TELLUS Experiment. Detection of transient phenomena associated with thunderstorms.

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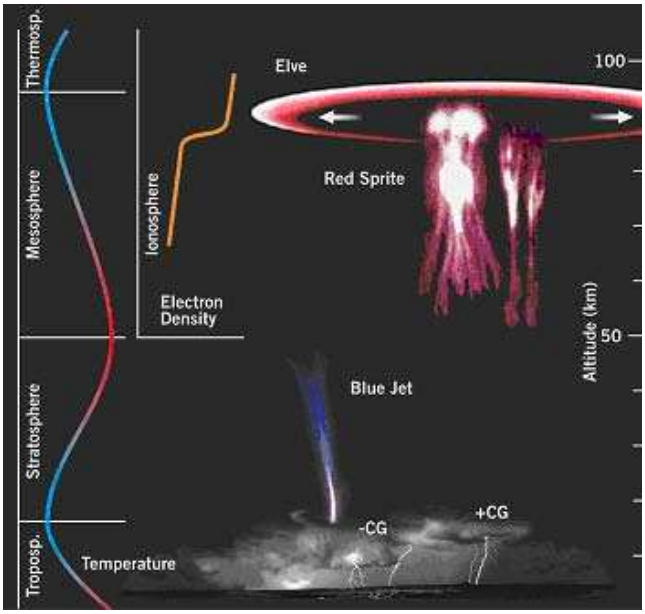
Abstract

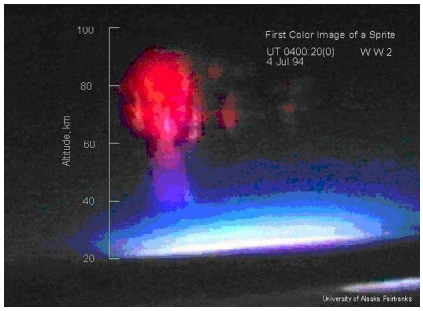
A set of instruments has been planned to detect in the near-Earth space TLEs and TGFs phenomena associated with thunderstorms as well as X/γ rays from sun and cosmic rays and fluxes of high-energy particles from the inner radiation belt. The instrumental set includes optical and UV photometers and video cameras as well as X/γ and particle detectors. Such instruments are planned to be installed on board a LEO satellite or the ISS in order to study the large energy transfer from the troposphere to the atmosphere, ionosphere and magnetosphere regions and the temporal stability of the Van Allen radiation belts. Also geomagnetic cavity perturbations produced by sun and cosmic rays can be investigated by these instruments. During the year 2009 also three patents were produced by the TELLUS team.

1 The Tellus experiment

Aim of the experiment is to detect tropospheric TLEs, lightnings and TGFs, to contribute to the understanding of TLEs interaction mechanisms with TGFs, to study the large energy transfer ($\simeq 250MW \div 1GW$ per event) produced by TLEs and TGFs from the troposphere to the atmosphere/ionosphere/magnetosphere and investigate the temporal stability of the Van Allen radiation belts. At this purpose specific instruments have been planned to be installed on board a LEO satellite and/or the International Space Station (ISS). The processes storm in the upper atmosphere generates intense luminous phenomena called TLEs (Transient Luminous Events). Observations of TLE have shown the existence of an intense dynamics of impulsive transfers of energy between the atmosphere and ionosphere. The most commonly observed from the ground are the "red sprites" (Stratospheric/mesospheric Perturbations Resulting from Intense Thunderstorm Electrification), a manifestation of electrical breakdown in the mesosphere. A graphic representation of the main TLEs phenomena is reported in figure 1 with a few details concerning Red Sprite characteristics. References are reported in the reference list.

