

Semi-periodicity in the air temperatures and humidity over the Czech Republic since 1961

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Abstract

The periodicity of meteorological / climatological variables can be distinguished as short-term (minutes to days), yearly, middle-term (several years to decennia) and long-term. In the case of medium-term climate series, we can rather talk about semi-periodicity. Mean lengths of the middle-term periods were search for data series of measured meteorological variables. The 38 selected meteorological stations were located in whole area of the Czech Republic. Air temperature shows periodicity with main length 8.6, 12, 17.3 and 20.3 years. Most important 12-years period is probably bound with solar activity cycles (length varies between 8 and 14 years, average 11 years). Situation by relative air humidity is more complicated, different periods occurs at different stations. However, six lengths were found in mean data for whole region: 5.1, 7.2, 12, 15.1, 18.9 and 21.3 years. The periodicity is important for occurrence of meteorological extremes as heath waves and droughts, which has ecological significance.

Keywords: middle-term periods, air temperature, relative air humidity, meteorological stations, solar activity cycles

Introduction and methods

Semi-periodic data series where the value (Y) changes depending on the position (X) in the period (interval), while the interval length may not be exactly constant and/or the amplitude of the data in the periods may change. Typical data are weather data, air temperatures for example.

Calculation was done in the IDSDataview software (MATĚJKA 2026) using procedure "Semiperiodicity". The procedure allows estimating the average period length. The principle of the procedure consists in setting the period length and dividing the data into discrete, consecutive intervals according to the variable X. The agreement between the distinguished intervals is expressed as the average variance of the data (Y) calculated over all positions in the respective interval (X_{id}: for first day of the interval X_{id} is equal to zero, for last day it is equal to length of interval minus one). Such a procedure is performed repeatedly for set of the period lengths (L) and a curve of the dependence of the average variance (V) on L is constructed. The most probable average period length corresponds to the local minimum of the average variance. Periods of different lengths can be combined in the data, which is then corresponded to by such a curve with several local minima. This method is similar to the "Phase Folding" method described in the literature.

Data was obtained from selected meteorological stations of the Czech Hydrometeorological Institute (opendata.chmi.cz). Selection was nearly the same as in MATĚJKA ET MODLINGER (2023). The average daily temperatures from selected meteorological stations during interval 1961 – 2024 were stored in a database table, similarly for relative air humidity up to 2025. Running 365-day averages were then calculated. Since temperatures are continuously increasing, a 2nd degree polynomial was used to remove the trend. Linear trend was applied by air humidity. Resulting data series oscillates around zero. The data of this series were used for the calculation by the Semi-periodicity procedure, and the result was a graph of the dependence of the average variance on the length of the interval.

Because the results for all selected stations are very similar (Table 1), so average temperature / humidity series was processed, too.

Because global climate would be moderated by solar activity (e.g. GRAY ET AL. 2010, ERLYKIN ET AL. 2009), it is possible find relation between air temperature cycles and solar activity cycles. A solar activity cycle (e.g. WIKIPEDIA; HATHAWAY 2015) is an approximately 11-year period of fluctuation in the Sun's magnetic field and energy output, characterized by varying numbers of sunspots, solar flares, and coronal loops. It has features of semi-periodicity, with variable period length and amplitude. The cycle progresses from a quiet solar minimum to a peak solar maximum, which includes a reversal of the Sun's magnetic poles. The cycles can range from 8 to 14 years in length (SPACEWEATHERLIVE), with average 11 years for cycles SC19 – SC25.

Results

Air temperature

Total mean increase of air temperature over 38 selected stations was 2.6 °C during 1961–2024, it represents 0.41 °C per 10 years. The highest plus differences from the long-time trend was approximately 1-2 °C. It was occurred in year-average before 10.11.1975 (+1.3 °C), 3.9.1983 (+1.5 °C), 12.12.1994 (+1.1 °C), 15.6.2007 (+2.0 °C), 6.4.2019 (+1.2 °C) and 8.9.2024 (+1.4 °C). Respective minus differences were at 5.3.1963 (-1.9 °C), 2.3.1981 (-1.2 °C), 17.8.1987 (-1.4; and several local minima in 1985), 18.1.1997 (-1.8 °C), 6.6.2006 (-1.3 °C), 5.1.2011 (-1.4 °C) and 28.12.2021 (-1.2 °C) (Fig. 1).

