# Influence of Solar Activity Cycles on Earth's Climate

*ESA ITT AO/1-4618/NL/AR*

Task 3 – Data Interpretation

WP 304 – Data Interpretation - Solar

Technical Note

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## Document status sheet

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# 1 Introduction

Solar activity is driven by the changes of the solar magnetic field. To understand solar magnetic activity we use abstract concepts and equations of mathematics. To describe it in real world we use various observed indicators. The solar magnetic activity often show non-linear, transient and chaotic behavior. For that reason we use wavelet methods. But how to understand and interpret the indicators? Therefore, in Section 2, we compare indicators with the mathematical concepts, such as the toroidal and poloidal magnetic field. We show how the indicators group sunspot number and C14 can tell us something about the toroidal magnetic field and poloidal magnetic field respectively. In Section 3 we continue with a comparison between the indicators by carrying out global linear correlation, global scale and local scale based wavelet correlation. Many new interesting results are obtained. Section 4 discusses the effect of using monthly versus 27 day averages. We finish with conclusions in Section 5.

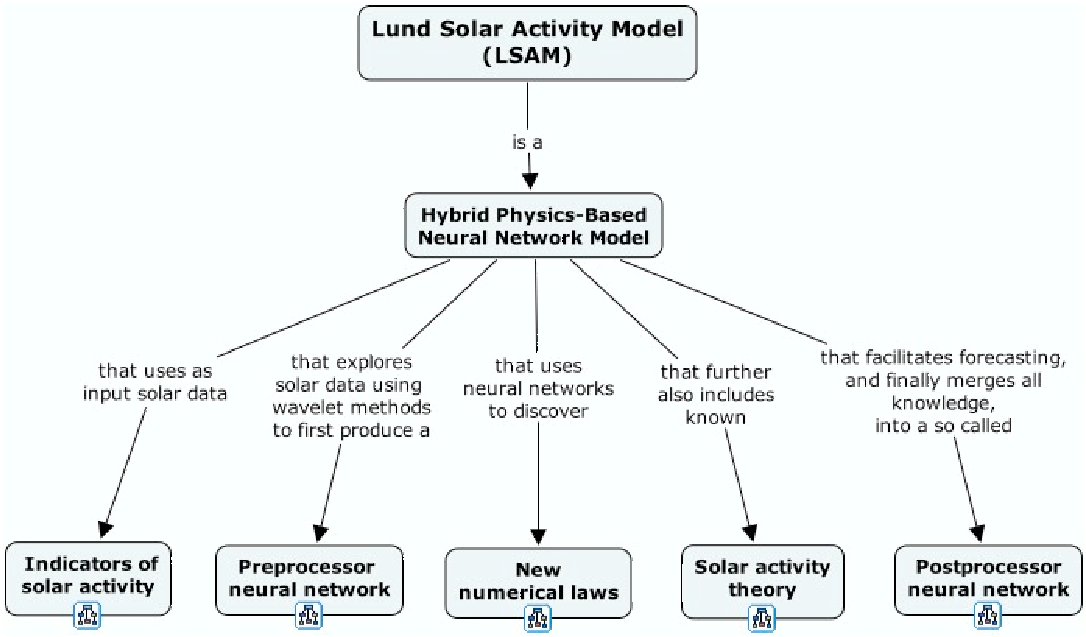


Figure 1: The concept map of the Lund Solar Activity Model (LSAM).

# 2 Interpretation of solar output data

Solar activity is mathematically defined by the changes of the solar magnetic field, change of topology and energy release. The solar activity is understood through the mathematical equations. Solar activity is explored using various physical indicators. The challenge is to combine mathematics and solar physics.

## 2.1 Lund Solar Activity Model

A new such approach to explore, understand and predict solar activity was introduced with "Lund Solar Activity Model" (LSAM) *Lundstedt* (2006). The concepts behind the model are described in the Concept-Map in Figure 1.

LSAM uses solar data as input. We use different kinds of indicators of solar activity (Figure 2) depending on time-scale of the solar activity. For very long-term solar activity, proxies such as $^{14}$C and $^{10}$Be are used. For studies of the main solar cycle various indexes are used, such as the sunspot number, group sunspot number, the radio intensity F10.7, E10.7 extreme UV proxy, Mount Wilson Sunspot index (MWSI) and Magnetic Plage Strength Index (MPSI). Even more physics-based parameters are used, such as the magnetic field (B), the mean field *Boberg et al.* (2002) and velocity flows. A new data set is under development of solar and sub solar flows from local-area helioseismic analyses *Jensen et al.* (2004).

LSAM is a so called hybrid physics-based neural network model. It means that we also intend

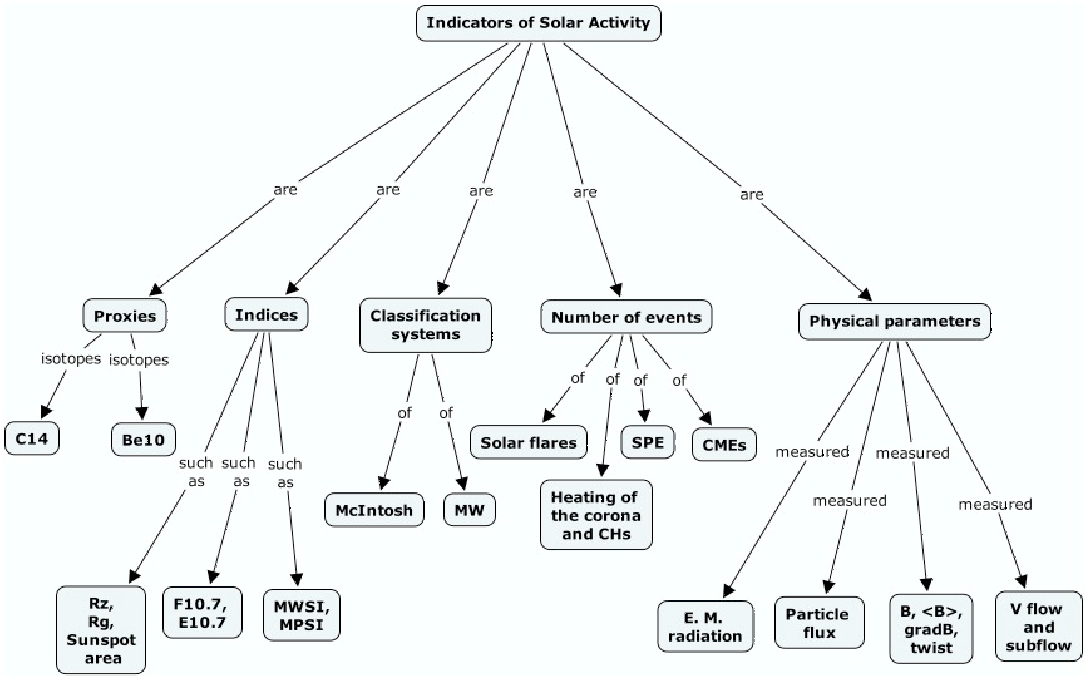


Figure 2: Indicators of solar activity.

to include known solar physics theory into the neural network model. The preprocessor neural network has only learned the solar physics from data. The numerical laws are also only using observed data. The linked Concept-Map Solar Activity Theory in Figure 1 describes how solar theory can be included.

However, first we need to define solar activity theoretically, i.e. what the neural network shall learn. We define it as the change of the magnetic field; its generation, regeneration and modulation. The change of the topology of the magnetic field and the release of energy transferred to magnetic fields by the convection.

The solar theory about the change of the magnetic field is modelled using MHD equations, i.e. coded as deterministic differential equations. The physics, described by the differential equations, needs therefore to be transferred to the neural network.

## 2.2 Wavelet methods

Today using wavelet techniques has become a common method of analyzing solar-terrestrial data. Good introductions to the use of wavelet transforms are given by *Torrence and Compo* (1998) and *Addison* (2002). Wavelet analysis is a powerful tool both to find the dominant mode of variation and also to study how it varies with time, by decomposing a non-linear time series into time-frequency space.

In *Lundstedt et al.* (2005) and *Lundstedt et al.* (2006) we described in detail Ampligrams and

Time-Scale Spectra (TSS) which can be looked up as a kind of band pass filtering in the Wavelet Coefficient Magnitude (WCM) domain. When the wavelet coefficient magnitudes (WCM) are plotted for the scale and the elapsed time, a so called scalogram is produced. Skeleton spectrum can be derived from scalograms. The scale maximal wavelet skeleton spectrum keeps only those wavelet components that are locally of maximum amplitude at any given time-scale. The instantly maximal wavelet skeleton spectrum keeps only those wavelet components that are locally of maximum amplitude at any given time.

The set of wavelet methods developed by *Liszka* (2003), and applied in *Lundstedt et al.* (2005) *Lundstedt et al.* (2006) are summarized in Figure 3.

Finally also Multi-Resolution Analysis (MRA) is carried out. The idea behind MRA is to separate the information to be analyzed into a "principal" (low pass) and a "residul" (high pass) part. The process of decomposition can then be applied again to both parts. Simplified mathematically, (*Mallat* (1998)) it can be described by the following equations

$$s = A_J + \sum_{j \leq J} D_j \tag{1}$$

where s is the signal, $A_J$ the approximation (principal part) at resolution level J and $D_j$ the detail (residul part) at level j. From the previous formula, it is seen that the approximations are related to one another by:

$$A_{J-1} = A_J + D_J \tag{2}$$

$$D_j = \sum_{k \in Z} C(j,k) \Psi_{j,k}(t) \tag{3}$$

where $D_j$ is the detail at level j, $C(j,k)$ the wavelet coefficient and $\Psi_{j,k}(t)$ the wavelet function. The wavelet used in this study was a Daubechies of order six. The dyadic scale is $a = 2^j \leq 2^J$ for level j. The resolution is given by $1/a$ or $2^{-j}$. The dyadic translation is given by $b = ka$.

### 2.3 Solar indicators explored with wavelet methods

In Figure 4 the solar activity, as indicated by the group sunspot number and sunspot number, is given in an ampligram for the period 1610 to 2005. The variability is shown for fractions of the maximum wavelet coefficient magnitude. The large variation of the solar activity amplitude is clearly seen, including several minima such as Maunder minimum (1645-1715), Dalton minimum (1795-1823), and the most recent maximum (after 1940). The sunspot indicator shows the 11 year cyclicity for the whole period except during the Maunder minimum. In lower panel only the weak signal, below 20%, of the WCM maximum is shown. It is interesting that even the very weak signal has structures.

In order to further study the cyclicity, revealing maximum and minimum, during the Maunder Minimum we carried out a Multi-Resolution Analysis of the annual $^{14}$C production rate (Figure 5). The variation is studied at different resolutions. At level four in the detailed part the 22-year cycle is clearly present during the Maunder Minimum. The 11-year cycle is also clearly seen at level three

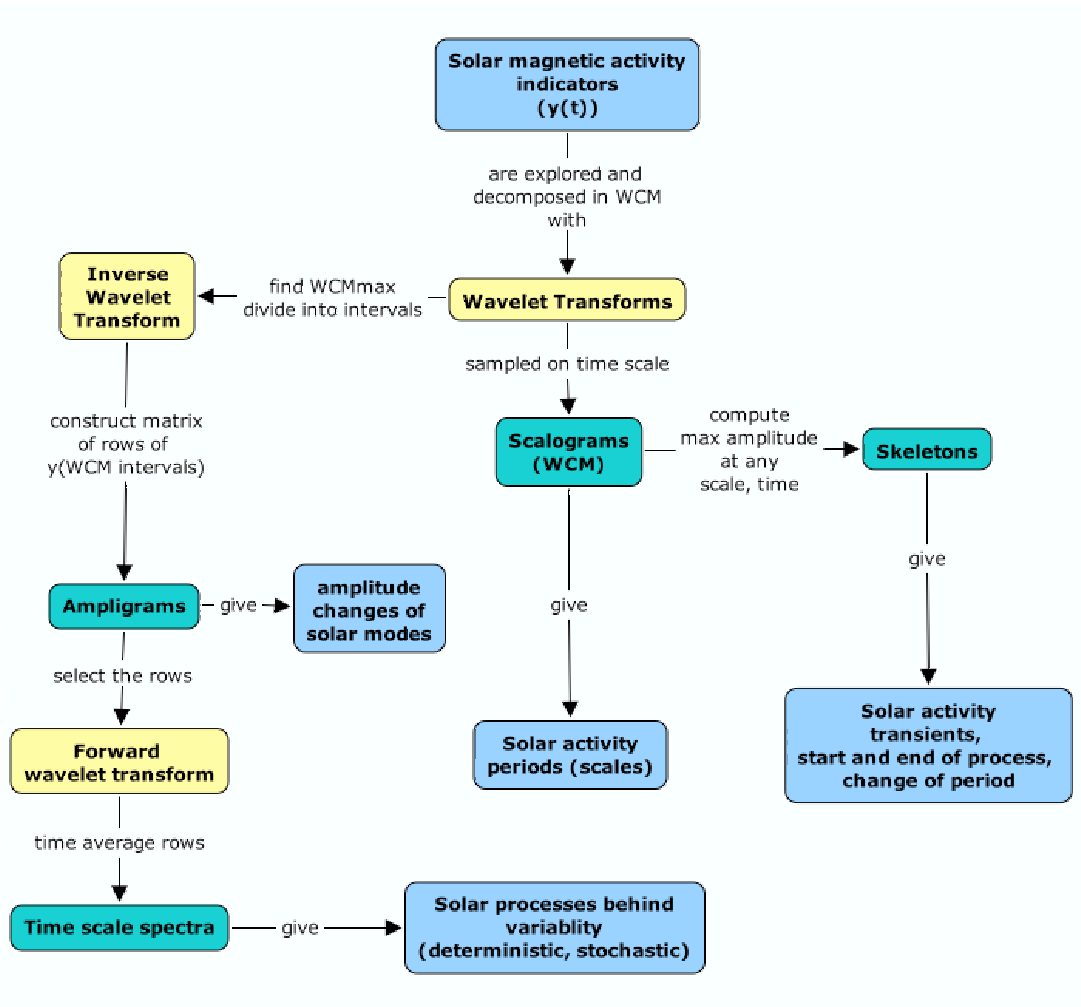


Figure 3: The set of developed wavelet methods described in Lundstedt et al., 2005.

in the detailed part. At the lowest resolution (approximation level four) several peaks appear. The strongest occur around 1600 and about 1780. These are not seen in the group sunspot number.

The found cyclicity for the solar indicator, $^{14}$C production rate, during the Maunder minimum shows that this indicator is better than the sunspot number. The difference is explained by that during the Maunder minimum strong toroidal magnetic flux tubes (as indicated by the sunspot number) were absent but weak ephemeral magnetic field (also indicated by the $^{14}$C production rate) were present.

During the latest solar cycle, the sunspot number has again shown to be a not so good indicator of the solar activity. On September 7, 2005, an X17 solar flare occurred (!) and we have had as many geomagnetic stormas and X-type solar flares in 2005 (i.e. close to sunspot minimum), as during Solar Max (2000)!

To improve the picture of the Sun's activity we need an indicator. describing the activity of the whole Sun from below the solar surface, on the surface to the corona. Using the sunspot number

we only describe the activity of largest flux tubes on the surface between about 35 degrees latitude.

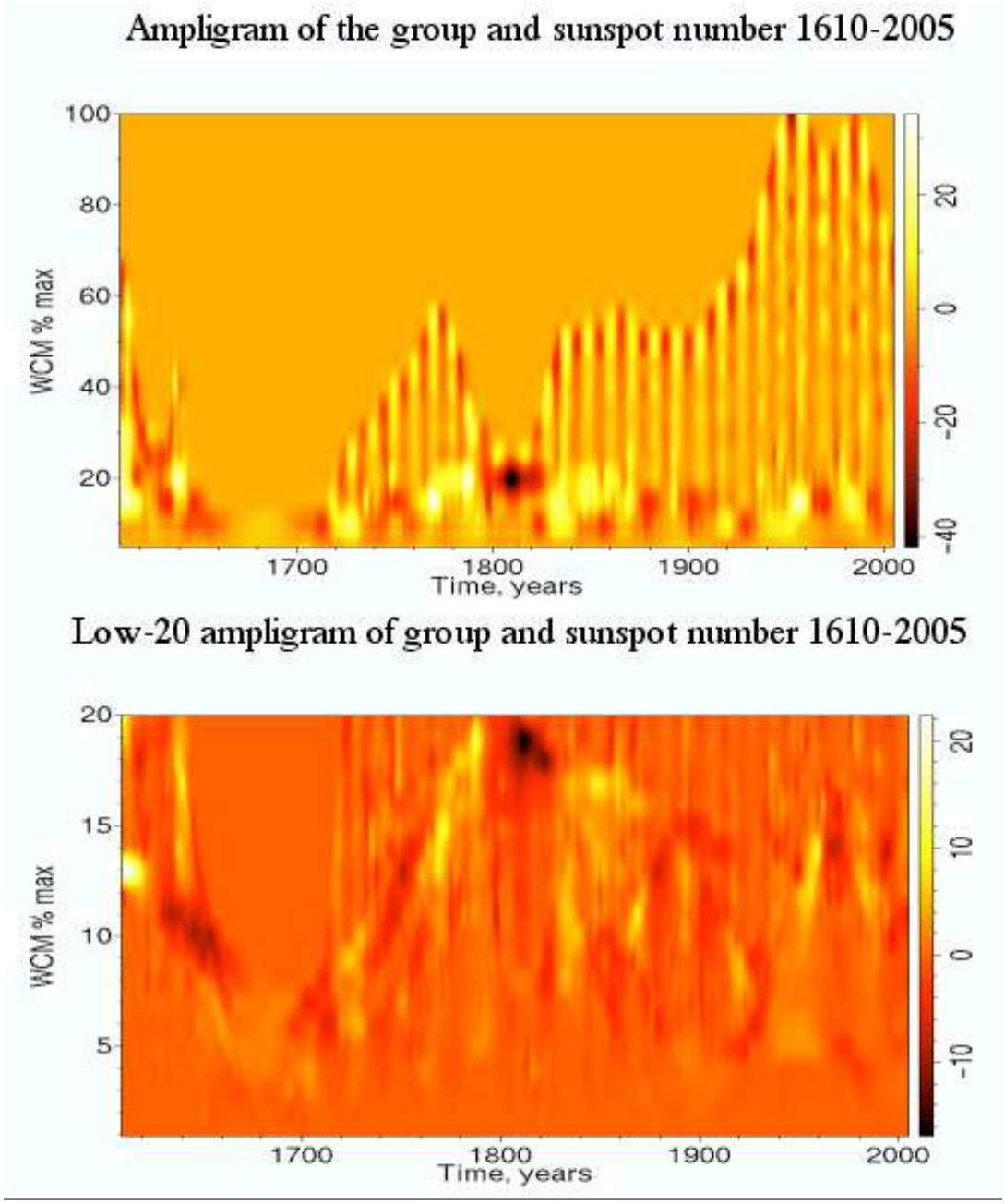


Figure 4: Ampligram of the group sunspotnumber 1610-1995 and the sunspot number 1995-2005. In the lower panel only the wek signal, below 20 % of WCM maximum. In the colour scale to the right, the zero represents the average value of the sunspot number.

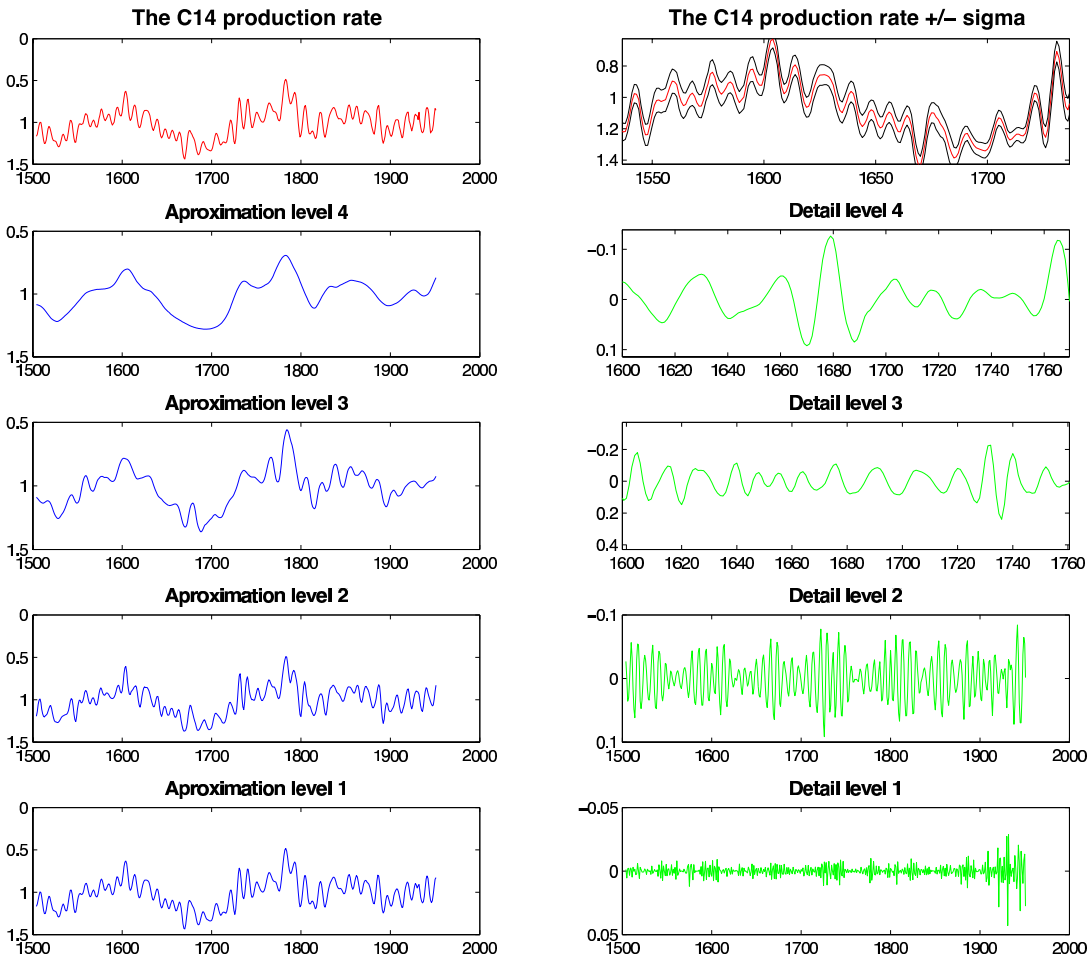


Figure 5: Multi resolution analysis of the $^{14}$C production rate. The 22-year cycle is clearly present during the Maunder minimum (zoomed in period) at detail level 4. The 11-year cycle is clearly present during the Maunder Minimum (zoomed in period) at detail level3.

