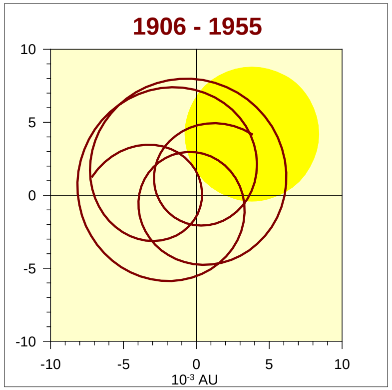
Very long-term solar-terrestrial variability related to the two basic types of the solar inertial motion

Ivanka Charvátová and **Pavel Hejda**



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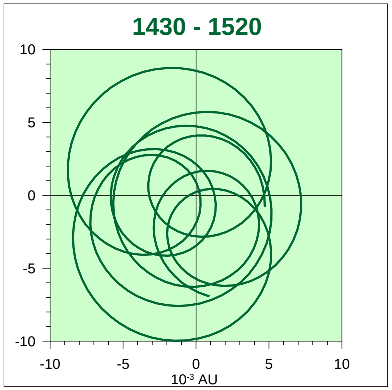
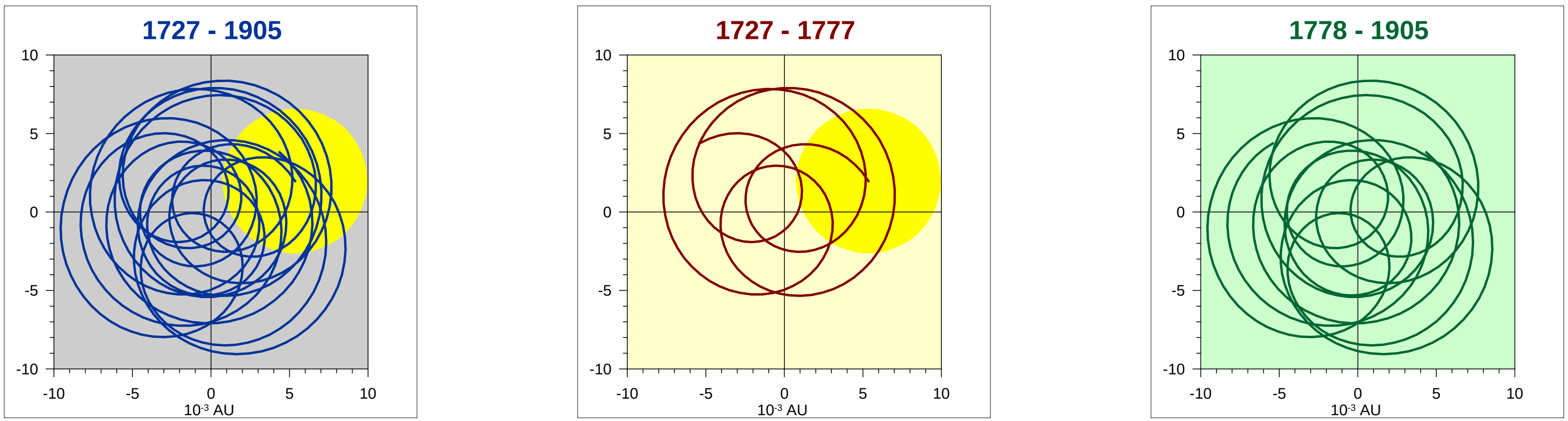
Invited talk



Solar inertial motion - SIM

Solar inertial motion is the motion of the Sun around the centre of mass of the Solar System due to variable positions of the giant planets (J-Jupiter, S-Saturn, U-Uranus, N-Neptune). The Sun moves inside a circular area which has a diameter of 0.02 AU (= 4.3 solar radii = 3.10^6 km). The Sun moves with a velocity between 9 and 16 m/s.



Charvátová (1988, 1990, 1997) divided the SIM into two basic types, the ordered ones in a trefoil according to the JS motion order and the other disordered (chaotic).

(Note: the conjunctions of the planets J and S occur once every 19.86 years, with each successive conjunction advancing by 117.3° in a prograde direction.) In case of the ordered trefoil motion, the Sun orbits the centre of mass of the solar system along a loop (arc) about once every 10 years (JS/2).

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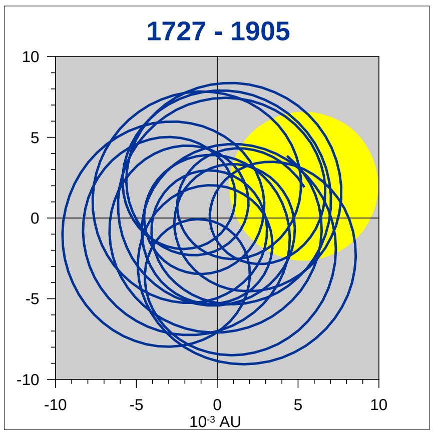
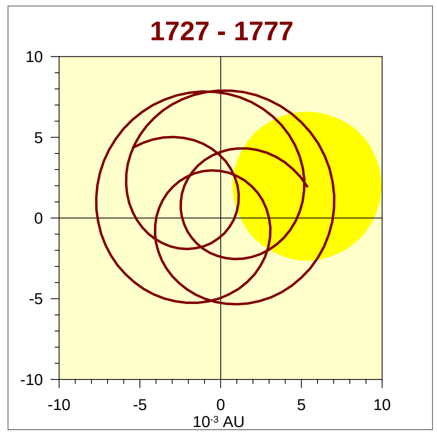
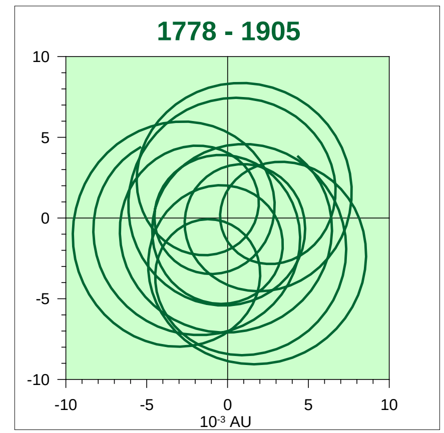






Charvátová, I., The solar motion and the variability of solar activity, Adv. Space Res., 8, 7, 147-150, 1988.
Charvátová, I., On the relation between solar motion and solar activity in the years 1730-1780 and 1910-60, Bull. Astr. Inst. Czech., 41, 200-204, 1990.
Charvátová, I., Solar-terrestrial and climatic variability during the last several millennia in relation to solar inertial motion, J. Coastal Res., 17, 343-354, 1995.
Charvátová, I., Solar motion (main article), in: Encyclopedia of Planetary Sciences, (Eds. J.H. Shirley and R.W. Fairbridge), Chapman and Hall, New York, 748-751, 1997.
Charvátová, I., Can origin of the 2400-year cycle of solar activity be caused by solar inertial motion? Annales Geophys., 18, 399-405, 2000.
Charvátová, I., Long-term predictive assessments of solar and geomagnetic activities made on the basis of the close similarity between the solar inertial motions in the intervals 1840-1905 and 1980-2045, New Astronomy, 14, 25-30, 2008.

Spectrum of periods in SIM characteristics

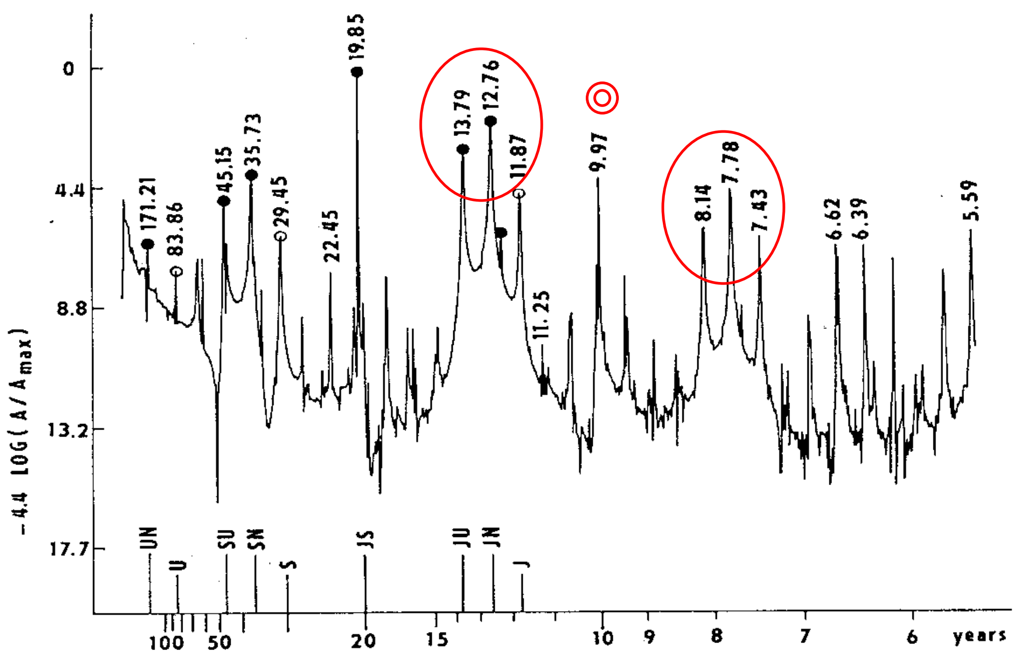


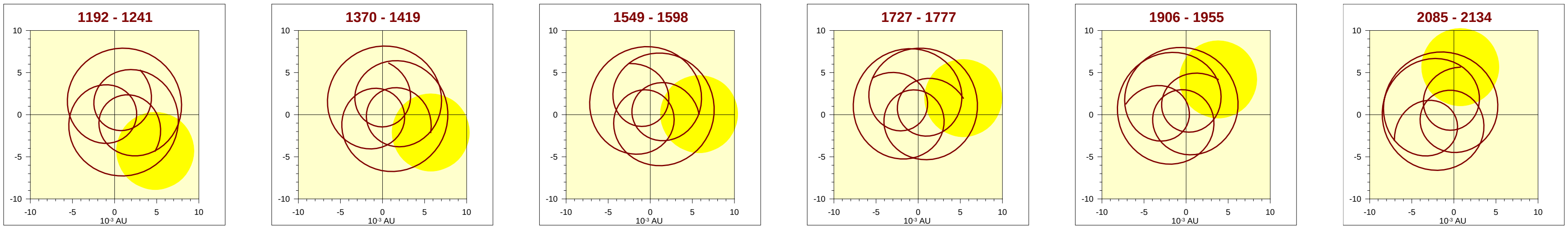
Figure 1
Harmonic analysis of ρ. The five outer planets were taken into consideration. Lag $\Delta t = 1$ year, $N = 4110$.

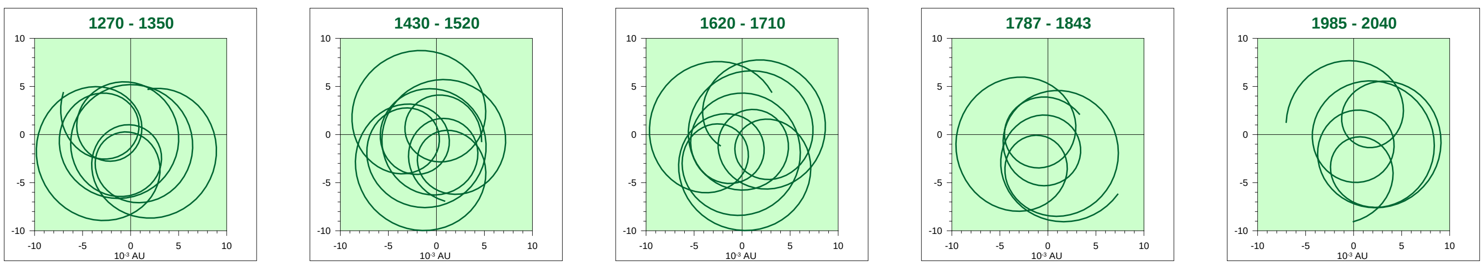
The multiples of periods (in years)

15 J	177.93
6 S	176.75
9 JS	178.73
5 SN	179.35
4 SU	181.45
14 JN	178.95
13 JU	179.56
14 JP	174.45
mean	**178.39**

Two basic types of SIM

The Sun returns to the ordered trefoil SIM after 178.7 years and this type of motion lasts about 50 years.



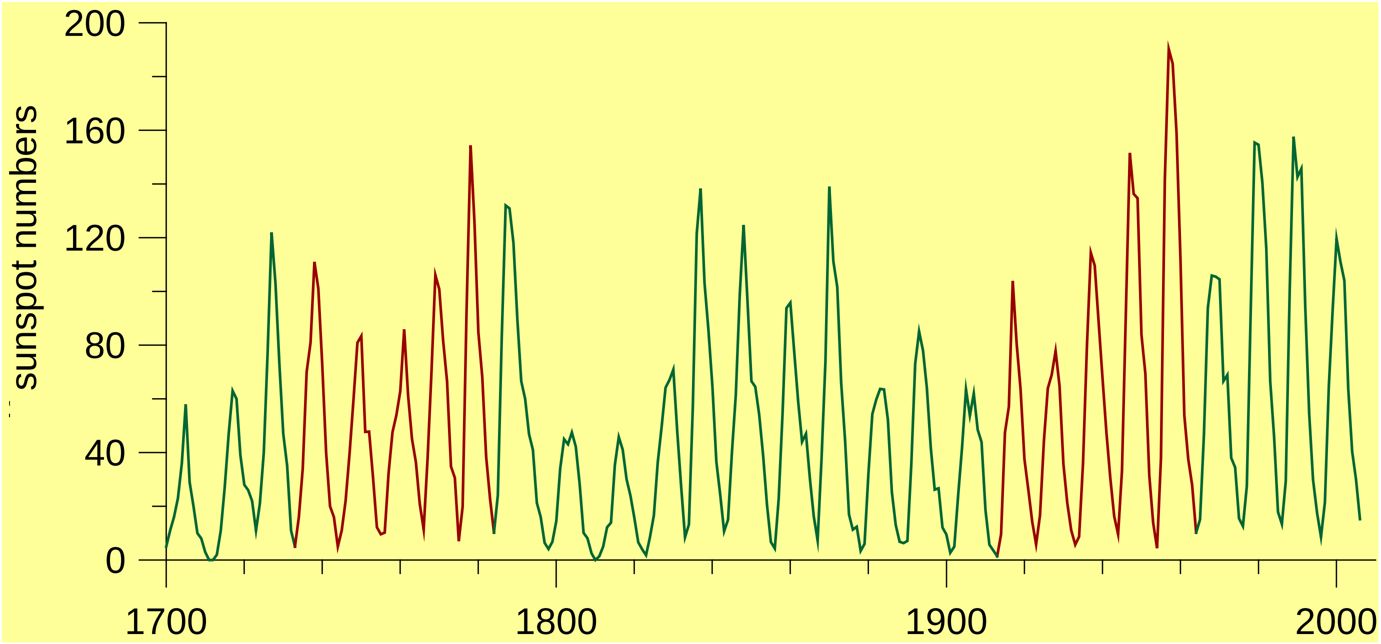


Wolf **Spörer** **Maunder** **Dalton** **???**

The most disordered parts of the SIM correspond with the prolonged minima (Grand decreases) of solar activity over the last millennium.