On each variance graph, it is possible to find minima for the length of the interval of 6343, 4373, and 3138 days (Table 1), similarly for average data series (Fig. 2). For several stations, the 7431-day interval was indicated. It is therefore clear that the data of average air temperatures superpose first three cycles (Figs. 3-5). Solar activity cycles fully correspond to the temperature B-period length.

The year-average temperature amplitude within any mentioned period is equal or higher than mean increase of temperatures during 1961–2024.

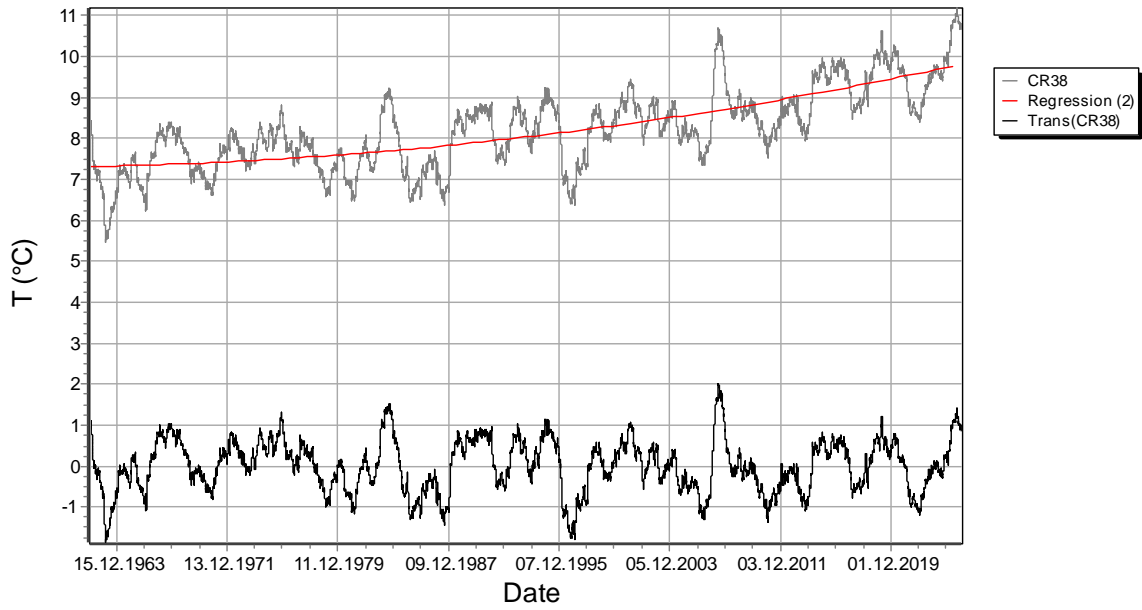


Fig. 1. Original data of running 365-day average temperatures for all selected stations (CR38), quadratic regression and residuals (Trans(CR38)), which represent processed data.

