Modern approach for determination of absolute climate eustasy

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ABSTRACT

A statistical method of the absolute eustasy (E_{Ca}) calculation, one of the major parameters of World Ocean (WO) level fluctuation, caused by climate change, is used. This parameter specifies to a sea level fluctuation relatively to its starting position and numerically is equal to sum of relative eustasy (Ec_r mm/year) and the value of "geological trend", i.e. the velocity of shore secular vertical *movement (±C mm/year)*

The starting position of sea level is its value at the beginning of the current global warming, which changes according to latitudes. Therefore, if level statistical series (LCS) covers the periods before and after the current climate fluctuation (so-called "long statistical series), it should be split into two fragments and Ec_a value calculation make by the second of them, using the equality $E_{Ca} = Ec_r \pm C$.

As along the WO shores geological trend varies widely (glacioizostatic processis, tectonics, ground' subsiding, etc.), where $C > Ec_r$, the sea level is reduced relatively to shore ($Ec_r<0$), but not relative to its starting value ($Ec_a > 0$). Throughout the WO regions $Ec_a > 0$, but has different values depending on the coefficient of thermal expansion of sea water and incoming discharge to WO, from the long-term stocks of land water. The main features of the $E_{Ca} = f\ (Ec_r, C)$, as well as Ec_a calculation are presented in table and conclusions.

Keywords: eustasy, level series, climate, subsiding.

INTRODUCTION

The current climate eustasy (E_C), or World Ocean (WO) sea-level rise - another long-term sea level rise is the result of the thermal expansion of ocean waters and the change of freshwater balance between WO and the land in favor of the former. Since it is provoked by climatic cycles and fluctuations having continuous in time and space character can be both negative and positive.

The current global warming was started in the 1880 's [2]. Before this period, ~ 150-200 years colder climatic fluctuation was acted and each was accompanied by appropriate E_C . Recent E_C followed the current fluctuation range of latitudes and time lag. In the high northern latitudes it is observed from the mid-1890 's, but in the middle and lower ones from 1900-1920 (on the Black Sea the global warming processes revealed in 1900-1905 's, but Ec since 1923-1925) [3],[5]. This process with even more time shifting has started in Antarctica (1950-1960). The research has been conducted with the help of EU funded project "SeaDataNet 2" and utilized the data collected in the project database.

DISCUSSION

A study of the current Ec has applied and cognitive values. At the present stage of the increased challenges generated, by it the clarification of its parameters through improved statistical methods for the analysis of the tested level series and new types of initialization of sea level monitoring became necessary. In regard to this goal, in 2000 's was organized space monitoring of WO surface fluctuations, but while it covered only relatively small part of WO and the number of such observations is not sufficient for the implementation of reliable scientific synthesis.

Therefore, the vast majority of Ec study is performed by level' statistical series (LSS), created on the data of the land-based measuring systems. They are more extensive and accessible, but have a significant disadvantage - content constant error resulting from so-called "geological trend (±C mm/year)", or coast secular vertical movement, on which the level measuring system is located. Because of the integral glaciological isostasy, tectonics, ground subsidence and other factors, the geological trend in some areas of WO is very large and heavily distorts the absolute value of the Ec_a. In the high latitude regions it surpasses its value even several times (Sywa station - Antarctica, Shpitsbergen – Arctica). At such shores sea level does not increase relatively to coast (fig. 1), but along some other ones it decreases very intensively (Antarctica, Canada, Fenoskandia).

Therefore the Ec value change relatively to the shore (relative eustasy - Ec_r), can be determined according (LSS). However, for the solution of many scientific and applied tasks, it is necessary sea level rise determination not on land, but from its starting position, i.e. since the period of the level fall (negative Ec) to the present one, when Ec > 0. This value is the absolute value of (E_{Ca}) of present climate eustasy, the local values of which are the input parameters for the implementation of many scientific and applied problems and determination of Ec true value both for entire WO and its specific regions.