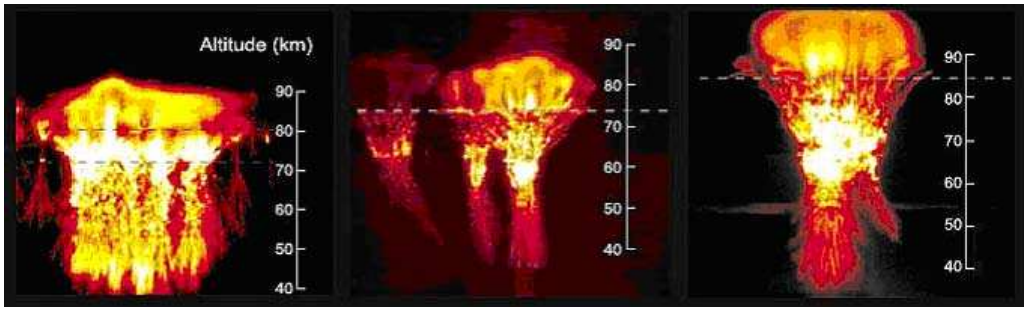


(a)



(b)

(c)



(d)

Figure 1: [a] Main tropospheric TLEs phenomena; [b] First imagine of a red sprite event detected by NASA in 1994 during the night between July 3 and 4; [c] Colored imagine of a sprite event over an intense lightning occurred in Africa at an altitude of 80-90 km; [d] Characteristic spatial dimensions of a red sprite event.

Above the storm formations intense emission of X/γ rays are observed. They are the so-called Terrestrial Gamma ray Flashes (TGF). The first detection of TGF above areas with thunderstorm has also provided the evidence of the flow of relativistic electrons in the upper atmosphere. A TGFs geographic distribution is given in figure 2. Adding information can be found in the publications reported in the reference list.

2 Intruments

For detecting TLEs and Lightnings two blocks of optical-UV instruments have been considered, one of which is nadir pointing and the other one limb oriented. Each block is constituted by 2 video cameras and 4 photometers with filters adapted to mainly detect red sprites, blue jets and lightnings, respectively. The main characteristics and a pictorial view of these instruments are reported in table 1 and figure 3 respectively.

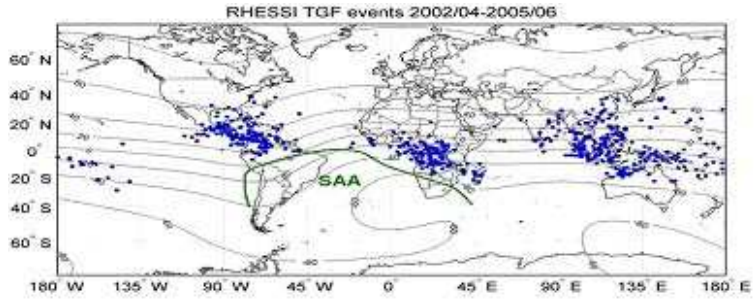


Figure 2: Geographical distribution of TGF events.

Two instrumental units have been designed to detect TGFs, one of which is nadir pointing and the other one tangent to the satellite orbit. Each unit (figure 4) consists of two different instruments combined and assembled together: an X/γ ray detector and a charged particle detector. The X/γ ray detector measures tropospheric X/γ emissions (studying the characteristics and sources of TGFs and their correlations with TLEs) and detect X/γ rays from sun and cosmic rays, thus investigating the effects of these radiations to the magnetospheric cavity. The charged particle detector may detect fluxes of high-energy charged particles from the inner radiation belt, which gives information about particle precipitation mechanisms and sources as well as stability of the Van Allen radiation belts.

Instrument	Function / Mode	Pointing mode	Run period	λ (nm)	Transition	FOV (deg) (nadir / limb)	Resolution (pixels)	Bit	Sampling Rate
Video Camera	Sprite camera	Nadir + Limb	Night	762±5		55 / 20	1024 x1024	10	30 fr/s
Video Camera	Lightning camera			600-800		55 / 20	1024 x1024	10	30 fr/s
Photometer	Trigger / Acquisition			762±5	O_2 (0,0)	55 / 20		12	50 - 20 μs
Photometer	Trigger / Acquisition			337±5	N_2 (2P)	55 / 20		12	50 - 20 μs
Photometer (single or 8 x 8 pixels)	Trigger / Acquisition			150-280	FUV / N2 LBH	55 / 20		12	50 - 20 μs
Photometer	Study of AGW/ Event acquisition			600-800	N1(1P) and OH	55 / 20		12	50 - 20 μs

Table1. Characteristics of video cameras and photometers planned to detect TLEs and lightnings.

