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FRACTAL ANALISYS METHODS IN ESTIMATION AND PREDICTION OF SOME METEOROLOGICAL PARAMETERS

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Abstract: The estimating methods of the meteorological parameters at Meteorology and Hydrology National Agency (ANMH) standard offers sufficient data to answered at the requirements of the population. Thus, it was ascertained that through the determination of fractal dimension of temporal series obtains different values for neighboring zones, values which should complete the already existing information and which should offer supplementary data concerning the efficiency of such stations.

Keywords: fractal geometry, fractal dimension, wind ministation.

1. STATISTICAL USED-UP METHODS IN CURRENT PREDICTION OF METEOROLOGICAL PHENOMENA

The modern world can't be imagined without waists for a certainly, exactly and more and more intelligent measurement. Any measurement operation supposes a number of metrological knowledge. In absence of measurement's strictness we can interpret as valuable a number of disturbances of collateral signals and we can get errors which could elucidate an important dilemma [3].

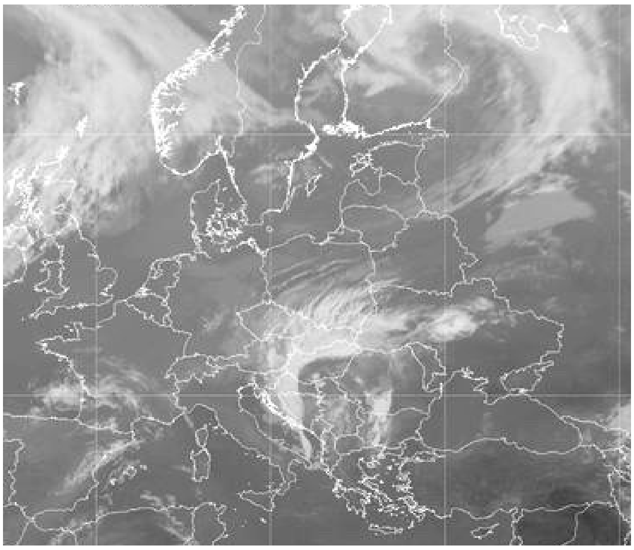

Figure 1

The meteorological predicts were more improved with the utilization of meteorological satellites which made not only the communication to be easy but permitted the data sampling on vast surfaces. In this sense an advantage is represented by the photographic images made in visible and infrared area (fig. 1).

Besides the classic methods of predictions, methods used successfully during the years, the Meteorological National Agency (ANM) has a great experience in the evaluation of statistical models, cumulated through an intense research activity. The statistical adaptation of digital models for the local forecast began in ANM in the years 1988 – 1989 (Otilia Diaconu, Ioana Masek, Mihaela Caian, Anca Badea. Thus, the first operative model was implemented in 1989, a *Perf. Prog-PP* model, for the forecast of extreme temperatures to Bucharest-Baneasa using input data from the *ECMWF* model.

Beginning with 1993, the bilateral cooperation between ANM and Meteo France made possible the development of statistical models for an elder number of stations and for several parameters using the *ECMWF*, *ARPEGE* and *ALADIN* models (Otilia Diaconu, Frederic Chavaux, Serge Farges). Thus there are developed and implemented in operative the following models:

- 1993 – *PP* model – forecast of the extreme temperatures to 48 meteorological stations from Romania, using the *ECMWF* model;

- 1997 – *PP* and *MOS* models – forecast of the extreme temperatures and the wind's speed to 130 meteorological stations, using the *ECMWF* model;

- 1998 – *PP* and *MOS* models – forecast of extreme temperatures, of the temperatures sexti-horary, the speed of the wind, nebulosity and rainfalls to 130 meteorological stations, using the *ARPEGE* model;

- 2000 – *MOS* models – forecast of extreme temperatures, of the tri-horary temperatures, the speed of the wind, nebulosity and the rainfalls to 140 meteorological stations, using the *ALADIN* model;2000 – *Kalman filter* – for correction of the tri-horary temperatures predicted by *ALADIN* model;

- 2001 – updated *MOS* models – forecast of extreme temperatures, of the sexti-horary temperatures, the speed of the wind, nebulosity and the rainfalls to 140 meteorological stations, using the *ARPEGE* model;

- 2002 – updated *MOS* Models – forecast of extreme temperatures, of the tri-horary temperatures, the speed of the wind, nebulosity and the rainfalls to 140 meteorological stations, using the *ALADIN* model.

