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DEVELOPMENT OF A CATALOGUE OF SOLAR FLARES DETECTED BY THE SAVNET STATION AT PUNTA LOBOS

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Abstract

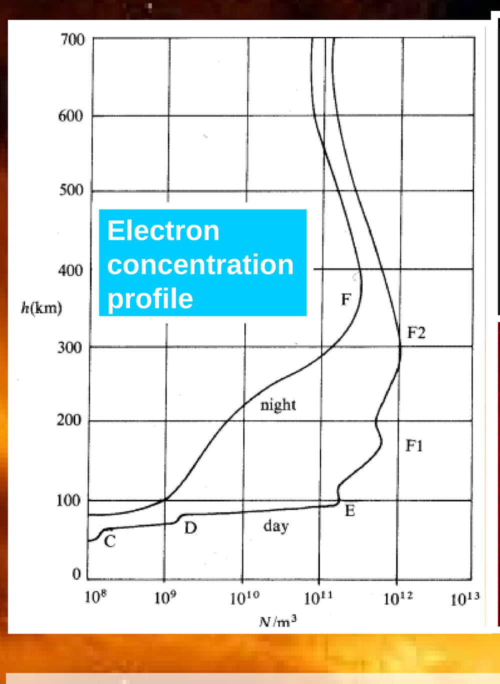
Solar flares emit intense X-ray fluxes that cause perturbations in the ionospheric D-region altering its electrical conductivity characteristics. GOES satellites measure X-ray fluxes from the full-disk of the Sun. These X-ray fluxes are classified as B, C, M, and X class. The electrical characteristics of VLF waves during their propagation within the Earth-ionosphere waveguide are used to study the low ionosphere. The variations of the phase of VLF signals during solar flares were registered during the periods April - December 2007, January-December 2009 and July –August 2010 by the SAVNET station antennae located at Punta Lobos (12°30' S; 76°47' W), Lima-Peru. We show in this work a preliminary database elaborated in order to catalog solar flares detected at Punta Lobos.

Introduction

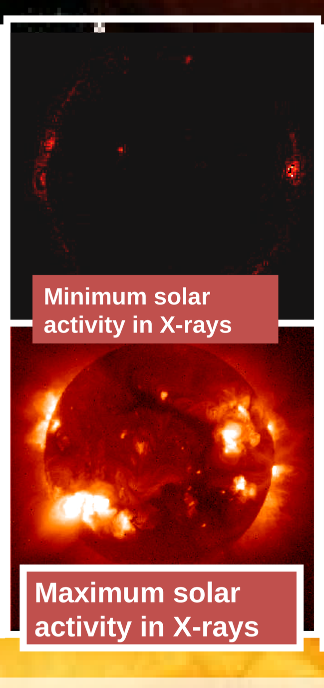
The radio receiver station at Punta Lobos has been operating since April 2007, and a catalogue of SPA (Sudden Phase Anomaly) due to solar events is being developed . A SPA is observed as a phase variation of VLF (Very Low Frequency, 3 – 30 kHz) waves.

Analysis of the signals VLF within Earth-ionosphere waveguide

The low ionosphere (D-region) is formed during daytime by photo ionization process due to solar Lyman-α photons (1216 Å) which ionize the neutral components of Earth's atmosphere. This region is monitored using the characteristics of VLF waves propagation on long distances within the EIW (Earth-ionosphere waveguide).