Based on these concerns, the purpose of the present study may be summarized as follows: to propose the way of E_{Ca} calculation using the statistical data series of Earth gauging systems, to determine the amount of Ec_r and E_{Ca} at points with the reference geological trend and present in the form of the main conclusions of the Ec_a calculation features along such shores.

During the eustasy each reading of water-level gauge system H_i, represents the sum of the following components:

$$H_i = H_o + C, \quad \text{at the elevating shores} \quad (1)$$

$$H_i = H_o - C, \quad \text{at the subsiding shores} \quad (2)$$

H_i - is a reading of the sea level, H_o-sum of hydro-meteorological component H_i, in observation moment (in sity) and the level eustasian changes relatively to the land by the same moment, C-geological trend, or a velocity of shore secular vertical movement.

After the relevant mathematical operations, statistical series of mean (annual, seasonal, monthly) levels can be presented as follows:

$$\{H_j\}_{j=1} \quad j = 1, 2, 3 \ldots N. \qquad (3)$$

N- is the number of the LSS members.

Using the method of least squares and linear regress, the mean sea surface level rising relatively to the shore, i.e. the relative climate eustasy Ec_r can be calculated with precision of millimeter. From equality (1) and (2) the absolute value of the current climate eustasy (E_{Ca} mm/year) represents the sum of the relative eustasy for a specified period of time and the geological trend.

$$E_{Ca} = E_{Cr} \pm C. \qquad (4)$$

However, because along the elevating shores, the sea level rising occurs in condition of relatively rising earth (C>0), geological trend decreases the value of the Ec_a (effect of unidirectional movement). Hence, along the shores the E_{Ca} should be calculated as a sum of the follows:

$$E_{Ca} = E_{Cr} + C. \qquad (5)$$

At the subsiding coast where there is C<0, the reverse process is noticed- trend causes the imaginary level increase, due to multi-directional movement of land and sea surface.

Therefore,

$$E_{Ca} = E_{Cr} - C \qquad (6)$$

A large part of the LSS contains data for both climatic fluctuations. Naturally, during the cold fluctuation WO level was dropping and Ec was negative. In the current period of climate warming Ec>0. The LSS, included data of both fluctuations, are called "long seriess" and should be reviewed according the appropriate method [3]. Such LSS should be divided onto fragments of negative and positive Ec data. Then, for both of them, independently from each other, the tendency of eustatic process development, its speed and other characteristics are determined in order listed above.

Several tide gauges (Aberdeen, Brest and et.cet), among them the tide gauge located on the perimeter of the Black Sea, have statistically reliable double fragment series. The most extensive are the stations of Poti (1873-2013), Batumi (1882-2013), Sevastopol (1875-1996), Odessa (1875-1997), Burgas (1896-1995), Varna (1895-1996) and others.

They are located on the perimeter of the sea, on the tectonically multi-directional shores. According to data from repeated geodetic surveys, Poti' coast settles with the speed $C \approx 6{,}0$ mm/year, and Batumi coast is elevated with the velocity equal to $C=1.0$ mm/year. At the coast of Poti the relative E_C for 1925-2013 years was accelerated to 1,6 mm/year and has reached 7,1 (0.71 m/century), but at Batumi it reached 2,7 mm/year, absolute one- 3,7 (0,37 m/century) respectively.

The Ec research around the perimeter of the WO showed, that along the vast majority of shores the water level rises ($Ec_r > 0$, fig. 1A), at some of them this process is expressed implicitly ($Ec_r \approx 0$, fig.1B), but at many others, on the contrary- the level sharply decreases ($Ec_r < < 0$, fig. 1C). Of course, such division of E_{ca} does not reflect its actual status, as the climate current warming covers the entire planet. Therefore, the increase of water level due to its thermal expansion has to be observed in WO all area, especially in the high-latitude waters, where the water thermal expansion coefficient is the highest. This fact clearly indicates that the Ec_a study by LSS must be made considering geological trend (table 1), the amount of which is determined by the geodetic and other proven methods.

