CONSTRUCTION OF MULTIDIMENSIONAL BASIS VECTORS FOR ANALYSIS AND PROGNOSIS

V. Penenko and E. Tsvetova
Institute of Computational Mathematics and Mathematical Geophysics SD RAS, Novosibirsk
e-mail Penenko@sscc.ru, tsvet@OMMFAO.sscc.ru

A new approach to construction of atmospheric circulation scenarios for making ecological predictions and planning is proposed. It is based on a combined use of hydrodynamic models and archived data on climate. The problem of long-term prediction of hydrodynamic background for ecological studies and planning has no unique solution until now. Its specificity is in the fact that the characteristic lifetime of the already existing and designed objects as the sources of anthropogenic impact on the climate system are, as a rule, much longer than the characteristic intervals of predictability of the current hydrodynamic models. This means that it is preferable to make use of the scenario approach in solving such problems. In construction of scenarios, both mathematical models and measurement data are generally used. It is clear that scenarios for ecological prediction should reflect actual situations on the climatic scale.

In the proposed technique, the set of scenarios is constructed. The technique is based on the combination of the methods of four system levels, namely, the method of factor analysis, methods of studying the sensitivity of models and functionals, methods of direct and inverse modeling with assimilation of actual data. The basic vectors and the corresponding phase subspaces are the key elements of the constructions.

Identification of the main factors that govern the behavior of the climate system fills a highly important place in the methodology of formation of scenarios and analysis of the results obtained by modeling. In terms of the main factors, it is possible to identify the manifestation of the climate system response to anthropogenic impact.

Following the ideas of factor analysis [1,2], the calculation of the orthogonal basis functions is made by the formulas

$$\vec{F}_p = \sum_{\beta=1}^{n} (a_{\beta p} / \lambda_p)\vec{\varphi}_\beta, \quad p = \overline{1, m \le n}. \tag{1}$$

Here $\{\vec{\varphi}_\beta, \beta = \overline{1,n}\}$ is the initial set of normalized vectors of the state functions. The components of the latter are centered about their mean values; λ_p are the eigenvalues ordered in diminution, and $\vec{a}_p = \{a_{\beta p};\ p, \beta = \overline{1,n}\}$ are the corresponding eigenvectors of $n \times n$ Gram's matrix that is built on the initial set $\{\vec{\varphi}_\beta\}$. The vectors $\{\vec{F}_p\}$ and $\{\vec{\varphi}_\beta\}$ are of the same block structure of the type:

$$\{\vec{\varphi}_\beta\} \equiv \{\vec{\varphi}_{i\beta}((\vec{x},t)_k),\ k = \overline{1,K},\ i = \overline{1,N}, (N \ge 1), \vec{x} = (x_1, x_2, x_3)\}, (\vec{x},t)_k \in D_t^h. \tag{2}$$

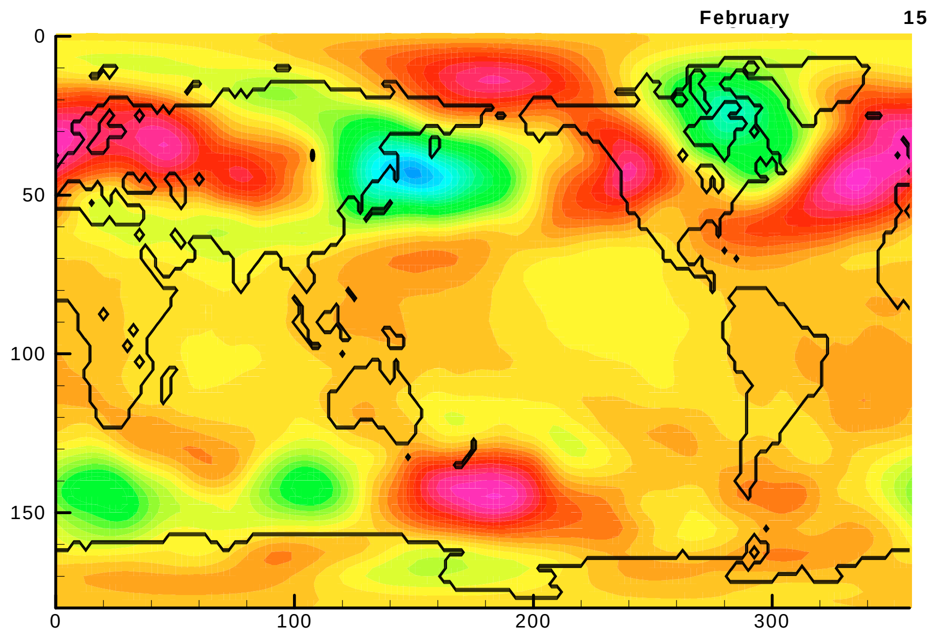
Here N is the number of different, in physical sense, components; D_t^h is the discrete analog of the space-time domain D_t. The structure of the grid in D_t^h and K, N are prescribed as input parameters. The values of K and N may be as great as it is required. The state functions of the climatic system, such as geopotential, temperature, the components of the velocity vector and others, the adjoint functions that correspond to them, sensitivity functions of the model may be included into the number of the vector's components. The union of the divers information and the choice of the inner product for the construction of the Gram's matrix are made with the help of variational principle and energetic functional of integral identity for the basic model of the processes.

