Hypothesis about natural global warming from 1900 till now.

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We performed linear multivariate regression analysis using available estimates of natural and anthropogenic influences and the observed surface temperature records from 1900 to 2012. We considered four parts of Earth surface - tropics (30S-30N), northern middle altitudes (30N-60N), Arctic (60N-75N) and southern altitudes (60S-30S). For each part (except southern altitudes) we developed very simple linear regression models representing temperature dynamics without anthropogenic influence. The monthly average tropical SST temperature anomaly dynamic could be adequately reproduced by only three factors - ENSO variability (Nino 3.4 index), volcanic aerosols in stratosphere and two climate shifts in 1925/1926 and 1987/1988 years. Middle altitudes SST temperature anomaly could be reproduced in general by the same factors, except ENSO which is changed on Pacific decadal oscillation (PDO) here. Continents in these parts have the same dynamic but with much more variability. Arctic temperature anomalies have in general the same dynamic as SST temperature anomalies of Atlantic ocean in northern middle altitudes (30N-60N). We didn't manage to build any adequate regression model for southern altitudes with or without anthropogenic influences, although it not looks like temperatures here determined by anthtropogenic influences. The results enable us to suggest a quantitive hypothesis alternative to anthropogenic about a reasons of observed in past century climate change.

1. Introduction

The prime indicator of global warming is, by definition, global mean temperature. The 20th century increase in global mean temperature has been well documented – there was an increase of about 0.75 °C between 1880 and 2008 (Intergovernmental Panel on Climate Change (IPCC) 2007).

Both natural and anthropogenic influences have caused twentieth century climate change but their relative roles and regional impacts are still under debate (Lean and Rind 2008). Studies based on atmosphere-ocean general circulation models (AOGCMs) conclude that increasing anthropogenic gas concentrations (greenhouse gases (GHGs) and tropospheric aerosols) produced 0.3–0.5 °C per century warming over the 1906–1996 period and were the dominant cause of global surface warming after 1976 (Allen et al. 2006). However, this warming was not straightforward – global temperature increased in the first part of the century, then slightly decreased in the years 1940-1970, then increased again and stayed almost flat during the last decade. Additionally temperatures have always fluctuated rapidly with amplitudes up to 0.5 °C over small time scales, e.g. years. Moreover, AOGCMs have not been able to reproduce all of these features (IPCC 2007). Lean and Rind (2008, 2009) performed multivariate linear regression analysis of the natural and anthropogenic influences on global surface temperature anomalies. They concluded that much of the variability in global climate arises from processes that can be identified and their impact on the global surface temperature quantified by direct linear association with the observations. And they were able to reconstruct the observed temperature anomalies only by associating the surface warming with anthropogenic forcing. We argue that it is possible to reconstruct adequately observed temperature anomalies with two climate regime shifts in 1925/1926 and in 1987/1988 years instead of anthropogenic forcing. The reality of these shifts and details highlighting their influence are described later in this article.

There was a remarkable article concerning 1987 climate regime shift in middle altitudes (Lo and Hsu 2010). They suggested the same hypothesis as in this study, that the main reason of recently observed warming is climate shift in 1987. They found unprecedented from early 1940s phenomenon in the late 1980s - temperature fluctuation synchronization in widespread areas of Northern Hemisphere. Analyzing spatial fields dynamic they concluded that this shift is a natural phenomenon and it was not simulated by CMIP3/IPCC climate models. We independently by means of very simple linear regression analysis noticed the possibility of climate shift in 1987, found the evidence of same shift in 1925/1926 (Yasunaka and Hanawa 2002) and in general reproduced temperature anomalies for altitudes from 30S to 75N without anthropogenic forcing.

2. Tropical belt (30S-30N)

Let's consider tropics (30S-30N), northern middle altitudes (30N-60N), Arctic (60N-75N) and southern altitudes (60S-30S) separately. At first we will consider tropical SST (Fig. 1). Most of variability here is explained by ENSO. Also the forcing of volcanic eruptions is clearly seen. And from first view these natural forcing should be accompanied by some continuous warming, which can be attributed to anthropogenic greenhouse gases. In this case tropical SST anomalies could be adequately reconstructed by linear regression with appropriate lags - one month for ENSO and four months for volcanic aerosols (Fig. 1).

