 elves, 800 sprites, 800 halos, 20 gigantic jets during 2004 and 2010 [4,5]. Using ISUAL data is very convenient because MCP Photometers bandwidths are very similar to the ISUAL spectrophotometers ones. The main difference between the two missions is the direction of the observation. ISUAL observed lightning and TLE from limb. ISUAL can differentiate temporally and spatially the lightning and TLE signals. A dataset includes events that are not listed by the ISUAL team like sprites, halos, elves or gigantic jets have been built. The purpose of our study is to validate that all these events are lightning or if some of them are dim TLEs.

3. Data analysis

We adapted two chemometrics approaches to analyse our dataset. Chemometrics is a research topic in physics and chemistry which emerged in the early 1970s [6]. This subject develops and applies mathematical and statistical methods to select optimal experimental procedures and to extract the maximum information about data from chemical analysis. The aim of this technic is to decrease the instrumental limits in order to understand system reactions or complex samples [7,8].

Two types of chemometric tools can get more information about TLEs and lightning without a priori consideration. The Principal Component Analysis [9] (PCA) was first used. It aims to express the structure of variation of a set of descriptive

variables of a data matrix. The photometer signals help us to characterize all the events of our database. Successive PCAs enabled us to locate and identify two types of events in our database, Figure 1. We used several PCAs like a hierarchical approach on time and photonic variables. We show that we have some lightning and dim elves without ambiguities.

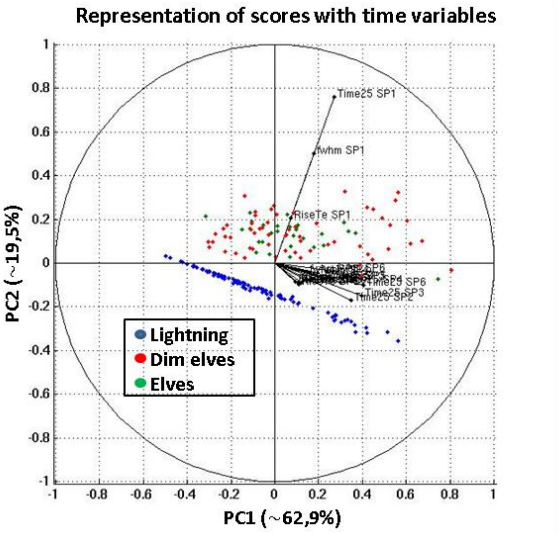

Figure 1: PCA result.

Nevertheless, it is impossible to deduce a model on photometric waveform of lightning and dim elves with this methodology. We needed to use a more complex chemometric tool.

We thus used a soft-modelling approach called PARAFAC [10] (PARAllel FACtor Analysis) to confirm those results. This algorithm works on 3-way data. We reorganize also our photometric signals from our dataset in a cube matrix. Then, it was possible to model our two main signal events, Figure 2. A dim elve signal is really hard to identify because this event is not visible in the image. Furthermore, their photometric signals are close correlated with lightning.

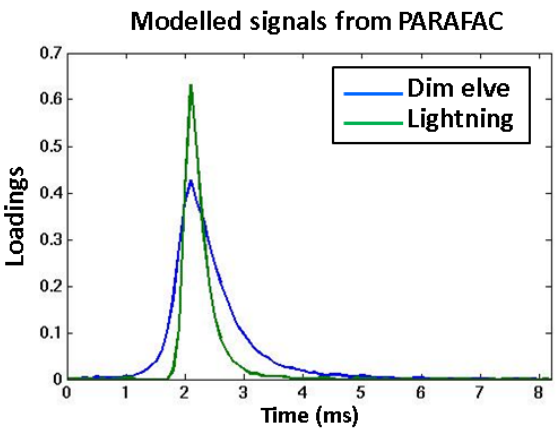

Figure 2: Result from PARAFAC study.

Our results confirm and complete those shown by Chang et al. [11].

4. Outlook

The presented work is the first step of implementation a classification methodology. The used of chemometrics tools demonstrate the feasibility of recognition dim elves in ISUAL dataset without bias.

5. References

[1] V. P. Pasko, Y. Yair, C. L. Kuo, Space Science Revue, 168 (2012) 475–516.

[2] E. Blanc et al, Journal of Geophysical research: Space Physics, 109 (A2), A02306 (2004).

[3] P. Hébert et al, paper number 134 of 9th ICSO International Conference proceedings, October 9th-12th 2012, Ajaccio, France.

[4] A. B. Chen et al, Journal of the Korean Astronomical Society, 38, 303-305 (2005).

[5] C. L. Kuo et al, Geophysical Research Letters, 32, L19103 (2005).

[6] W. H. Lawton, E. A. Sylvestre, Technometrics, 13, 617 (1971).

[7] M. Offroy et al, Analytica Chemical Acta, 674, 220-226 (2010).

[8] S. Piqueras, L. Duponchel, M. Offroy, et al, 85 (13), 6303-6311 (2013).

[9] D.L. Massart et al, Handbook of Chemometrics and Qualimetrics: Part A, Elsevier, Amsterdam, 1997.

[10] R. Bro, Chemometrics and Intelligent Laboratory Systems, 38, 149-171 (1997).

[11] S. C. Chang et al, Journal of Geophysical Research, 115, A00E46 (2010).