Signals in Reverse Time from Heliogeophysical Random Processes and their Employment for the Long-term Forecast

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Quantum mechanical principle of weak causality admits signaling in reverse time for the genuine random processes. It reflects in the heuristic equation of macroscopic nonlocality. Series of the long-term experiment had been revealed availability of the advanced response of random dissipative probe processes in the lab detectors to the large-scale dissipative heliogeophysical processes with big random component. The level of advanced correlation and time shift allowed to put forward the forecasting problem. This problem has been solved and successfully tested on all available experimental data of enough volume for the of long-term forecast series of the solar and geomagnetic activity.

1. Introduction

Since 1930-th phenomenon of quantum nonlocality has been attracting attention, above of all in connection with apparent violation of relativity. Indeed quantum correlations occur through a spacelike interval, that is possible namely due to absence of any local carriers of interaction. But it remains to be strange, because such correlations imply possible reversal of time ordering. The mainstream of quantum information research avoids this question, as from the outset it had been realized that quantum nonlocal channel could transmit through spacelike interval only *unknown* information, and therefore for the communication purposes one should use an ancillary classical channel. Therefore that question becomes irrelevant.

Cramer [1,2] suggested an elegant transactional interpretation of quantum nonlocality leaned upon Wheeler-Feynman action-at-a-distance theory. By Cramer transaction through spacelike interval need not superluminal speed, it carries out by a couple of the signals traveling in direct and reverse time. It is very natural idea, because Wheeler-Feynman theory is nonlocal itself. Cramer was also the first who explicitly distinguished the principles of strong (local) and weak (nonlocal) causality [1]. The latter implies a possibility of signal transmission in reverse time, but only related with unknown states, or in other terms with genuine random processes. The weak causality admits extraction information from the future without any classical paradoxes. Although Cramer's works had some internal contradiction – explanation of quantum phenomena on the base of classical Wheeler-Feynman theory, now the successively quantum versions of action-at-a-distance theory have been developed [3,4]. On the other hand, as it was generally believed that quantum nonlocality existed only at the micro-level, Cramer supposed that that strong causality might be violated only at this level. However the idea about persistence of nonlocality in the macroscopic limit was put forward from different standpoints [5-9]. In addition the important experimental results were obtained by Kozyrev before the emergence of these ideas, in the framework of causal mechanics concept (and interpreted in another terms), which demonstrated phenomena very similar to macroscopic nonlocality [10], in particular advanced correlations for the (random) dissipative processes [11-13].

The progress in quantum mechanics shed a new light on Kozyrev's works inspired the authors on performance of own experiments [14-25]. As a result, the availability of advanced correlations, that is in literal sense the signals in reverse time, has been reliable revealed for some large-scale random dissipative astrophysical and geophysical source-processes and the probe-processes in the lab detectors highly protected against the local impacts. The correlation magnitude and advancement value proved to be large. It allowed to suggest employment of this phenomenon for the forecast of such source-processes.

In this paper we present the approach to and result of solving the forecast problem for the random component of solar and geomagnetic activity on the base of measurement of nonlocal correlation detector signals in reverse time.

2.Model of macroscopic nonlocal transaction

In spite of the recent progress [5-9], development of the successive theory of macroscopic entanglement (which has to resemble classical thermodynamics, i.e. to operate with the macroscopic parameters) is difficult task and such theory is absent at present. For some cases the macroscopic consequences of entanglement were theoretically predicted, and corresponding experiments were performed [26,27], but they included only deterministic processes, irrelevant to the time reversal problem. At microscopic level the idea of experimental detection of time reversed events was suggested [28], but it have not been realized yet. On the other hand, an important feature of Kozyrev's experiments was dissipativity of the processes. Although it is known that dissipativity leads to decoherence, recently the constructive role of dissipativity in entanglement generation was discovered [29,30].

On the base of those ideas the following heuristic equation of macroscopic nonlocality, relating the entropy production per particle in the probe-process (detector) $\dot{S}_d$ and the density of total entropy production in the sources $\dot{s}$ with symmetrical retardation and advancement has been suggested [14,16,18,19]:

$$\dot{S}_d = \sigma \int \frac{\dot{s}}{x^2} \delta\left(t^2 - \frac{x^2}{v^2}\right) dV , \tag{1}$$

where a cross-section $\sigma \sim \hbar^4 / m_e^2 e^4$, m_e is electron mass, e is elementary charge, $\dot{s}$ is density of the entropy production in the sources, x is distance, t is time, propagation velocity v for diffusion entanglement swapping can be very small, the integral is taken over the source volume.

