Probing Climate Change in Greece with a 2m dish radio telescope

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Abstract. We study the effect of solar activity on the climate in Greece. We search for correlations between solar and terrestrial indicators. The solar proxies which are representative of the activity of our star include the number of sunspots, the intensity of solar radiation, the radio flux at 10.7cm and the galactic cosmic rays. Earth's weather indicators include six parameters, temperature, relative air humidity, wind direction and intensity, atmospheric pressure and precipitation. The solar data span several years starting from 1975 to 2005, including decades-long variations. The meteorological data come from 12 stations located in various parts of Greece. The main part of the research is the unique experiment in Greece which aims to continuously monitor and record the solar radio flux at 10.7 cm using a 2m paraboloid radio telescope (the pilot project of the THERMOpYlae Hellenic radio telescope).

1 Introduction

The Solar cycle(s) (11, 22yr etc) is (are) the manifestation of the solar magnetic field. Its variations are examined in climate research when probing the impact of the sun's activity in climate change, compared to the human factors. The solar magnetic activity research is based on multiwavelength astronomical observations from Earth and Space. Its proxies include observations of the sunspot number, solar irradiance, ultraviolet radiation, flares, the magnetic cycle, solar cosmic rays [1] and the radio flux at 10.7cm (eg. [2]).

The number of sunspots is the most basic component of periodic solar activity and shows the course of the 11-year cycle of the sun [3]. Recent studies [4] question the sunspot number correlation with the rest of the solar activity proxies and hence with geophysical applications within the ~11yr (Schwabe) cycle. The author emphasizes the importance of understanding the Schwabe periodicity.

The total Solar Irradiance (TSI) has been considered constant, and for this reason the parameter solar constant is introduced. Records exist since 1978, i.e. for a time interval too short for climate studies on a meaningful timescale. Variability of TSI has been detected, caused by the solar magnetic field. This variability is studied in relation to climate change in general (eg. [5]). A related research on regional climate changes hinted the presence of such correlation (eg. [6]).

[7] reviews less direct ways of the solar impact on the terrestrial climate. For example, one mechanism reveals climate change and its periodicities via the solar participation on Earth's orbital and axis variations through exertion of gravitational force and torque together with other bodies of the solar system. This impact is on a time scale of a few tens to few hundreds of kyrs. Other mechanisms and for longer time include (see references therein [7]): Encounters of the solar system with interstellar clouds possibly contributing to global warming as the solar irradiance decreases due to the interstellar dust; the resulting bow shock of the encounter could reduce the heliosphere exposing Earth to more galactic cosmic ray flux; matter from interstellar clouds could increase the Sun's luminosity and hence precipitation and could trigger age(s) of extremely low temperatures.

2 Methodology

We are searching for possible correlations between the solar indices and the meteorological parameters.

The time range chosen for the graphs is the period from 1975 to 2005. In this time interval, we have measurements for both solar and meteorological data in their entirety. This time range covers two complete 11-year solar cycles the 21st from 1976 to 1986, the 22nd from 1986 to 1996 and part of the 23rd cycle starting in 1996 and ending in 2008.

Within this period the four solar indices show three maxima and three minima.

2.1. The 10.7cm Solar Radio Flux

The $F_{10.7}$ radio flux data were derived from the SOLAR2000 model, an empirical model for accurately characterizing the variability of solar radiation across the solar spectrum. It is designed to provide the initial numerical data for the creation of new models of the planetary atmosphere and its study. The extracted base file from SOLAR2000 used covers the period from 14 February 1947 to 31 May 2002 ([8], Feb 1947-present).

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1.1.1 Solar Flux Monitor

Greece is acquiring its own solar flux monitor comprised of a small 'dish' antenna to continuously monitor the 2800MHz (or 10.7cm) radio flux (see Fig 1). The 2m radio telescope will result from a converted S-band satellite dish on an altazimuth mount. The dish is currently at the Campus of the Hellenic Open University, and is planned to be moved to a radio quiet or semi-quiet area, when the conversion is completed.

