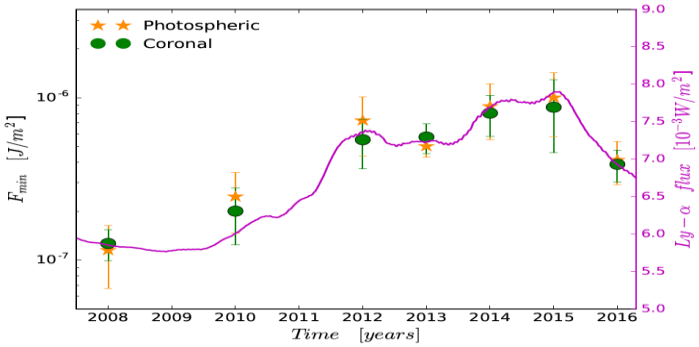
Remote Sensing of the lower ionosphere (SAVNET)

- daytime ionospheric sensitivity versus solar activity cycle
  F_{min} (> 6 keV) compared to solar Lyman-α photon flux → ionospheric indice to mimic Lyman-alpha fluz



AGU PUBLICATIONS
JGR
Journal of Geophysical Research: Space Physics

RESEARCH ARTICLE
10.1002/2017JA024493

Key Points:
- Daytime lower ionosphere sensitivity to solar X-flares inferred from VLF measurements using a parameter called the minimum X-ray fluence
- The minimum X-ray fluence value shows no dependence with the size of solar flares
- Long-term minimum X-ray fluence variation correlates with the level of solar Lyman α flux and anticorrelates with the ionospheric sensitivity

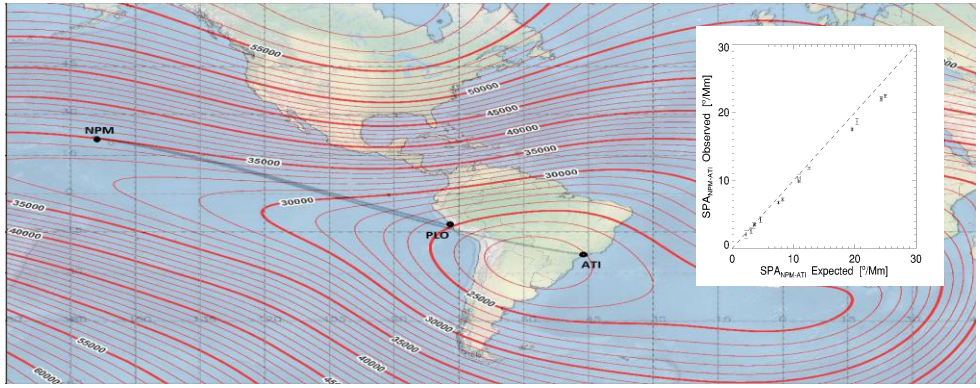
Lower Ionosphere Sensitivity to Solar X-ray Flares Over a Complete Solar Cycle Evaluated From VLF Signal Measurements

Edith L. Macotela[1], Jean-Pierre Raulin[2], Jyrki Manninen[1], Emília Correia[2,3], Tauno Turunen[1], and Antonio Magalhães[2]

[1]Sodankylä Geophysical Observatory, University of Oulu, Sodankyla, Finland, [2]Centro de Radio Astronomia e Astrofisica Mackenzie, Universidade Presbiteriana Mackenzie, Sao Paulo, Brazil, [3]National Institute for Space Research, Sao José dos Campos, Sao Paulo, Brazil

Abstract The daytime lower ionosphere behaves as a solar X-ray flare detector, which can be monitored

- The South Atlantic Anomaly – SAA (António, Liliana)
  First evidence of the effects on the quiescent reference height



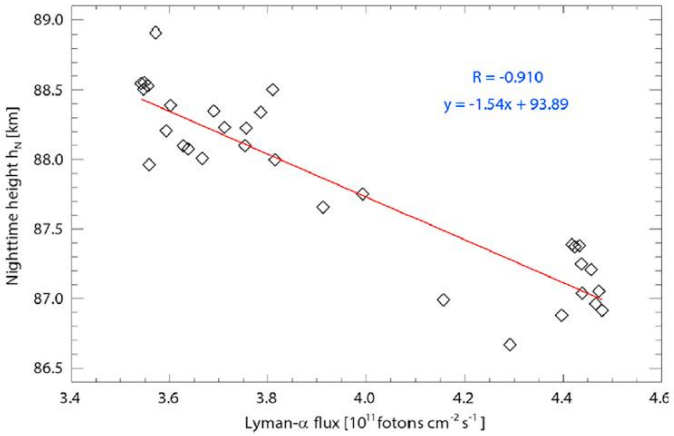
Ionosphere D-layer lowering in the region of the South Atlantic Magnetic Anomaly

