Long-term changes in UV and EUV solar radiation

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RESUMEN

Hay indicios de que la irradiancia solar total (TSI) podría presentar las mismas variaciones a largo plazo que la longitud del ciclo (SCL). Esta variación corresponde a la periodicidad de 80-90 años, llamada el ciclo de Gleissberg. Se espera que cuando SCL disminuya, TSI aumente. En el presente trabajo se analizan datos estratosféricos, ionosféricos y solares de los cuales se infiere que las radiaciones UV y EUV presentan variaciones a largo plazo que no dependen del número de manchas solares Rz. Llamamos a estas variaciones de la irradiancia UV(SCL) y EUV(SCL), ya que ambas parecen tener periodicidades a largo plazo como la de SCL. En este caso se espera que cuando SCL decrezca, UV(SCL) y EUV (SCL) también decrezcan. Datos de índices directos de la radiación UV y EUV apoyan esta hipótesis. A partir de datos ionosféricos de dos ciclos solares consecutivos, estimamos que la relación entre EUV(SCL) y EUV total, es de 1% y del 2% para un ciclo corto y largo respectivamente.

PALABRAS CLAVE: Relaciones Sol-Tierra, actividad solar, ionosfera.

ABSTRACT

Total solar irradiance (TSI) may present the same long-term variation as the solar cycle length (SCL), corresponding to the Gleissberg cycle. It is expected that when SCL decrease, TSI increase. The analysis of stratospheric, ionospheric and solar data suggesting that UV and EUV solar radiation have long-term variations that do not depend on the sunspot number, Rz. The part of the UV and EUV solar flux associated to SCL, called UV(SCL) y EUV(SCL), varies in such a way that when SCL decreases, this radiation decreases. Direct indices of EUV and UV available data support this hypothesis. Through ionospheric data we estimated that EUV (SCL) is 1% and 2% of the total EUV solar flux, for a short and a long solar cycle respectively.

KEY WORDS: Sun-Earth relationships, solar activity, ionosphere.

INTRODUCTION

A possible cause of climate change may be a change in solar radiation (Hoyt and Schatten, 1993; Friis-Christensen and Lassen, 1992, 1993; Lee *et al.*, 1995). Yet it has not been possible to demonstrate any physically plausible mechanism whereby changes in solar activity could influence climate. One possibility is that the variation of the Northern Hemisphere land air temperature might be modulated by the solar activity as represented by sunspot cycle length SCL (Friis Christensen and Lassen, 1991, 1992, 1993). SCL may be an indicator of long-term changes in total solar irradiance (TSI).

Results from Nimbus-7 suggest that TSI varied by about 0.14% (2 Watt/m^2 peak-to-peak over a period of about 11 years (1979–1992). This does not rule out larger changes occurring over a greater period of time.

More than 70% of TSI is concentrated in the near-UV, visible and near-infrared portions of the spectrum, between 320 and 1000 nm. About 0.2% of TSI appears at UV and X-ray wavelengths shorter than 320 nm. The remainder of the TSI is at infrared and radio wavelengths longer than 1000 nm. Variations in certain ranges, such as the UV and EUV, which could produce important changes in stratospheric and ionospheric parameters, might not be noticed in TSI.

Changes in solar energy or in its distribution would produce changes in the troposphere as well as in other atmospheric regions such as the ionosphere and the stratosphere.

If changes in solar energy shown by SCL exist, they should be better observed in the upper atmosphere, as it is less influenced by anthropogenic activity and the effects are more linear with solar activity.

Space and time variations of meteorological parameters are mainly due to the visible/infrared solar radiation intercepted by the Earth, while the main body of the ionosphere arises from atmospheric absorption of solar radiation in wavelengths less than 102.6 nm (EUV). The spectral range mainly involved in stratospheric heating is from 200 to 300 nm (UV).