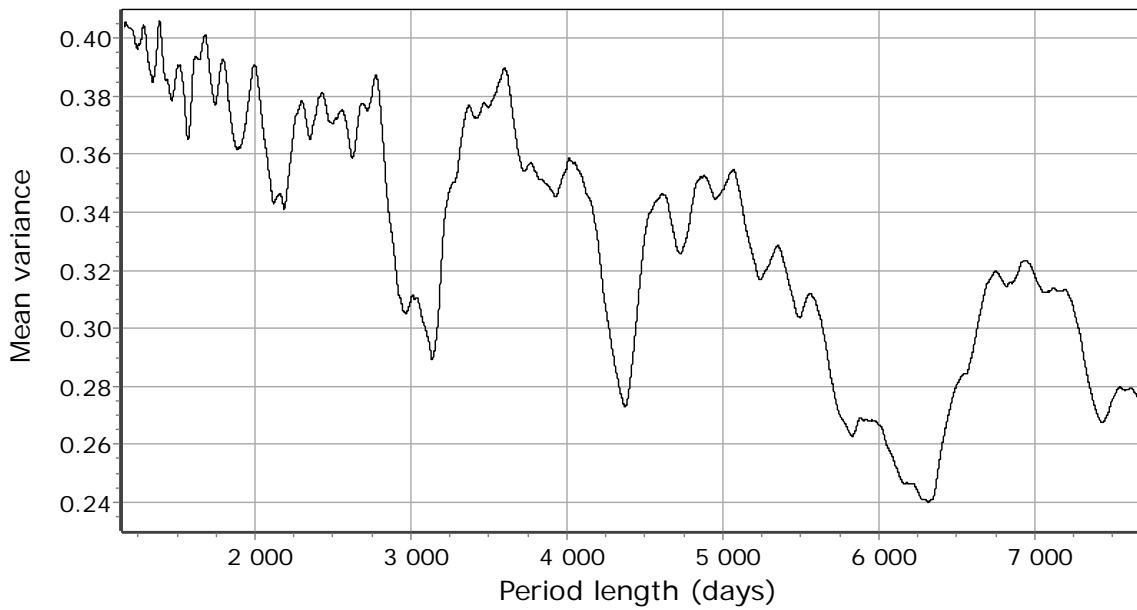


Fig. 2. Mean data variance according to the period length.

Table 1. Mean length (in number of days) of the main periods in data of 365-days air temperature running averages on the selected meteorological stations in the Czech Republic. Data 1961-2024 according to CHMI. Basic periods are marked A, B, C and D. The A' period is hint slightly. AVG – arithmetic average. CR38 – periods calculated from average data from all 38 stations.

Station indicative	A	A'	B	C	D
B1HOLE01	3141		4371	6343	
B1PROT01	3139		4375	6316	
B1STRZ01	3150		4310	6345	7446
B2BTUR01	3138		4373	6318	7439
B2KMYS01	3137		4375	6273	7433
B2KUCH01	3136		4375	6272	
B2LEDN01	3139		4375	6317	7440
B2NEDV01	3138		4373	6275	
B2VMEZ01	3137		4375	6320	7436
C1CHUR01	3137		4374	6343	
C1VRAZ01	3136	2966	4375	6345	7433
C2CBUD01 *	3136		4377	6274	7439
C2JHRA01	3137		4377	6311	7431
C2TABO01	3133	2967	4373	6147	7434
C2VBRO01	3137	2970	4381	6344	7469
H3HRAD01	3139		4370	6313	
H3SVRA01	3138		4373	6344	7430
L1KLAT01	3137	2966	4376	6148	7438
L2KRAL01	3137	2966	4375	6145	7438
L2PRIM01	3137	2952	4372	6147	
L3CHEB01	3078		4374	6151	
O1CERV01	3139		4375	6322	
O1LYSA01	3139		4371	6342	
O1MOSN01	3136		4376	6312	
O1OPAV01	3133		4375	6144	
O2OLOM01	3138		4371	6318	
O2PASE01	3150		4368	6348	
O3PRER01	3140	2966	4374	6324	7442
O3VALM01	3138	2966	4372	6324	7430
P1PKAR01	3138		4371	6316	
P1PKLE01	3136	2966	4373	6153	
P1PRUZ01	3136		4373	6151	
P2BRAN01	3137		4372	6160	
P2SEMC01	3138		4369	6152	
P3PRIB01	3142		4382	6346	7438
U1DOKS01	3077		4368	6149	
U1ZATE01	3133		4374	6149	
U2LIBC01	3138		4373	6273	
AVG	3134.9	2965.0	4372.0	6265.1	7438.5
CR38 (days)	3138	2967	4373	6315	7431
CR38 (years)	8.59	8.12	11.97	17.29	20.34

* The České Budějovice station was added to the original set (Matějka et Modlinger 2023).