Fig. 1. The 2m S-band Dish at the premises of the Hellenic Open University Campus. The dish is currently under conversion to a radio telescope capable to monitor the 10.7cm solar flux.

The idea of the 10.7cm measurement is based on a similar experiment held successfully at the Dominion Radio Astrophysical Observatory (DRAO) (eg. [9,10] and references therein).

In order our system to perform as an efficient 'radio solar flux' antenna, we have designed the new control system to offer variety of drive modes relative to the position of the sun. Currently we are finalizing this modern interface, so that our system can be driven either manually or under the control of a general-purpose modern-day computer (locally and/or remotely).

2.2 Solar Data

The solar data at our disposal consist of time series measurements of the Solar Number (SN), the F10.7 cm radio flux, the total Solar Radiation (TSI) and the Cosmic Galactic Radiation (GCR). The data were pulled out of the corresponding databases. I.e.

- Sunspot number from the Royal Observatory of Belgium, Brussels, World Data Center SILSO (Sunspot Index and Long-term Solar Observations) and for the period between 1/1/1818 to 30/6/2021 (SILSO, 1818-2021).
- Total Solar irradiance (TSI) data were retrieved from NOOA (ACRIM3composite_nnava3, [11]).
- Galactic cosmic ray (GCR) data were retrieved from NOOA (BRI: Bartol Research Institute [12]). They are in annual records from 1957 to 2012.

2.3 Meteorological Data

Meteorological parameters include temperature (in ^{o}C), precipitation, wind direction (in ^{o}, with 0^{o} being the north), pressure, relative humidity (%), wind force in knots and atmospheric pressure in mm Hg.

The data were obtained from the Hellenic Meteorological Service (EMY). They are time series from 1955 to 2016 and consist of eight observations per day, every three hours, at 00:00, 03:00, 06:00, 09:00, 09:00, 12:00, 15:00, 18:00 and 21:00 and record temperature in degrees Celsius, relative humidity in percentage (%), wind force, and precipitation (measured in millimetres, mm). We have twelve-hour records at 00:00 and 18:00 for the years from 1975 to 2004. All records are in coordinated universal time (UTC).

The data were collected from twelve meteorological stations (MS) dispersed from north to south and from east to west (see Fig. 2).

Fig. 2. The position of the MS used across Greece.

The parameters are averaged appropriately so that their variations can be compared with variations from the solar magnetic activity.

3 Results

In Figs. 3 to 9 we show an indicative preliminary result of all the meteorological parameters from the meteorological station (MS) of Ioannina (terrestrial coordinates: Lat 39.69^{o}N, Long 20.83^{o}E, Height 475, top panel) compared with the four solar parameters (daily values, bottom panel).