Antonio Magalhães[1], Jean-Pierre Raulin[1], Edith L. Macotela[2]
1- CRAAM/EE/UPM, São Paulo, Brazil
2- SGO, Sodankyla, Finland

Abstract-In this paper we analyse the effects of 14 solar flare events over a long VLF propagation path with the very remarkable property of crossing nearly the sinking centre of the South Atlantic Magnetic Anomaly (SAMA). The phase variations of the VLF transmitter signal (NPM: 21.4 kHz) on Lualualei, Hawaii, recorded at the stations Punta Lobos (Peru) and Atibaia (Brazil) between 2007 March and 2011 September, were taken as input to this work. The results suggest a descent of about 2 km of the lower ionosphere quiescent reflection height, possibly correlated with the weakening of the Earth magnetic field in the SAMA region.

Remote Sensing of the lower ionosphere (SAVNET)

- Nighttime reference height (Hn):TT → Hn modulation on different timescale



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Nighttime lower ionosphere height estimation from the VLF modal interference distance

Jorge Samanes [a,b,*], Jean-Pierre Raulin [c], Jinbin Cao [a], Antonio Magalhães [c]

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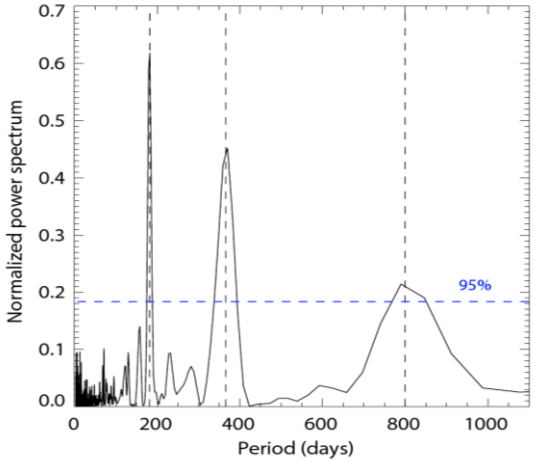
[c] Centro de Rádio Astronomia e Astrofísica Mackenzie (CRAAM), Universidade Presbiteriana Mackenzie, São Paulo, Brazil



Semi- and anual variation

~ 2 years (QBO) variations

Anticorellated with solar activity

SGR J1550-5418 on 2009, January 22

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. ???, XXXX, DOI:10.1002/,

Modeling lower ionospheric plasma-chemical evolution and VLF signal modulation by a series of SGR X-ray bursts

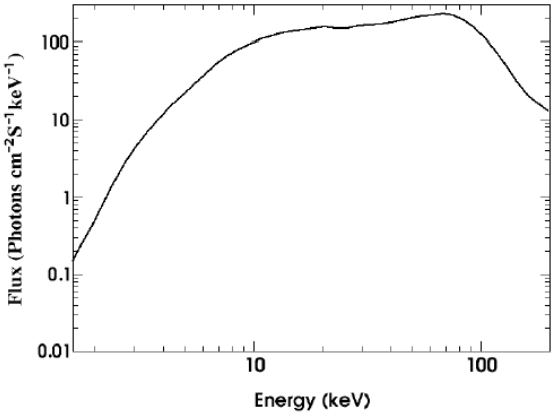
Sourav Palit,[1] and Jean-Pierre Raulin[1]

