SHORT TERM GLOBAL DT PREDICTION USING (60-70)-YEARS PERIODICITY

by

Alexey A. Lyubushin and Leonid B. Klyashtorin (Russia)

Reprinted from

ENERGY &
ENVIRONMENT

VOLUME 23 No. 1 2012

MULTI-SCIENCE PUBLISHING CO. LTD.
5 Wates Way, Brentwood, Essex CM15 9TB, United Kingdom

SHORT TERM GLOBAL DT PREDICTION USING (60-70)-YEARS PERIODICITY

Alexey A. Lyubushin[1], Leonid B. Klyashtorin[2]

[1] Institute of the Physics of the Earth, Russian Academy of Sciences, Moscow, Russia. 123995, Moscow, Russia, Bolshaya Gruzinskaya, 10; e-mail: lyubushin@yandex.ru
Phone: +7-499-254-23-50, Fax: +7-499-766-26-54.
[2] Federal Institute for Fisheries and Oceanography (VNIRO), 107140 Moscow, Bolshaya Krasnoselskaya, 17, Russia. e-mail: klyashtorin@mtu-net.ru

ABSTRACT

The variations of climate with periods within the narrow-banded range from 60 up to 70 years are considered. The existence of climate variations with these periods is proved by time-frequency spectral analysis of scalar time series and by joint multiple spectral analysis of 3 well-known synchronous climatic time series covering the time interval 553-1973. Prediction of global temperature anomaly *dT* based on applying cyclic trend with period 66 years was made for the future time interval of the length 20 years. The main peculiarity of this prediction is the decreasing of global *dT* (i.e. global cooling instead of global warming) which started at 2008 and will be continuing during 2011-2030. Estimates of cyclic trends for temperature anomalies of North and South hemispheres separately give periods 69 and 63 years correspondently. These results are based on using of *dT* data for time interval 1850-2010. They confirm the earlier results of authors which was published at 2003 about starting the global cooling process at 2008. If the global cooling cyclic trend for nearest 20 years will be approved this will have a serious consequences in changing of global energetic politics. For example, extensive plans about using Arctic resources in the near future, as is now frequently announced by governments in connection with the melting ice cover of the Arctic Ocean, are out of question.

INTRODUCTION

The climate system possesses a series of periodic variations. The most famous are Milankovitch cycles with periods 26, 41 and 93 thousands years which are connected with precession of Earth's orbit (Hays, Imbrie, Shackleton, 1976). There exist a number of decadal periodicities in climatic time series which are associated with periodicity of solar activity or El Nino phenomena (Ghil and Vautard, 1991; Mock and Hibler, 1976; Mitchell, Jr., Stockton and Meko, 1979). In this article we continue investigation of climate periodicities with periods from 60 up to 70 years which we previously published (Klyashtorin and Lyubushin, 2003, 2007) based on analysis of instrumental global temperature anomaly for the period 1861-1999AD and Greenland mean winter temperatures reconstruction time series for time interval 553-1973AD (Dansgaard, W. et al., 1975).

The existence of low-frequency periodic components provides the possibility to improve prediction of time series. It is well known that the problem of forecasting future values of a time series according to its behavior in the past is one of the most complicated in applied statistics. The classical approach invokes the use of correlations (linear statistical dependence) of neighboring signal values and forecasts for one or more steps ahead formed as a sum of a defined number of the previous values, using the weighting coefficients. Implementing this generates a linear autoregression model (Box, Jenkins, 1970). The values of weight coefficients (autoregression coefficients) are determined by minimization of the sum of these past forecast's error squares. However, while forecasting not for only one but for several steps ahead, as in classical linear models, the forecast variances begin growing rapidly and several steps later yields an asymptotic limit, which is the value of general variance of the signal. The latter means that the autoregression prediction is reduced to a trivial level, when a simple mean value of the signal calculated from the previous values is used as the predictor.