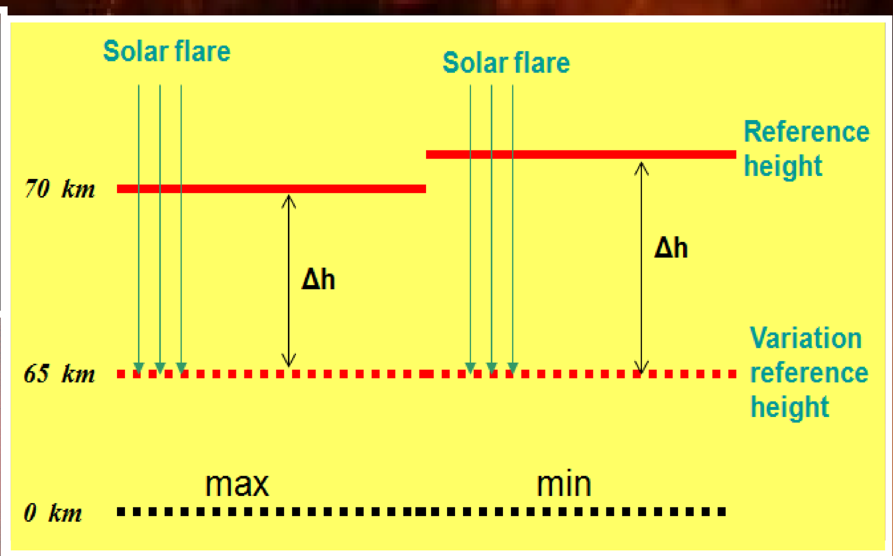


Electron concentration profile



Minimum solar activity in X-rays

Maximum solar activity in X-rays



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

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 $v << 2\pi\omega$

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

The conductivity parameter

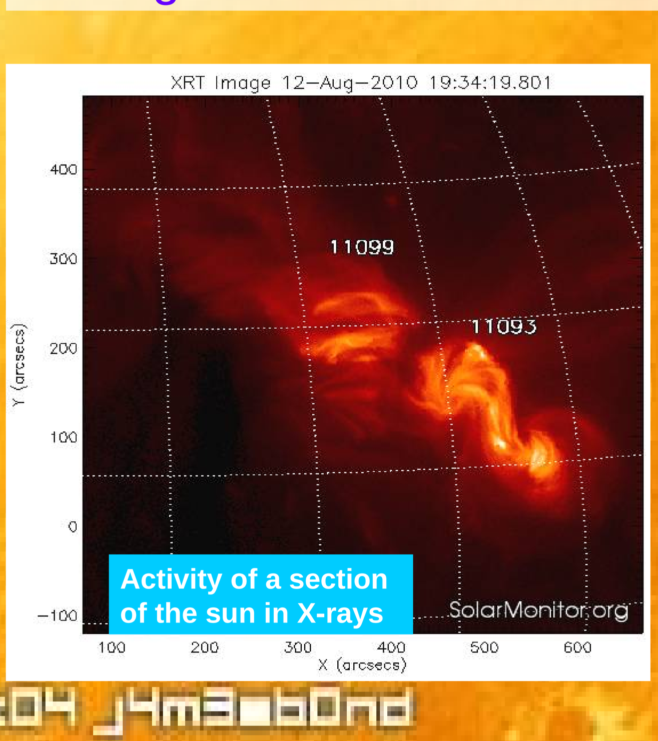
$$\Omega(h) = \Omega_0 \exp\beta(h - h_0)$$

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

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

Development of the catalogue

Solar flare events are mainly detected at PLO between 1100 and 2300UT. Thus, in order to develop this catalogue, 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 PLO data, and the phase variations which directly related to incident X-ray power are measure. The following figures represent an example of how the catalogue was made.