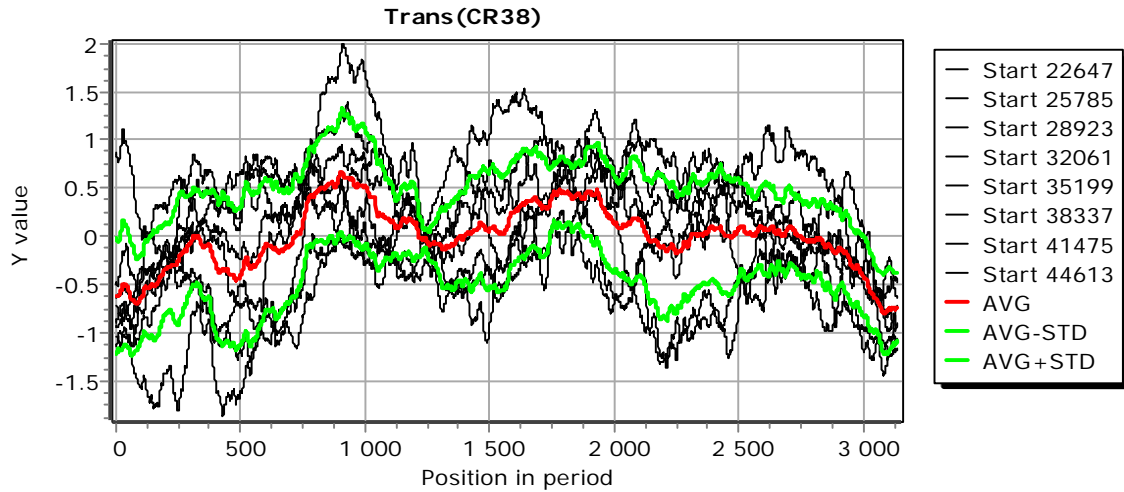


Fig. 3. Data variability with the period length 3138 days. Start indicates number of days since 1.1.1900 (=1).

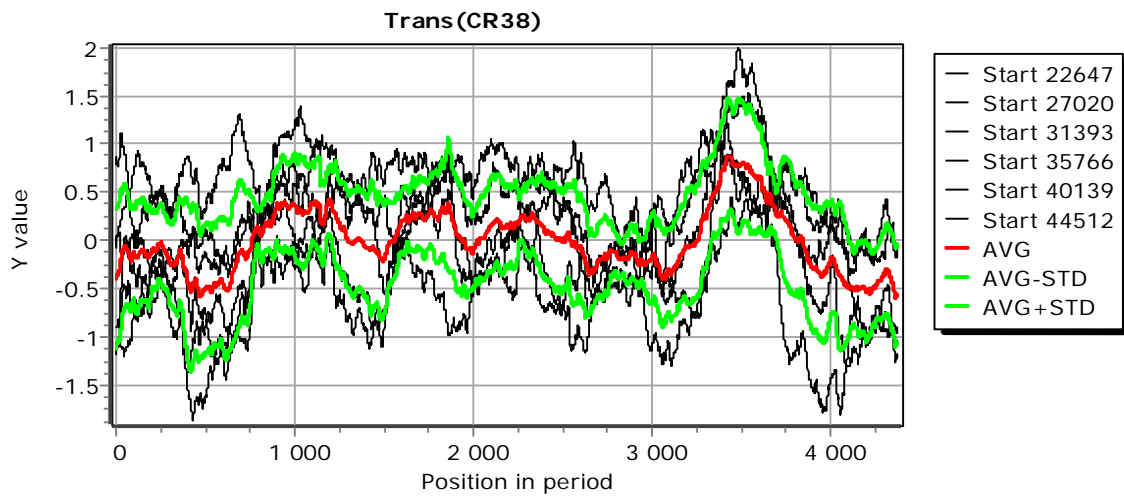


Fig. 4. Data variability with the period length 4373 days. Start indicates number of days since 1.1.1900 (=1).