Examples of maps achieved through implementation of the statistical algorithms, *ARPEGE* model, are presented in figure 2.

The methods presented previously permit, with a satisfactory accuracy, the approximation of short and very short-term meteorological conditions on vast surfaces of country. Based on them and on the real data sampled previously by meteorological stations it can realize maps which to present the configuration of one parameter to a certain moment (figure 3).

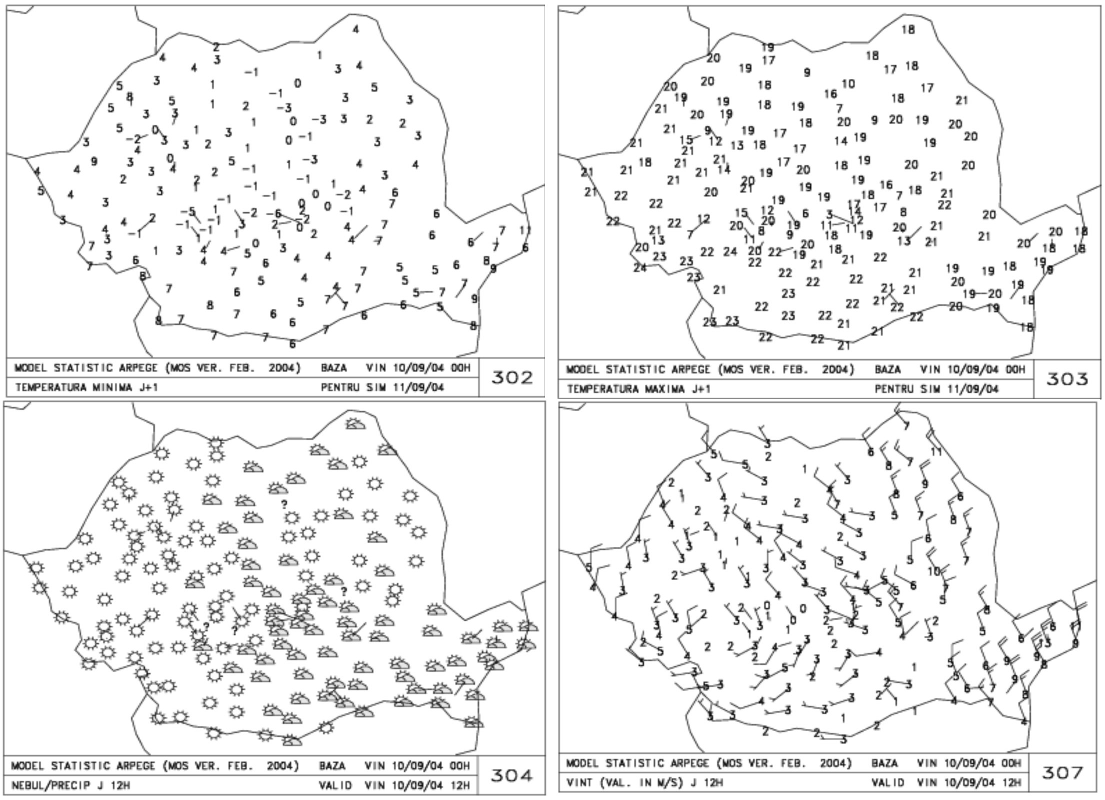

Figure 2

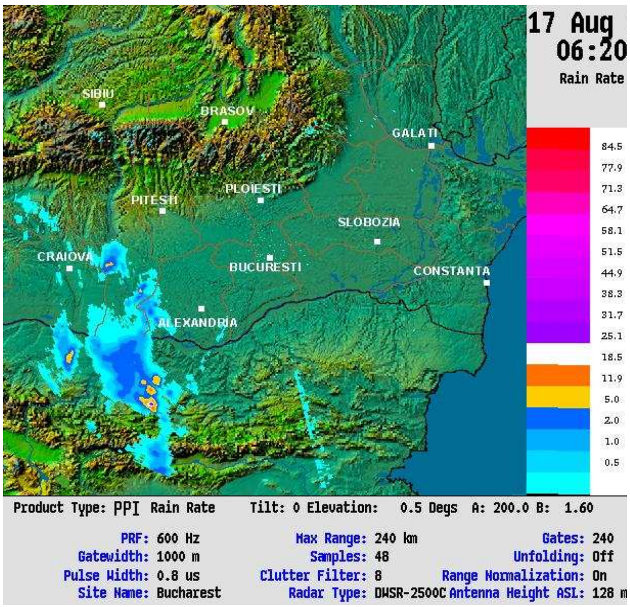

Figure 3

2. METHODS FOR ANALYSIS OF NOISES TYPE DIGITAL SERIES USED-UP IN THE COMPLEXITY SCIENCE

The Complexity Science study complex systems which define oneselves through some attributes:

- Sensitivity to initial conditions: the evolution of the system is depending on the minor differences inherent to reproduction of an experiment; minor initial fluctuations can be amplified during the time, undefined more.

