

Global Warming Acceleration

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Abstract

This publication analyzes changes of global warming rates (GWR) expressed in Centigrade per year ($^{\circ}\text{C}/\text{y}$) and introduces a parameter “global warming acceleration” (GWA) expressed in Centigrade per year per year ($^{\circ}\text{C}/\text{y}^2$). GWA may be applied for prediction of the GWR for the next decade. If the current decrease of GWA will continue for the next 11 years, Global Warming Rate will increase from the current $+0.017\text{ }^{\circ}\text{C}/\text{y}$ to $+0.019\text{ }^{\circ}\text{C}/\text{y}$, for land+ocean.

Glossary

a	= GWR = global warming rate, parameter “a” in linear trendline: $T(y) = (y-n) * a + b$, average change of global surface temperature per year in the trendline period, $^{\circ}\text{C}/\text{y}$ ([8] Formula 1)
Ave	average
GWA	Global Warming Acceleration, $^{\circ}\text{C}/\text{y}^2$ ([Centigrade per year per year] [$^{\circ}\text{C y}^{-2}$])
GWR	= a = Global Warming Rate – average change of global surface temperature per year in the trendline period, $^{\circ}\text{C}/\text{y}$
Ref	reference
TL	trendline

Units

The temperature change unit is °C.

Global warming rate, average change of global surface temperature per year in the trendline period is in °C/y.

The global warming acceleration (yearly change of the global warming rate) is in °C/y² [Centigrade per year per year].

Global Warming Rate

According to IPCC [9] *"Since 1970 the global average temperature has been rising at a rate of 1.7°C per century"*.

According to NASA [10] *"The majority of the warming has occurred since 1975, at a rate of roughly 0.15 to 0.20°C per decade"*.

According to NOAA's 2020 Annual Climate Report [11] *"the combined land and ocean temperature has increased at an average rate of 0.13 degrees Fahrenheit (0.08 degrees Celsius) per decade since 1880; however, the average rate of increase since 1981 (0.18°C / 0.32°F) has been more than twice that rate"*.

Publication [8] includes 61 years trendlines and the average global warming rate per year in the trendline period.

Formulas

Formula 1 - Linear trendline

$$T(y) = (y-n) * a + b$$

T(y) global surface temperature above 1850-1900 baseline in year y [°C]
n the year before the trendline start point, i.e., for trendline in period
 1961-2022 n=1960

a, b parameters related to the linear function displayed on Excel trendline chart

Formula 2 - Global Warming Rate, GWR

$$GWR = a \text{ [}^\circ\text{C/y]}$$

Formula 3 - Global Warming Acceleration, GWA

$$GWA = \Delta a / \Delta y \text{ [}^\circ\text{C/y}^2\text{]}$$

Formula 4 - Δa

$$\Delta a = a(i+1) - a(i)$$

a(i+1) average change of global surface temperature per year in trendline "i+1" period = parameter "a" of trendline "i+1" (from Excel chart formula) [$^\circ\text{C/y}$]

a(i) average change of global surface temperature per year in trendline "i" period = parameter "a" of trendline "i" (from Excel chart formula) [$^\circ\text{C/y}$]

Formula 5 - Δy

$$\Delta y = \text{CenterTL}(i+1) - \text{CenterTL}(i)$$

CenterTL(i+1) center of trendline "i+1" [year]

CenterTL(i) center of trendline "i" [year]

Formula 6 - CenterTL

$$\text{CenterTL}(i) = \text{Average}(\text{start year of trendline TL}(i), \text{end year of of trendline TL}(i))$$

