Колебания уровня Каспийского моря: история исследований и методы прогнозирования

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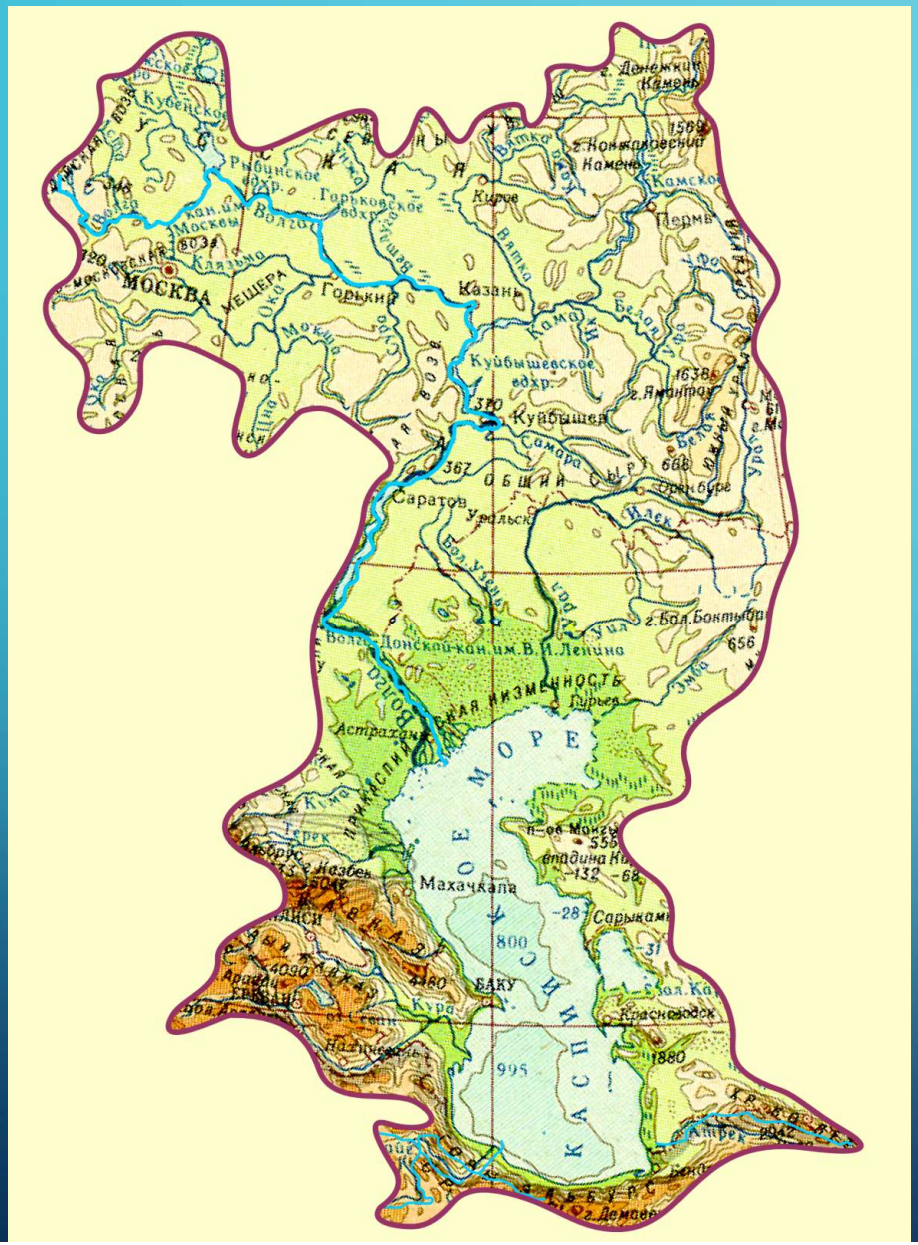
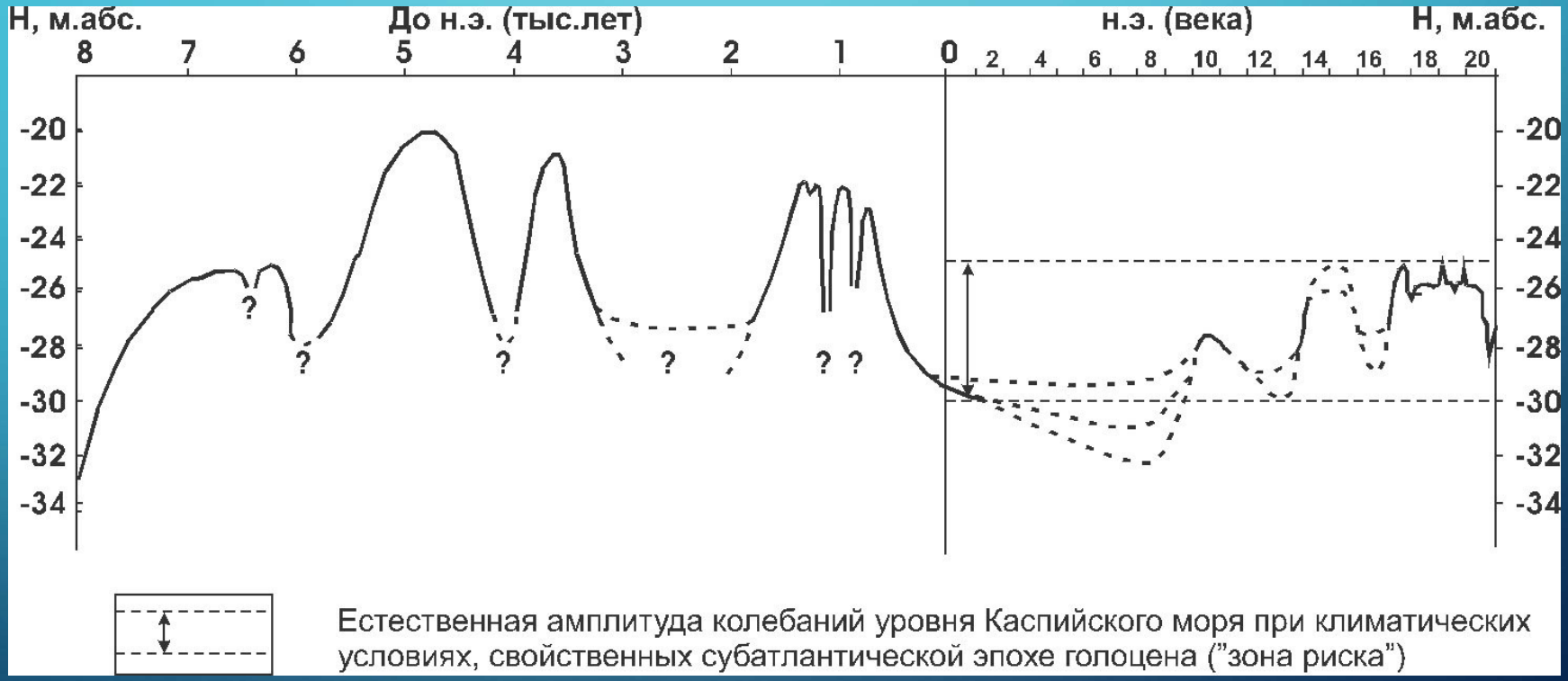
Научная конференция по изменению климата в регионе Каспийского моря, 27-28 октября 2021