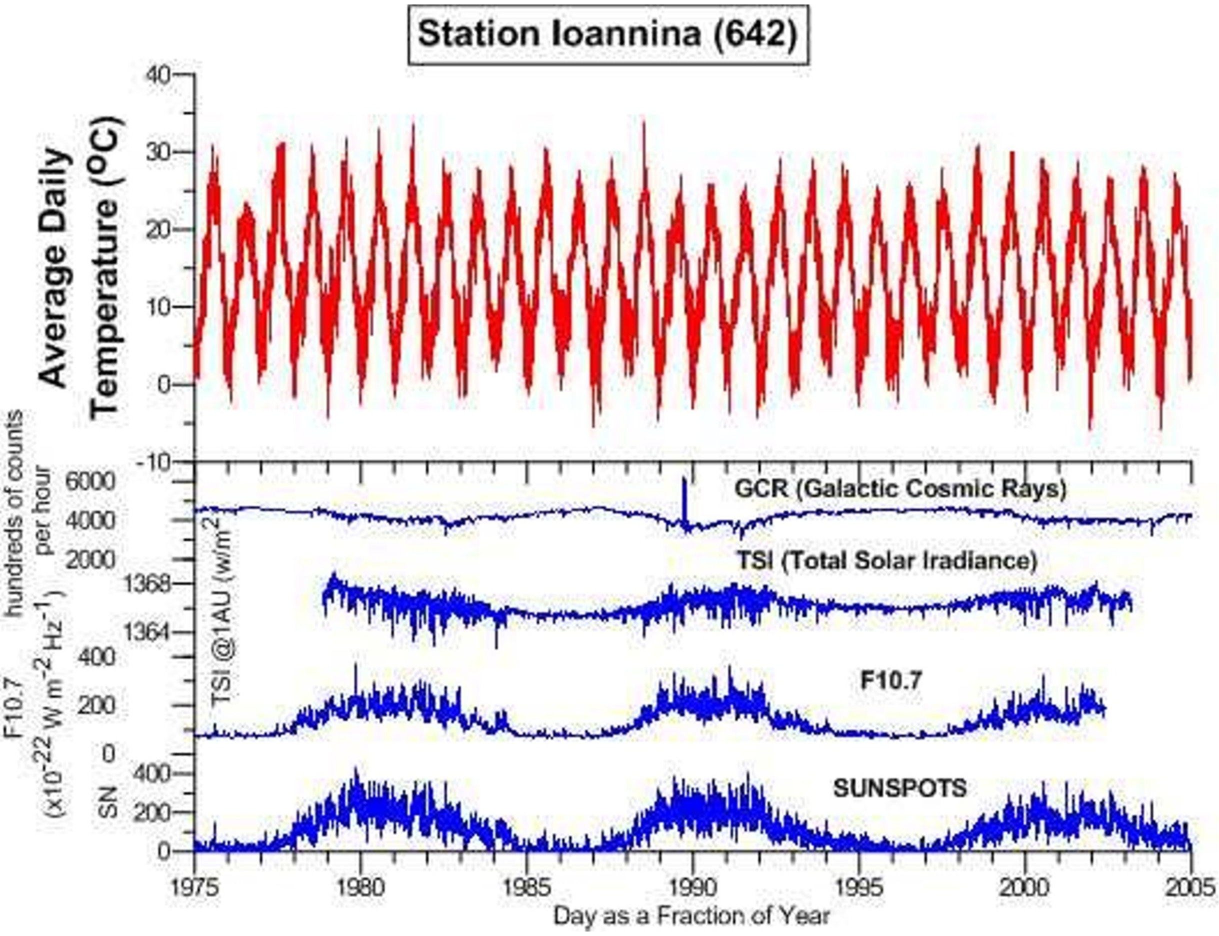

Fig. 3. The mean daily temperature from the MS of Ioannina plotted against the daily values of the four solar parameters mentioned.