Period Applied for Calculations of Trendlines

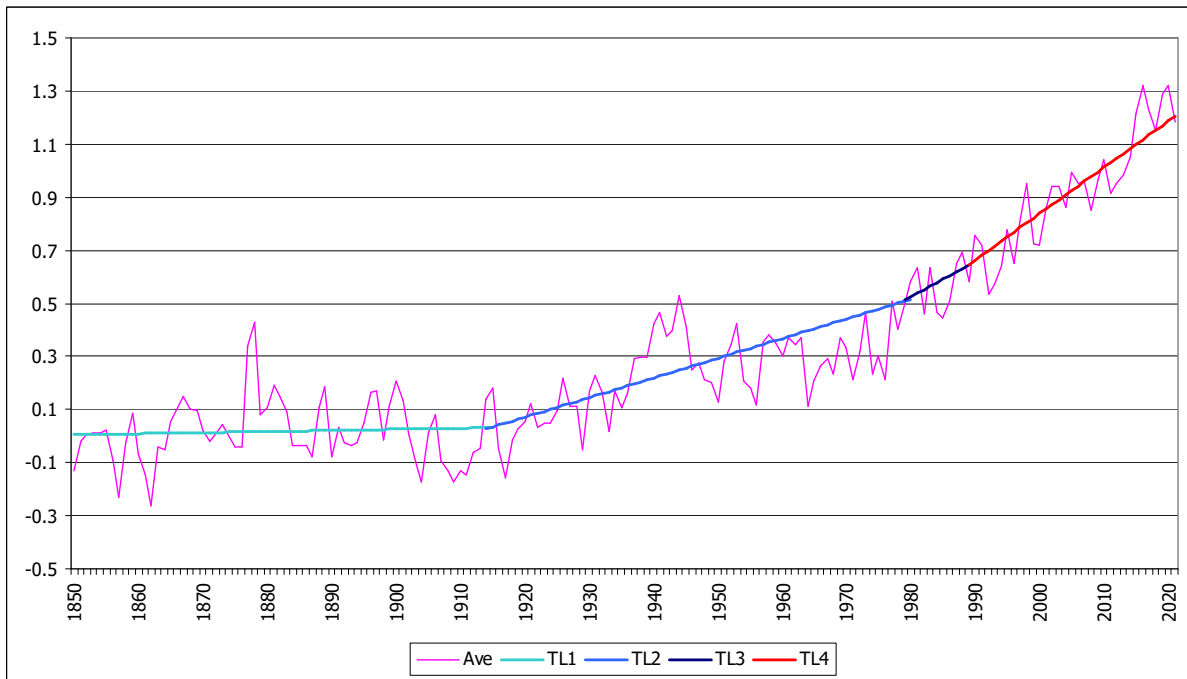
The period applied in [8] for calculations of trendlines is 61 years. This is also the trendlines period applied in the current work. The starting points of the trendlines are every 10 years from 1850 (1880 for ocean only).

Databases Applied

- NASA [1] [2]
- NOAA [3]
- Berkeley Earth (LBL) [4] [5] [6] [7]

Global Surface Temperature Changes over Land and Ocean

Chart 1 - Trendlines, land+ocean, 1850-1900 baseline [8] [°C]

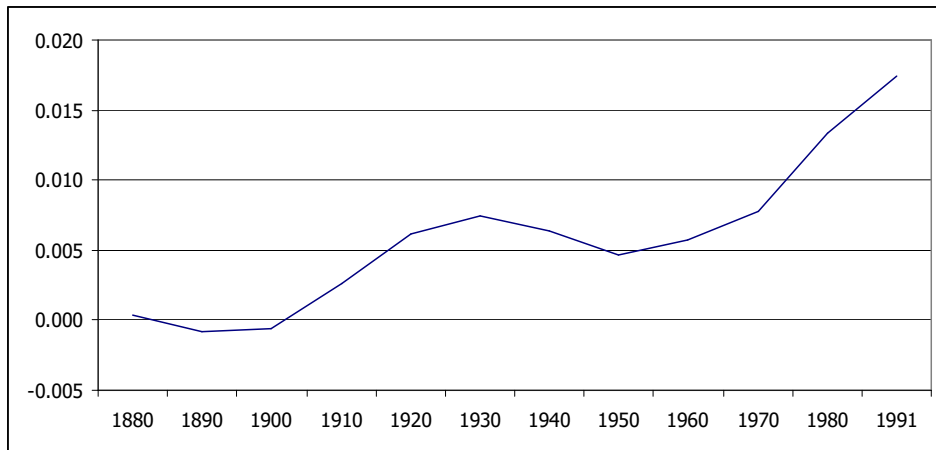


Ave average of all databases [°C]