MAXIMUM IONOSPHERIC ELECTRON DENSITY ANOMALY (NMAXA)

If the Northern Hemisphere land air temperature anomaly correlates with solar cycle length (SCL) (Friis

Christensen and Lassen, 1991, 1992, 1993), and considering SCL as a solar activity parameter of long-term change and a measure of TSI variability, some ionospheric parameters might also be correlated with SCL. Adler *et al.* (1997a) used the maximum electron density of the ionosphere, Nmax, measured around 400 km height at several stations over the period 1949-1995. They suggested that the linear relation between Nmax and Rz, includes an additional term

$$NmaxA = b' \ SCL + c' \qquad (1)$$

where b' and c' are constants, and b'>0. Thus NmaxA and SCL are in phase.

From (1) it develops that SCL may provide a measure of the long-term variability of the solar energy output in the EUV spectrum range.

LOWER STRATOSPHERIC TEMPERATURE ANOMALY (LSTA)

The solar spectral range mainly involved in stratospheric heating, that is the 200-300 nm range, may be obtained from the lower stratospheric temperature measured at 10-15 km height.

The available 15-year record of stratospheric temperature was too short to associate directly with SCL. However, Adler *et al*. (1997b) detected that the lower stratospheric temperature variation from the mean, LSTA, is in phase with NmaxA.

Assuming that this behavior was also present before 1979, we conclude that LSTA could be in phase with SCL. If so, SCL may provide a measure of the long-term variability of the solar energy output in the spectrum range 200-300 nm.

LONG-TERM VARIATIONS IN EUV AND UV SOLAR RADIATION

Since Nmax depends directly on solar EUV radiation, it is interesting that NmaxA decreases when the solar cycle is shorter, that is when solar activity is supposed to increase. Conversely, when NmaxA increases, SCL is longer. The same is true for LSTA, associated to the solar UV radiation (200-300-nm).

An explanation of these results may be as follows. Suppose that the UV and EUV solar radiations that reach the Earth, present two kinds of time variations:

(1) UV(Rz) and EUV(Rz), associated to Rz variations.

(2) UV(SCL) and EUV(SCL), independent of Rz and associated with SCL variations.

$$UV = UV(Rz) + UV(SCL) \qquad (2)$$

and

$$EUV = EUV(Rz) + EUV(SCL) \qquad (3)$$

such that $UV(Rz) \gg UV(SCL)$ and $EUV(Rz) \gg EUV(SCL)$. For long and short cycles, equation (2) can be written as

$$UV_l = UV(Rz)_l + UV(SCL)_l \quad and \ UV_s = UV(Rz)_s + UV(SCL)_s$$

respectively, where subscript l means "long" and subscript s means "short" $UV(Rz)_l < UV(Rz)_s$ and $UV(SCL)_l > UV(SCL)_s$. If $UV(Rz) \gg UV(SCL)$, UV_s is always greater than UV_l. The same holds for EUV (equation 3).

Direct UV and EUV indices have been found to support a decrease in UV(SCL) and in EUV(SCL) when SCL decreases, and an increase in UV(SCL) and in EUV(SCL) when SCL increases.

In the last 15-20 years since 1979, satellite measurements of direct indices of the solar EUV include the photo-electron current Ipe measured on board Pioneer Venus Orbiter, indicating the 55-130 nm solar spectral range; the Mg II core-to-wing ratio (Mg II c/w ratio) indicating the 170-300 nm spectral range, the 200-205 nm integrated flux, and the Lyman α (121.6 nm) intensity line.