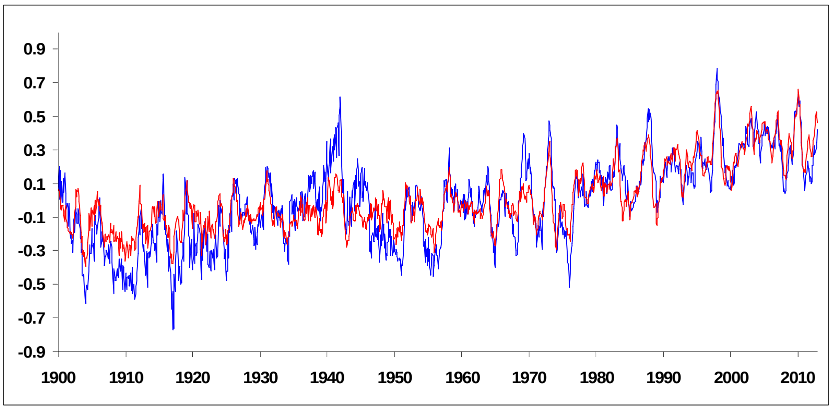

Fig. 1. Blue line - observations, red line - linear regression model.

But it is possible to notice that linear regression without anthropogenic forcing reproduce quite well anomalies from middle 80th till now (Fig. 2), but fails to reproduce previous period with obtained coefficients. From the other side regression by ENSO and volcanic aerosols reproduce period from 1950 till middle 80th (Fig. 3), but inadequate later. This suggests that there may be a climate regime shift somewhere in the middle 80th. So we added another determining climate factor

- climate regime index, a step function witch equals zero before shift and equals one after. In this case temperature anomalies reproduced without anthropogenic forcing at least from 1950s (Fig. 4).

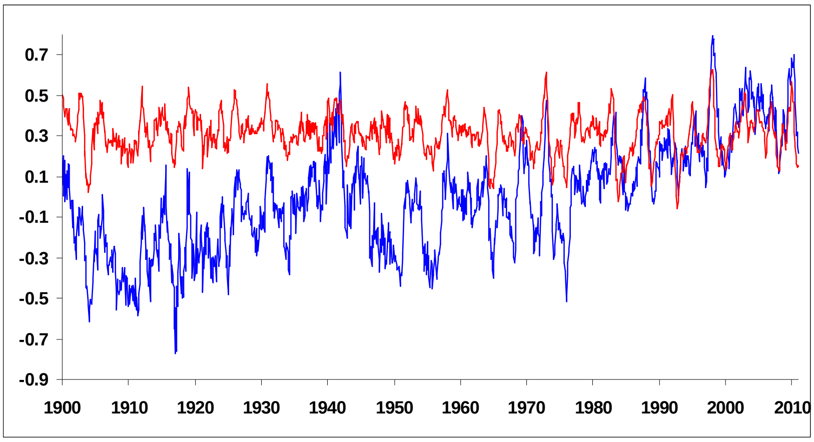

Fig. 2. Blue line - observations, red line - linear regression model.

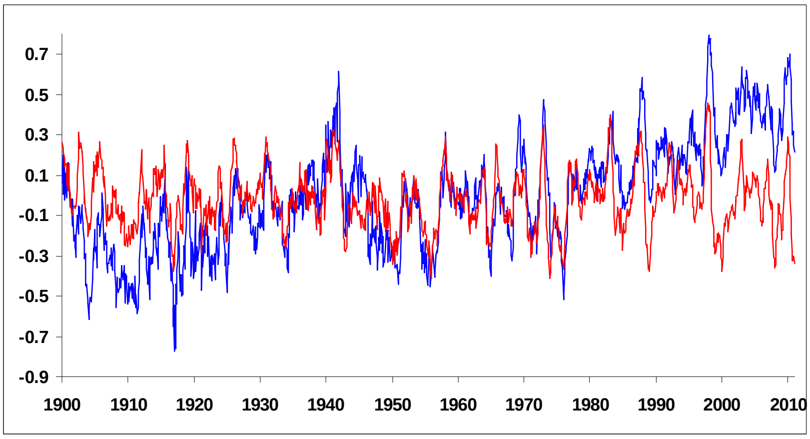

Fig. 3. Blue line - observations, red line - linear regression model.

