

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 $^{\circ}\text{C}/\text{y}$ to +0.019 $^{\circ}\text{C}/\text{y}$, 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

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

$\text{CenterTL}(i+1)$ center of trendline “i+1” (year)
 $\text{CenterTL}(i)$ center of trendline “i” (year)

Formula 6 - CenterTL

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

Period Applied for Calculations of Trendlines

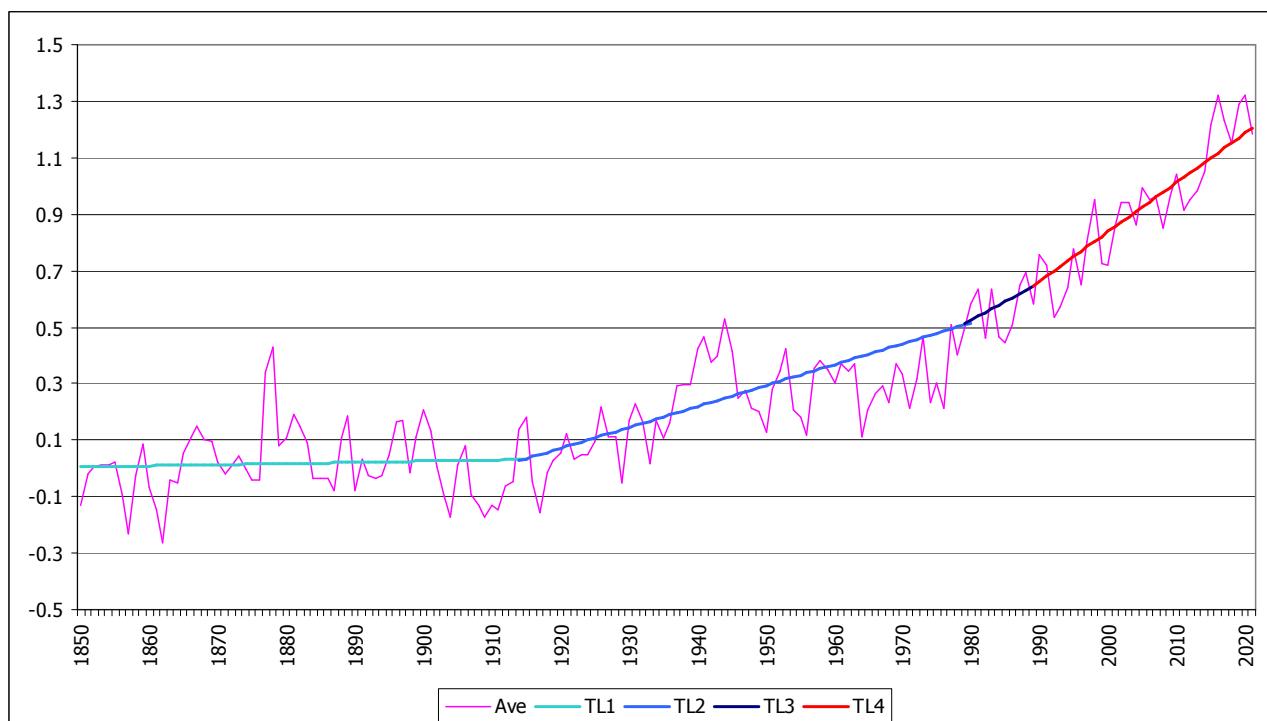
The period applied in (8) for calculations of trendlines is 61 years. This is also the trendlines period applied in the current work. The starting points of the trendlines are every 10 years from 1850 (1880 for ocean only).

