Prediction of solar flaring and CME activity by means of COnceptual MODelling (COMOD) technology for reconstruction of complex systems

B.F.Fomin[1], T.L.Kachanova[1], M.L. Khodachenko[3],
N.K. Belisheva[2], H. Lammer[3], A. Hanslmeier[4],
H.K. Biernat[3], H.O. Rucker[3]

[1] *Dept. of Automation & Control Processes, St.Petersburg State Electrotechnical University, Prof.Popov Str. 5, 197376, St.Petersburg, Russia*
[2] *Polar-Alpine Garden Institute, Kola Science Center, Russian Academy of Science, Apatity, Murmansk reg., Russia*
[3] *Space Research Institute, Austrian Academy of Sciences, Schmiedlstr. 6, 8042, Graz, Austria*
[4] *Institut für Geophysik Astrophysik und Meteorologie, Univ.-Platz 5, A-8010 Graz, Austria*

Abstract.

The idea of Space-Weather forecast and prediction of geo-efficient phenomena of solar activity by means of COnceptual MODelling (COMOD) technology is proposed. This technology is a new approach for reconstruction analysis of open complex systems. Operation and structure of the COMOD technology are described. Recent applications of the COMOD technology in the analysis of geospheric and biospheric effects of the solar activity and geocosmic factors are summarized.

Key words: Solar activity – Space Weather – Geocosmic factors – Open systems – Reconstruction analysis – Behaviour stereotypes

1. Introduction.

This paper deals with an innovation idea of the application of modern methods of informatics and structural analysis of complex systems for the tasks of space physics and biology with the purpose of a better understanding of complex solar-terrestrial connections and their biospheric effects.

The main reason for initiation of the present research cycle is due to the fact that our Sun is an active star. This activity impacts planet Earth and human society in numerous ways. Terrestrial climate, ozone concentrations in the stratosphere and atmospheric drag on satellites all respond to variations in the Sun's radiative output. Astronauts, airline passengers, and satellite electronics are all affected by the energetic particles produced in solar flares and coronal mass ejections (CMEs). Electric power grid systems, communication and navigation netsworks can all be interrupted by geomagnetic storms driven by blasts in the solar wind. Such a close Sun-Earth connection makes the investigations of the Sun and prediction of its activity to be of vital importance.

There exist now a number of solar monitoring programs which allow to register various eruptive events on the Sun and to estimate their potential geo-efficiency. The weak side of these programs consists in the fact that all of them deal with the flares and CMEs which have already happened, whereas the question of how to predict powerful energetic events on the Sun still remains to be open. In the present moment there exists just one empirical criterion: sigmoidal (S-shaped) magnetic structures in the solar active regions observed in X-rays have been shown to be precursors to CMEs, existing in some cases for several days before an eruption (Sterling & Hudson 1997). Thus, besides of its applied aspects, the task of understanding the mechanisms and prediction of different phenomena of the solar activity represents one of the main challenges to the modern space physics. In our investigation we try

to make a step forward in tackling this unsolved problem and to define which of the observable (measurable) parameters of the Sun/Heliosphere-Earth/Geosphere system are phenomenologycally connected to the processes of the solar activity, so that they need to be specially controlled in order to forecast solar flares and CMEs. It should be emphasized that in our search of these key indicator-parameters we do not limit our view only to the Sun. Under a special consideration are possible geospheric and biospheric manifestations of solar flare and CME precursors. Since we are dealing with a significantly multi-aspect problem, it is too early to report about its complete solving. In fact the investigations which we are speaking about here are in their initial phase, and we report in this paper just some particular results obtained within the scope of solving the general problem.

Our strong expectations regarding the new experimental data about the Sun are connected with the future international solar research programmes and space missions, among which central position belongs to the planned by NASA space mission STEREO specially aimed to the study of solar CMEs. Besides, we would like to mark specially our interest in establishing of active links and possible collaborations with colleagues working in similar branches as we do, in order to have exchange with ideas and to discuss different possibilities to apply the obtained results.

