Simulation of climatic anomalies at the beginning of 21st century in the areas of Salvador and Porto Alegre cities on the basis of the physical-statistical heat-balance model of the “ocean – atmosphere” system.

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Abstract.

There is made a simulation of semi-annual sea-surface temperature (SST) and semi-annual total of precipitation in Salvador and Porto Alegre cities on the basis of physical-statistical heat-balance model of the “ocean - atmosphere” system that was constructed with taking into account of solar activity. Also there is represented a long-term forecast of anomalies of semi-annual totals of precipitation in these regions. The represented forecasts are constructed basing on the fact that during the proximate 50 years there is expected a considerable lowering of the solar activity, at least, within the centenarian cycle.

The comparative analysis of correlations between semi-annual SST and semi-annual total of precipitation in the indicated regions has shown firstly, that the correlations are different, and, secondly, that they may change on the boundary of centuries. It coincides with the simulated changing of a trend of the average-annual temperature of Southern America and, to all appearances, is connected with the change of the global energy and circulation processes.

Introduction.

The happening global warming now is a fact difficult to contest with. The world public is concerned by the changes of regional climate connected with it. The amount of climatic anomalies increases in many regions. At the same time there is still no reliable enough system of early warning of these anomalies and connected with them threats to economic and other human activities. It essentially hampers the reducing of their economic and social consequences.

The existing dynamic models, as a rule, are based on the registration of a great number of physical parameters. The inaccuracy of definition of the initial conditions and description of physical processes during long enough time of integration, eventually, leads to accumulation of a considerable error and decrease of reliability of obtained outcomes. In despite of known advantages of such approach the existence of objective physical, technical and mathematical problems will demand a lot of research time for obtaining reliable long-range forecastings.

In this situation, the use of statistical and physical-statistical models is quite justified.

In the present work the simplified heat-balance physical-statistical model of “ocean – atmosphere” system based on the taking into account of solar activity influence on the greenhouse effect is used for simulation of regional climatic parameters (Brasil). The statistical part of the model allows in the conditions of not totally clear physical processes in the system to construct a closed climatic model (Budovy, Khorozov et al., 2004).

Build-up principles and features of heat-balance physical-statistical model of “ocean – atmosphere” system (MOAS-PSHB).

The existence of correlation connections between solar activity and temperature (Borisenkov and Pasetskii, 1988; Friis-Christensen and Lassen, 1991; Lassen and Friis-Christensen, 1995), which are well viewed when the large intervals of averaging are used (Fig. 1), allows to assume the existence of some physical mechanism (Fig. 2) that implements influence of solar activity on the climate-making processes.

Such mechanism can have time constants itself. If it has time constants of about 11 years or more the immediate correlation between 11-years cycle of solar activity and temperature can be not detected even if the solar activity is the only one climate-making factor. In this case a short-term influence of solar activity on temperature can be detected only with using of simulation.

For the purposes of simulation the “ocean – atmosphere” system is represented in the form of the following layers (Budovy, Khorozov et al., 2004):

Upper layer – is the atmosphere and a thin surface layer of the global ocean lower which the solar radiation practically does not penetrate;

Middle layer – is a layer of the global ocean with an intensive water circulation;

Lower layer – is a bulk of ocean with a weak water circulation.

A peculiarity of the offered model is that there is considered the integral heat exchange between singled out layers and environment, but the inside physical processes of layers are not considered. The influence of processes that take place inside the layers is characterized by the effective coefficients of the equations of heat balance (Eq. 1-8). These coefficients are defined by Monte-Carlo method on the basis of available data of meteorological observations of global temperature (Fig. 3).