Databases Applied

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

Global Surface Temperature Changes over Land and Ocean

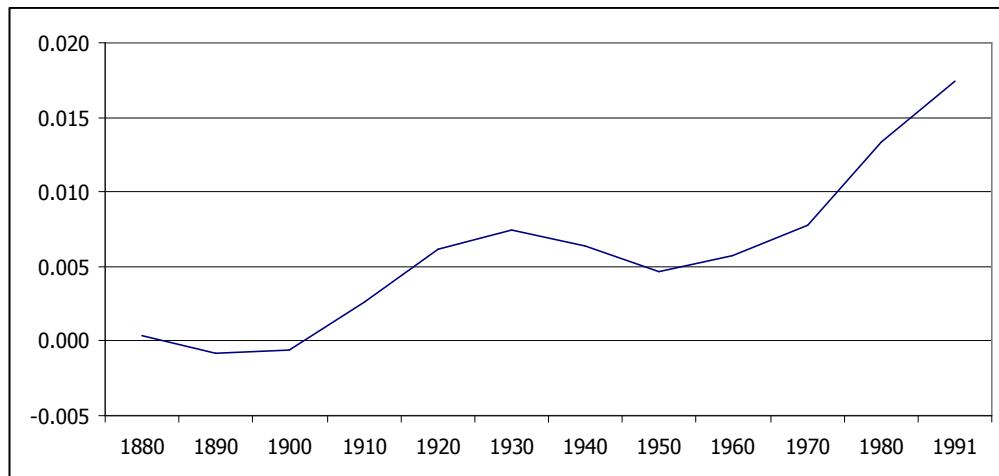
Chart 1 - Trendlines, land+ocean, 1850-1900 baseline (8) (°C)



Ave average of all databases (°C)

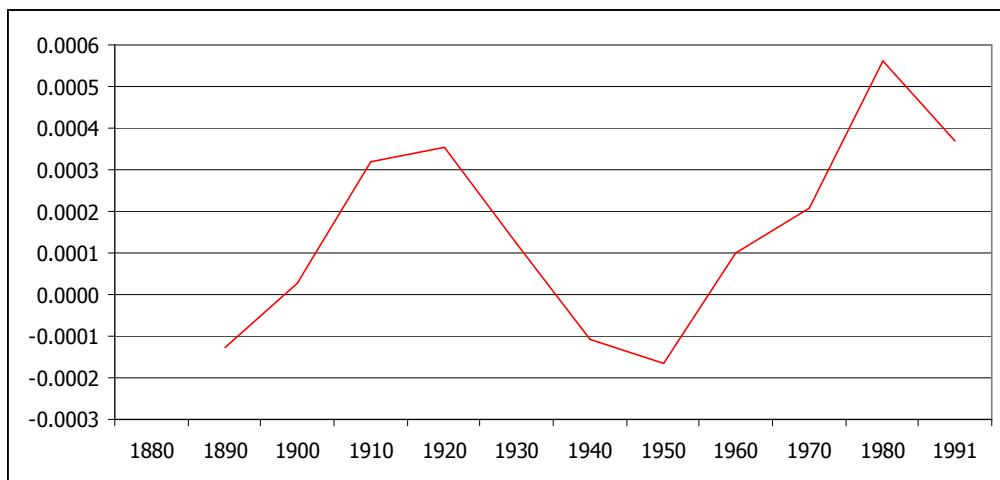
Table 1 - Global Warming Rate (GWR), land+ocean

| i | Trendline | Trendline period | | | Trendline | GWR | | | Global |
|-------|-----------|------------------|------|-------|-----------|-----------|-----------|-----------|-------------------|
| | ID | from | to | years | Center | Δy | a | Δa | Warming |
| | Symbol | TL(i) | | | CenterTL | Formula 6 | Formula 5 | Formula 1 | Acceleration |
| Units | | year | year | years | year | years | °C/y | °C/y | °C/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 (°C/y)

