Global Warming Baselines Conversion Factors

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Abstract

This publication includes a conversion table between various baselines of global surface temperature changes.
The conversion factor from 1951-1980 to 1850-1900 baseline is +0.31°C for land+ocean, +0.49°C for land only, and +0.29°C for ocean only.

Glossary

Ave	average
BL	baseline
CF	conversion factor between baselines or reference periods
DB	dataset, database
LBL	Berkeley Earth (Lawrence Berkeley Laboratory)

Units

The temperature change unit in this work is °C.

Global Temperature Databases

There are few databases of annual averages of global surface temperature changes.
Each database applies its own baseline.

This work includes the following databases:

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

Air Temperature and Surface Temperature

The difference between the air temperature and surface temperature is explained in [9].
Air temperature is measured at a standard height of 1.2 m above the ground surface. Air temperature can be quite different from surface temperature. In general, air temperatures above a surface reflect the same trends as ground surface temperatures, but ground temperatures are likely to be more extreme [9].

Global Warming Baselines

The EU aims to be climate-neutral by 2050 – an economy with net-zero greenhouse gas emissions [7].
The EU policy is "*in line with the Paris Agreement to keep the global temperature increase to well below 2°C and pursue efforts to keep it to 1.5°C*" [7].
The EU determines the "global temperature increase" according to the IPCC baseline 1850-1900 [8].

IPCC Report 2011 [8] page 5 note 9: "*The period 1850–1900 represents the earliest period of sufficiently globally complete observations to estimate global surface temperature and, consistent with AR5 and SR1.5, is used as an approximation for pre-industrial conditions*".

However, all main databases apply other baselines than IPCC and EU. NASA [1] [2] and Berkeley Earth [4] [5] [6] apply the 1951-1980 baseline, and NOAA[3] applies the 20th century baseline, 1901-2000.
The NASA and NOA databases are from 1880 and not 1850.
It takes a lot of effort to find conversion factors between the IPCC 1850-1900 baseline and the main exiting databases, which have different baselines. The example of such efforts may be a long blog on site Climate Lab Book - Defining 'pre-industrial' [10], concluded with the following statement of Mark Bassham: "*IPCC AR5 (WG1 report), Figure 12.40 (page 1100) indicates a difference between 'pre-industrial' temperatures and the 1980-1999 Reference Period (non-standard, only 20 years long instead of the usual 30) of EXACTLY 0.5°C. Note that 'pre-industrial' means different things to different IPCC Chapter Lead Authors*".

Conversion Factors for Land+Ocean

Table 1 - Global surface temperature change databases for land+ocean

	NASA	NOAA	LBL
Reference	[1] [2]	[3]	[4] [5]
Units	°C	°C	°C
from	1880	1880	1850
to	2021	2020	2021
Years	142	141	172
Baseline (BL)	1951-1980	1901-2000	1951-1980
BL years	30	100	30
Decimal places	2	2	3
Ave in BL	+0.0003	+0.0004	+0.0171

Publication [10] includes the following conversion factor: "*IPCC AR5 (WG1 report), Figure 12.40 (page 1100) indicates a difference between 'pre-industrial' temperatures and the 1980-1999 Reference Period … of EXACTLY 0.5°C*".

The publication of the European Commission's Competence Center on Composite Indicators and Scoreboards [11] includes the following conversion factor to the 1850-1900 baseline: "*Global temperature change (1850-2012): IPCC AR5: change from 1850-1900 baseline to 1986-2005 is 0.61 ± 0.10°C*".

IPCC 2021 Report [8] p5 item A.1.2 indicates the following relations between the 1850-1900 baseline and other periods: "*Global surface temperature in the first two decades of the 21st century (2001–2020) was 0.99 [0.84 to 1.10] °C higher than 1850–1900. Global surface temperature was 1.09 [0.95 to 1.20] °C higher in 2011–2020 than 1850–1900*".

The above publications require determination of averages in additional reference periods:

- 1980-1999 [10]
- 1986-2005 [11]
- 2001-2020 [8]
- 2011-2020 [8]

Table 2 - Baselines and reference periods

BL	NASA	NOAA	LBL			IPCC	IPCC
Reference	[1] [2]	[3]	[4.1] [5.1]	[10]	[11]	[8.1]	[8.2]
DB BL	1951-1980	1901-2000	1951-1980				
1850-1900			-0.30	+0.00	+0.00	+0.00	+0.00
1901-2000	-0.03	+0.00	-0.02				
1951-1980	+0.00	+0.04	+0.02				
1980-1999	+0.32	+0.34	+0.36	+0.50			
1986-2005	+0.42	+0.45	+0.47		+0.61		
2001–2020	+0.73	+0.72	+0.77			+0.99	
2011-2020	+0.84	+0.82	+0.88				+1.09

DB BL Baseline of the database

The green background highlights the baseline period of the data.
The values in the above table for NASA, NOAA and LBL were calculated as averages in other reference periods.