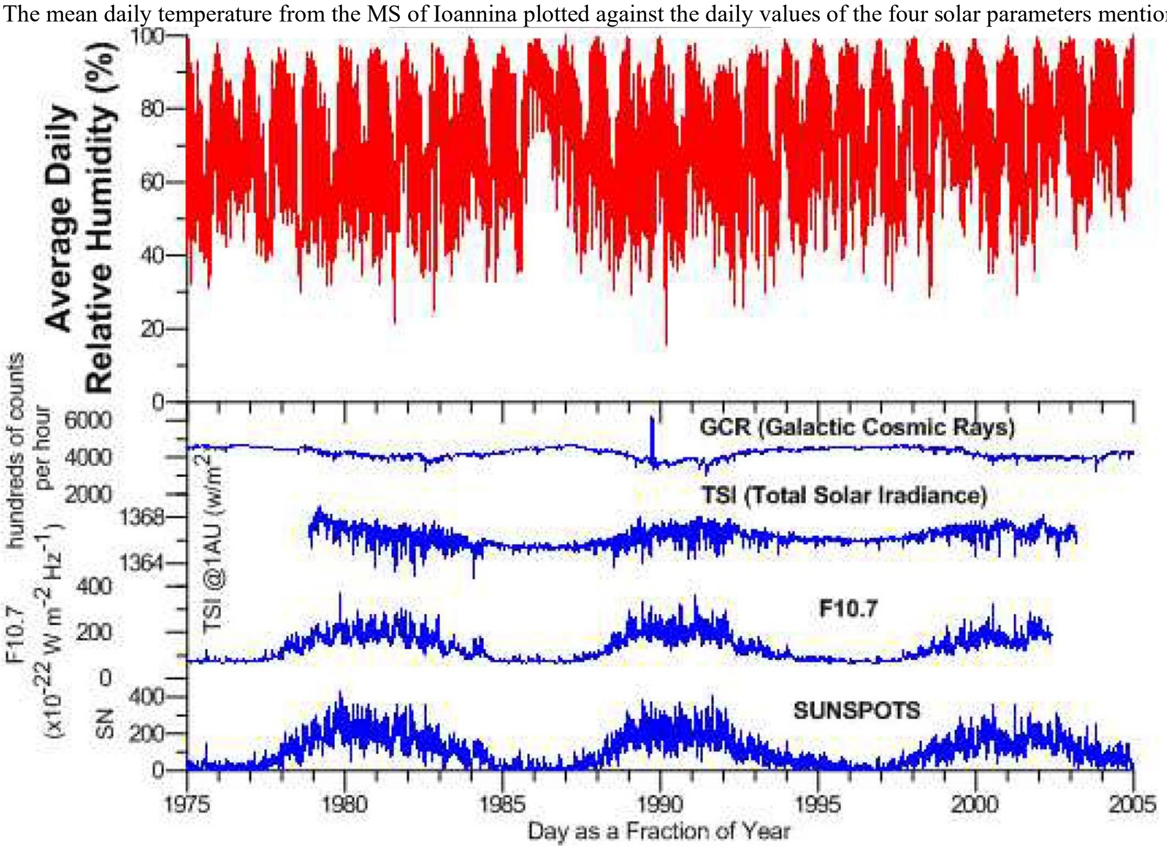

Fig. 4. As in Fig. 3, but the average relative Humidity is depicted.

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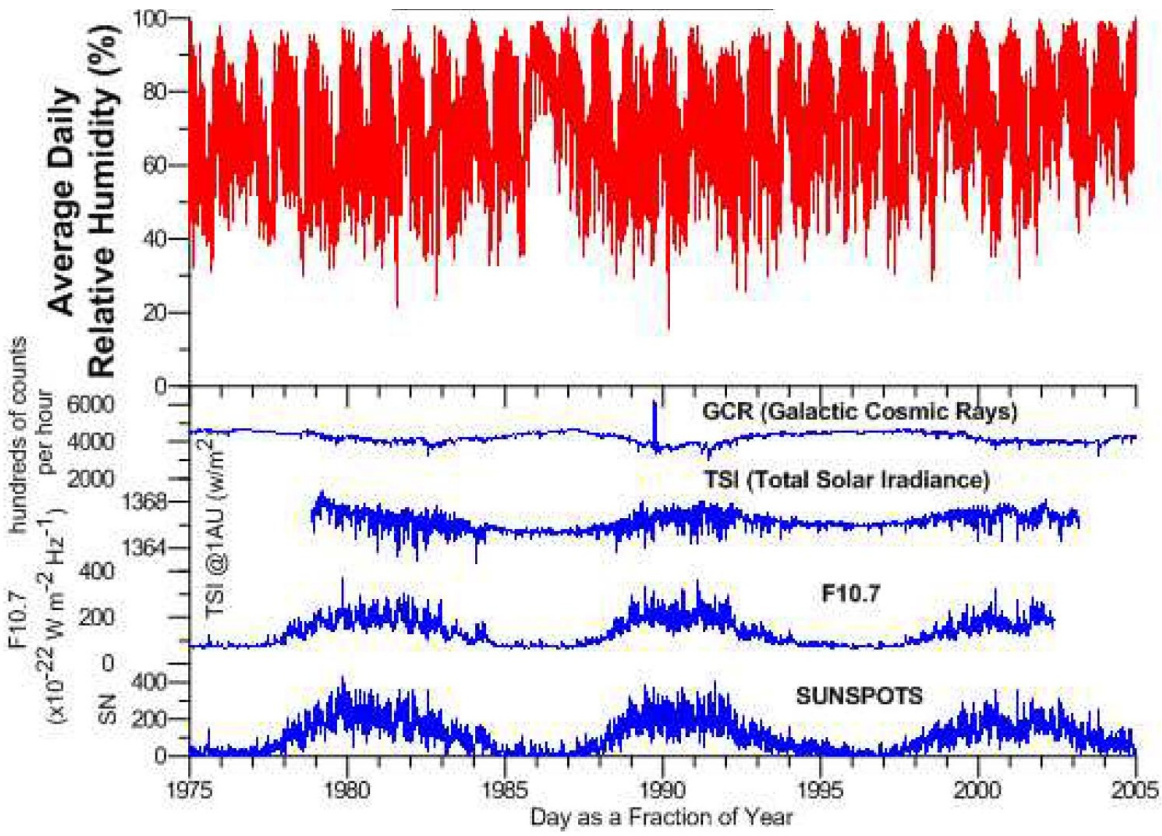