CASPIAN SEA AND CATCHMENT AREA

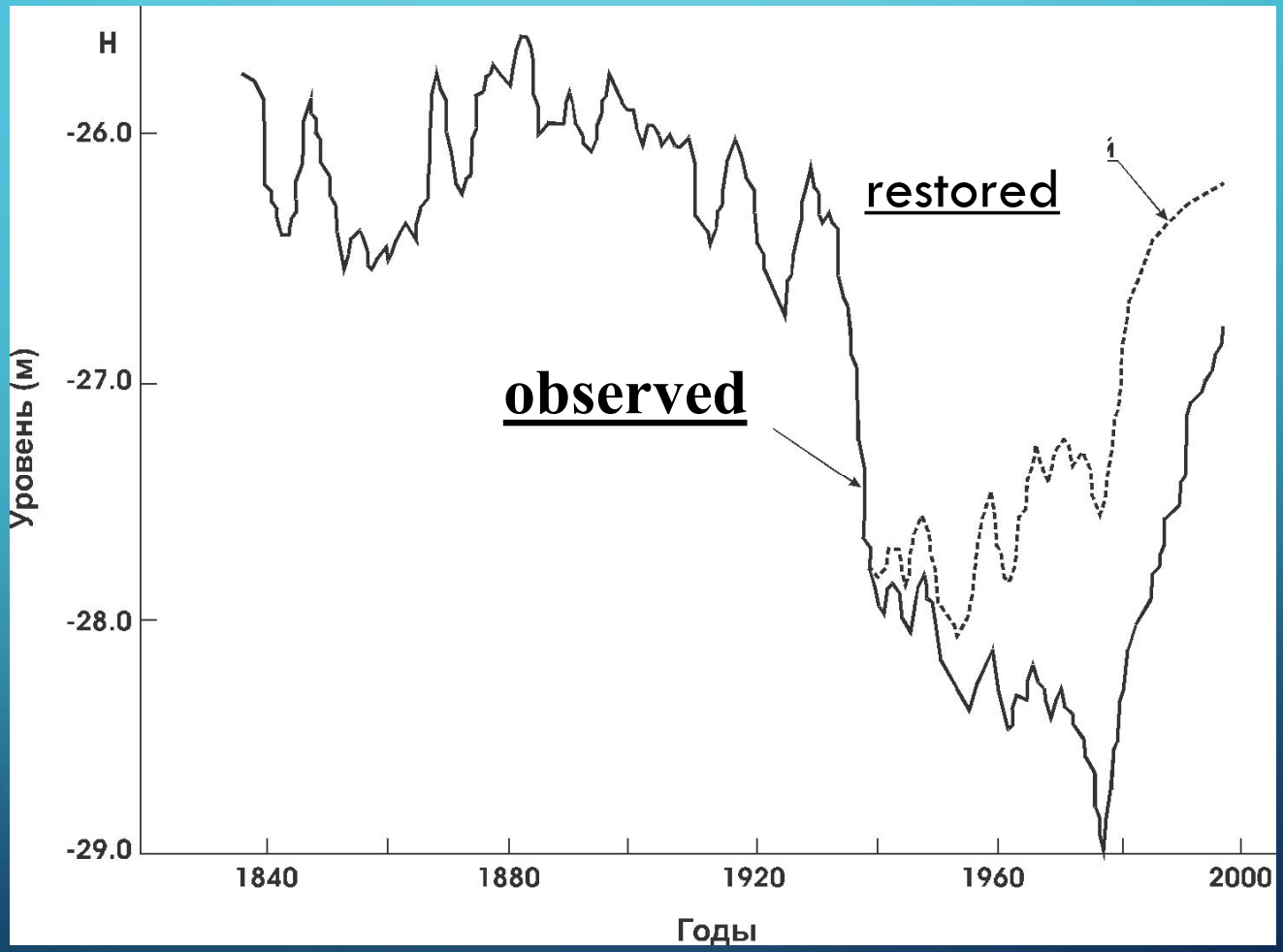


LOSSES ON THE CASPIAN SEA SHORE: RUSSIA AND IRAN