Axis x is the center of the 61 years trendline period

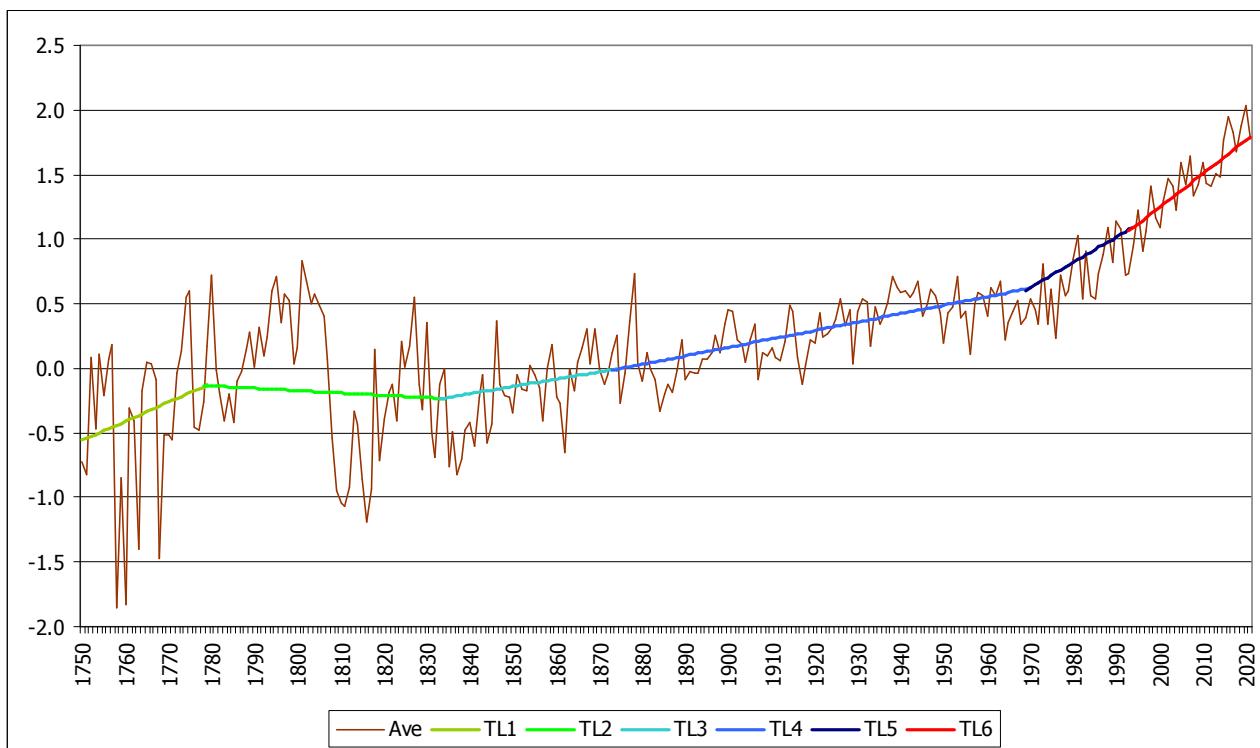
Chart 3 - GWA - Global Warming Acceleration, land+ocean ($^{\circ}\text{C}/\text{y}^2$)



Axis x is the center of the 61 years trendline period

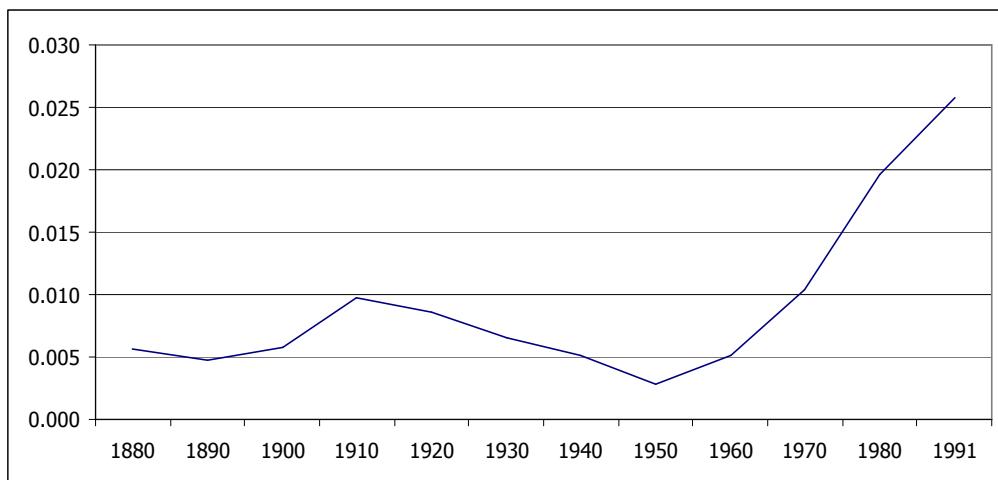
From 1960 the GWA is above zero, which means the Global Warming Rate (GWR) ($^{\circ}\text{C}/\text{y}$) is increasing. The negative slope of GWA between 1980 and 1991 means a slower increase of GWR.