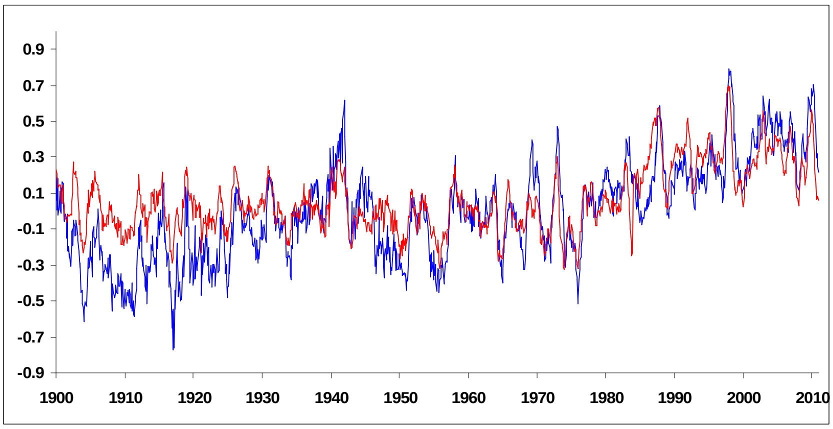

Fig. 4. Blue line - observations, red line - linear regression model.

We considering different parts (Pacific, Atlantic, Indian) of tropical SST and found that regime shift was localized in 1987. But we didn't know any climate shift in that time. So we began to search publications about shifts in late 80th. At first we found evidence for biological or ecological regime shifts. There were observed shifts in birds populations (Veit et. al 1996), fish populations (Chavez et. al 2003), combined physical and biological variables (Hare and Mantua, 2000; de Young et. al 2004), local ecosystems (Tian et. al 2008) and even in global carbon cycle (Sarmiento et. al 2010). Then we find an article about regime shifts in the northern hemisphere SST field (Yasunaka and Hanawa 2002). They applied an empirical orthogonal function (EOF) analysis and detected six regime shifts in the period from 1910s to the 1990s: 1925/1926, 1945/1946, 1957/1958, 1970/1971, 1976/1977 and 1988/1989. But from 1950s temperature anomalies were reproduced by linear regression without shifts in 1957/1958, 1970/1971, 1976/1977. Yasunaka and Hanawa give answer: "According to spatial pattern correlation between SST difference maps of regime shifts, it is found that the 1945/1946, 1957/1958, 1970/1971 and 1976/1977 regime shifts are similar pattern, while the 1925/1926 and 1988/1989 regime shifts are somewhat different." And according to this we added another shift of the same magnitude in climate regime index between 1925 and 1926 (so step function equals -1 before 1926, 0 between 1926 and 1987 and 1 after). In these case we got adequate reconstruction from 1900 till now (Fig. 5). Quite remarkable moment is that linear regression coefficients can be fitted by the data from 1910 till 1940 (15 years to both side from shift in 1925/1926) and quite well reproduce the whole period from 1900 till now (Fig. 6).

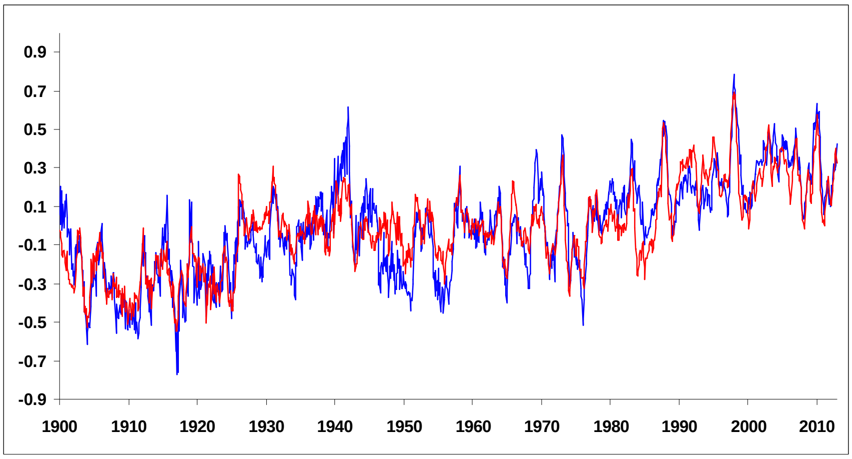

Fig. 5. Blue line - observations, red line - linear regression model.