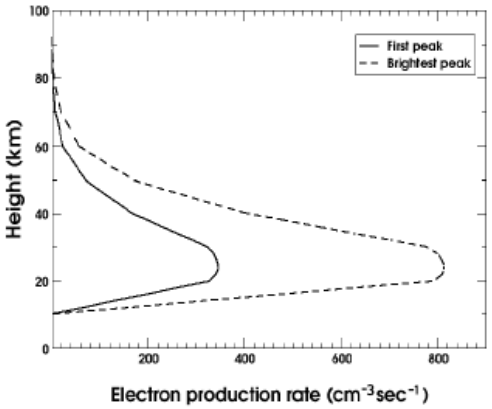
Abstract. Enhanced ionization by X-ray and γ-ray from astrophysical transient sources like, X-ray bursts from soft γ ray repeater (SGR), Gamma ray bursts (GRB) etc. may cause sudden modification of plasma properties in earth's lower ionosphere and middle atmosphere. Corresponding sudden enhancement in electron-ion densities can readily be detected as modifications observed in Very Low Frequency (VLF) signal amplitude and phase. Multiple Very Low Frequency (VLF) receivers in South America, with an unprecedented high time resolution of 20 ms, detected one such series of bursts from SGR J1550-5418 on 22 January 2009. Due to lack of other suitable means of observation corresponding to this part of the atmosphere, the VLF detection and analysis of transient ionizing events (mostly solar flares) has emerged as an excellent method to investigate various chemical and plasma characteristics at those heights. Events like SGR bursts, GRBs, with sharp modulation in their radiation time-profile and very high energy photon abundance provide most unique opportunities of such studies. Here, with the help of some computational modeling we thoroughly analyze the detected signal amplitude variation during the mentioned SGR X-ray bursts. Combination of Monte Carlo ionization rate computation, a one dimensional atmospheric chemistry module and VLF wave guide mode calculation with Long-Wave Propagation Capability (LWPC) code is employed to reconstruct the signal modulation. In the process we gain some valuable insight on the chemical and dynamic properties of lower ionosphere and part of the atmosphere below it.

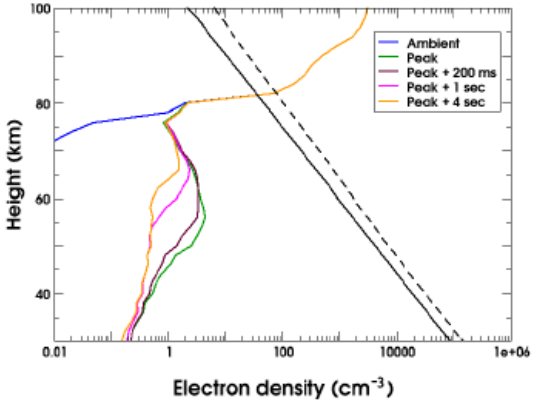
Response of Earth's upper atmosphere and VLF propagation to celestial X-ray ionization: Investigation with Monte Carlo simulation and LWPC

Sourav Palit,[1] and Jean-Pierre Raulin[1]

Abstract. Ionization of Earth's upper atmosphere by celestial and terrestrial sources of radiation is the driver of most of the significant physical and chemical evolution occurring over a large range of timescales. Part of the atmosphere, called ionosphere, owes it's existence to the ionization of neutral molecules by Cosmic ray and solar ultraviolet. Solar flares which are prominent mostly in EUV and soft X-rays modulate the lower part of the ionosphere for few minutes up to few hours. Currently plenty of signatures of hard X-ray and gamma ray ionization effects on the middle and upper atmosphere due to extragalactic sources like, Gamma ray bursts (GRB), Short gamma repeaters (SGR) etc. has been observed. Such events, which form spikes of ionizing radiation, are manifested in impulsive ionization and gradual decay due to atmospheric recombination processes. Such ionization spikes which approximate a delta function in time is the most ideal and simplest candidate to investigate the basics of the influence on the atmospheric chemistry and plasma characteristics, caused by such sources. Here we investigate numerically the effect of such ionization impulse at various layers of the Earth's atmosphere and those on Very low frequency (VLF) radio wave propagation. With the help of a Monte Carlo simulation and a simple ion-chemistry model we investigate various scenarios in terms of different source and VLF propagation characteristics. We also try to justify our assumption that in terms of their effect on atmosphere and VLF, any actual source of ionization, such as solar flare, may be considered as a bunch of consecutive ionization spikes of varying source strength.