Global Surface Temperature Changes over Land

Chart 4 - Trendlines, land only, 1850-1900 baseline (8) (°C)Table 2 - Global Warming Rate (GWR), land only

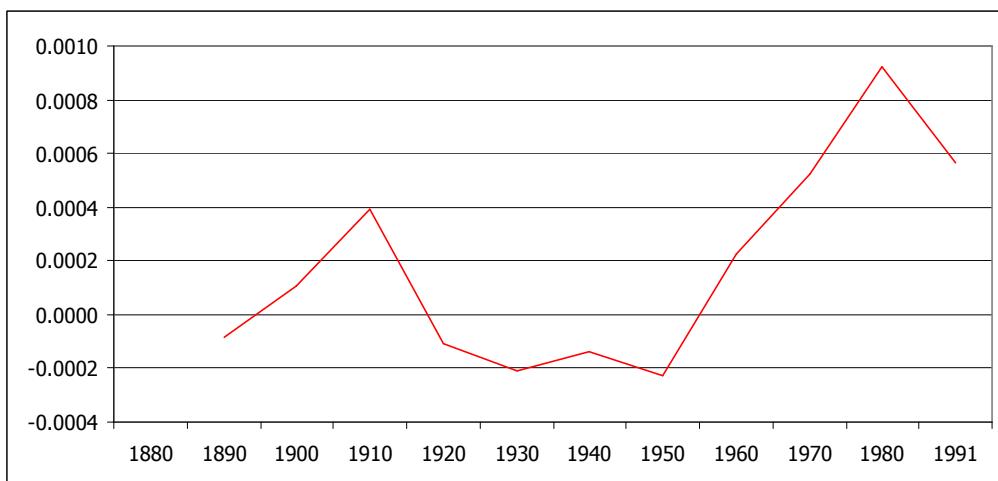
| i | Trendline ID | Trendline period | | | Trendline Center | GWR | | | | Global Warming Acceleration |
|---------|--------------|------------------|------|-------|------------------|--------------------|----------------------|-------------|----------------------|-----------------------------|
| | | from | to | years | | CenterTL Formula 6 | Δy Formula 5 | a Formula 1 | Δa Formula 4 | |
| Symbol | TL(i) | | | | | | | | | |
| Formula | | year | year | years | year | years | °C/y | °C/y | °C/y ² | |
| Units | | | | | | | | | | |
| 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)



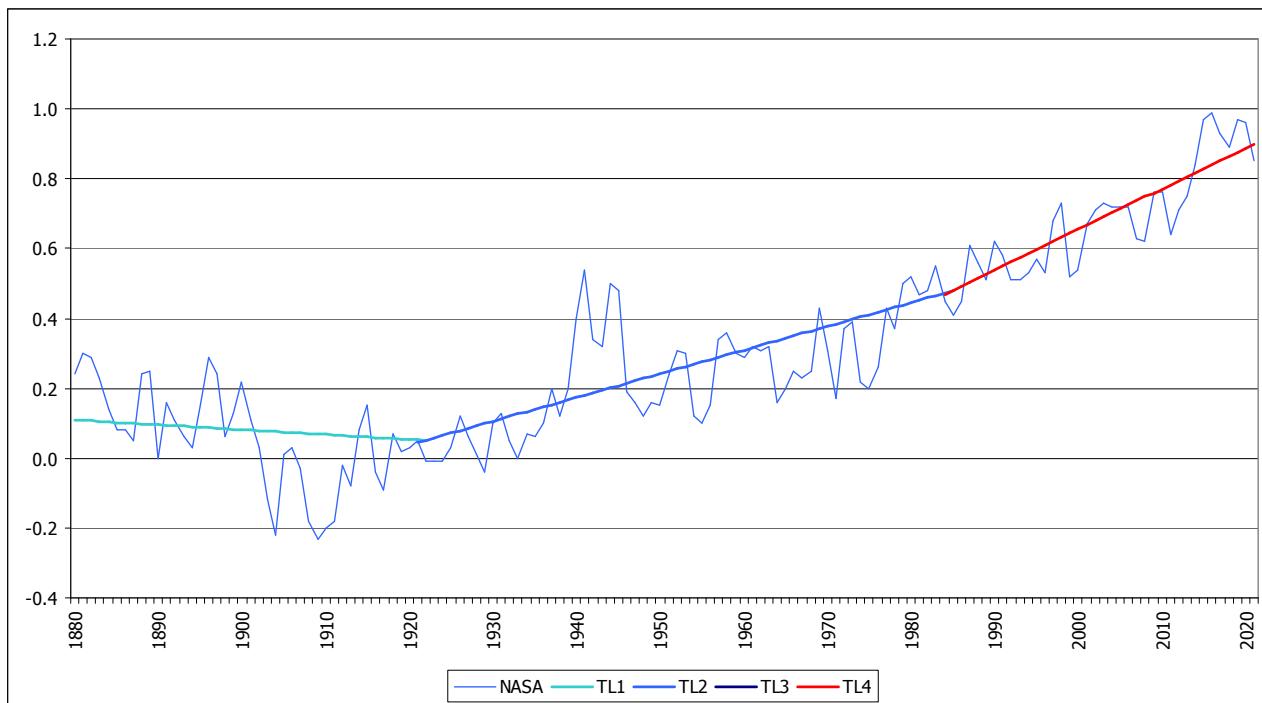
Axis x is the center of the 61 years trendline period