Solar inertial motion and solar activity (observed data)

While the „chaotic“ orbits differ from one another, the ordered (trefoil) orbits are nearly the same. If solar variability is really caused by the SIM, the motion of the Sun along nearly identical orbits should create the same series of sunspot cycles. From 1700 AD to the present, two trefoil intervals occurred: 1727-1777 and 1906-1956 AD.



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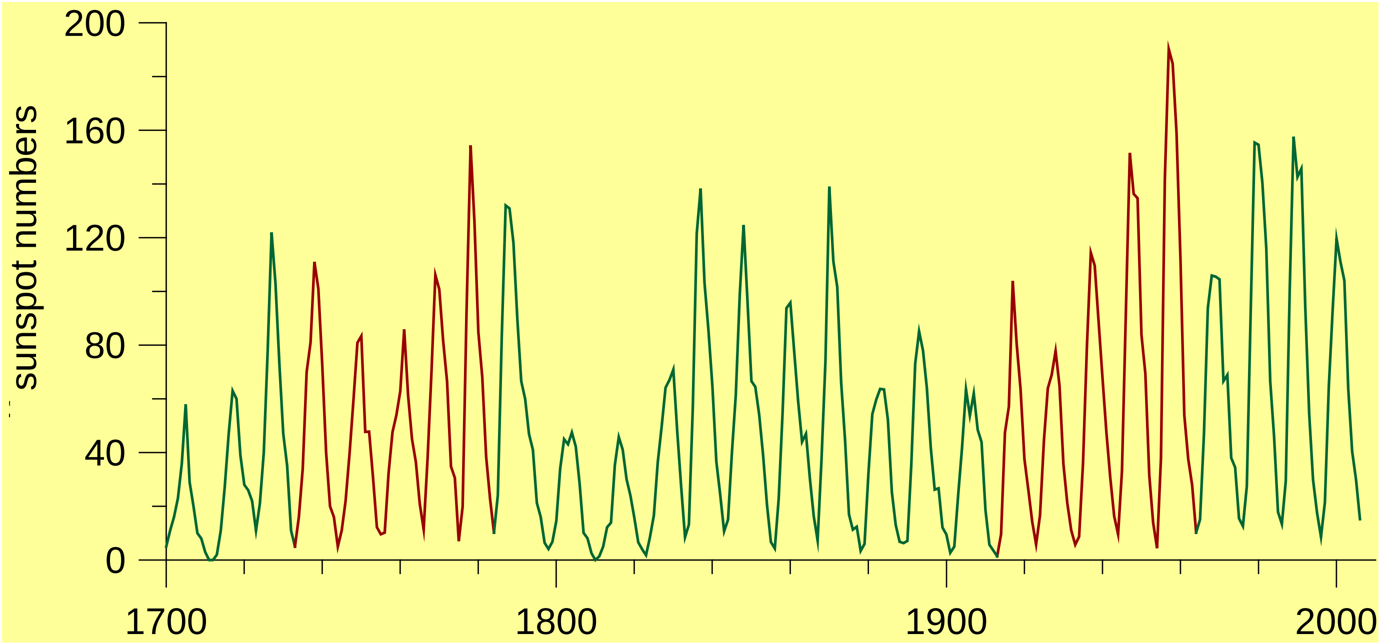

Moving correlation between two groups of five sunspots cycles …

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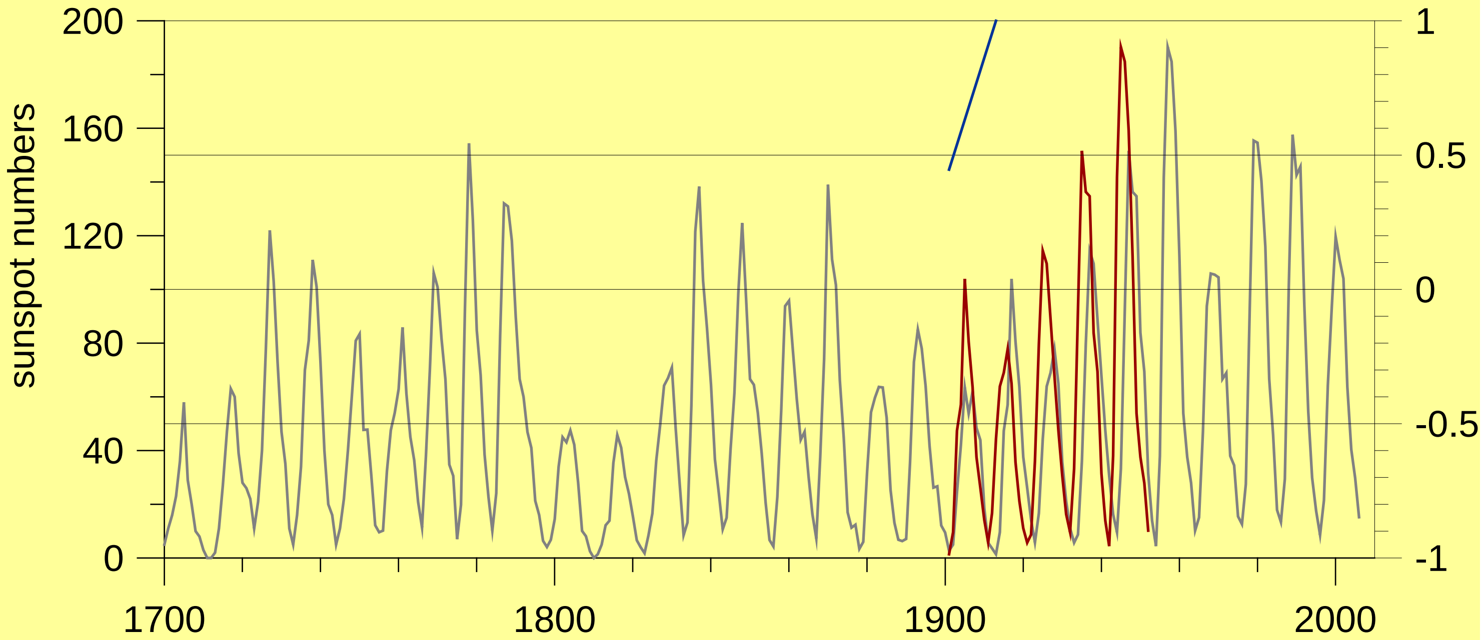

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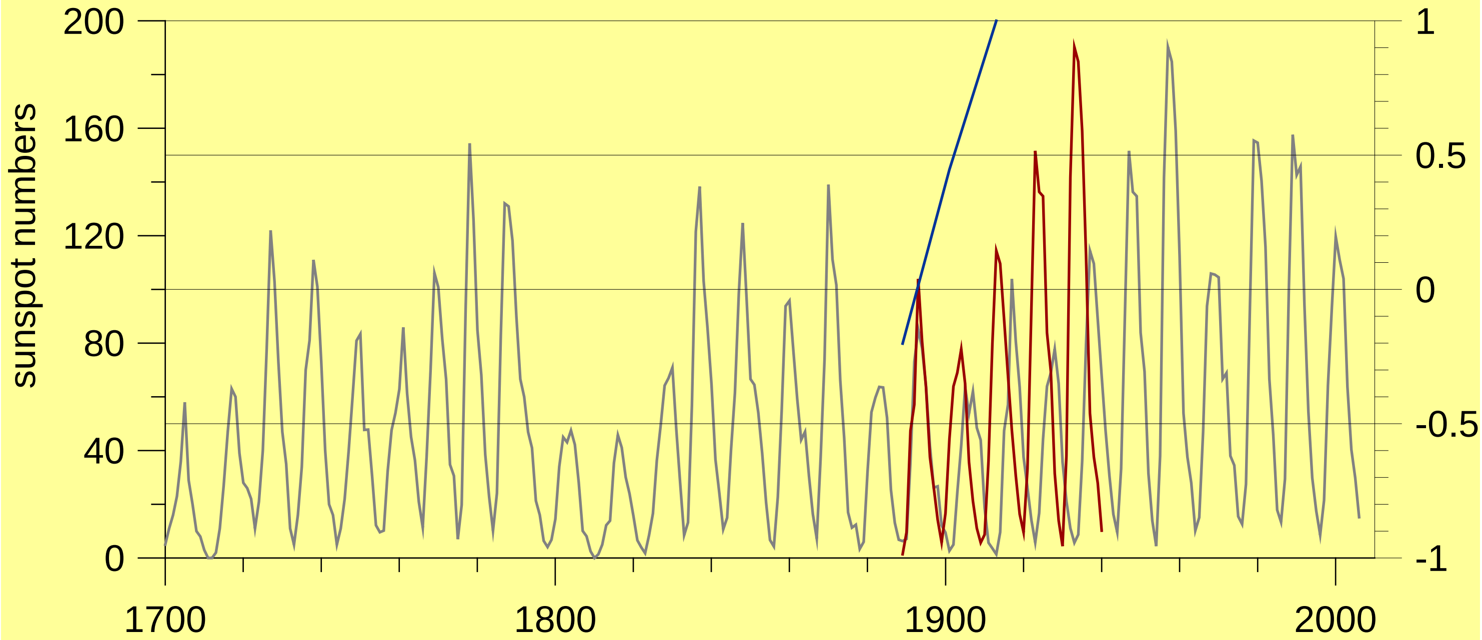

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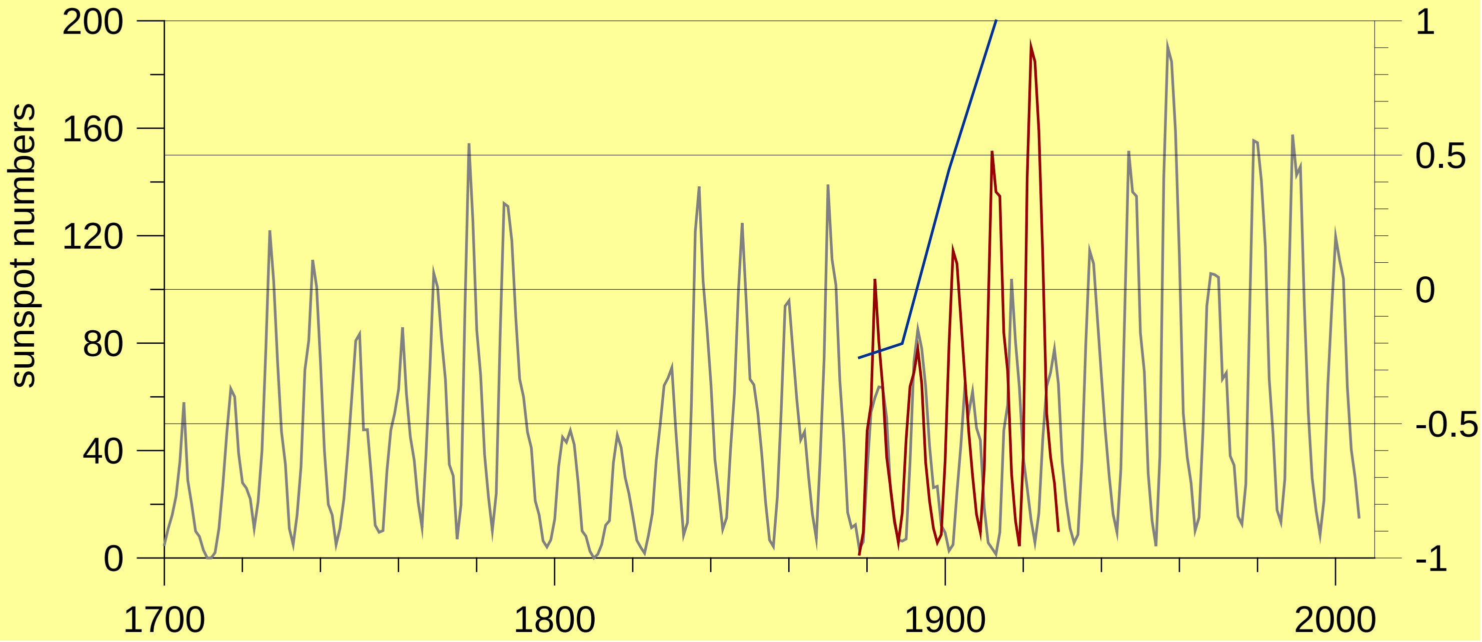

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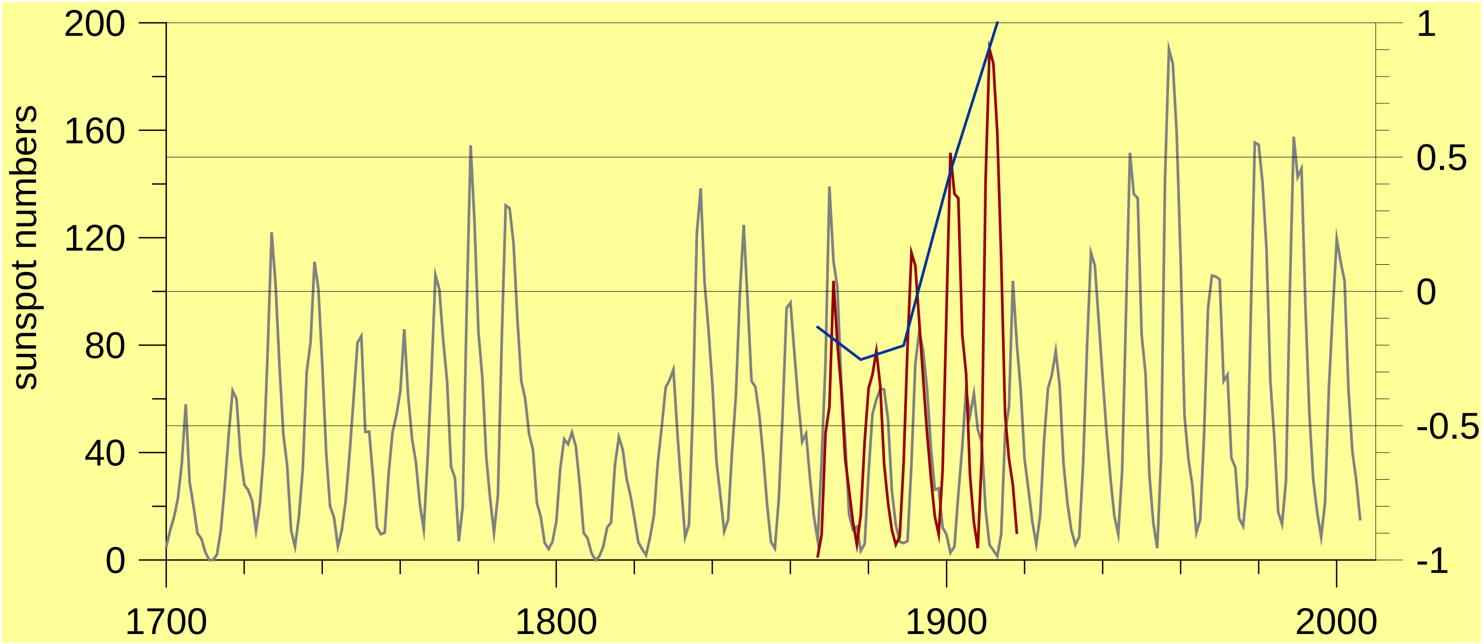