Intermediate SGR repeater bursts can be detected in the ionosphere

The AFINSA network https://theafinsa.wordpress.com/

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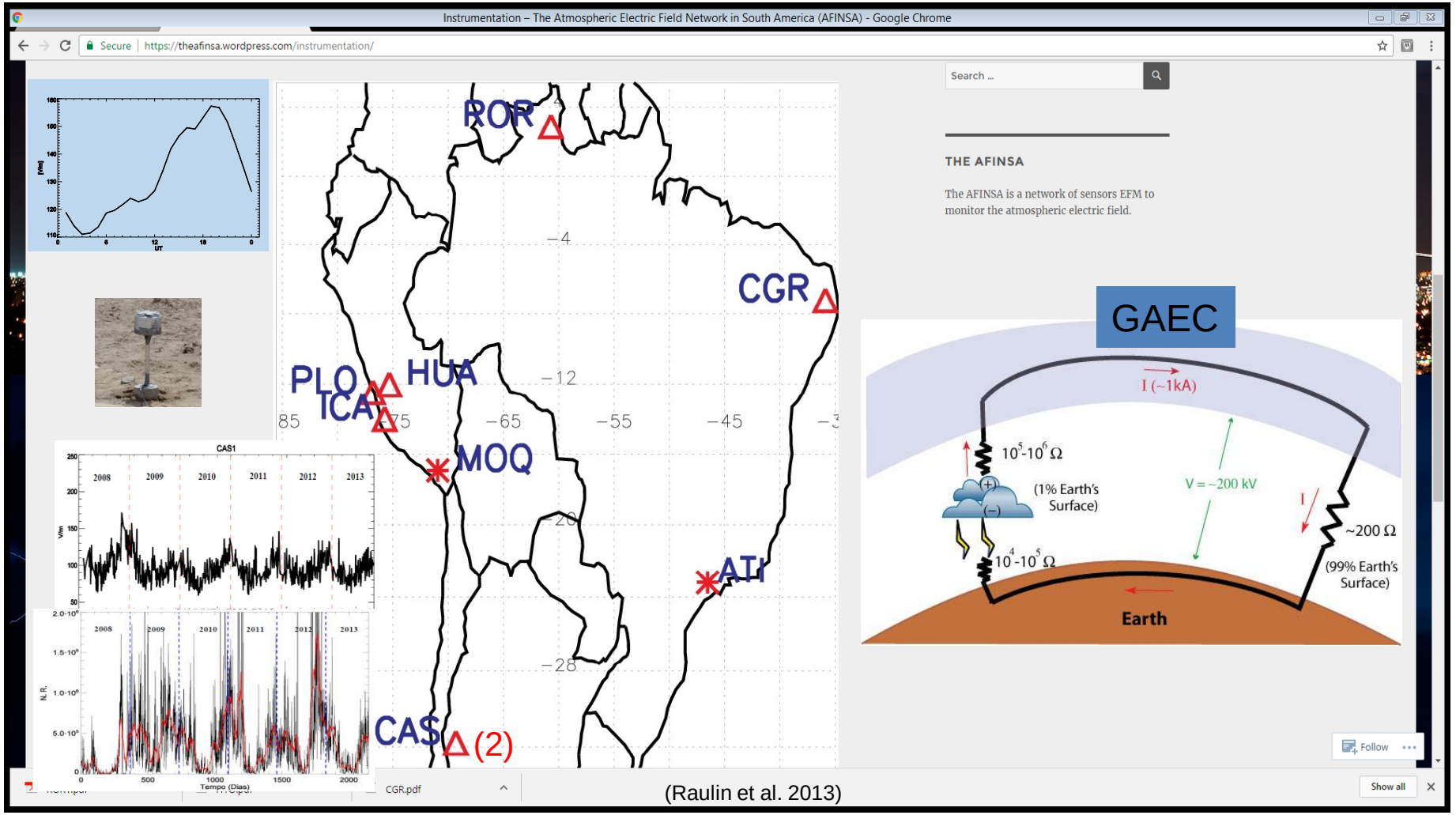
Atmospheric Electric Field - GAEC



(Raulin et al. 2013)

Fair weather EF curve → relation to Carnegie; global distribution of lightning

Departure from Fair weather EF curve → effects of solar (SEP, flares) and geophysical (storms, Forbush decrease) disturbances