Let us demonstrate correspondence of heuristic (1) with the strict quantum mechanical result developed for a dilute spin gas [9]. In Ref. [9], for partition of the system A-B, the following equation is obtained:

$$S_A \approx \frac{N_A N_B}{N-1} rt(2 - \log_2 e) , \tag{2}$$

where numbers of particles $N_A + N_B = N$, r is collision rate.

For adaptation (1) to conditions of model (2), forget about time shift and integrate over time, neglecting the irrelevant integration constant. Then (1) in the steady-state regime reduces to:

$$S_d = \sigma \int \frac{s}{x^2} dV . \tag{3}$$

Consider the detector as a small part A of the large homogeneous system. Correspondingly our "sources" proves to be the part B. Then:

$$\frac{S_A}{N_A} = \sigma \frac{S_B}{L^2} , \tag{4}$$

where L is the space size of the system.

Now slightly transform (2), taking into account assumption that mean free path compatible to the size of the enclosing volume [9]. That is $t = L / \langle v_r \rangle$, therefore $rt = \sigma Ln$, where $n = N / V$. On the other hand, $Ln \approx N / L^2$, $rt \approx \sigma N / L^2$. Assume $N >> 1$. At last use ln (not $\log_2$) in the entropy definition (because it was always adopted in our entropy calculation [14,16,18,19]). As a result we can rewrite (2):

$$\frac{S_A}{N_A} \approx \sigma \frac{0.3863 N_B}{L^2} . \tag{5}$$

We have obvious correspondence (4) and (5) with $S_B \approx 0.3863 N_B$.

This correspondence encourage to consider the equation of macroscopic nonlocality (1) as at least a not too bad approximation of reality.

Eq.(1) in it simples form its completely time symmetric. It is a consequence of time symmetry of original Wheeler-Feynman approach. Known agreement with observed time asymmetry was achieved by *ad hoc* emitter-absorber phase relation leading to destructive and constructive interference for the advanced and retarded fields respectively. Hoyle and Narlikar [4] have proved that observed time asymmetry emerges from absorption asymmetry: efficiency of absorption of the advanced field is less than (perfect) of the retarded one (although their theory does not predict how much less). They have explained it by the cosmological reasons: the fact is only Steady-state and Quasi-steady-state cosmological models provide such asymmetry. But their proof itself [4] did not refer to any cosmological conditions and could be applied, e.g. for a radiating charge in a cavity. Therefore absorption asymmetry reflects time asymmetry at more deep level in spirit of Kozyrev [10]. Observational consequence of the absorption asymmetry, if there is an intermediate medium, has to be prevailing advanced nonlocal correlation over retarded one.

Nonlocal nature of macroscopic correlations can be tested by two ways. They both are based on the causal analysis [25, 31-35].

The first way is verification of violation of strong causality. The causality function of arbitrary classical variables X and Y defined as $\gamma = i_{Y|X} / i_{X|Y}$ that is as the ratio of independence functions: $i_{Y|X} = S(Y|X) / S(Y)$, $i_{X|Y} = S(X|Y) / S(X)$, where S are corresponding Shannon conditional and marginal entropies By definition $\gamma > 1$ means that Y is cause and X is effect. Principle of strong causality is:

$$\gamma > 1 \Rightarrow \tau < 0, \tag{6}$$

where τ is time shift of the correlation maximum of Y relative to X. Violating of (6) means signaling in reverse time, that is sufficient condition of nonlocality. Note, for quantum variables we have to use von Neumann entropies and consequently, instead of γ, more complicated function of course of time [25]. But as below we use only classical output of measuring device, we may employ γ without limitations.

The second way is verification of the following Bell-like inequality:

$$i_{X|Z} \geq \max\,(i_{X|Y}, i_{Y|Z}), \tag{7}$$

where local connection of the processes X, Y, Z is possible only along the causal chain $Z \rightarrow Y \rightarrow X$. Violation of (7) is sufficient condition of nonlocal nature of correlation X and Z. Note, that similar to usual Bell inequalities, violation of (7) does not forbid existence of *nonlocal* hidden variables [25].