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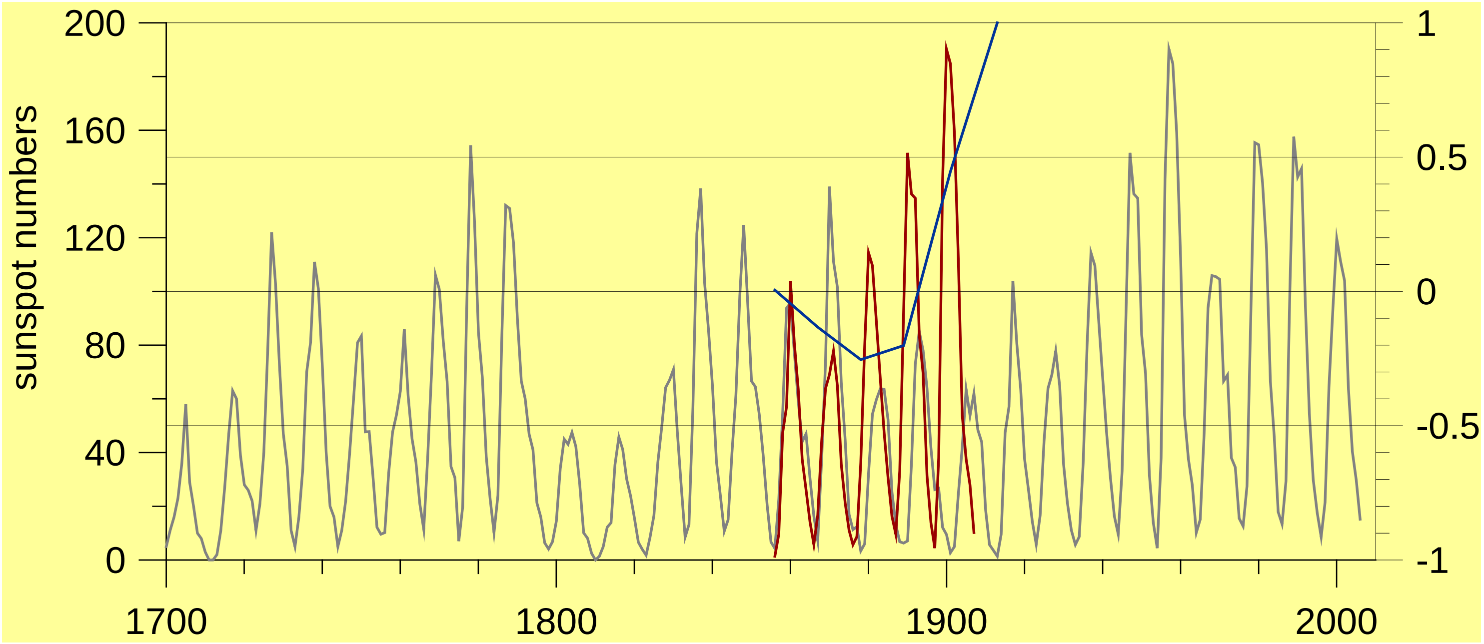

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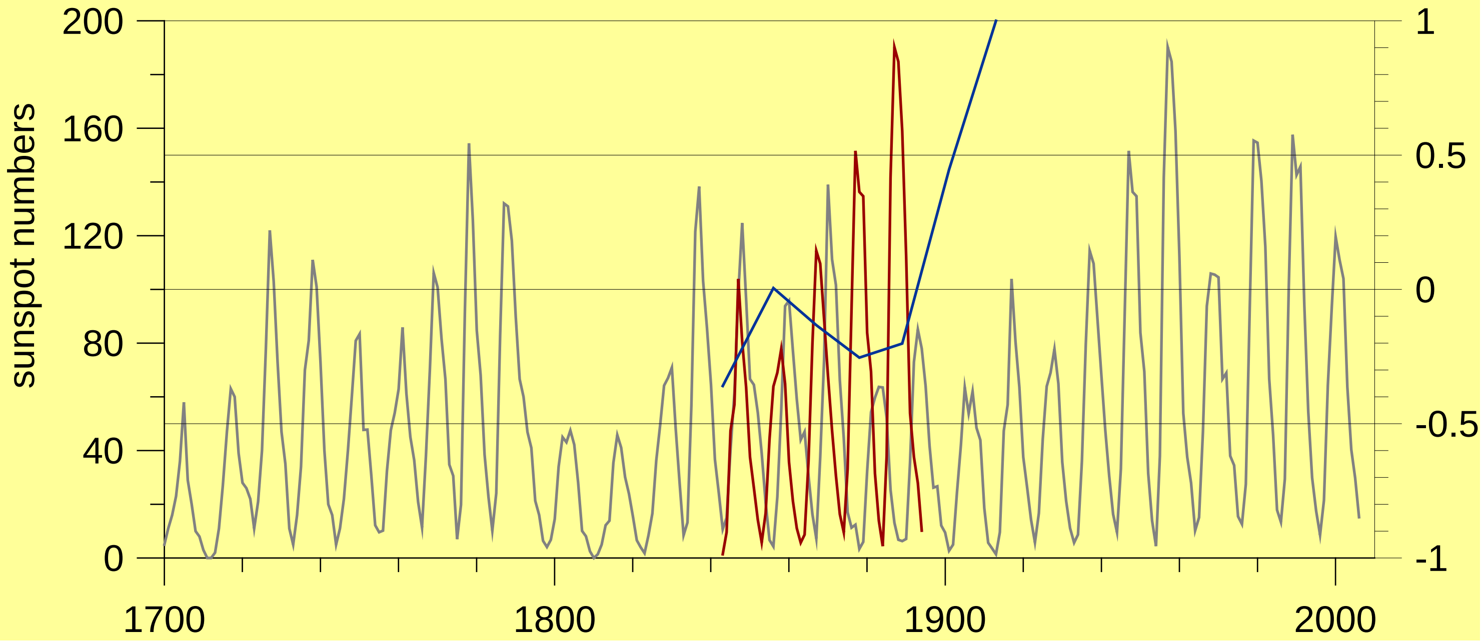

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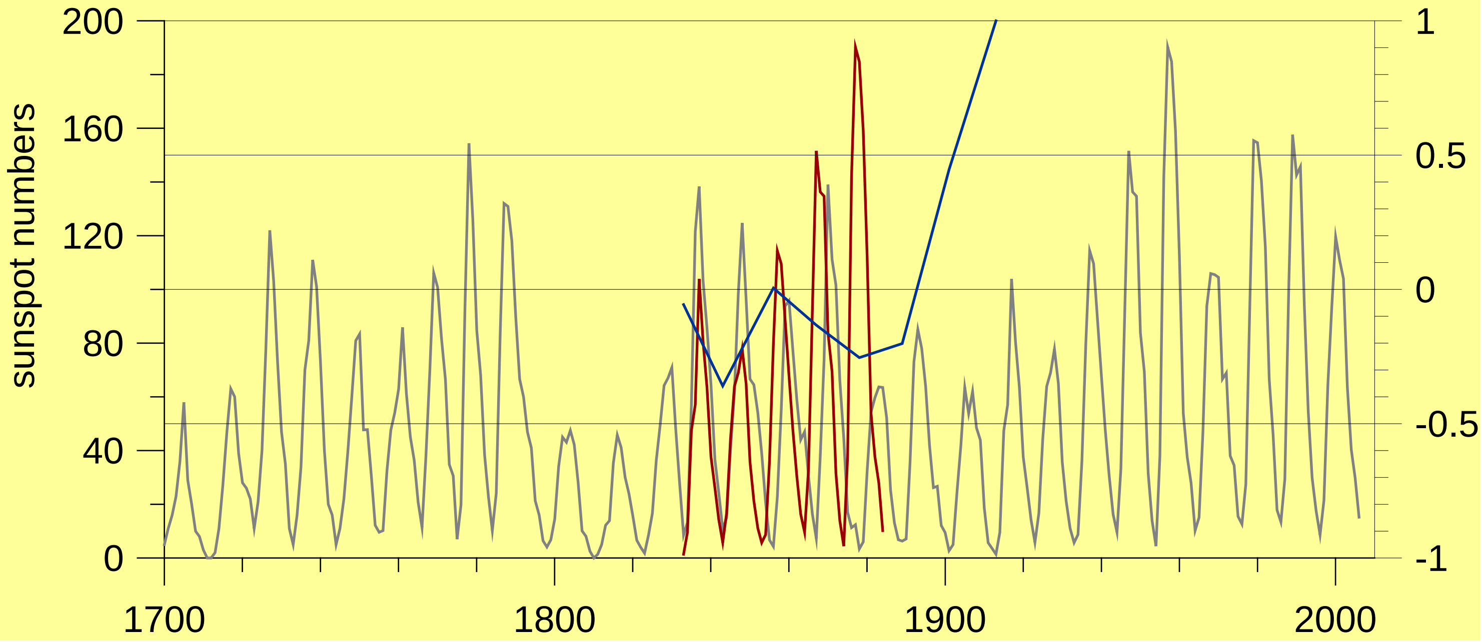

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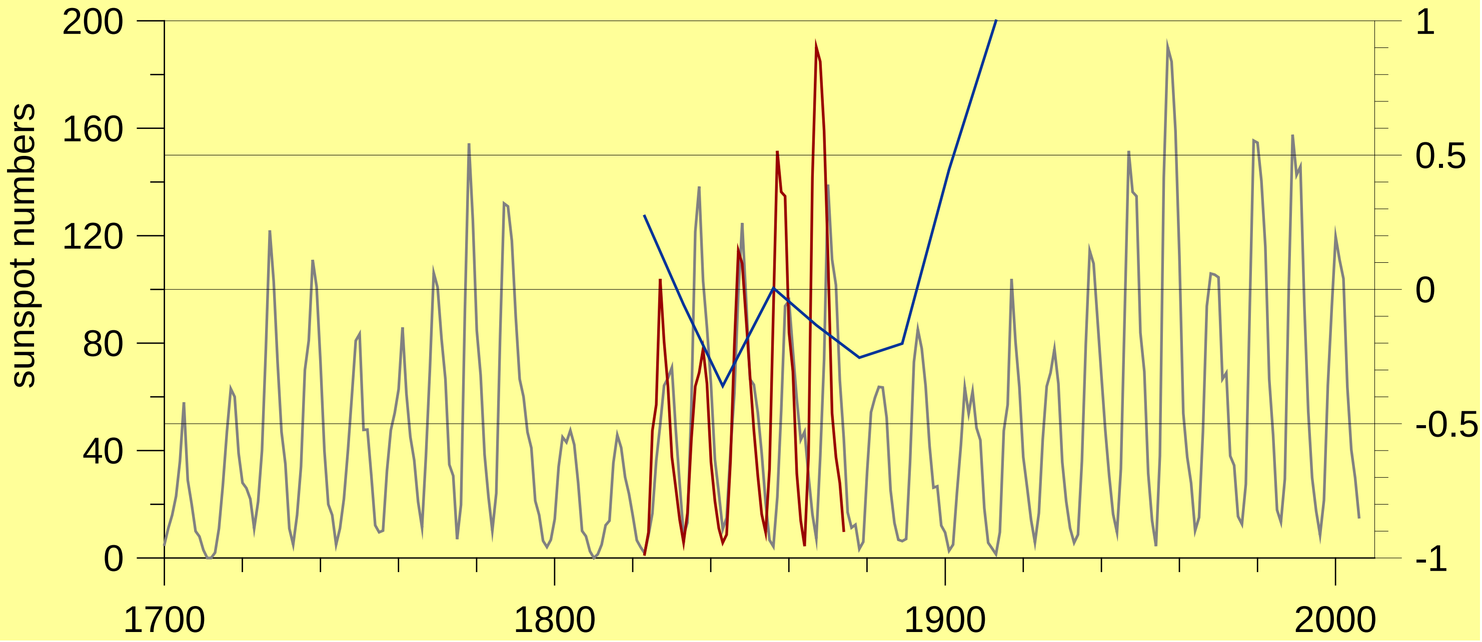

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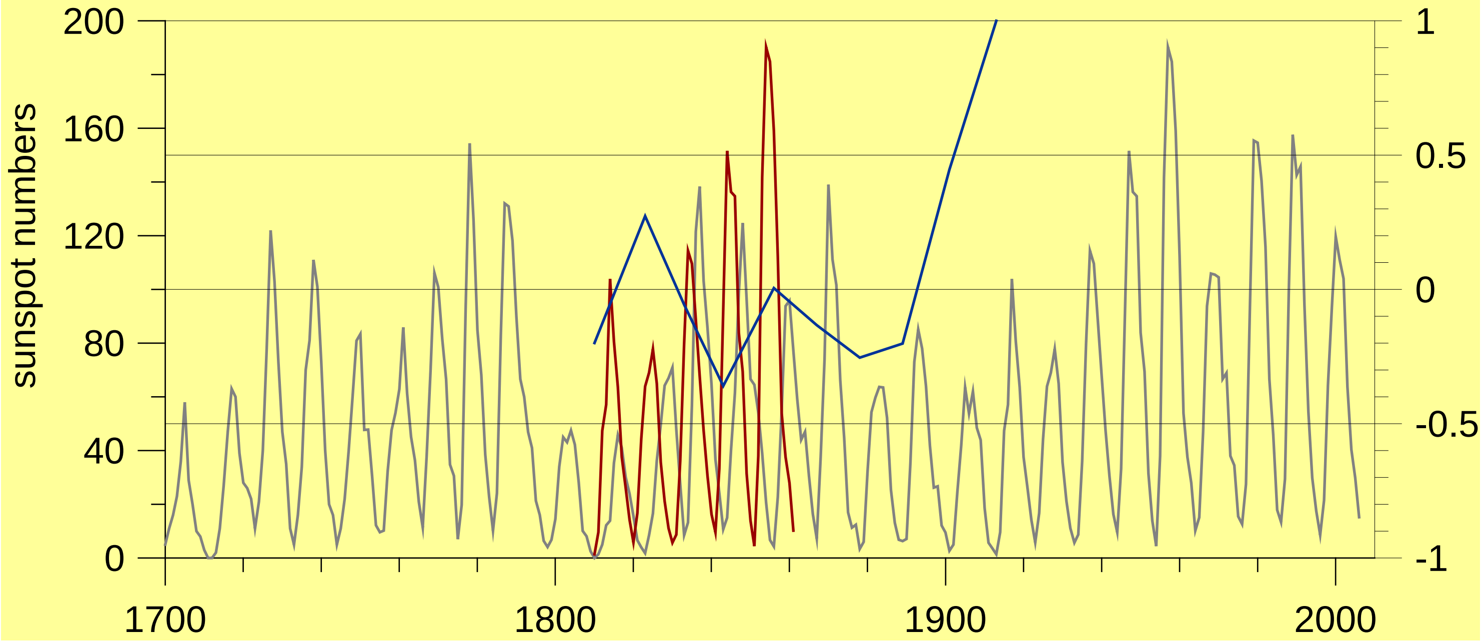