The AFINSA network https://theafinsa.wordpress.com/

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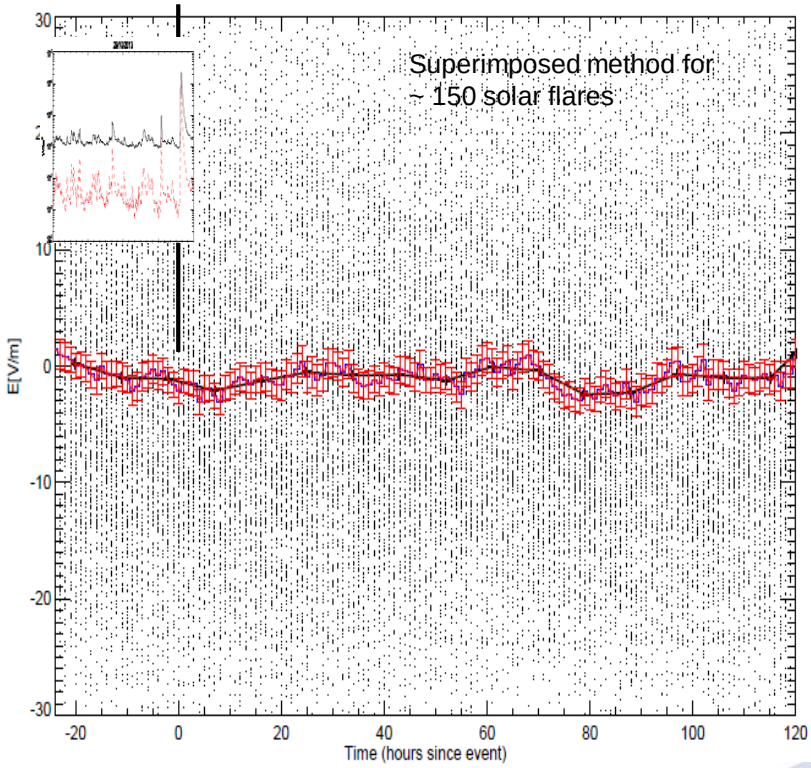
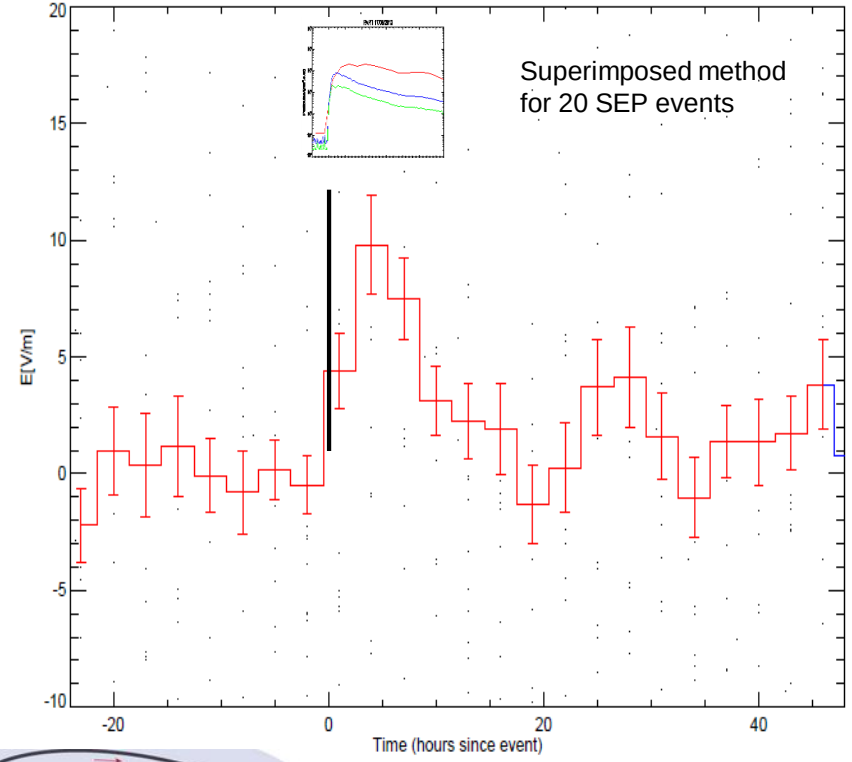
Atmospheric Electric Field - GAEC

Daily Atmospheric EF Excesses from fair weather curves



No detected effect



~ +10 % increase