3. Experiments

As it is not possible to measure $\dot{S}_d$ and $\dot{s}$ in (1) directly, we have to evaluate for the concrete source and probe processes the theoretical expressions relating the entropies with the observables: $\dot{S}_d = F(P_d, \{p_d\})$, $\dot{s} = f(P_s, \{p_s\})$, where P_s is measured parameter of the source-process, P_d is the same of the probe-process (detector signal), $\{p\}$ is set of other parameters of the processes, influencing on the entropy, which must be known unless they are stable. This problem has been solved for three types of the probe-processes: spontaneous variations of weakly polarized electrodes in an electrolyte [14, 16-18, 22], spontaneous variations of dark current of the photomultiplier [22] and fluctuations of ion mobility in a small electrolyte volume [36]. The problem is quite solvable also for any source-process, though we used for quantitative verification of (1) only a rather simple example of Ohmic dissipation [14,16-18, 22].

The experiments were performed with mentioned three types of detectors. In their construction the main attention was paid to exclusion of all possible local impacts (temperature and the like). The design of the experimental setups and their parameters are described in detail in [14-18].

The experiments with controlled (deterministic) lab source-processes (phase transition, etc) demonstrated, of course, only retarded correlations [15, 36].

The main effort was directed to detection of correlations with the spontaneous (random) source-processes in the environment: the meteorological, ionospheric, geomagnetic and solar activity in the long-term experiments in 1993-2003. The full description of the data, their processing and interpretation is presented in [14, 16-25]. The main results are:

1. Signals of different detectors spaced up to 40 *km* turned out correlated and this correlation can not be explained by a local impact of any common factors.

2. Magnitudes of the detector signals are satisfactory corresponded to predictions of Eq.(1).

3. The most prominent fact is reliable detection of the advanced response of the probe-processes to the all above source ones. Both inequalities (6) and (7) are violated. Maxima of the correlation functions of the detector signals and the indices of source-activity are observed at advancement of order 10 hours – 100 days and its magnitude is as much as 0.50 – 0.95. Both the advancement and correlation magnitudes increase with the source spatial scale. Advanced correlation always more than retarded, their ratio is 1.1 – 2.6.

Of course, existence of the different sources called for data prefiltration for signal separation. But the prefiltration also was called for suppression of deterministic periodic components for increase the signal/noise ratio in the advanced domain.

It turned out that contributions of the solar and geomagnetic activity in the detector signal could be more readily separated. The best index of the solar activity proved to be the radio wave flux R at frequency range

610 – 2800 *MHz*, that is emitted from the level of upper chromosphere – low corona (that is level of maximum dissipation in the solar atmosphere). The optimal frequency with in this range changed from year to year. The best index of the geomagnetic activity proved to be *Dst*-index reflecting the most large-scale dissipative processes in the magnetosphere.

In Fig 1 an example of correlation function of the solar activity and detector signal is shown, in Fig. 2 – the same for geomagnetic activity (by the same realization). In both cases maximal correlation corresponds to advancement 42 days (known retardation of geomagnetic activity relative to solar one is insignificant in this scale). The value 42 days was rather typical, although the processes turned out strongly non-stationary and for different realizations position of the maximum varied from 33 to 130 days.