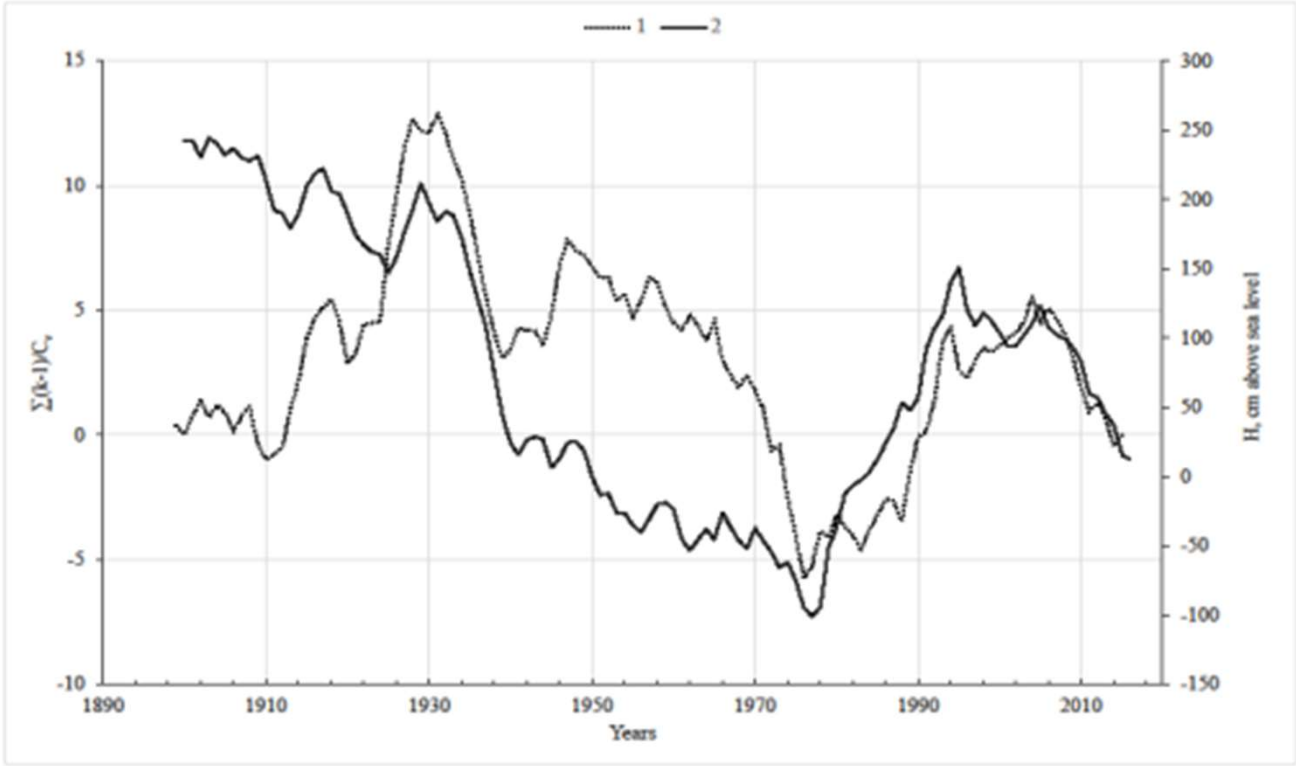
Fluctuations of the Caspian Sea level for recent 10 thousand years