$$\frac{d(C_eT_e)}{dt} = F_s - F_e - F_m \tag{1}$$

$$\frac{d(C_mT_m)}{dt} = F_m - F_d \tag{2}$$

$$\frac{d(C_dT_d)}{dt} = F_d \tag{3}$$

$$F_s = F_{so}(1 - K_W W)(K_\nu + K_r e^{-K_{sr}R_r^{N_s}}) \tag{4}$$

$$R_r = (A_{xr} + B_{xr}W)10^{\frac{aT_e}{b+T_e}} \tag{5}$$

$$F_e = T_e^{\,4} K_e e^{-K_{er}R_r^{N_e}} \tag{6}$$

$$F_m = L_m(T_e - T_m) \tag{7}$$

$$F_d = L_d(T_m - T_d) \tag{8}$$

$$t = f(T_e,\ T_m,\ T_e',\ T_m',\ T_e'',\ T_m'') \tag{9}$$

Where:

C_e; C_m; C_d – effective heat capacities, accordingly, of the upper, middle and lower layers;

T_e; T_m; T_d – effective temperatures, accordingly, of the upper, middle and lower layers.

F_{so} – stream of solar radiation reaching the upper layer if the Sun has no spots;

F_s – stream of solar radiation being absorbed by the upper layer;

K_W – coefficient of energy effectiveness of an average solar spot;

W – Wolf number;

K_r - percentage of long wave solar radiation;

$K_\nu = 1 - K_r$

K_{sr} , N_s – coefficients, defining effective reflective ability of a layer of condensation products (for solar radiation);

R_r – effective dimensionless thickness of a layer of condensation products;

A_{xr} ; B_{xr} – coefficients of linear regression;

a = 7.63 ; **b** = 241.9

F_e – radiation stream from the upper layer into space;

K_e – effective coefficient of radiation of the upper layer;

K_{er}; N_e – coefficients, defining effective reflective ability of a layer of condensation products (for effective radiation of the upper layer);

F_m – heat stream from the upper layer into the middle one;

F_d – heat stream from the middle layer into the inferior one;

L_m; L_d – effective coefficients of heat exchange, accordingly, between: upper and middle, middle and inferior layers.

t – surface temperature of air

It is such representation that allows to construct the closed model despite of presence of the set of complex and not quite studied physical processes in the "ocean - atmosphere" system. Within the model the concrete climatic parameters are defined as statistical dependences on effective temperatures of the layers and their derivatives (statistical part of the model – Eq. 9).
The researches have shown that the obtained form of statistical dependence is applicable for simulation of a wide range of parameters of global and regional climate: temperature, amount of precipitation, parameters ENSO and NAO, amount of tropical Atlantic hurricanes etc.
The computing experiments demonstrate a good correspondence between simulated values of climatic parameters and their observed and reconstructed values of the past thousand years (Budovy, Khorozov et al., 2004).
In particular, the obtained model of global temperature (Fig. 3), in contradistinction to models based on anthropogenous effect, well enough explains the main climatic events of the past thousand years (warming of a climate in 12th-13th centuries and at the end of the second millennium, and also a small glacial epoch within 15th-17th centuries).
As the model explains known changes of a climate in the past (Fig. 3) it allows to suspect a correctness of the key idea put in its basis.

Simulation of regional climatic parameters.

The adaptation of MOAS-PSHB (calculation of coefficients of a statistical part of the model) was carried out according to the data of observations for the period of 1950-1990 years (the training data sample). The observed data of 1991-2004 years (independent data sample) were used for check of outcomes of the simulation.
On the presented figure (Fig. 4) it is visible that the model well imitates semi-annual values SST (coefficients of correlation between the observed and calculated values of temperature by independent sampling - 0.75-0.84).
Model as a whole imitates satisfactorily also semi-annual totals of precipitations in Salvador (Fig. 5) and Porto Alegre cities (coefficients of correlation by independent sample between calculated and actual values (1985 – 1995 years) – 0.6-0.9).
Thus, the obtained outcomes demonstrate that the model MOAS-PSHB is quite applicable at least for the simulation of parameters ENSO and obtaining of the estimate prognoses of anomalies of amount of precipitation in selected regions of Brazil.

The forecast of precipitation amount in the areas of Salvador and Porto Alegre cities.