Table 1 - Global Warming Rate (GWR), land+ocean

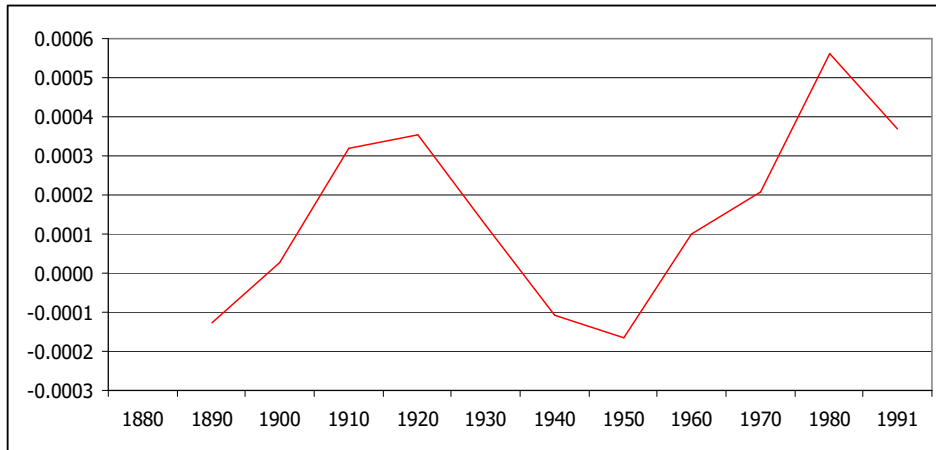
i	Trendline ID	Trendline period			Trendline Center	GWR			Global Warming Acceleration
Symbol Formula	TL(i)	from	to	years	CenterTL Formula 6	Δy Formula 5	a Formula 1	Δa Formula 4	GWA Formula 3
Units		year	year	years	year	years	$^{\circ}\text{C}/\text{y}$	$^{\circ}\text{C}/\text{y}$	$^{\circ}\text{C}/\text{y}^2$
1	TL1	1850	1910	61	1880		+0.000417		
2	TL2	1860	1920	61	1890	10	-0.000865	-0.001282	-0.000128
3	TL3	1870	1930	61	1900	10	-0.000578	+0.000287	+0.000029
4	TL4	1880	1940	61	1910	10	+0.002629	+0.003207	+0.000321
5	TL5	1890	1950	61	1920	10	+0.006173	+0.003544	+0.000354
6	TL6	1900	1960	61	1930	10	+0.007406	+0.001233	+0.000123
7	TL7	1910	1970	61	1940	10	+0.006335	-0.001071	-0.000107
8	TL8	1920	1980	61	1950	10	+0.004676	-0.001659	-0.000166
9	TL9	1930	1990	61	1960	10	+0.005681	+0.001005	+0.000101
10	TL10	1940	2000	61	1970	10	+0.007744	+0.002063	+0.000206
11	TL11	1950	2010	61	1980	10	+0.013362	+0.005618	+0.000562
12	TL12	1961	2021	61	1991	11	+0.017436	+0.004074	+0.000370

Chart 2 - GWR – Global Warming Rate, land+ocean [$^{\circ}\text{C}/\text{y}$]



Axis x is the center of the 61 years trendline period

Chart 3 - GWA - Global Warming Acceleration, land+ocean [°C/y²]



Axis x is the center of the 61 years trendline period

From 1960 the GWA is above zero, which means the Global Warming Rate (GWR) [°C/y] is increasing. The negative slope of GWA between 1980 and 1991 means a slower increase of GWR.

Global Surface Temperature Changes over Land

Chart 4 - Trendlines, land only, 1850-1900 baseline [8] [°C]