AVERAGE ANNUAL VALUES OF OBSERVED AND RESTORED SEA LEVEL



THE CASPIAN SEA WATER LEVEL FORECAT



The difference-integral curve of the inflow to the Caspian Sea (1) and its water level changes (2))

METHOD OF KRITSKIY & MENKEL

$$\Delta W_i = W_i - W_{i-1} = V_i - e_i F_0 - 1/2 e_i A(W_{i-1} + W_i)$$

$$W_i = \frac{1 - 1/2 e_i A}{1 + 1/2 e_i A} W_{i-1} + \frac{V_i - 1/2 e_i F_0}{1 + 1/2 e_i A}$$

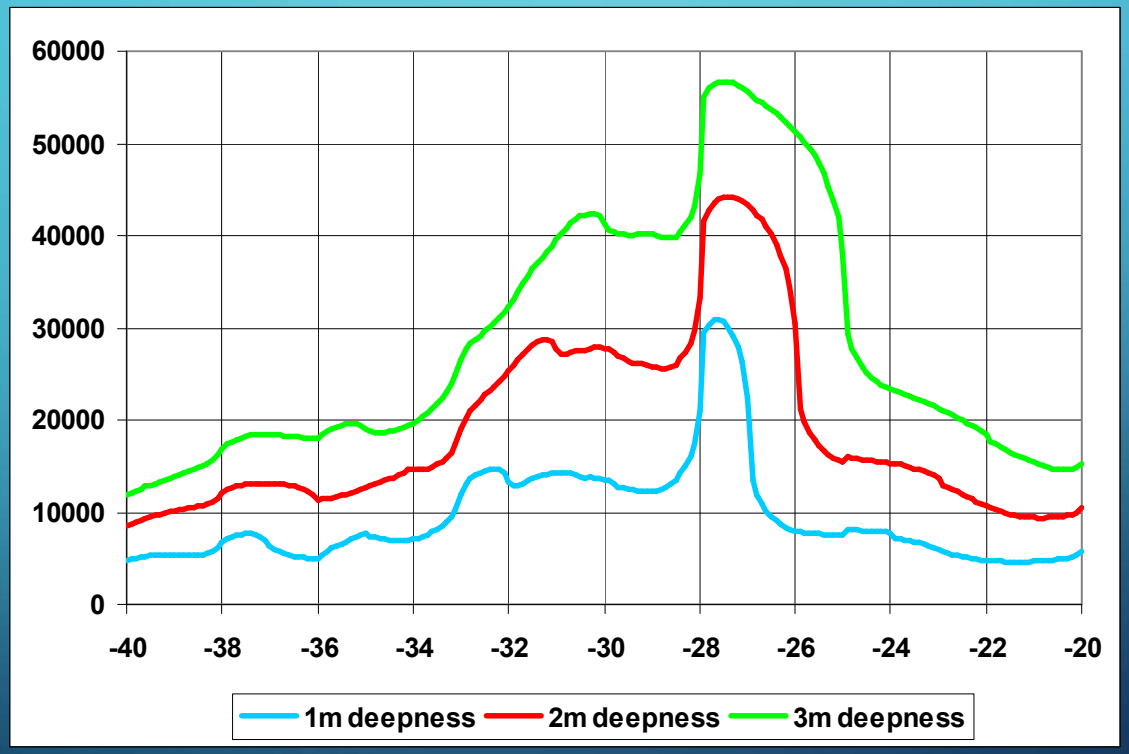
$$F_i = F_* + A(W_i - W_*)$$

$$\Delta w_i = w_i - w_{i-1} = W_i - W_{i-1} = V_i - e_i \{F_* + 1/2(w_i + w_{i-1})\} =$$