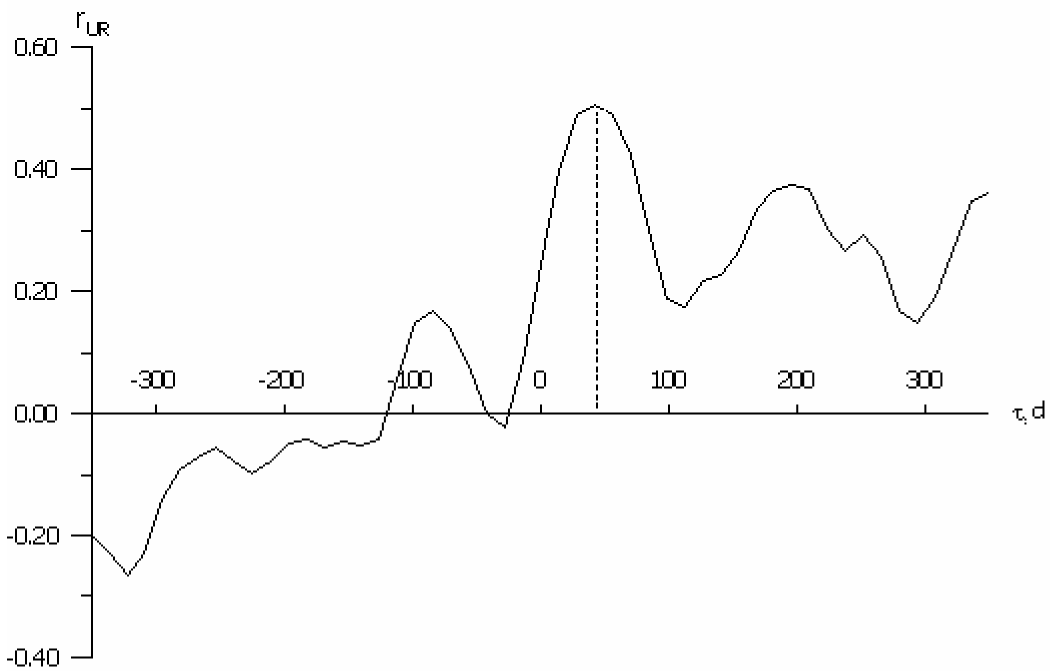

Fig.1. *Correlation function r_{UR} of the detector signal U and solar activity R by low-pass filtered data T > 28 dqys. Negative time shift τ, days, corresponds to retardation U relative to R, positive one - to advancement.*

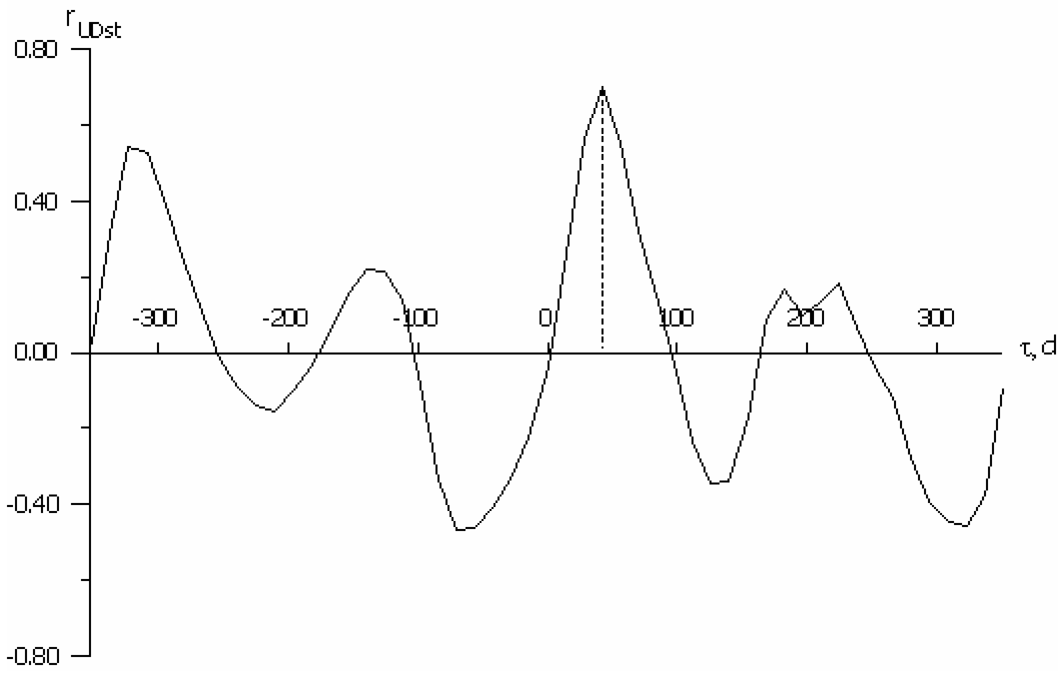

Fig. 2. *Correlation function r_{UDst} of the detector signal U and geomagnetic activity Dst by data filtered in period range 364 > T > 28 days. Negative time shift τ, days, corresponds to retardation U relative to Dst, positive one – to advancement.*

4. Forecasting algorithm.

Availability of the advanced correlation allowed to demonstrate the possibility of the forecast of random component of the solar and geomagnetic activity by the detector signal by means of shift of the realizations [17-24].

But for the real forecast such simplest approach fails, since, first, the processes are far from δ-correlated ones, therefore big errors are unavoidable and, second, position of the main correlation maximum is instable because of non-stationarity of the processes and one can use it only for *a posteriori* demonstration.