# 3 Correlation study of solar data

The solar data in the ISAC database are pair-wise correlated in order to see common features and differences. We study data with daily resolution or better. In addition to the data identified in "WP 201–Solar Output" we also include the neutron flux data from CLIMAX. We start with computing linear correlation coefficients for daily data, next we proceed with wavelet based global correlation, and finally wavelet based local correlation.

On the following pages we use the names of the solar parameters as defined in WP 201. To improve the readability of this document the definition of the parameters are given in Table 1.

| | |
|---|---|
| MPSI | Magnetic Plage Strength Index |
| MWSI | Mount Wilson Sunspot Index |
| CI | Coronal Index |
| lg GOES >10 MeV p | 10-logarithm of >10 MeV proton flux at geostationary orbit |
| lg GOES X-ray | 10-logarithm of X-ray flux |
| E10.7 | Solar EUV index based on F10.7 |
| FI | Optical Flare Index |
| Ca II plage area | Plage area derived from Ca II images of the Sun at Mt. Wilson |
| F10.7 | Solar radio flux at 10.7 cm wavelength adjusted for variation in Earth orbit |
| SSA | Sunspot Area Index |
| TSI | Total Solar Irradiation |
| UV | UV radiation derived from the Mg II absorption line |
| Rz | Sunspot number |
| abs SMMF | Absolute value of Wilcox Solar Observatory Solar Mean Magnetic Field |
| aa | Geomagnetic aa index |
| Kp | Geomagnetic Kp index |
| Ap | Geomagnetic Ap index |
| Dst | Geomagnetic Dst index |
| B | Solar wind magnetic field |
| Bzn GSE | Northward component of solar wind magnetic field in Geocentric Solar Ecliptic coordinate system |
| Bzs GSE | Southward component of solar wind magnetic field in Geocentric Solar Ecliptic coordinate system |
| Bzn GSM | Northward component of solar wind magnetic field in Geocentric Solar Magnetospheric coordinate system |
| Bzs GSM | Southward component of solar wind magnetic field in Geocentric Solar Magnetospheric coordinate system |
| n | Solar wind particle density |
| V | Solar wind bulk velocity |
| Rg | Group sunspot number |
| CLIMAX | Neutron count rate at Climax neutron monitor |

Table 1: Definition of solar parameters. All parameters are daily averages. See also WP 201.

### 3.1 Global linear correlation

We start with computing the linear correlation coefficients for the daily solar data. This is useful in the subsequent discussions on how various solar parameters co-vary during different time periods and on different scales. Table 2 shows the linear correlation of the sunspot number $R_z$ and the other solar parameters.

| Rz | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.87 ( 0.73, 0.94) | 25 | 0.26 ( 0.24, 0.28) | 12718 | 12855 |
| MWSI | 0.74 ( 0.60, 0.84) | 56 | 0.21 ( 0.20, 0.23) | 11883 | 12855 |
| CI | 0.66 ( 0.44, 0.80) | 42 | 0.05 ( 0.03, 0.06) | 23375 | 23375 |
| lg GOES >10 MeV p | 0.22 ( 0.11, 0.32) | 296 | 0.01 (-0.02, 0.04) | 4062 | 4107 |
| lg GOES X-ray | 0.82 ( 0.29, 0.96) | 8 | 0.10 ( 0.07, 0.13) | 4107 | 4107 |
| E10.7 | 0.92 ( 0.85, 0.96) | 36 | 0.45 ( 0.44, 0.47) | 14782 | 20195 |
| FI | 0.63 ( 0.43, 0.77) | 49 | 0.08 ( 0.06, 0.10) | 10226 | 10226 |
| Ca II plage area | 0.84 ( 0.72, 0.91) | 47 | 0.09 ( 0.07, 0.10) | 25349 | 25349 |
| F10.7 | 0.95 ( 0.90, 0.97) | 40 | 0.43 ( 0.42, 0.44) | 17902 | 21230 |
| SSA | 0.88 ( 0.83, 0.91) | 128 | 0.37 ( 0.36, 0.38) | 42204 | 47808 |
| TSI | 0.35 ( 0.01, 0.61) | 35 | -0.17 (-0.19,-0.15) | 7220 | 9084 |
| UV | 0.90 ( 0.73, 0.96) | 17 | 0.43 ( 0.41, 0.45) | 7148 | 9641 |
| **Rz** | - ( -, -) | - | - ( -, -) | - | - |
| abs SMMF | 0.38 ( 0.16, 0.57) | 68 | 0.02 (-0.00, 0.04) | 10644 | 10912 |
| aa | 0.19 ( 0.11, 0.26) | 628 | 0.00 (-0.01, 0.01) | 50128 | 50128 |
| Kp | 0.13 ( 0.04, 0.22) | 456 | -0.00 (-0.01, 0.01) | 26753 | 26753 |
| Ap | 0.12 ( 0.06, 0.19) | 875 | 0.00 (-0.01, 0.01) | 26753 | 26753 |
| Dst | -0.18 (-0.25,-0.10) | 577 | -0.01 (-0.02, 0.01) | 17621 | 17621 |
| B | 0.25 ( 0.12, 0.37) | 212 | 0.01 (-0.00, 0.03) | 15340 | 15340 |
| Bzn GSE | 0.14 ( 0.11, 0.18) | 2488 | 0.02 ( 0.00, 0.03) | 15340 | 15340 |
| Bzs GSE | -0.15 (-0.18,-0.12) | 3778 | 0.01 (-0.01, 0.02) | 15340 | 15340 |
| Bzn GSM | 0.14 ( 0.12, 0.17) | 7466 | 0.01 (-0.00, 0.03) | 15340 | 15340 |
| Bzs GSM | -0.13 (-0.15,-0.11) | 7763 | 0.01 (-0.01, 0.02) | 15340 | 15340 |
| n | -0.09 (-0.19, 0.03) | 311 | 0.00 (-0.02, 0.02) | 15340 | 15340 |
| V | -0.04 (-0.16, 0.08) | 269 | -0.00 (-0.02, 0.01) | 14945 | 15340 |
| Rg | 0.94 ( 0.91, 0.95) | 120 | 0.50 ( 0.49, 0.50) | 65012 | 65012 |
| CLIMAX | -0.70 (-0.84,-0.47) | 33 | -0.02 (-0.04,-0.01) | 18694 | 19082 |

Table 2: Rz correlated against the other parameters. This table is identical to Table 15.

The table contains 6 columns. The first column gives the parameter under study, the second column ($r_{x,y}$) is the correlation coefficient with the 95% confidence limits within parenthesis. As we are correlating two time series we must compensate for serial correlation, which lowers the number of independent observation, when computing the confidence limits (*Quenouille*, 1952; *von Storch and Zwiers*, 1999). The third column ($n_e$) is the effective number of independent observations. This should be compared to the total number of observations ($n$, column 6). We see for example that the linear correlation between $R_z$ and MPSI is 0.87 $(0.73, 0.94)$ at the 95% level with only $n_e = 25$ independent observations as compared to the $n = 12855$ daily values in the data set. It

seen from the table that none of the correlation intervals contain the 0 correlation, which means that all parameters are correlated with $R_z$ and some parameters are highly correlated. However, the dominant effect here is the approximate 11 year cycle that exists in all parameters. Taking the daily difference (columns 4 and 5) suppresses long term variability and focuses on the day-to-day changes. The correlation now drops significantly and several parameters are now uncorrelated.

Basically all correlation coefficients keep the same sign in going from daily data to daily difference data, however, there is one exception, namely the $R_z$-TSI correlation. For daily data the correlation is $r_{x,y} = 0.35$ while for daily difference data the correlation is $r_{\Delta x,\Delta y} = -0.17$. This may be understood from the model that the sunspots blocks lights and thereby lowering the solar irradiance, giving a negative correlation from day-to-day. However, during times of increased number of sunspots the area covered by bright features, like plages, also increases giving a net solar irradiance increase.

Tables for all the other parameters in the ISAC database are found in Appendix 1. We choose to display all tables in the appendix for completeness. However, in the next sections we concentrate our analysis to the total solar irradiation, UV radiation, and cosmic ray flux. These parameters are known to have a direct impact on Earth's climate and are important to the analysis in the other working packages under WP 300.

### 3.2 Global scale based wavelet correlation

As indicated in the previous section it is seen that in computing the linear correlation between two parameters different underlying physical processes are mixed together which may lead to confusing results when forming a temporal average. In this section we will study the linear correlation of the solar parameters at different wavelet filtered levels, thereby separating processes that work on different scales.

Each solar parameter time series is decomposed into corresponding details and approximation using the Maximal Overlap Discrete Wavelet Transform (MODWT) (*Percival and Walden*, 2002; *Cornish et al.*, 2003). The signal $x$ is the sum of the details $D_{x,j}$ and approximation $A_x$

$$x = \sum_{j=1}^{J} D_{x,j} + A_x, \tag{4}$$

where the level $j$ goes from 1 to $J$. We then compute the linear correlation at each scale

$$r_j = C(D_{x,j}, D_{y,j}) \tag{5}$$

again compensating for serial correlation when computing the confidence intervals.

In Figure 6 the scale based linear correlation between TSI and $R_z$ is shown. Each box in the figure shows the approximate period (width) and the 95% confidence limits (height) at each level. We now get a more detailed picture of the correlation between $R_z$ and TSI as compared to global linear correlation above. We see that the correlation is very strong and positive at periods longer than 5.6 years. The correlation then decreases for shorter periods, crossing zero around 2 years, and

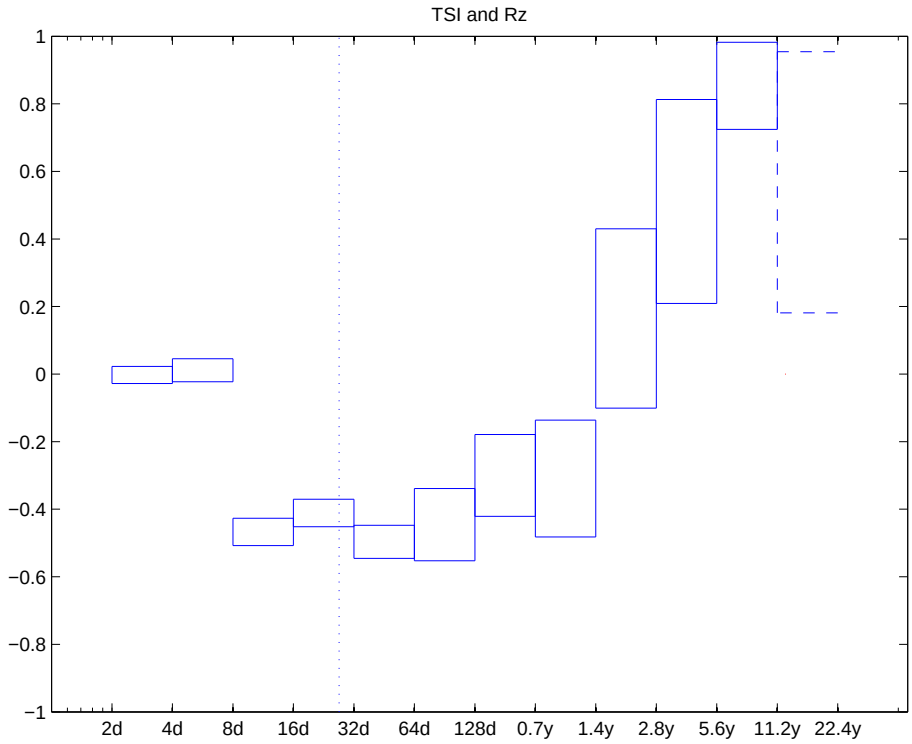


Figure 6: Scale based correlation between TSI and $R_z$. The width of the boxes indicates the approximate periods that each level covers. The heights of the boxes gives the 95% confidence limits. The dotted vertical line marks the 27 day period.

then becoming negative. This is in line with the findings from Table 2. It is clear from Figure 6 that if $R_z$ is used as a proxy for TSI care has to be taken to which process that should be modelled if any temporal averaging is used. If we study periods in the range 8 days to 1.4 years there is a quite strong negative correlation which could be related to the sunspot blocking. For periods longer than 2.8 years, or even 5.6 years, the correlation is strongly positive probably due to the fact that bright regions and sunspots correlate on these time scales.

Another interesting time series is the neutron count data from CLIMAX as it serves as a proxy for cosmic rays. The cosmic ray flux is anti-correlated with $R_z$ because strong heliospheric magnetic flux shields the Earth from cosmic rays. Table 2 shows a strong anti-correlation ($-0.70$). In Figure 7 the correlation at different scales is shown. The correlation is consistently negative, although it is rather weak for periods less than 2.8 years. Thus, on long time scales $R_z$ may serve as a good proxy for the cosmic ray flux, but not on shorter time scales.

The 10.7 cm radio flux (F10.7) is often used as a proxy for the solar UV radiation. F10.7 and $R_z$ are also highly correlated at time scales longer than the solar rotation period (27 days). See Table 11 on page 30 for the global correlation of F10.7 with the other parameters. The UV radiation is estimated from observations of the Mg II core-to-wing ratio (see WP 201). The UV index extends back to 1979. From Figure 8 it is seen that F10.7 is highly correlated with the UV index at all scales longer than 27 days. The correlation reaches above 0.8 at 16–32 days, then decreases slightly

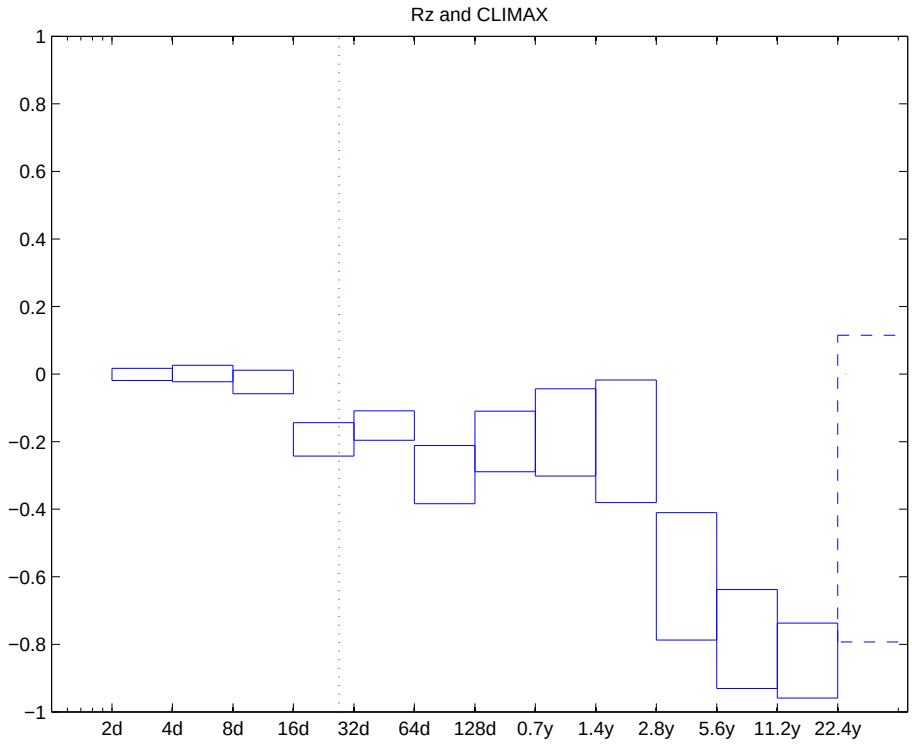


Figure 7: Scale based correlation between $R_z$ and CLIMAX. The width of the boxes indicates the approximate periods that each level covers. The heights of the boxes gives the 95% confidence limits. The dotted vertical line marks the 27 day period.

to around 0.7 at 64–128 days, and then goes above 0.8 at longer time scales.

### 3.3 Local scale based wavelet correlation

The analysis is further refined by using wavelet coherence analysis (*Grinsted et al.*, 2004). In the previous section we looked at the linear correlation at different scales for the complete time period of the data set. Strong negative or positive correlation clearly indicates co-varying time series on the specific scale. However, a correlation coefficient of 0 may indicate that there is no correlation between the time series, or that there is a correlation but the time series are out of phase. Using the wavelet coherence analysis we study the time varying correlation and phase over the different scales. In Figure 9 we apply the analysis to TSI and $R_z$. In the top panel the wavelet coherence is shown and for comparison $R_z$ is shown in the bottom panel. For periods longer than 64 Carrington rotations (about 5 years) there is a significant correlation with no phase difference (right pointing arrows). At one year period (Period=13) the correlation is more patchy, and when there is a correlation the signals are basically out of phase which is in agreement with the negative correlation of Figure 6. But it also seen that the correlation mainly exists during the declining and minimum phases of $R_z$.

In Figure 10 the wavelet coherence is shown for $R_z$ and CLIMAX. A significant and strong anti-

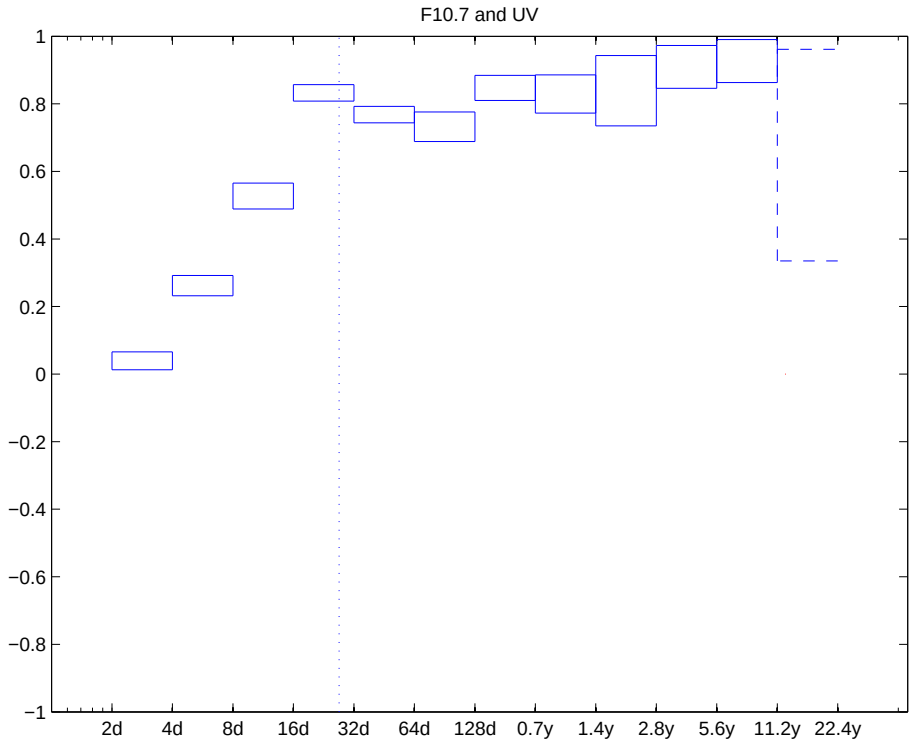


Figure 8: Scale based correlation between $F10.7$ and UV. The width of the boxes indicates the approximate periods that each level covers. The heights of the boxes gives the 95% confidence limits. The dotted vertical line marks the 27 day period.

correlation is present at all times for periods longer than about 100 Carrington rotations (7 years) but for shorter periods the signals only occasionally correlate.

In Figure 11 the wavelet coherence is shown for F10.7 and the UV index. It is seen that there exists a strong and significant correlation over a large range of scales at all times. The arrows also indicate that the two parameters are in phase. However, there are some patchy features at periods of 2–4 Carrington rotations (54–108 days), and also at around 8 Carrington rotations in the later part, indicating only weak correlation.

### 3.4 Summary of correlation study

Here we summarise our findings from the correlation study:

- All solar output parameters show a significant correlation due to the underlying approximate 11 year cycle.
- TSI and $R_z$ show a complex relation in that they are anti-correlated for periods shorter than about one year and then becomes positively correlated for longer time scales.

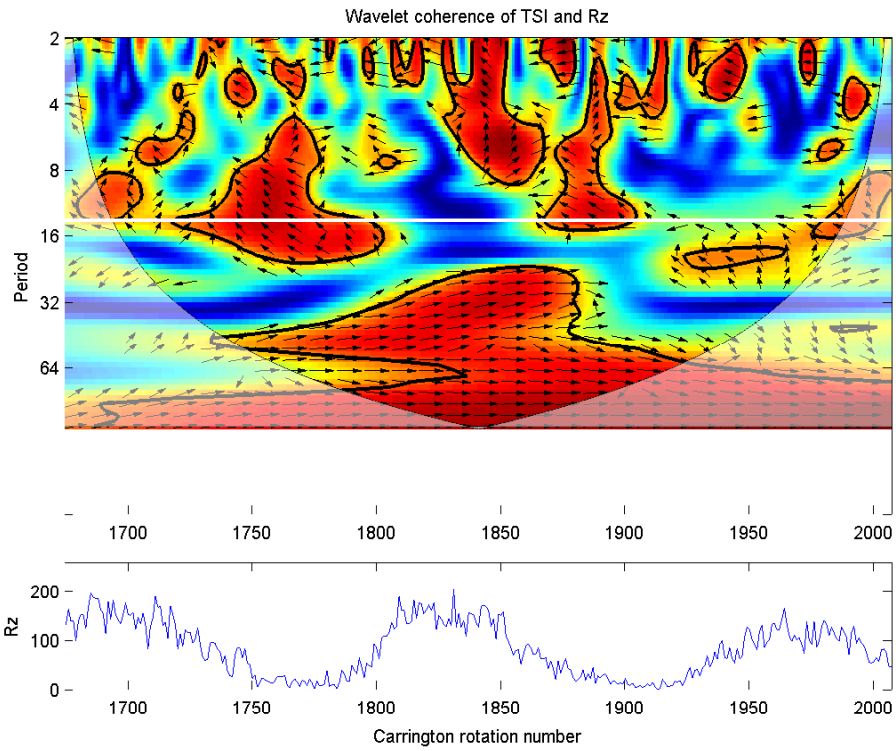


Figure 9: Wavelet coherence between TSI and $R_z$. Upper panel: Weak correlation is coloured blue and strong correlation red. The black heavy lines indicate a significant correlation at the 95% level. Arrows indicates any phase shift. An arrow pointing to the right means no phase shift, an arrow pointing down means that TSI leads $R_z$ by 90 degrees, an arrow pointing up means that TSI lags $R_z$ by 90 degrees, and an arrow pointing to the left means that they are 180 degrees out of phase. The period is given in units of Carrington rotations. The two thick white lines marks 1 year and 11 year periodicities. Lower panel: The sunspot number $R_z$ is shown for comparison.