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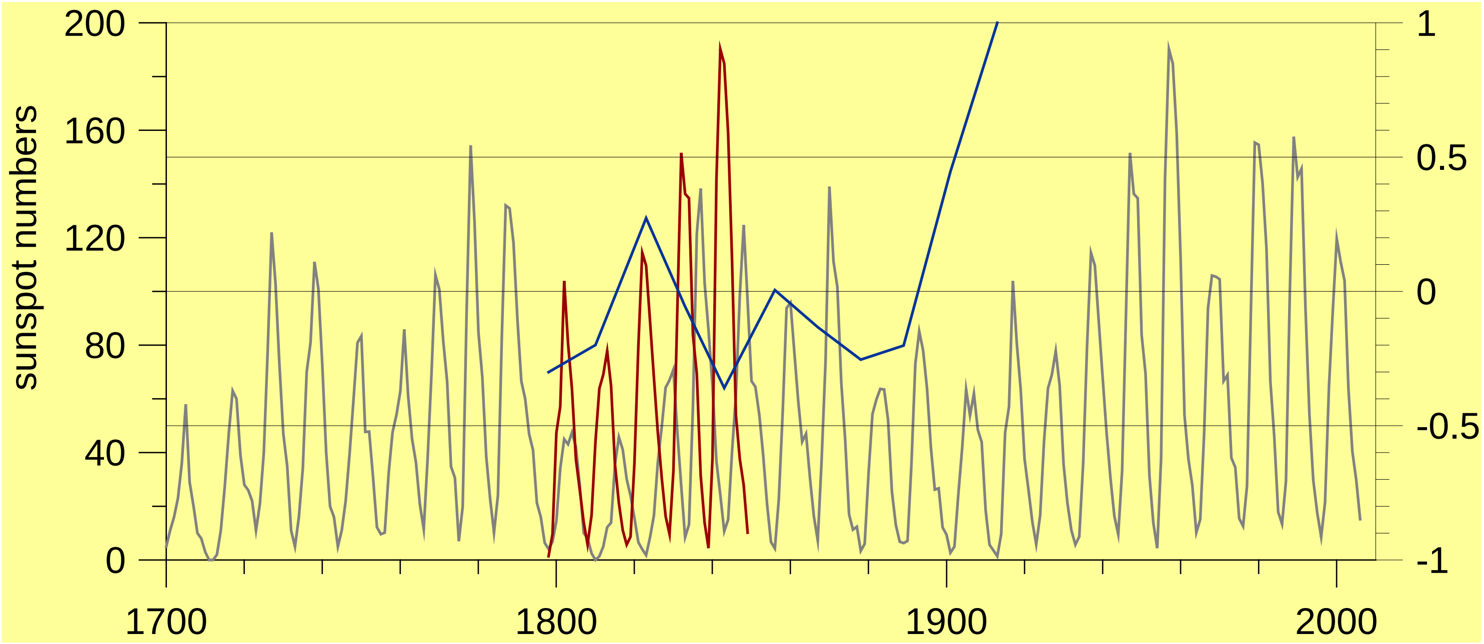

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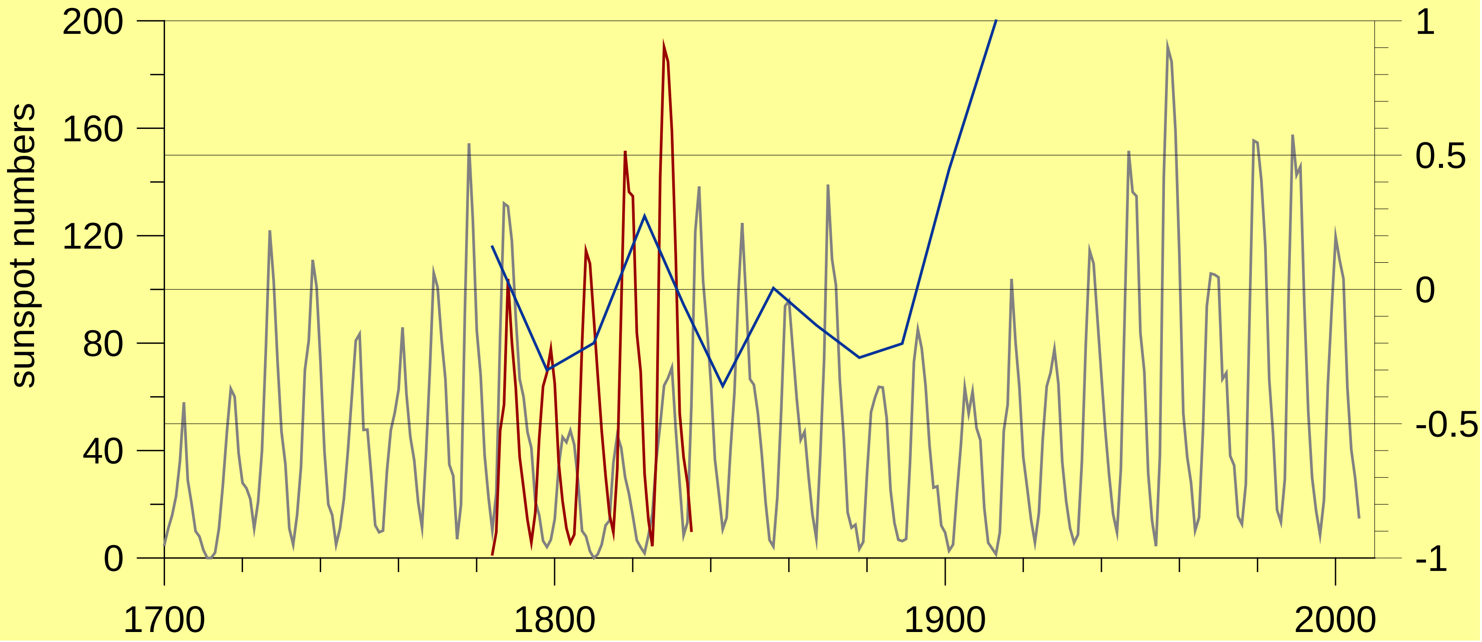

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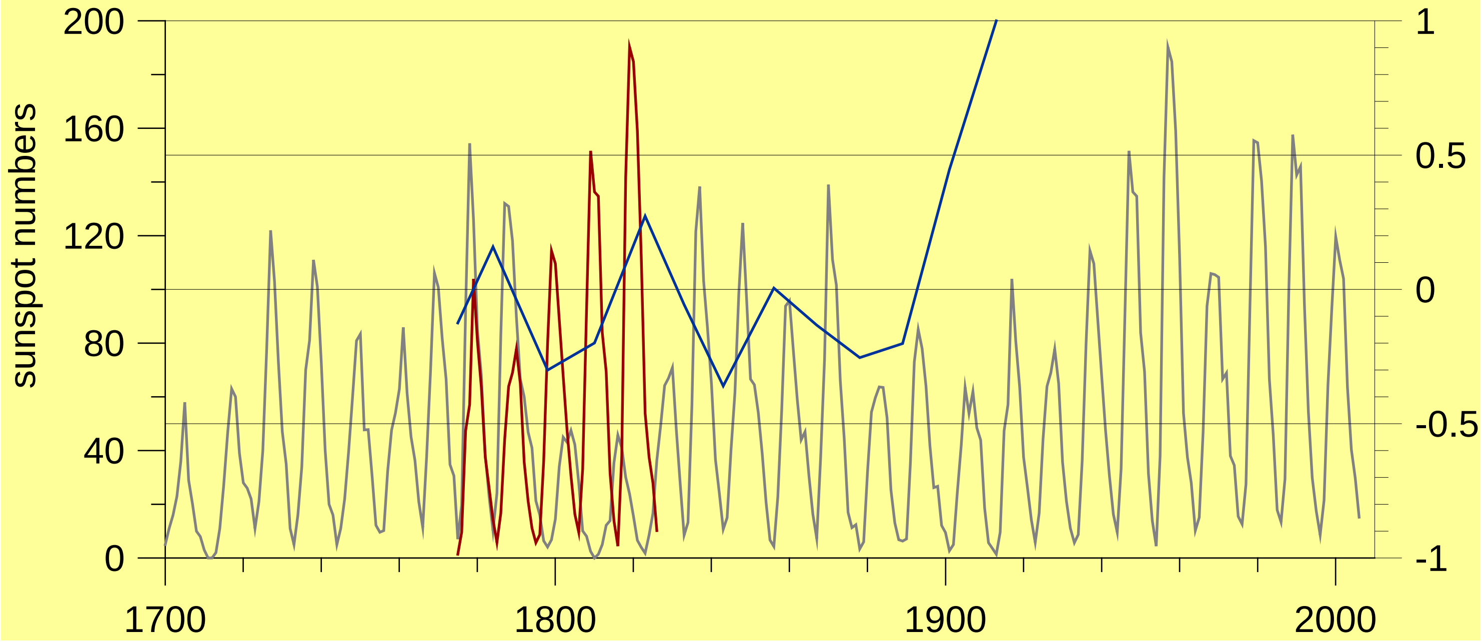

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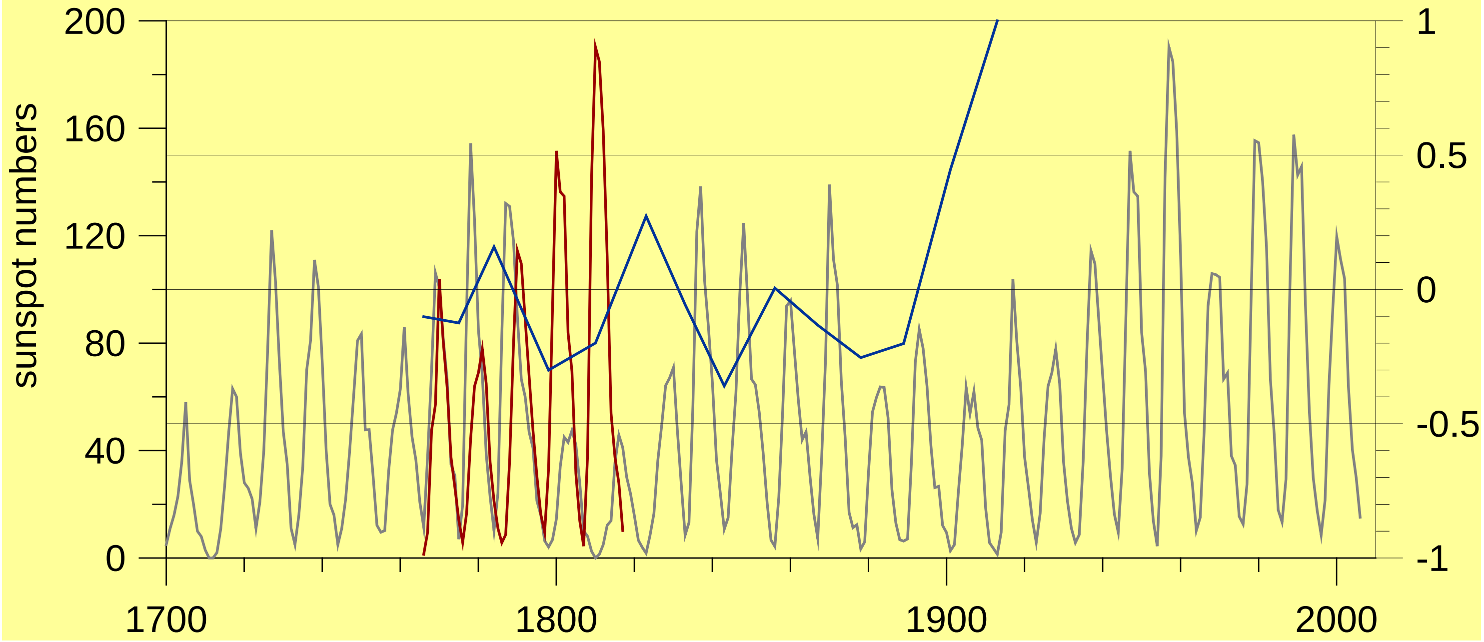

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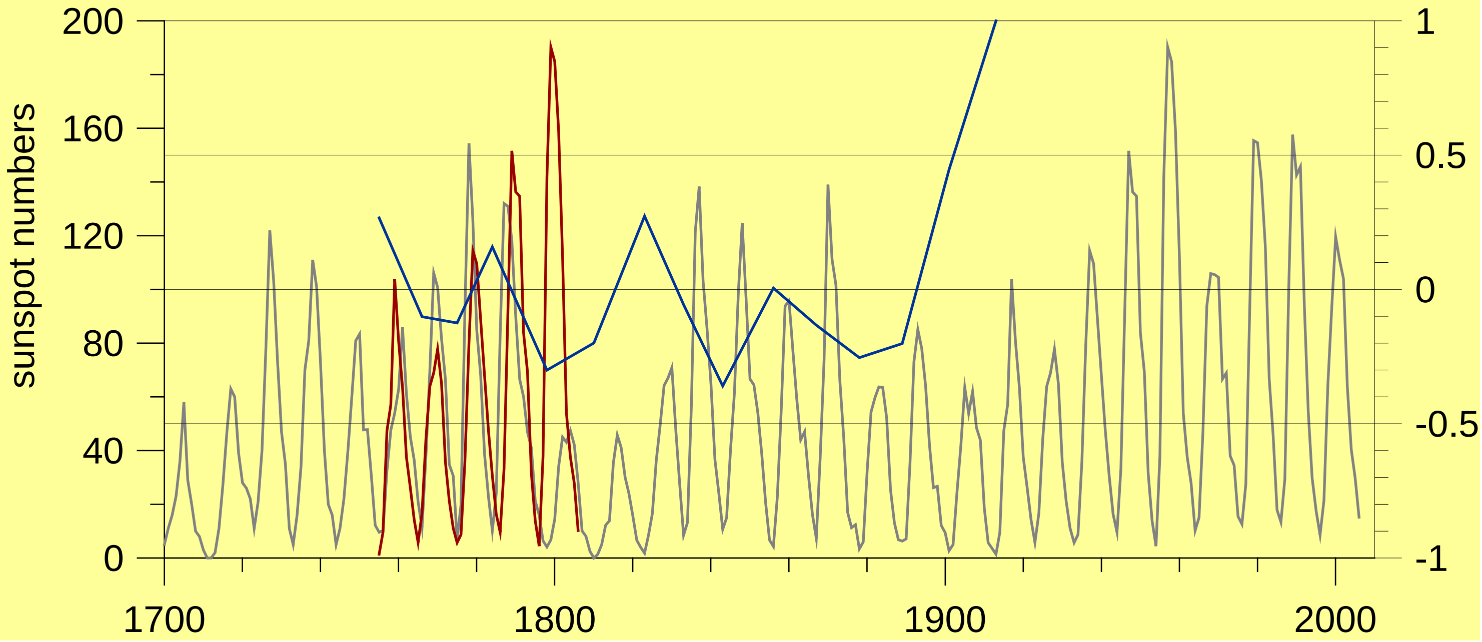

