SEA LEVEL AND GLOBAL EARTH TEMPERATURE CHANGES HAVE COMMON OSCILLATIONS

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ABSTRACT. Singular Spectrum Analysis (SSA) of Global Mean Sea Level (GMSL) and Global Average Earth Temperature (HadCRUT4) data revealed presence of quasiperiodic components with periods of 60, 20 and 10 years in both time series. 60-year component of sea level is anticorrelated with long-periodic changes in temperature, while 10 and 20-year components are correlated. The question what can be the nature of these common oscillations is discussed.

Key words: Climate Change, Sea Level, Earth Temperature.

1. Introduction

Recently approved IPCC Fifth Assessment Report (2013) presents comprehensive analysis of different aspects of Climate Change. Southends of scientist all over the world took part in this work. In recent decades the amount of data about the Earth from satellites and ground-based observational networks has drastically increased. New report contains useful indexes, time series and data grids and maps upon the climatic processes, affecting ocean, atmosphere, glaciers, ice sheets, etc. Manifestation of Global Warming is found in different components of Earth's system. The main goal of IPCC is to estimate their contribution into the warming trends and predict them into the future.

Using SSA – flexible and powerful time series analysis technique, we are investigating presence of different periodicities in such global indexes as Mean Sea Level and Average Earth Temperature. To our surprise, similar oscillations can be found in both indexes. Not very much studies are dedicated to this subject. But it is especially interesting to reveal the nature of this oscillations, because there are other processes, which demonstrate presence of similar periodicities.

For example, similarity of temperature changes and Earth rotation velocity was mentioned already in (Lambek, 1980) monograph. In (Zotov, 2012) we also compare recently reconstructed Chandler excitation with 20-year component of temperature changes and found correlations. Here, using new releases of climatological indexes, we are trying to put all this similarities together in the line with the ideas of (Zotov, 2012; Lambek 1980; Sidorenkov 2009).

2. Data and method

Singular Spectrum Analysis (SSA) (Golyadina S.A. 2004) is a generalization of Principal Component Analysis (Jollife, 2001) and is widely used in time series processing for decomposition of time series into so-called Principal Components (PCs), which represent main patterns of signal variability (Zotov, 2011). Not going into details, SSA allows to decompose time series into PCs of different periods and filter out noises. The main parameter of the method is lag L, which should be chosen heuristically. The name of the method comes from Singular Numbers (SNs), which correspond to the signal components and sometimes should be grouped.

We used Global Average Earth Temperatures time series HadCRUT4 produced by the Met Office Hadley Centre and the Climatic Research Unit at the University of East Anglia (http://www.metoffice.gov.uk/hadobs/hadcrut4/). It is a combination of CRUTEM4 land-surface air temperature dataset and the HadSST3 sea-surface temperature (SST) dataset. In Fig. 1, top, HadCRUT4, its previous version HadCRUT3, and HadSST3 time series are represented. It is seen, that global Earth's temperature (HadCRUT4) is mostly defined by the sea-surface temperature (HadSST3). Parabolic trend shows temperature increase of $\sim 0.7^0$ in 150 yrs caused by the global warming and greenhouse effect. Trend for HadCRUT3 is lower. While most of IPCC studies are dedicated to these trends and their projections, we will pay attention to the remaining oscillations.

SSA was applied to the HadCRUT4 time series after parabolic trend was removed. Lag parameter $L = 20$ years was selected. Three main PCs were found to have quasi 60, 20 and 10 years periods. They are shown in Fig. 2. Earlier we already performed such an analysis for HadCRUT3 (Zotov, 2012). New results are quite similar (but with smaller amplitudes). They can also be compared to the obtained in (Qian, 2010).