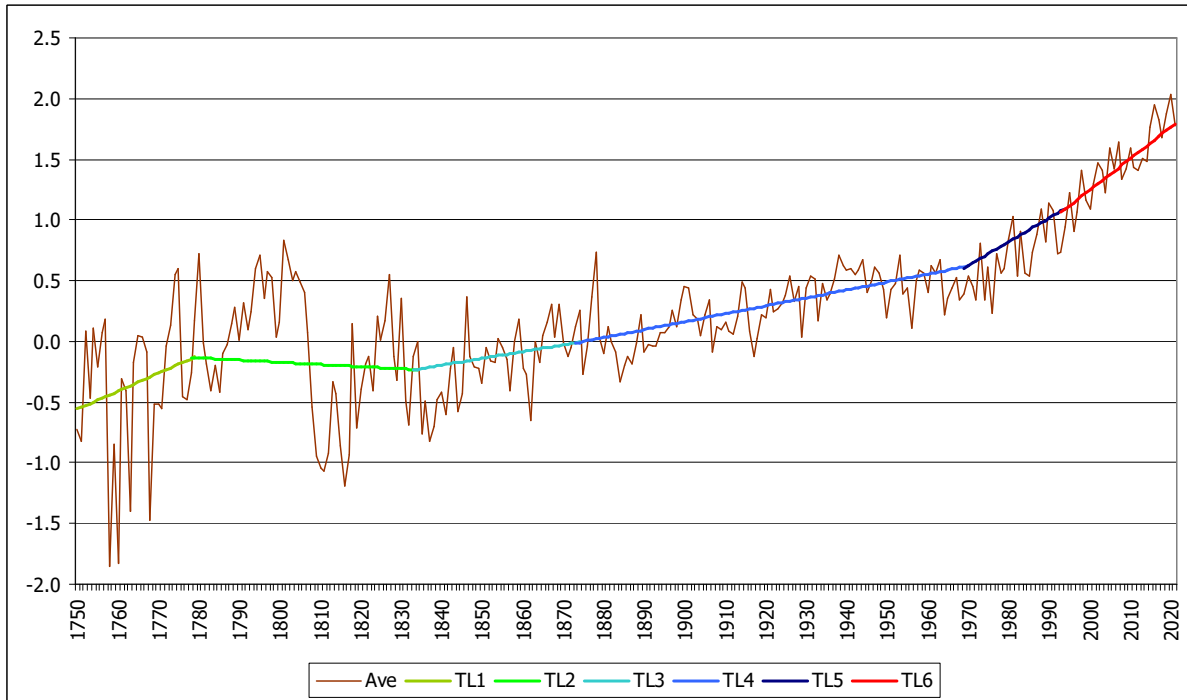
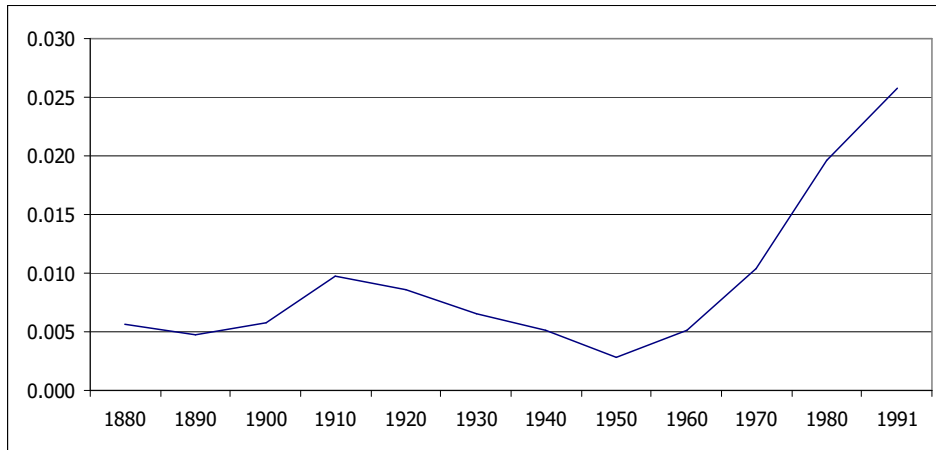