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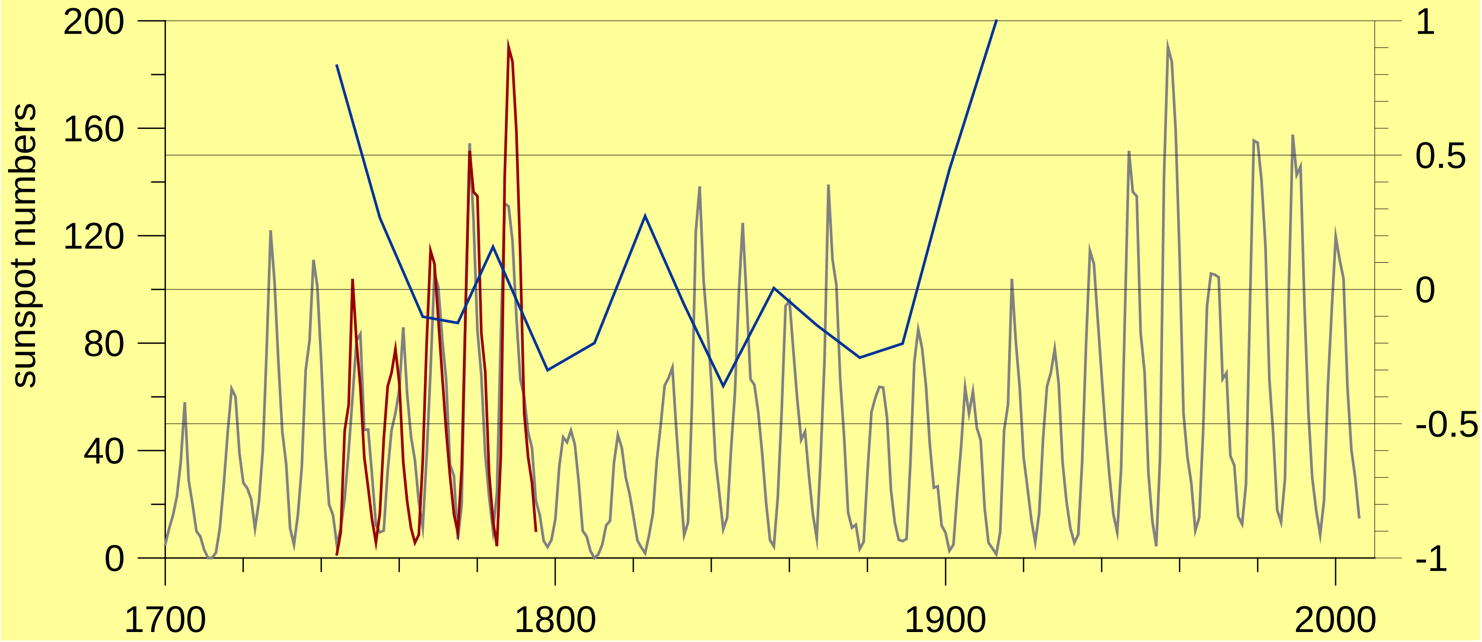

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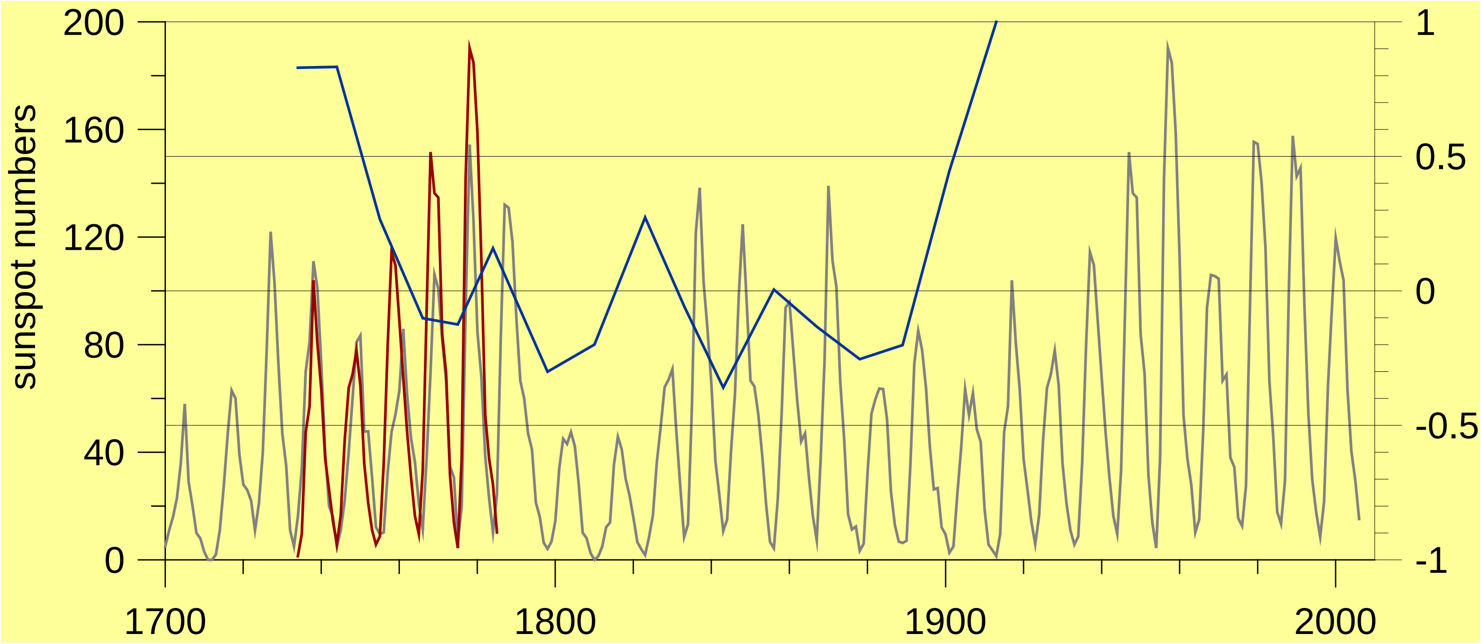

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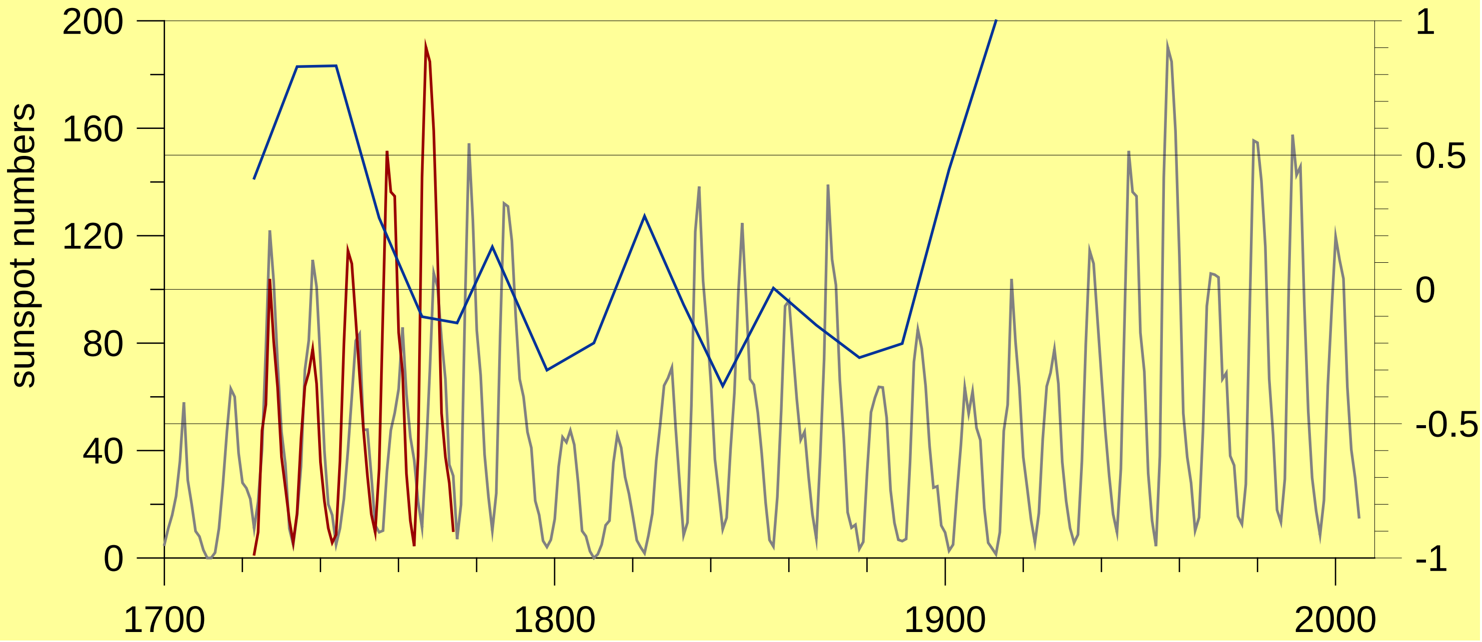

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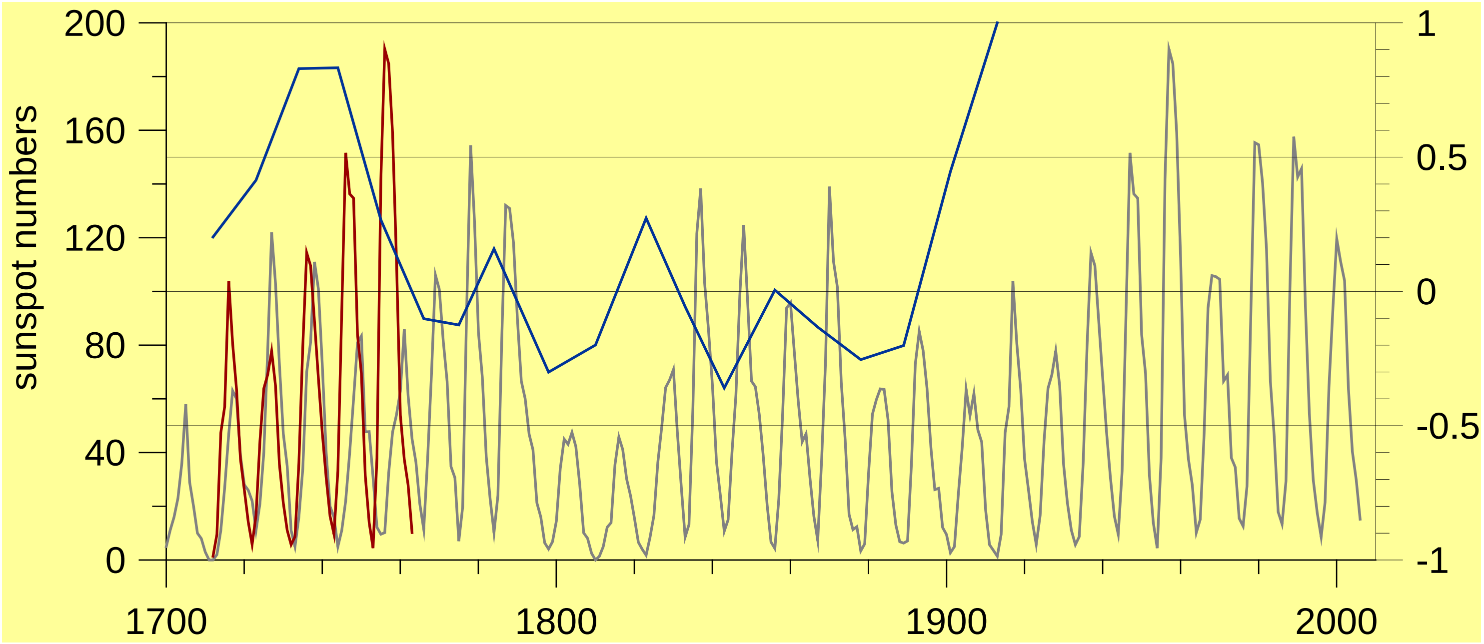

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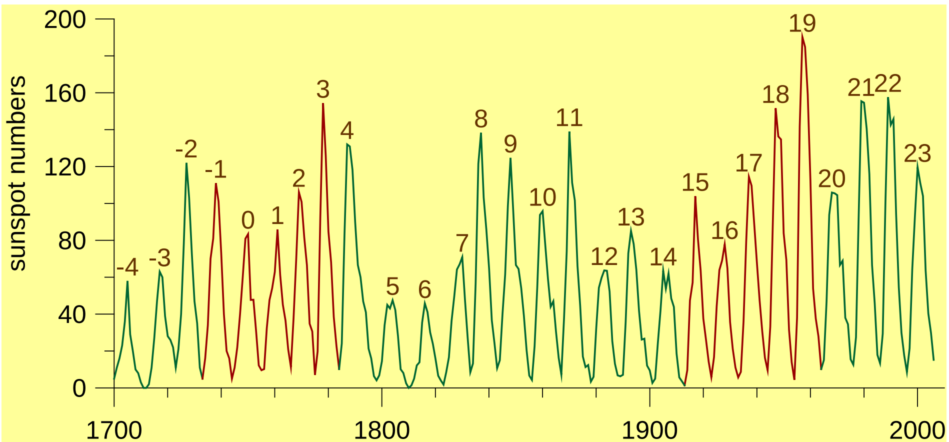
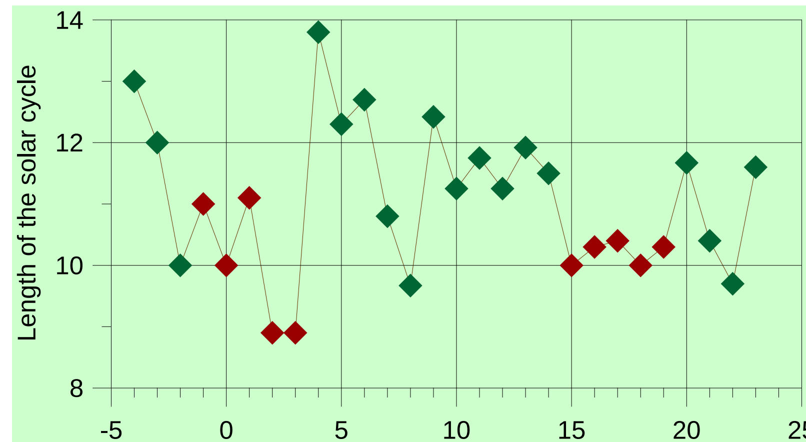
Solar inertial motion and solar activity (observed data)

The correlation between cycles -1 to 3 and 15 to 19 is tight. The length of the respective five cycles is nearly constant and equal to 10.1 years, on the average. This value corresponds to the duration of Sun’s motion along one loop arc.