Fig. 5. As in Fig. 3, but for the average relative Humidity.

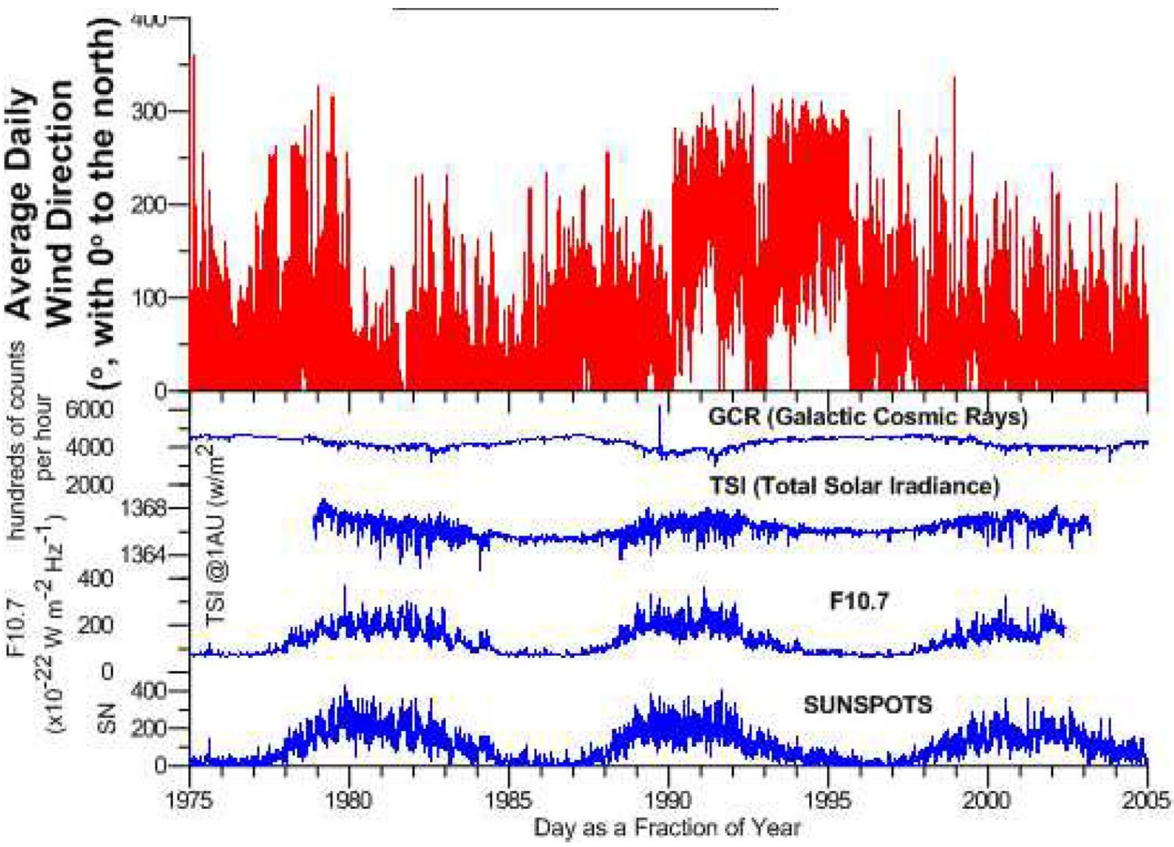

Fig. 6. As in Fig. 3, but for