Conclusions

a) If the sea level rises relatively to coast, at the elevating shores, i.e. the relative eustasy $Ec_o > 0$, then the absolute eustasy is superior to the coast elevating velocities ($Ec_a > C$ and $Ec_a = Ec_r + C$).

b) If the sea level does not rise relatively to the shore, along the elevating coast, i.e. the relative eustasy neutral, $Ec_r \approx 0$, it is approximately equal to the shore elevating velocity, ($Ec_a \approx C$).

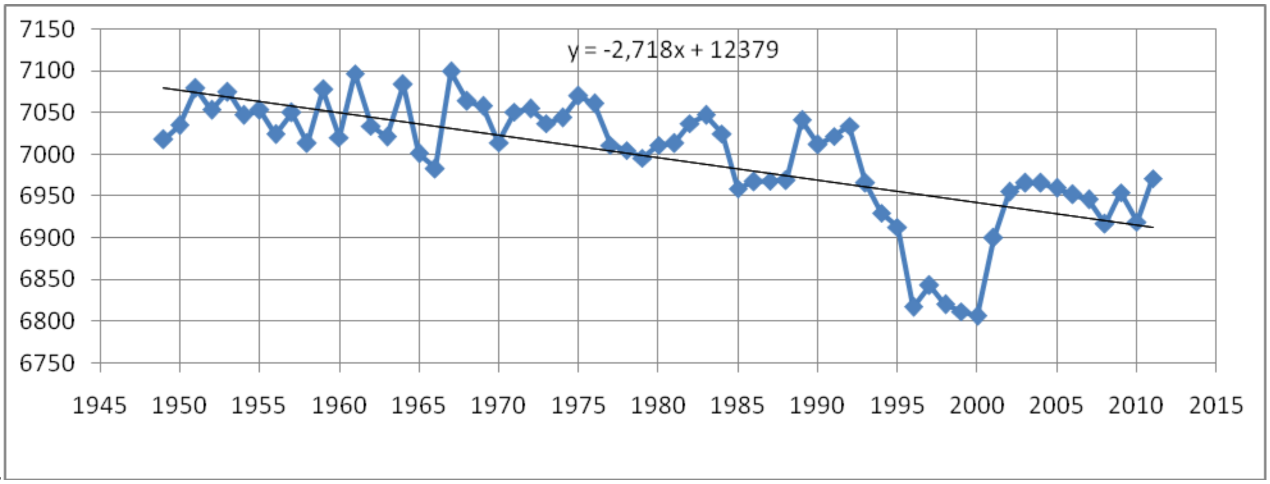
c). Along the coast where the sea level drops relatively to the shore ($Ec_o < 0$), absolute eustasy is less than shore secular elevation velocity $Ec_a < C$.

d). Along the subsiding coasts an inverse relation between Eca, Eco and C is observed. There is occurred the imaginary increase of E_{Ca} value by C, i.e. $E_{ca} = E_{co} + C$.