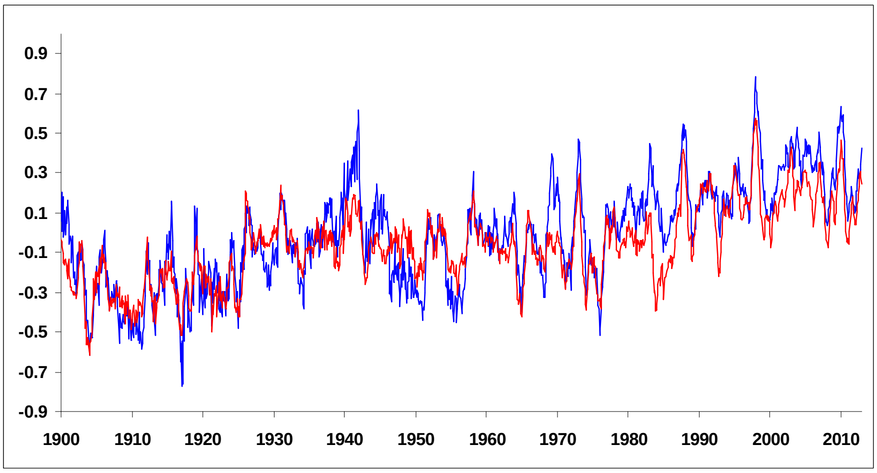

Fig. 6. Blue line - observations, red line - linear regression model.

So tropical SST could be reproduced by three factors ENSO variations, volcanoes and regime shift index. What about hole tropical belt including land areas? Temperatures over land introduce more short term variability, which is not reproduced, but in general dynamic is reproduced (Fig. 7). As Pacific ocean occupies near half of this area, it could happen so, that we reproduce only Pacific anomalies. So we performed separate linear regression analysis for different parts of tropics - Pacific ocean, Indian ocean, Atlantic ocean and land areas. It was found that in general linear regression reproduce anomalies for each part. Pacific ocean reproduced with near the same quality as whole belt. Indian and especially Atlantic ocean have more variability and less correlation with used ENSO Nino34 index.

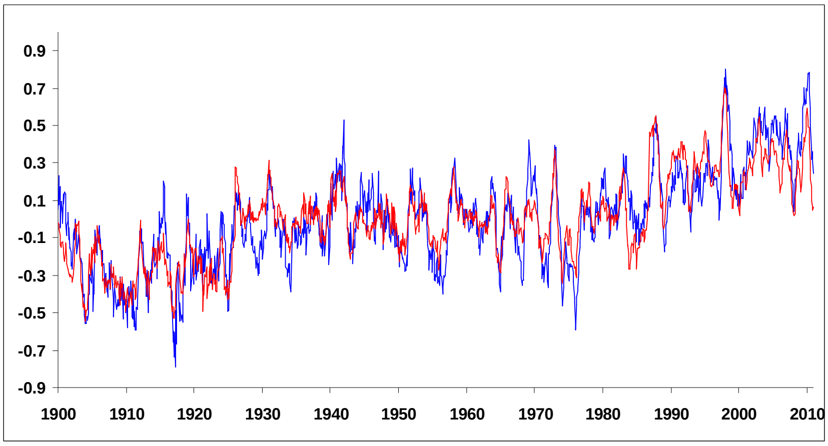

Fig. 7. Blue line - observations, red line - linear regression model.

3. Northern altitudes (30N-90N)

We considered two parts in northern altitudes - northern middle altitudes (30N-60N) and Arctic (60N-75N). There were only small number of temperature observations most of studied period in polar region (75N-90N) so we omitted it. We performed the same linear regression analysis for middle altitude SST, as for tropics. Here instead of ENSO we used Pacific decadal oscillation index and as in the tropics the same time series of volcanic aerosols and climate regime index. Again SST reproduced quiet well (Fig. 8). And as in the tropics linear regression coefficients can be fitted by the data from 1900 till 1940 and quite well except for volcanic eruptions reproduce the whole period from 1900 till now (Fig. 9). If we will use anthropogenic forcing instead of climate regime index here like in fig. 1 of tropics, reproduction of SST anomalies before 1950 is worse (Fig. 10). As in the tropics land areas introduce more short term variability (and more than in the tropics, because land area here is bigger). In general observed temperature anomalies reproduced, of course except short term variability.

