Estimates of the contribution of key natural modes and anthropogenic forcing to global surface temperature trend at different temporal horizons

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The contribution of changes in radiative forcing (RF) associated with changes in the concentration of greenhouse gases (GHG) and the key natural intra-centennial modes of global and regional climate variability to the global surface air temperature (GST) trend at different time horizons is estimated. Estimates are performed from the average annual data for the GST for the period 1850-2017 (http://www.metoffice.gov.uk/hadobs/hadcrut4/). Anthropogenic influence is characterized by the GHG RF for the period 1851-2012 (http://data.giss.nasa.gov/). The key modes of natural climatic variability are characterized by the Atlantic Multidecadal Oscillation (AMO) index for the period 1856-2017, Pacific Decadal Oscillation (PDO) index for the period 1854-2017 and El Nino/Southern Oscillation (ENSO) index Nino-3.4 for the period 1870-2017 (http://www.esrl.noaa.gov/psd/data/). The contributions are estimated as the changes of the model trends under different conditions over various time windows (temporal horizons).

The intervals used for the GST trends estimation range from several years to several decades. The empirical models of the GST used for the estimation are three-component autoregressive (AR) models with the account of the influence of the GHG RF, AMO, PDO and ENSO effects similarly to Refs. [1,2]. The optimal empirical model relating the GST to AMO and GHG RF (for maximum lags up to 25 years) takes the following form:

$$T_n = a_0 + a_1 T_{n-1} + a_2 I_{GHG,n-16} + a_3 I_{AMO,n-23} + \xi_n, \quad (1)$$

where T is the GST, n is the discrete time (years), I_{GHG} is the GHG RF, I_{AMO} is the slow AMO component, ξ_n is noise (residual model errors). When estimating with a maximum lag of 23 years from the whole period under analysis, the values of the coefficients in (1) with their 95% confidence intervals appear as follows: a_0 = -0.22 (±0.07) K, a_1 = 0.41 (±0.16), a_2 = 0.18 (±0.05)K/(Wm^{-2}), a_2 = -0.21 (±0.15), the mean squared prediction error (MSE) equals 0.0096 K^2.

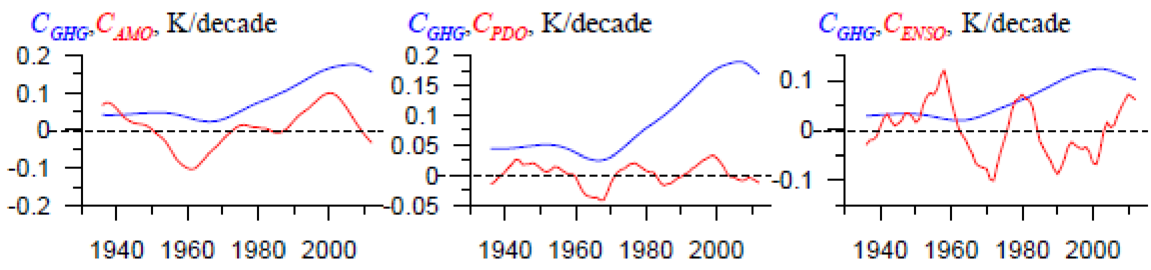

Figure 1. (a) (b) (c)

Figure 1a shows the estimated contribution of AMO (red) and GHG RF (blue) to the GST trend over 15-year time windows versus the window endpoint. The estimates are computed as the difference between the model GST responses to the actually observed forcings and the hypothetical forcings, the latter being the constant GHG RF at the level of 1850 and constant AMO index at its mean observed value.

Analogous results for the other models analyzed here are reported below in a similar form. Thus, the AR model corresponding to (1) but with unit time lags reads

$$T_n = a_0 + a_1 T_{n-1} + a_2 I_{GHG,n-1} + a_3 I_{AMO,n-1} + \xi_n, \quad (1a)$$

with a_0 = -0.22 (±0.08) K, a_1 = 0.43 (±0.18), a_2 = 0.14 (±0.05) $K/(Wm^{-2})$, a_3 = 0.22 (±0.16), and the MSE of 0.0101 K^2. It gives slightly less accurate forecast than model (1).

The optimal AR model for the GST with the PDO index I_{PDO} and GHG RF reads

$$T_n = a_0 + a_1 T_{n-1} + a_2 I_{GHG,n-16} + a_3 I_{PDO,n-12} + \xi_n, \quad (2)$$

with a_0 = -0.20 (±0.07) K, a_1 = 0.48 (±0.16), a_2 = 0.17 (±0.05) $K/(Wm^{-2})$, a_3 = 0.01 (±0.02), and the MSE of 0.0108 K^2. Figure 1b shows estimates of contribution of PDO (red) and GHG RF (blue) to the GST trend in 15-year windows with the use of model (2). The corresponding model with unit lags reads

$$T_n = a_0 + a_1 T_{n-1} + a_2 I_{GHG,n-1} + a_3 I_{PDO,n-1} + \xi_n, \quad (2a)$$

with a_0 = -0.17 (±0.07) K, a_1 = 0.58 (±0.15), a_2 = 0.11 (±0.04) $K/(Wm^{-2})$, a_3 = -0.00 (±0.02), and the MSE of 0.0107K^2.

The optimal AR model for the GST with the ENSO index I_{ENSO} and GHG RF reads

$$T_n = a_0 + a_1 T_{n-1} + a_2 I_{ENSO,n-2} + a_3 I_{GHG,n-10} + \xi_n, \quad (3)$$

with a_0 = -0.08 (±0.06) K, a_1 = 0.77 (±0.13), a_2 = -0.07 (±0.03), a_3 = 0.05 (±0.04)$K/(Wm^{-2})$ and the MSE of 0.0111K^2. Figure 1c shows the estimated contribution of ENSO (red) and GHG RF (blue) to the GST trend in 15-year windows with the use of model (3). The corresponding model with unit time lags reads

$$T_n = a_0 + a_1 T_{n-1} + a_2 I_{GHG,n-1} + a_3 I_{ENSO,n-1} + \xi_n, \quad (3a)$$

with a_0 = -0.11 (±0.06) K, a_1 = 0.67 (±0.14), a_2 = 0.07 (±0.04) $K/(Wm^{-2})$, a_3 = 0.02 (±0.04) and the MSE of 0.0124 K^2.

According to the obtained estimates the optimal time lag in AR models is 23 years for the AMO, 12 years for the PDO, 2 years for the ENSO, ranging from 10 to 16 years for the GHG. For 15-year intervals, the contribution of the AMO reaches the value of 0.1 K/decade, the contribution of the PDO is insignificant (less than 0.03 K/decade), and the GHG contribution reaches 0.2 K/decade. The GHG contribution over 15-year intervals is comparable to the contribution of the AMO and the ENSO with the contribution of the PDO being insignificant. With widening the temporal interval over which the contribution to the GST trend is estimated, the contribution of the AMO and the ENSO decreases, the GHG contribution dominating over long temporal intervals.

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References

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