A more effective solution, which increases the "long-range ability" of the predictor, is achieved by applying the cyclic trend of the time series. If we succeed in this, forecasting of several steps ahead is reduced to a simple extrapolation of the trend function values to future time intervals of a given length. Due to the existence of strong harmonic components for climatic time series "long-range" forecasting is possible by invoking the cyclic trend within a given period. For this style of forecasts, the key factor determining its efficiency is the correct determination of the period of the dominant cyclic trend (after which, determination of amplitudes and phases of harmonics become the exclusive technical problem). It should be emphasized that after analyzing real data, we have rejected using any model containing several harmonics, and retained just one, which represents the dominant oscillation. This decision was made after consideration of the need for the enhanced statistical significance of our forecasts, for which it is necessary to introduce the minimum necessary number of parameters to the model.

In (Klyashtorin and Lyubushin, 2003, 2007) the dominating period 64 years was determined from the instrumental global *dT* data, and a cyclic trend prediction was made for the time interval 2000-2030AD. According to this prediction the "global warming" would stop at 2008 and a "global cooling" would begin, continuing up to 2030. According to time spectral analysis of Greenland ice core data the 60-years climate periodicity has existed for at least 1000 years.

In this paper we confirm the existence of near 60 years climatic periodicity by adding analysis of 2 more tree rings time series and the continuing "global cooling" trend up to 2030 by analyzing instrumental global *dT* data for time interval 1850-2010.