Table 2 - Global Warming Rate (GWR), land only

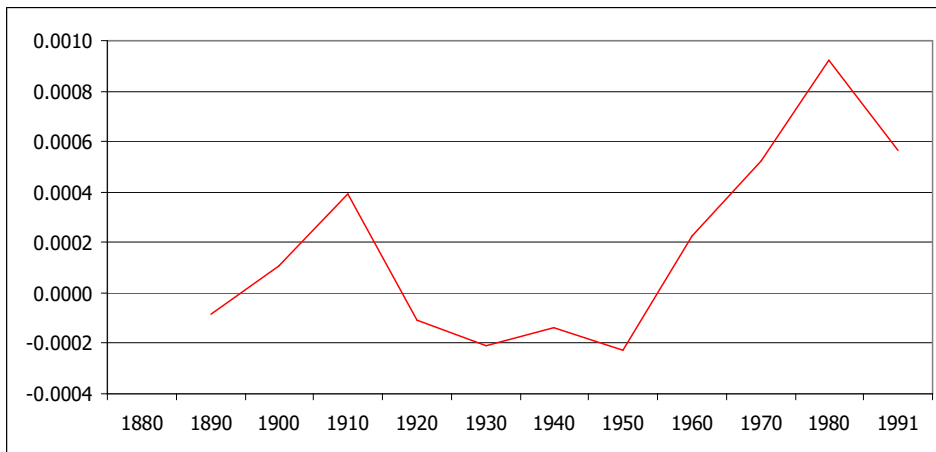
i	Trendline ID	Trendline period			Trendline Center	GWR			Global Warming Acceleration
		from	to	years		Δy	a	Δa	
Symbol Formula	TL(i)	CenterTL Formula 6			Formula 5	Formula 1	Formula 4	Formula 3	
Units		year	year	years	year	years	°C/y	°C/y	°C/y ²
1	TL1	1850	1910	61	1880		+0.005583		
2	TL2	1860	1920	61	1890	10	+0.004718	-0.000865	-0.000087
3	TL3	1870	1930	61	1900	10	+0.005764	+0.001046	+0.000105
4	TL4	1880	1940	61	1910	10	+0.009694	+0.003930	+0.000393
5	TL5	1890	1950	61	1920	10	+0.008613	-0.001081	-0.000108
6	TL6	1900	1960	61	1930	10	+0.006541	-0.002072	-0.000207
7	TL7	1910	1970	61	1940	10	+0.005145	-0.001396	-0.000140
8	TL8	1920	1980	61	1950	10	+0.002857	-0.002288	-0.000229
9	TL9	1930	1990	61	1960	10	+0.005129	+0.002272	+0.000227
10	TL10	1940	2000	61	1970	10	+0.010380	+0.005251	+0.000525
11	TL11	1950	2010	61	1980	10	+0.019618	+0.009238	+0.000924
12	TL12	1961	2021	61	1991	11	+0.025828	+0.006210	+0.000565

Chart 5 - GWR – Global Warming Rate, land only [°C/y]



Axis x is the center of the 61 years trendline period

Chart 6 - GWA - Global Warming Acceleration, land only [°C/y²]



Axis x is the center of the 61 years trendline period

Global Surface Temperature Changes over the Ocean

Chart 7 - Trendlines, ocean only, 1850-1900 baseline [8] [°C]

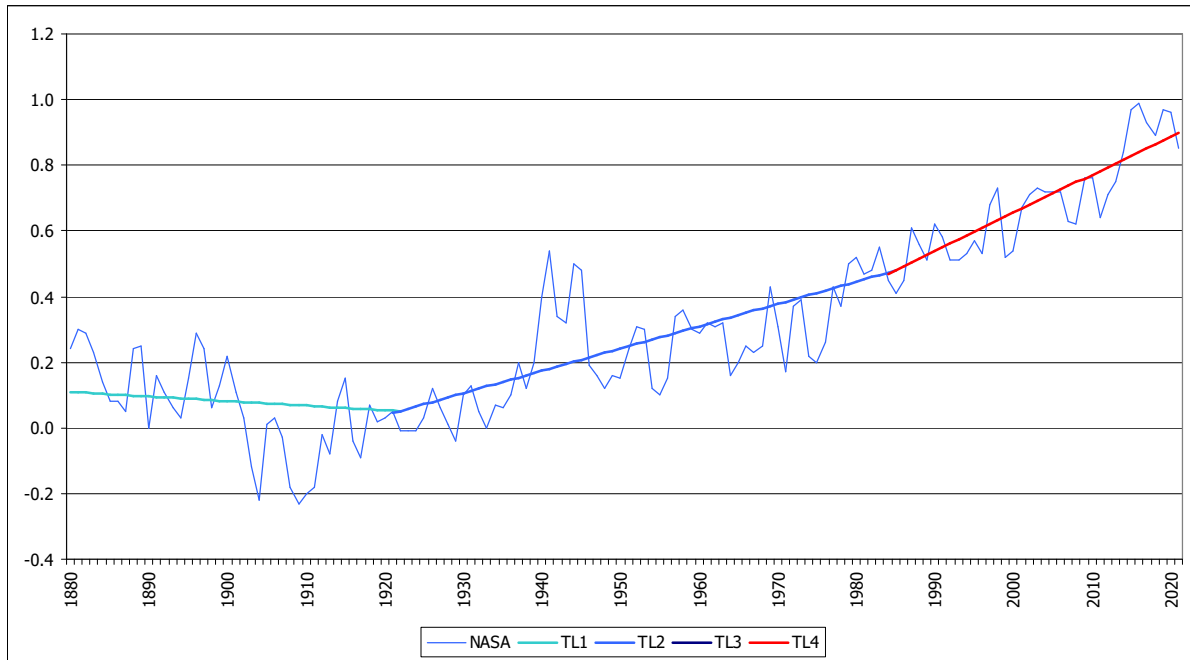
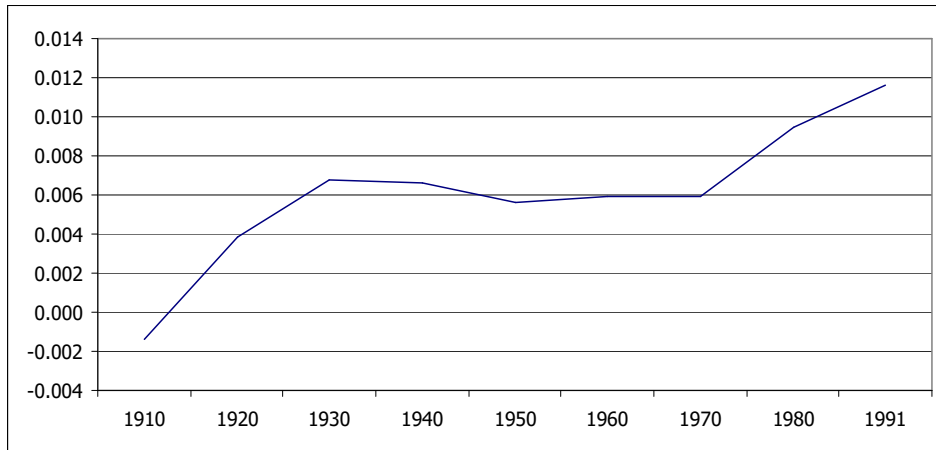