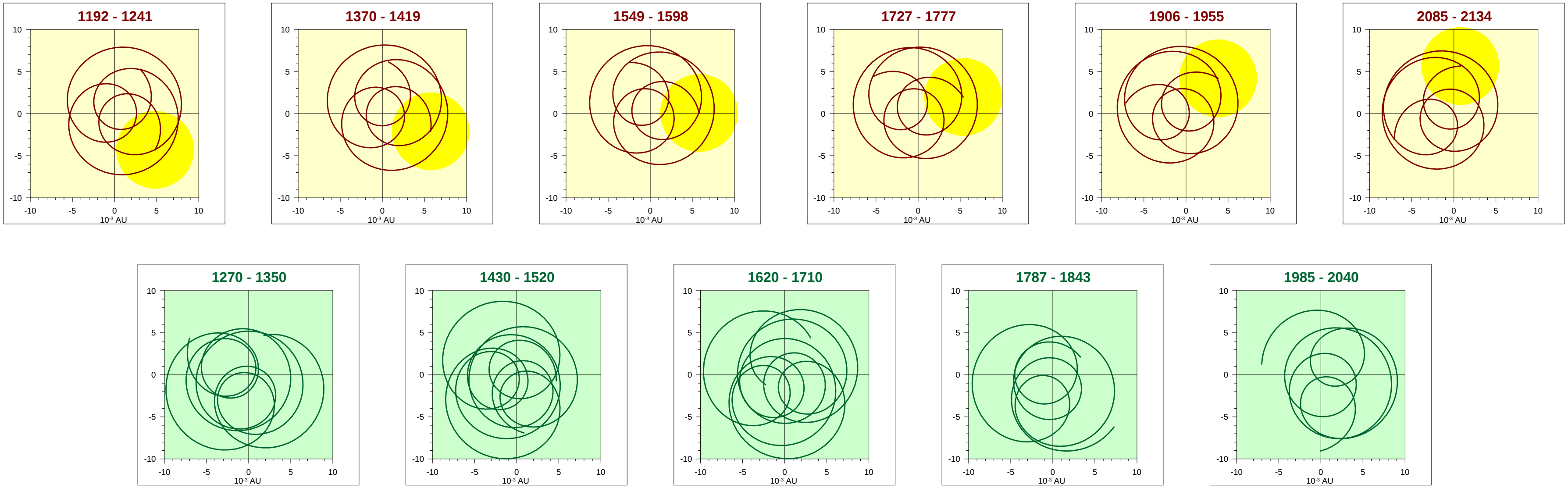




Possible interrelations between the 300-year record of the yearly sunspot numbers and the SIM was studied using the recently developed technique of synchronization analysis. Phase synchronization of the sunspot cycle and the SIM was found and statistically confirmed in three epochs (1734–1790, 1855–1875 and 1907–1960) of the whole period 1700–2000. These results give quantitative support to the hypothesis that there is a weak interaction between the solar activity and the SIM.

M. Paluš , J. Kurths, U. Schwarz, N.Seehafer, D. Novotná, I. Charvátová: The solar activity cycle is weakly synchronized with the solar inertial motion, Physics Letters A 365 (2007) 421–428.

Disordered parts of SIM (green)



Wolf **Spörer** **Maunder** **Dalton** **next?**

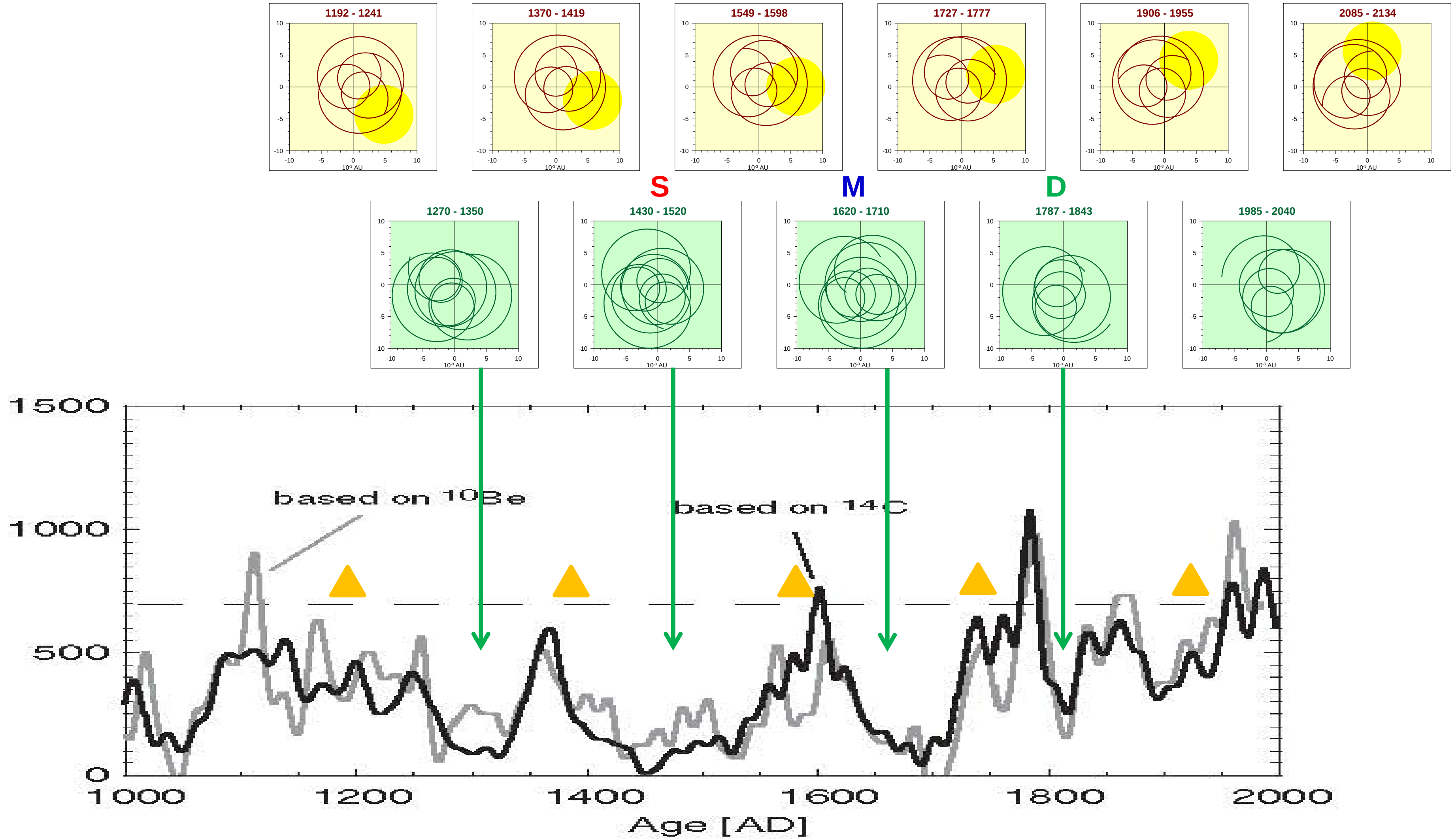
The most disordered parts of the SIM correspond with the prolonged minima (Grand decreases) of solar activity over the last millennium.

Spörer type (long and deep) – **S**

Maunder type (shorter and deep) – **M**

Dalton type (short and deep) - **D**

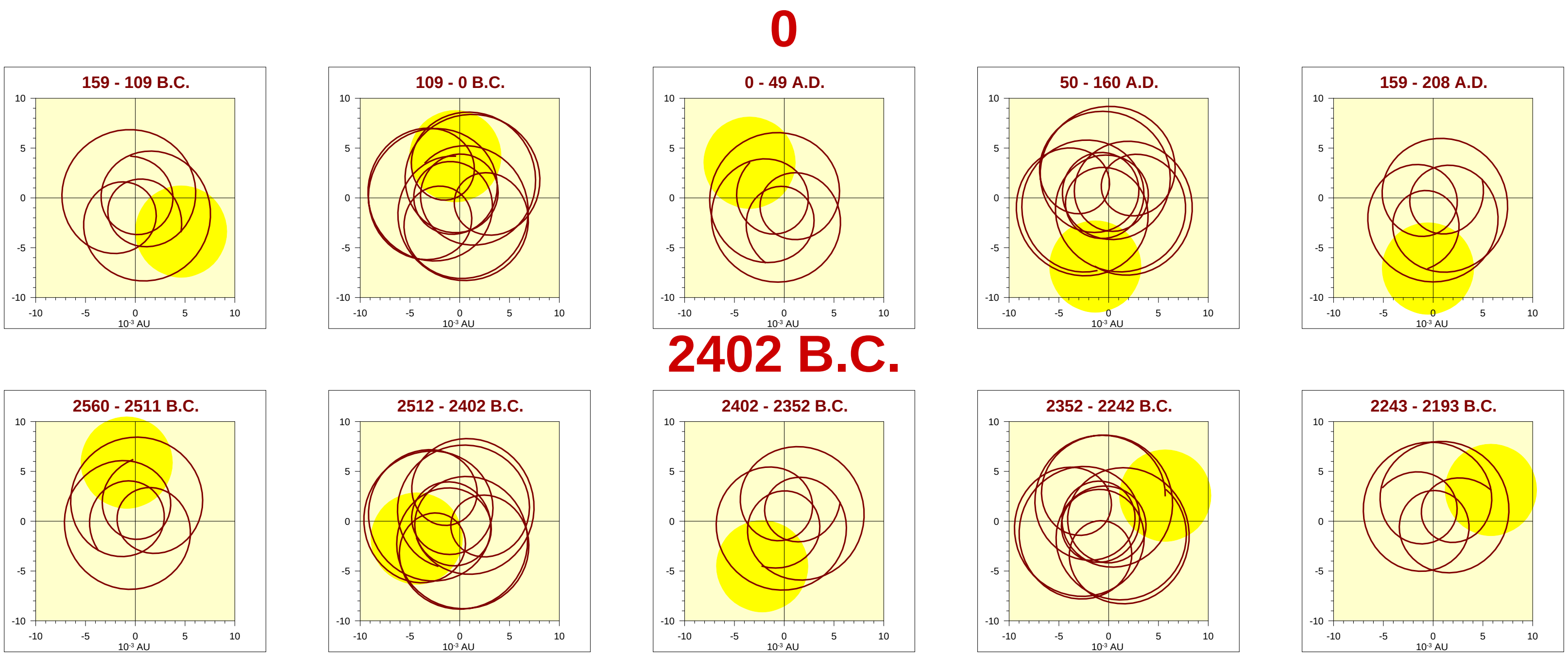
Disordered parts of SIM – solar grand minima



Solar modulation function [MeV] (from Muscheler et al., Quaternary Sci. Rev. 26, (2007) 82-97)

Two basic types of SIM

The extended trefoil intervals long 370 years in steps of 2402 years



The regularity of the 178.7-year cycle is periodically (2402 years) disturbed by a 370-year long segment of exceptional and nearly stable motion of the Sun along a trefoil to quasitrefoil orbit. This period corresponds with the period found in radiocarbon series.

The extended trefoil intervals long 370 years in steps of 2402 years

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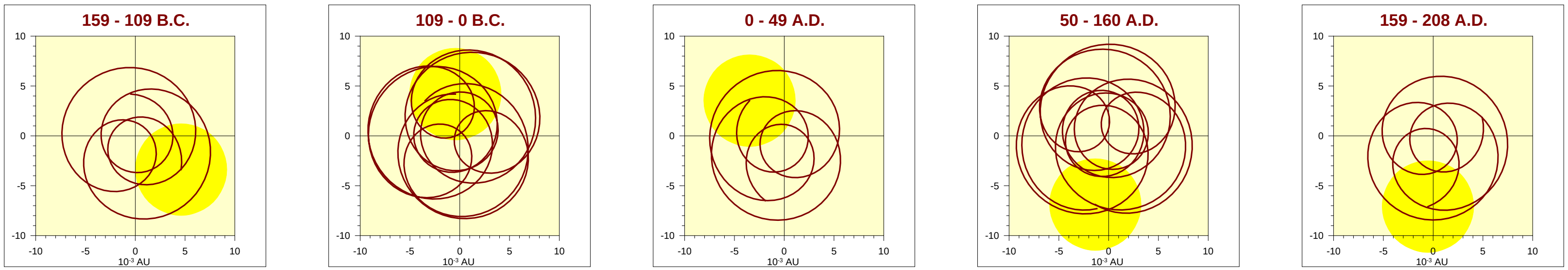
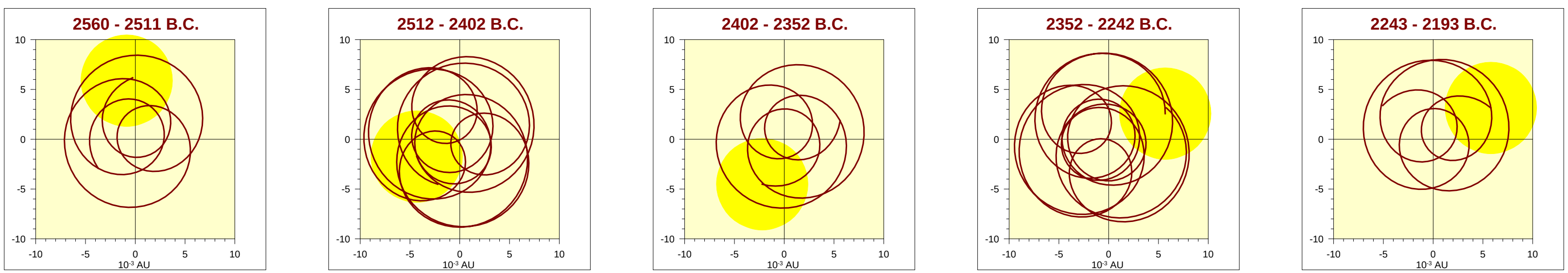
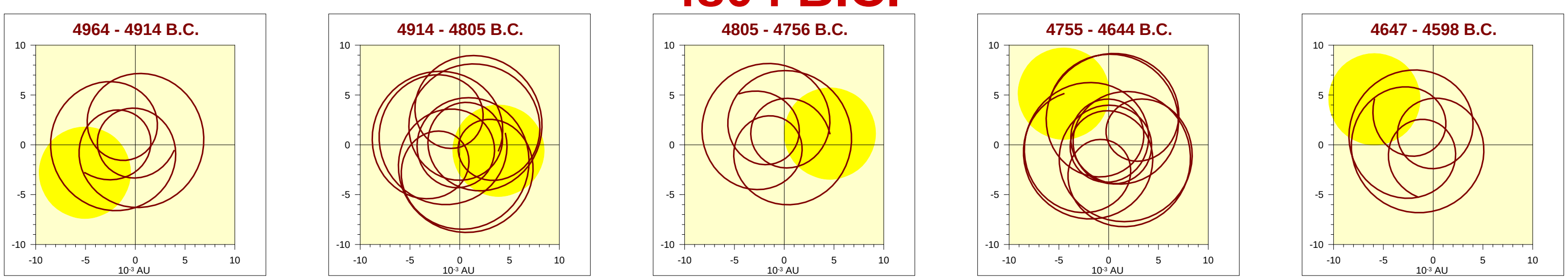


