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Sudden Phase Anomalies Registered by the SAVNET-ICA Station

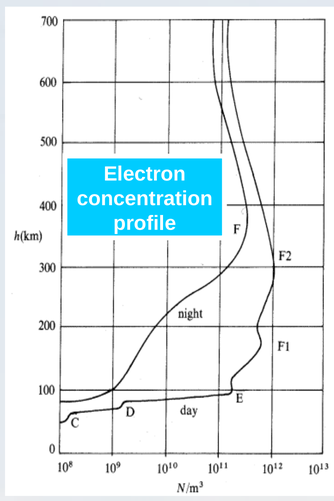
Macotela, E. [1]; Raulin, J-P. [2]; Guevara, W. [1]; Bertoni, F. [2] Samanes, J. [2]; Rivero H. [2]; Hadano, R. [2]; Euribe, C. [3]; Franco, E. [3]

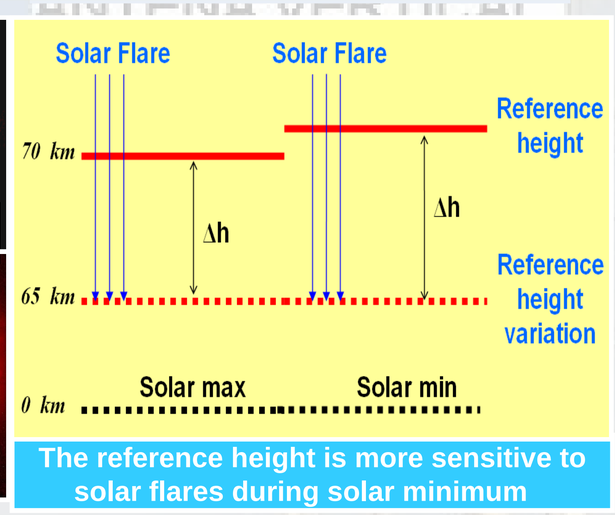
[1] Comisión Nacional de Investigación y Desarrollo Aeroespacial, Peru
[2] Centro de Radio Astronomía e Astrofísica Mackenzie (CRAAM), São Paulo, UF, Brazil
[3] Universidad Nacional "San Luís Gonzaga" de Ica, Peru

Introduction

- The method based on the Very Low Frequency (VLF: 3 – 30 kHz) wave propagation within Earth-ionosphere waveguide is used to study electrical characteristics of the low ionosphere (D-region) which is ionized by solar Lyman-α photons.
- Solar X-ray flux is the main responsible for ionization excess in the low ionosphere. This excess is identified as sudden phase anomalies or SPAs events which is observed as a phase advance.
- In this work we study the relation between solar X-ray flares registered by GOES Satellites and the subsequent ionospheric disturbances that were detected by SAVNET ICA during March 2010.

Location of VLF transmitters that can be tracked at the SAVNET-ICA receiver





The reference height is more sensitive to solar flares during solar minimum

Analysis of VLF signals within the Earth-ionosphere waveguide

- The equation of Appleton-Hartree for the refraction index

$$\eta^2 = 1 - \frac{X}{U - T \pm \sqrt{Y^2 \cos^2\theta + T^2}}$$

- When **B** = 0 and $\nu \ll 2\pi\omega$

$$\eta^2 = 1 - i\frac{\omega_0^2}{\omega\nu}$$

- The conductivity parameter Ω

$$\Omega(h) = \Omega_0 \exp\beta(h - h_0)$$

- Phase variation as a function of the variation of the reference height of the base of the ionosphere

$$\Delta\varphi = 360\frac{d}{\lambda}\left(\frac{1}{2R} + \frac{\lambda^2}{16 h_0^3}\right)\Delta h$$

Instrumentation

Each SAVNET station is composed by three electromagnetic sensors which collect the data. The signals are then amplified and digitalized.