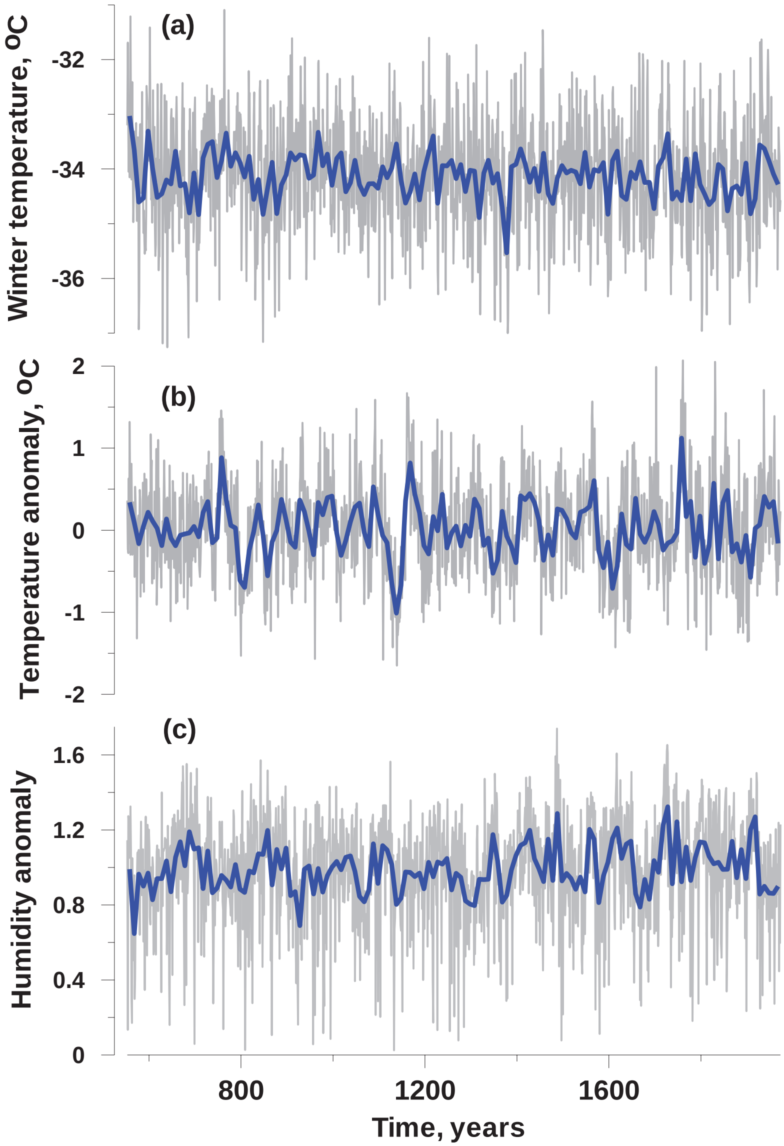

Figure 1. Graphics of 3 synchronous climatic time series covering time interval 553-1973AD. Grey lines correspond to 1 year sampling time interval whereas bold blue lines correspond to time series of successive 10-years mean values which will be analyzed further on. Graphic (a) presents reconstruction of mean winter temperatures in Greenland by measurements of ^{18}O concentration within ice cores. Graphic (b) presents temperature anomaly in Sweden estimated by tree rings of arctic pine. Graphic (c) corresponds to the (553-1973AD) fragment of a very long time series of humidity estimate in Southern California by tree rings of mountain pine for 6000 B.C. till 1979 A.D.

DATA

Signal (a) presents reconstruction of mean winter temperatures in Greenland for time interval 553-1973AD based on analysis of ice cores (Dansgaard, W. et al., 1975). Polar glaciers contain paleo-climatic information in the form of the isotopic composition of the oxygen as described by deviation of the heavy oxygen isotope O^{18} concentration in the ice from that of Standard Mean Ocean Water. The most suitable location to perform global paleo-temperature reconstruction using this method is the central region of the Greenland ice sheet, where the conditions for snow and ice accumulation are believed to have remained stable over the last 2000 years. Reconstruction of temperature in the ice cores is based on the so-called "isotopic effect". Some proportion of water molecules are known to contain heavy oxygen O^{18} instead of the more "usual" O^{16} isotope. The proportion of heavy molecules in water vapor is lower than in oceanic water, but increases as the temperature increases. Water evaporated from the vast surface of the North Atlantic was transferred by the atmospheric streams into the Greenland region where it was precipitated as snow and then turned into ice layers. Concentrations of heavy isotopes O^{18} in the ice specimens can be determined with a high accuracy using the mass-spectrometry.

Signal (b) presents temperature anomaly in Sweden estimated by tree rings of arctic pine (Briffa K.R. et al., 1990) for time interval 500-1980AD.

Signal (c) presents a very long time series of humidity estimate in Southern California by tree rings of mountain pine for 6000 B.C. till 1979 A.D. (Graybill, Rose and Nials, 1994). We analyze these signals within their shared common time interval of 553-1973AD - see Fig.1.

Global and Northern/Southern Hemispheres temperature anomalies (Lawrimor J., et al., 2001) could be downloaded from the internet address:
http://www.cru.uea.ac.uk/cru/data/temperature/

MULTIPLE SPECTRAL COHERENCE MEASURE

Next we performed a joint analysis of the 3 time series (a), (b) and (c) with the purpose of detecting frequency bands where these signals have synchronous variations, although amplitudes of these variations could be less than "individual" variations in other frequency bands. For this purpose we need to apply the concept of multiple coherence measure which is an extension of usual squared coherence spectrum between 2 time series.

The multiple spectral measure of coherence $\lambda(\tau,\omega)$ was proposed in (Lyubushin, 1998) for purposes of earthquake prediction by extracting coherent effects in variations of multidimensional geophysical monitoring time series within moving time window. It is constructed as the module of the product of component-by-component canonical coherences (Hannan, 1970)