Table 3 - Global Warming Rate (GWR), ocean only

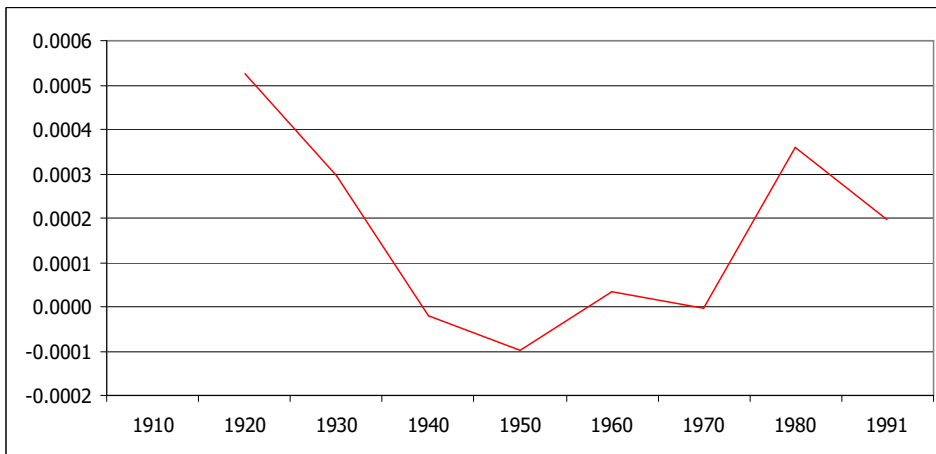
i	Trendline ID	Trendline period			Trendline Center	GWR			Global Warming Acceleration
	TL(i)	from	to	years	CenterTL Formula 6	Δy Formula 5	a Formula 1	Δa Formula 4	GWA Formula 3
Units		year	year	years	year	years	°C/y	°C/y	°C/y ²
1	TL1	1880	1940	61	1910		-0.001397		
2	TL2	1890	1950	61	1920	10	+0.003850	+0.005246	+0.000525
3	TL3	1900	1960	61	1930	10	+0.006790	+0.002940	+0.000294
4	TL4	1910	1970	61	1940	10	+0.006577	-0.000213	-0.000021
5	TL5	1920	1980	61	1950	10	+0.005600	-0.000978	-0.000098
6	TL6	1930	1990	61	1960	10	+0.005928	+0.000328	+0.000033
7	TL7	1940	2000	61	1970	10	+0.005895	-0.000032	-0.000003
8	TL8	1950	2010	61	1980	10	+0.009489	+0.003593	+0.000359
9	TL9	1961	2021	61	1991	11	+0.011652	+0.002163	+0.000197

Chart 8 - GWR – Global Warming Rate, ocean only [°C/y]