- $R_z$ and cosmic ray flux are basically only correlated for time scales longer than a couple of years.
- F10.7 and UV are highly correlated at all times over many scales. However, there are several occasions when they are uncorrelated only monthly time scales.

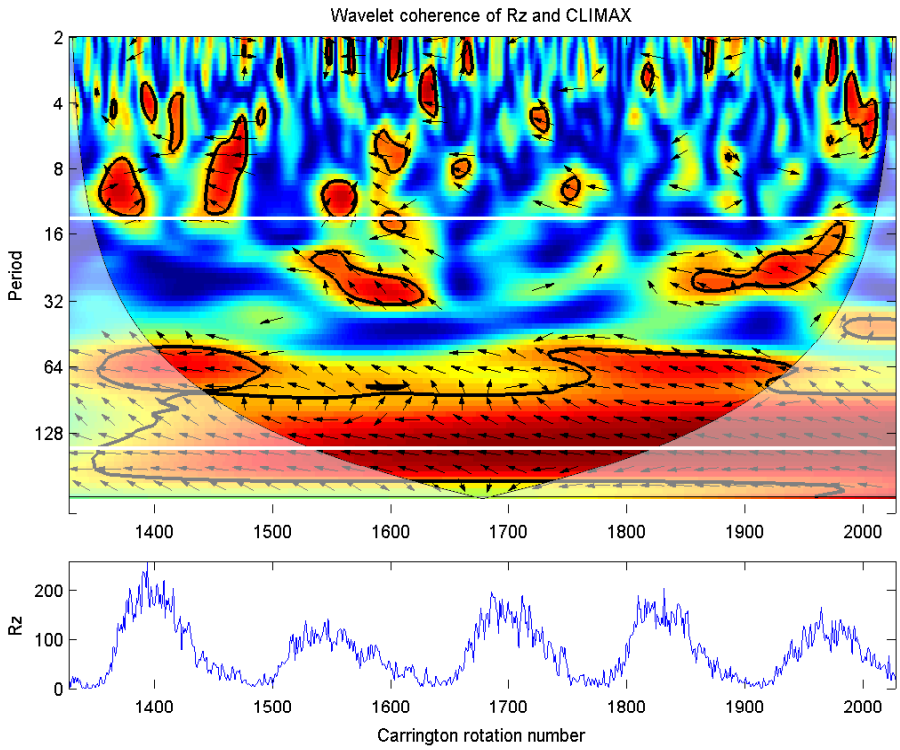


Figure 10: Wavelet coherence between $R_z$ and CLIMAX. Upper panel: Weak correlation is coloured blue and strong correlation red. The black heavy lines indicate a significant correlation at the 95% level. Arrows indicates any phase shift. An arrow pointing to the right means no phase shift, an arrow pointing down means that $R_z$ leads CLIMAX by 90 degrees, an arrow pointing up means that $R_z$ lags CLIMAX by 90 degrees, and an arrow pointing to the left means that they are 180 degrees out of phase. The period is given in units of Carrington rotations. The two thick white lines marks 1 year and 11 year periodicities. Lower panel: The sunspot number $R_z$ is shown for comparison.

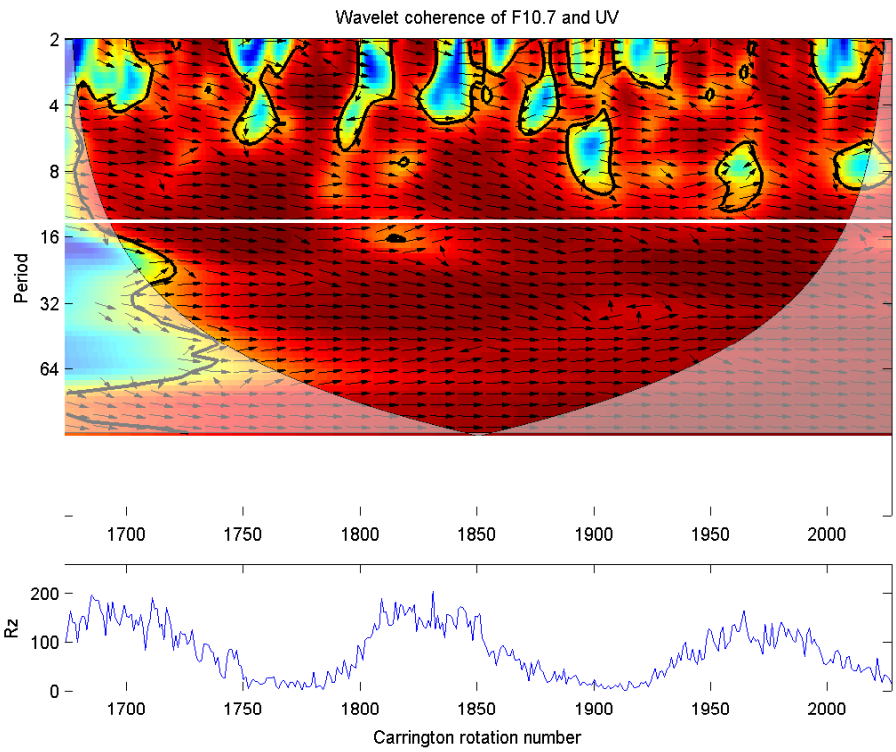


Figure 11: Wavelet coherence between $F10.7$ and UV. Upper panel: Weak correlation is coloured blue and strong correlation red. The black heavy lines indicate a significant correlation at the 95% level. Arrows indicates any phase shift. An arrow pointing to the right means no phase shift, an arrow pointing down means that $F10.7$ leads UV by 90 degrees, an arrow pointing up means that $F10.7$ lags UV by 90 degrees, and an arrow pointing to the left means that they are 180 degrees out of phase. The period is given in units of Carrington rotations. The two thick white lines marks 1 year and 11 year periodicities. Lower panel: The sunspot number $R_z$ is shown for comparison.

# 4 Monthly averages versus 27 day averages

The Sun rotates with a period of 27 days at the equator as seen from the orbiting Earth. The rotation decreases with solar latitude with a period of 29 days at 30° and 33 days at 60° . Sunspots appear within ±40° latitude and typically closer to the equator. The average rotation period of the Sun is 27.275 days which is also known as the the Carrington rotation period. We here study the effects of using calendar monthly averages on sunspot numbers compared to using 27 day averages.

It is clear from a theoretical viewpoint that monthly averages of the sunspot number should be avoided. Firstly, the number of days per month varies, from 28 to 31 days. Secondly, as long lived sunspots on average reappears after 27.275 days means that a monthly average will include the same features twice. From a practical viewpoint it is not clear how the two averaging methods will affect any subsequent analysis. In the following we compute monthly averages from daily $R_z$ resulting in the time series

$$x(n) = \frac{1}{m_n} \sum_{d=a_n}^{a_n+m_n-1} R_z(d) \tag{6}$$

where $n$ is an integer counting the months, $m_n$ is the number of days in month $n$, $a_n$ is the first day in month $n$, and $R_z(d)$ is the daily sunspot number. Then, another time series is created that contains 27 day averages using the same sampling times as in the monthly average time series

$$y(n) = \frac{1}{27} \sum_{d=b_n}^{b_n+27-1} R_z(d) \tag{7}$$

where

$$b_n = \begin{cases} a_n + (m_n - 27)/2 & \text{for } m_n = 29, 31 \\ a_n + (m_n - 1 - 27)/2 & \text{for } m_n = 28, 30. \end{cases} \tag{8}$$

In principle we could set $b_n = a_n$ but using the equation above the 27-day-average will be approximately centred on the month. Finally, the difference is obtained as

$$z(n) = x(n) - y(n). \tag{9}$$

The monthly average ($x$), 27 day average ($y$), and the difference ($z$) are plotted in Figure 12. The monthly and 27 day averages are almost not distinguishable from each other in the plot, however, from the difference the individual differences shows up. The largest difference occurs slightly before 1840 and has a value of $z = -22$. The standard deviation is $\sigma_z = 2.5$.

The wavelet power is also computed on $z$ (Figure 13). It is seen that there is significant power at periods at about one year and shorter, located around sunspot maxima where the largest differences are expected. The individual significant areas at longer periods, e.g. at 1.5-2 year around 1970 and 1990, may not be real features although they are significant. It is difficult to come to a strong conclusion from the wavelet power plot, it merely shows that there may be fluctuations in $z$ in the range 0.25 years to 1 year.

To summarise, we may argue theoretically that monthly averages should be avoided and 27 day averages should be used instead as it is closer to the Carrington rotation period. However, it is not obvious from real data what impact the two averaging schemes will have on subsequent correlation

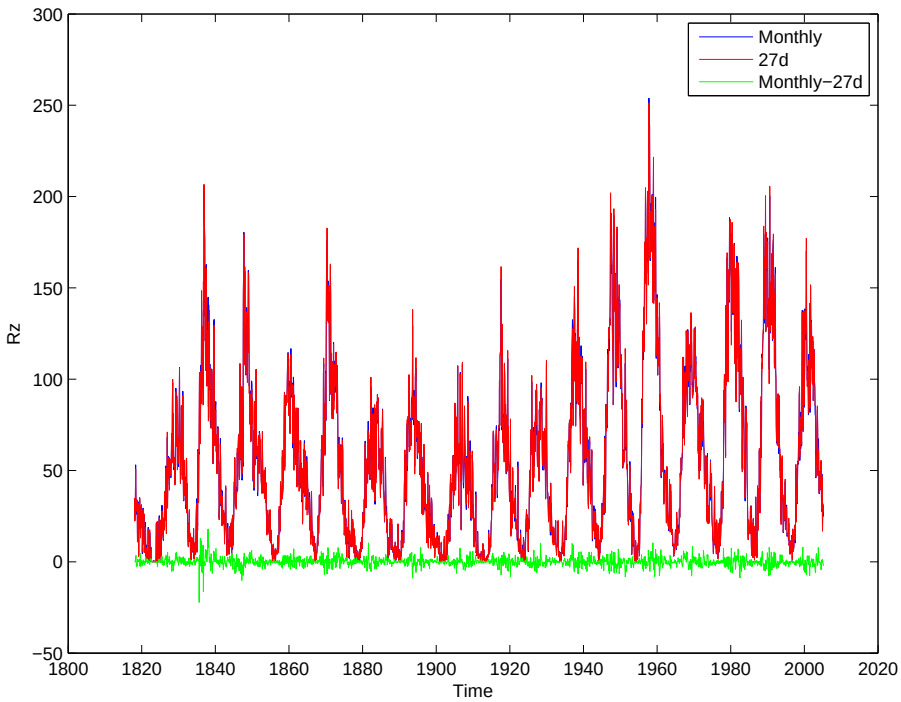


Figure 12: The figure shows the monthly (blue) and 27 day (red) averages of $R_z$, and the difference (green).

studies with climate data. The wavelet power (Figure 13) indicates that there is some residual power at periods around 0.25–1 years. The resonance between 27 days and 30 days corresponds to 0.74 years, and the 27–31 day resonance is 0.57 years, in accordance with the 0.25–1 years interval. Thus, if a Sun–climate correlation is found at those periods, based on monthly averages, one should consider to also look at 27 day averages to see if the correlation still holds.

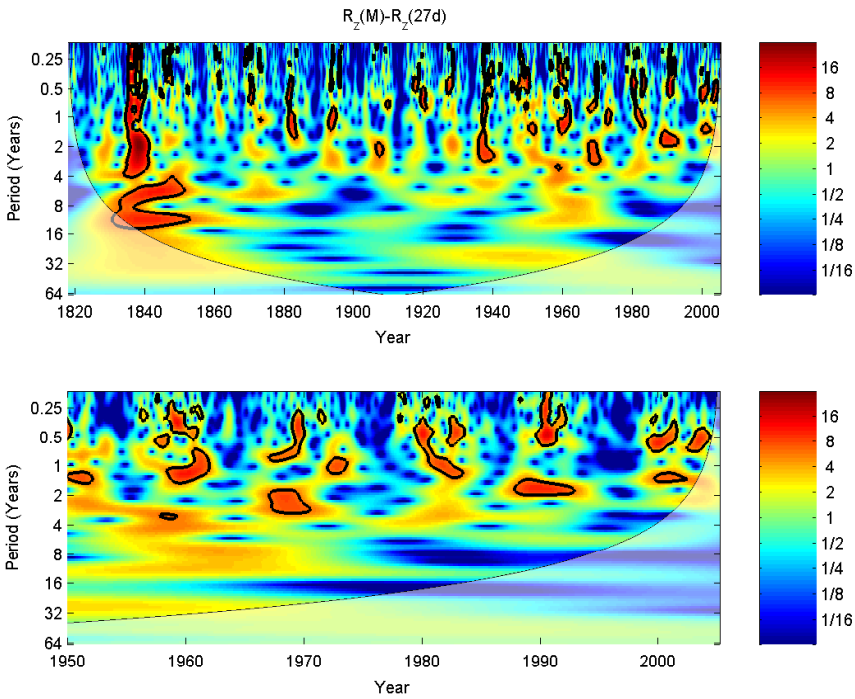


Figure 13: The top panel shows the wavelet power for the complete extent of the sunspot number ($R_z$), while the lower panel is the same figure but starting at 1950. Blue indicates weak power and red strong power. The black curves indicates where the power is significant at the 95% level.

# 5 Conclusions

It has been shown here that when solar activity is discussed it is insufficient to speak in terms of sunspot numbers and 11-year cycles as there are wide range of processes taking place on different time scales. The prime cause of all solar variability is the changing solar magnet field. For example, sunspots are caused by strong magnetic flux penetrating the photosphere and thereby suppressing outgoing radiation leading to a lowering of TSI. However, sunspots appears in active regions where also bright features like plages appear giving a positive contribution to the TSI. On larger scales there are also a network of fields giving increased brightness with a positive contributing to the TSI. This complex response of the TSI to magnetic fields is partly seen in the TSI–$R_z$ correlation in Figure 6. A similar correlation is seen between F10.7 and TSI (Figure 14). Thus, any solar–climate study that uses $R_z$ or F10.7 as a proxy for TSI must be carefully thought through. If monthly averages are used there will be a mixture of processes working on different temporal scales that will have the opposite effect on TSI. We therefore suggest that the scale based approach should be used when $R_z$ or F10.7 is used as a proxy for TSI so that the solar–climate relation is studied on a scale-by-scale basis.

$R_z$ and CLIMAX shows a simpler relation in the sense that they are anti-correlated on all scales, although the correlation is very weak for temporal variations shorter than 2.8 years (Figure 7). The weak correlation that is seen on time scales shorter than 2.8 years are only occasional covariation as seen in Figure 10. A similar conclusion is reached if F10.7 is used (Figures 14 and 16). Thus, if $R_z$ or F10.7 are used as a proxy for the cosmic ray flux one can only expect to find a strong Sun–climate correlation at time scales of several years and longer. A weak, or lack of, Sun–climate correlation on time scales from months to about 2–3 years using $R_z$ as a proxy for cosmic rays can not be used to rule out a relation.

Finally, we studied the F10.7 and UV correlation. These parameters are highly correlated on all time scales longer than the solar rotation period (27 days) (Figure 8). However, there are times when the correlation seems to vanish for variations on time scales of a few months (Figure 11). Thus, the use of F10.7 as a proxy for UV is well suited for a Sun–climate study. However, for monthly averages one must be aware that the correlation might disappear.

The use of monthly averages versus 27 day averages on solar output data were also discussed. From a theoretical viewpoint it is clear that the 27 day averages should be used. From the analysis of observed data it was seen that the use of monthly averages will introduce artificial variation with periods in the range 0.25 to 1 years during times of larger sunspot numbers. However, it is not clear to what extent it will affect any subsequent analysis.

In solar–climate relations the description of climate is much more scientifically advanced than the solar part. If a Sun–climate relation breaks down one must look at the solar mechanism at work to rule out the possibility that the solar output parameter used is uncorrelated with the proposed physical mechanism.

# Appendix 1: Linear correlation tables

On the following pages the linear correlation between each pair of solar output data from the ISAC database are shown. $r_{x,y}$ (95) is the linear correlation coefficient with the 95% confidence interval, $n_e$ is the number of effective observations, $r_{\Delta x,\Delta y}$ is the linear correlation coefficient for the daily difference data, and $n$ is the total number of data points.

Note that we display all computed correlation coefficients, distributed over 27 tables, for completeness.

## MPSI

| MPSI | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| **MPSI** | - ( -, -) | - | - ( -, -) | - | - |
| MWSI | 0.71 ( 0.54, 0.83) | 49 | 0.51 ( 0.49, 0.52) | 12277 | 12872 |
| CI | 0.73 ( 0.41, 0.89) | 19 | 0.02 (-0.00, 0.03) | 11783 | 12034 |
| lg GOES >10 MeV p | 0.24 ( 0.12, 0.35) | 261 | -0.02 (-0.05, 0.01) | 4124 | 4124 |
| lg GOES X-ray | 0.83 ( 0.15, 0.98) | 7 | 0.04 ( 0.01, 0.07) | 4124 | 4124 |
| E10.7 | 0.92 ( 0.80, 0.97) | 19 | 0.30 ( 0.29, 0.32) | 10648 | 11820 |
| FI | 0.56 ( 0.30, 0.74) | 42 | 0.04 ( 0.02, 0.06) | 10139 | 10226 |
| Ca II plage area | 0.86 ( 0.52, 0.97) | 10 | 0.09 ( 0.06, 0.12) | 4793 | 5459 |
| F10.7 | 0.91 ( 0.79, 0.96) | 23 | 0.22 ( 0.20, 0.24) | 9576 | 12855 |
| SSA | 0.74 ( 0.56, 0.86) | 38 | 0.15 ( 0.13, 0.16) | 12701 | 12866 |
| TSI | 0.53 ( 0.20, 0.75) | 29 | -0.07 (-0.09,-0.05) | 8902 | 9084 |
| UV | 0.96 ( 0.87, 0.99) | 15 | 0.47 ( 0.45, 0.49) | 5521 | 9658 |
| Rz | 0.87 ( 0.73, 0.94) | 25 | 0.26 ( 0.24, 0.28) | 12718 | 12855 |
| abs SMMF | 0.39 ( 0.15, 0.59) | 58 | 0.03 ( 0.02, 0.05) | 10918 | 10918 |
| aa | 0.06 (-0.02, 0.14) | 600 | 0.00 (-0.01, 0.02) | 12872 | 12872 |
| Kp | 0.08 (-0.03, 0.19) | 299 | 0.01 (-0.01, 0.02) | 12872 | 12872 |
| Ap | 0.08 ( 0.01, 0.16) | 674 | 0.00 (-0.01, 0.02) | 12872 | 12872 |
| Dst | -0.14 (-0.21,-0.07) | 758 | -0.00 (-0.02, 0.01) | 12872 | 12872 |
| B | 0.25 ( 0.09, 0.39) | 154 | -0.01 (-0.03, 0.00) | 12765 | 12765 |
| Bzn GSE | 0.14 ( 0.08, 0.19) | 1252 | -0.00 (-0.02, 0.01) | 12735 | 12765 |
| Bzs GSE | -0.16 (-0.22,-0.09) | 774 | 0.00 (-0.02, 0.02) | 12676 | 12765 |
| Bzn GSM | 0.13 ( 0.11, 0.16) | 5986 | 0.00 (-0.01, 0.02) | 12714 | 12765 |
| Bzs GSM | -0.14 (-0.17,-0.12) | 6395 | 0.00 (-0.02, 0.02) | 12648 | 12765 |
| n | -0.11 (-0.21, 0.01) | 309 | -0.01 (-0.02, 0.01) | 12765 | 12765 |
| V | -0.07 (-0.21, 0.08) | 184 | -0.00 (-0.02, 0.01) | 12765 | 12765 |
| Rg | 0.87 ( 0.68, 0.95) | 18 | 0.10 ( 0.08, 0.12) | 9477 | 9477 |
| CLIMAX | -0.69 (-0.86,-0.36) | 21 | -0.03 (-0.05,-0.01) | 12872 | 12872 |

Table 3: MPSI correlated against the other parameters

**MWSI**

| MWSI | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.71 ( 0.54, 0.83) | 49 | 0.51 ( 0.49, 0.52) | 12277 | 12872 |
| **MWSI** | - ( -, -) | - | - ( -, -) | - | - |
| CI | 0.56 ( 0.31, 0.74) | 42 | -0.00 (-0.02, 0.02) | 11780 | 12034 |
| lg GOES >10 MeV p | 0.22 ( 0.13, 0.31) | 401 | -0.02 (-0.05, 0.02) | 4124 | 4124 |
| lg GOES X-ray | 0.67 ( 0.20, 0.89) | 13 | 0.06 ( 0.02, 0.09) | 4124 | 4124 |
| E10.7 | 0.72 ( 0.53, 0.84) | 42 | 0.25 ( 0.23, 0.26) | 11820 | 11820 |
| FI | 0.53 ( 0.37, 0.67) | 90 | 0.03 ( 0.00, 0.05) | 9421 | 10226 |
| Ca II plage area | 0.58 ( 0.27, 0.78) | 28 | 0.01 (-0.02, 0.04) | 4521 | 5459 |
| F10.7 | 0.78 ( 0.64, 0.87) | 51 | 0.28 ( 0.26, 0.29) | 12855 | 12855 |
| SSA | 0.83 ( 0.75, 0.89) | 84 | 0.20 ( 0.19, 0.22) | 12154 | 12866 |
| TSI | -0.05 (-0.29, 0.20) | 65 | -0.43 (-0.45,-0.41) | 8289 | 9084 |
| UV | 0.70 ( 0.48, 0.84) | 34 | 0.28 ( 0.26, 0.30) | 8058 | 9658 |
| Rz | 0.74 ( 0.60, 0.84) | 56 | 0.21 ( 0.20, 0.23) | 11883 | 12855 |
| abs SMMF | 0.30 ( 0.13, 0.45) | 125 | 0.02 (-0.00, 0.03) | 10918 | 10918 |
| aa | 0.11 ( 0.05, 0.17) | 1155 | 0.01 (-0.01, 0.03) | 12511 | 12872 |
| Kp | 0.11 ( 0.04, 0.19) | 609 | 0.01 (-0.01, 0.03) | 12872 | 12872 |
| Ap | 0.12 ( 0.07, 0.18) | 1278 | 0.01 (-0.01, 0.03) | 12592 | 12872 |
| Dst | -0.15 (-0.20,-0.10) | 1301 | 0.01 (-0.00, 0.03) | 12872 | 12872 |
| B | 0.20 ( 0.10, 0.30) | 336 | -0.00 (-0.02, 0.02) | 12765 | 12765 |
| Bzn GSE | 0.11 ( 0.07, 0.15) | 2327 | -0.00 (-0.02, 0.01) | 12040 | 12765 |
| Bzs GSE | -0.14 (-0.19,-0.09) | 1529 | -0.01 (-0.03, 0.01) | 11986 | 12765 |
| Bzn GSM | 0.12 ( 0.10, 0.14) | 6573 | -0.00 (-0.02, 0.02) | 12045 | 12765 |
| Bzs GSM | -0.11 (-0.13,-0.09) | 6931 | -0.01 (-0.03, 0.01) | 11955 | 12765 |
| n | -0.08 (-0.15, 0.00) | 640 | 0.02 ( 0.00, 0.04) | 12529 | 12765 |
| V | 0.03 (-0.07, 0.13) | 380 | -0.00 (-0.02, 0.01) | 12765 | 12765 |
| Rg | 0.62 ( 0.38, 0.78) | 40 | 0.00 (-0.02, 0.02) | 9435 | 9477 |
| CLIMAX | -0.53 (-0.71,-0.28) | 46 | 0.00 (-0.02, 0.02) | 12872 | 12872 |