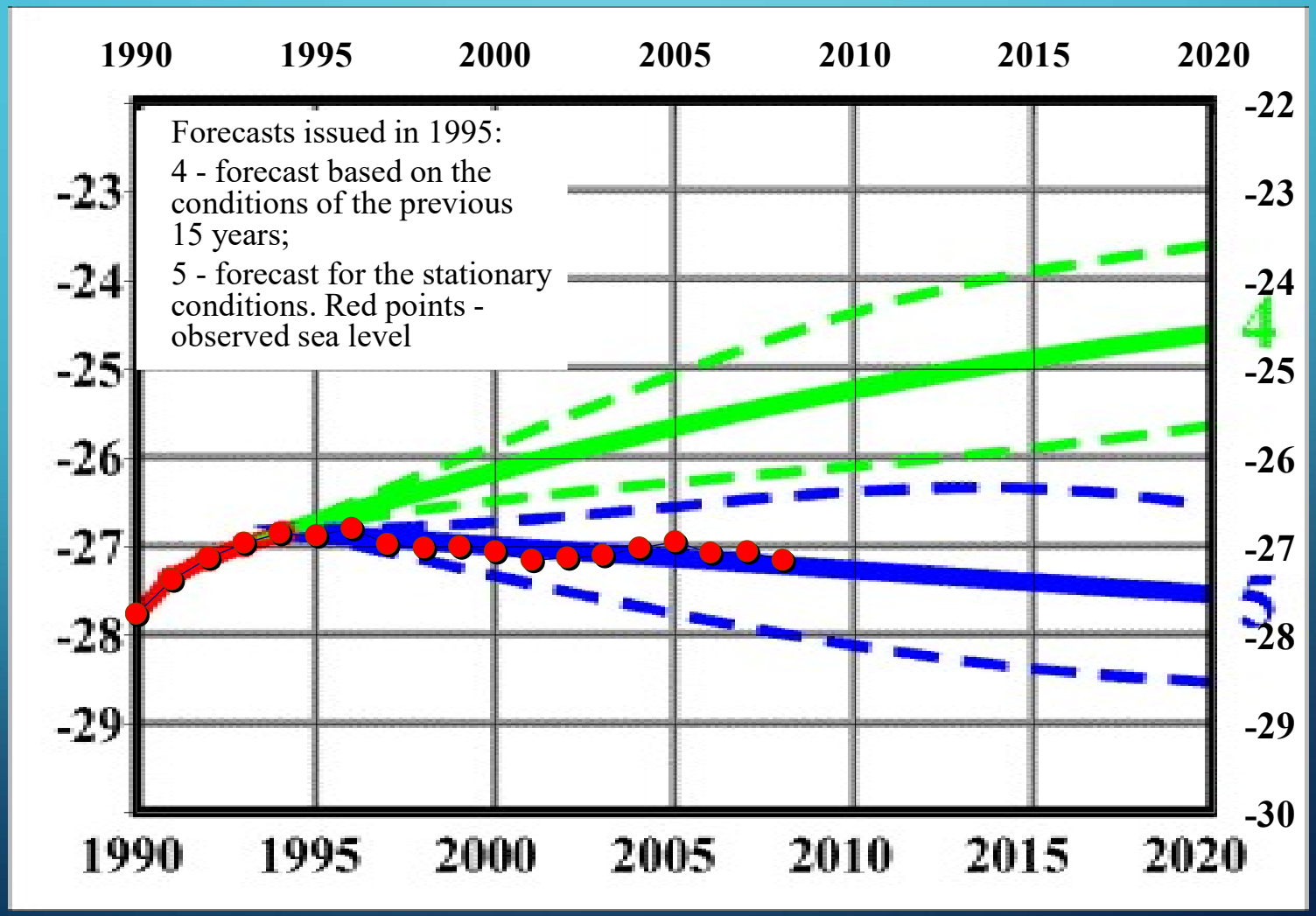
$$= v_i - 1/2(e_i - e_* + e_*)A(w_i + w_{i-1})$$

$$w_i = \frac{1 - 1/2 A e_*}{1 + 1/2 A e_*} w_{i-1} + \frac{v_i}{1 + 1/2 A e_*}$$