the average daily wind direction.

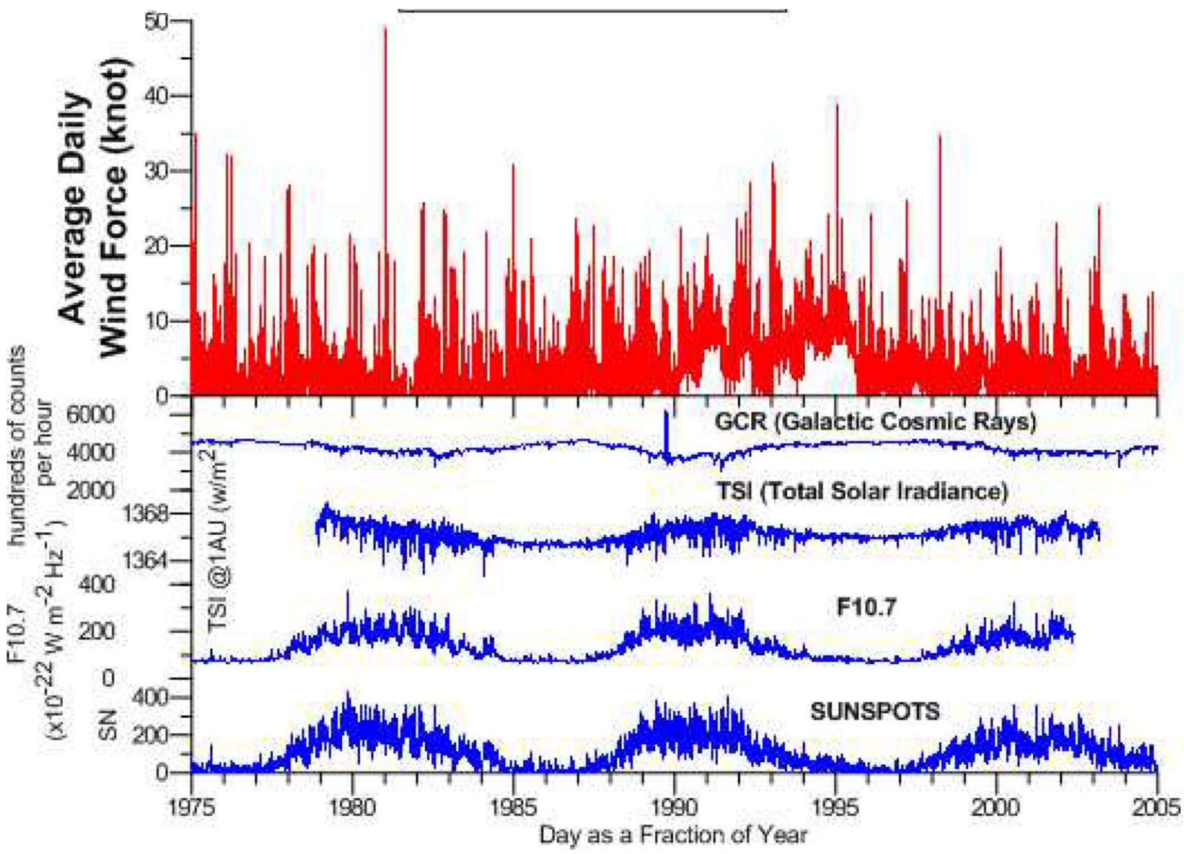

Fig. 7. As in Fig. 3, but for the average daily wind force.