GMSL time series were taken from CSIRO web site

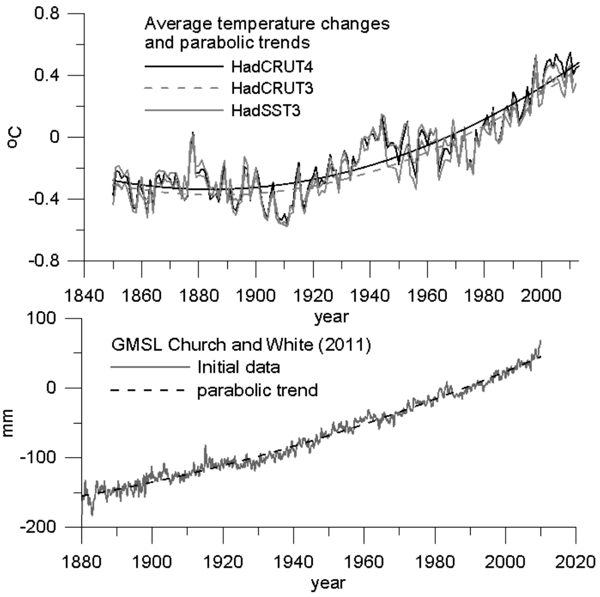

Figure 1: Initial time series of Earth Average Temperatures (top) and Sea Level (bottom) with parabolic fits.

http://www.cmar.csiro.au/sealevel/sl_data_cmar.html. They were derived from the Sea Level Gauges data using PCs of satellite altimetry (Church and White, 2011). The initial time series are represented in Fig. 1, bottom. Average Sea Level rise of $\sim$ 1.8 mm/yr over the last century is caused by the temperature growth (Church et al., 2011). This trend is one of the main subject of IPCC research, but we will remove it before SSA. Main PCs obtained with SSA parameter $L = 240$ months (20 years) are compared to the temperature PCs in Fig 2. They also have the main periods close to 60, 20 and 10 years. Earlier SSA of Sea Level was performed by Shen et al. (2013), similar components were found.

3. Results and discussion

It is seen from Fig. 2 that temperature and Sea Level PCs have similar behaviour. PC 1 has $\sim$ 60-year period, it is obtained from SN 1; PC 2 has $\sim$ 20 year period, it is obtained from SN 2 for temperature and SN 2+3 for GMSL; PC 3 has quasi-10-year variability, it is obtained as a sum of SN 3+4 for temperature and SN 4+5 for GMSL.

PC 1 (Fig 2, top) of temperature changes is anticorrelated with GMSL PC 1. Inversion of the y-scale of the latter makes the correspondence evident. PC 2 (middle) and PC 3 (bottom), on the contrary, are correlated. Maxima and minima of PC 2 repeat with $\sim$ 20-year period and more or less correspond to each other. For HadCRUT3 correlation was even better (Zotov, 2012).

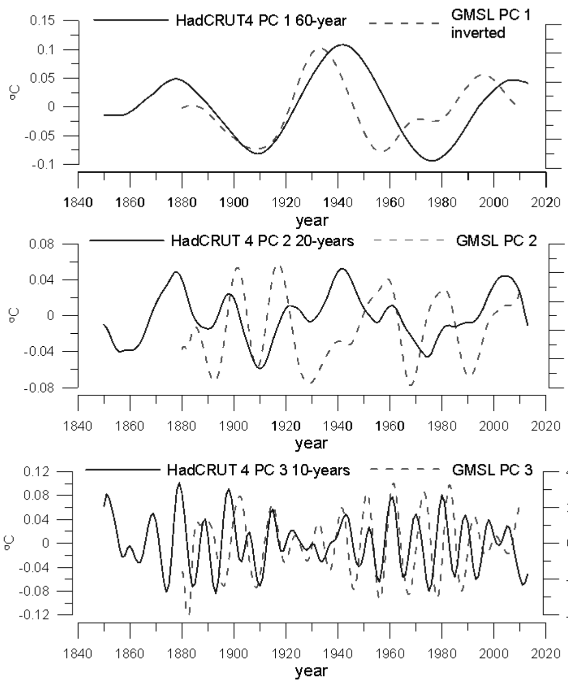

Figure 2: Comparison of three principal components of Average Temperature and Sea Level detrendet changes.