Loop signals: $V = 2\pi\mu_0 bA\cos(\theta) H_0 f$

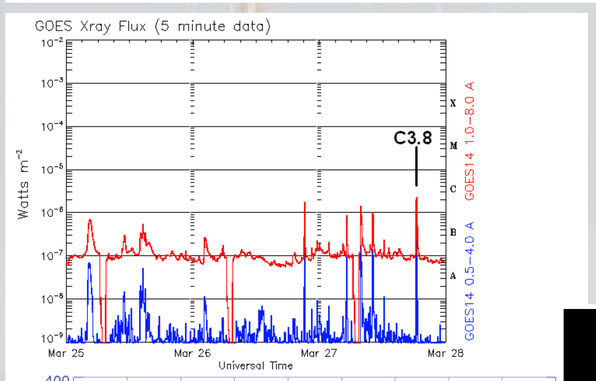
Antenna sensitivity: $S = \frac{V}{B_0} = 2\pi\mu_0 f A_e \cos\rho$

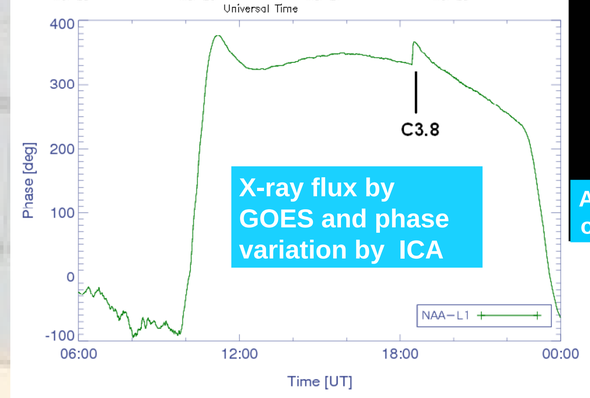
SPA due solar flares

Solar flare events are mainly detected at ICA between 1100 and 2300 UT. Thus, to develop this work, X-ray fluxes detected by GOES satellite during this time period and greater than B2.0 (0.2 microwatts/m²) have been considered. These data are then compared with the ICA data, and the phase variations which are directly related to incident X-ray power are measured.

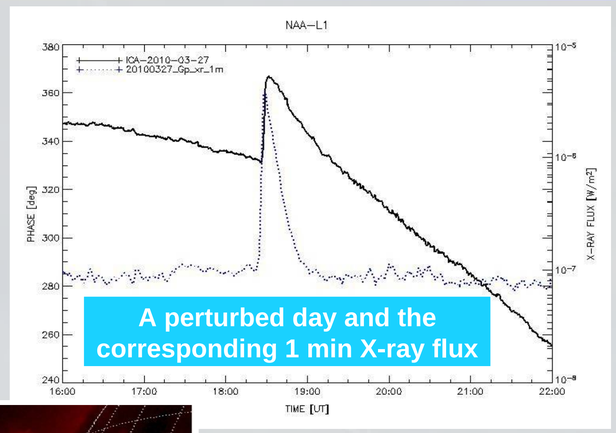
Edited Events for 2010 Mar 27

Event	Begin	Max	End	Obs	Q	Type	Loc/Frq	Particulars	Reg#
1910	1823	1829	1833	G14	5	XRA	1-8A	C3.8 1.2E-03	1057

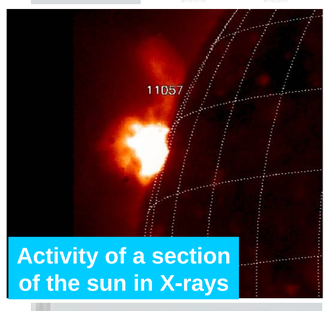




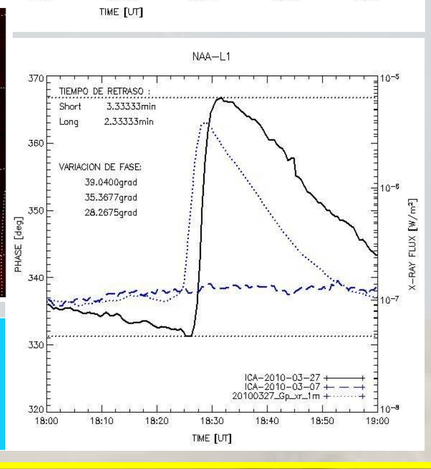
X-ray flux by GOES and phase variation by ICA