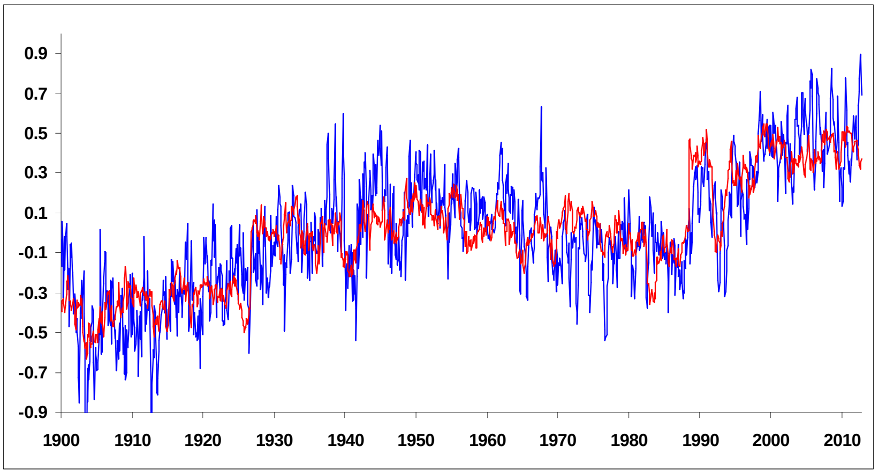

Fig. 8. Blue line - observations, red line - linear regression model.

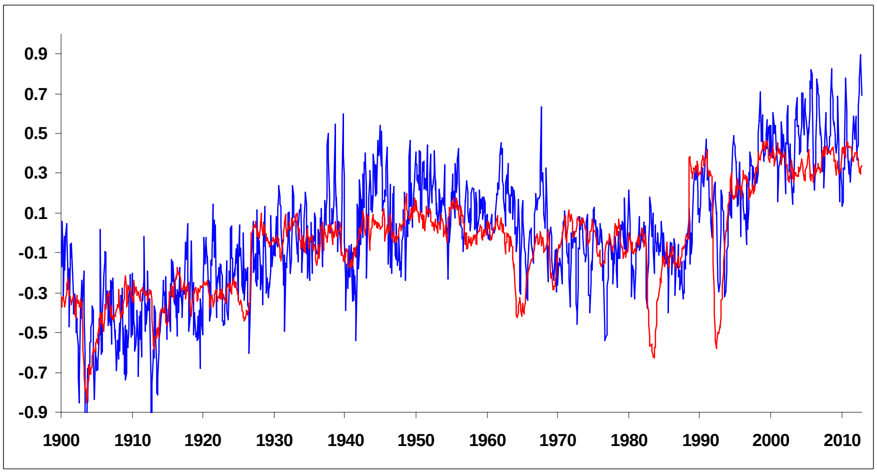

Fig. 9. Blue line - observations, red line - linear regression model.

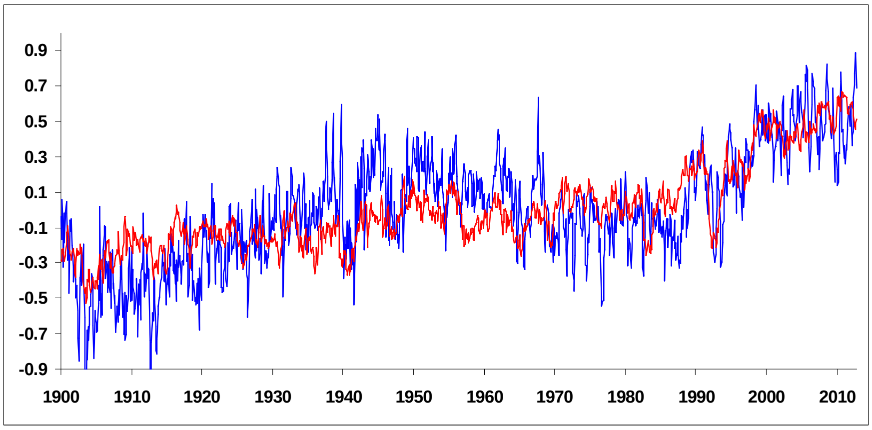

Fig. 10. Blue line - observations, red line - linear regression model.