Average Earth Temperatures are strongly dependent on the sea-surface temperatures, as seen from Fig. 1, top. It is quite reasonable to expect synchronous sea level changes, reflecting temperature changes. Increase of temperature could force expansion of the upper ocean layer and steric (without mass changes) sea level increase. Melting of land ice also could give a non-steric input, but it cools the ocean at the place of discharge and influence the salinity. The problem is that we see correlation for PC 2 and PC 3, but we observe anticorrelation on the time-scale of PC 1. With increase of temperature sea level rises for the 20-year PC 2 and 10-year PC 3, but drops on the 60-year scale of PC 1. It means that mechanisms of interconnections are different at these scales. Processes of different physical nature could be at the origin of these changes. Anyway, they should involve only upper ocean, because deeper ocean requires hundreds of years to be involved (private conversations with L. Polyak). It's interesting to note, that century-scale Length of Day (LOD) is anticorrelated with temperature PC 1 (Zotov, 2012). Increase of temperature on this scale is accompanied by the increase of Earth rotation velocity and Sea Level decrease. This is enigmatic. At this time-scale we know only Atlantic Multidecadal Oscillation, which caould be responsible. For a joke, we can also mention that Jupiter (12-year) and Saturn (30-year) common multiple revolution period is 60 years.

Speaking about PC 2, it has some similarity with reconstructed Chandler excitation envelope (Zotov, 2012). Earlier we proposed, that Moon orbital regression cycle could be responsible for this variations. Regression influence the position of the moon orbit, its inclinations changes from 18.3^o to 28.6^o during this period. Fig. 3 represents 18.6-year lunar tidal wave, Chandler excitation envelope, PC 2 of temperature and sea level changes. LSM-fits with harmonics of 18.6-year period are also represented for every component. The phases of fitted harmonics found to be more or less consistent to each other and to the tidal wave. Sea Level fit precedes the temperature fit by $\sim 30^o$. Though all the tides should have been excluded from Tide Gauges data while calculating GMSL, there still could be some miss-modelling and tide-driven circulation changes and water flow, which influence the Sea Level on 18.6-year scale (from discussion with R. Ray).

Correspondence of maxima and minima on Fig. 2 is well seen. Periods of PCs 2 could be 21, 20 or 19 years. Its hard to estimate them precisely on a 150-year interval. Though 20-year harmonic fit gives for GMSL and temperature larger amplitudes, then 18.6-year fit, we still put forward the hypothesis, that Moon orbital nodes regression could modulate Chandler excitation, Sea Level, and even Earth's temperature changes. The picture could be distorted by influence of other processes, but we can distinguish repeatability.

There are works (IPCC report 2013; Foster, Rahmstorf, 2011) explaining variations in temperature by combined influence of Volcanoes and El Nino, but these factors can not be periodic.

Speaking about 10-year PC 3 (Fig. 2, bottom), correlation for it is even more evident, then for PC 2. The Sun 11-years variability, most likely, has no relation to this variability. Comparison of HadCRUT3 10-year PC with Wolf sunspot numbers made in (Zotov, 2012) has shown, that they are out of phase.

4. Conclusions

SSA of detrended Earth's Global Average Temperature and Sea Level revealed presence of similar components of quasi 60, 20 and 10 - year periods. 60-year components of temperature and sea level are anticorrelated while two others are correlated. The nature of connection between temperature and sea level changes with this periods should be investigated.

It is interesting, that 60-year components is also reflected in the Length of Day changes and $\sim 20-year$ component presents in the reconstructed Chandler excitation envelope. We think, that some external factor could modulate these global geophysical processes. For quasi-20-year scale changes of PC 2 we propose the influence of the Moon orbital nodes regression cycle with 18.6-year period as such a factor.

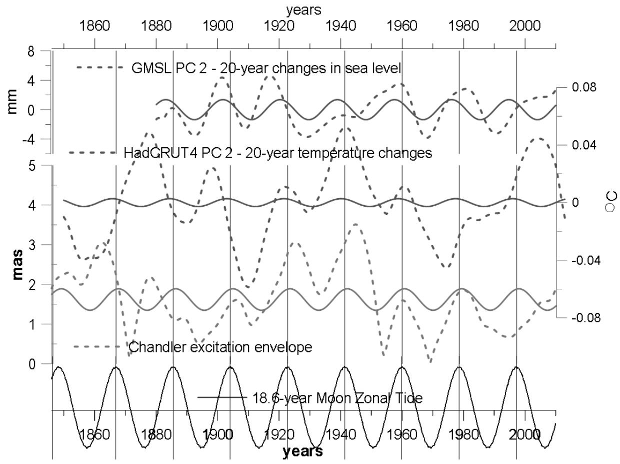

Figure 3: 18.6-year zonal tide from IERS model, Chandler excitation envelope, Earth Average Temperatures and Sea Level and their LSM fits by 18.6-year harmonic.

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