- Auto-establishing: phenomenon of spontaneous and unpredictable arrangement generated by the interactions between quasi-identical subsystems and which involve the establishment of the critical status whereat minor disturbances can release major effects.

A complex system is defined through its structure. Fundamental in facts it can’t be analyzed through fractionally decomposition.

From above results that a classic approach is improper and therefore a development of a specific approach methodology is necessary to understand and use the complex systems. We can say conclusively that: the study of Complexity permits the development of new concepts, methods, models, techniques of evaluation and technologies being highly useful to overtake some limits required by present paradigm.

The fractal geometry takes offence and studies forms having an irregular appearances both in space and time, with properties of auto-similarity and measurable in spaces with un-whole dimension, differed of the topologic dimension (*DT*) and the one of Euclidian space (*DE*) in which these are sinked, ($DT < df < DE$); (*df* – fractal dimension, fractionally). Pragmatic applications in areas as telecommunications (the fractal aerial), mechanics (simulation of the fragmentation and solidification process, the surfaces quality study, diagnosis through evaluation of non-periodical signals (noises) structure, the composite materials and biomaterials characterization, the study of the wear process etc.), biology (the quantitative evaluation of the tumors, the study of the morphogenesis process, the operative evaluation of state of health etc.), economy (the diagnosis of stability on macroeconomic scale, the diagnosis of some economic process), sociology, etc. draw scientists attention and direct the scientific research in this new direction.

Consideration of the temporal series with irregular appearances as being similar to rugose profiles, permitted them characterization, based on fractal estimators as: *the capacitive dimension*, *the Hurst exponent*, *the h exponent*, *the b exponent*, *the smooth dimension*, etc. In principle, this way of evaluation identifies properties of correlation on large scale (the Hurst exponent) respectively of auto-similarity, on the basis of the relation:

$$M(\lambda) \sim \lambda^D \tag{1}$$

where *M* is a scalar which characterizes a certain property associated with the temporal series analyzed depending on the choose scale (resolution) λ. In case that a such relation can be identified, the founded *D* exponent becomes a quantity associated to the studied series (fractal exponent) and can be used-up for the discrimination/classification of the “noises” with important implications in the modern diagnosis.

For determination of the fractal dimension, in this paper, was used-up the Hurst exponent. Being given the signal $s(t)$ and his time derivative $s'(t)$, for the moment *t* and the window *t* it can determine the follow quantity:

$$R(t,\tau) = \max(s(\xi)) - \min(s(\xi)),\ \xi \in (t\ ,\ t+\tau) \tag{2}$$

$$S(t,\tau) = \mathrm{std}(s'(\xi)),\ \xi \in [t\ ,\ t+\tau),$$

where *std* is the standard error. For a constant value τ is determined the average of relation $R(t_i,\tau)\ /\ S(t_i,\tau)$ calculated for all successive intervals, non-interlaced $[t_i\ ,\ t_i+\ \tau)$, fact that lead to relation $< R(\tau)\ /\ S(\tau) >$. Then, it’s looking for a power law as:

$$\left\langle \frac{R(\tau)}{S(\tau)} \right\rangle = k \cdot \tau^{H_M} \tag{3}$$

where H_M is the Hurst exponent.