Table 4: MWSI correlated against the other parameters

**CI**

| CI | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.73 ( 0.41, 0.89) | 19 | 0.02 (-0.00, 0.03) | 11783 | 12034 |
| MWSI | 0.56 ( 0.31, 0.74) | 42 | -0.00 (-0.02, 0.02) | 11780 | 12034 |
| **CI** | - ( -, -) | - | - ( -, -) | - | - |
| lg GOES >10 MeV p | 0.23 ( 0.08, 0.36) | 181 | -0.01 (-0.04, 0.02) | 3286 | 3286 |
| lg GOES X-ray | 0.84 (-0.60, 1.00) | 4 | 0.05 ( 0.01, 0.08) | 3213 | 3286 |
| E10.7 | 0.72 ( 0.48, 0.86) | 31 | 0.11 ( 0.09, 0.12) | 20195 | 20195 |
| FI | 0.49 ( 0.21, 0.70) | 39 | -0.01 (-0.03, 0.01) | 9669 | 9861 |
| Ca II plage area | 0.57 ( 0.25, 0.78) | 27 | 0.03 ( 0.02, 0.05) | 16300 | 16800 |
| F10.7 | 0.71 ( 0.49, 0.85) | 32 | 0.09 ( 0.07, 0.10) | 20074 | 20409 |
| SSA | 0.56 ( 0.36, 0.72) | 60 | 0.04 ( 0.03, 0.05) | 23375 | 23375 |
| TSI | 0.53 ( 0.21, 0.75) | 29 | 0.06 ( 0.04, 0.08) | 8810 | 8810 |
| UV | 0.81 ( 0.49, 0.94) | 14 | 0.10 ( 0.08, 0.12) | 8322 | 8820 |
| Rz | 0.66 ( 0.44, 0.80) | 42 | 0.05 ( 0.03, 0.06) | 23375 | 23375 |
| abs SMMF | 0.46 ( 0.21, 0.65) | 50 | 0.03 ( 0.01, 0.05) | 10091 | 10091 |
| aa | 0.10 ( 0.05, 0.16) | 1106 | 0.01 (-0.00, 0.02) | 23366 | 23375 |
| Kp | 0.10 ( 0.01, 0.20) | 415 | 0.01 (-0.00, 0.02) | 23375 | 23375 |
| Ap | 0.09 ( 0.03, 0.15) | 1088 | 0.01 (-0.00, 0.02) | 23375 | 23375 |
| Dst | -0.19 (-0.27,-0.10) | 467 | -0.01 (-0.02, 0.01) | 16800 | 16800 |
| B | 0.27 ( 0.12, 0.41) | 161 | 0.02 (-0.00, 0.03) | 14609 | 14609 |
| Bzn GSE | 0.14 ( 0.09, 0.19) | 1376 | 0.01 (-0.01, 0.03) | 14305 | 14609 |
| Bzs GSE | -0.15 (-0.19,-0.12) | 2988 | -0.01 (-0.03, 0.01) | 14318 | 14609 |
| Bzn GSM | 0.15 ( 0.12, 0.17) | 6995 | 0.01 (-0.00, 0.03) | 14309 | 14609 |
| Bzs GSM | -0.13 (-0.16,-0.11) | 7221 | -0.01 (-0.02, 0.01) | 14310 | 14609 |
| n | -0.08 (-0.18, 0.03) | 359 | 0.01 (-0.01, 0.02) | 14502 | 14609 |
| V | -0.03 (-0.13, 0.08) | 352 | -0.01 (-0.02, 0.01) | 14609 | 14609 |
| Rg | 0.68 ( 0.46, 0.83) | 36 | 0.05 ( 0.03, 0.06) | 20818 | 20818 |
| CLIMAX | -0.77 (-0.89,-0.54) | 27 | 0.00 (-0.01, 0.02) | 18261 | 18261 |

Table 5: CI correlated against the other parameters

## lg GOES >10 MeV p

| lg GOES >10 MeV p | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.24 ( 0.12, 0.35) | 261 | -0.02 (-0.05, 0.01) | 4124 | 4124 |
| MWSI | 0.22 ( 0.13, 0.31) | 401 | -0.02 (-0.05, 0.02) | 4124 | 4124 |
| CI | 0.23 ( 0.08, 0.36) | 181 | -0.01 (-0.04, 0.02) | 3286 | 3286 |
| **lg GOES >10 MeV p** | - ( -, -) | - | - ( -, -) | - | - |
| lg GOES X-ray | 0.25 ( 0.13, 0.35) | 278 | 0.08 ( 0.05, 0.11) | 4125 | 4125 |
| E10.7 | 0.30 ( 0.15, 0.44) | 157 | 0.01 (-0.03, 0.04) | 3072 | 3072 |
| FI | 0.28 ( 0.21, 0.35) | 733 | 0.04 ( 0.01, 0.07) | 3651 | 3651 |
| Ca II plage area | NaN ( NaN, NaN) | NaN | NaN ( NaN, NaN) | NaN | 0 |
| F10.7 | 0.28 ( 0.16, 0.38) | 269 | -0.02 (-0.05, 0.01) | 4107 | 4107 |
| SSA | 0.29 ( 0.19, 0.38) | 362 | -0.02 (-0.05, 0.01) | 4083 | 4118 |
| TSI | 0.14 (-0.01, 0.28) | 173 | 0.05 ( 0.02, 0.08) | 3500 | 3560 |
| UV | 0.25 ( 0.13, 0.36) | 251 | 0.02 (-0.01, 0.05) | 4125 | 4125 |
| Rz | 0.22 ( 0.11, 0.32) | 296 | 0.01 (-0.02, 0.04) | 4062 | 4107 |
| abs SMMF | 0.02 (-0.06, 0.11) | 525 | 0.03 ( 0.00, 0.06) | 3684 | 4113 |
| aa | 0.25 ( 0.19, 0.30) | 1221 | 0.10 ( 0.07, 0.13) | 4125 | 4125 |
| Kp | 0.15 ( 0.09, 0.21) | 986 | 0.06 ( 0.02, 0.09) | 3864 | 4125 |
| Ap | 0.27 ( 0.22, 0.32) | 1309 | 0.09 ( 0.06, 0.12) | 4094 | 4125 |
| Dst | -0.27 (-0.34,-0.21) | 857 | -0.01 (-0.05, 0.02) | 3920 | 4125 |
| B | 0.17 ( 0.12, 0.22) | 1351 | 0.05 ( 0.01, 0.08) | 3790 | 4017 |
| Bzn GSE | 0.12 ( 0.08, 0.16) | 2477 | 0.01 (-0.02, 0.04) | 4017 | 4017 |
| Bzs GSE | -0.10 (-0.14,-0.06) | 2601 | -0.02 (-0.05, 0.01) | 4017 | 4017 |
| Bzn GSM | 0.12 ( 0.08, 0.16) | 2235 | 0.01 (-0.02, 0.04) | 4017 | 4017 |
| Bzs GSM | -0.08 (-0.12,-0.04) | 2355 | -0.02 (-0.05, 0.01) | 4017 | 4017 |
| n | -0.01 (-0.07, 0.05) | 1155 | 0.04 ( 0.01, 0.07) | 3855 | 4017 |
| V | 0.09 ( 0.02, 0.17) | 671 | 0.03 (-0.01, 0.06) | 3383 | 4017 |
| Rg | -0.02 (-0.15, 0.10) | 243 | 0.00 (-0.07, 0.08) | 670 | 729 |
| CLIMAX | -0.27 (-0.38,-0.15) | 249 | 0.02 (-0.01, 0.05) | 3762 | 4125 |

Table 6: lg GOES >10 MeV p correlated against the other parameters

## lg GOES X-ray

| lg GOES X-ray | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.83 ( 0.15, 0.98) | 7 | 0.04 ( 0.01, 0.07) | 4124 | 4124 |
| MWSI | 0.67 ( 0.20, 0.89) | 13 | 0.06 ( 0.02, 0.09) | 4124 | 4124 |
| CI | 0.84 (-0.60, 1.00) | 4 | 0.05 ( 0.01, 0.08) | 3213 | 3286 |
| lg GOES >10 MeV p | 0.25 ( 0.13, 0.35) | 278 | 0.08 ( 0.05, 0.11) | 4125 | 4125 |
| **lg GOES X-ray** | - ( -, -) | - | - ( -, -) | - | - |
| E10.7 | 0.82 (-0.90, 1.00) | 4 | 0.13 ( 0.10, 0.17) | 3072 | 3072 |
| FI | 0.40 ( 0.10, 0.64) | 38 | 0.04 ( 0.00, 0.07) | 3111 | 3651 |
| Ca II plage area | NaN ( NaN, NaN) | NaN | NaN ( NaN, NaN) | NaN | 0 |
| F10.7 | 0.85 ( 0.29, 0.98) | 7 | 0.13 ( 0.10, 0.16) | 4107 | 4107 |
| SSA | 0.73 ( 0.28, 0.92) | 12 | 0.14 ( 0.11, 0.17) | 4118 | 4118 |
| TSI | 0.51 (-0.21, 0.87) | 9 | -0.06 (-0.09,-0.02) | 3560 | 3560 |
| UV | 0.85 ( 0.15, 0.98) | 6 | 0.15 ( 0.12, 0.18) | 4125 | 4125 |
| Rz | 0.82 ( 0.29, 0.96) | 8 | 0.10 ( 0.07, 0.13) | 4107 | 4107 |
| abs SMMF | 0.29 (-0.10, 0.60) | 28 | -0.01 (-0.05, 0.02) | 4033 | 4113 |
| aa | 0.08 (-0.06, 0.22) | 196 | -0.02 (-0.05, 0.01) | 3710 | 4125 |
| Kp | 0.08 (-0.11, 0.26) | 110 | 0.00 (-0.03, 0.03) | 3861 | 4125 |
| Ap | 0.09 (-0.01, 0.18) | 409 | -0.02 (-0.05, 0.01) | 3726 | 4125 |
| Dst | -0.10 (-0.22, 0.02) | 272 | 0.02 (-0.01, 0.05) | 3863 | 4125 |
| B | 0.28 ( 0.04, 0.50) | 62 | -0.02 (-0.06, 0.01) | 3679 | 4017 |
| Bzn GSE | 0.17 ( 0.12, 0.21) | 1992 | -0.01 (-0.04, 0.03) | 3533 | 4017 |
| Bzs GSE | -0.15 (-0.19,-0.11) | 2320 | 0.00 (-0.03, 0.04) | 3487 | 4017 |
| Bzn GSM | 0.18 ( 0.14, 0.22) | 1948 | -0.01 (-0.04, 0.02) | 3554 | 4017 |
| Bzs GSM | -0.11 (-0.15,-0.07) | 2047 | 0.00 (-0.03, 0.03) | 3487 | 4017 |
| n | -0.19 (-0.42, 0.07) | 62 | 0.03 (-0.00, 0.06) | 3684 | 4017 |
| V | 0.04 (-0.22, 0.30) | 56 | -0.04 (-0.07,-0.01) | 4017 | 4017 |
| Rg | 0.65 ( 0.46, 0.78) | 55 | 0.19 ( 0.12, 0.26) | 729 | 729 |
| CLIMAX | -0.67 (-0.96, 0.30) | 6 | 0.03 (-0.00, 0.06) | 4125 | 4125 |

Table 7: lg GOES X-ray correlated against the other parameters

**E10.7**

| E10.7 | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.92 ( 0.80, 0.97) | 19 | 0.30 ( 0.29, 0.32) | 10648 | 11820 |
| MWSI | 0.72 ( 0.53, 0.84) | 42 | 0.25 ( 0.23, 0.26) | 11820 | 11820 |
| CI | 0.72 ( 0.48, 0.86) | 31 | 0.11 ( 0.09, 0.12) | 20195 | 20195 |
| lg GOES >10 MeV p | 0.30 ( 0.15, 0.44) | 157 | 0.01 (-0.03, 0.04) | 3072 | 3072 |
| lg GOES X-ray | 0.82 (-0.90, 1.00) | 4 | 0.13 ( 0.10, 0.17) | 3072 | 3072 |
| **E10.7** | - ( -, -) | - | - ( -, -) | - | - |
| FI | 0.61 ( 0.36, 0.78) | 38 | 0.15 ( 0.13, 0.17) | 9647 | 9647 |
| Ca II plage area | 0.85 ( 0.66, 0.94) | 22 | 0.08 ( 0.06, 0.10) | 13834 | 13834 |
| F10.7 | 0.98 ( 0.95, 0.99) | 32 | 0.85 ( 0.85, 0.86) | 12399 | 20195 |
| SSA | 0.85 ( 0.74, 0.91) | 50 | 0.38 ( 0.37, 0.40) | 16780 | 20195 |
| TSI | 0.51 ( 0.16, 0.74) | 27 | -0.21 (-0.24,-0.18) | 4685 | 8596 |
| UV | 0.98 ( 0.92, 0.99) | 13 | 0.68 ( 0.66, 0.70) | 3555 | 8606 |
| Rz | 0.92 ( 0.85, 0.96) | 36 | 0.45 ( 0.44, 0.47) | 14782 | 20195 |
| abs SMMF | 0.45 ( 0.19, 0.65) | 49 | 0.02 ( 0.00, 0.04) | 9687 | 9877 |
| aa | 0.11 ( 0.03, 0.19) | 575 | 0.00 (-0.01, 0.02) | 20195 | 20195 |
| Kp | 0.13 ( 0.02, 0.24) | 303 | 0.00 (-0.01, 0.02) | 20195 | 20195 |
| Ap | 0.12 ( 0.04, 0.20) | 550 | 0.01 (-0.01, 0.02) | 20195 | 20195 |
| Dst | -0.20 (-0.29,-0.11) | 453 | -0.02 (-0.03,-0.00) | 16586 | 16586 |
| B | 0.29 ( 0.14, 0.43) | 158 | -0.00 (-0.02, 0.01) | 14395 | 14395 |
| Bzn GSE | 0.16 ( 0.12, 0.21) | 1899 | 0.00 (-0.01, 0.02) | 14395 | 14395 |
| Bzs GSE | -0.16 (-0.21,-0.12) | 1533 | -0.01 (-0.02, 0.01) | 14395 | 14395 |
| Bzn GSM | 0.16 ( 0.14, 0.19) | 6884 | 0.00 (-0.01, 0.02) | 14395 | 14395 |
| Bzs GSM | -0.15 (-0.17,-0.12) | 7250 | -0.00 (-0.02, 0.01) | 14395 | 14395 |
| n | -0.09 (-0.19, 0.02) | 366 | -0.01 (-0.02, 0.01) | 14395 | 14395 |
| V | -0.05 (-0.15, 0.06) | 345 | -0.00 (-0.02, 0.01) | 14222 | 14395 |
| Rg | 0.90 ( 0.80, 0.95) | 30 | 0.21 ( 0.20, 0.23) | 17852 | 17852 |
| CLIMAX | -0.79 (-0.90,-0.59) | 26 | -0.04 (-0.06,-0.03) | 17797 | 18047 |

Table 8: E10.7 correlated against the other parameters

**FI**

| FI | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.56 ( 0.30, 0.74) | 42 | 0.04 ( 0.02, 0.06) | 10139 | 10226 |
| MWSI | 0.53 ( 0.37, 0.67) | 90 | 0.03 ( 0.00, 0.05) | 9421 | 10226 |
| CI | 0.49 ( 0.21, 0.70) | 39 | -0.01 (-0.03, 0.01) | 9669 | 9861 |
| lg GOES >10 MeV p | 0.28 ( 0.21, 0.35) | 733 | 0.04 ( 0.01, 0.07) | 3651 | 3651 |
| lg GOES X-ray | 0.40 ( 0.10, 0.64) | 38 | 0.04 ( 0.00, 0.07) | 3111 | 3651 |
| E10.7 | 0.61 ( 0.36, 0.78) | 38 | 0.15 ( 0.13, 0.17) | 9647 | 9647 |
| **FI** | - ( -, -) | - | - ( -, -) | - | - |
| Ca II plage area | 0.58 ( 0.20, 0.81) | 20 | 0.04 (-0.00, 0.08) | 2561 | 3286 |
| F10.7 | 0.65 ( 0.44, 0.79) | 45 | 0.19 ( 0.18, 0.21) | 10226 | 10226 |
| SSA | 0.65 ( 0.49, 0.77) | 72 | 0.09 ( 0.07, 0.11) | 10226 | 10226 |
| TSI | 0.15 (-0.09, 0.38) | 69 | -0.04 (-0.07,-0.02) | 9084 | 9084 |
| UV | 0.57 ( 0.28, 0.76) | 33 | 0.10 ( 0.08, 0.12) | 9185 | 9185 |
| Rz | 0.63 ( 0.43, 0.77) | 49 | 0.08 ( 0.06, 0.10) | 10226 | 10226 |
| abs SMMF | 0.27 ( 0.10, 0.42) | 131 | -0.02 (-0.04,-0.01) | 10226 | 10226 |
| aa | 0.12 ( 0.06, 0.18) | 941 | -0.02 (-0.04, 0.00) | 8321 | 10226 |
| Kp | 0.14 ( 0.05, 0.22) | 495 | 0.00 (-0.02, 0.02) | 8807 | 10226 |
| Ap | 0.13 ( 0.07, 0.19) | 1039 | -0.03 (-0.05,-0.00) | 8412 | 10226 |
| Dst | -0.13 (-0.19,-0.08) | 1225 | 0.01 (-0.01, 0.03) | 9070 | 10226 |
| B | 0.22 ( 0.11, 0.33) | 294 | 0.01 (-0.01, 0.03) | 8596 | 10226 |
| Bzn GSE | 0.13 ( 0.09, 0.16) | 2816 | 0.00 (-0.02, 0.02) | 7886 | 10226 |
| Bzs GSE | -0.12 (-0.17,-0.08) | 1709 | -0.01 (-0.03, 0.01) | 7902 | 10226 |
| Bzn GSM | 0.13 ( 0.10, 0.15) | 5766 | -0.00 (-0.02, 0.02) | 7966 | 10226 |
| Bzs GSM | -0.10 (-0.13,-0.08) | 6169 | -0.01 (-0.03, 0.01) | 7873 | 10226 |
| n | -0.03 (-0.10, 0.05) | 677 | -0.01 (-0.03, 0.01) | 8537 | 10226 |
| V | 0.02 (-0.07, 0.10) | 519 | 0.00 (-0.02, 0.02) | 10226 | 10226 |
| Rg | 0.61 ( 0.34, 0.78) | 34 | 0.02 (-0.01, 0.04) | 7011 | 7304 |
| CLIMAX | -0.45 (-0.67,-0.16) | 40 | 0.01 (-0.01, 0.03) | 10226 | 10226 |

Table 9: FI correlated against the other parameters

## Ca II plage area

| Ca II plage area | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.86 ( 0.52, 0.97) | 10 | 0.09 ( 0.06, 0.12) | 4793 | 5459 |
| MWSI | 0.58 ( 0.27, 0.78) | 28 | 0.01 (-0.02, 0.04) | 4521 | 5459 |
| CI | 0.57 ( 0.25, 0.78) | 27 | 0.03 ( 0.02, 0.05) | 16300 | 16800 |
| lg GOES >10 MeV p | NaN ( NaN, NaN) | NaN | NaN ( NaN, NaN) | NaN | 0 |
| lg GOES X-ray | NaN ( NaN, NaN) | NaN | NaN ( NaN, NaN) | NaN | 0 |
| E10.7 | 0.85 ( 0.66, 0.94) | 22 | 0.08 ( 0.06, 0.10) | 13834 | 13834 |
| FI | 0.58 ( 0.20, 0.81) | 20 | 0.04 (-0.00, 0.08) | 2561 | 3286 |
| **Ca II plage area** | - ( -, -) | - | - ( -, -) | - | - |
| F10.7 | 0.84 ( 0.65, 0.93) | 23 | 0.06 ( 0.05, 0.08) | 13834 | 13834 |
| SSA | 0.71 ( 0.57, 0.81) | 69 | 0.06 ( 0.04, 0.07) | 25349 | 25349 |
| TSI | 0.34 (-0.13, 0.68) | 19 | -0.06 (-0.10,-0.01) | 2235 | 2235 |
| UV | 0.88 ( 0.15, 0.99) | 5 | 0.18 ( 0.14, 0.22) | 2245 | 2245 |
| Rz | 0.84 ( 0.72, 0.91) | 47 | 0.09 ( 0.07, 0.10) | 25349 | 25349 |
| abs SMMF | 0.37 (-0.06, 0.68) | 22 | -0.02 (-0.05, 0.02) | 3516 | 3516 |
| aa | 0.12 ( 0.03, 0.20) | 559 | 0.00 (-0.01, 0.02) | 21181 | 25349 |
| Kp | 0.12 ( 0.00, 0.24) | 266 | 0.00 (-0.01, 0.02) | 17049 | 19357 |
| Ap | 0.12 ( 0.03, 0.20) | 526 | -0.00 (-0.02, 0.01) | 16253 | 19357 |
| Dst | -0.18 (-0.33,-0.03) | 162 | 0.00 (-0.02, 0.02) | 9219 | 10225 |
| B | 0.16 (-0.04, 0.34) | 99 | -0.01 (-0.03, 0.02) | 7061 | 8034 |
| Bzn GSE | 0.08 ( 0.06, 0.11) | 5116 | -0.01 (-0.03, 0.01) | 6512 | 8034 |
| Bzs GSE | -0.13 (-0.16,-0.10) | 5057 | 0.02 (-0.01, 0.04) | 6448 | 8034 |
| Bzn GSM | 0.09 ( 0.06, 0.12) | 4194 | 0.00 (-0.02, 0.03) | 6524 | 8034 |
| Bzs GSM | -0.11 (-0.14,-0.08) | 4298 | 0.04 ( 0.01, 0.06) | 6465 | 8034 |
| n | -0.09 (-0.15,-0.03) | 1140 | -0.02 (-0.04, 0.00) | 6862 | 8034 |
| V | -0.15 (-0.31, 0.01) | 143 | -0.01 (-0.03, 0.01) | 8034 | 8034 |
| Rg | 0.82 ( 0.70, 0.90) | 45 | 0.07 ( 0.05, 0.08) | 25349 | 25349 |
| CLIMAX | -0.69 (-0.88,-0.31) | 17 | -0.02 (-0.04,-0.00) | 11686 | 11686 |