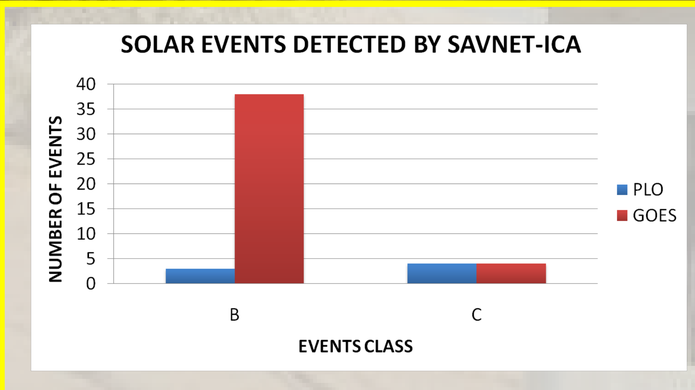
A perturbed day and the corresponding 1 min X-ray flux



Activity of a section of the sun in X-rays



Computation of the phase variation for an event of C3.8 class



Results and conclusions

- The minimum X-ray flux producing a significant ionospheric disturbance detected at ICA station was B4.5; this flux was detected using propagation paths NAA-ICA.
- Almost all X-ray flares greater than C2.5 class were detected by all propagation path. However, for class B X-ray fluxes, large differences were noticed between the GOES and ICA detections. These discrepancies can be explained by the sensibility of the ionospheric wave path.
- We found that all events registered at ICA were detected principality by NAA-ICA and NDK-ICA propagation paths and much less events was detected by NPM-ICA propagation path. It can be due interferences that opaque the signals.

EVENTS DETECTED BY GOES SATELLITES										EVENTS DETECTED BY SAVNET ICA (14°02' S ; 75°45' W)											
										NAA-Y		NPM-Y		NAA-L		NDK-L1		NPM-L2		NLK-L2	
FECHA	INICIO	MAX	FINAL	OBS		Q	TIPO	CLASE	#REG	ICA	DeltaPh	ICA	DeltaPh	ICA	DeltaPh	ICA	DeltaPh	ICA	DeltaPh	ICA	DeltaPh
2010-03-04	1603	1611	1616	G14	+	5	XRA	C2.2	1052	detected	21	N.D		detected	22	tedected	27	N.D		detected	38
2010-03-12	1802	1827	1845	G14		5	XRA	C2.3	1054	detected	26	N.D		detected	26	detected	43	N.D		/////	
2010-03-25	1432	1437	1443	G14	+	5	XRA	B6.0	1057	detected	10	N.D		detected	8	detected	11	N.D		N.D	
	1500	1504	1509	G14	+	5	XRA	B4.5	1057	detected	3	N.D		detected	3	detected	6	N.D		N.D	
2010-03-26	2108	2116	2119	G14	+	5	XRA	C2.5	1057	detected	10	detected	40	detected	9	detected	23	detected	41	detected	38
2010-03-27	1823	1829	1833	G14		5	XRA	C3.8	1057	detected	52	detected	60	detected	55	detected	56	detected	63	detected	53

References

[1] Raulin et. al. ***The South America VLF NETwork (SAVNET)*** in Earth, Moon, and Planets, v. 104, n. 1-4, p. 247-261, Apr. 2009.

[2] Pacini A., ***Dependencia das Propiedades da regiao-D Ionosférica com o Ciclo de Atividade Solar***, INPE, 2006.

Acknowledgements

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