Arctic (60N-75N) monthly temperature anomalies are highly variable. May be the reason is small square of area mostly covered by land. So we performed regression analysis for yearly averaged temperature anomalies. We argue that climate anomalies in this region determined mainly by inflow of warm waters from North Atlantic. As a proxy for this factor we used North Atlantic SST in northern middle altitudes (30N-60N, 75W-0W). Main trends of arctic temperature anomalies are reproduced (Fig. 11). And again remarkable moment coefficients of regression can be fitted only by data from 1900 till 1940 with small changes in quality. As dynamic of SST anomalies in northern middle altitudes could be reproduced without anthropogenic forcing, so Arctic temperatures also could be reproduced without anthropogenic forcing.

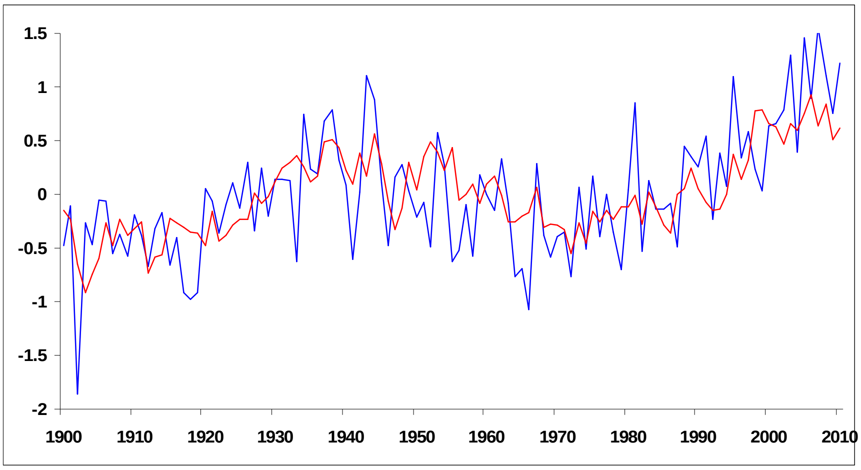

Fig. 11. Blue line - observations, red line - linear regression model.

4. Southern altitudes (30S-90S)

Temperature observations are rare in this region. We think that they are especially rare in Antarctic continent. So we considered two variants - temperatures in hole region (30S-90S) (Fig. 13) and SST in altitudes 30S-60S (Fig. 14). We weren't able to develop any adequate regression model with or without anthropogenic forcing for the observed dynamics. But CMIP5/IPCC climate models also didn't simulate this region properly (Fig. 13 and Fig. 14). Most remarkable difference is near zero trend after 1980 in observations and big trend in models. In general observations show warming trend in 20th century, but it not looks like forced by anthropogenic greenhouse gases, because most of warming occurred before 1980 and after 1980 dynamic is near flat.

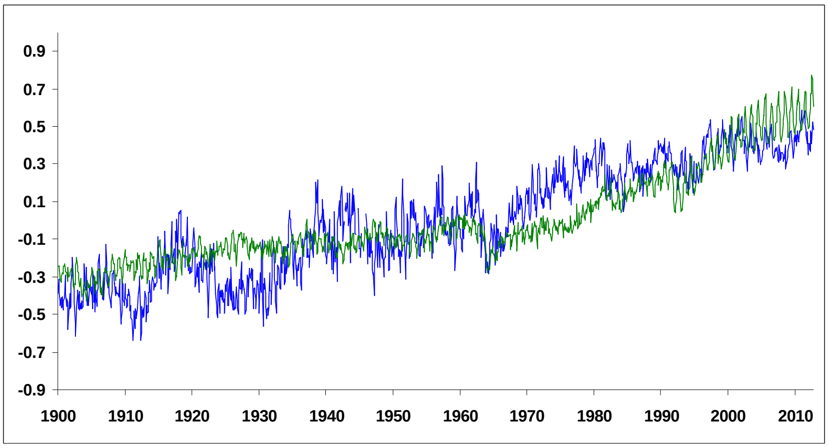

Fig. 13. Blue line - observations, green line - CMIP5/IPCC climate models mean.