Axis x is the center of the 61 years trendline period

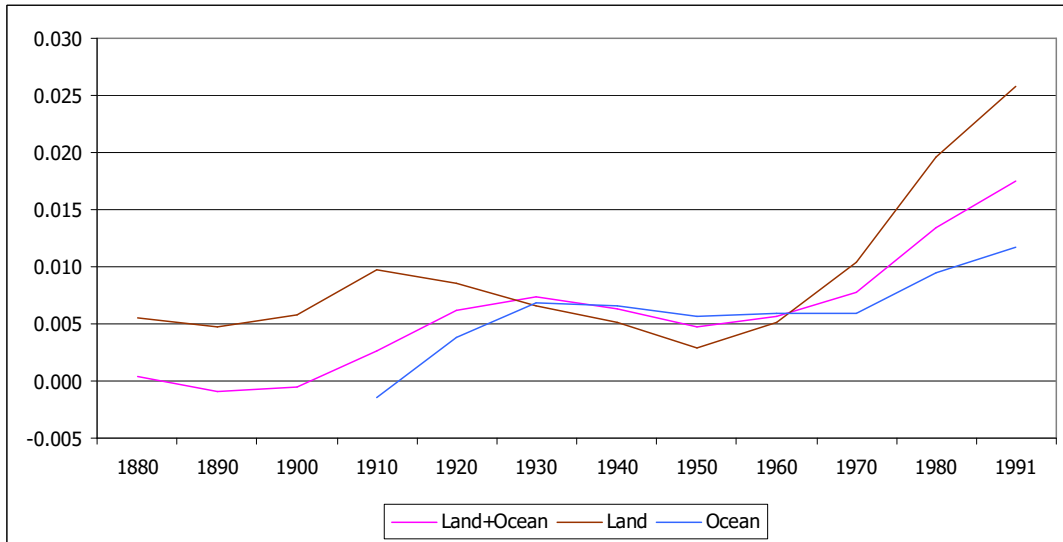
Chart 9 - GWA - Global Warming Acceleration, ocean only [°C/y²]



Axis x is the center of the 61 years trendline period

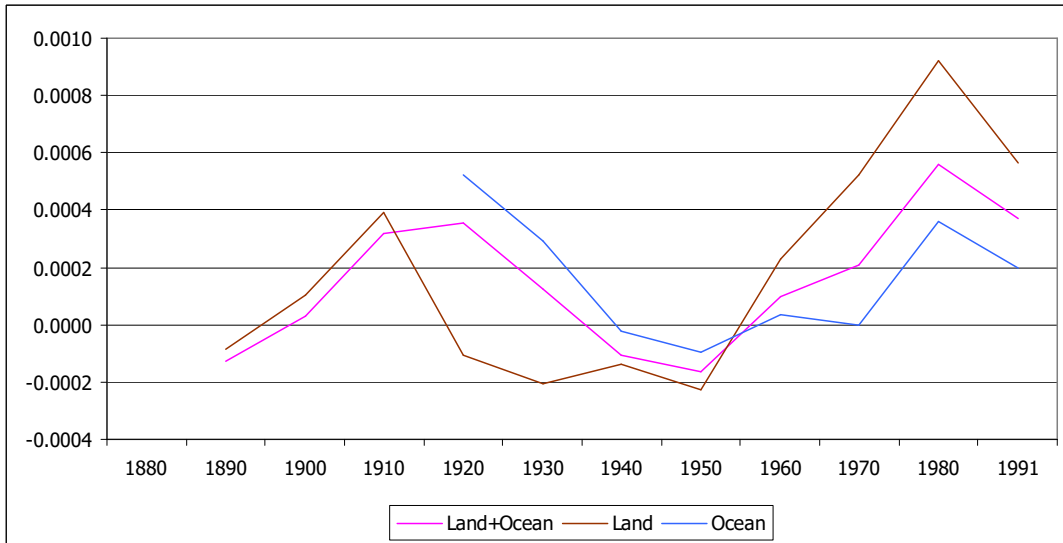
All Global Warming Rates and Acceleration

Chart 10 - All GWR – Global Warming Rate [°C/y]



Axis x is the center of the 61 years trendline period

Chart 11 - All GWA - Global Warming Acceleration [°C/y2]