$$\lambda(\tau,\omega) = \prod_{j=1}^{m} |\nu_j(\tau,\omega)| \tag{1}$$

Here, $m \geq 2$ is the total number of jointly analyzed time series; ω is frequency; τ is the time coordinate of the right-hand end of the moving time window consisting of a definite number of neighboring samples; and $\nu_j(\tau,\omega)$ is the canonical coherence of the j-th scalar time series, which describes the strength of coupling of this series with all the other series. The quantity $|\nu_j(\tau,\omega)|^2$ is the generalization of the ordinary squared spectrum of coherence between two signals for the case, when the second signal is not scalar but vector. The inequality $0 \le |\nu_j(\tau,\omega)| \le 1$ is fulfilled, and the closer the value of $|\nu_j(\tau,\omega)|$ to unity, the stronger the linear relation of variations at the frequency in the time window with the coordinate τ of the j-th series to analogous variations in all other series. Accordingly, the quantity $0 \le \lambda(\tau,\omega) \le 1$, due to its construction, describes the effect of the cumulative coherent (synchronous, collective) behavior of all the signals.

Note that due to the construction of the quantity $\lambda(\tau,\omega)$, its values fall within the interval [0,1], and the closer the corresponding value to unity, the stronger the relation between variations in the components of the multidimensional time series at the frequency for the time window with the coordinate τ. It should be emphasized that the comparison of absolute values of the statistics $\lambda(\tau,\omega)$ is possible only for the same number m of simultaneously processed time series, because, due to formula (1), if m increases, $\lambda(\tau,\omega)$ decreases as the product of m, resulting in values smaller than unity. In our case $m = 3$. To realize this method, it is necessary to have an estimate of the spectral matrix of the initial multidimensional series in each time window. We chose to use the model of vector autoregression (Marple, Jr., 1987) of the 6th order which provides sufficient spectral resolution for short time windows.

EXISTENCE OF 60-70 YEARS CLIMATIC PERIODICITIES: TIME-FREQUENCY SPECTRAL AND JOINT MULTIPLE SPECTRAL ANALYSIS

Time-frequency 2D diagrams (a,b,c) in the left-hand column of Fig.2 present temporal dynamics of spectral composition whereas right-hand column of 1D graphics give results of averaging power spectral estimates from all moving time windows. It is evident that signals (a) and (b) each contain a near 60-years component: for the ice cores signal (a) from Greenland it exists at the final part of observation, during last 1000 years (taking into account the 640 years length of the moving time window) whereas the tree ring signal (b) from Sweden contains this component throughout the time interval 553-1973AD. The tree ring signal (c) from California has a periodic component with near 70 years period.

Figure 2(d) presents results of the joint multidimensional spectral analysis of 3 signals (a), (b) and (c) simultaneously with the purpose of detecting periods where these signals are the most coherent. Using spectral statistics (1) suppresses individual noise within each signal and underlines common periodic components. The left-column 2D time-frequency diagram at Fig.2(d) yields evidence of the existence of common periodic variations within all the analyzed signals with periods from 50 up to 70 years. The mean values of multiple coherence presented at the right-column 1D Fig.2(d) supports ~60 years as the period of maximum coherent effect.