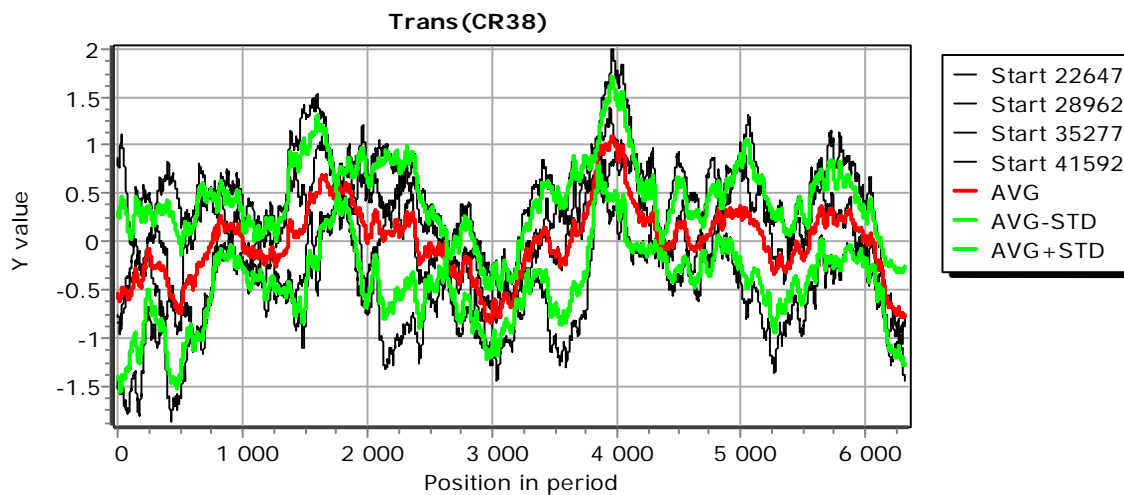


Fig. 5. Data variability with the period length 6315 days. Start indicates number of days since 1.1.1900 (=1).

The temperature extraordinary heats mirror in some ecological processes. For instance, the bark beetle (*Ips typographus*) felling of Norway spruce in the Czech Republic according to LOS (2001-2025) shows irregular periodicity (Fig. 6) with maxima in years 2020 and 2009. The big calamity was observed in the Šumava Mts. (the region of Modrava) at 1996. Mean distance between these events was also 12 years.

The above-mentioned temperature period lengths, or rather the longest twenty-year period, also correspond to the period length found in the analysis of beech tree ring widths, which are correlated with solar activity cycles (KOMITOV 2021).