2. COMOD technology.

2.1 General description.

The COnceptual MODelling (COMOD) technology (Kachanova & Fomin 1996, 1997,1998a,b,c) can be applied to perform the task of detection of phenomenological links and correlations between various experimental parameters which describe the Sun/Heliosphere-Earth/Geosphere system in its dynamics end complexity. It provides a scientific basis for reconstruction of the considered complex system. The COMOD technology deals with systems that, in broad sense are open dynamic systems. It is oriented to the extraction of common variability mechanisms of complex systems and investigation of these mechanisms by means of conceptual models. Only experimental data about a studied object/system or phenomenon are used as initial information in COMOD technology. The inductive approach to a reconstruction idea realization is the base of COMOD technology. It contains no searching procedures, but is oriented to qualitative methods for which the system dimension is inessential. The COMOD technology reaches its results by revealing different types of the system behaviour and variety of possible (virtual) states. The system reconstruction in COMOD technology is based on the analysis of typical forms of its local and global behaviour and on the exploration of the nature of internal interactions and links within the system. The COMOD technology essence is determined by the non-linear simulation paradigm. Since the time of its development, the COMOD technology was successfully tested in comparison with the "neuron network" algorithm and applied in a number of branches, including medicine (diagnostics of diseases) and industry (management optimisation) (Kachanova & Fomin 1998b).

2.2. Structure of the COMOD technology. Main functional blocks.

Advantage of technology:

- problems are considered in their natural complexity (no simplifications or idealizations are needed);
- operates with empiric data obtained from observations and measurements;
- minimizes risks and time/energy losses for achievement of an aim / optimal solution;
- provides a complete, scientifically correct knowledge on the considered problems.

COMOD-technology involves in its operation three groups of users: 1) *System analysts*; 2) *Subject analysts*; 3) *Specialized experts*

System analysts are system reconstruction experts, professionally working with the system reconstruction technology. They control and provide consistence and completeness of the system solution.

Subject analysts are experts in a certain subject area, who are familiar as well with the system reconstruction language and formalism. They support with their expertise the obtaining of complete solutions of given applied tasks.

Specialized experts (analysts) are experts in a certain subject area, who have a scientific and practical experience of work with particular problems under consideration. They provide interpretation of the system solution using traditional for the given subject area scientific language.

Solutions of considered problems are obtained by the system analysts. Subject experts do not take part in creation of the system solution, but they are responsible for scientifically correct formulation of a problem and providing of primary empirical data. Subject experts are dealing as well with interpretation of the obtained knowledge about a complex system, which creates a scientific basis for the applied solutions, Fig 1.