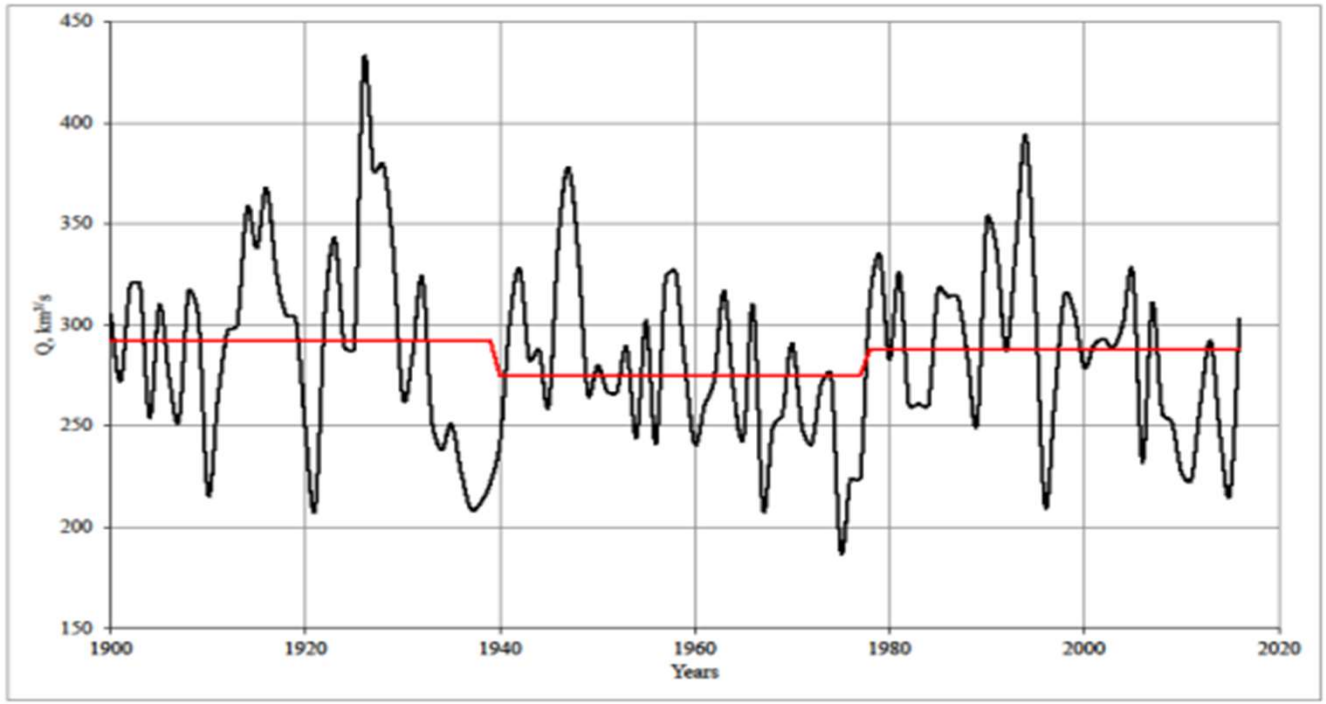
DEPENDENCE OF SHALLOW WATER AREA ON THE SEA LEVEL



COMPARISON OF OBSERVATION AND FORECAST



the Caspian Sea water level forecat



The regime of the mean inflow to the Caspian Sea (— average value for a period)

the Caspian Sea water level forecast

Statistical characteristics of total surface inflow to the Caspian Sea for different observation periods

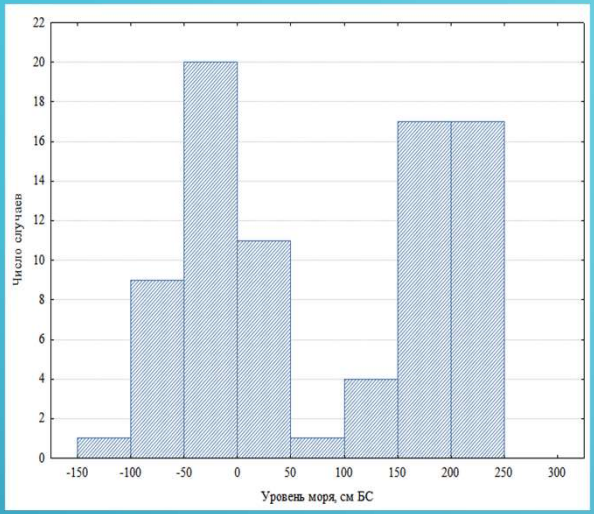
Period	The length of the time-series, years	Average inflow, km^3	Variation coefficient	Asymmetry (Cs/Cv)	The first autocorrelation coefficient r (1)
1900-2017	117	287	0,16	1,8	0,38
1900-1939	40	292	0,18	1,8	0,54
1940-1977	38	276	0,15	1,0	0,22
1978-2016	39	294	0,14	1,5	0,21

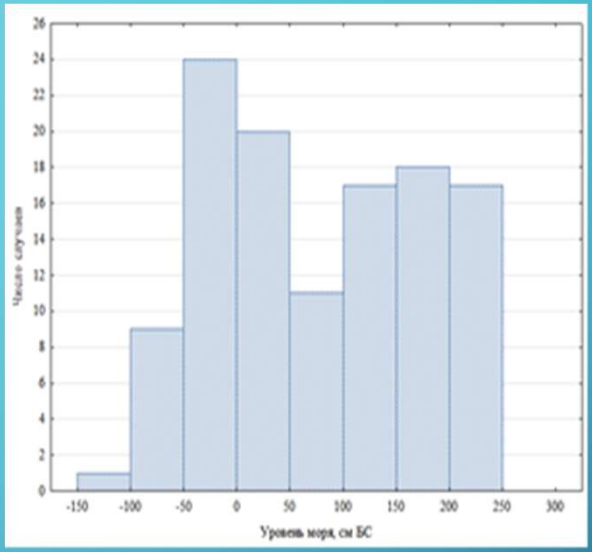
the Caspian Sea water level forecast

Statistical characteristics of the time-series of the Caspian Sea level simulated using different models of inflow variability