The effect of Rz was filtered from the EUV direct indices as in the Nmax case (Adler *et al*., 1997a). The residuals obtained were termed anomalies. In Figure 1 the indices anomlies, which are UV(SCL) and EUV(SCL) indicators, decrease when SCL decreases.
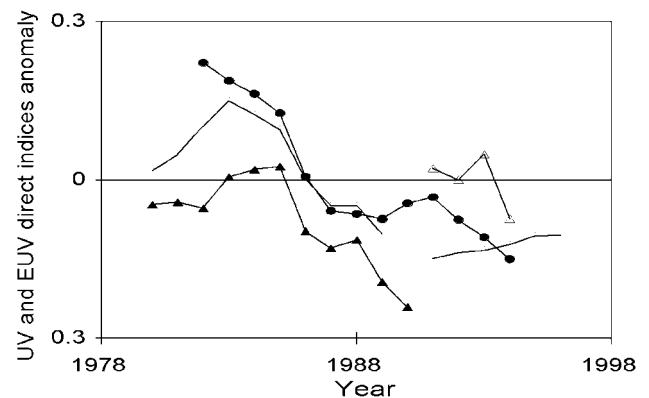

Fig. 1. Mean annual anomaly of Lyman α (solid circle), Mg II c/w (open circle), Ipe (solid triangle), and 200-205 nm integrated flux (open triangle) Data obtained from: http://www.ngdc.noaa.gov.

EUV(SCL) VARIATION ESTIMATES

The following rough estimation of EUV(SCL) percentage variation uses Nmax data from Slough. The mean Nmax value, $\overline{N}$max, and NmaxA for a short and a long solar cycle were calculated. Cycles 19 (Apr.1954-Sep.1964) and 20 (Oct.1964-May 1976) were selected as the short and long solar cycle respectively. We find $\overline{N}$max$_s$ = 8.72 x 10^5 cm^{-3}, NmaxA$_s$ = 0.79 x 10^4 cm^{-3}, $\overline{N}$max$_l$ = 6.66 x 10^5 cm^{-3}, and NmaxA$_l$ = 1.13 x 10^4 cm^{-3}.

With these values we obtain the NmaxA percentage relative to Nmax, which is practically the EUV(SCL) percentage relative to EUV.

The results for a short cycle are EUV(SCL)$_s$ = 1% of EUV and EUV(Rz)$_s$ = 99% of EUV. For a long cycle EUV(SCL)$_l$ = 2% of EUV and EUV(Rz)$_l$ = 98% of EUV.

The ratio of EUV(SCL)$_l$ to EUV(SCL)$_s$ is

$$\frac{EUV(SCL)_l}{EUV(SCL)_S} = 1.13/. = 1.42 \Rightarrow 142\% \quad . \qquad (4)$$

CONCLUSIONS

The maximum ionospheric electron density anomaly NmaxA is in phase with SCL in the period 1949–1995. Thus SCL appears to be a possible indicator of long-term changes in EUV solar radiation at wavelengths < 102 nm.

The lower stratospheric temperature anomaly LSTA in the period 1979-1994 is in phase with NmaxA. If this association holds outside of the data period indicated, LSTA should be in phase with SCL. In this case SCL could be considered as a possible indicator of long-term changes in the 200 to 300 nm solar spectrum range.

These results suggest that EUV and UV solar fluxes are composed of two terms, one associated to Rz variations and other to SCL variations. The first term increases with decreasing SCL as the second term decreases, and the first term decreases with increasing SCL as the second term increases.

Direct indices of EUV and UV for 1979-1996, when SCL decreased, support the assumption that the UV and EUV terms associated to SCL variations decrease when SCL decreases. A rough estimation of the EUV variation associated to SCL based on ionospheric data, indicates that EUV(SCL) is 1% and 2% of the total EUV solar flux, for a short and a long solar cycle respectively. Althouhg this variation is quite small in percentage terms, is much biggern than the 0.25% expected in TSI, so it should be taken into account in atmospheric processes involving long term variations in UV and EUV solar radiation (i.e., ionization processes, ozone depletion, stratospheric temperature variability).

Since only two consecutive cycles (19 and 20) have been considered, and not the maximum and the minimum of the 80-90 year oscillation, the estimated value of 142% for the ratio EUV(SCL)$_l$ to EUV(SCL)$_s$ would be the minimum variation expected.

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