Chart 6 - GWA - Global Warming Acceleration, land only (°C/y²)



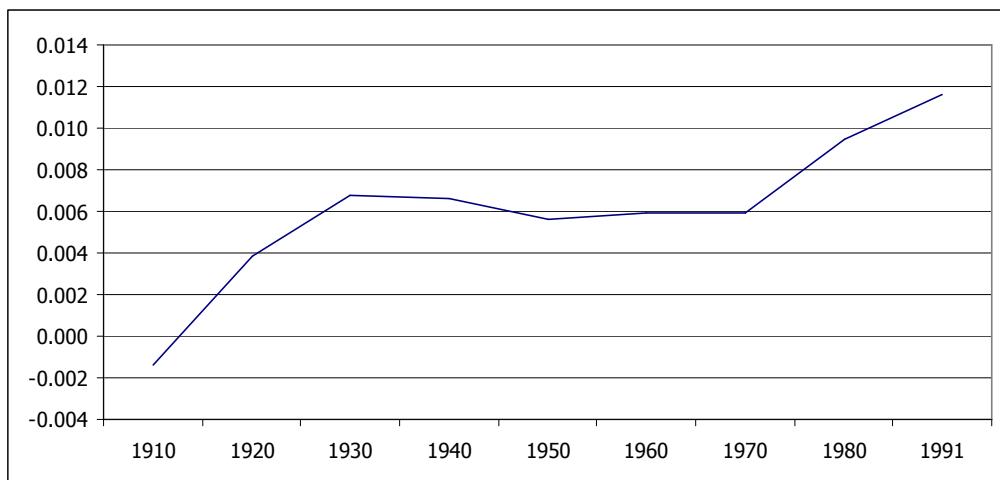
Axis x is the center of the 61 years trendline period

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

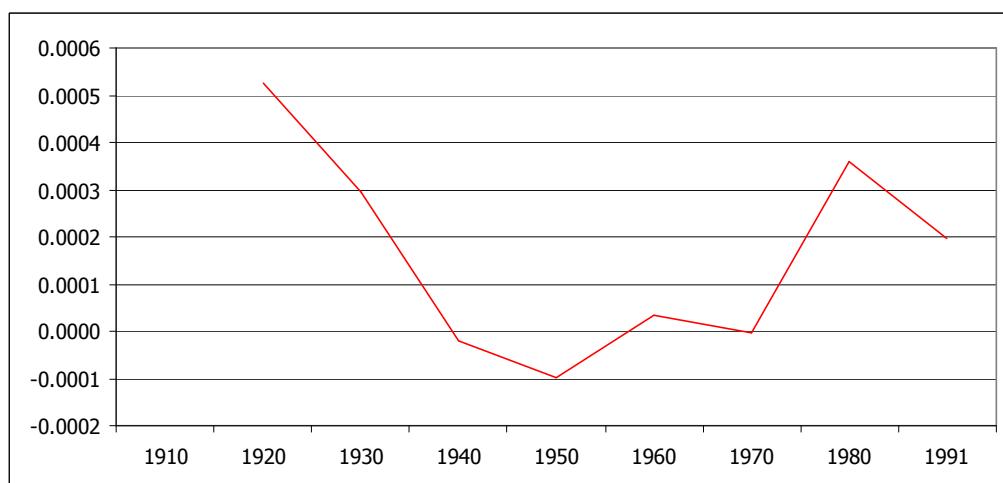
| i | Trendline ID | Trendline period | | | Trendline Center | GWR | | | Global Warming Acceleration |
|--------|--------------|------------------|-----------|-----------|------------------|-----------|-----------|-----------|-----------------------------|
| | | from | to | years | | Center | TL | Δy | |
| Symbol | TL(i) | Formula | Formula 6 | Formula 5 | Formula 1 | 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)