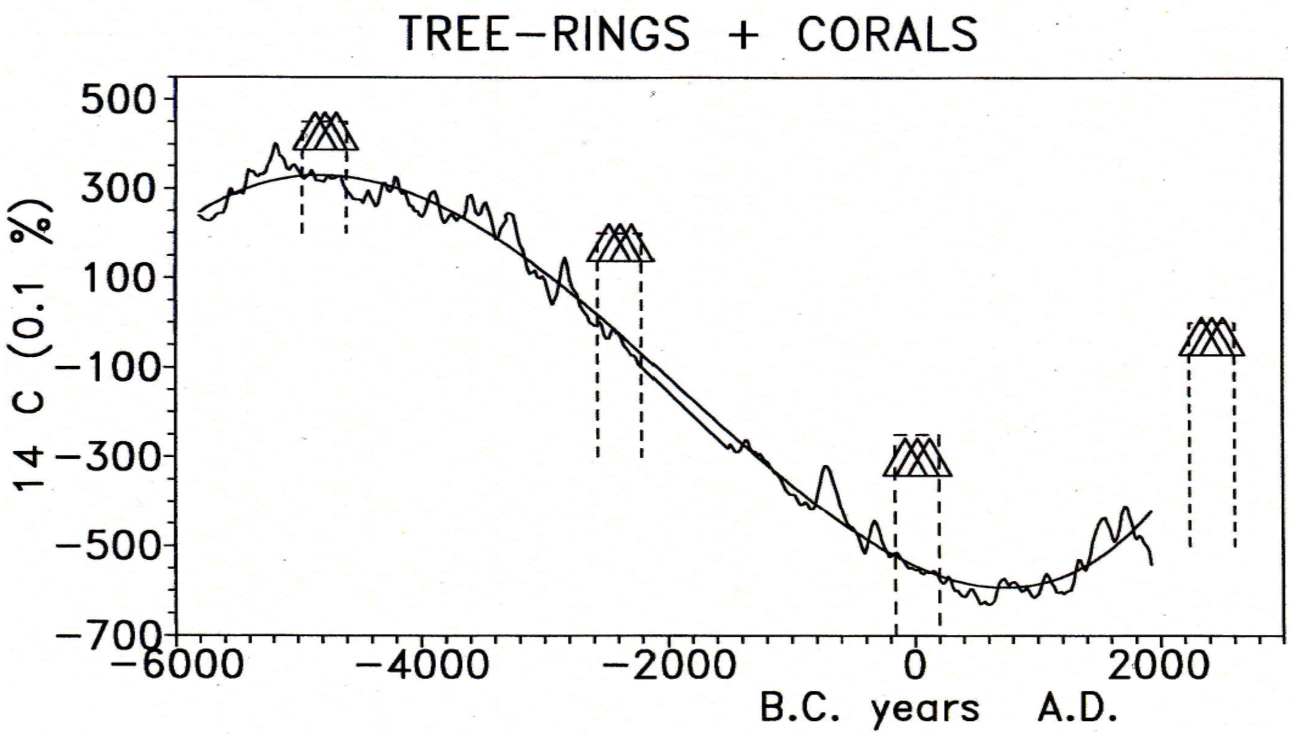
2402 B.C.



4804 B.C.

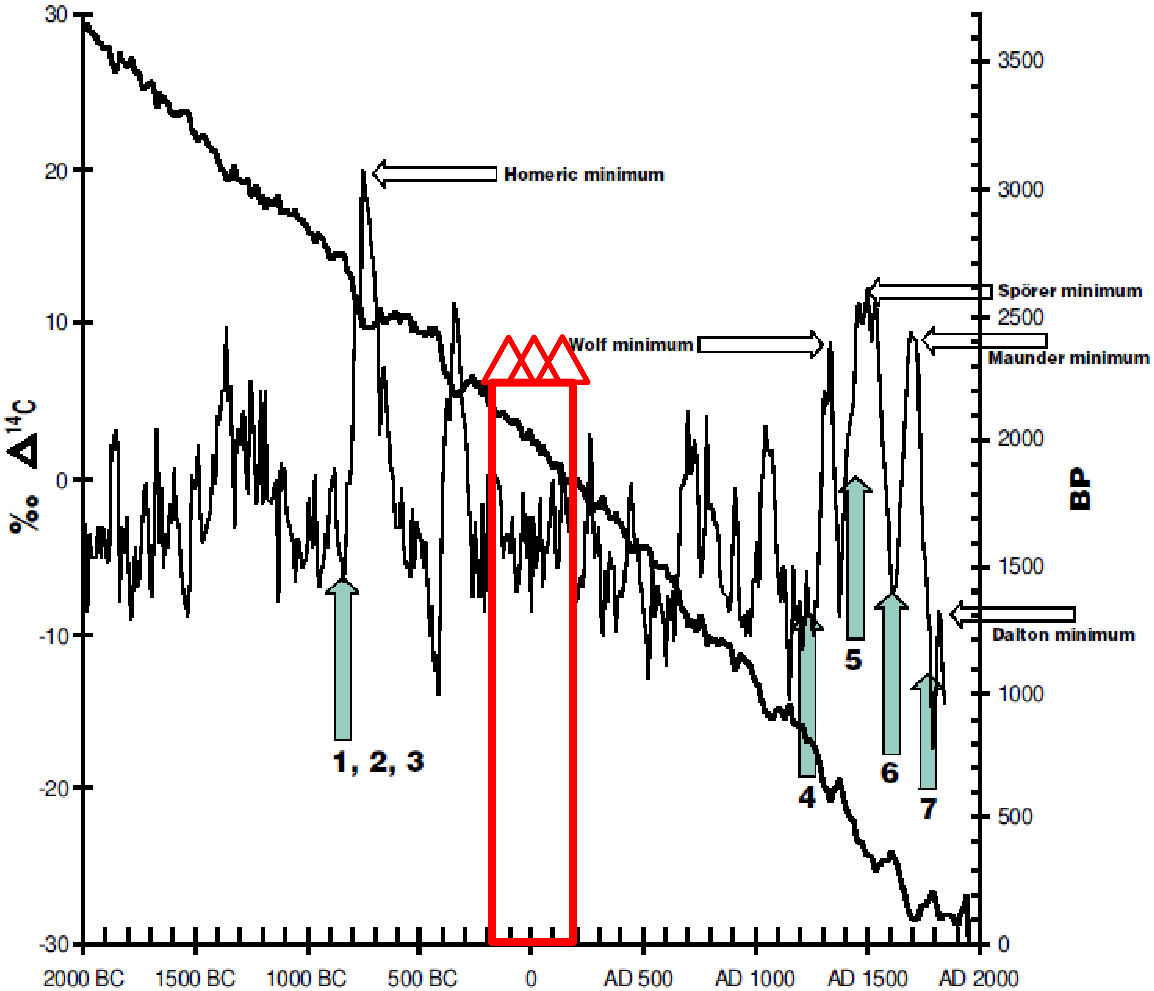


Evidence of the 2402-year cycle in 14C time series



Marine model 14C ages calculated from the bidecadal atmospheric tree-ring data and a smoothing spline from coral data (Stuiver and Braziunas, *Radiocarbon 35*, 1993). The most stationary parts of the record (low variance) coincide with the extended trefoil intervals. The greatest minima of solar activity appeared in the second half of the 2402 year cycle.

Features of the 2402-year cycle in 14C time series

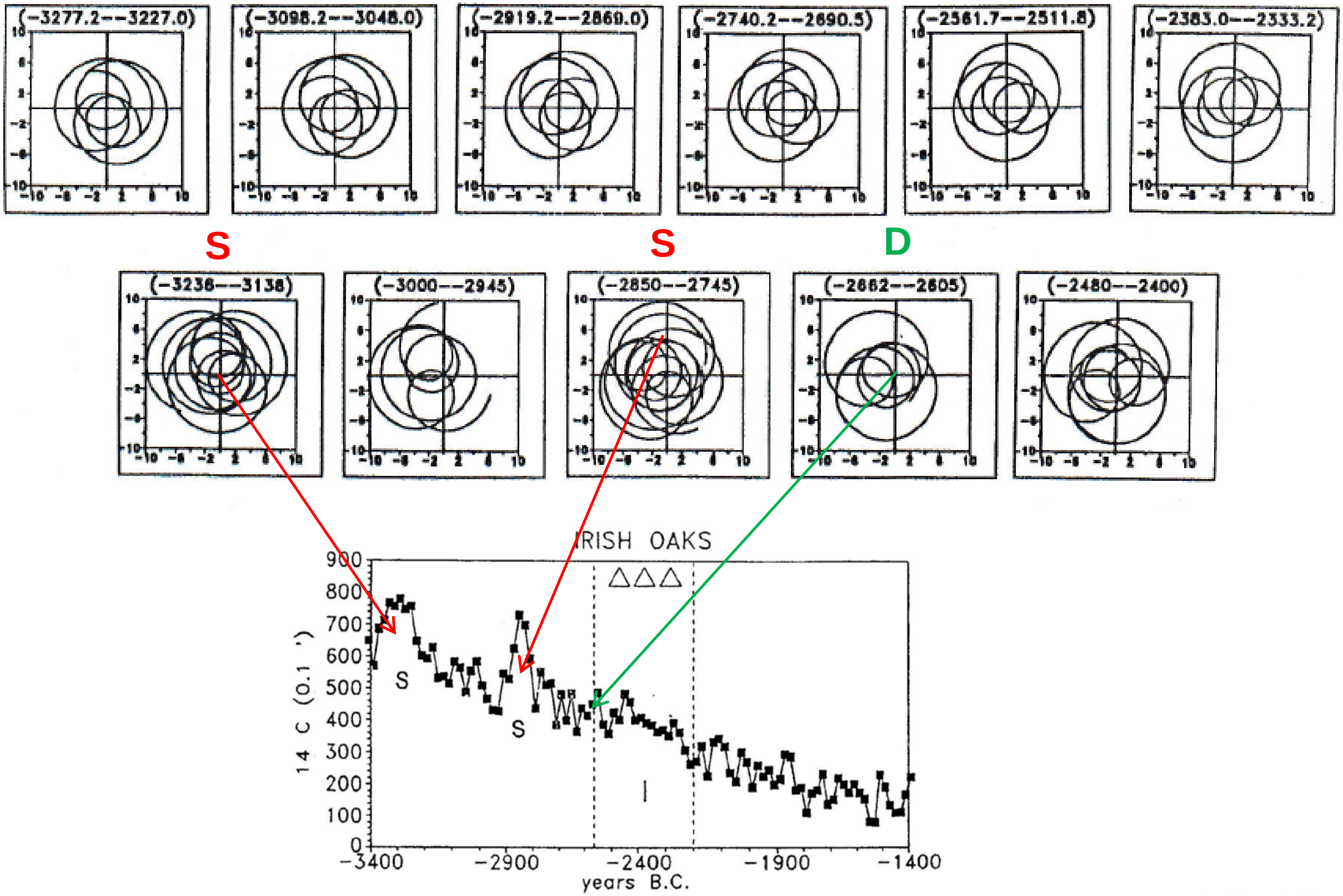


Detrended $\Delta^{14}C$ versus calendar age (thin line). Radiocarbon versus calendar ages (thick line).

The most stationary parts of the record (low variance) coincide with the extended trefoil intervals. The greatest minima of solar activity appeared in the second half of the 2402 year cycle.

Mauquoy et al., Holocene, 2004.

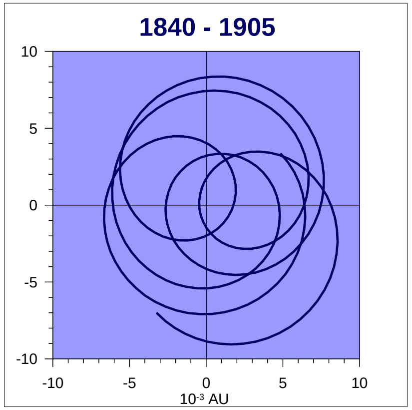
3277 B.C. – 2333 B.C.

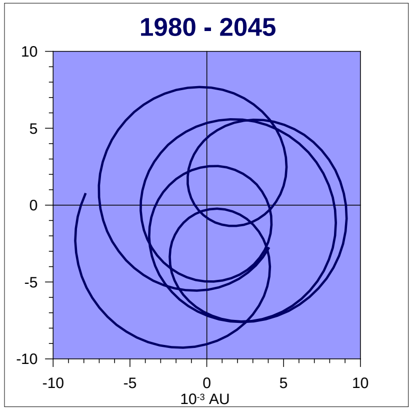


Space Climate 5, Oulu, June 2013

Two basic types of SIM

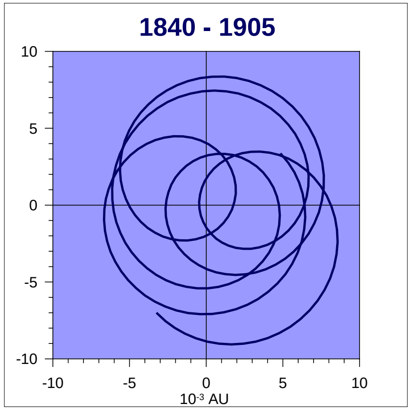
Solar orbits in the years 1840-1905 and 1980-2045

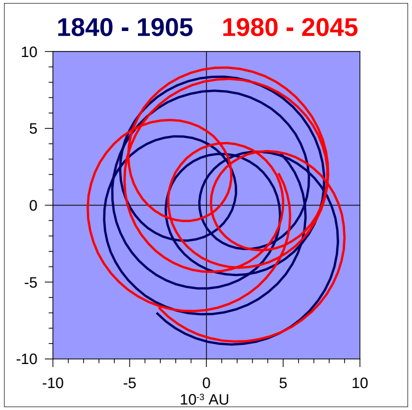




SIM sequences in the years 1840-1905 and 1980-2045 are similar – after a rotation of about 90º.

