SOLAR ACTIVITY INFLUENCE ON THE
DANUBE RIVER FLOW, FLUX, IV

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Abstract. Spectral decomposition theorem has been applied for solar activity influence to Danube river flow/flux on a station computation. Following cross- correlations a seven year lag has been found between sunspot umbrae total areas and maximal river flow/flux, as well as a seventeen year lag for minimal Danube river flow/flux. Chi-square test has been applied for obtained results signification.

With a short review of previous results concerning total sunspot, total penumbrae and total faculae areas.

1. ORIGINS

There are natural phenomena which may be predicted, with more or less accuracy, if we suppose that they have an oscillatory character. We may say that such events are quasiperiodic. Solar activity, quantity of water in riverbeds, as we know, have also fluctuations of such kind. Because of practical use it would be of enormous benefit if we could foresee the surplus or the lack of water and prepare us for floods or droughts.

In the last ten years I tried to find, if it is at all existing, a connection between Solar phenomena (at the time being between sunspot, umbrae, penumbrae and faculae total areas) a river level, resp. river flow/flux in Danube and Sava rivers.

2. DATA AND DATA PROCESSING

J.-C. Pecker in (Pecker, 1987), confirmed my opinion that the simultaneous use of data, measured on numerous stations along a river, in the case of solar- terrestrial influence study, may lead to distortion instead to correlations improvement. So, I used always only data collected on one station.

Following data notations have been used:

time series for SOLAR ACTIVITY (yearly means)::

GRCS – TOTAL SUNSPOT AREAS, expressed in millionth parts of the visible solar hemisphere, corrected for sphericity (MPOTVSH.CFS), published in Royal Greenwich Observatory, Daily Sunspot Areas,

GRFS – TOTAL FACULAE AREAS, expressed in MPOTVSH.CFS published in Royal Greenwich Observatory, Daily Sunspot Areas,

GRPS – TOTAL SUNSPOT PENUMBRAE AREAS, expressed in MPOTVSH.CFS published in Royal Greenwich Observatory, Daily Sunspot Areas,

GRUS – TOTAL SUNSPOT UMBRAE AREAS, expressed in MPOTVSH.CFS published in Royal Greenwich Observatory, Daily Sunspot Areas;

time series for DANUBE RIVER FLOW/FLUX (yearly means)::

BEQV – MAXIMAL RIVER FLOW/FLUX, expressed in m^3/s,

BEQS – MAIN RIVER FLOW/FLUX, expressed in m^3/s,

BEQN – MINIMAL RIVER FLOW/FLUX, expressed in m^3/s.

I had, at my disposal, GR series starting by year 1874 until 1982 (daily observations), and river flow/flux series since 1931 to 1990 (monthly means).

The computer processing program limited my investigations, in the case of GR series, to the section between 1923 and 1982, and the river flow/flux data to the period between 1931 and 1990.

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), has been applied for periodogram construction. Each peak in the spectral periodicity function graph has been standing for a harmonic. The most outstanding one points toward the MAJOR FREQUENCY (PERIOD), and the next ones toward HIGHER HARMONICS, toward the so-called OVERTONES.

Search for paired up independent oscillations with the same periods (frequencies), has been carried out.

The next supposition was that we have to do with two stationary time series, x_t, and y_t, and that we wish to asses the extent to which we can use the past of x_t to predict y_t; cross-correlations have been 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.

For some practical reasons I took 40 year long time series sections and looked for the highest cross-correlation values, between solar influence and maximal or minimal river flow/flux.

Fourier series residuals have been calculated for significance level evaluation. In the continuation a comparison of such frequency histogram with normal distribution function has been constructed. Chi-square test has been used as a conclusion.

3. PREVIOUS RESULTS

In Jovanović (1991b), GRCS versus BOQV, (6 of 7 independent harmonics are identical) a 7 year lag has been confirmed. Chi-square test value of 0.42285 with 1 degree of freedom and a significance level of 0.515518 has been obtained. In GRCS versus BOQN case, (2 of 5 independent harmonics are identical), a lag of 8 years came up. It is interesting to mention that the greatest cross-correlation value has been found in the case GRCS versus BOQS, even higher than in two other cases.

Same computer program application to total areas of faculae, GRFS, versus BOQV, has been followed by 8 identical of 10 independent harmonics, and a 7 years lag has been found (Jovanović, 1995a). Chi-square test gave the value of 0.998804 with 1 degree of freedom and a significance level of 0.3176. In the case of minimal river flow, GRFS versus BOQN, there were 8 of 13 independent harmonics identical. Chi-test showed a value 0.359449 with a degree of freedom and a significance level of 0.545512!

7 year lag was followed by the highest cross-correlations value in the case GRFS versus BOQV, where there are 6 identical of eleven independent oscillations (Jovanović, 1995b). Chi-square test gave the value of 3.5281 with 3 degrees of freedom and a significance level of 0.317944. For minimal river flow/flux (4 of 13 independent oscillations) there was a 9 year lag. For Chi-square test a value 3.10184 with 2 degrees of freedom and a significance level of 0.212053 has been obtained.