Table 3 - Estimation of conversion factor from 1951-1980 to 1850-1900 baseline according to reference [10] and NASA database [°C]

Ref	from	to	°C
[10]	1850-1900	1980-1999	+0.50
NASA	1951-1980	1980-1999	+0.32
Δ	1850-1900	1951-1980	+0.18
CF	1951-1980	1850-1900	+0.18

CF estimated conversion factor [°C]

Table 4 - Estimation of conversion factor from 1951-1980 to 1850-1900 baseline according to reference [11] and NASA database [°C]

Ref	from	to	°C
[11]	1850-1900	1986-2005	+0.61
NASA	1951-1980	1986-2005	+0.42
Δ	1850-1900	1951-1980	+0.19
CF	1951-1980	1850-1900	+0.19

Table 5 - Estimation of conversion factor from 1951-1980 to 1850-1900 baseline according to reference [8.1] and NASA database [°C]

Ref	from	to	°C
[8.1]	1850-1900	2001–2020	+0.99
NASA	1951-1980	2001–2020	+0.73
Δ	1850-1900	1951-1980	+0.26
CF	1951-1980	1850-1900	+0.26

Table 6 - Estimation of conversion factor from 1951-1980 to 1850-1900 baseline according to reference [8.2] and NASA database [°C]

Ref	from	to	°C
[8.2]	1850-1900	2011-2020	+1.09
NASA	1951-1980	2011-2020	+0.84
Δ	1850-1900	1951-1980	+0.26
CF	1951-1980	1850-1900	+0.26

Berkeley Earth (LBL) Database [4.1] [5.1] includes records from 1850, allowing calculation of averages in 1951-1980 and 1850-1900 periods for land+ocean. The difference between the averages in both periods is an estimation of the conversion factor from 1951-1980 to 1850-1900 baselines.

Table 7 - Estimation of conversion factor from 1951-1980 to 1850-1900 baseline according to LBL [4.1] [5.1] database [°C]

Ref	from	to	°C
[4.1] [5.1]	1951-1980	1850-1900	-0.30
CF	1951-1980	1850-1900	+0.30

Berkeley Earth (LBL) [4.2] [5.2] clearly indicates the conversion factor between 1951-1980 and 1850-1900 baselines: "*The global mean temperature in 2021 is estimated to have been 1.21 °C above the average temperature from 1850-1900, a period often used as a pre-industrial baseline for global temperature targets. This temperature in 2021 is equivalent to 0.90 °C above the 1951-1980 average which is often used as a reference period for comparing global climate analyses*".

Table 8 - LBL [4.2] [5.2] conversion factor from 1951-1980 to 1850-1900 baseline [°C]

Ref	from	to	°C
[4.2] [5.2]	1850-1900	2021	+1.21
[4.2] [5.2]	1951-1980	2021	+0.90
Δ	1850-1900	1951-1980	+0.31
CF	1951-1980	1850-1900	+0.31

Table 9 - All estimations of the conversion factor from 1951-1980 to 1850-1900 baseline for land+ocean [°C]

Ref	[10]	[11]	[8.1]	[8.2]	[4.1] [5.1]	[4.2] [5.2] *
	°C	°C	°C	°C	°C	°C
CF	+0.18	+0.19	+0.26	+0.26	+0.30	**+0.31**

* selected conversion factor

Among all above options, the only case of direct conversion between 1951-1980 and 1850-1900 baseline is Berkeley Earth [4.2] [5.2]: "*The global mean temperature in 2021 is estimated to have been 1.21 °C above the average temperature from 1850-1900, a period often used as a pre-industrial baseline for global temperature targets. This temperature in 2021 is equivalent to 0.90 °C above the 1951-1980 average which is often used as a reference period for comparing global climate analyses*".

The conversion factor from 1951-1980 to 1850-1900 baseline for land+ocean selected for further analysis and conversion of the databases in this work is +0.31°C.

Table 10 - Databases and baselines for estimations of conversion factor from **1901-2000** to 1850-1900 baseline

BL	NASA	NOAA	LBL
Reference	[1] [2]	[3]	[4.1] [5.1]
DB BL	1951-1980	1901-2000	1951-1980
1850-1900			-0.30
1901-2000	-0.03	+0.00	-0.02
1951-1980	+0.00	+0.04	+0.02

Table 11 - Estimation of conversion factor from 1901-2000 to 1850-1900 baseline according to LBL [4.1] [5.1] database [°C]

Ref	from	to	°C
LBL	1951-1980	1850-1900	-0.30
LBL	1951-1980	1901-2000	-0.02
Δ	1850-1900	1951-1980	-0.28
CF	1901-2000	1850-1900	+0.28

Table 12 - Estimation of conversion factor from 1901-2000 to 1850-1900 baseline according to conversion factor from 1951-1980 to 1850-1900 and NASA database [°C]

Ref	from	to	°C
CF	1951-1980	1850-1900	+0.31
NASA	1951-1980	1901-2000	-0.03
CF	1901-2000	1850-1900	+0.28

Table 13 - Estimation of conversion factor from 1901-2000 to 1850-1900 baseline according to conversion factor from 1951-1980 to 1850-1900 and NOAA database [°C]

Ref	from	to	°C
CF	1951-1980	1850-1900	+0.31
NOAA	1951-1980	1901-2000	-0.04
CF	1901-2000	1850-1900	+0.27

Table 14 - All estimations of the conversion factor from 1901-2000 to 1850-1900 baseline for land+ocean [°C]

Ref	LBL	NASA	NOAA	Ave *
	°C	°C	°C	°C
CF	+0.28	+0.28	+0.27	**+0.28**

* selected conversion factor

As there is no example of direct conversion from 1901-2000 to 1850-1900 baseline, the average of all estimations +0.28°C will be applied for further analysis and conversion of the databases in this work.