For the solution of the real problem the algorithm has been elaborated, based on the convolution of impulse transfer characteristic with multitude of the preceding detector signal values. On the “training” interval $[t_1, t_n]$ the impulse transfer characteristic $g(\tau)$ is computed, which relates the detector signal X and forecasted parameter (activity index) Y with advancement $\Delta t = t - t_n$, by solving the convolution equation:

$$Y(t) = \int_{t_1}^{t_n} g(\tau) X(t-\tau) d\tau \ . \tag{8}$$

Solving of (8) in the discrete form is reduced to the system of linear equations $\{\boldsymbol{Y}=\boldsymbol{XK}\}$. The components of $\boldsymbol{K}$ vector are equivalent to coefficients of plural cross-regression (for the case of Gaussian distribution). The number of equations n equals to the advancement of the forecast. $\boldsymbol{X}$ is the square matrix $n \times n$, the strings are formed from values of the detector signal on the training interval. The first string consists of the values with time index from 1 to n, the second – from 2 to n+1, etc. The sequential values of the Y are corresponding to the each string of matrix. The system is solved by Gauss method. The stability of the results are achieved by an optimal regularization. Practically the advancement is chosen equal to expected average position of correlation maximum. The total training interval for Y ends by the last observed value, while for X – preceding on Δt.

The computed by such way transfer characteristic then is used for the calculation of the only value of the forecasted parameter Y with the advancement Δt. For this purpose the direct problem (8) is solved by X interval ended by the last observed value. On the next day the training interval moved forward and the next value Y is forecasted. Such procedure allow to minimize influence of non-stationarity. To suppress the residual instability the received sequence goes through an optimal low-pass postfiltration.

This method is more preferential over often employed in the akin context (of uncertainty of the cross-correlation function maximum) the plural regression method on correlation matrix calculation, since the suggested one does not require any additional hypothesis about the probability distribution. It is essential, for the reason that distribution very seldom is the eigendistribution, what is needed for singleness of the regression problem traditional solution, and it is not nearly always Gaussian,. what is needed for correspondence of this solution to the maximal likelihood criterion.

5. Experimental forecasting

For test of the method in the regime of real forecast simulation, all obtained detector signal hourly time series of sufficient length – not less than one year for R and two years for Dst (because of shortcoming of the series length, especially valuable with wide-band prefiltration necessary for Dst). Only data of the electrode detector U (which was the most reliable) satisfied this requirement. Results of day by day forecasting series (with duration less than observed ones at the expense of corresponding prefiltration and employment of initial segments as training ones) were compared with factual evolution of Dst or R. Quality of the forecast was assessed by standard deviation of the curves ε in corresponding absolute units, that is nT for Dst and 10^{-22} $Wm^{-2}Hz^{-1}$ for R. The optimal postfiltration in the almost all cases had pass period $T > 14$ days.

In the algorithm described above, the every point of forecasted curves, presented below. is result of computation by selected observed data, minimal volume of which is determined by the forecast advancement (determining duration of the training interval) and by the filter parameters. It should be stressed that only the long-period random component is forecasted, that is the forecast is background, although the nonlocality effect in itself admits the forecast of individual powerful events [20].

In Fig. 3 the solar forecast by the same data (and with the same prefiltration $T > 28^d$) as for Fig. 1 is shown. Advancement of the forecast $\Delta t = 35^d$, error $\varepsilon = 0.88$. Without postfiltration $\Delta t = 42^d$, $\varepsilon = 1.16$.