Solar orbits in the years 1840-1905 and 1980-2045





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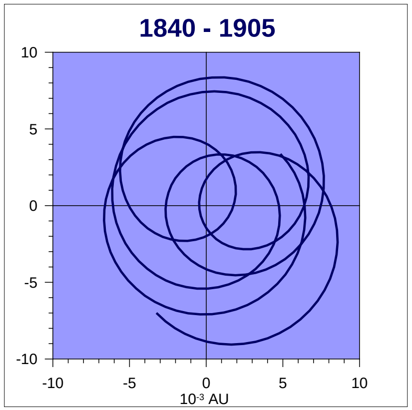
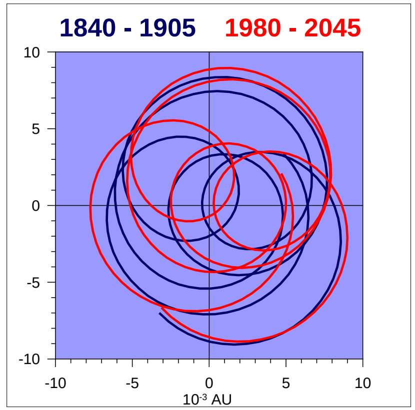


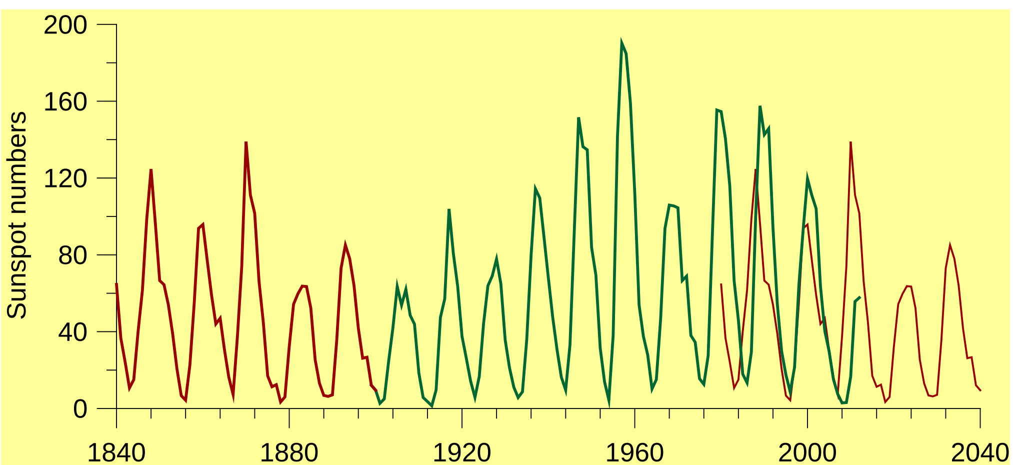


SIM sequences in the years 1840-1905 and 1980-2045 are similar – after a rotation of about 90º.

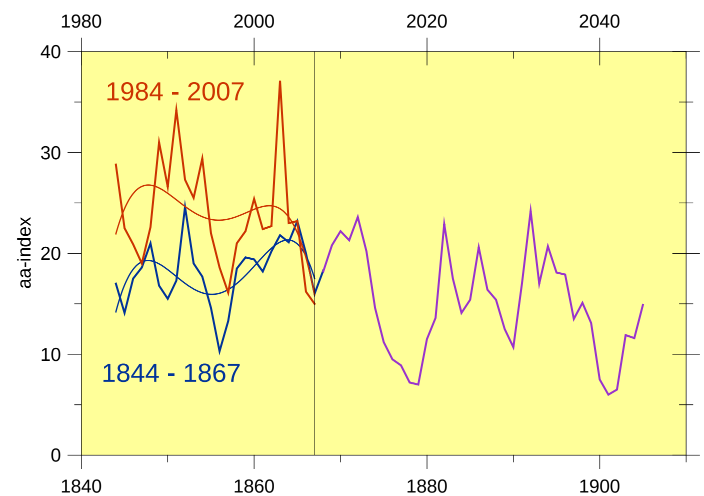
Charvátová (New Astronomy 14, 2005) elaborated prediction of solar activity based on this similarity.

The similarity assumption proved true for solar cycles 22 and 23 but failed on recent cycle 24 (unexpected behavior of solar activity).

Does the solar minimum started earlier than expected?



Sunspot numbers between 1840 and 2012 (thick line) and predictive assessment for 1980-2040 based on similarity assumption (thin line).



aa-index for periods 1844-1847 and 1984-2007 and predictive assessment for period 2008-2040

Possible mechanisms

are subject of two invited talks in this section:

- *Katya Georgieva, P. Semi, B. Kirov: Planetary influences on solar activity from the point of view of the flux-transport dynamo*
- *P. Charbonneau: Sensivity of the solar dynamo to external multiperiodic forcing*

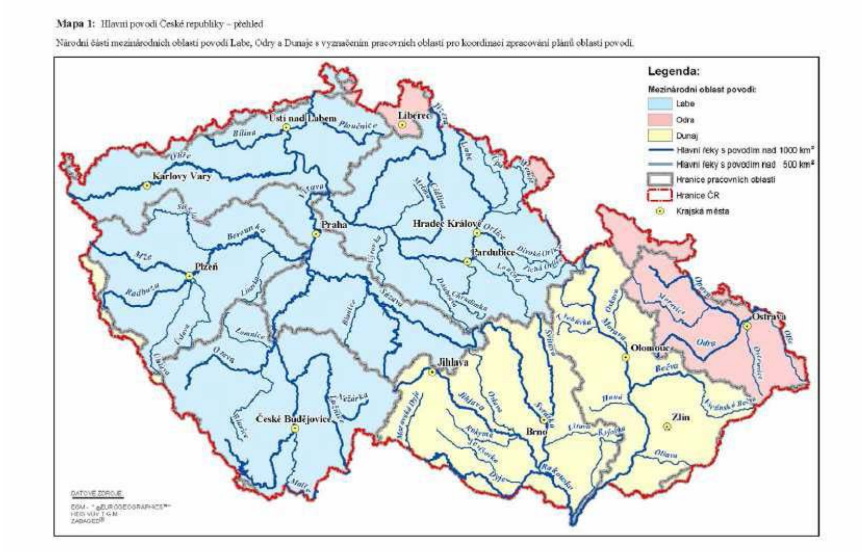
It is discussed how, and to which extend, the cyclic solutions of the solar dynamo are sensitive to imposed long-timescale, low-amplitude forcing in their source terms.

Conclusions

- Responses of two basic types of the solar inertial motion (SIM) in solar-terrestrial (ST) phenomena were described.
- Responses of the ordered (trefoil) intervals of the SIM in ST-phenomena such as the prolonged temperature maxima or series of 10 years long sunspot cycles have been found.
- The prolonged solar (temperature) minima appeared during intermediate intervals where chaotic curve of the SIM occurred.
- Very long (nearly 370 years) intervals of the solely trefoil orbit of the SIM occurred in steps of 2402 years: 158 BC -- AD 208, 2560 BC -- 2193 BC, etc.
- A stable behaviour of ST-phenomena during these long intervals was shown.
- The deepest and longest solar (temperature) minima (of the Spörer or Maunder types) occurred in the second half of the 2402 years cycle in accordance with the respective most disordered types of the SIM.
- The SIM is computable in advance: The recent SIM is comparable with that of the second half of the 19th century. Corresponding behaviour of ST-phenomena can be tested.

Appendix: Solar inertial motion and floods in Bohemia

Recent disastrous floods in the Czech Republic (Moravia 1997, Bohemia 2002, *2013*) increased the interest of hydrologists in the historical floods. The most reliable data are available from Vltava river basin, because the capital Prague lies on the lower reach of Vltava river.

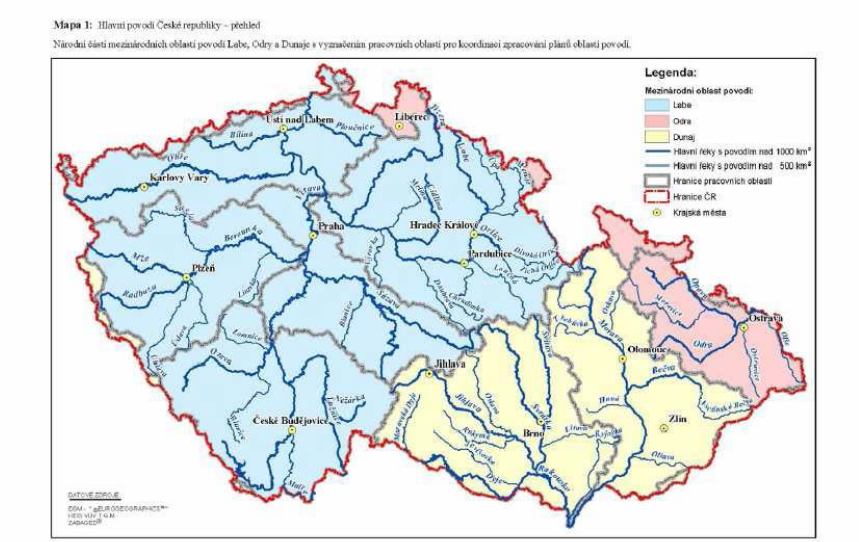


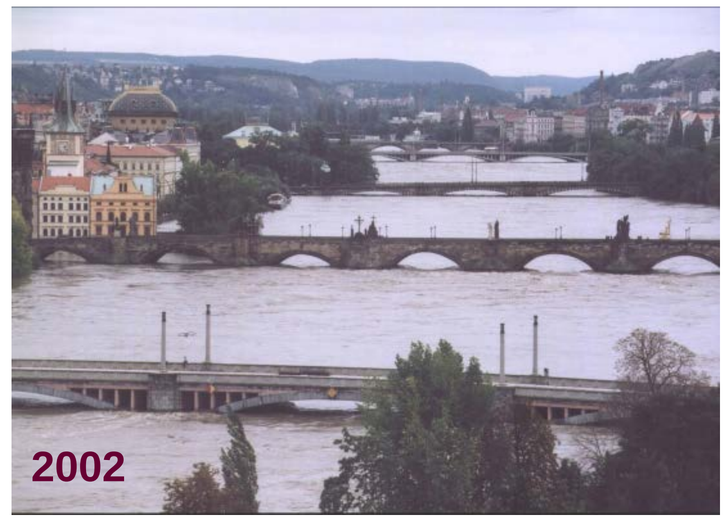
THE KARLSBRÜCKE AT PRAGUE AFTER THE RECENT FLOOD.—[See Page 790.]

Elleder L.: Variability of seasonality and frequency of disastrous floods in Vltava river basin taken from documentary sources (in Czech), In: Extremal hydrological phenomena in river basins, Workshop 2005.

Solar inertial motion and floods in Bohemia

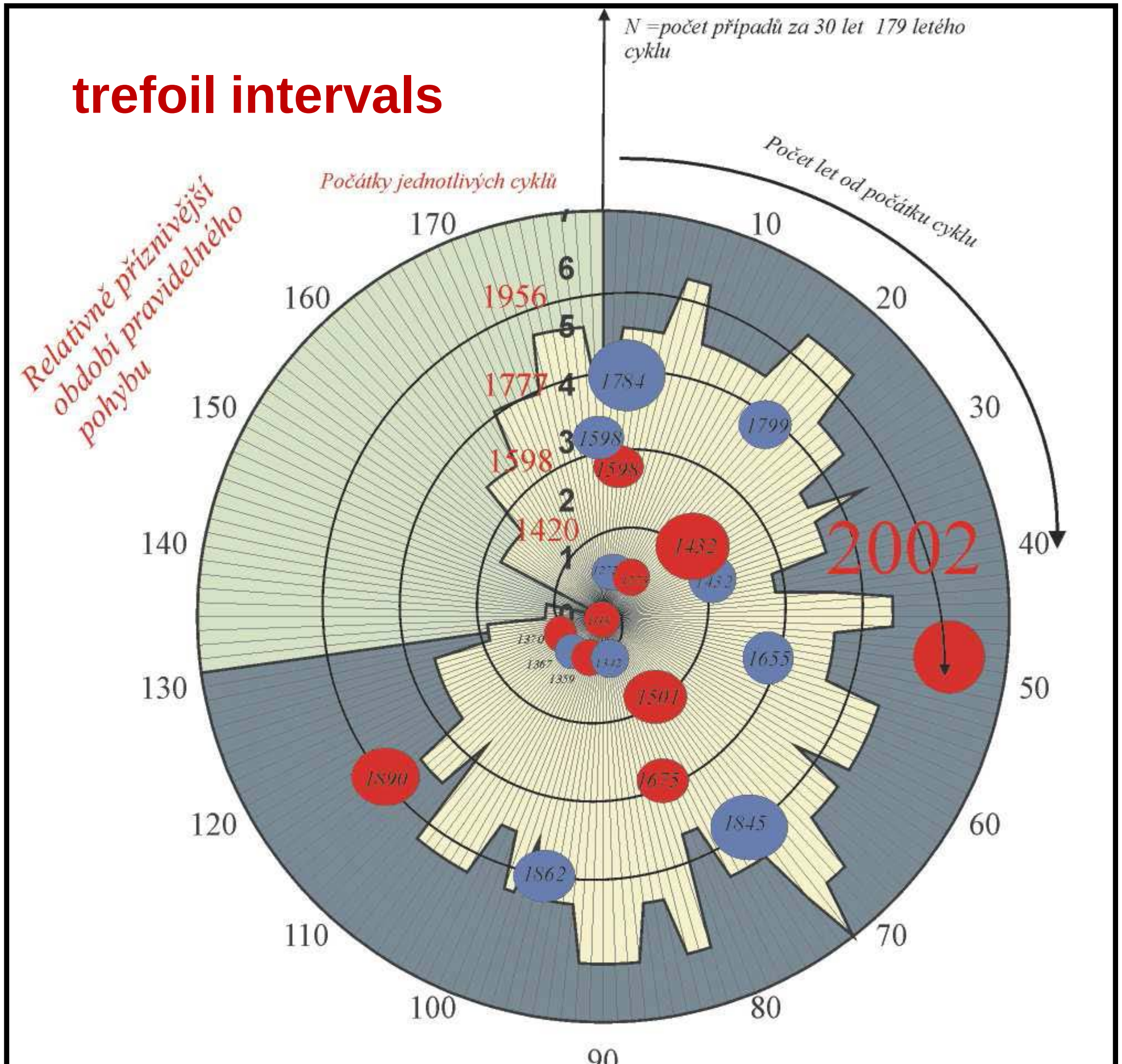
Floods of the summer synoptic type occur as a consequence of heavy continuous precipitation over a few days, which can be combined with intense downpours. The trajectory and speed of cyclones with respect to the Czech territory is of key importance. These are mainly cyclones of Mediterranean origin passing to the north.





Floods in Bohemia thus provide useful information about the type of atmospheric circulation in the entire (central) European region. Twenty disastrous floods were recorded in the last millennium. Elleder (2005) ordered them according to the 179 cycle of the SIM.

Solar inertial motion and floods in Bohemia



The great (disastrous) floods recorded in Vltava river basin (Bohemia, Czech Republic) since AD 1000 and their 30 year moving frequency.

The floods are drawn along the spiral in 179 year cycle. The intervals of the last 50 years without the disastrous floods correspond to the trefoil intervals of the SIM. Summer floods (red) and winter floods (blue) are drawn by the circles. N – number of floods. The figure is taken from Elleder (2005).

The human memory is rather short. Long period without disastrous floods weakened the risk reception. The hunger for building land in the 20^{th} century have been putting more pressure on the countryside including river's floodplains. Floodplain forests were cut down and the areas were built up.