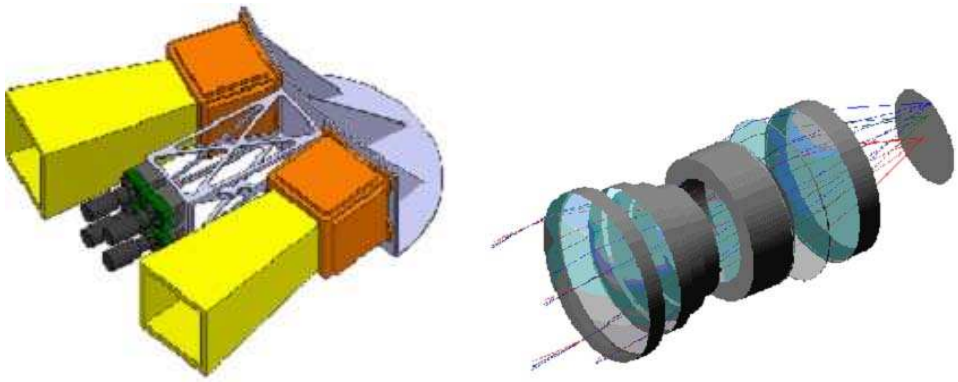


Figure 3: Photometers and video cameras layout (left) and optical design (right).

3 Conclusions.

Optical-UV instruments (photometers and video cameras), as well as an X/γ ray detector and a charged particle detector have been considered and planned to be installed on board a LEO satellite and/or the ISS to investigate tropospheric TLEs, lightnings and TGFs. Aim of the experiment is to contribute to the understanding of TLEs interaction mechanisms with TGFs, study the large energy transfer produced by TLEs and TGFs from the troposphere to the atmosphere/ionosphere/magnetosphere region of the near-Earth space and investigate the temporal stability of the Van Allen radiation belts. Also perturbations produced by sun and cosmic rays to the geomagnetic cavity will be considered in the study. The activity carried out in 2009 by the TELLUS team includes three patents.

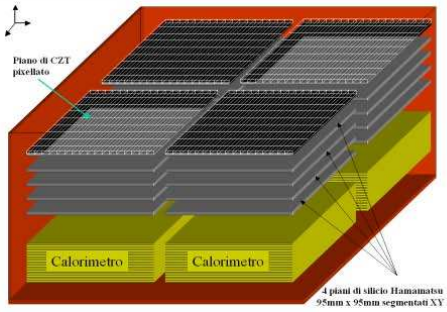
<table>
<tr><td rowspan="2">TGF
Instrumental
Unit</td><td>Structure:
The detector is constituted by 4 towers placed side by side and each one constituted by:
1 CZT plane with pixels
(or SDD with or without scintillator)
4 Hamamatsu Is planes 95mm x 95mm segmented XY
1 CSV calorimeter, 40 ÷ 60 mm</td><td> 
</td></tr>
<tr><td>Characteristics:</td><td colspan="2">▪ Energy range for X/γ from 10 keV to 20 MeV
▪ Energy range for electrons from 1 MeV to 200 MeV
▪ Energy resolution better than 5%
▪ Angular resolution better than 4°
▪ Detector trigger rate: 2 kHz
▪ Time mark accuracy 0.1s</td></tr>
</table>

Figure 4: Structure and characteristics of a TGF instrumental unit.

List of references including publications and patents during the year 2009

1. Sgrigna, V. and Conti, L., 2009. Earthquake preparation and warning: science, methods and technologies, Novapublishers, in press.

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8. Dwyer, J.R., and D.M. Smith, A comparison between Monte Carlo simulations of runaway breakdown and terrestrial gamma ray flashes observations, Geophys. Res. Let, 32, L22804, 2005.

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Patents

1. Year 2009. Title: A new technique for the signal waveform reconstruction by multi-channel selection and retroaction variable differential amplification (patent pending RM2009A000001). Authors: Conti, L., Sgrigna, V., and Zilpimiani, D.

2. Year 2009. Title: Amplification calibration system for acquisition devises of analog signals (patent pending RM2009A000200). Authors: Conti, L., Sgrigna, V., and Zilpimiani, D.

3. Year 2009. Title: Signal conditioning board for filtering and feedback multichannel amplification in data acquisition systems of analog signals (patent pending RM2009A000207). Authors: Conti, L., Sgrigna, V., and Zilpimiani, D.