Axis x is the center of the 61 years trendline period

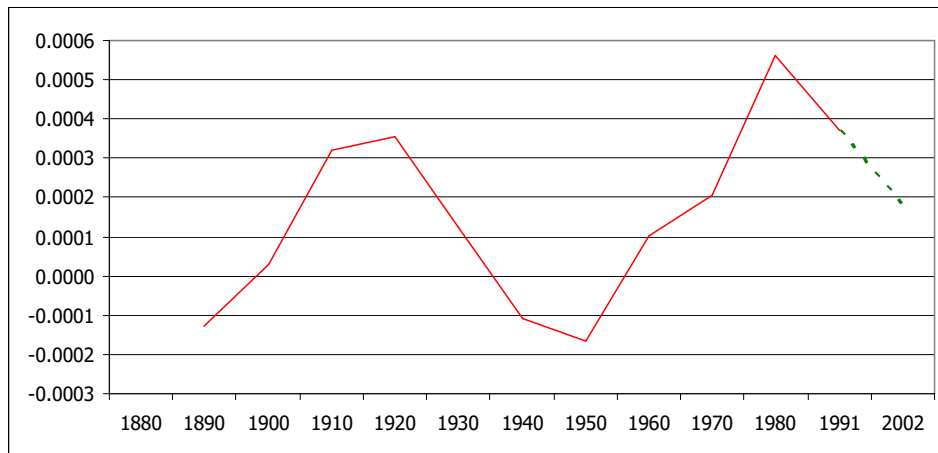
Prediction of Next Decade Global Warming Rate Using GWA

Table 4 - Prediction of next decade Global Warming Rate using GWA for land+ocean

Trendline period			Trendline Center	GWR			Global Warming Acceleration	
from	to	years	Center	Δy	a	Δa	GWA	ΔGWA
year	year	years	year	years	$^{\circ}\text{C}/\text{y}$	$^{\circ}\text{C}/\text{y}$	$^{\circ}\text{C}/\text{y}^2$	$^{\circ}\text{C}/\text{y}^2$
1950	2010	61	1980	10	+0.013362	+0.013362	+0.000562	
1961	2021	61	1991	11	+0.017436	+0.004074	+0.000370	-0.000191
1972	2032	61	2002	11	+0.019405	+0.001969	+0.000179	-0.000191

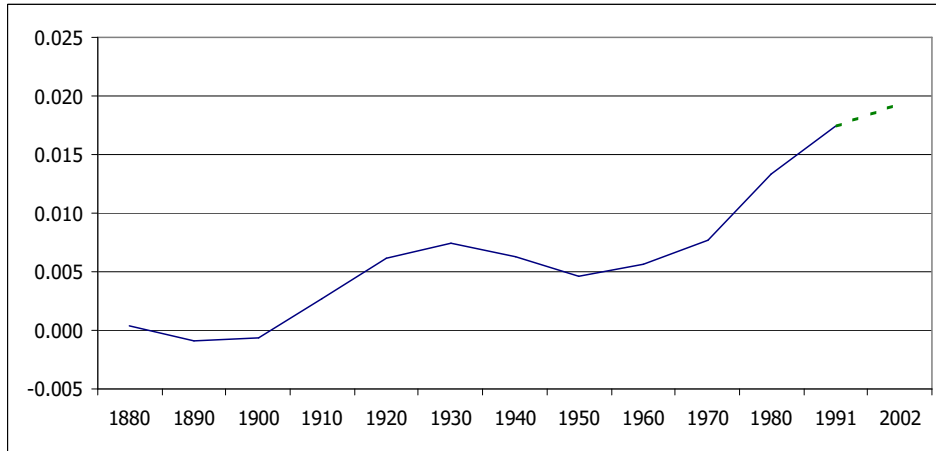
Currently, the Global Warming Acceleration (GWA) is decreasing $-0.000191^{\circ}\text{C}/\text{y}^2$. If this decrease will continue for the next 11 years, the GWA for the 1972-2032 (center 2002) trendline will be $+0.000179^{\circ}\text{C}/\text{y}^2$, which will result in the Global Warming Rate $+0.019405^{\circ}\text{C}/\text{y}$, for land+ocean.

Chart 12 - Prediction of Global Warming Acceleration - GWA for the next decade, land+ocean [$^{\circ}\text{C}/\text{y}^2$]



Axis x is the center of the 61 years trendline period

Chart 13 - Prediction of Global Warming Rate - GWR for the next decade, land+ocean [$^{\circ}\text{C}/\text{y}^2$]



Axis x is the center of the 61 years trendline period

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