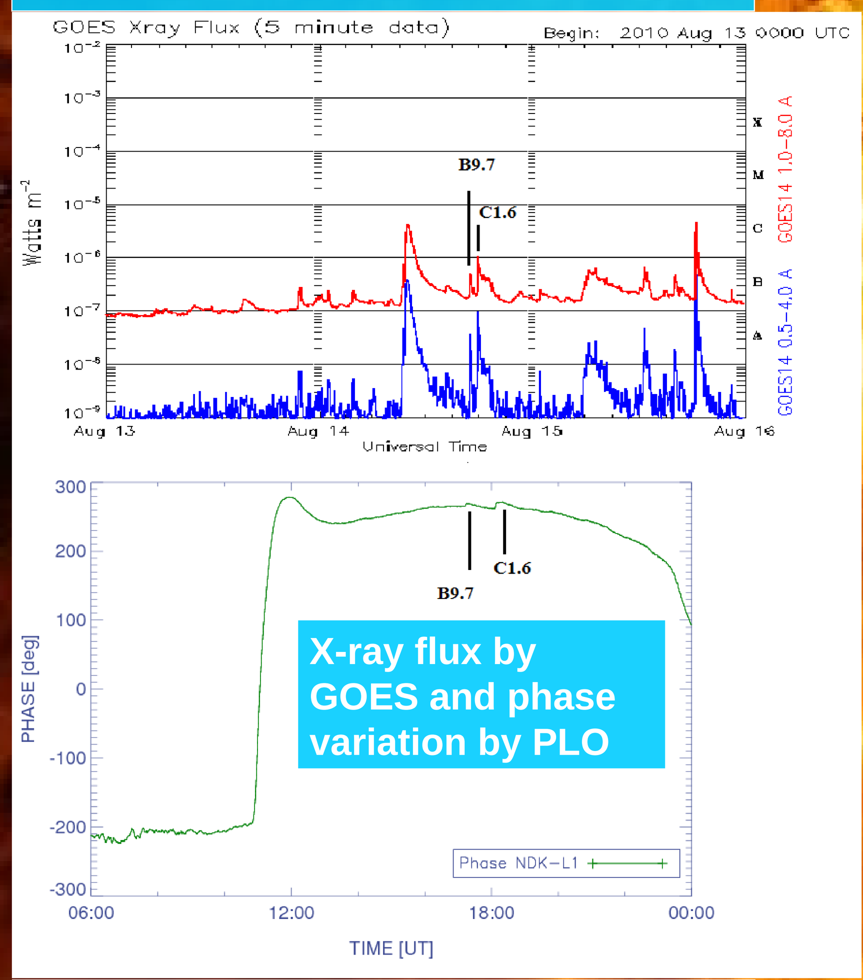


Activity of a section of the sun in X-rays

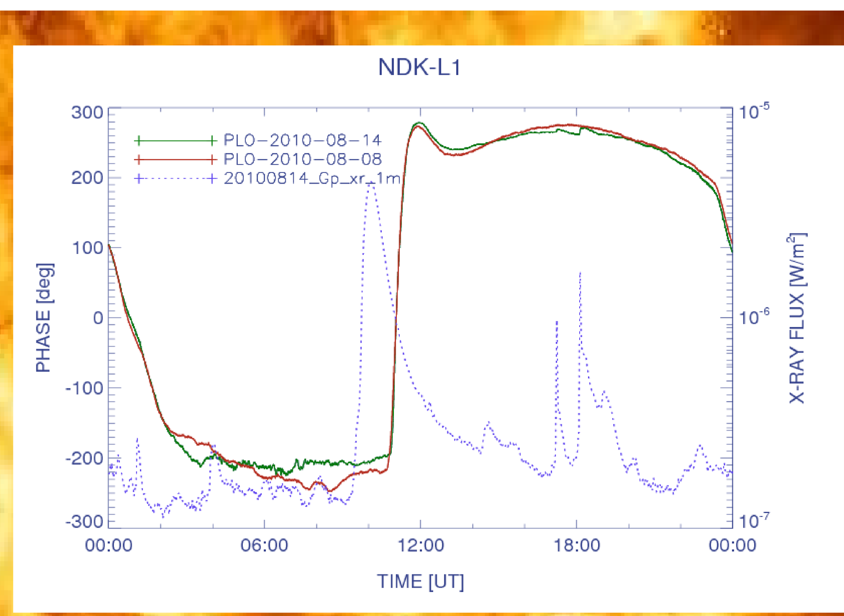
Edited Events for 2010 Aug 14

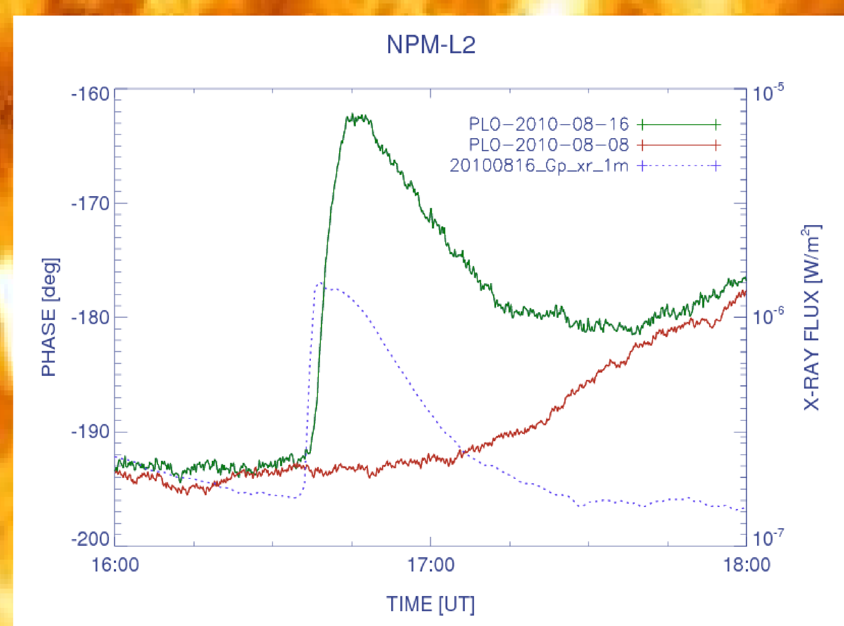
Event	Begin	Max	End	Obs	Q	Type	Loc/Frq	Particulars		Reg#
2610 +	A0014	////	1244	HOL	3	DSF	N22E39	16	B.0A	
2500 +	0027	0031	0040	LEA	2	FLA	N18W46	SF		1099
2510 +	0057	0057	0105	LEA	3	FLA	N17W46	SF		1099
2510 +	0102	0106	0112	G14	5	XRA	1-8A	B2.7	1.2E-04	1099
2530 +	0352	0401	0414	G14	5	XRA	1-8A	B2.5	2.8E-04	1099
2540 +	0938	1005	1031	G14	5	XRA	1-8A	C4.4	9.9E-03	1099
2570 +	0939	1000	1030	SVI	3	FLA	N11W53	SF	ERU	1093
2540 +	0941	0959	1110	SVI	3	FLA	N17W52	SF	ERU	1099
2540 +	0952	////	1009	SVI	C	RSP	025-180	II/1	406	1099
2550 +	1038	1039	1040	SVI	G	RBR	606	170		
2590	1709	1714	1716	G14	5	XRA	1-8A	B9.7	2.0E-04	1099
2600	1803	1808	1810	G14	5	XRA	1-8A	C1.6	3.6E-04	1099
2600 +	1807	1807	1813	HOL	3	FLA	N19W54	SF		1099