Table 10: Ca II plage area correlated against the other parameters

**F10.7**

| F10.7 | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.91 ( 0.79, 0.96) | 23 | 0.22 ( 0.20, 0.24) | 9576 | 12855 |
| MWSI | 0.78 ( 0.64, 0.87) | 51 | 0.28 ( 0.26, 0.29) | 12855 | 12855 |
| CI | 0.71 ( 0.49, 0.85) | 32 | 0.09 ( 0.07, 0.10) | 20074 | 20409 |
| lg GOES >10 MeV p | 0.28 ( 0.16, 0.38) | 269 | -0.02 (-0.05, 0.01) | 4107 | 4107 |
| lg GOES X-ray | 0.85 ( 0.29, 0.98) | 7 | 0.13 ( 0.10, 0.16) | 4107 | 4107 |
| E10.7 | 0.98 ( 0.95, 0.99) | 32 | 0.85 ( 0.85, 0.86) | 12399 | 20195 |
| FI | 0.65 ( 0.44, 0.79) | 45 | 0.19 ( 0.18, 0.21) | 10226 | 10226 |
| Ca II plage area | 0.84 ( 0.65, 0.93) | 23 | 0.06 ( 0.05, 0.08) | 13834 | 13834 |
| **F10.7** | - ( -, -) | - | - ( -, -) | - | - |
| SSA | 0.89 ( 0.82, 0.94) | 57 | 0.39 ( 0.38, 0.40) | 19218 | 21230 |
| TSI | 0.39 ( 0.04, 0.65) | 32 | -0.30 (-0.32,-0.27) | 6435 | 9084 |
| UV | 0.95 ( 0.85, 0.98) | 16 | 0.45 ( 0.42, 0.48) | 3473 | 9641 |
| Rz | 0.95 ( 0.90, 0.97) | 40 | 0.43 ( 0.42, 0.44) | 17902 | 21230 |
| abs SMMF | 0.41 ( 0.17, 0.60) | 62 | 0.01 (-0.01, 0.03) | 10912 | 10912 |
| aa | 0.11 ( 0.04, 0.19) | 711 | 0.00 (-0.01, 0.02) | 21230 | 21230 |
| Kp | 0.13 ( 0.03, 0.23) | 365 | 0.00 (-0.01, 0.02) | 21230 | 21230 |
| Ap | 0.13 ( 0.05, 0.20) | 711 | 0.01 (-0.01, 0.02) | 21230 | 21230 |
| Dst | -0.20 (-0.28,-0.11) | 525 | -0.02 (-0.03,-0.00) | 17621 | 17621 |
| B | 0.28 ( 0.15, 0.41) | 190 | 0.00 (-0.01, 0.02) | 15340 | 15340 |
| Bzn GSE | 0.16 ( 0.12, 0.20) | 2280 | 0.00 (-0.01, 0.02) | 15340 | 15340 |
| Bzs GSE | -0.17 (-0.20,-0.13) | 3506 | -0.00 (-0.02, 0.01) | 15340 | 15340 |
| Bzn GSM | 0.16 ( 0.14, 0.18) | 7326 | 0.01 (-0.01, 0.02) | 15340 | 15340 |
| Bzs GSM | -0.15 (-0.17,-0.13) | 7633 | -0.00 (-0.02, 0.01) | 15340 | 15340 |
| n | -0.09 (-0.20, 0.03) | 279 | -0.00 (-0.02, 0.01) | 15340 | 15340 |
| V | -0.04 (-0.17, 0.08) | 243 | 0.00 (-0.01, 0.02) | 15340 | 15340 |
| Rg | 0.90 ( 0.81, 0.95) | 32 | 0.18 ( 0.17, 0.19) | 17852 | 17852 |
| CLIMAX | -0.75 (-0.88,-0.54) | 30 | -0.03 (-0.04,-0.02) | 18864 | 19082 |

Table 11: F10.7 correlated against the other parameters

**SSA**

| SSA | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.74 ( 0.56, 0.86) | 38 | 0.15 ( 0.13, 0.16) | 12701 | 12866 |
| MWSI | 0.83 ( 0.75, 0.89) | 84 | 0.20 ( 0.19, 0.22) | 12154 | 12866 |
| CI | 0.56 ( 0.36, 0.72) | 60 | 0.04 ( 0.03, 0.05) | 23375 | 23375 |
| lg GOES >10 MeV p | 0.29 ( 0.19, 0.38) | 362 | -0.02 (-0.05, 0.01) | 4083 | 4118 |
| lg GOES X-ray | 0.73 ( 0.28, 0.92) | 12 | 0.14 ( 0.11, 0.17) | 4118 | 4118 |
| E10.7 | 0.85 ( 0.74, 0.91) | 50 | 0.38 ( 0.37, 0.40) | 16780 | 20195 |
| FI | 0.65 ( 0.49, 0.77) | 72 | 0.09 ( 0.07, 0.11) | 10226 | 10226 |
| Ca II plage area | 0.71 ( 0.57, 0.81) | 69 | 0.06 ( 0.04, 0.07) | 25349 | 25349 |
| F10.7 | 0.89 ( 0.82, 0.94) | 57 | 0.39 ( 0.38, 0.40) | 19218 | 21230 |
| **SSA** | - ( -, -) | - | - ( -, -) | - | - |
| TSI | 0.07 (-0.21, 0.34) | 51 | -0.23 (-0.25,-0.21) | 7855 | 9084 |
| UV | 0.78 ( 0.56, 0.89) | 26 | 0.31 ( 0.28, 0.33) | 7879 | 9652 |
| Rz | 0.88 ( 0.83, 0.91) | 128 | 0.37 ( 0.36, 0.38) | 42204 | 47808 |
| abs SMMF | 0.34 ( 0.16, 0.51) | 100 | 0.03 ( 0.01, 0.05) | 10885 | 10918 |
| aa | 0.19 ( 0.13, 0.26) | 791 | 0.01 (-0.00, 0.01) | 47819 | 47819 |
| Kp | 0.14 ( 0.06, 0.21) | 644 | 0.01 (-0.01, 0.02) | 26764 | 26764 |
| Ap | 0.14 ( 0.09, 0.20) | 1216 | 0.01 (-0.01, 0.02) | 26764 | 26764 |
| Dst | -0.19 (-0.26,-0.13) | 768 | -0.02 (-0.03,-0.00) | 17632 | 17632 |
| B | 0.24 ( 0.13, 0.34) | 313 | 0.00 (-0.01, 0.02) | 15340 | 15340 |
| Bzn GSE | 0.13 ( 0.10, 0.17) | 3275 | 0.00 (-0.01, 0.02) | 15340 | 15340 |
| Bzs GSE | -0.16 (-0.18,-0.13) | 4694 | 0.01 (-0.01, 0.02) | 15340 | 15340 |
| Bzn GSM | 0.13 ( 0.11, 0.16) | 7664 | 0.00 (-0.01, 0.02) | 15340 | 15340 |
| Bzs GSM | -0.13 (-0.15,-0.11) | 7945 | 0.00 (-0.01, 0.02) | 15340 | 15340 |
| n | -0.08 (-0.17, 0.01) | 454 | -0.01 (-0.03, 0.01) | 15340 | 15340 |
| V | -0.00 (-0.10, 0.10) | 388 | -0.00 (-0.02, 0.01) | 15270 | 15340 |
| Rg | 0.79 ( 0.71, 0.85) | 111 | 0.25 ( 0.25, 0.26) | 44305 | 44430 |
| CLIMAX | -0.61 (-0.77,-0.39) | 46 | -0.04 (-0.05,-0.02) | 18895 | 19093 |

Table 12: SSA correlated against the other parameters

**TSI**

| TSI | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.53 ( 0.20, 0.75) | 29 | -0.07 (-0.09,-0.05) | 8902 | 9084 |
| MWSI | -0.05 (-0.29, 0.20) | 65 | -0.43 (-0.45,-0.41) | 8289 | 9084 |
| CI | 0.53 ( 0.21, 0.75) | 29 | 0.06 ( 0.04, 0.08) | 8810 | 8810 |
| lg GOES >10 MeV p | 0.14 (-0.01, 0.28) | 173 | 0.05 ( 0.02, 0.08) | 3500 | 3560 |
| lg GOES X-ray | 0.51 (-0.21, 0.87) | 9 | -0.06 (-0.09,-0.02) | 3560 | 3560 |
| E10.7 | 0.51 ( 0.16, 0.74) | 27 | -0.21 (-0.24,-0.18) | 4685 | 8596 |
| FI | 0.15 (-0.09, 0.38) | 69 | -0.04 (-0.07,-0.02) | 9084 | 9084 |
| Ca II plage area | 0.34 (-0.13, 0.68) | 19 | -0.06 (-0.10,-0.01) | 2235 | 2235 |
| F10.7 | 0.39 ( 0.04, 0.65) | 32 | -0.30 (-0.32,-0.27) | 6435 | 9084 |
| SSA | 0.07 (-0.21, 0.34) | 51 | -0.23 (-0.25,-0.21) | 7855 | 9084 |
| **TSI** | - ( -, -) | - | - ( -, -) | - | - |
| UV | 0.56 ( 0.24, 0.77) | 28 | -0.07 (-0.10,-0.04) | 5096 | 9084 |
| Rz | 0.35 ( 0.01, 0.61) | 35 | -0.17 (-0.19,-0.15) | 7220 | 9084 |
| abs SMMF | 0.27 ( 0.08, 0.44) | 101 | -0.01 (-0.03, 0.01) | 8514 | 9084 |
| aa | -0.01 (-0.08, 0.06) | 713 | -0.00 (-0.02, 0.02) | 9084 | 9084 |
| Kp | 0.01 (-0.10, 0.12) | 308 | -0.02 (-0.04,-0.00) | 9084 | 9084 |
| Ap | -0.01 (-0.08, 0.07) | 775 | -0.00 (-0.02, 0.02) | 9084 | 9084 |
| Dst | -0.03 (-0.09, 0.04) | 885 | -0.00 (-0.02, 0.02) | 9084 | 9084 |
| B | 0.17 ( 0.04, 0.30) | 210 | 0.01 (-0.01, 0.03) | 9084 | 9084 |
| Bzn GSE | 0.09 ( 0.06, 0.12) | 4790 | 0.01 (-0.01, 0.03) | 9084 | 9084 |
| Bzs GSE | -0.09 (-0.12,-0.07) | 4809 | -0.02 (-0.04,-0.00) | 9084 | 9084 |
| Bzn GSM | 0.09 ( 0.06, 0.12) | 4448 | 0.01 (-0.01, 0.03) | 9084 | 9084 |
| Bzs GSM | -0.09 (-0.11,-0.06) | 4682 | -0.02 (-0.04, 0.00) | 9084 | 9084 |
| n | -0.06 (-0.14, 0.03) | 519 | 0.01 (-0.01, 0.03) | 9084 | 9084 |
| V | -0.11 (-0.20,-0.01) | 406 | -0.07 (-0.09,-0.05) | 8693 | 9084 |
| Rg | 0.52 ( 0.14, 0.77) | 23 | 0.06 ( 0.04, 0.09) | 6253 | 6253 |
| CLIMAX | -0.48 (-0.72,-0.14) | 30 | -0.01 (-0.03, 0.01) | 9071 | 9084 |

Table 13: TSI correlated against the other parameters

**UV**

| UV | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.96 ( 0.87, 0.99) | 15 | 0.47 ( 0.45, 0.49) | 5521 | 9658 |
| MWSI | 0.70 ( 0.48, 0.84) | 34 | 0.28 ( 0.26, 0.30) | 8058 | 9658 |
| CI | 0.81 ( 0.49, 0.94) | 14 | 0.10 ( 0.08, 0.12) | 8322 | 8820 |
| lg GOES >10 MeV p | 0.25 ( 0.13, 0.36) | 251 | 0.02 (-0.01, 0.05) | 4125 | 4125 |
| lg GOES X-ray | 0.85 ( 0.15, 0.98) | 6 | 0.15 ( 0.12, 0.18) | 4125 | 4125 |
| E10.7 | 0.98 ( 0.92, 0.99) | 13 | 0.68 ( 0.66, 0.70) | 3555 | 8606 |
| FI | 0.57 ( 0.28, 0.76) | 33 | 0.10 ( 0.08, 0.12) | 9185 | 9185 |
| Ca II plage area | 0.88 ( 0.15, 0.99) | 5 | 0.18 ( 0.14, 0.22) | 2245 | 2245 |
| F10.7 | 0.95 ( 0.85, 0.98) | 16 | 0.45 ( 0.42, 0.48) | 3473 | 9641 |
| SSA | 0.78 ( 0.56, 0.89) | 26 | 0.31 ( 0.28, 0.33) | 7879 | 9652 |
| TSI | 0.56 ( 0.24, 0.77) | 28 | -0.07 (-0.10,-0.04) | 5096 | 9084 |
| **UV** | - ( -, -) | - | - ( -, -) | - | - |
| Rz | 0.90 ( 0.73, 0.96) | 17 | 0.43 ( 0.41, 0.45) | 7148 | 9641 |
| abs SMMF | 0.42 ( 0.16, 0.62) | 53 | 0.03 ( 0.01, 0.05) | 9576 | 9647 |
| aa | 0.10 ( 0.00, 0.20) | 391 | 0.00 (-0.02, 0.02) | 9660 | 9660 |
| Kp | 0.12 (-0.02, 0.26) | 188 | -0.00 (-0.02, 0.02) | 9660 | 9660 |
| Ap | 0.11 ( 0.02, 0.20) | 441 | 0.01 (-0.01, 0.03) | 9660 | 9660 |
| Dst | -0.16 (-0.24,-0.07) | 534 | -0.01 (-0.03, 0.01) | 9660 | 9660 |
| B | 0.29 ( 0.11, 0.45) | 111 | -0.00 (-0.02, 0.02) | 9551 | 9551 |
| Bzn GSE | 0.16 ( 0.11, 0.22) | 1314 | 0.01 (-0.01, 0.03) | 9551 | 9551 |
| Bzs GSE | -0.16 (-0.22,-0.10) | 1006 | 0.01 (-0.01, 0.03) | 9551 | 9551 |
| Bzn GSM | 0.16 ( 0.13, 0.19) | 4099 | 0.01 (-0.01, 0.03) | 9551 | 9551 |
| Bzs GSM | -0.14 (-0.17,-0.11) | 4534 | 0.01 (-0.01, 0.03) | 9551 | 9551 |
| n | -0.12 (-0.26, 0.02) | 189 | -0.02 (-0.04, 0.00) | 9551 | 9551 |
| V | -0.02 (-0.17, 0.12) | 179 | -0.01 (-0.03, 0.01) | 9551 | 9551 |
| Rg | 0.92 ( 0.70, 0.98) | 11 | 0.22 ( 0.19, 0.24) | 6263 | 6263 |
| CLIMAX | -0.77 (-0.92,-0.43) | 15 | -0.03 (-0.05,-0.01) | 9544 | 9660 |

Table 14: UV correlated against the other parameters

**Rz**

| Rz | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.87 ( 0.73, 0.94) | 25 | 0.26 ( 0.24, 0.28) | 12718 | 12855 |
| MWSI | 0.74 ( 0.60, 0.84) | 56 | 0.21 ( 0.20, 0.23) | 11883 | 12855 |
| CI | 0.66 ( 0.44, 0.80) | 42 | 0.05 ( 0.03, 0.06) | 23375 | 23375 |
| lg GOES >10 MeV p | 0.22 ( 0.11, 0.32) | 296 | 0.01 (-0.02, 0.04) | 4062 | 4107 |
| lg GOES X-ray | 0.82 ( 0.29, 0.96) | 8 | 0.10 ( 0.07, 0.13) | 4107 | 4107 |
| E10.7 | 0.92 ( 0.85, 0.96) | 36 | 0.45 ( 0.44, 0.47) | 14782 | 20195 |
| FI | 0.63 ( 0.43, 0.77) | 49 | 0.08 ( 0.06, 0.10) | 10226 | 10226 |
| Ca II plage area | 0.84 ( 0.72, 0.91) | 47 | 0.09 ( 0.07, 0.10) | 25349 | 25349 |
| F10.7 | 0.95 ( 0.90, 0.97) | 40 | 0.43 ( 0.42, 0.44) | 17902 | 21230 |
| SSA | 0.88 ( 0.83, 0.91) | 128 | 0.37 ( 0.36, 0.38) | 42204 | 47808 |
| TSI | 0.35 ( 0.01, 0.61) | 35 | -0.17 (-0.19,-0.15) | 7220 | 9084 |
| UV | 0.90 ( 0.73, 0.96) | 17 | 0.43 ( 0.41, 0.45) | 7148 | 9641 |
| **Rz** | - ( -, -) | - | - ( -, -) | - | - |
| abs SMMF | 0.38 ( 0.16, 0.57) | 68 | 0.02 (-0.00, 0.04) | 10644 | 10912 |
| aa | 0.19 ( 0.11, 0.26) | 628 | 0.00 (-0.01, 0.01) | 50128 | 50128 |
| Kp | 0.13 ( 0.04, 0.22) | 456 | -0.00 (-0.01, 0.01) | 26753 | 26753 |
| Ap | 0.12 ( 0.06, 0.19) | 875 | 0.00 (-0.01, 0.01) | 26753 | 26753 |
| Dst | -0.18 (-0.25,-0.10) | 577 | -0.01 (-0.02, 0.01) | 17621 | 17621 |
| B | 0.25 ( 0.12, 0.37) | 212 | 0.01 (-0.00, 0.03) | 15340 | 15340 |
| Bzn GSE | 0.14 ( 0.11, 0.18) | 2488 | 0.02 ( 0.00, 0.03) | 15340 | 15340 |
| Bzs GSE | -0.15 (-0.18,-0.12) | 3778 | 0.01 (-0.01, 0.02) | 15340 | 15340 |
| Bzn GSM | 0.14 ( 0.12, 0.17) | 7466 | 0.01 (-0.00, 0.03) | 15340 | 15340 |
| Bzs GSM | -0.13 (-0.15,-0.11) | 7763 | 0.01 (-0.01, 0.02) | 15340 | 15340 |
| n | -0.09 (-0.19, 0.03) | 311 | 0.00 (-0.02, 0.02) | 15340 | 15340 |
| V | -0.04 (-0.16, 0.08) | 269 | -0.00 (-0.02, 0.01) | 14945 | 15340 |
| Rg | 0.94 ( 0.91, 0.95) | 120 | 0.50 ( 0.49, 0.50) | 65012 | 65012 |
| CLIMAX | -0.70 (-0.84,-0.47) | 33 | -0.02 (-0.04,-0.01) | 18694 | 19082 |

Table 15: Rz correlated against the other parameters

**abs SMMF**

| abs SMMF | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.39 ( 0.15, 0.59) | 58 | 0.03 ( 0.02, 0.05) | 10918 | 10918 |
| MWSI | 0.30 ( 0.13, 0.45) | 125 | 0.02 (-0.00, 0.03) | 10918 | 10918 |
| CI | 0.46 ( 0.21, 0.65) | 50 | 0.03 ( 0.01, 0.05) | 10091 | 10091 |
| lg GOES >10 MeV p | 0.02 (-0.06, 0.11) | 525 | 0.03 ( 0.00, 0.06) | 3684 | 4113 |
| lg GOES X-ray | 0.29 (-0.10, 0.60) | 28 | -0.01 (-0.05, 0.02) | 4033 | 4113 |
| E10.7 | 0.45 ( 0.19, 0.65) | 49 | 0.02 ( 0.00, 0.04) | 9687 | 9877 |
| FI | 0.27 ( 0.10, 0.42) | 131 | -0.02 (-0.04,-0.01) | 10226 | 10226 |
| Ca II plage area | 0.37 (-0.06, 0.68) | 22 | -0.02 (-0.05, 0.02) | 3516 | 3516 |
| F10.7 | 0.41 ( 0.17, 0.60) | 62 | 0.01 (-0.01, 0.03) | 10912 | 10912 |
| SSA | 0.34 ( 0.16, 0.51) | 100 | 0.03 ( 0.01, 0.05) | 10885 | 10918 |
| TSI | 0.27 ( 0.08, 0.44) | 101 | -0.01 (-0.03, 0.01) | 8514 | 9084 |
| UV | 0.42 ( 0.16, 0.62) | 53 | 0.03 ( 0.01, 0.05) | 9576 | 9647 |
| Rz | 0.38 ( 0.16, 0.57) | 68 | 0.02 (-0.00, 0.04) | 10644 | 10912 |
| **abs SMMF** | - ( -, -) | - | - ( -, -) | - | - |
| aa | 0.11 ( 0.05, 0.17) | 1140 | -0.03 (-0.05,-0.01) | 10874 | 10918 |
| Kp | 0.13 ( 0.05, 0.21) | 640 | -0.06 (-0.08,-0.04) | 10332 | 10918 |
| Ap | 0.12 ( 0.06, 0.17) | 1265 | -0.02 (-0.04,-0.01) | 10804 | 10918 |
| Dst | -0.11 (-0.16,-0.05) | 1258 | 0.03 ( 0.01, 0.05) | 10291 | 10918 |
| B | 0.23 ( 0.13, 0.32) | 388 | -0.00 (-0.02, 0.01) | 10530 | 10822 |
| Bzn GSE | 0.12 ( 0.08, 0.15) | 2951 | 0.02 ( 0.00, 0.04) | 10822 | 10822 |
| Bzs GSE | -0.09 (-0.13,-0.04) | 1965 | 0.01 (-0.00, 0.03) | 10822 | 10822 |
| Bzn GSM | 0.12 ( 0.09, 0.14) | 5965 | 0.02 ( 0.00, 0.04) | 10822 | 10822 |
| Bzs GSM | -0.08 (-0.10,-0.05) | 6364 | 0.01 (-0.01, 0.03) | 10822 | 10822 |
| n | -0.01 (-0.08, 0.07) | 630 | 0.02 ( 0.00, 0.04) | 10662 | 10822 |
| V | 0.04 (-0.05, 0.13) | 484 | -0.09 (-0.11,-0.07) | 8832 | 10822 |
| Rg | 0.44 ( 0.17, 0.65) | 45 | 0.01 (-0.01, 0.03) | 7315 | 7534 |
| CLIMAX | -0.48 (-0.66,-0.25) | 56 | 0.01 (-0.01, 0.03) | 10088 | 10918 |