4. RECENT RESULTS

The highest cross-correlations value corresponds to the lag of 7 years in the case of GRUS4180 versus BOQV4887, solar umbrae total areas influence to MAXIMAL RIVER FLOW/FLUX, meaning that *maximal river flow/flux may follow, after a 7 year lag, the maximal solar umbrae total areas.*

Periodogram for GRUS series shows that there are twelwe independent fundamental oscillations. Four of them have their responses in four of ten independent frequencies of the series for maximal river flow/flux, BEQV. The third overtone of the BEQV series corresponds to the first overtone of the GRUS series, the fourth to the eighth, the first to the tenth and the nineth of the BOQV series to the eleventh of the GRUS series.

The major frequency of BEQV has the period of 3.75 years, the first overtone of 2.31 years, the second of 12.00 years, the tfird of 59.99 years, the fourth of 4.24 years, the fifth of 2.61 years, the sixth of 6.67 years, the seventh of 3.33 years, the eighth of 5 years, and the nineth of 2.07 years.

Chi-squire test for BOQV's four of ten independent frequencies gives the value of 0.93606066 with 3 degree of freedom and a significance level of 0.816717.

MINIMAL RIVER FLOW/FLUX shows an another picture of influence. According to cross-correlations table for GRUS4180 versus BOQN4887, *minimal river flow/flux will probably follow, after a lag seventeen years, the maximal total area of solar umbrae.*

Periodogram for BOQN series has thirteen peaks and the same number of independent oscillations. The major frequency has a period of 59.99 years, the first overtone of 7.50 years, the second of 1 year, the third of 2.40 years, the fourth of 2.61 years, the fifth of 3.33 years, the sixth of 20 years, the seventh of 3.75 years, the eighth of 4.28 years, the nineth of 12.00 years, the tenth of 3.00 years, the eleventh of 2.07, and the twelveth overtone has a period of 5.99 years.

The major frequency of BEQN series corresponds to the first overtone of the GRUS series, the first overtone to the second overtone, the sixth to the third, the eighth to the eighth, and the eleventh overtone of the BOQN series to the eleventh overtone of the GRUS series.

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Chi-squire test for five of thirteen independent frequencies of BOQN series gives the value of 4.01641 with 2 degree of freedom and a significance level of 0.134229.

5. CONCLUSION

The spectral decomposition theorem, according to periodograms and corresponding cross-correlations, calculated for the index of solar activity known as the TOTAL UM-BRAE AREA on the visible solar hemisphere, corrected for sphericity, expressed in millionth parts of the visible solar hemisphere, GRUS series, from one side, and MAX-IMAL DANUBE RIVER FLOW/FLUX series, BOQV, expressed in m^3/s observed on a station, from the other side, gives us the right to announce that, in statistical sense, the solar activity may influence, with the accuracy given, the maximal river flow/flux, with a seven year lag, and the MINIMAL DANUBE RIVER FLOW/FLUX, after a lag of seventeen (11+6=17) years.

References

Jovanović, B. D.: 1986, *Bull. Obs. Astron. Belgrade*, **136**, 73.
Jovanović, B. D.: 1987, *Bull. Appl. Math. Budapest*, **49**, 39.
Jovanović, B. D.: 1988, *Bull. Appl. Math. Budapest*, **50**, 117.
Jovanović, B. D.: 1989, *Bull. Appl. Math. Budapest*, **51**, 47.
Jovanović, B. D.: 1990, *Bull. Appl. Math. Budapest*, **55**, 107.
Jovanović, B. D.: 1991a, *Bull. Appl. Math. Budapest*, **60**, 281.
Jovanović, B. D.: 1991b, *Bull. Appl. Math. Budapest*, **60**, 199.
Jovanović, B. D.: 1993a, *Bull. Appl. Math. Budapest*, **64**, 65.
Jovanović, B. D.: 1993b, *Publ. Obs. Astron. Belgrade*, **44**, 128.
Jovanović, B. D.: 1993c, *Bull. Appl. Math. Budapest*, **68**, 47.
Jovanović, B. D.: 1993d, *Bull. Appl. Math. Budapest*, **66**, 87.
Jovanović, B. D.: 1994a, *Bull. Appl. Math. Budapest*, **71**, 73.
Jovanović, B. D.: 1994b, Uredjenje, korišćenje i zaštita voda Vojvodine, Novi Sad, 17.
Jovanović, B. D.: 1995a, *Publ. Obs. Astron. Belgrade*, **49**, 191.
Jovanović, B. D.: 1995b, Abstracts of B'Hellenic Astronomical Conference Thessaloniki, 17.
Jovanović, B. D.: 1995c, Abstracts of the 4th European and 39th Italian Astronomical Society Meeteng, Catania, 91.
Pecker, J.-C.: 1987, Compendium in Astronomy, D. Reidel, Dordrecht, 156.
***: Royal Greenwich Observatory, Daily Sunspot Areas, National Geophysical Data Center, Boulder, Colo., USA.