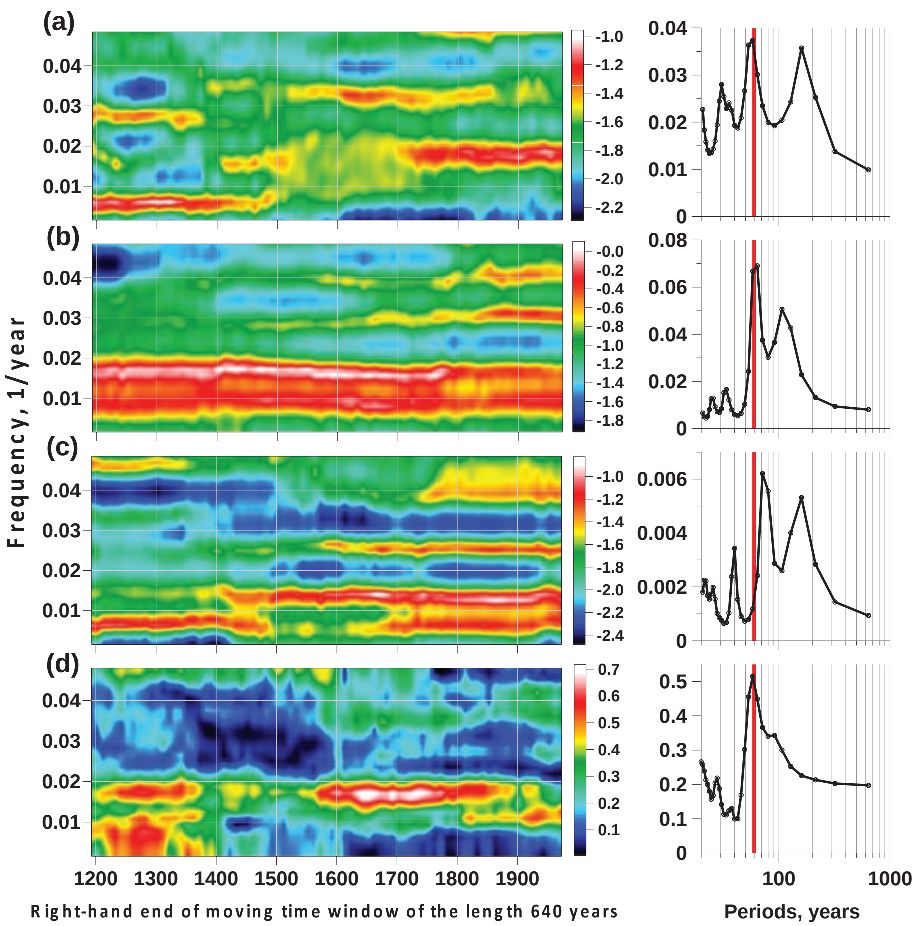

Figure 2. Time-frequency diagrams (a), (b) and (c) from left-hand column correspond to evolution of decimal logarithm of power spectra estimates of time series (a), (b) and (c) from Fig.1 after coming to 10 years sampling time intervals (bold blue lines at Fig.1) within moving time window of 640 years length (i.e. 64 values of 10-years samples). Maximum entropy AR(10) spectral density estimates within each time window were used. Time-frequency diagram (d) from left-hand column presents evolution of multiple spectral coherence measure of signals (a), (b) and (c) within moving time window of 640 years length. Vector AR(6)-model for estimating 3-dimensional spectral matrix within each time window was used. Graphics from right-hand column present spectral functions in dependence on periods obtained by averaging spectral estimates from all moving time windows from corresponding time-frequency diagrams from left-hand column. Thus, right-column graphics (a), (b) and (c) present mean spectral density estimates of signals (a), (b) and (c), whereas right-column graphic (d) presents mean multiple coherence measure of signals (a), (b) and (c). Vertical red lines indicate period of 60 years.

FITTING CYCLIC TRENDS TO TEMPERATURE ANOMALIES

The next step is to apply a cyclic trend predictor, similar to the method from (Klyashtorin and Lyubushin, 2003, 2007), and include the recent instrumental data to update temperature anomaly , which are now available for time interval 1850-2010.

These observations provide a basis for the prediction of behavior of low-frequency variations of global *dT* for the near-future decadal time intervals. First, we selected the interval length of 30 years (approximately half of the period of the dominant harmonic). Then, we evaluated parameters of the linear trend for the entire time interval and subtracted it from the analyzed time series of *dT*. To the resulting residual (after subtraction of the linear trend) we fit the best harmonics with some period (our dominant cyclic trend) and finally, we calculated the values for the time period 2000-2030. When this is done, we then return the eliminated general linear trend to the whole. The standard deviation of the residual after subtraction of the linear and cyclical trends will thus set the intervals of errors of the forecast.