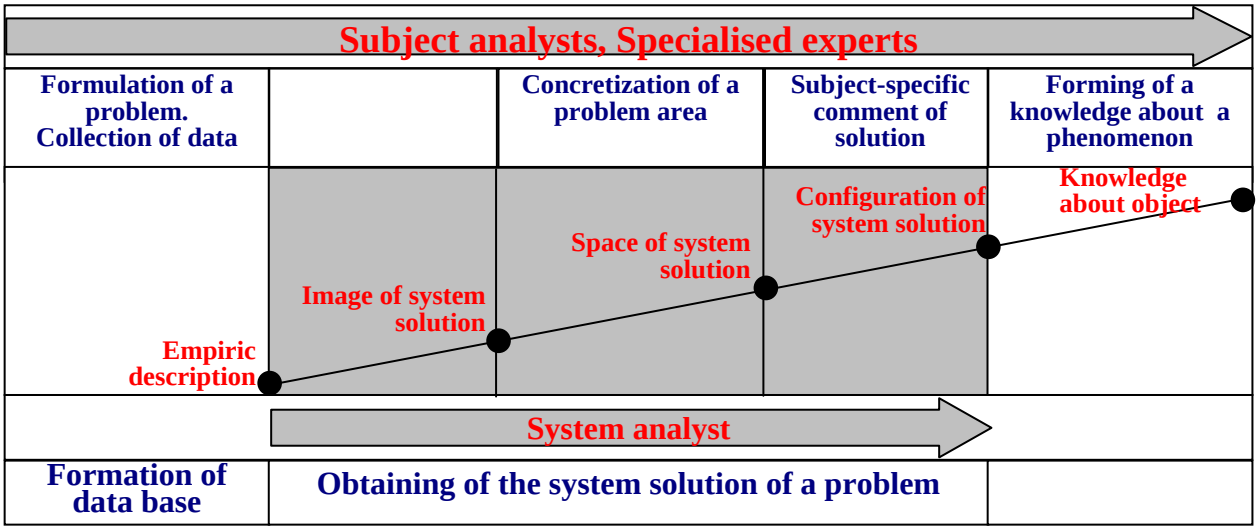

Fig. 1. Problem solution by COMOD technology

The system solution of a problem is obtained automatically. The processes of solution selection, verification, and testing of completeness, are made automatically. Solutions are presented in a form of standard reports which are generated automatically.

For each group of users COMOD-technology creates the solution of problem in a certain normative form: a) *Image of the system solution*, b) *Space of the system solution*, c) *Configuration of the system solution* (Fig. 2).

Image of the system solution is a documented presentation of the system solution addressed to the system analyst. It represents the obtained knowledge about a problem in general and demonstrates the completeness of the problem description. The last is achieved by means of indices (parameters), their variability and multiple correlations; system invariants of structure relations and their features; identificators of mechanisms of interactions and states.

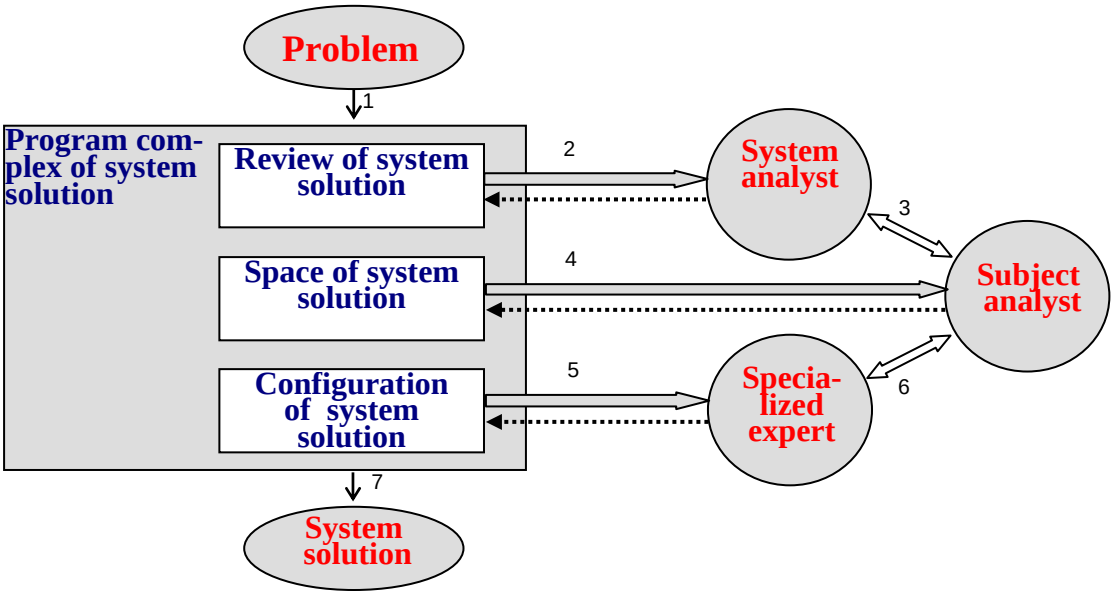

Fig. 2. Interaction of users with COMOD-technology.