The represented below forecasts are constructed basing on the fact that during the proximate 50 years there is expected a considerable lowering of the solar activity, at least, within the centenarian cycle.
On Fig. 6-7 there are represented the results of simulation of semi-annual (03-08 months) values of sea-surface temperature (NINO 1+2) and totals of precipitations in

Salvador and Porto Alegre cities accordingly. On Fig. 8 there are shown the same graphics but for 09-02 months. As we can note, the character of correlations between anomalies of semi-annual sea-surface temperature and totals of precipitations in the selected regions firstly, is different, and secondly, changes on the boundary of centuries. It is interesting, that at the same time the trend of average annual temperature on the territory of Southern America changes also (Fig. 9).

The results of simulation shown on this graph are also obtained with the use of the model MOAS-PSHB. It is important to emphasize that the coefficients of all models were defined independently. The trend of temperature (Fig. 9) can conditionally be divided into the three parts: rise - till 1991, the period of relative stabilization of temperature - 1991-2003 years, temperature drop - after 2003.

For the more detailed analysis of the discovered effect in the Table 1 there are represented different coefficients of correlation.

The table 1. Coefficients of correlation between semi-annual values of the total of precipitations and SST-NINO 1+2 (Between actual values – f-f; Between simulated values – m-m).

Months	Years	Salvador		Porto Alegre	
		f-f	m-m	f-f	m-m
03 – 08	1950-1995	-0.26	-0.48	0.31	0.44
	2005-2050		-0.75		0.80
09 – 02	1950-1995	-0.11	-0.02	0.50	0.43
	2005-2050		0.63		0.22

It can be noted that:

- The coefficients calculated for the second half of 20th century both for the actual and for the simulated values differ between themselves a little bit. It shows that the model quite adequately reproduces the correlations between the amount of precipitation and SST.
- The coefficients calculated for the first half of 21st century considerably differ from the corresponding coefficients calculated for the second half 20th century. Moreover in Salvador city (09 - 02 months) the coefficient of correlation even changes the sign. It points on the fact that on the boundary of centuries the character of correlation between the amount of precipitation and SST can really have considerable change.

Such a change of correlation connections at all does not show disadvantages of the simulation, on the contrary – it reflects the possible change of energy and circuital processes in the "ocean – atmosphere" system which is expected in 21st century, and corresponds to the concept of presented model (Fig. 2, 3 and 9)

Thus, if the considered concept is basically correct, it becomes clear that the use of statistical analysis of correlations between parameters ENSO and climatic parameters is obviously insufficient for the estimation of possible regional climatic anomalies.

The simulation of development of global energy processes in the "ocean – atmosphere" system (MOAS-PSHB) especially in conditions of possible change of the climatic tendencies can give considerably more reliable outcomes.

Conclusions.

The following conclusions can be made from the aforesaid:

- The existing connections between ENSO and amount of precipitation are rather complicated and in a high degree depend on the development of global energy processes. That's why the estimations of climatic anomalies will hardly be effective on the basis of a simple statistical analysis, especially during change of the character of energy processes in the "ocean – atmosphere" system.
- SST and the amount of precipitation of the considered regions depend most likely on the same global energy processes in the "ocean – atmosphere" system, at the same time the immediate influence of ENSO on the climate is hardly significant. Therefore it's more preferable to use for simulation of regional climatic parameters the models of the "ocean – atmosphere" system (for example, MOAS-PSHB).
- In accordance with outcomes of simulation in the area of Salvador city the probability of considerable deficit of precipitations in March - August of 2008, 2009, 2018, 2019 years (Fig. 6) and excessively great amount of precipitations in September – February of 2008-2009 and 2009-2010 years (Fig. 8) is high. In the area of Porto Alegre city the probability of a great amount of precipitations is high in March - August of 2008, 2009, 2018, 2019 years (Fig. 7). All above enumerated half-years correspond to the forecasted El-NINO episodes. Besides, in the area of Salvador city a lot of precipitation is expected in March - August of 2005, 2012 and 2022 years (Fig. 6) which correspond to forecasted La-NINA episodes.