Table 16: abs SMMF correlated against the other parameters

**aa**

| aa | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.06 (-0.02, 0.14) | 600 | 0.00 (-0.01, 0.02) | 12872 | 12872 |
| MWSI | 0.11 ( 0.05, 0.17) | 1155 | 0.01 (-0.01, 0.03) | 12511 | 12872 |
| CI | 0.10 ( 0.05, 0.16) | 1106 | 0.01 (-0.00, 0.02) | 23366 | 23375 |
| lg GOES >10 MeV p | 0.25 ( 0.19, 0.30) | 1221 | 0.10 ( 0.07, 0.13) | 4125 | 4125 |
| lg GOES X-ray | 0.08 (-0.06, 0.22) | 196 | -0.02 (-0.05, 0.01) | 3710 | 4125 |
| E10.7 | 0.11 ( 0.03, 0.19) | 575 | 0.00 (-0.01, 0.02) | 20195 | 20195 |
| FI | 0.12 ( 0.06, 0.18) | 941 | -0.02 (-0.04, 0.00) | 8321 | 10226 |
| Ca II plage area | 0.12 ( 0.03, 0.20) | 559 | 0.00 (-0.01, 0.02) | 21181 | 25349 |
| F10.7 | 0.11 ( 0.04, 0.19) | 711 | 0.00 (-0.01, 0.02) | 21230 | 21230 |
| SSA | 0.19 ( 0.13, 0.26) | 791 | 0.01 (-0.00, 0.01) | 47819 | 47819 |
| TSI | -0.01 (-0.08, 0.06) | 713 | -0.00 (-0.02, 0.02) | 9084 | 9084 |
| UV | 0.10 ( 0.00, 0.20) | 391 | 0.00 (-0.02, 0.02) | 9660 | 9660 |
| Rz | 0.19 ( 0.11, 0.26) | 628 | 0.00 (-0.01, 0.01) | 50128 | 50128 |
| abs SMMF | 0.11 ( 0.05, 0.17) | 1140 | -0.03 (-0.05,-0.01) | 10874 | 10918 |
| **aa** | - ( -, -) | - | - ( -, -) | - | - |
| Kp | 0.89 ( 0.88, 0.89) | 4673 | 0.84 ( 0.84, 0.84) | 23120 | 26798 |
| Ap | 0.96 ( 0.96, 0.96) | 7118 | 0.94 ( 0.94, 0.94) | 22484 | 26798 |
| Dst | -0.73 (-0.74,-0.71) | 4047 | -0.60 (-0.61,-0.59) | 15609 | 17651 |
| B | 0.53 ( 0.50, 0.56) | 2564 | 0.52 ( 0.51, 0.53) | 12978 | 15340 |
| Bzn GSE | 0.12 ( 0.10, 0.14) | 8856 | 0.01 (-0.01, 0.03) | 12547 | 15340 |
| Bzs GSE | -0.50 (-0.51,-0.48) | 9690 | -0.55 (-0.56,-0.54) | 12574 | 15340 |
| Bzn GSM | 0.06 ( 0.04, 0.08) | 11167 | -0.01 (-0.02, 0.01) | 12614 | 15340 |
| Bzs GSM | -0.55 (-0.57,-0.54) | 11295 | -0.58 (-0.60,-0.57) | 12576 | 15340 |
| n | 0.06 ( 0.02, 0.09) | 3142 | 0.25 ( 0.23, 0.27) | 13095 | 15340 |
| V | 0.58 ( 0.55, 0.60) | 2216 | 0.42 ( 0.40, 0.43) | 15316 | 15340 |
| Rg | 0.18 ( 0.09, 0.26) | 533 | -0.00 (-0.01, 0.01) | 46750 | 46750 |
| CLIMAX | -0.24 (-0.32,-0.15) | 488 | -0.10 (-0.11,-0.09) | 19357 | 19357 |

Table 17: aa correlated against the other parameters

## Kp

| Kp | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.08 (-0.03, 0.19) | 299 | 0.01 (-0.01, 0.02) | 12872 | 12872 |
| MWSI | 0.11 ( 0.04, 0.19) | 609 | 0.01 (-0.01, 0.03) | 12872 | 12872 |
| CI | 0.10 ( 0.01, 0.20) | 415 | 0.01 (-0.00, 0.02) | 23375 | 23375 |
| lg GOES >10 MeV p | 0.15 ( 0.09, 0.21) | 986 | 0.06 ( 0.02, 0.09) | 3864 | 4125 |
| lg GOES X-ray | 0.08 (-0.11, 0.26) | 110 | 0.00 (-0.03, 0.03) | 3861 | 4125 |
| E10.7 | 0.13 ( 0.02, 0.24) | 303 | 0.00 (-0.01, 0.02) | 20195 | 20195 |
| FI | 0.14 ( 0.05, 0.22) | 495 | 0.00 (-0.02, 0.02) | 8807 | 10226 |
| Ca II plage area | 0.12 ( 0.00, 0.24) | 266 | 0.00 (-0.01, 0.02) | 17049 | 19357 |
| F10.7 | 0.13 ( 0.03, 0.23) | 365 | 0.00 (-0.01, 0.02) | 21230 | 21230 |
| SSA | 0.14 ( 0.06, 0.21) | 644 | 0.01 (-0.01, 0.02) | 26764 | 26764 |
| TSI | 0.01 (-0.10, 0.12) | 308 | -0.02 (-0.04,-0.00) | 9084 | 9084 |
| UV | 0.12 (-0.02, 0.26) | 188 | -0.00 (-0.02, 0.02) | 9660 | 9660 |
| Rz | 0.13 ( 0.04, 0.22) | 456 | -0.00 (-0.01, 0.01) | 26753 | 26753 |
| abs SMMF | 0.13 ( 0.05, 0.21) | 640 | -0.06 (-0.08,-0.04) | 10332 | 10918 |
| aa | 0.89 ( 0.88, 0.89) | 4673 | 0.84 ( 0.84, 0.84) | 23120 | 26798 |
| **Kp** | - ( -, -) | - | - ( -, -) | - | - |
| Ap | 0.86 ( 0.85, 0.86) | 4787 | 0.81 ( 0.81, 0.82) | 23114 | 26798 |
| Dst | -0.71 (-0.73,-0.69) | 2833 | -0.59 (-0.60,-0.58) | 15678 | 17651 |
| B | 0.49 ( 0.45, 0.52) | 1578 | 0.49 ( 0.48, 0.50) | 13146 | 15340 |
| Bzn GSE | 0.07 ( 0.04, 0.09) | 7508 | -0.03 (-0.05,-0.01) | 13098 | 15340 |
| Bzs GSE | -0.46 (-0.48,-0.44) | 8490 | -0.54 (-0.55,-0.53) | 13131 | 15340 |
| Bzn GSM | 0.00 (-0.02, 0.02) | 10529 | -0.06 (-0.07,-0.04) | 13151 | 15340 |
| Bzs GSM | -0.52 (-0.54,-0.51) | 10672 | -0.57 (-0.58,-0.56) | 13146 | 15340 |
| n | -0.00 (-0.05, 0.04) | 2034 | 0.23 ( 0.21, 0.25) | 13377 | 15340 |
| V | 0.67 ( 0.64, 0.69) | 1518 | 0.50 ( 0.49, 0.51) | 14581 | 15340 |
| Rg | 0.12 ( 0.02, 0.22) | 375 | 0.00 (-0.01, 0.02) | 22994 | 23375 |
| CLIMAX | -0.25 (-0.35,-0.15) | 314 | -0.07 (-0.09,-0.06) | 18928 | 19127 |

Table 18: Kp correlated against the other parameters

**Ap**

| Ap | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.08 ( 0.01, 0.16) | 674 | 0.00 (-0.01, 0.02) | 12872 | 12872 |
| MWSI | 0.12 ( 0.07, 0.18) | 1278 | 0.01 (-0.01, 0.03) | 12592 | 12872 |
| CI | 0.09 ( 0.03, 0.15) | 1088 | 0.01 (-0.00, 0.02) | 23375 | 23375 |
| lg GOES >10 MeV p | 0.27 ( 0.22, 0.32) | 1309 | 0.09 ( 0.06, 0.12) | 4094 | 4125 |
| lg GOES X-ray | 0.09 (-0.01, 0.18) | 409 | -0.02 (-0.05, 0.01) | 3726 | 4125 |
| E10.7 | 0.12 ( 0.04, 0.20) | 550 | 0.01 (-0.01, 0.02) | 20195 | 20195 |
| FI | 0.13 ( 0.07, 0.19) | 1039 | -0.03 (-0.05,-0.00) | 8412 | 10226 |
| Ca II plage area | 0.12 ( 0.03, 0.20) | 526 | -0.00 (-0.02, 0.01) | 16253 | 19357 |
| F10.7 | 0.13 ( 0.05, 0.20) | 711 | 0.01 (-0.01, 0.02) | 21230 | 21230 |
| SSA | 0.14 ( 0.09, 0.20) | 1216 | 0.01 (-0.01, 0.02) | 26764 | 26764 |
| TSI | -0.01 (-0.08, 0.07) | 775 | -0.00 (-0.02, 0.02) | 9084 | 9084 |
| UV | 0.11 ( 0.02, 0.20) | 441 | 0.01 (-0.01, 0.03) | 9660 | 9660 |
| Rz | 0.12 ( 0.06, 0.19) | 875 | 0.00 (-0.01, 0.01) | 26753 | 26753 |
| abs SMMF | 0.12 ( 0.06, 0.17) | 1265 | -0.02 (-0.04,-0.01) | 10804 | 10918 |
| aa | 0.96 ( 0.96, 0.96) | 7118 | 0.94 ( 0.94, 0.94) | 22484 | 26798 |
| Kp | 0.86 ( 0.85, 0.86) | 4787 | 0.81 ( 0.81, 0.82) | 23114 | 26798 |
| **Ap** | - ( -, -) | - | - ( -, -) | - | - |
| Dst | -0.76 (-0.77,-0.75) | 4222 | -0.68 (-0.69,-0.67) | 15581 | 17651 |
| B | 0.53 ( 0.50, 0.55) | 3541 | 0.51 ( 0.50, 0.52) | 12943 | 15340 |
| Bzn GSE | 0.11 ( 0.09, 0.13) | 9315 | -0.00 (-0.02, 0.01) | 12581 | 15340 |
| Bzs GSE | -0.51 (-0.53,-0.50) | 10002 | -0.55 (-0.57,-0.54) | 12609 | 15340 |
| Bzn GSM | 0.06 ( 0.04, 0.07) | 11211 | -0.02 (-0.04,-0.00) | 12646 | 15340 |
| Bzs GSM | -0.57 (-0.58,-0.55) | 11339 | -0.59 (-0.60,-0.58) | 12615 | 15340 |
| n | 0.05 ( 0.02, 0.08) | 4199 | 0.21 ( 0.19, 0.23) | 13098 | 15340 |
| V | 0.54 ( 0.51, 0.56) | 2807 | 0.40 ( 0.39, 0.41) | 15229 | 15340 |
| Rg | 0.10 ( 0.03, 0.17) | 730 | 0.00 (-0.01, 0.01) | 23147 | 23375 |
| CLIMAX | -0.24 (-0.30,-0.17) | 841 | -0.12 (-0.13,-0.11) | 19127 | 19127 |

Table 19: Ap correlated against the other parameters

**Dst**

| Dst | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | -0.14 (-0.21,-0.07) | 758 | -0.00 (-0.02, 0.01) | 12872 | 12872 |
| MWSI | -0.15 (-0.20,-0.10) | 1301 | 0.01 (-0.00, 0.03) | 12872 | 12872 |
| CI | -0.19 (-0.27,-0.10) | 467 | -0.01 (-0.02, 0.01) | 16800 | 16800 |
| lg GOES >10 MeV p | -0.27 (-0.34,-0.21) | 857 | -0.01 (-0.05, 0.02) | 3920 | 4125 |
| lg GOES X-ray | -0.10 (-0.22, 0.02) | 272 | 0.02 (-0.01, 0.05) | 3863 | 4125 |
| E10.7 | -0.20 (-0.29,-0.11) | 453 | -0.02 (-0.03,-0.00) | 16586 | 16586 |
| FI | -0.13 (-0.19,-0.08) | 1225 | 0.01 (-0.01, 0.03) | 9070 | 10226 |
| Ca II plage area | -0.18 (-0.33,-0.03) | 162 | 0.00 (-0.02, 0.02) | 9219 | 10225 |
| F10.7 | -0.20 (-0.28,-0.11) | 525 | -0.02 (-0.03,-0.00) | 17621 | 17621 |
| SSA | -0.19 (-0.26,-0.13) | 768 | -0.02 (-0.03,-0.00) | 17632 | 17632 |
| TSI | -0.03 (-0.09, 0.04) | 885 | -0.00 (-0.02, 0.02) | 9084 | 9084 |
| UV | -0.16 (-0.24,-0.07) | 534 | -0.01 (-0.03, 0.01) | 9660 | 9660 |
| Rz | -0.18 (-0.25,-0.10) | 577 | -0.01 (-0.02, 0.01) | 17621 | 17621 |
| abs SMMF | -0.11 (-0.16,-0.05) | 1258 | 0.03 ( 0.01, 0.05) | 10291 | 10918 |
| aa | -0.73 (-0.74,-0.71) | 4047 | -0.60 (-0.61,-0.59) | 15609 | 17651 |
| Kp | -0.71 (-0.73,-0.69) | 2833 | -0.59 (-0.60,-0.58) | 15678 | 17651 |
| Ap | -0.76 (-0.77,-0.75) | 4222 | -0.68 (-0.69,-0.67) | 15581 | 17651 |
| **Dst** | - ( -, -) | - | - ( -, -) | - | - |
| B | -0.37 (-0.41,-0.34) | 2447 | -0.26 (-0.27,-0.24) | 13363 | 15340 |
| Bzn GSE | -0.02 (-0.04, 0.01) | 7452 | 0.15 ( 0.14, 0.17) | 13381 | 15340 |
| Bzs GSE | 0.44 ( 0.42, 0.46) | 7986 | 0.44 ( 0.43, 0.45) | 13415 | 15340 |
| Bzn GSM | 0.06 ( 0.04, 0.08) | 9496 | 0.18 ( 0.17, 0.20) | 13426 | 15340 |
| Bzs GSM | 0.52 ( 0.51, 0.54) | 9697 | 0.49 ( 0.47, 0.50) | 13429 | 15340 |
| n | 0.18 ( 0.15, 0.21) | 2987 | 0.19 ( 0.18, 0.21) | 13589 | 15340 |
| V | -0.46 (-0.50,-0.43) | 1869 | -0.39 (-0.40,-0.37) | 14494 | 15340 |
| Rg | -0.18 (-0.27,-0.08) | 389 | -0.00 (-0.02, 0.01) | 13890 | 14243 |
| CLIMAX | 0.29 ( 0.20, 0.36) | 487 | 0.18 ( 0.17, 0.19) | 17324 | 17651 |

Table 20: Dst correlated against the other parameters

**B**

| B | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.25 ( 0.09, 0.39) | 154 | -0.01 (-0.03, 0.00) | 12765 | 12765 |
| MWSI | 0.20 ( 0.10, 0.30) | 336 | -0.00 (-0.02, 0.02) | 12765 | 12765 |
| CI | 0.27 ( 0.12, 0.41) | 161 | 0.02 (-0.00, 0.03) | 14609 | 14609 |
| lg GOES >10 MeV p | 0.17 ( 0.12, 0.22) | 1351 | 0.05 ( 0.01, 0.08) | 3790 | 4017 |
| lg GOES X-ray | 0.28 ( 0.04, 0.50) | 62 | -0.02 (-0.06, 0.01) | 3679 | 4017 |
| E10.7 | 0.29 ( 0.14, 0.43) | 158 | -0.00 (-0.02, 0.01) | 14395 | 14395 |
| FI | 0.22 ( 0.11, 0.33) | 294 | 0.01 (-0.01, 0.03) | 8596 | 10226 |
| Ca II plage area | 0.16 (-0.04, 0.34) | 99 | -0.01 (-0.03, 0.02) | 7061 | 8034 |
| F10.7 | 0.28 ( 0.15, 0.41) | 190 | 0.00 (-0.01, 0.02) | 15340 | 15340 |
| SSA | 0.24 ( 0.13, 0.34) | 313 | 0.00 (-0.01, 0.02) | 15340 | 15340 |
| TSI | 0.17 ( 0.04, 0.30) | 210 | 0.01 (-0.01, 0.03) | 9084 | 9084 |
| UV | 0.29 ( 0.11, 0.45) | 111 | -0.00 (-0.02, 0.02) | 9551 | 9551 |
| Rz | 0.25 ( 0.12, 0.37) | 212 | 0.01 (-0.00, 0.03) | 15340 | 15340 |
| abs SMMF | 0.23 ( 0.13, 0.32) | 388 | -0.00 (-0.02, 0.01) | 10530 | 10822 |
| aa | 0.53 ( 0.50, 0.56) | 2564 | 0.52 ( 0.51, 0.53) | 12978 | 15340 |
| Kp | 0.49 ( 0.45, 0.52) | 1578 | 0.49 ( 0.48, 0.50) | 13146 | 15340 |
| Ap | 0.53 ( 0.50, 0.55) | 3541 | 0.51 ( 0.50, 0.52) | 12943 | 15340 |
| Dst | -0.37 (-0.41,-0.34) | 2447 | -0.26 (-0.27,-0.24) | 13363 | 15340 |
| **B** | - ( -, -) | - | - ( -, -) | - | - |
| Bzn GSE | 0.53 ( 0.52, 0.55) | 7511 | 0.45 ( 0.43, 0.46) | 12706 | 15340 |
| Bzs GSE | -0.50 (-0.51,-0.48) | 9014 | -0.41 (-0.43,-0.40) | 12754 | 15340 |
| Bzn GSM | 0.52 ( 0.50, 0.53) | 11569 | 0.45 ( 0.43, 0.46) | 12785 | 15340 |
| Bzs GSM | -0.48 (-0.50,-0.47) | 11687 | -0.42 (-0.43,-0.40) | 12775 | 15340 |
| n | 0.30 ( 0.25, 0.34) | 1657 | 0.35 ( 0.34, 0.37) | 13077 | 15340 |
| V | 0.09 ( 0.03, 0.14) | 1438 | 0.11 ( 0.10, 0.13) | 14795 | 15340 |
| Rg | 0.25 ( 0.10, 0.40) | 144 | -0.01 (-0.03, 0.01) | 11761 | 12052 |
| CLIMAX | -0.32 (-0.44,-0.17) | 172 | -0.11 (-0.12,-0.09) | 15328 | 15340 |

Table 21: B correlated against the other parameters

## Bzn GSE

| Bzn GSE | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.14 ( 0.08, 0.19) | 1252 | -0.00 (-0.02, 0.01) | 12735 | 12765 |
| MWSI | 0.11 ( 0.07, 0.15) | 2327 | -0.00 (-0.02, 0.01) | 12040 | 12765 |
| CI | 0.14 ( 0.09, 0.19) | 1376 | 0.01 (-0.01, 0.03) | 14305 | 14609 |
| lg GOES >10 MeV p | 0.12 ( 0.08, 0.16) | 2477 | 0.01 (-0.02, 0.04) | 4017 | 4017 |
| lg GOES X-ray | 0.17 ( 0.12, 0.21) | 1992 | -0.01 (-0.04, 0.03) | 3533 | 4017 |
| E10.7 | 0.16 ( 0.12, 0.21) | 1899 | 0.00 (-0.01, 0.02) | 14395 | 14395 |
| FI | 0.13 ( 0.09, 0.16) | 2816 | 0.00 (-0.02, 0.02) | 7886 | 10226 |
| Ca II plage area | 0.08 ( 0.06, 0.11) | 5116 | -0.01 (-0.03, 0.01) | 6512 | 8034 |
| F10.7 | 0.16 ( 0.12, 0.20) | 2280 | 0.00 (-0.01, 0.02) | 15340 | 15340 |
| SSA | 0.13 ( 0.10, 0.17) | 3275 | 0.00 (-0.01, 0.02) | 15340 | 15340 |
| TSI | 0.09 ( 0.06, 0.12) | 4790 | 0.01 (-0.01, 0.03) | 9084 | 9084 |
| UV | 0.16 ( 0.11, 0.22) | 1314 | 0.01 (-0.01, 0.03) | 9551 | 9551 |
| Rz | 0.14 ( 0.11, 0.18) | 2488 | 0.02 ( 0.00, 0.03) | 15340 | 15340 |
| abs SMMF | 0.12 ( 0.08, 0.15) | 2951 | 0.02 ( 0.00, 0.04) | 10822 | 10822 |
| aa | 0.12 ( 0.10, 0.14) | 8856 | 0.01 (-0.01, 0.03) | 12547 | 15340 |
| Kp | 0.07 ( 0.04, 0.09) | 7508 | -0.03 (-0.05,-0.01) | 13098 | 15340 |
| Ap | 0.11 ( 0.09, 0.13) | 9315 | -0.00 (-0.02, 0.01) | 12581 | 15340 |
| Dst | -0.02 (-0.04, 0.01) | 7452 | 0.15 ( 0.14, 0.17) | 13381 | 15340 |
| B | 0.53 ( 0.52, 0.55) | 7511 | 0.45 ( 0.43, 0.46) | 12706 | 15340 |
| **Bzn GSE** | - ( -, -) | - | - ( -, -) | - | - |
| Bzs GSE | 0.16 ( 0.14, 0.17) | 12609 | 0.31 ( 0.29, 0.32) | 11915 | 15340 |
| Bzn GSM | 0.90 ( 0.89, 0.90) | 13300 | 0.92 ( 0.91, 0.92) | 11986 | 15340 |
| Bzs GSM | 0.14 ( 0.12, 0.16) | 13367 | 0.29 ( 0.27, 0.31) | 11910 | 15340 |
| n | 0.25 ( 0.23, 0.27) | 8387 | 0.24 ( 0.22, 0.26) | 12721 | 15340 |
| V | 0.00 (-0.02, 0.03) | 6287 | 0.03 ( 0.01, 0.04) | 15340 | 15340 |
| Rg | 0.14 ( 0.10, 0.19) | 1760 | 0.00 (-0.02, 0.02) | 11812 | 12052 |
| CLIMAX | -0.17 (-0.21,-0.12) | 2081 | -0.15 (-0.16,-0.13) | 15340 | 15340 |