It is known a relation theoretical defined between H_M and the associated fractal dimension D_f:

$$Df = 2 - H_M \tag{4}$$

In this situation, knowing the calculation method of the fractal dimension and of the Hurst exponent (H_M > 0,5 persistence; H_M < 0,5 anti-persistence) it can design a device which to process on-line acquired analogical series or the series of generated values an to reverse the Hurst exponent value and the associated fractal dimension, as well as the time variation of this dimension. The device will contain four generating sets of temporal series having required fractal dimensions. One such facilitation becomes elemental in the stage of study concerning the capacity of a new method to estimate a fractal exponent, respectively to estimate programs through standard sequences. From the four achieved generators it was used for recorded meteorological data processing only that based on the “Takayasu” generating method which is based on the connection between *Df* and the slope of β power spectrum associated to a signal. For this reason it can proceed to generate a Fourier spectrum having $2 \cdot L$ samples with aleatory phase. Through the utilization of invert Fourier transform is generated a series of data having the length of $2 \cdot L$. The middle sequence, coped and having *L* samples constitutes practical the output from generating block. Between the β exponent and the fractal dimension associated to the data series is determined theoretical a relation as:

$$Df = \frac{5+\beta}{2} \tag{5}$$

This theoretical basis stood on the base of achievement of the algorithm for data analysis in this work [4].

3. THE UTILIZATION OF THE FRACTAL ANALYSIS IN THE LONG TERM PREDICTION OF SOME METEOROLOGICAL PARAMETERS FROM A CERTAIN GEOGRAPHIC ZONE

Known under various another names (digital measurement systems, computerized acquisition systems, measurement systems based on microprocessor etc.), the computerized measurement systems are first characterized by fact that, from a certain point of the system, the electrical intelligence signal is converted from an analogical to a digital form. The devices are designed in the virtual instrumentation technology – a rush area found at the limit between hardware and software and which justifies a major tendency of modern technology namely dematerialization of the products. The such named “box equipment” can be replaced with the virtual equipment, and the assemblage of one device by various electronic components can be substituted by a software which emulate the device running, software achieved in a meta-language – object oriented program – named LabView [9].

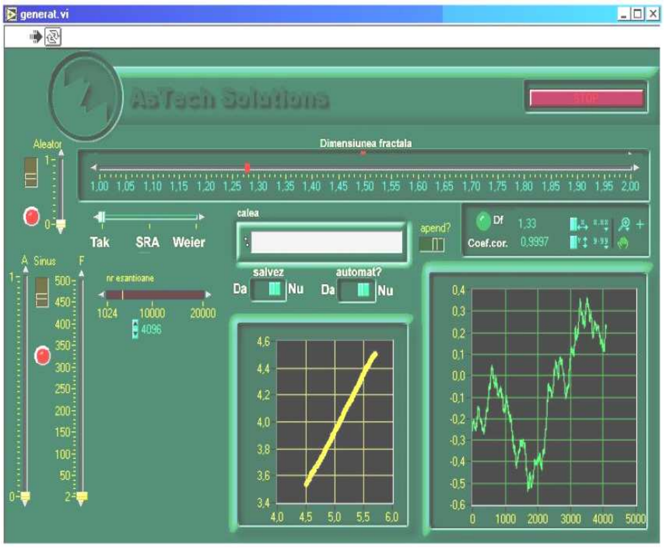

Figure 4

The values of some meteorological factors sampled for a certain zone and graphical represented give the image of a noise electrical signal. It is about a non-periodic fluctuation which attends as often as not a signal. The modern researches show that in that noise, which the most specialists tried to remove it through complex filtering operations, is hidden many useful information [7]. In classic acceptance, especially came from communi-cations theory, a noise is the consequence of: some inherent imperfections in the electronic components, of the thermal agitation which manifest oneself in any material (the thermal noise) or of the interaction with undesirable aleatory phenomena (as in the case of the noise inducted by the geomagnetic disturbances or the electric discharges). The noise notion was defined in the context of another important dimension, the one of signal. Thus, in the presence of the noise, the signal that it wants to be received could be distorted or deformed up to the loss of the signification. From this perspective, the noise must to be eliminated how much possible. Thus it was created a preconcept what associate to the word "noise" something to remove, something what has not to appears, without signification … [6].

In a new accept, the function itself of one system is able to generate a non-periodical fluctuation similar to a noise but which can be signification and information carrier ... The study of these noises and the identification of some estimating methods of these became a major preoccupation of physicists in last period [8].

In order to permit the utilization of the fractal analysis in the experimental research and default in practical applications it was achieved a virtual device for the fractal analysis of non-periodical series (the figure 4). The device permits the complex study of one numerical series acquired or loaded from a file which contains signals stored in ASCII code. After the selection of the signal what must to be analyzed is opened a window what permits:

- a preliminary numerical processing which consists of the centering of the signal (the extract of the average component), the differentiation or the digital integration,
- the selection of the method of fractal dimension determination from that five different methods figured in the LabFractView toolbox,
- the selection of the minimum and maximum window, respective of the number of windows from this interval,
- the maximum number of analyzed data *N*,
- the initial position from the series of stored data.