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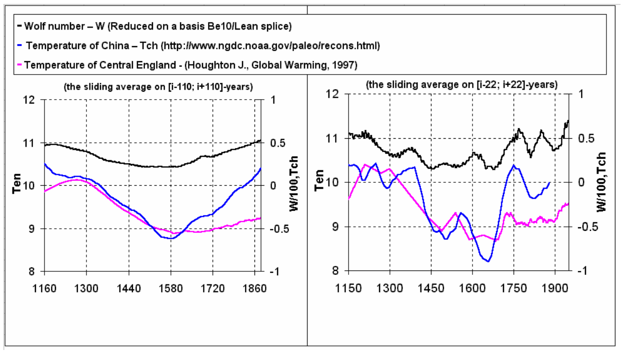

Fig. 1. The reconstructed and actual temperatures of Central England and China. Wolf number.

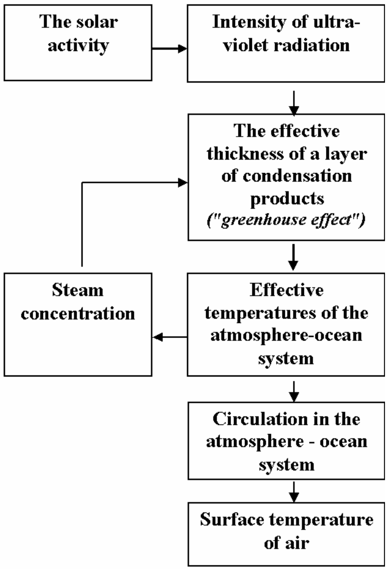

Fig. 2. The scheme of the probable mechanism of solar activity influence on surface temperature.

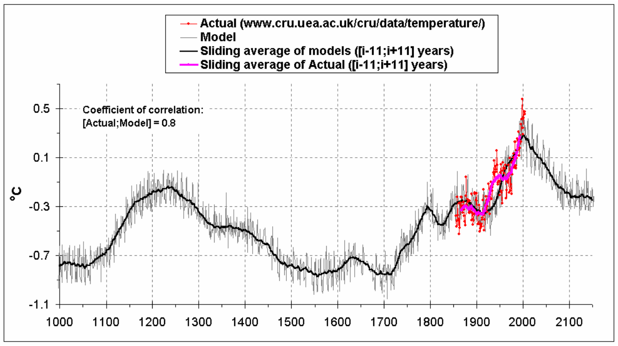

Fig. 3. Global temperature anomalies (from the base period 1961-90).

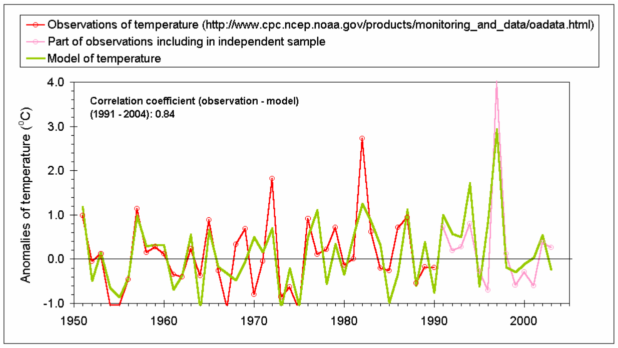

Fig. 4. Anomalies (base period: 1951-1980 years) of semi-annual (09 - 02 months) sea-surface temperature (NINO1+2).

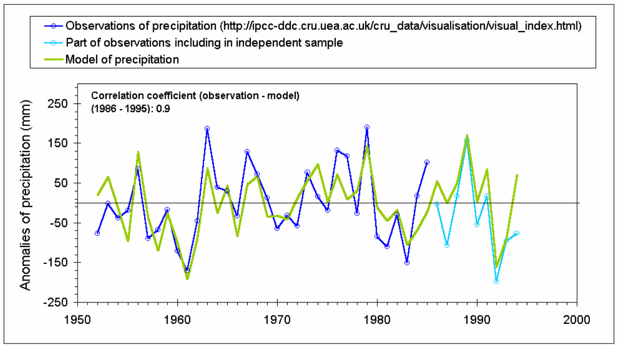

Fig. 5. Anomalies (base period: 1951-1980 years) of semi-annual (09 - 02 months) sum of precipitation in Salvador city.