The eigenvalue problem for Gram's matrix is solved under conditions

$$\lambda_p = \sum_{\beta=1}^{n} a_{\beta p}^2 = \max_{\langle a_{\beta p} \rangle}, \quad p = \overline{1,n}. \tag{3}$$

The maximums are sought on the set of values of the Fourier coefficients of the initial vectors $\{\vec{\varphi}_\beta\}$ decomposition with respect to the vectors of the sought basis $\{\vec{F}_p\}$. It is done by successive exhaustion process of subspaces beginning with the dimension n to 1.

The basis (1) and phase subspaces are derived to study the variability of the climatic system dynamics [3]. That is why the parameter n is taken equal to the number of years in Reanalysis data base [4]. The time interval in D_t^h is accepted as long as 1 month with daily behavior in 12 hours. The resolution in horizontal directions (x_1, x_2) of the global system, is taken as $2{,}5^\circ \times 2{,}5^\circ$ in spherical coordinates. The number of vertical levels is prescribed as a parameter, from 1 to 20. The parameter N is taken in dependence on the goal of the study as well. The month interval is a compromise between the informative quality and the amount of calculations. Thus, the set of 12 monthly basis vectors is produced from 40-year Reanalysis data (1960-1999). It is used to discover the main factors and analyze the multi-year atmospheric dynamics and quality of the atmosphere.



In Fig. the fragment of the first month main factor (FMMF) of the geopotential at 500 mb corresponding February 15, 00.00 is demonstrated. The space-time behavior of the FMMF shows not many almost stationary extrema areas that can be interpreted as energy active zones.

Taking into account the constructions mentioned above, a new type of geophysical hydrodynamics models has been introduced. It can be called the model with "guide". In such models, long time-space observations and the bases of the type (1) are used to form the special phase spaces, the so-called "guides". The models of hydrodynamics and pollutant transport are used here as interpolants which assimilate the elements of the guiding phase space under the given optimal criteria. The fields of application of such models are: reconstruction of the state functions from the current monitoring data in real time, diagnosis of the processes, formation of scenarios for ecological forecast and design, etc. The principle advantage of the approach is the fact that predictability is no longer crucial for it because the method is based on the use of the model and observed data.

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References

1. Harman, H.H. Modern Factor Analysis. 1976. 3rd Ed. Univ. of Chicago Press, Chicago.
2. Preisendorfer, R.W. Principle Component Analysis in Meteorology and Oceanography. Elsevier, 1988.
3. Penenko V.V., Tsvetova E.A. Formation of atmospheric circulation scenarios for climate and ecological studies. Atmos. Oceanic Opt. Vol.14. N 6-7, 444-448.
4. E. Kalnay, M. Kanamitsu, R. Kistler, et al., The NCEP/NCAR 40-year reanalysis project. Bull. Amer. Meteor. Soc. **77**, 437–471 (1996).