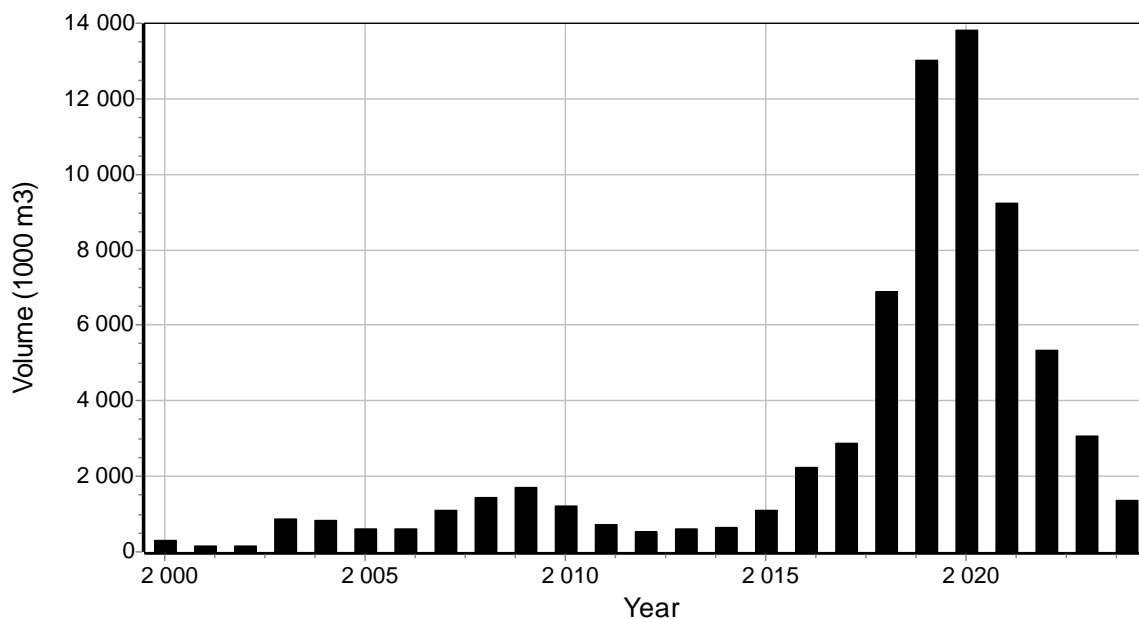


Fig. 6. The bark beetle felling of Norway spruce in the Czech Republic according to LOS (2001-2025).

Relative air humidity

Variation in air humidity is less regular, nevertheless several periods of different lengths was found (Fig. 7). Significant break in the data series occurred near 29.7.1995 (probability of F less than 0.1 %). This break is located near middle of data. Mean yearly decrease of air humidity was 0.101% and 0.169% in first and second interval, respectively. The firstly mentioned break 1994/1995 was in analyse of data from meteorological station Churáňov (Matějka 2014)

Data variance graph (Fig. 8) reveals periods of different lengths, which are observed in single stations. The most evident lengths are 1858 days (5.1 years), 2608 days (7.2 years), 4382 days (12 years), 5523 days (15.1 years), 6886 days (18.9 years) and 7769 days (21.3 years). The pronounced period of 15.1 years (Fig. 9) points to distance between synchronized wet and dry years (8.2 years) and between dry and wet ones (6.9 years).

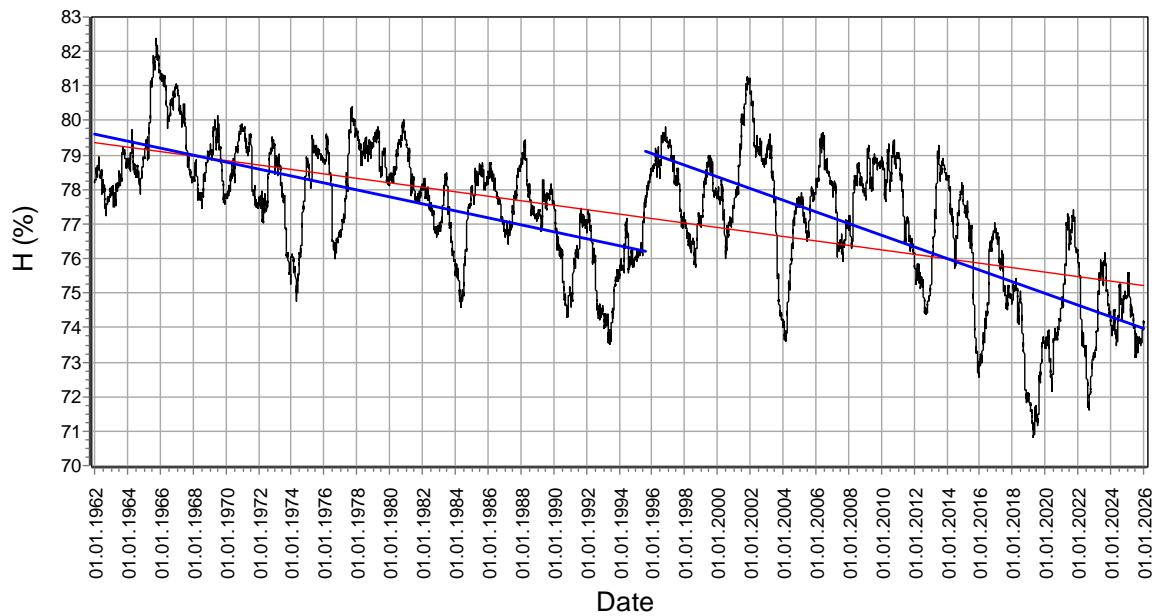


Fig. 7. Original data of running 365-day average relative air humidity for all selected stations (CR38) and linear regression (red) and broken line regression (blue).