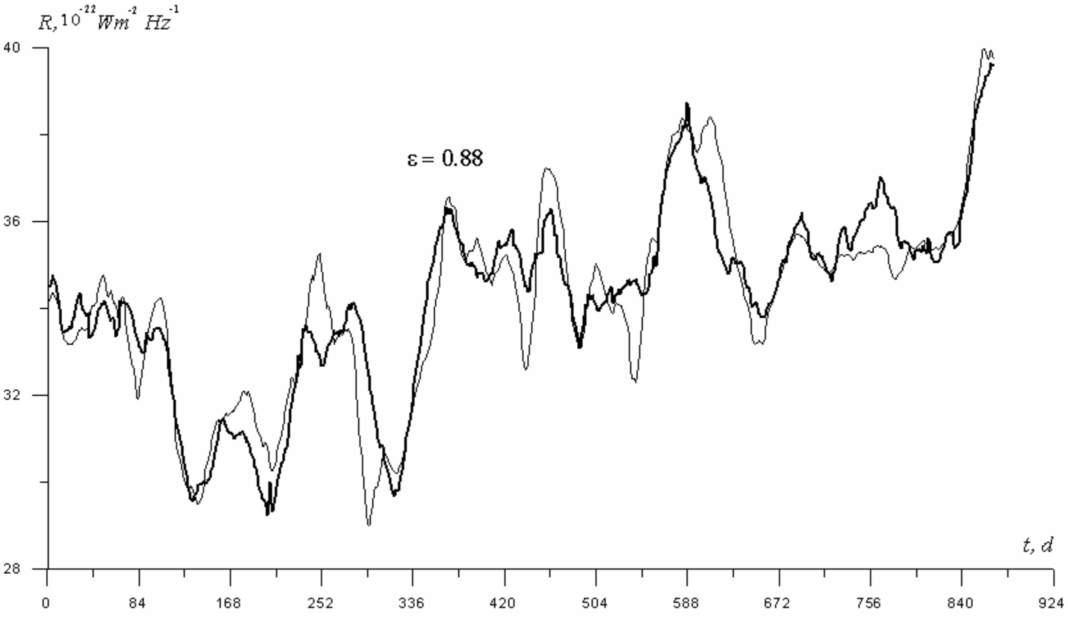

Fig. 3. *The forecast of solar activity R (at 610 MHz) with advancement 35 days(fine line) compared to the factual curve(thick line). The origin of time count corresponds to 3/20/1995.*

In Fig. 4 the geomagnetic forecast by the same data (and with the same prefiltration $364^d > T > 28^d$) as for Fig. 2 is shown. Advancement of the forecast $\Delta t = 35^d$, error $\varepsilon = 1.7$. Without postfiltration $\Delta t = 42^d$, but $\varepsilon = 2.4$.

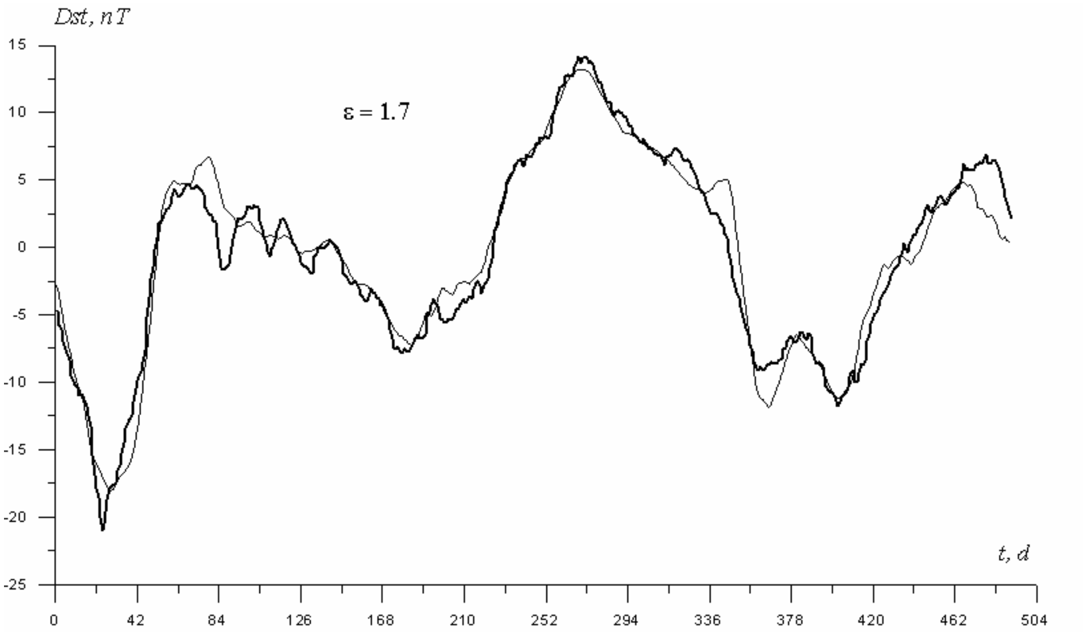

***Fig. 4**. The forecast of geomagnetic activity Dst with advancement 35 days (fine line) compared to the factual curve (thick line). The origin of time count (days) corresponds to 9/19/1995.*

In Fig. 5 the solar forecast for the time of beginning of the next in turn solar cycle is shown. As the moment of beginning is a random event, it is interesting to test capability of the method. For this reason prefiltration for this case is $T > 7^d$ 1 The forecasting curve was postfiltered also with $T > 7^d$. Resulting advancement $\Delta t = 39^d$ and error $\varepsilon = 5.2$ are only slightly less than without postfiltration: $\Delta t = 42^d$, $\varepsilon = 5.4$. It is seen that cycle beginning (sharp increase of R at 125 d) is well predicted.