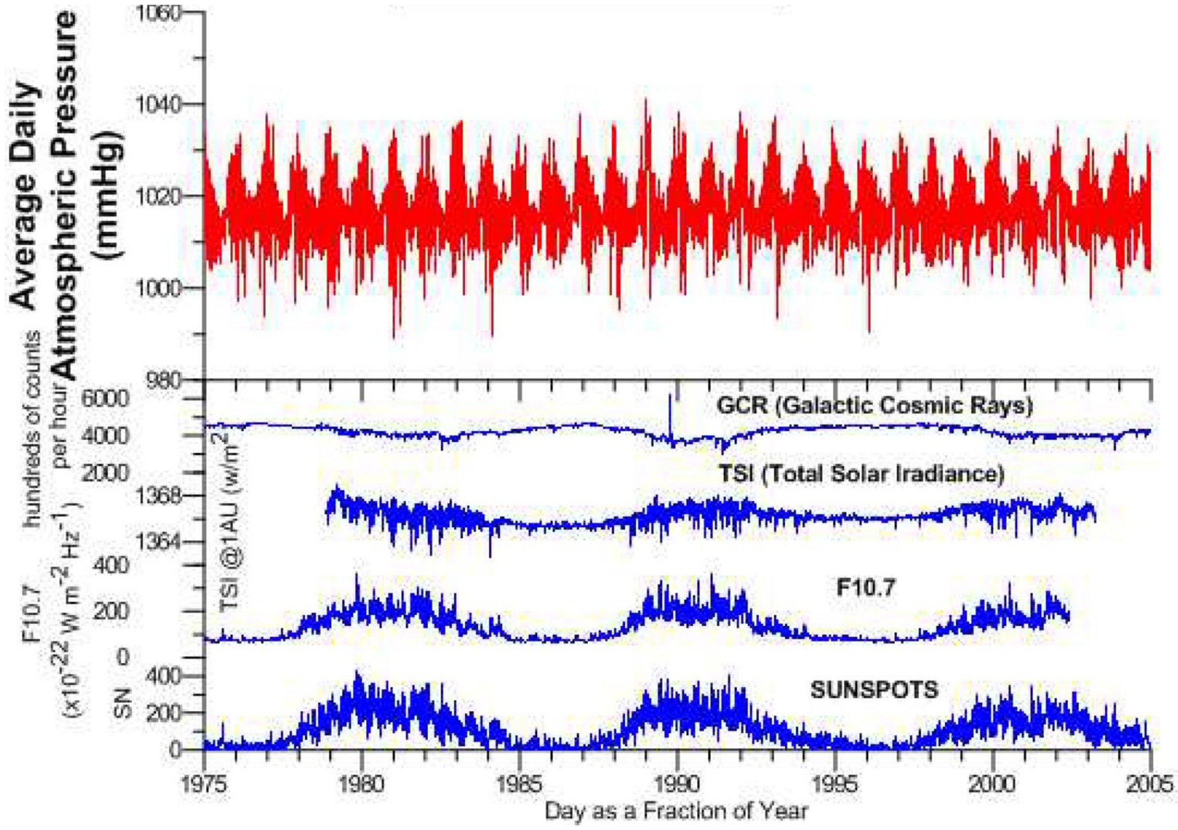

Fig. 8. As in Fig. 3, but for the average daily atmospheric pressure.

