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FACULAE AREAS AND DANUBE RIVER FLOW. I

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Abstract. The spectral decomposition theorem has been applied for searching the solar activity influence on Danube river flow at a station. According to cross-correlations a seven-year lag has been found between solar faculae areas and maximal river flow, as well as a nine-year lag for minimal river flow. Chi square test has been applied for the obtained results signification.

1. ORIGINS

Agriculture, several branches of industry and economics, as well as water resources investigations are interested in river flow fluctuations. Therefore it is of profound interest to know, to predict, the surplus or lack of water. For the time being we are still unable to influence the whole situation with our scientific tools and to change it according to our needs. So, we observe carefully the whole process, and use mathematics for predicting floods and droughts in riverbeds.

One suspects that solar activity effects many phenomena on Earth. For that reason we chose in this paper faculae areas as river flow fluctuations producers, after using previously total sunspot areas (Jovanović, 1986, 1987, 1989, 1990, 1991a, 1991b, 1993a, 1993b, 1993c, 1994a), sunspot umbrae areas (Jovanović, 1994b).

2. DATA AND DATA PROCESSING METHODS

The TOTAL FACULAE AREA on the visible solar hemisphere, corrected for sphericity, has been chosen as the solar activity parameter.

According to Jean-Claude Pecker the use of many stations together, may distort the results instead to ameliorate the eventually existing correlation between Sun activity and water flow in Danube river for example. Therefore we chose only one station and the maximal and minimal river flow series obtained by day by day observations.

The following data notations are used : time series for SOLAR ACTIVITY (yearly means) (GRFS–total areas of faculae, expressed in millionth parts of the visible solar hemisphere, published in Royal Greenwich Observatory); time series for DANUBE RIVER FLOW (yearly means) (BOQV–maximal river flow expressed in m^3/sec, BOQN–minimal river flow expressed in m^3/sec).

We had at our disposal GRFS series starting from the year 1874 until 1982 (daily observations), and river flow series since 1931 to 1990 (monthly means).

Because of the computer processing program we took the faculae areas between 1923 and 1982, and the river flow data between 1931 and 1990.

Supposing that we have to do with two stationary time series, x_t and y_t, and that we wish to assess the extent to which we can use the past x_t to predict y_t, cross-correlations are used as a criterion of evaluation. If the processes are zero-mean, we define then, by means of cross- correlations, the expected value of y_t.

Following the SPECTRAL DECOMPOSITION THEOREM, which states that the energy, or variance, of any time series can be broken down into the contribution of statistically independent oscillations of different frequencies (periods), we constructed periodograms for the series mentioned before. Each peak in the spectral periodicity function stands for a harmonic. The most outstanding one stands for the *major frequency (period)*, and the next ones for *higher harmonics*, the so-called *overtones.*

For some practical reasons we took 40 years long time series sections and looked for the highest cross-correlation values, due to solar influence, to maximal and minimal river flow.

The next step was the construction of corresponding periodograms for GRFS, BOQV and BOQN series.

The search for paired up independent oscillations with the same frequencies (periods) was the following step in our analysis.

In conclusion Fourier series residuals have been calculated. A comparison of such a frequency histogram with normal distribution function has been carried out. Finally the Chi-square test has been applied to all cases.

3. RESULTS

Let us discuss, first, the results for *maximal river flow.* The greatest cross-correlation value stands for zero year lag. Time series used were GRFS4180 and BOQV4887, so we conclude that *maximal river flow will follow, after seven-year lag, the faculae maximum.* The periodogram for GRFS shows that there are ten independent oscillations. Eight of them have their responses in eight of ten independent frequencies in the series for maximal flow, BOQV. The second overtone of the BOQV series corresponds to the major frequency of the first series. The fourth overtone of the GRFS has its pair in the eighth, the third in the fourth, the fifth in the major frequency, the sixth in the seventh, the seventh in the fifth, the ninth in the first overtone, and the eighth overtone of GRFS series in the ninth overtone of the BOQV series.

The major frequency of GRFS has the period of 12.000 years, the first overtone of 30.003 years, the second of 5.999 years, the third of 4.286 years, the fourth of 5.000 years, the fifth of 3.749 years, the sixth of 3.3 years, the seventh of 2.609 years, the eighth of 2.069 years and the ninth of 2.507 years. The oscillations are placed according to their contribution to the compounded function.

The major frequency of BOQV has the period of 3.749 years, the first overtone of 2.308 years, the second of 12.000 years, the third of 5.998 years, the fourth of 4.286 years, the fifth of 2.609 years, the sixth of 6.667 years, the seventh of 3.333 years, the eighth of 5.000 years, and the ninth overtone of 2.069 years.

The Chi-square test for BOQV's eight of ten independent frequencies gives the value of 0.998804 with one degree of freedom and a significance level of 0.3176.

Minimal river flow shows another picture of influence. According to cross-correlation tables *minimal river flow follows, after a lag of nine years, the maximal faculae area.*

According to the periodogram for BOQN series there are thirteen peaks to which correspond thirteen independent frequencies. The major one has a period of 59.988 years, the first overtone of 7.501 years, the second of 5 years, the third of 2.399 years, the fourth of 2.609 years, the fifth of 3.333 years, the sixth of 3.500 years, the seventh of 3.749 years, the eighth of 4.286 years, the ninth of 12.000 years, the tenth of 3.000 years, the eleventh of 2.069 years and the twelfth overtone of 5.999 years.

The ninth overtone of the BOQN series corresponds to the major frequency of the GRFS series, the twelfth to the second overtone, the second to the fourth, the eighth to the third, the seventh to the fifth, the fifth to the sixth, the fourth to the seventh, and the eleventh overtone of the BOQN series to the ninth overtone of the GRFS series.

Chi-square test for eight of thirteen independent frequencies of BOQN series gives the value 0.359449 with one degree of freedom and a significance level of 0.548812.

4. CONCLUSION

The spectral decomposition theorem, according to cross-correlations and periodograms, calculated for the index of solar activity known as the TOTAL FACULAE AREA on the visible solar hemisphere, corrected for sphericity, expressed in millionth parts of the visible solar hemisphere, GRFS, on one hand, and MAXIMAL, BOQV series, as well as MINIMAL DANUBE RIVER FLOW, BOQN series, expressed in m^3/sec, observed for a station, on the other, gives us the right to announce that the solar activity may influence, with the accuracy given, the maximal river flow, with a seven-year lag, and the minimal river flow after a lag of nine years.

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