In this sequence of operations the main issue is the choice of period **T** of a cyclic trend. As we are interested in the prediction for only a rather short interval of time (30 years), it is logical to select a value of **T** which in the best way reflects cyclic dynamics of *dT* just for the most recent period of instrumental observations.

For a determination of **T** the following approach was used. We set some interval of probable values of **T**. It is possible to find harmonics for each period of a cyclic trend from this long time interval. The best way is through fitting variations of *dT* after removal of the general linear trend. The residual after removing a cyclic trend with a given period will be characterized by standard deviations dependent upon values for the entire period. We then select the period **T** setting the conditions by using the period providing the minimum standard deviation of the residuals.

30-YEARS AHEAD CLIMATE PREDICTION USING *DT* CYCLIC TRENDS

Figure 3 presents the results of applying these cyclic trend predictors to instrumental temperature anomalies. Fig.3(a) is taken from (Klyashtorin and Lyubushin, 2003) for comparison with the updated *dT* data which became available during 2000-2010. Fig.3(b) provides evidences that our previous cyclic trend predictor caught the main features of global *dT*, and, that it is in good accordance with the more recent data: the “global warming” process really stopped at 2008 and the bend in the trend toward “global cooling” could actually be recognized.

Figure 3(c) compares cyclic trend predictors separately for Global, North and South hemispheres. It should be noticed the difference between dominant harmonics periods (66 years for global *dT* and 69 and 63 years for North and South hemispheres). Thus, according to these predictors, “cooling” of the South hemisphere began 2 years earlier than “global cooling” and it will stop at 2030, whereas global and North hemisphere cooling will continue.