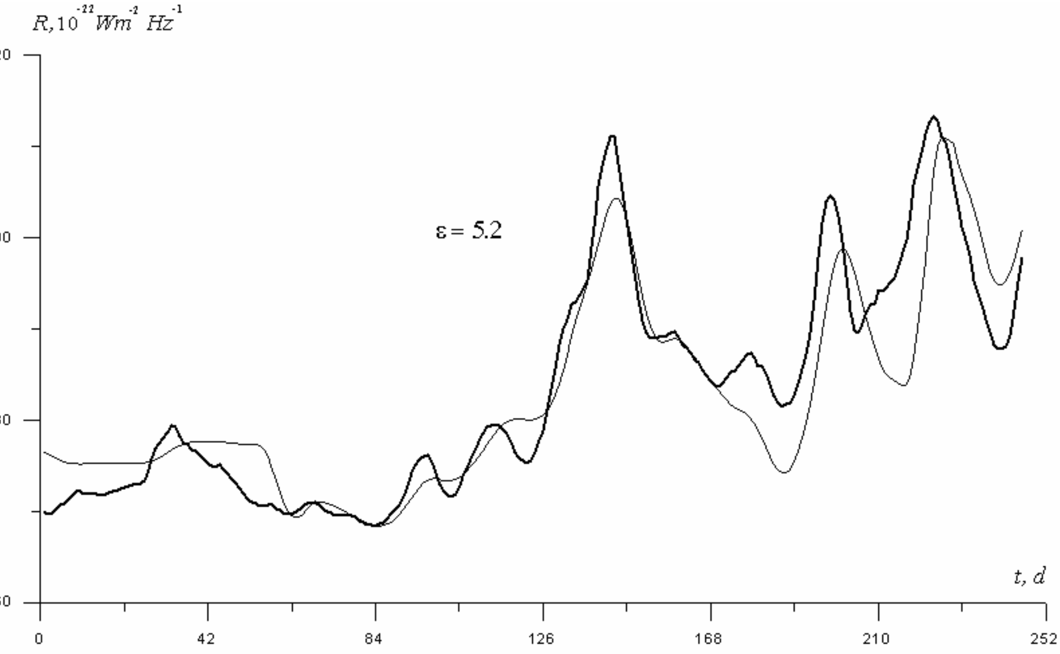

Fig. 5. *The forecast of solar activity R (at 2800 MHz) with advancement 39 days (fine line) compared to the factual curve (thick line). The origin of time count (days) corresponds to 3/21/1997.*

In Fig. 6 the solar forecast by data of the most recent experiment [22, 23] provided the most advancement is shown. Prefiltration was $28^d < T < 183^d$, postfiltration – $T > 14^d$. Resulting $\Delta t = 123^d$, $\varepsilon = 2.0$, while without postfiltration $\Delta t = 130^d$, $\varepsilon = 2.4$.

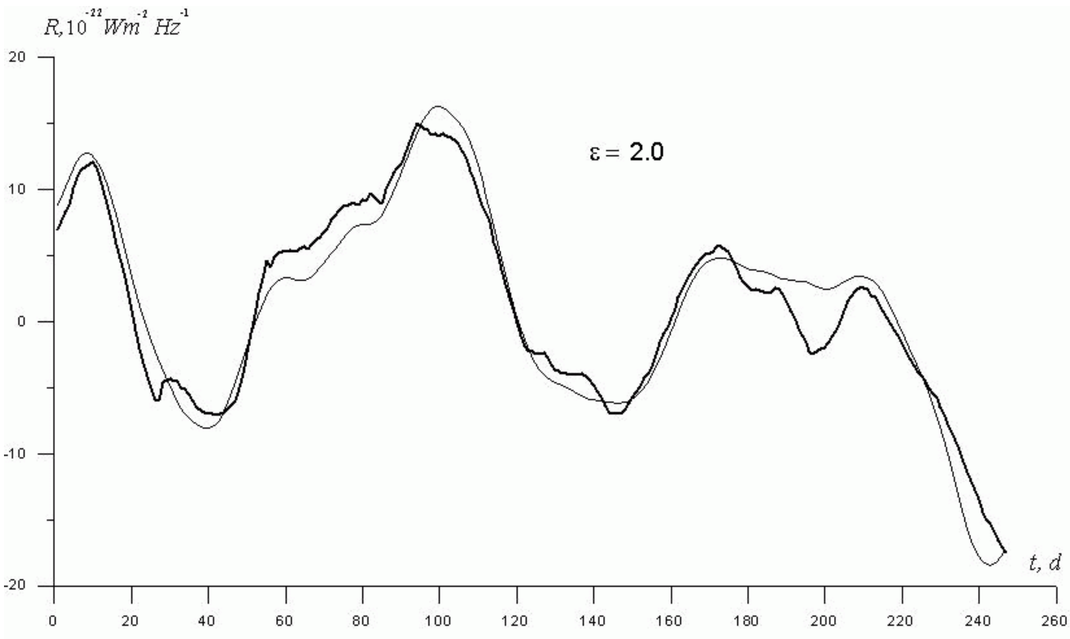

Fig. 6. *The forecast of solar activity R (at 1415 MHz) with advancement 123 days (fine line) compared to the factual curve (thick line). The origin of time count (days) corresponds to 2/20/2003.*