Table 22: Bzn GSE correlated against the other parameters

**Bzs GSE**

| Bzs GSE | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | -0.16 (-0.22,-0.09) | 774 | 0.00 (-0.02, 0.02) | 12676 | 12765 |
| MWSI | -0.14 (-0.19,-0.09) | 1529 | -0.01 (-0.03, 0.01) | 11986 | 12765 |
| CI | -0.15 (-0.19,-0.12) | 2988 | -0.01 (-0.03, 0.01) | 14318 | 14609 |
| lg GOES >10 MeV p | -0.10 (-0.14,-0.06) | 2601 | -0.02 (-0.05, 0.01) | 4017 | 4017 |
| lg GOES X-ray | -0.15 (-0.19,-0.11) | 2320 | 0.00 (-0.03, 0.04) | 3487 | 4017 |
| E10.7 | -0.16 (-0.21,-0.12) | 1533 | -0.01 (-0.02, 0.01) | 14395 | 14395 |
| FI | -0.12 (-0.17,-0.08) | 1709 | -0.01 (-0.03, 0.01) | 7902 | 10226 |
| Ca II plage area | -0.13 (-0.16,-0.10) | 5057 | 0.02 (-0.01, 0.04) | 6448 | 8034 |
| F10.7 | -0.17 (-0.20,-0.13) | 3506 | -0.00 (-0.02, 0.01) | 15340 | 15340 |
| SSA | -0.16 (-0.18,-0.13) | 4694 | 0.01 (-0.01, 0.02) | 15340 | 15340 |
| TSI | -0.09 (-0.12,-0.07) | 4809 | -0.02 (-0.04,-0.00) | 9084 | 9084 |
| UV | -0.16 (-0.22,-0.10) | 1006 | 0.01 (-0.01, 0.03) | 9551 | 9551 |
| Rz | -0.15 (-0.18,-0.12) | 3778 | 0.01 (-0.01, 0.02) | 15340 | 15340 |
| abs SMMF | -0.09 (-0.13,-0.04) | 1965 | 0.01 (-0.00, 0.03) | 10822 | 10822 |
| aa | -0.50 (-0.51,-0.48) | 9690 | -0.55 (-0.56,-0.54) | 12574 | 15340 |
| Kp | -0.46 (-0.48,-0.44) | 8490 | -0.54 (-0.55,-0.53) | 13131 | 15340 |
| Ap | -0.51 (-0.53,-0.50) | 10002 | -0.55 (-0.57,-0.54) | 12609 | 15340 |
| Dst | 0.44 ( 0.42, 0.46) | 7986 | 0.44 ( 0.43, 0.45) | 13415 | 15340 |
| B | -0.50 (-0.51,-0.48) | 9014 | -0.41 (-0.43,-0.40) | 12754 | 15340 |
| Bzn GSE | 0.16 ( 0.14, 0.17) | 12609 | 0.31 ( 0.29, 0.32) | 11915 | 15340 |
| **Bzs GSE** | - ( -, -) | - | - ( -, -) | - | - |
| Bzn GSM | 0.14 ( 0.12, 0.15) | 13222 | 0.29 ( 0.27, 0.30) | 12005 | 15340 |
| Bzs GSM | 0.90 ( 0.89, 0.90) | 13269 | 0.92 ( 0.91, 0.92) | 11909 | 15340 |
| n | -0.18 (-0.20,-0.16) | 9444 | -0.18 (-0.20,-0.17) | 12751 | 15340 |
| V | 0.01 (-0.01, 0.03) | 7273 | -0.03 (-0.05,-0.01) | 15340 | 15340 |
| Rg | -0.15 (-0.18,-0.13) | 7340 | 0.02 (-0.00, 0.03) | 11820 | 12052 |
| CLIMAX | 0.15 ( 0.12, 0.19) | 3235 | -0.01 (-0.03, 0.00) | 15340 | 15340 |

Table 23: Bzs GSE correlated against the other parameters

**Bzn GSM**

| Bzn GSM | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.13 ( 0.11, 0.16) | 5986 | 0.00 (-0.01, 0.02) | 12714 | 12765 |
| MWSI | 0.12 ( 0.10, 0.14) | 6573 | -0.00 (-0.02, 0.02) | 12045 | 12765 |
| CI | 0.15 ( 0.12, 0.17) | 6995 | 0.01 (-0.00, 0.03) | 14309 | 14609 |
| lg GOES >10 MeV p | 0.12 ( 0.08, 0.16) | 2235 | 0.01 (-0.02, 0.04) | 4017 | 4017 |
| lg GOES X-ray | 0.18 ( 0.14, 0.22) | 1948 | -0.01 (-0.04, 0.02) | 3554 | 4017 |
| E10.7 | 0.16 ( 0.14, 0.19) | 6884 | 0.00 (-0.01, 0.02) | 14395 | 14395 |
| FI | 0.13 ( 0.10, 0.15) | 5766 | -0.00 (-0.02, 0.02) | 7966 | 10226 |
| Ca II plage area | 0.09 ( 0.06, 0.12) | 4194 | 0.00 (-0.02, 0.03) | 6524 | 8034 |
| F10.7 | 0.16 ( 0.14, 0.18) | 7326 | 0.01 (-0.01, 0.02) | 15340 | 15340 |
| SSA | 0.13 ( 0.11, 0.16) | 7664 | 0.00 (-0.01, 0.02) | 15340 | 15340 |
| TSI | 0.09 ( 0.06, 0.12) | 4448 | 0.01 (-0.01, 0.03) | 9084 | 9084 |
| UV | 0.16 ( 0.13, 0.19) | 4099 | 0.01 (-0.01, 0.03) | 9551 | 9551 |
| Rz | 0.14 ( 0.12, 0.17) | 7466 | 0.01 (-0.00, 0.03) | 15340 | 15340 |
| abs SMMF | 0.12 ( 0.09, 0.14) | 5965 | 0.02 ( 0.00, 0.04) | 10822 | 10822 |
| aa | 0.06 ( 0.04, 0.08) | 11167 | -0.01 (-0.02, 0.01) | 12614 | 15340 |
| Kp | 0.00 (-0.02, 0.02) | 10529 | -0.06 (-0.07,-0.04) | 13151 | 15340 |
| Ap | 0.06 ( 0.04, 0.07) | 11211 | -0.02 (-0.04,-0.00) | 12646 | 15340 |
| Dst | 0.06 ( 0.04, 0.08) | 9496 | 0.18 ( 0.17, 0.20) | 13426 | 15340 |
| B | 0.52 ( 0.50, 0.53) | 11569 | 0.45 ( 0.43, 0.46) | 12785 | 15340 |
| Bzn GSE | 0.90 ( 0.89, 0.90) | 13300 | 0.92 ( 0.91, 0.92) | 11986 | 15340 |
| Bzs GSE | 0.14 ( 0.12, 0.15) | 13222 | 0.29 ( 0.27, 0.30) | 12005 | 15340 |
| **Bzn GSM** | - ( -, -) | - | - ( -, -) | - | - |
| Bzs GSM | 0.23 ( 0.21, 0.24) | 12825 | 0.32 ( 0.30, 0.34) | 12000 | 15340 |
| n | 0.24 ( 0.22, 0.26) | 11426 | 0.24 ( 0.22, 0.25) | 12799 | 15340 |
| V | 0.00 (-0.02, 0.02) | 9341 | 0.02 ( 0.01, 0.04) | 15340 | 15340 |
| Rg | 0.14 ( 0.11, 0.16) | 5885 | -0.00 (-0.02, 0.02) | 11815 | 12052 |
| CLIMAX | -0.17 (-0.20,-0.15) | 7267 | -0.15 (-0.17,-0.13) | 15340 | 15340 |

Table 24: Bzn GSM correlated against the other parameters

**Bzs GSM**

| Bzs GSM | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | -0.14 (-0.17,-0.12) | 6395 | 0.00 (-0.02, 0.02) | 12648 | 12765 |
| MWSI | -0.11 (-0.13,-0.09) | 6931 | -0.01 (-0.03, 0.01) | 11955 | 12765 |
| CI | -0.13 (-0.16,-0.11) | 7221 | -0.01 (-0.02, 0.01) | 14310 | 14609 |
| lg GOES >10 MeV p | -0.08 (-0.12,-0.04) | 2355 | -0.02 (-0.05, 0.01) | 4017 | 4017 |
| lg GOES X-ray | -0.11 (-0.15,-0.07) | 2047 | 0.00 (-0.03, 0.03) | 3487 | 4017 |
| E10.7 | -0.15 (-0.17,-0.12) | 7250 | -0.00 (-0.02, 0.01) | 14395 | 14395 |
| FI | -0.10 (-0.13,-0.08) | 6169 | -0.01 (-0.03, 0.01) | 7873 | 10226 |
| Ca II plage area | -0.11 (-0.14,-0.08) | 4298 | 0.04 ( 0.01, 0.06) | 6465 | 8034 |
| F10.7 | -0.15 (-0.17,-0.13) | 7633 | -0.00 (-0.02, 0.01) | 15340 | 15340 |
| SSA | -0.13 (-0.15,-0.11) | 7945 | 0.00 (-0.01, 0.02) | 15340 | 15340 |
| TSI | -0.09 (-0.11,-0.06) | 4682 | -0.02 (-0.04, 0.00) | 9084 | 9084 |
| UV | -0.14 (-0.17,-0.11) | 4534 | 0.01 (-0.01, 0.03) | 9551 | 9551 |
| Rz | -0.13 (-0.15,-0.11) | 7763 | 0.01 (-0.01, 0.02) | 15340 | 15340 |
| abs SMMF | -0.08 (-0.10,-0.05) | 6364 | 0.01 (-0.01, 0.03) | 10822 | 10822 |
| aa | -0.55 (-0.57,-0.54) | 11295 | -0.58 (-0.60,-0.57) | 12576 | 15340 |
| Kp | -0.52 (-0.54,-0.51) | 10672 | -0.57 (-0.58,-0.56) | 13146 | 15340 |
| Ap | -0.57 (-0.58,-0.55) | 11339 | -0.59 (-0.60,-0.58) | 12615 | 15340 |
| Dst | 0.52 ( 0.51, 0.54) | 9697 | 0.49 ( 0.47, 0.50) | 13429 | 15340 |
| B | -0.48 (-0.50,-0.47) | 11687 | -0.42 (-0.43,-0.40) | 12775 | 15340 |
| Bzn GSE | 0.14 ( 0.12, 0.16) | 13367 | 0.29 ( 0.27, 0.31) | 11910 | 15340 |
| Bzs GSE | 0.90 ( 0.89, 0.90) | 13269 | 0.92 ( 0.91, 0.92) | 11909 | 15340 |
| Bzn GSM | 0.23 ( 0.21, 0.24) | 12825 | 0.32 ( 0.30, 0.34) | 12000 | 15340 |
| **Bzs GSM** | - ( -, -) | - | - ( -, -) | - | - |
| n | -0.17 (-0.18,-0.15) | 11529 | -0.17 (-0.19,-0.16) | 12756 | 15340 |
| V | 0.00 (-0.02, 0.02) | 9492 | -0.03 (-0.05,-0.02) | 15340 | 15340 |
| Rg | -0.14 (-0.17,-0.12) | 6117 | 0.01 (-0.01, 0.03) | 11820 | 12052 |
| CLIMAX | 0.13 ( 0.10, 0.15) | 7583 | -0.04 (-0.05,-0.02) | 15340 | 15340 |

Table 25: Bzs GSM correlated against the other parameters

**n**

| n | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | -0.11 (-0.21, 0.01) | 309 | -0.01 (-0.02, 0.01) | 12765 | 12765 |
| MWSI | -0.08 (-0.15, 0.00) | 640 | 0.02 ( 0.00, 0.04) | 12529 | 12765 |
| CI | -0.08 (-0.18, 0.03) | 359 | 0.01 (-0.01, 0.02) | 14502 | 14609 |
| lg GOES >10 MeV p | -0.01 (-0.07, 0.05) | 1155 | 0.04 ( 0.01, 0.07) | 3855 | 4017 |
| lg GOES X-ray | -0.19 (-0.42, 0.07) | 62 | 0.03 (-0.00, 0.06) | 3684 | 4017 |
| E10.7 | -0.09 (-0.19, 0.02) | 366 | -0.01 (-0.02, 0.01) | 14395 | 14395 |
| FI | -0.03 (-0.10, 0.05) | 677 | -0.01 (-0.03, 0.01) | 8537 | 10226 |
| Ca II plage area | -0.09 (-0.15,-0.03) | 1140 | -0.02 (-0.04, 0.00) | 6862 | 8034 |
| F10.7 | -0.09 (-0.20, 0.03) | 279 | -0.00 (-0.02, 0.01) | 15340 | 15340 |
| SSA | -0.08 (-0.17, 0.01) | 454 | -0.01 (-0.03, 0.01) | 15340 | 15340 |
| TSI | -0.06 (-0.14, 0.03) | 519 | 0.01 (-0.01, 0.03) | 9084 | 9084 |
| UV | -0.12 (-0.26, 0.02) | 189 | -0.02 (-0.04, 0.00) | 9551 | 9551 |
| Rz | -0.09 (-0.19, 0.03) | 311 | 0.00 (-0.02, 0.02) | 15340 | 15340 |
| abs SMMF | -0.01 (-0.08, 0.07) | 630 | 0.02 ( 0.00, 0.04) | 10662 | 10822 |
| aa | 0.06 ( 0.02, 0.09) | 3142 | 0.25 ( 0.23, 0.27) | 13095 | 15340 |
| Kp | -0.00 (-0.05, 0.04) | 2034 | 0.23 ( 0.21, 0.25) | 13377 | 15340 |
| Ap | 0.05 ( 0.02, 0.08) | 4199 | 0.21 ( 0.19, 0.23) | 13098 | 15340 |
| Dst | 0.18 ( 0.15, 0.21) | 2987 | 0.19 ( 0.18, 0.21) | 13589 | 15340 |
| B | 0.30 ( 0.25, 0.34) | 1657 | 0.35 ( 0.34, 0.37) | 13077 | 15340 |
| Bzn GSE | 0.25 ( 0.23, 0.27) | 8387 | 0.24 ( 0.22, 0.26) | 12721 | 15340 |
| Bzs GSE | -0.18 (-0.20,-0.16) | 9444 | -0.18 (-0.20,-0.17) | 12751 | 15340 |
| Bzn GSM | 0.24 ( 0.22, 0.26) | 11426 | 0.24 ( 0.22, 0.25) | 12799 | 15340 |
| Bzs GSM | -0.17 (-0.18,-0.15) | 11529 | -0.17 (-0.19,-0.16) | 12756 | 15340 |
| **n** | - ( -, -) | - | - ( -, -) | - | - |
| V | -0.44 (-0.48,-0.40) | 1747 | -0.28 (-0.30,-0.27) | 15200 | 15340 |
| Rg | -0.07 (-0.16, 0.03) | 389 | -0.01 (-0.02, 0.01) | 11783 | 12052 |
| CLIMAX | 0.12 ( 0.00, 0.24) | 255 | 0.08 ( 0.07, 0.10) | 15340 | 15340 |

Table 26: n correlated against the other parameters

**V**

| V | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | -0.07 (-0.21, 0.08) | 184 | -0.00 (-0.02, 0.01) | 12765 | 12765 |
| MWSI | 0.03 (-0.07, 0.13) | 380 | -0.00 (-0.02, 0.01) | 12765 | 12765 |
| CI | -0.03 (-0.13, 0.08) | 352 | -0.01 (-0.02, 0.01) | 14609 | 14609 |
| lg GOES >10 MeV p | 0.09 ( 0.02, 0.17) | 671 | 0.03 (-0.01, 0.06) | 3383 | 4017 |
| lg GOES X-ray | 0.04 (-0.22, 0.30) | 56 | -0.04 (-0.07,-0.01) | 4017 | 4017 |
| E10.7 | -0.05 (-0.15, 0.06) | 345 | -0.00 (-0.02, 0.01) | 14222 | 14395 |
| FI | 0.02 (-0.07, 0.10) | 519 | 0.00 (-0.02, 0.02) | 10226 | 10226 |
| Ca II plage area | -0.15 (-0.31, 0.01) | 143 | -0.01 (-0.03, 0.01) | 8034 | 8034 |
| F10.7 | -0.04 (-0.17, 0.08) | 243 | 0.00 (-0.01, 0.02) | 15340 | 15340 |
| SSA | -0.00 (-0.10, 0.10) | 388 | -0.00 (-0.02, 0.01) | 15270 | 15340 |
| TSI | -0.11 (-0.20,-0.01) | 406 | -0.07 (-0.09,-0.05) | 8693 | 9084 |
| UV | -0.02 (-0.17, 0.12) | 179 | -0.01 (-0.03, 0.01) | 9551 | 9551 |
| Rz | -0.04 (-0.16, 0.08) | 269 | -0.00 (-0.02, 0.01) | 14945 | 15340 |
| abs SMMF | 0.04 (-0.05, 0.13) | 484 | -0.09 (-0.11,-0.07) | 8832 | 10822 |
| aa | 0.58 ( 0.55, 0.60) | 2216 | 0.42 ( 0.40, 0.43) | 15316 | 15340 |
| Kp | 0.67 ( 0.64, 0.69) | 1518 | 0.50 ( 0.49, 0.51) | 14581 | 15340 |
| Ap | 0.54 ( 0.51, 0.56) | 2807 | 0.40 ( 0.39, 0.41) | 15229 | 15340 |
| Dst | -0.46 (-0.50,-0.43) | 1869 | -0.39 (-0.40,-0.37) | 14494 | 15340 |
| B | 0.09 ( 0.03, 0.14) | 1438 | 0.11 ( 0.10, 0.13) | 14795 | 15340 |
| Bzn GSE | 0.00 (-0.02, 0.03) | 6287 | 0.03 ( 0.01, 0.04) | 15340 | 15340 |
| Bzs GSE | 0.01 (-0.01, 0.03) | 7273 | -0.03 (-0.05,-0.01) | 15340 | 15340 |
| Bzn GSM | 0.00 (-0.02, 0.02) | 9341 | 0.02 ( 0.01, 0.04) | 15340 | 15340 |
| Bzs GSM | 0.00 (-0.02, 0.02) | 9492 | -0.03 (-0.05,-0.02) | 15340 | 15340 |
| n | -0.44 (-0.48,-0.40) | 1747 | -0.28 (-0.30,-0.27) | 15200 | 15340 |
| **V** | - ( -, -) | - | - ( -, -) | - | - |
| Rg | -0.09 (-0.19, 0.01) | 390 | -0.01 (-0.03, 0.00) | 11635 | 12052 |
| CLIMAX | -0.14 (-0.27,-0.01) | 222 | -0.25 (-0.27,-0.24) | 13974 | 15340 |

Table 27: V correlated against the other parameters

**Rg**

| Rg | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | 0.87 ( 0.68, 0.95) | 18 | 0.10 ( 0.08, 0.12) | 9477 | 9477 |
| MWSI | 0.62 ( 0.38, 0.78) | 40 | 0.00 (-0.02, 0.02) | 9435 | 9477 |
| CI | 0.68 ( 0.46, 0.83) | 36 | 0.05 ( 0.03, 0.06) | 20818 | 20818 |
| lg GOES >10 MeV p | -0.02 (-0.15, 0.10) | 243 | 0.00 (-0.07, 0.08) | 670 | 729 |
| lg GOES X-ray | 0.65 ( 0.46, 0.78) | 55 | 0.19 ( 0.12, 0.26) | 729 | 729 |
| E10.7 | 0.90 ( 0.80, 0.95) | 30 | 0.21 ( 0.20, 0.23) | 17852 | 17852 |
| FI | 0.61 ( 0.34, 0.78) | 34 | 0.02 (-0.01, 0.04) | 7011 | 7304 |
| Ca II plage area | 0.82 ( 0.70, 0.90) | 45 | 0.07 ( 0.05, 0.08) | 25349 | 25349 |
| F10.7 | 0.90 ( 0.81, 0.95) | 32 | 0.18 ( 0.17, 0.19) | 17852 | 17852 |
| SSA | 0.79 ( 0.71, 0.85) | 111 | 0.25 ( 0.25, 0.26) | 44305 | 44430 |
| TSI | 0.52 ( 0.14, 0.77) | 23 | 0.06 ( 0.04, 0.09) | 6253 | 6253 |
| UV | 0.92 ( 0.70, 0.98) | 11 | 0.22 ( 0.19, 0.24) | 6263 | 6263 |
| Rz | 0.94 ( 0.91, 0.95) | 120 | 0.50 ( 0.49, 0.50) | 65012 | 65012 |
| abs SMMF | 0.44 ( 0.17, 0.65) | 45 | 0.01 (-0.01, 0.03) | 7315 | 7534 |
| aa | 0.18 ( 0.09, 0.26) | 533 | -0.00 (-0.01, 0.01) | 46750 | 46750 |
| Kp | 0.12 ( 0.02, 0.22) | 375 | 0.00 (-0.01, 0.02) | 22994 | 23375 |
| Ap | 0.10 ( 0.03, 0.17) | 730 | 0.00 (-0.01, 0.01) | 23147 | 23375 |
| Dst | -0.18 (-0.27,-0.08) | 389 | -0.00 (-0.02, 0.01) | 13890 | 14243 |
| B | 0.25 ( 0.10, 0.40) | 144 | -0.01 (-0.03, 0.01) | 11761 | 12052 |
| Bzn GSE | 0.14 ( 0.10, 0.19) | 1760 | 0.00 (-0.02, 0.02) | 11812 | 12052 |
| Bzs GSE | -0.15 (-0.18,-0.13) | 7340 | 0.02 (-0.00, 0.03) | 11820 | 12052 |
| Bzn GSM | 0.14 ( 0.11, 0.16) | 5885 | -0.00 (-0.02, 0.02) | 11815 | 12052 |
| Bzs GSM | -0.14 (-0.17,-0.12) | 6117 | 0.01 (-0.01, 0.03) | 11820 | 12052 |
| n | -0.07 (-0.16, 0.03) | 389 | -0.01 (-0.02, 0.01) | 11783 | 12052 |
| V | -0.09 (-0.19, 0.01) | 390 | -0.01 (-0.03, 0.00) | 11635 | 12052 |
| **Rg** | - ( -, -) | - | - ( -, -) | - | - |
| CLIMAX | -0.72 (-0.87,-0.46) | 26 | -0.02 (-0.03,-0.00) | 15056 | 15704 |