Distribution parameter	Observation	Markov model of inflow	Semi-Markovian model of inflow			
			Mean root square deviation of the "mean inflow" parameter			
			0,1	4	10	15
Mean level, m	-27,2	-28,27	-28,25	-28,25	-28,24	-28,23
Asymmetry (Cs)	0,11	0,12	0,16	0,18	0,19	0,17
Mean root square deviation, m	0,97	0,73	0,63	0,66	0,79	0,95
R(1)	0,99	0,976	0,97	0,97	0,98	0,99

A





The Histogram of the Caspian sea level for different periods

a **b**

a – 1900-1979 b– 1900-2016 гг.

the Caspian Sea water level forecast

The differential equation of water balance of Caspian Sea looks like:

$$\frac{dh}{dt} = -\alpha h(t) + g(t)$$

where h -is the sea level; α - is the parameter dependent on the coast steepness and g is the resulting of the processes of inflow and evaporation from sea surface minus the precipitation on its surface. It is supposed also, that g is the stationary Markov process with autocorrelation coefficient and a dispersion known.

the Caspian Sea water level forecast

The solution of Markov equation in the form of bilinear decomposition on systems of orthogonal polynoms

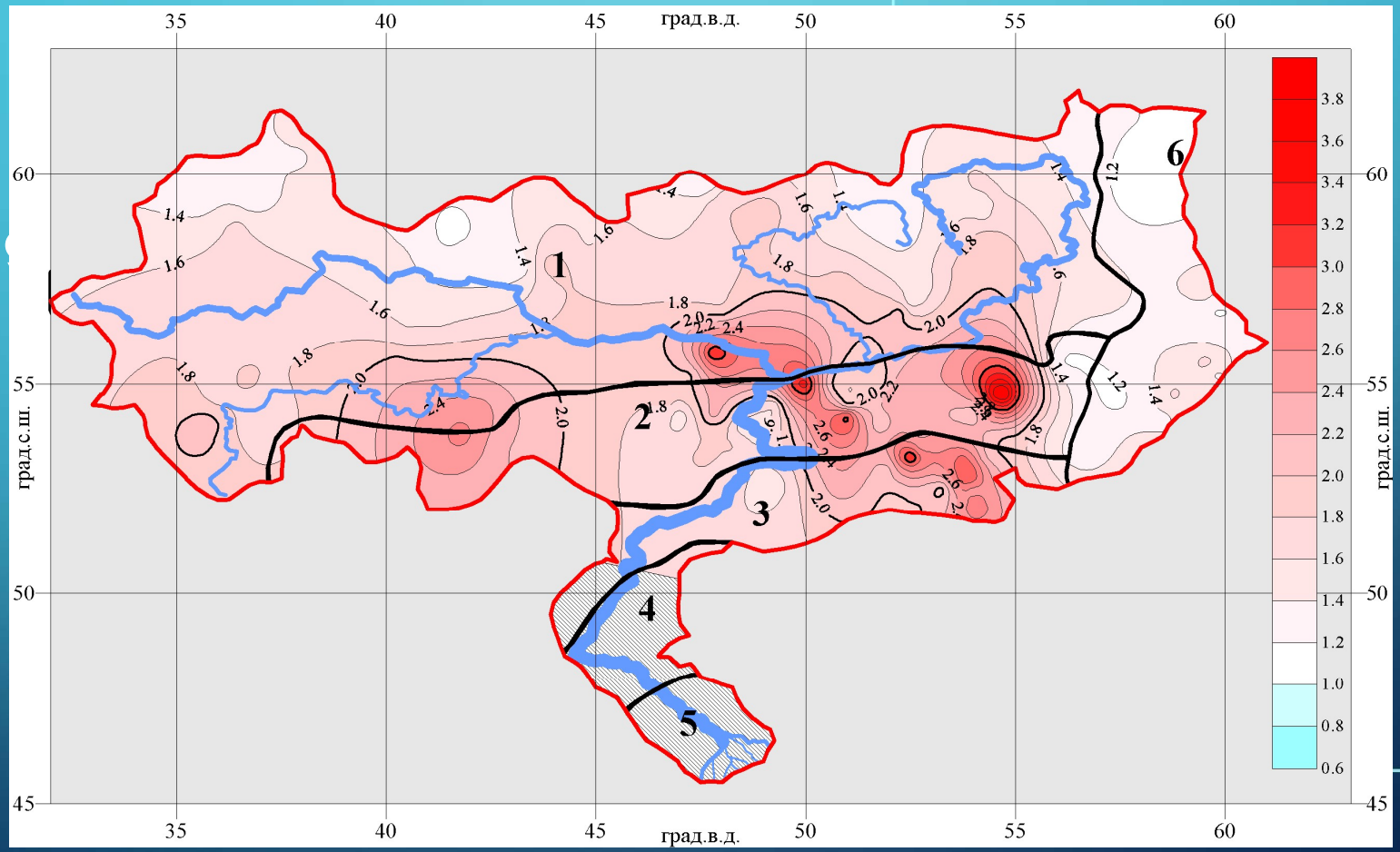
The two-dimensional density satisfies to Markov equation (under some conditions) if I t the sum of the following kind