In Fig. 7 the geomagnetic forecast by the same data and with the same pre- and postfiltration as for Fig. 6 is shown. Resulting $\Delta t = 123^d$, $\varepsilon = 2.9$, while without postfiltration $\Delta t = 130^d$, $\varepsilon = 3.5$.

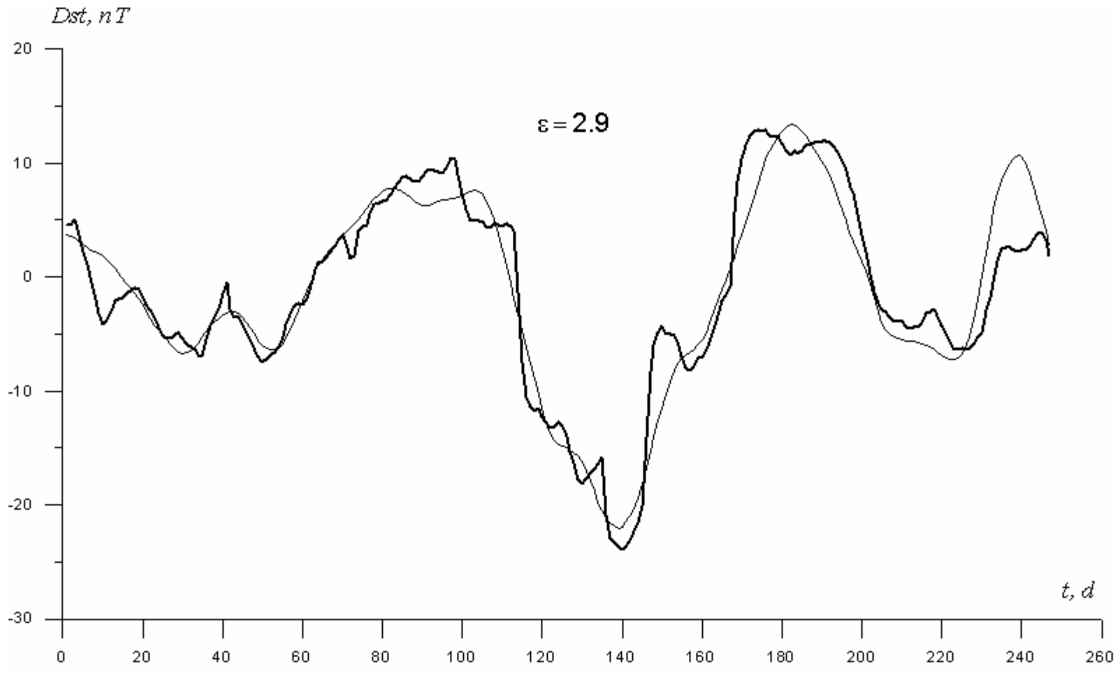

Fig. 7. *The forecast of geomagnetic activity Dst with advancement 123 days (fine line) compared to the factual curve (thick line). The origin of time count (days) corresponds to 2/20/2003.*

6. Conclusion

We have considered the model of macroscopic nonlocality describing the unusual advanced correlation of the dissipative processes. The experimental data have confirmed observability of such correlation for large-scale natural dissipative processes. Among them the most easy for detection proved to be the random component of solar and geomagnetic activity. The pragmatic forecasting algorithm on the nonlocal correlations has been elaborated.

Employment of nonlocal correlation allowed to realize the background long-term forecast of solar and geomagnetic activity with acceptable for all the practical purposes accuracy. Probably, this idea may be also implemented for the forecasts of the dissipative processes with big random component. It should be stressed that suggested method is unique one namely by the possibility of forecasting of the *random* component. All existing approaches to the forecasting problem are deterministic (in spite of employment of statistical cross- or auto-regression algorithms), the random component represents for them unavoidable error. Therefore the described method is essentially complimentary to the customary ones.

Acknowledgement

This work was supported by RFBR (grant 05-05-64032).

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