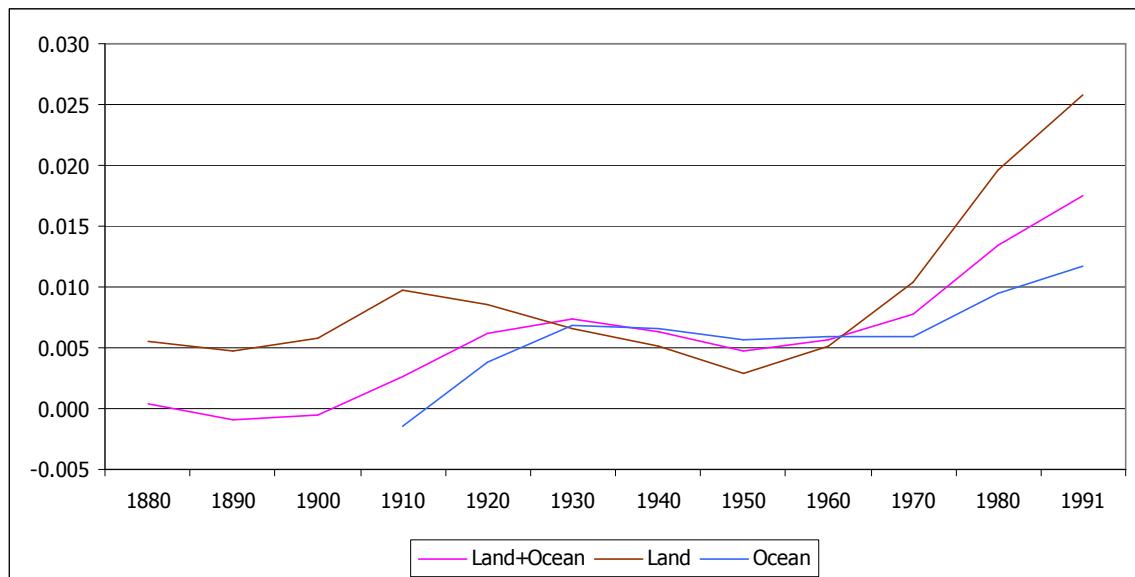
Axis x is the center of the 61 years trendline period

Chart 9 - GWA - Global Warming Acceleration, ocean only (°C/y²)

