Terrestrial Gamma-Ray Flashes and associated electron emissions at satellite altitude : some properties and modelling using Monte-Carlo simulations.

D. Sarria[1], P.L. Blelly[1], F. Forme[1]

[1] *IRAP, Université Paul Sabatier, CNRS, OMP, Toulouse, France*

Terrestrial gamma-ray flashes are natural bursts of X and gamma-rays that are likely to be emitted at an altitude of about 10 to 20 km, and correlated to thunderstorms. Once produced, the flux of gamma-rays is altered by the filtering of the atmosphere and can eventually be detected by a satellite. We first present a home Monte-Carlo model for Terrestrial Gamma-Ray flashes particles transport in Earth's atmosphere, and we validate it by comparison with a benchmark GEANT4 simulation with similar settings. Then, using our home model, we discuss some properties of the photons and electrons/positrons at the altitude of the satellite, focusing on spatial dispersion, From all the gathered information, we finally propose a semi-analytical model to describe the final spatial photon dispersion at satellite altitude, depending on source properties.

1. General presentation

Terrestrial gamma-ray flashes are natural bursts of X and gamma-rays that are likely to be emitted at an altitude of about 10 to 20 km, and correlated to thunderstorms. Once produced, the flux of gamma-rays is altered by the filtering of the atmosphere and can eventually be detected by a satellite. This last can only measure a residual of the initial burst, constituted of scattered (or not scattered) primary photons and secondary emitted electrons, positrons and photons. One way to approach this problem is to build a numerical model of the transport of the high energy particles involved. For this purpose, we developed a numerical Monte Carlo model which solves the transport in the atmosphere of both relativistic electrons/positrons and gamma-rays. This model makes it possible to track all particles (photons, electrons and positrons) in the whole earth environment (considering the atmosphere and the geomagnetic field) to get any information about everything happening in the transport of the particles from source to satellite altitude. Particularly, we discuss the story of the particles, from emission to escape, their energies and their spatial dispersion, depending on the source properties.

We first present our home model and validate it by comparison with a benchmark GEANT4 simulation with similar settings.
A comparison is shown in figure 1. Then, using our model, we discuss some properties of the photons and electrons/positrons at the altitude of the satellite, focusing spatial dispersion at satellite altitude (600 km). From all the gathered information, we build a semi-analytical model to describe this photon dispersion, depending on source properties. This model is build with help of the geometry presented in figure 2.

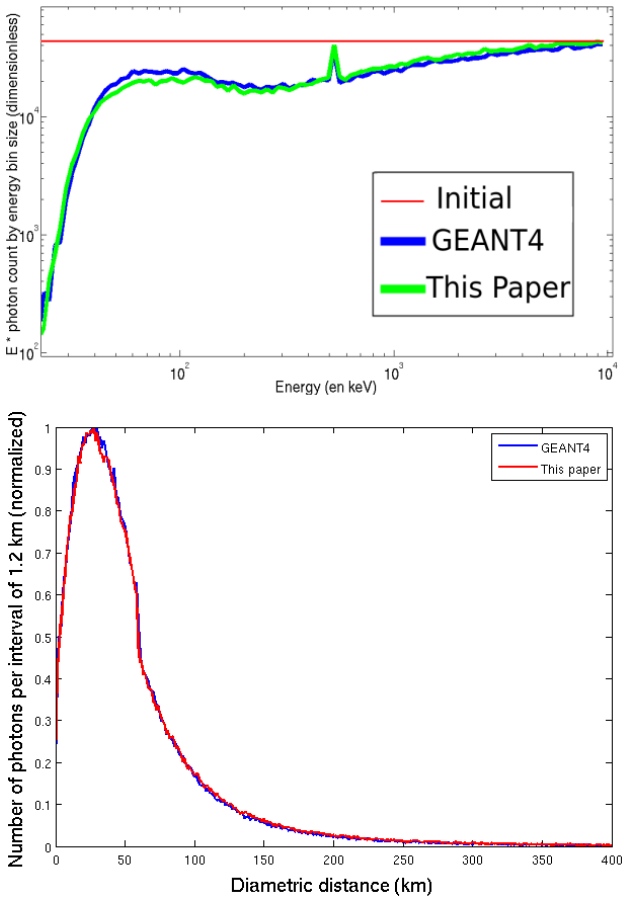

Figure 1: Comparison between GEANT4 et our home model. The initial simulation settings are similar. The resulting photon spectra at h_f=100 km altitude are presented, as well as the diametric distance (d) distribution (d is defined in Figure 2).

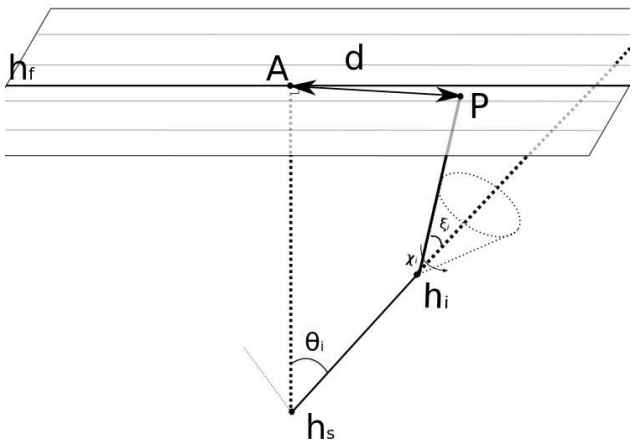

Figure 2: Simple geometry of a photon emitted at an altitude h_s interacting only once at an altitude h_i and reaching the final altitude h_f. The detection sphere is defined as a sphere centred on Earth's centre, of radius of $R_e + h_f$. A is the projection of the local vertical of the initial position of the photon over the detection sphere. P is the position of the photon when it reaches the surface of the same sphere. The diametric distance d is defined as the distance between points A and P over the surface of the detection sphere.