Table 28: Rg correlated against the other parameters

## CLIMAX

| CLIMAX | Daily | | Daily differences | | |
|---|---|---|---|---|---|
| Parameters | $r_{x,y}$ (95) | $n_e$ | $r_{\Delta x,\Delta y}$ (95) | $n_e$ | $n$ |
| MPSI | -0.69 (-0.86,-0.36) | 21 | -0.03 (-0.05,-0.01) | 12872 | 12872 |
| MWSI | -0.53 (-0.71,-0.28) | 46 | 0.00 (-0.02, 0.02) | 12872 | 12872 |
| CI | -0.77 (-0.89,-0.54) | 27 | 0.00 (-0.01, 0.02) | 18261 | 18261 |
| lg GOES >10 MeV p | -0.27 (-0.38,-0.15) | 249 | 0.02 (-0.01, 0.05) | 3762 | 4125 |
| lg GOES X-ray | -0.67 (-0.96, 0.30) | 6 | 0.03 (-0.00, 0.06) | 4125 | 4125 |
| E10.7 | -0.79 (-0.90,-0.59) | 26 | -0.04 (-0.06,-0.03) | 17797 | 18047 |
| FI | -0.45 (-0.67,-0.16) | 40 | 0.01 (-0.01, 0.03) | 10226 | 10226 |
| Ca II plage area | -0.69 (-0.88,-0.31) | 17 | -0.02 (-0.04,-0.00) | 11686 | 11686 |
| F10.7 | -0.75 (-0.88,-0.54) | 30 | -0.03 (-0.04,-0.02) | 18864 | 19082 |
| SSA | -0.61 (-0.77,-0.39) | 46 | -0.04 (-0.05,-0.02) | 18895 | 19093 |
| TSI | -0.48 (-0.72,-0.14) | 30 | -0.01 (-0.03, 0.01) | 9071 | 9084 |
| UV | -0.77 (-0.92,-0.43) | 15 | -0.03 (-0.05,-0.01) | 9544 | 9660 |
| Rz | -0.70 (-0.84,-0.47) | 33 | -0.02 (-0.04,-0.01) | 18694 | 19082 |
| abs SMMF | -0.48 (-0.66,-0.25) | 56 | 0.01 (-0.01, 0.03) | 10088 | 10918 |
| aa | -0.24 (-0.32,-0.15) | 488 | -0.10 (-0.11,-0.09) | 19357 | 19357 |
| Kp | -0.25 (-0.35,-0.15) | 314 | -0.07 (-0.09,-0.06) | 18928 | 19127 |
| Ap | -0.24 (-0.30,-0.17) | 841 | -0.12 (-0.13,-0.11) | 19127 | 19127 |
| Dst | 0.29 ( 0.20, 0.36) | 487 | 0.18 ( 0.17, 0.19) | 17324 | 17651 |
| B | -0.32 (-0.44,-0.17) | 172 | -0.11 (-0.12,-0.09) | 15328 | 15340 |
| Bzn GSE | -0.17 (-0.21,-0.12) | 2081 | -0.15 (-0.16,-0.13) | 15340 | 15340 |
| Bzs GSE | 0.15 ( 0.12, 0.19) | 3235 | -0.01 (-0.03, 0.00) | 15340 | 15340 |
| Bzn GSM | -0.17 (-0.20,-0.15) | 7267 | -0.15 (-0.17,-0.13) | 15340 | 15340 |
| Bzs GSM | 0.13 ( 0.10, 0.15) | 7583 | -0.04 (-0.05,-0.02) | 15340 | 15340 |
| n | 0.12 ( 0.00, 0.24) | 255 | 0.08 ( 0.07, 0.10) | 15340 | 15340 |
| V | -0.14 (-0.27,-0.01) | 222 | -0.25 (-0.27,-0.24) | 13974 | 15340 |
| Rg | -0.72 (-0.87,-0.46) | 26 | -0.02 (-0.03,-0.00) | 15056 | 15704 |
| **CLIMAX** | - ( -, -) | - | - ( -, -) | - | - |

Table 29: CLIMAX correlated against the other parameters

# Appendix 2: Global scale based correlation

Here a few selected scale based correlation plots are shown from the 351 possible combinations.

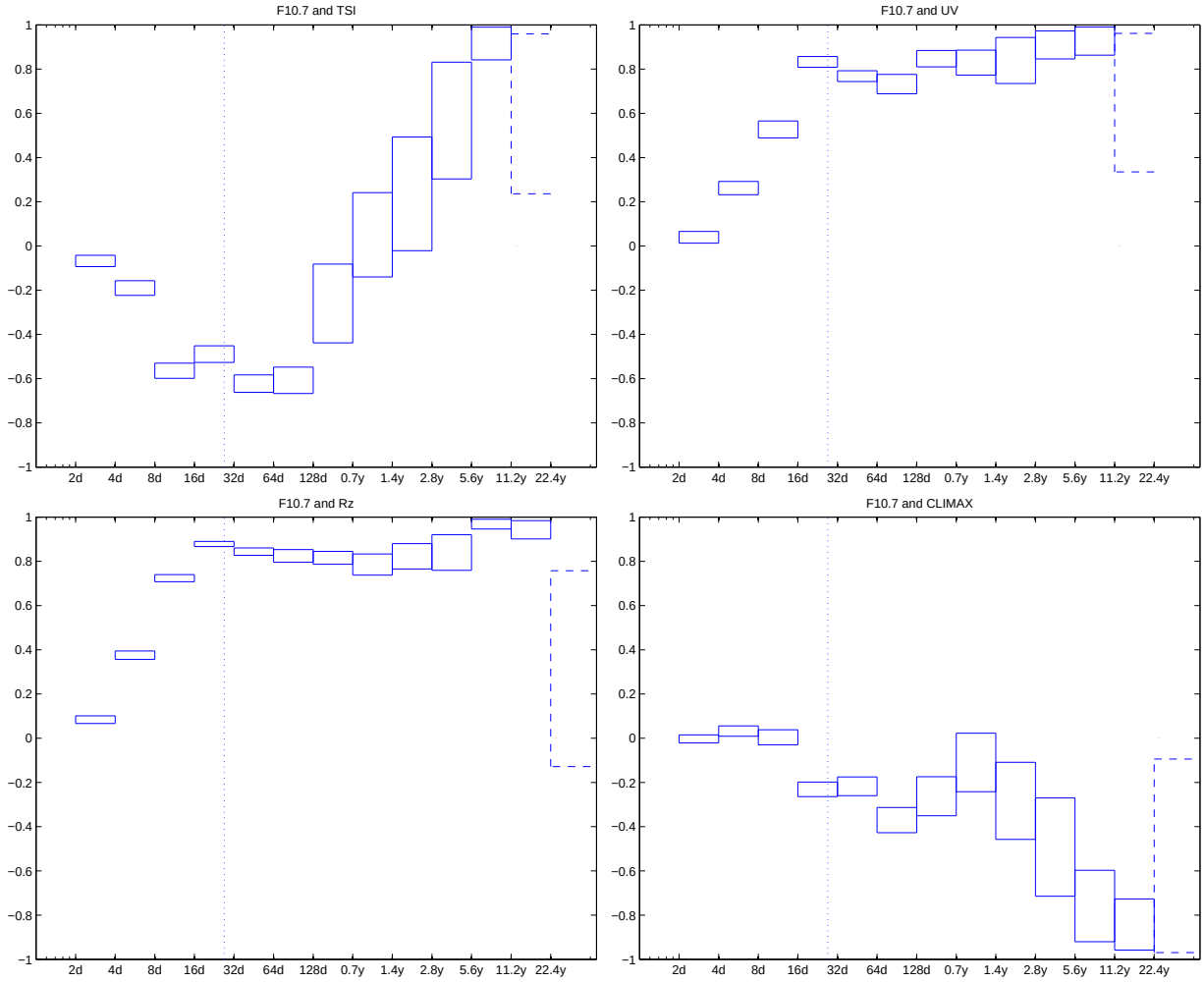


Figure 14: Scale based correlation for (F10.7,TSI), (F10.7,UV), (F10.7,$R_z$), and (F10.7,CLIMAX)

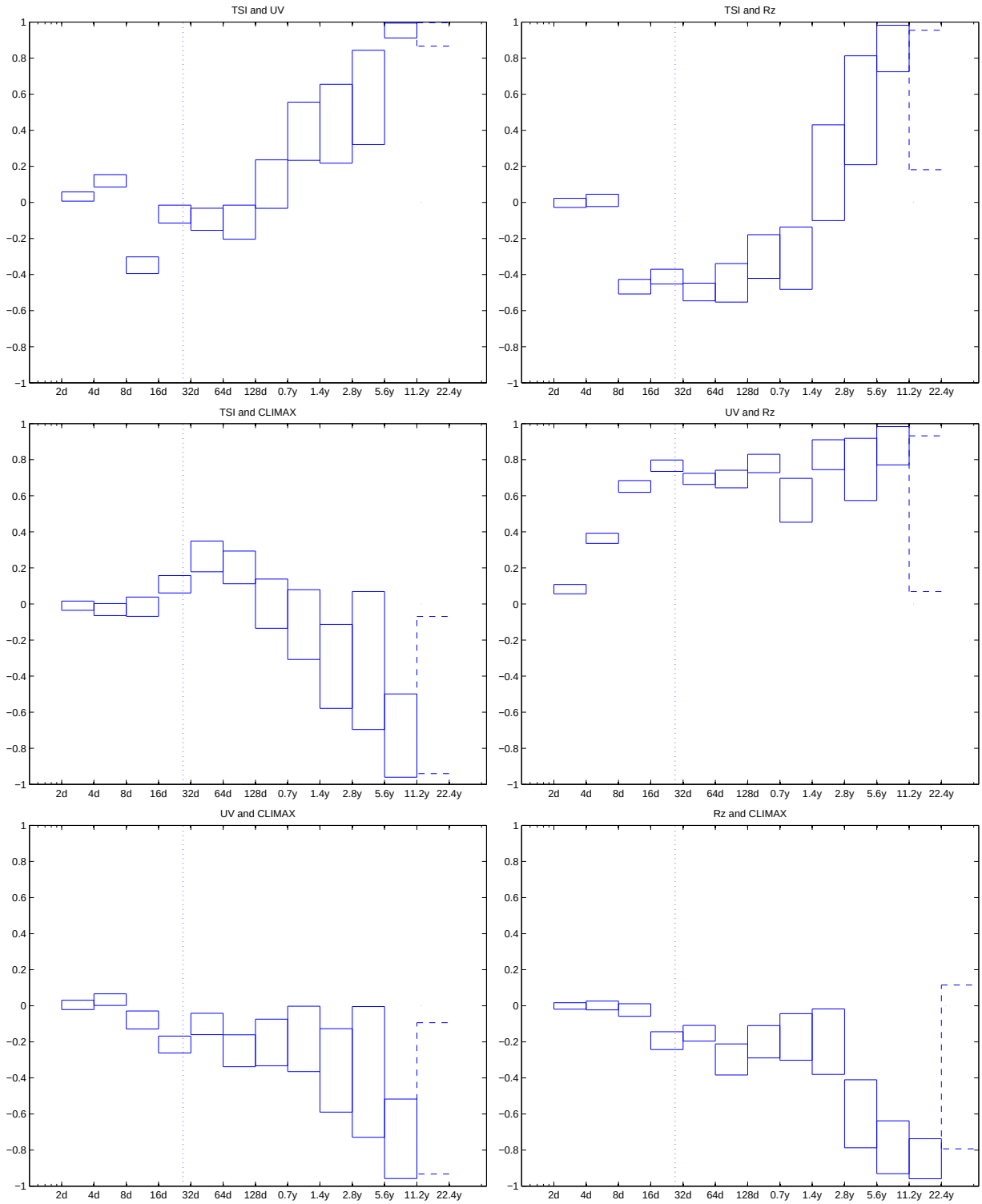


Figure 15: Scale based correlation for (TSI,UV), (TSI,$R_z$), (TSI,CLIMAX), (UV, $R_z$), (UV,CLIMAX), and ($R_z$,CLIMAX).

# Appendix 3: Local scale based correlation

Here a few selected wavelet coherence plots are shown from the 351 possible combinations.

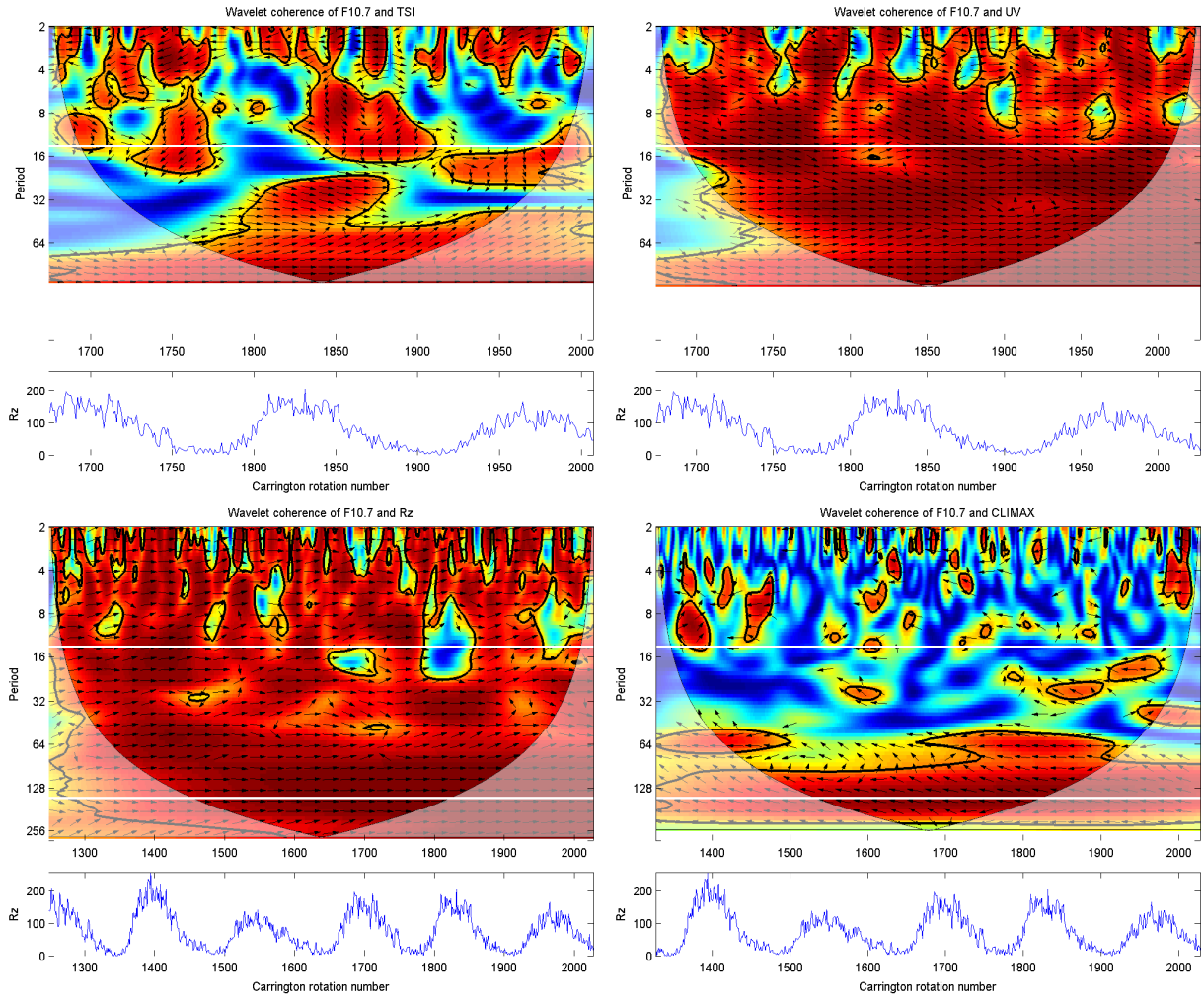


Figure 16: Wavelet coherence for (F10.7,TSI), (F10.7,UV), (F10.7,$R_z$), and (F10.7,CLIMAX)

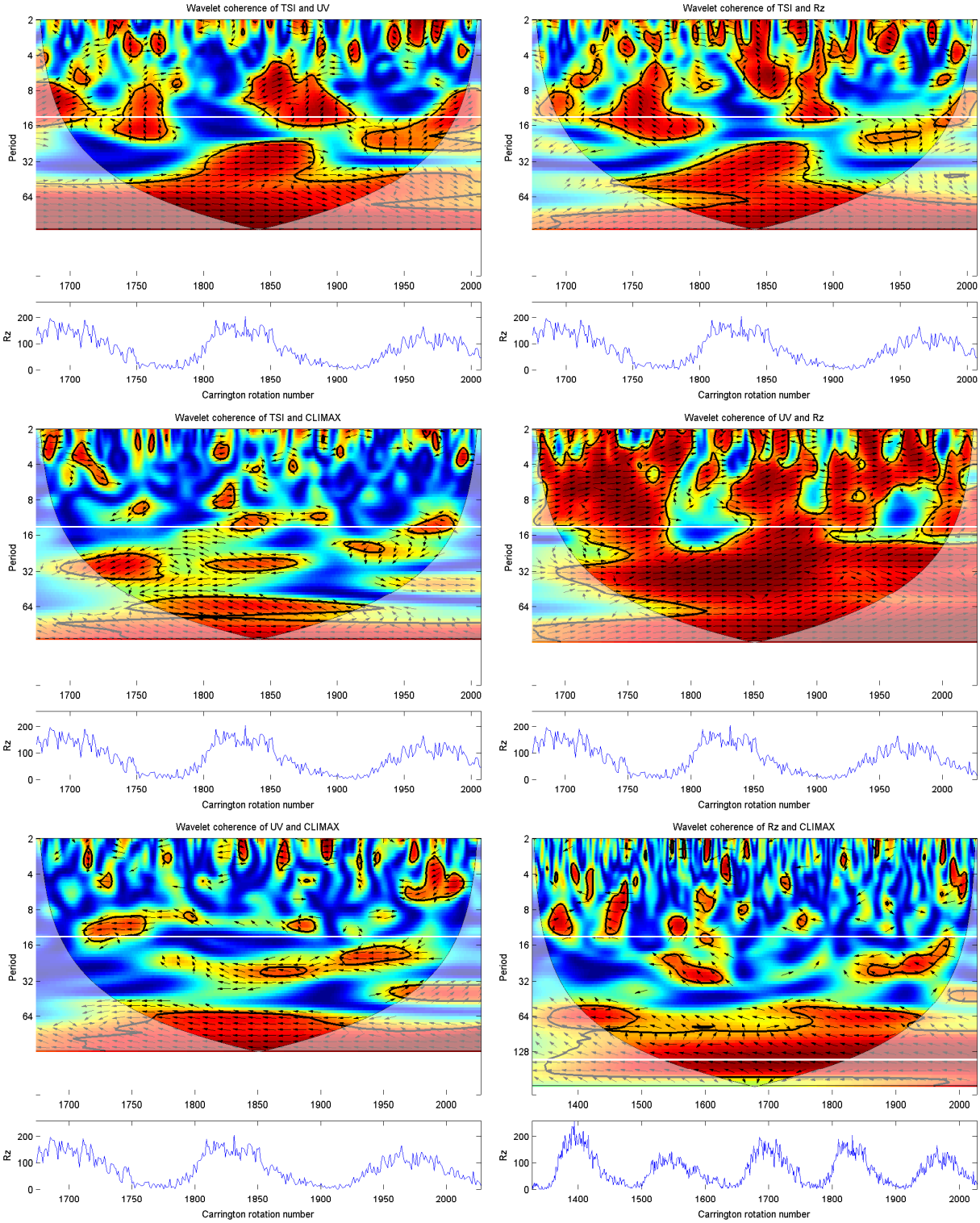


Figure 17: Wavelet coherence for (TSI,UV), (TSI,$R_z$), (TSI,CLIMAX), (UV, $R_z$), (UV,CLIMAX), and ($R_z$,CLIMAX).

## References


Addison, P. S., *The Illustrated Wavelet Transform Handbook*, Institute of Physics Publishing, 2002.

Boberg, F., H. Lundstedt, J. T. Hoeksema, P. H. Scherrer, and W. Lui, Solar mean magnetic field variability: A wavelet approach to WSO and SOHO/MDI observations, *Journal of Geophysical Research*, *107*(A10), doi:10.1029/2001JA009195, 2002.

Cornish, C. R., D. B. Percival, and C. S. Bretherton, The wmtsa wavelet toolkit for data analysis in the geosciences, *Eos Trans. AGU*, *84*(46), fall Meet. Suppl., Abstract NG11A-0173, 2003.

Grinsted, A., J. C. Moore, and S. Jevrejeva, Application of the cross wavelet transform and wavelet coherence to geophysical time series, *Nonlinear processes in geophysics*, *11*, 561–566, 2004.

Jensen, J. M., H. Lundstedt, M. J. Thompson, F. P. Pijpers, and S. P. Rajaguru, Application of local-area helioseismic methods as predicters of space weather, in *Proc. SOHO 14 – GONG 2004: Helio- and Asteroseismology: Towards a Golden Future, Yale 12–16th July 2004*, edited by D. Danesy, ESA SP-599, pp. 497–500, ESA Publicasions Division, Noordwijk, The Netherlands, 2004.

Liszka, L., Cognitive information processing in space physics and astrophysics, Pachart Publishing House, Tucson, 2003.

Lundstedt, H., Solar activity modelled and forecasted: a new approach, *Advances in Space Research*, p. In press, 2006.

Lundstedt, H., L. Liszka, and R. Lundin, Solar activity explored with new wavelet methods, *Annales Geophysicae*, *23*, 1505–1511, 2005.

Lundstedt, H., L. Liszka, R. Lundin, and R. Muscheler, Long-term solar magnetic activity explored with wavelet methods, *Annales Geophysicae*, *24*, 1–10, 2006.

Mallat, S., *A wavelet tour of signal processing*, Academic Press, 1998.

Percival, D. B., and A. T. Walden, *Wavelet methods for time series analysis*, Cambridge University Press, 2002.

Quenouille, M. H., *Assoicated measurements*, Butterworths Scientific Publications, 1952.

Torrence, C., and G. P. Compo, A practical guide to wavelet analysis, *Bulletin of the American Meteorological Society*, *79*, 61–78, 1998.

von Storch, H., and F. W. Zwiers, *Statistical analysis in climate research*, Cambridge University Press, 1999.