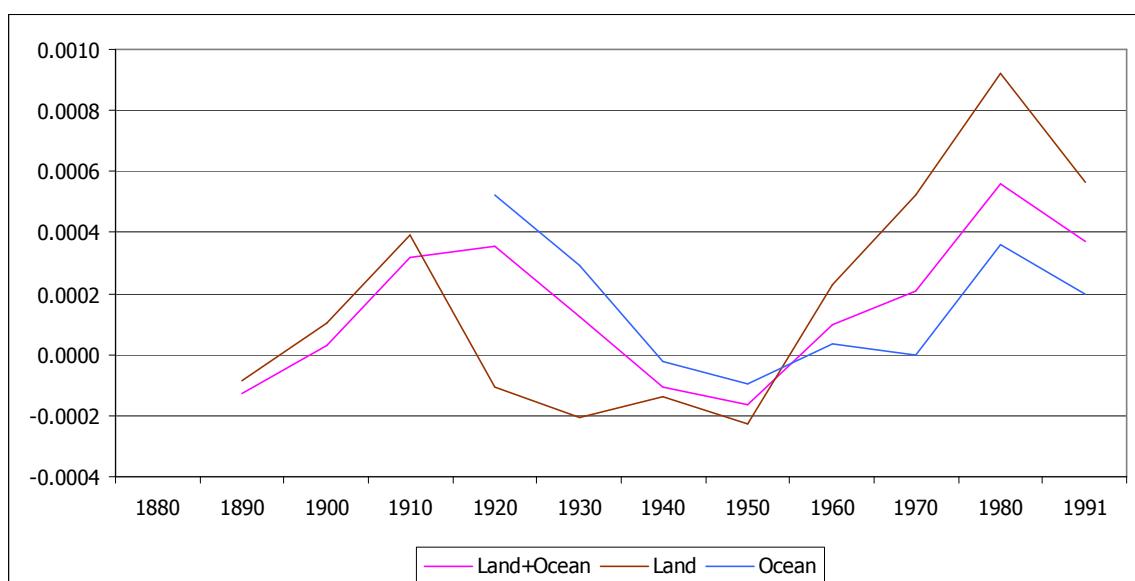


Axis x is the center of the 61 years trendline period

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

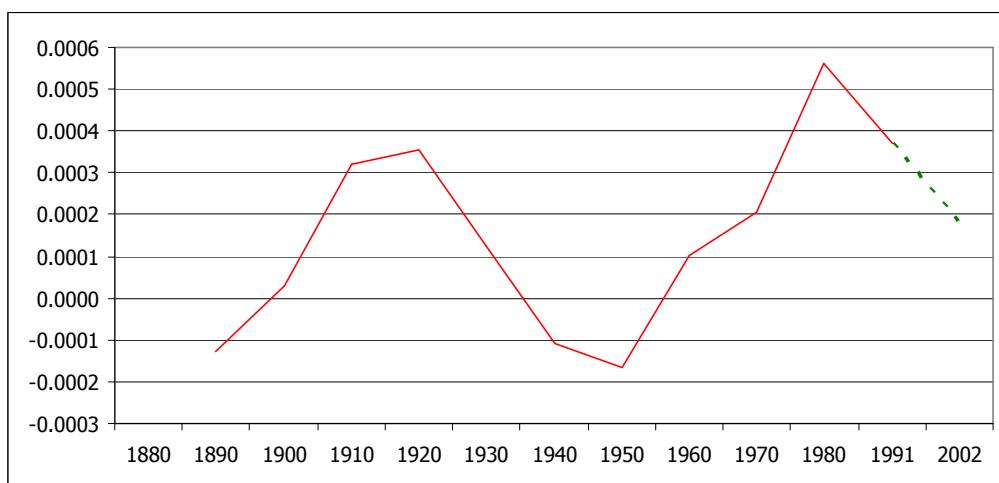
Prediction of Next Decade Global Warming Rate Using GWA

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 | CenterTL Formula 6 | Δy Formula 5 | a Formula 1 | Δa Formula 4 | GWA Formula 2 | GWA Formula 3 | ΔGWA | | |
| year | year | years | year | years | °C/y | °C/y | °C/y ² | °C/y ² | °C/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 | | | |

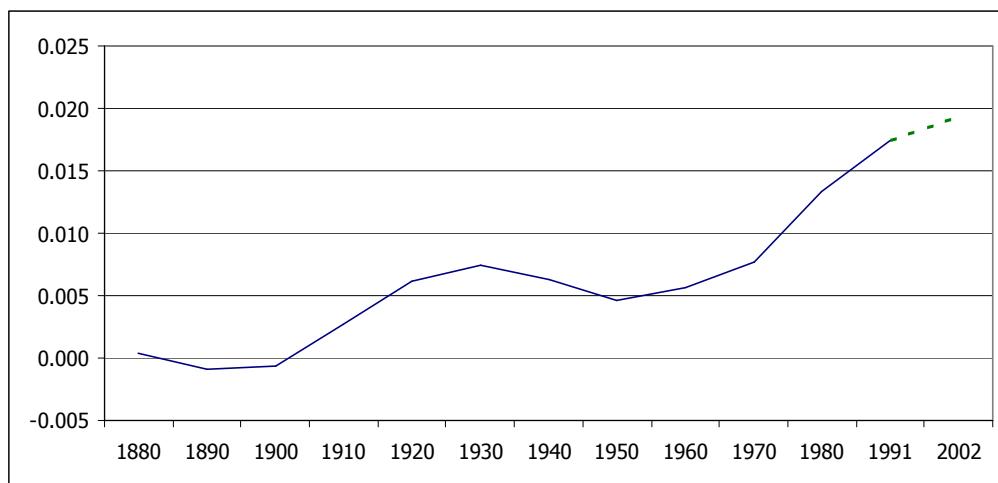
Currently, the Global Warming Acceleration (GWA) is decreasing $-0.000191^{\circ}\text{C}/\text{y}^2$. If this decrease will continue for the next 11 years, the GWA for the 1972-2032 (center 2002) trendline will be $+0.000179^{\circ}\text{C}/\text{y}^2$, which will result in the Global Warming Rate $+0.019405^{\circ}\text{C}/\text{y}$,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



Axis x is the center of the 61 years trendline period

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