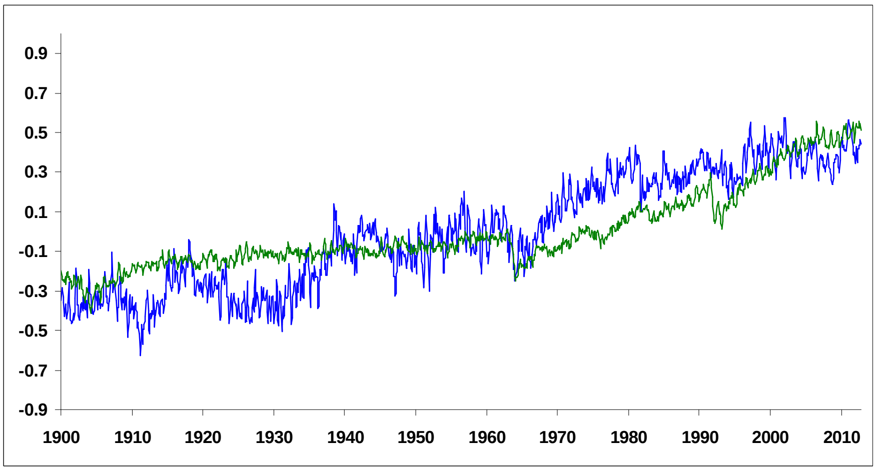

Fig. 14. Blue line - observations, green line - CMIP5/IPCC climate models mean.

5. Analysis and datasets

Most of the used datasets are freely available at Climate Explorer site (climexp.knmi.nl). And all the calculations were made in Excel by means of standard functions. A reconstruction of monthly mean surface temperature anomalies, T_R, from input parameters is performed by following equation:

$$T(t) = c_o + \sum_{i=1}^{n} c_i \cdot X_i(t - \Delta t_i), \quad (1)$$

Here X_i are determining climate factors; Δt_i are the lags in months; c_i - the fitted coefficients and n – the number of harmonics in regression. The fitted coefficients are obtained by standard Excel function for multivariate linear regression.

In presented analysis we used several reconstructions of observed temperature anomalies - HadSST2, Reynolds v2, HadCRUT4 and NCDC datasets. For the period from 1900 till the beginning of 1980s we used HadSST2 and later Reynolds v2 as SST anomalies (as we thought that remote sensing data is more precise). Then we need to analyze land areas or combined land and ocean areas we used HadCRUT4. And as there were big spaces in southern altitudes HadCRUT4 time series we used NCDC reconstruction for this area (30S-90S). Anthropogenic influence, volcanic aerosols, ENSO and Pacific decadal oscillation were considered as factors determining observed temperature anomalies. Volcanic aerosols in the stratosphere were compiled by Sato et al. (1993) from records kept since 1850 and updated from climexp.knmi.nl till now. Warming greenhouse gases were considered as a proxy for the anthropogenic forcing as the other components (land use, snow albedo changes and tropospheric aerosols) are very uncertain. We used the same anthropogenic greenhouse gases forcing as in GISS global climate models (http://data.giss.nasa.gov/modelforce/). As a proxy for ENSO we considered Nino34 index obtained from HadISST1. And for the PDO we used reconstruction from HadSST2. All used datasets except anthropogenic greenhouse gases forcing were prepared and downloaded from Climate Explorer.

5. Summary

There is always a risk that multiple regression analysis may misattribute significance to unrelated factors. From this point of view a number of empirical analyses were critically considered by Benestad and Schmidt (2009). But as we look more broadly at the field the same risk exists for all models – statistical ones, those based on simple ordinary equations, and AOGCMs. For example, AOGCMs are based on known, well-established physical laws but they include many parameters that are tuned during calibration and the verification process. Of course we have much more freedom to tune coefficients during multiple regression and have only qualitative thoughts about involved physical mechanisms, so the presented relationships should be considered as a possible connection between different influences and climate. However, our empirical model captures most of the variance in the surface temperature record. It is a strong argument for proposed relationships being quite similar to those occurring in the real world.

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