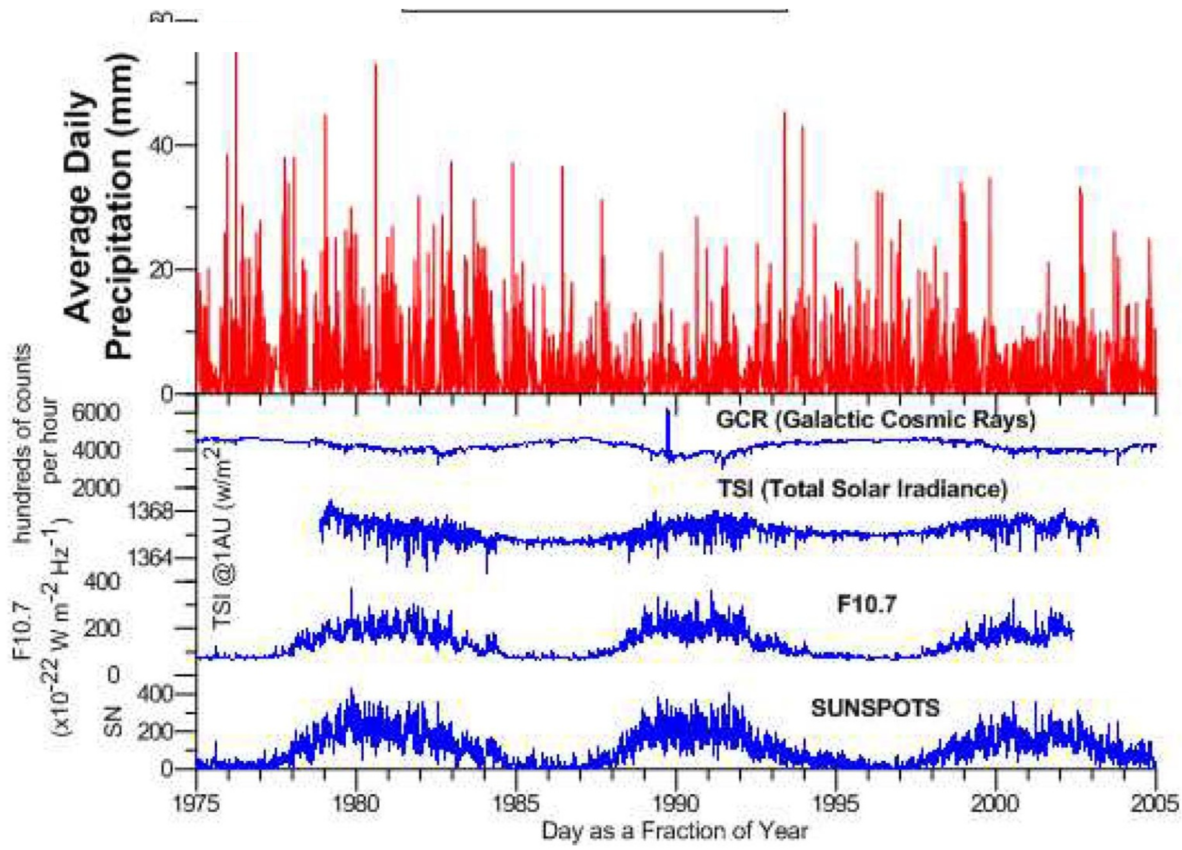

Fig. 9. As in Fig. 3, but for the average daily precipitation.

4 Conclusions

At present we cannot say with certainty whether there is a correlation between meteorological parameters in Greece and solar variations or not. Some correlation is hinted in Fig. 3 following the maxima and minima of the temperature and the rest of the meteorological parameters with respect to the solar curves. However, it is not completely clear and further process of the data need to be applied. Similar results are seen in the graphs only for the Florina, Mikra, Larissa and Heraklion.

This is a very preliminary result, and we obviously have to plot the data differently, for example rebinning the data for more appropriate time periods indicated for example by the solar parameters' variations, solar cycle(s), etc.

There is another issue that poses difficulties in this kind of research: The fact that there is no continuous recording for all the solar parameters for the same time interval (eg. [13]). An idea to examine is to use reconstructed data (eg. [14]).

We have also presented the Hellenic solar flux monitor. We have designed its new control system to offer a variety of drive modes relative to the position of the sun. Our system can be driven locally or remotely using a general-purpose modern-day computer. The manual driving of the system is included for calibration purposes and for astronomical observations when the sun is set.

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