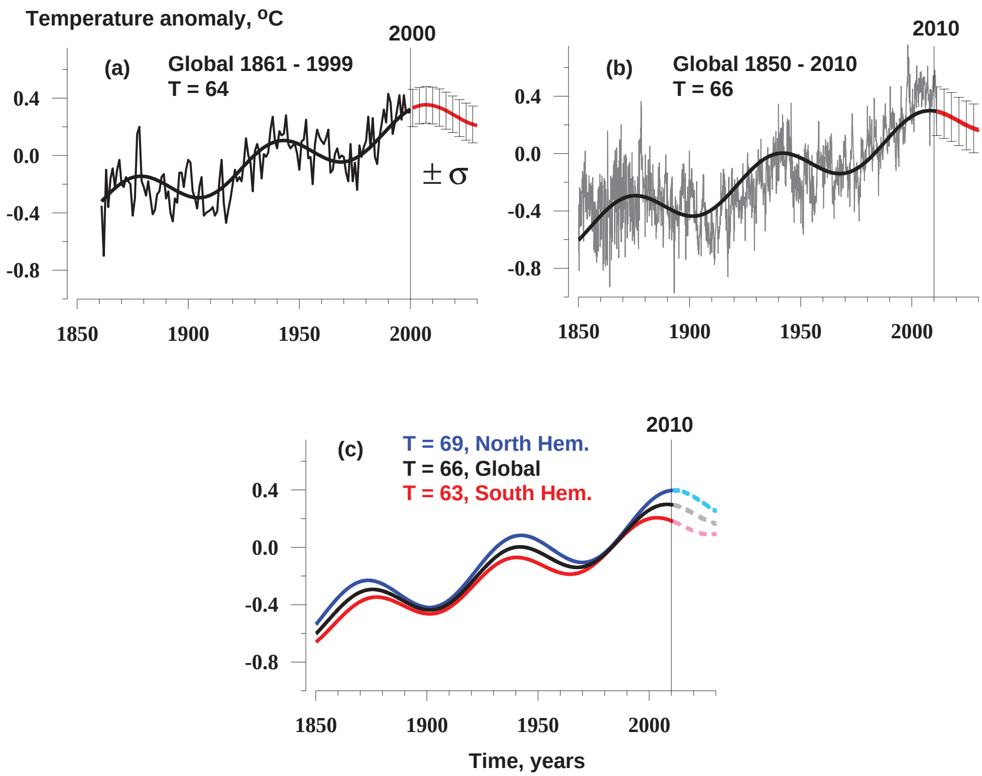

Figure 3. Cyclic trends of instrumental temperature anomalies and their using for prediction. Graphics (a): thin black line - annual global *dT* for time interval 1861-1999AD; bold black line - best fitted cyclic trend with period 64 years; red line with standard deviation error bars - interpolation of cyclic trend to time interval 2000-2030 proposed for prediction of global *dT* in the paper published at 2003. Graphics (b): thin black line - monthly global *dT* for time interval 1850-2010AD; bold black line - best fitted cyclic trend with period 66 years; red line with standard deviation error bars - interpolation of cyclic trend to time interval 2011-2030. Graphic (c): red, black and blue lines corresponds to best fitted cyclic trends of Southern Hemisphere, Global and Northern Hemisphere monthly temperature anomalies with periods 69, 66 and 63 years correspondently; dashed lines after 2010 present prognostic interpolations of cyclic trends for time interval 2011-2030.

CONCLUSION

The existence of 60-70 periodical components of climate variations during the recent 1000 years provides a simple and effective tool for making temperature anomaly prediction for 20-30 years ahead using cyclic trend predictors via continuing use of renewed estimates of current dominating period. It should be noticed that conclusions about bending the climate dynamic from “global warming” to “global cooling” were derived from different data analysis in papers (Landscheidt, 2003; Loehle, 2009(a,b); Zhen-Shan and Xian, 2007). The existence of periodic components in natural climate variations with periods from 55 to 70 years were obtained by different authors, for instance (Schlesinger and Ramankutty, 1994; Knudsen et al., 2011).

The climate variations with periods 60-70 years cause the response in the volume of catches of the main oceanic fishes (Klyashtorin, 2001; Klyashtorin and Lyubushin, 2007). Taking into account natural periodic variations of oceanic fishes catches which are caused by climate cyclic trends is extremely important for prediction of ocean food resources consuming (Klyashtorin, 2001; Klyashtorin, Borisov and Lyubushin, 2009). Near 70-years periodicity was derived in (Soutar and Isaacs, 1974; Soutar and Crill, 1977) in their analyses of the anoxic Santa Barbara sediment cores. Although there exist other periodic components of climate variation with periods 6-8 and 20 years the component with 60-70 years period is the most prominent (Klyashtorin and Lyubushin, 2007; Zhen-Shan and Xian, 2007). In the paper (Knudsen et al., 2011) a hypothesis that climate oscillation with periods 55-70 years was directly forced by periodic changes in solar activity was tested and rejected. From our point of view the reason for such periodicity could be the nonlinear climate dynamics and existing of some hidden climate attractor with quasi-periodic trajectory which is similar to the leafs of well known Lorentz attractor. Thus, the reason for existing of 60-70 periodicity lays inside the nonlinear character of climate dynamic and it is not induced by some cosmic or other external factors.

ACKNOWLEDGEMENTS

The authors feel great gratitude to Dr. Gary Sharp of the Center for Climate/Ocean Resources Study, Salinas, California, USA, for his continued support of our investigations, including his comments and editorial contributions to this paper.

REFERENCES

1. Box, G. and Jenkins, G., 1970, Time series analysis: Forecasting and control, San Francisco: Holden-Day.
2. Briffa K.R. et al., 1990, A 1400 year tree-ring record of summer temperatures in Fennoscandia. *Nature* 346:434–439.
3. Dansgaard, W. et al., 1975, Climatic changes, Norsemen and modern man. *Nature* 255:24-28.
4. Ghil, M., Vautard, R., 1991, Interdecadal oscillations and the warming trend in global temperature time series. *Nature* 350:324-327.
5. Graybill, D.A., M.R. Rose, and F.L. Nials, 1994, Tree-rings and climate: implications for Great Basin paleoenvironmental studies, High Level Radioactive Waste Management: *Proceedings of the Fifth Annual International Conference*, 2569-2573.