The recorded processed data represent the supervised speed of the wind a portable meteorological ministration in two different zones:

- in Suceava, on the roof of the laboratories building of Electrical Engineering Department (building C), for 1 month, from 01 of July to 03 of August 2005;
- on the "Stone ring" island, on Danube, from the zone of Capidava locality (24 km from Cernavodã, down-stream), for 10 days, between 04 and 13 of August 2005.

The data were graphical represented and after these analyses it could conclude the following:

- the speed of the wind variation in Suceava have aleatory signal appearance similar with a signal generated

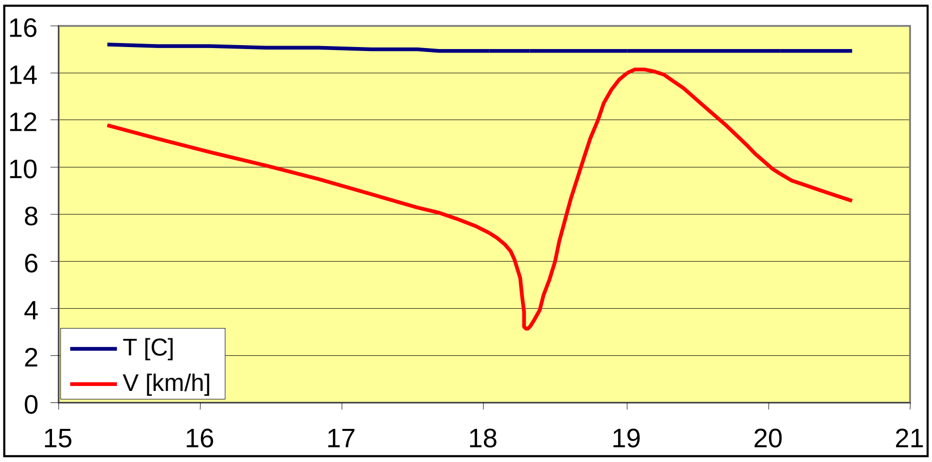

Figure 5.
The temperature and speed of the wind evolution in Suceava, in the afternoon of 17th July 2005

with the fractal generator described previously even if the analyzed sample was sampled on a short time interval (figure 5);

- the temperature or wind variation in Capidava zone was much more slowly, thing explained by the thermal inertia of the air and by the air movements on the flow direction of the river (figure 5). However, is ascertained a noise evolution for these parameters also, but in a much more long interval and in predictable limits.

After the fractal analysis of the series what represented values of wind speed on the maximum period of registrations there was put in evidence values total different of the fractal dimension of proper temporal series. Thus, for Suceava zone the value of the fractal dimension was 1, 301 and for Capidava zone was 1, 127.

3. CONCLUSION

The estimating methods of the meteorological parameters at Meteorology and Hydrology National Agency (ANMH) standard offers sufficient data to answered at the requirements of the population. With all these, through the fact that they are valid just for a short and very short time and because they are valid for very large surfaces, they could not be exploited in electric power stations, in solar or wind ministration.

For a correct emplacement of the solar and of the wind station with a maximum efficiency is necessary the determination of a “mark” of the wind speed evolution or of the encloud degree for limitary territorial zones. This “mark” must to have on the base the previous meteorological recordings for that place, recordings which can be processed through the classic meteorological methods (average, mean deviation, etc.) and using the statistical algorithms and the new implemented models to world level in meteorology. In order to complete the evolution of a meteorological parameter in a good limited zone it was consisted as necessary the finding of other data estimation and processing methods.

Thus, it was ascertained that through the determination of fractal dimension of temporal series obtains different values for neighboring zones, values which should complete the already existing information and which should offer supplementary data concerning the efficiency of such stations.

The sampled and processed data by now, as well as the limited access of the authors to databases sampled on a long time in the zones of interests taking into account that these parameters evolve continuously during a calendar year (statistically it seems that in the last years also the climate suffered elemental modifications), have no allowed yet the obtaining of some firm, rigorous and certified conclusions.

However, is consisted clearly that a signal with a higher fractal dimension (toward the value 2) corresponds of some sudden and in large limits changes of the signal, therefore in those zones is not recommended the emplacement of the wind stations (the case of the obtained data amongst the Suceava town).

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