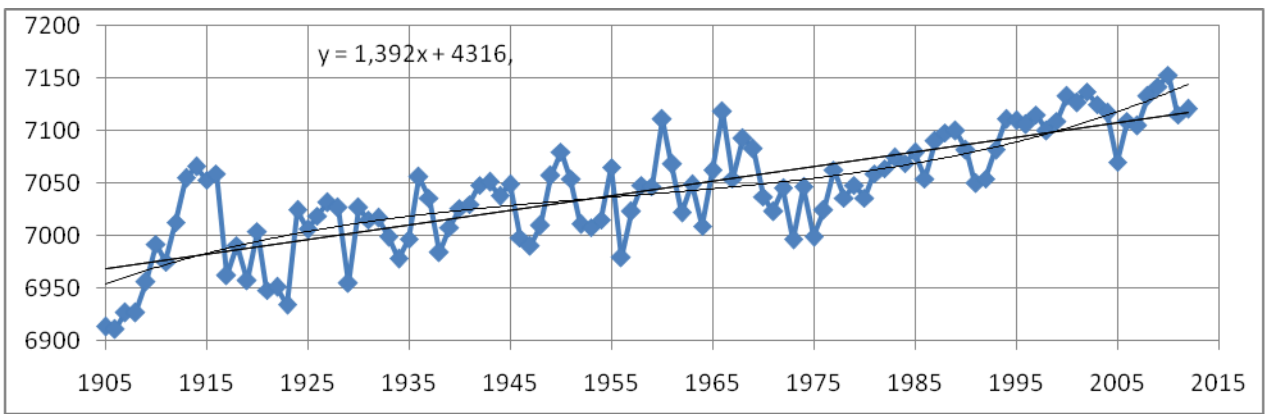
Table 1. The absolute climate eustasy at gauging stations with different value and direction of geological trend (mm/year)

Station	Region	Latitude	MSL series for Ec_a, year	Tendension of Geological trend (C)	Ec_r mm/year	Ec_a mm/year
Shpitsbergen	Arctic Ocean	N 78 08	1949-2011	C>0	-2,7	C>> Ec_a C- (-2,7)
Aberdeen	North sea	N 51 90	1896-2013	C>0	1,3	C + 1,3
Brest	The Channal	N 48 10	1906-2013	C<0	1,39	C +1,4
Batumi*	Black sea	N 42 41	1925-2013	C>0	2,7	2,7+1,0 =3,7
Poti*	Black sea	N 42 40	1925-2013	C<<0	-7,1	-5,6-(-7,2)=1,6
Sydney FD	Tasman sea	S 11 15	1925-2012	C>0	1,2	C+1,2
Argentine Island	Shouth ocean	S 65 15	1960-2013	C>0	1,3	C +1,3

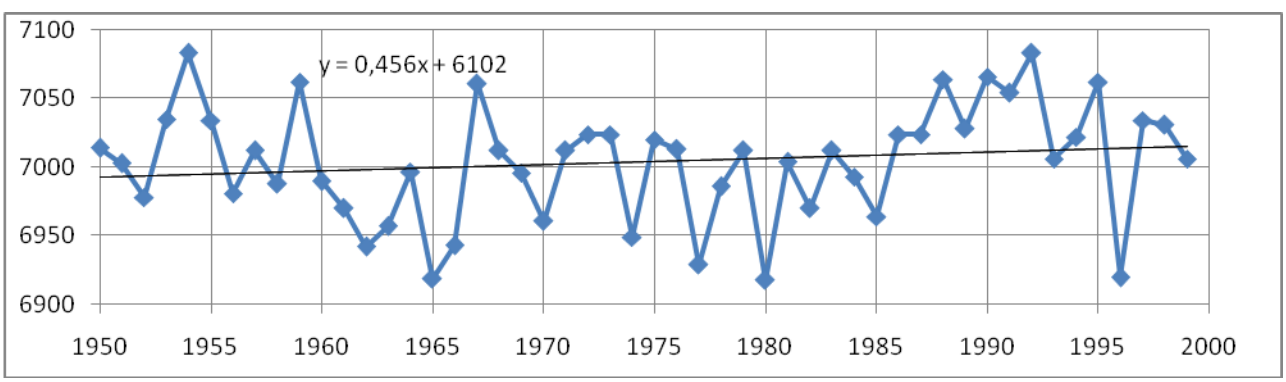
* The relatively low values of E_c at Poti are caused by the influence of the Rioni river cold waters, in mouth of which Poti' oceanographic station is located



A.



B.



C.

Fig. 1. Sentury variation of sea level along the WO coast with diferent geological trend and directions of vertical movument

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