1 – transmission of primary data; 2 – generation of the system solution review and checking of the solution by the system analyst; 3 – interaction between system and subject analysts in order to define the limits of space of the system solution; 4 – generation of space of the system solution and checking of the solution by the subject analyst; 5 – generation of configuration of the system solution and interpretation of the solution by the specialized expert; 6 – interaction between the subject analyst and specialized expert in order to define the capacity and content of the interpreted system solution of the problem; 7 – distribution of the solution.

Space of the system solution is documented presentation of the system solution addressed to the subject analyst. It represents the obtained knowledge about a problem by means of a portrait images of the solution. Portrait images describe in details each formal object with all its attributes.

Configuration of the system solution is documented presentation of the system solution addressed to the specialized expert. It represents the obtained knowledge about a problem by means of an analytic note which describes the results of the system analysis regarding any particular component of the solution and provides the scientific interpretation of these components.

Each normative form of documented presentation of the system solution has a certain structure (Fig. 3).

Image of the system solution consists of 5 parts: a) *empiric description of a problem*; general parts of b) *statistic*-, c) *structural*-, d) *system*- and e) *realistic portraits*.

Empiric description of a problem is a part of an image of the system solution, characterizing a completeness of a problem consideration and validity of data about to the problem.

Statistic portrait (general part) is a part of an image of the system solution, characterizing in general the sufficiency of the considered volume of data for creation of the problem solution via the observed variability of indices (parameters).

Structural portrait (general part) is a part of an image of the system solution, characterizing in general the sufficiency of manifestation of the problem complexity in attributes of the structure ratios.

System portrait (general part) is a part of an image of the system solution, characterizing in general the completeness of the obtained knowledge about the problem by means of a set of structure invariants, their relations and attributes.

Realistic portrait (general part) is a part of an image of the system solution, characterizing a possibility of qualitative and quantitative verification of the problem complexity in the obtained solution.