$$p(t,x,y) = p(x)p(y)\left[1+\sum_{k=1}^{\infty} e^{-\lambda_k t}\varphi_k(x)\varphi_k(y)\right]$$

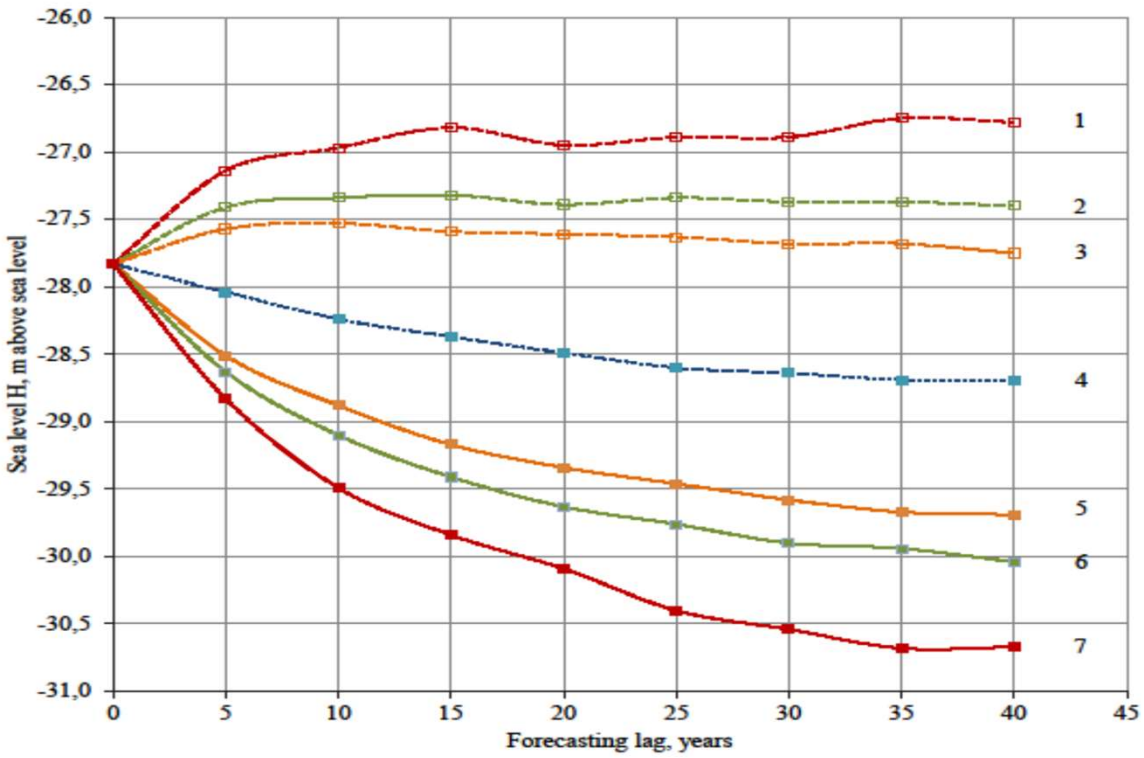
where λ_k are positive numbers, so as $0 < \lambda_1 \le \lambda_2 \le \lambda \ldots \le \lambda_k . < \ldots$, and $\varphi_k(x)$ and $\varphi_k(y)$ form the system of orthogonal functions with the weight $p(x)$.

the Caspian Sea water level forecast

Chang



the Caspian Sea water level forecast

The Caspian Sea level predicted for the lead time of up to 40 years with the probability:

1 - 1.0%; 2 - 5.0%; 3 - 10.0%; 4 - 50.0%; 5 - 90.0%; 6 - 95.0%; 7 - 99.0%.