6. Hannan E.J., 1970, Multiple time series. John Wiley and Sons, Inc., N.Y., London, Sydney, Toronto.

7. Hays, J.D.; Imbrie, J.; Shackleton, N.J., 1976, Variations in the Earth's Orbit: Pacemaker of the Ice Ages. *Science* 194:1121–1132.

8. Knudsen M.F., et al., 2011, Tracking the Atlantic Multidecadal Oscillation through the last 8,000 years, *Nat. Commun.* 2:178 doi: 10.1038/ncomms1186.

9. Klyashtorin, L.B.., 2001, Climate change and long-term fluctuations of commercial catches: the possibility of forecasting. *FAO Fisheries Technical Paper No. 410* Rome, FAO. ftp://ftp.fao.org/docrep/fao/005/y2787e/y2787e01.pdf

10. Klyashtorin L.B. and A.A. Lyubushin, 2003, On the coherence between dynamics of the world fuel consumption and global temperature anomaly. *Energy & Environment* 14:773-782.

11. Klyashtorin L.B. and Lyubushin A.A., 2007, *Cyclic Climate Change and Fish Productivity* /Editor of English version of the book Dr. Gary D. Sharp, Center for Climate/Ocean Resources Study, Salinas, California, USA. – Moscow, VNIRO Publishing (2007)
http://alexeylyubushin.narod.ru/Climate_Changes_and_Fish_Productivity.pdf

12. Klyashtorin, L.B., V. Borisov, and A. Lyubushin. 2009. Cyclic changes of climate and major commercial stocks of the Barents Sea. *Marine Biology Research* 5:4-17.

13. Landscheidt, T. 2003. New Little Ice Age instead of global warming? *Energy and Environment* 14:327-350.

14. Lawrimor J., et al., 2001, Climate Assessment. *Bull. of the American Meteorological Society*, 82:1304-1380.

15. Loehle, C. 2009. Cooling of the global ocean since 2003. *Energy & Environment* 20:99-102.

16. Loehle C., 2009, Trend Analysis of Satellite Global Temperature Data. *Energy & Environment* 20:1087-1098.

17. Lyubushin A.A., 1998, Analysis of Canonical Coherences in the Problems of Geophysical Monitoring. *Izvestiya, Physics of the Solid Earth* 34:52-58.

18. Marple S.L.(Jr.), 1987, Digital spectral analysis with applications. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

19. Mitchell, Jr., JM, Stockton, CW, Meko, DM. , 1979, Evidence of a 22-year rhythm of drought in the western United States related to the Hale solar cycle since the 17th century. *In: McCormac, BM, Seliga, TA, editors. Solar-terrestrial influences on weather and climate*. Dordrecht, Holland: Kluwer Acad. Publ; 1979. p.125-143.

20. Mock, SJ, Hibler III, WD., 1976, The 20-Year oscillation in Eastern North American temperature records. *Nature* 261:484–486.

21. Soutar, A. and J.D. Isaacs, 1974, Abundance of pelagic fish during the 19th and 20th centuries as recorded in anaerobic sediments of the California. *Fish. Bull.* 72:257-273.

22. Soutar, A. and P.A., 1977, Crill. Sedimentation and climatic patterns in the Santa Barbara Basin during the 19th and 20th centuries. *Bull. Geol. Soc. of America* 88:1161-1172.

23. Schlesinger, M.E. and N. Ramankutty. 1994. An oscillation in the global climate system of period 65-70 years. *Nature* 367(6465):723-726.

24. Zhen-Shan, L. and S. Xian, 2007, Multi-scale analysis of global temperature changes and trend of a drop in temperature in the next 20 years. *Meteorology and Atmospheric Physics*. 95:115-121.