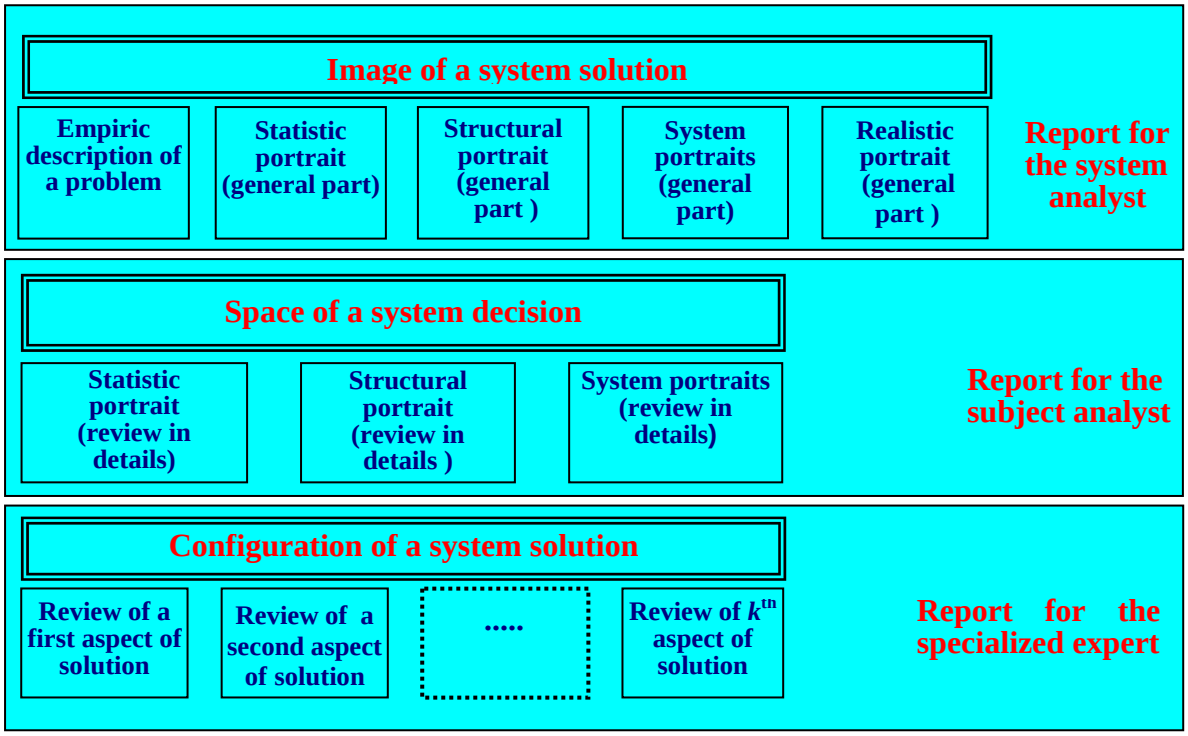

Fig. 3. Structure of normative forms of a system solution

Space of the system solution consists of 3 parts: *detailed reviews of* a) *statistic*-, b) *structural*- and c) *system portraits*.

Statistic portrait (detail review) is a cross-section of the space of the system solution, obtained after statistic analysis of selected distributions. It clarifies variability of indices by means of complete sets of their of statistic features and projection of these features onto sub-sets of the goal indices.

Structural portrait (detail review) is a cross-section of the space of the system solution, obtained during structural analysis of interrelations. It clarifies pair interconnections of indices, structure of binary interrelations, and a character of connection with the goal indices.

System portrait (detail review) is the space of the system solution itself, obtained during the system reconstruction analysis. It describes the complexity of a studied problem by means of complete set of the system invariants clarifying the mechanisms of formation of the typical system behavior schemes and etalon states. Invariants defined by sub-sets of goal indices are identified.

Configuration of a system solution is the space of the system solution, which includes as well the results of its system expertise. Such a representation of the system solution is divided onto sections which number is determined by the number of detected system goal invariants.

Review of solution aspect is a part of *Configuration of the system solution* describing a particular aspect of the solution. It is dedicated for interpretation of a certain system invariant in order to prepare practical application of the obtained solution of a problem.

3. Study of geo- and biospheric effects of cosmic factors by means of the COMOD technology.

3.1. Analysis of connections between ozone variations, functional state of human organism and various geo-cosmic agents.

The local Total Ozone Content (TOC) data in St.Petersburg area (Russia) were considered together with the global geocosmic data, including the indices of Solar activity, proton fluxes, the parameters of the interplanetary media and the local meteorological agents, as well as with the indices of human organism state measured on patients with the bronchial asthma (BA). It has been detected that the TOC has a negative connection with local variations of humidity, atmospheric pressure, and the value of natural electric field gradient, but it is positively correlated with forming of clouds and neutron count. TOC has also positive connection with B_x component of interplanetary magnetic field (IMF), hydrodynamic pressure and velocity of the solar wind, and >60 Mev protons. At the same time it is negatively correlated with the number of sunspots, B_z component of IMF, and 10 Mev protons. This means that current state of the magnetosphere and near the Earth solar wind conditions influence the TOC in a complex way and under certain circumstances increase the TOC in the atmosphere can take place.

Investigation of relation between the TOC and indices of the human functional state reveals that the TOC may have a negative connection with summary content of immune-globulin and corticosteroid hormones in peripheral blood and the reactions on diverse allergens. This is demonstrated by decrease of allergen reactions of BA patients. At the same time, the patient's anxiety increases with increase of the TOC. Personal reaction on the variability of the TOC is depended also on age of a patient.

3.2. Geo-cosmic influence on a human psychological state.

The research cycle performed at high latitude station shows that local variations of the geomagnetic field may have an effect on the functional state of a human brain. Analysis of the correlation between the brain state and the structure and intensity of the magnetic field variations shows that the reasons for stable and unstable psychological states may be related to features of geomagnetic disturbances, their structure and character (periodic, non-periodic). We found that stable functioning of the brain requires a sort of optimal level of geomagnetic activity expressed in the form of periodic oscillations within a certain amplitude and frequency range. An essential role here play geomagnetic pulsations. Considerable fall in the level of geomagnetic activity, as well as appearance on non-periodic disturbances may cause unstable emotional states (Belisheva N.K. et al. 1995).