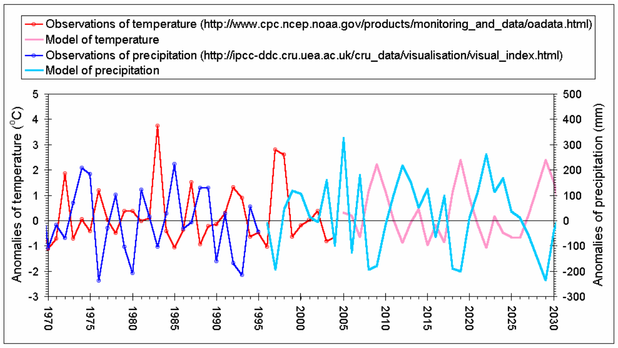

Fig. 6. Anomalies (base period: 1951-1980 years) of semi-annual (03 - 08 months) sum of sum of precipitation in Salvador city and of the sea-surface temperature (NINO1+2).

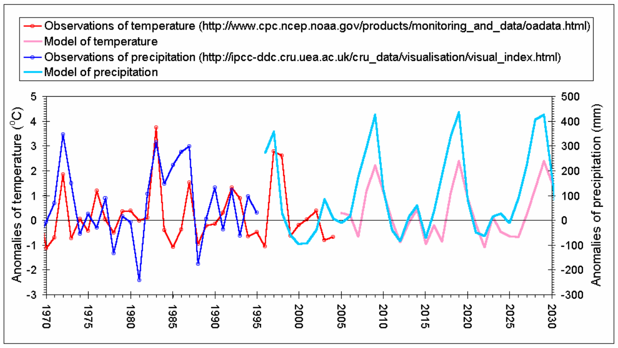

Fig. 7. Anomalies (base period: 1951-1980 years) of semi-annual (03 - 08 months) sum of sum of precipitation in Porto Alegre city and of the sea-surface temperature (NINO1+2).

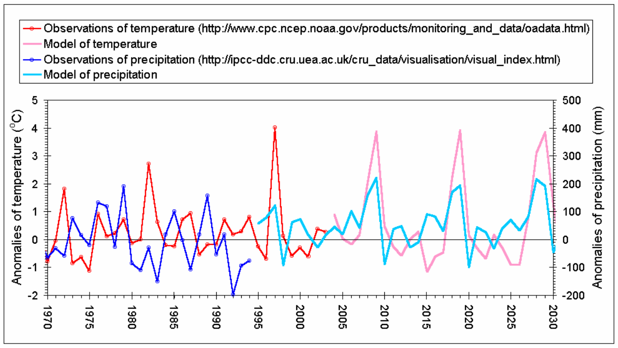

Fig. 8. Anomalies (base period: 1951-1980 years) of semi-annual (09 - 02 months) sum of sum of precipitation in Salvador city and of the sea-surface temperature (NINO1+2).

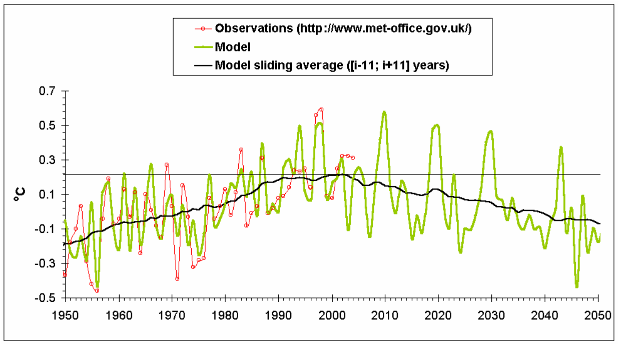

Fig. 9. Anomalies (base period: 1961-1990 years) of the annual surface temperature of South America (60S-10N, 80W-35W).