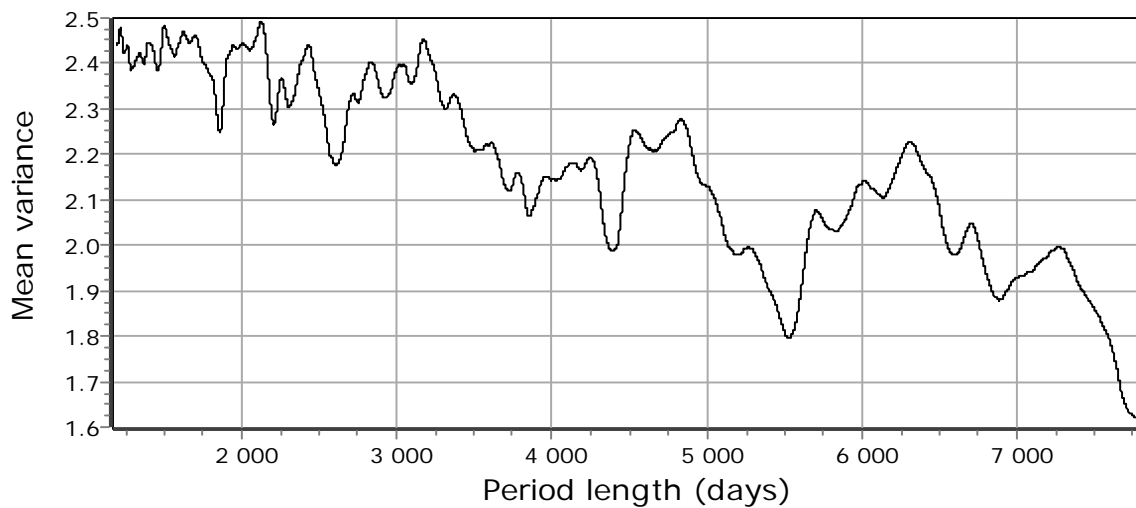


Fig. 8. Mean air humidity data variance according to the period length.

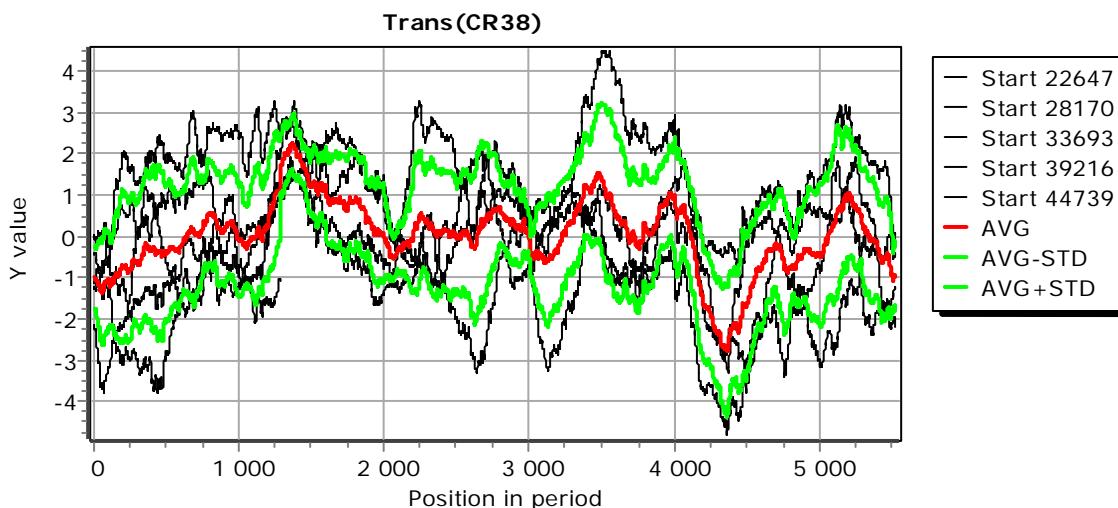


Fig. 9. Air humidity data variability with the period length 5523 days. Start indicates number of days since 1.1.1900 (=1). Distance between maximum and minimum is 2997 days (8.2 years), between minimum and subsequent maximum is slightly shorter 2526 days (6.9 years).

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