3.3. Effect of geocosmic factors on the bacterial growth.

There is a concept under discussion in medical circles concerning the connection between the epidemiological oscillations and sunspot cycles. The genesis of such possible relationship is not yet completely understood. The goal of our research has been to assess the importance of the global and local geocosmical agents for the growth of pathogenic and nonpathogenic microflora. Our investigations are based on the experimental material concerning growth of pathogenic and nonpathogenic microflora on the human skin and in the cases of lung diseases. The 22 indices of solar data and 7 indices of local geomagnetic activity were used for finding of the relationship between bacterial growth and various geocosmic agents. It has been detected that the growth of the pathogenic microflora has negative correlation with the solar activity Wolf numbers, the solar wind plasma density and its variability. A positive correlation of the pathogenic microflora growth takes place with the IMF variability and the solar wind dynamic pressure. The growth of nonpathogenic microflora shows positive correlation with variability of the B_z component of IMF, solar wind velocity and the IMF

variability. The negative connection was found between the growth of nonpathogenic microflora and the intensity of energetic protons (10 Mev, 60Mev) fluxes. Performed investigation reveals that the pathogenic microflora appears to be more strongly affected by the environmental factors than the nonpathogenic one. This is because the last is mainly controlled by the host organism. It has been detected as well that the maximum of the pathogenic microflora growth takes place during the periods of low geomagnetic activity.

4. Conclusion.

Application of the COMOD technology allows to discover specific connections between various parameters characterising the solar-terrestrial system. In our research we pay the main attention to finding a correlation between the parameters related to the solar activity and the specific processes in the atmosphere and biosphere of the Earth. Some of these detected correlations are reported in this paper. As one can see the processes of solar activity and their manifestation in the near Earth space produce a significant biospheric influence and may be responsible for the specific reactions in not only technological processes, but also in the human and social behaviour. This aspect of the solar-terrestrial connections requires a special study. It is very possible also that not only flaring and eruptive events on the Sun, but also the processes forerunning them, produce an influence on the terrestrial environment. Because of the complexity of the solar-terrestrial connections quite natural seems a possibility to detect some specific features and behaviour aspects which forerun the strong solar activity events and therefore can serve as their precursor-indicators for the space weather forecasting purposes. Search for these specific parameters and connections appears as the subject of our future work.

Acknowledgements: NKB, HL and HKB are thankful to the ÖAD-RFBR project No.I.12/04 and the Austria-Russia Academic exchange programme. MLK thanks the FWF project P16919-N08 for supporting his work.

References.

Belisheva N.K. et al., 1995, Qualitative and quantitative evaluation of the effect of geomagnetic field variations on the functional state of the human brain, Biophysics, **40**, No5, 1007-1014.

Kachanova, T.L., Fomin, B.F., 1996, "A new theoretical concept of signed ballance and systemological platform of COMOD technology", In Proceedings of the 2nd International Symposium on Intelligent Systems (June. 1-4, St.Petersburg, Russia), Moscow RUDN-PAIMC 33-38.

Kachanova, T.L., Fomin, B.F., 1997, "Reconstruction of Complex systems behaviour using experimental data", SPbETU Publishing Center, St.Petersburg, Russia (in Russian).

Kachanova, T.L., Fomin, B.F., 1998a, "A new methodological platform of systemology", SPbETU Publishing Center, St.Petersburg, Russia (in Russian).

Kachanova, T.L., Fomin, B.F., 1998b, "Symmetries, interactions in localities, behaviour components of complex systems", SPbETU Publishing Center, St.Petersburg, Russia (in Russian).

Kachanova, T.L., Fomin, B.F., 1998c, "COMOD technology. Systemology of phenomenon", SPbETU Publishing Center, St.Petersburg, Russia (in Russian).

Sterling & Hudson 1997, *ApJ*, **491**, L55.