A quiet day compared with a perturbed day and the corresponding 1 min X-ray flux



X-ray flux by GOES and phase variation by PLO



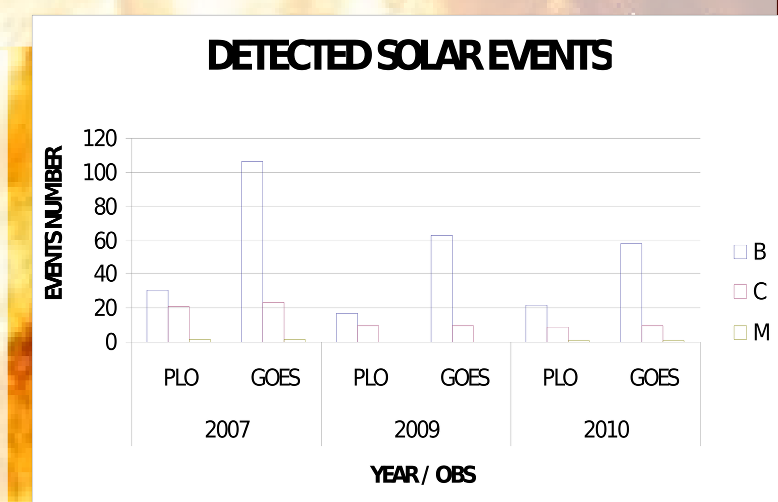


Computation of the phase variation for an event of class C1.4

Results and conclusions

The minimum X-ray flux producing a significant ionospheric disturbance detected at PLO station during 2007 was B3.5; this flux was detected using propagation paths NDK-PLO and NLK-PLO. Correspondingly, in 2009 we find a minimum of B3.1 using NDK-PLO and in 2010 the minimum was B3.4 using NAA-PLO propagation paths.

Almost all X-ray flares greater than C class were detected by PLO. However, for class B X-ray fluxes, large differences were noticed between the GOES and PLO detections. These discrepancies can be explained by the sensibility of the ionospheric wave path and the solar activity conditions.



August 16, 2010

EVENTS DETECTED BY GOES SATELLITES										EVENTS DETECTED BY "SAVNET" PLO STATION - PERU (12°30' S ; 76°48' W)											
										NAA-V		NWC-V		NAU-L1		NDK-L1		NPM-L2		NLK-L2	
DATE	BEGIN	MAX	END	OBS		Q	TYPE	CLASE	#REG	PLO	DeltaPh	PLO	DeltaPh	PLO	DeltaPh	PLO	DeltaPh	PLO	DeltaPh	PLO	DeltaPh
16/08/2010	1134	1142	1151	G14	+	5	XRA	B5.6	1099	////		N.D		N.D		N.D		N.D		////	
	1358	1405	1410	G14	+	5	XRA	B3.8	1099	////		N.D		N.D		N.D		N.D		////	
	1516	1521	1528	G14		5	XRA	B7.6	1099	////		N.D		N.D		N.D		N.D		////	
	1634	1639	1651	G14		5	XRA	C1.4	1099	////		N.D		detected	38.25	detected	15.84	detected	30.52	////	
	1807	1815	1821	G14	+	5	XRA	B3.9	1099	////		N.D		N.D		N.D		N.D		////	

This catalogue, when completed, will represent a record of solar flares detected by the PLO receiving station; it will also contain the minimum X-ray flux capable of producing an ionospheric disturbance and by which propagation path the solar flare was detected.

References and Acknowledgements

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

[2] Raulin et. al. 2009. ***The South America VLF NETwork (SAVNET): Development, installation status, first results.*** Geofísica Internacional 48(3), p. 253-261, Jun. 2009.

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

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