Table 15 - Conversion factors to 1850-1900 baseline for land+ocean [°C]

from BL:	Land+Ocean
1850-1900	+0.00
1901-2000	+0.28
1951-1980	+0.31

Conversion Factors for Land Only

IPCC 2021 Report [8] p5 item A.1.2 indicates the following relations between the 1850-1900 baseline and other periods: "*Global surface temperature was 1.09 [0.95 to 1.20] °C higher in 2011–2020 than 1850–1900, with larger increases* ***over land (1.59*** *[1.34 to 1.83] °C) than over the ocean (0.88 [0.68 to 1.01] °C)*".
According to the NASA database, the average temperature change for land only in the 2011–2020 period was 1.24°C above the 1951-1980 baseline.

According to Berkeley Earth (LBL) [4] [5] "*in 2021, the land average temperature was 1.70 ± 0.04 °C above the average temperature from 1850 to 1900*".
According to the NASA database, the temperature change for land only in 2021was 1.32°C above the 1951-1980 baseline.

Table 16 - Databases for land only

	NASA	LBL
Reference	[1] [2]	[6]
Units	°C	°C
Records	annual	monthly
from	1880	1750
to	2021	2021
years	142	272
Baseline (BL)	1951-1980	1951-1980
BL years	30	30
Decimal places	2	3
Ave in BL	+0.0010	+0.0010

Table 17 - Baselines and reference periods

	IPCC	LBL	NASA	LBL
Reference	[8]	[4] [5]	[1] [2]	[6]
1850-1900	+0.00	+0.00		-0.49
1901-2000				+0.00
1951-1980			+0.00	+0.00
2011-2020	+1.59		+1.24	+1.17
2021		+1.70	+1.32	+1.24

Table 18 - Estimation of conversion factor from 1951-1980 to 1850-1900 baseline according to reference [8] and NASA database [°C]

Ref	from	to	°C
[8]	1850-1900	2011-2020	+1.59
NASA	1951-1980	2011-2020	+1.24
Δ	1850-1900	1951-1980	+0.35
CF	1951-1980	1850-1900	+0.35

Table 19 - Estimation of conversion factor from 1951-1980 to 1850-1900 baseline according to reference [4] [5] and NASA database [°C]

Ref	from	to	°C
[4] [5]	1850-1900	2021	+1.70
NASA	1951-1980	2021	+1.32
Δ	1850-1900	1951-1980	+0.38
CF	1951-1980	1850-1900	+0.38

Berkeley Earth (LBL) database [6] is from 1750, which allows calculations of averages in any reference period. In the current work, annual averages were calculated based on the LBL [6] monthly data from January to December for each year of the database. The annual results of these calculations are publicly available in publication [12].

Table 20 - Estimation of conversion factor from 1951-1980 to 1850-1900 baseline according to Berkeley Earth (LBL) [6] [°C]

Ref	from	to	°C
LBL [6]	1951-1980	1850-1900	-0.49
CF	1951-1980	1850-1900	+0.49

Table 21 - All estimations of the conversion factor from 1951-1980 to 1850-1900 baseline for land only [°C]

Ref	[8]	[4] [5]	LBL [6] *
	°C	°C	°C
CF	+0.35	+0.38	**+0.49**

* selected conversion factor

There is no example of direct conversion from 1951-1980 to 1850-1900 baseline for land only.
IPCC [8] and NASA [4] [5] options apply 2 separate sources of information.
The Berkeley Earth (LBL) [6] option is the favorite option as the conversion factor was calculated using only one source of data.
The Berkeley Earth (LBL) [6] option +0.49°C is selected and will be applied for further analysis and conversion of the databases in this work.

Table 22 - Estimation of conversion factor from **1901-2000** to 1850-1900 baseline according to Berkeley Earth (LBL) [6] [°C]

Ref	from	to	°C
LBL [6]	1901-2000	1850-1900	-0.49
CF	1901-2000	1850-1900	**+0.49**

Table 23 - Conversion factors to 1850-1900 baseline for land only [°C]

from BL:	Land
1850-1900	+0.00
1901-2000	+0.49
1951-1980	+0.49

Conversion Factors for Ocean Only

IPCC 2021 Report [8] p5 item A.1.2 describes the following relations between the 1850-1900 baseline and other periods: "*Global surface temperature was 1.09 [0.95 to 1.20] °C higher in 2011–2020 than 1850–1900, with larger increases over land (1.59 [1.34 to 1.83] °C) than over the* ***ocean (0.88*** *[0.68 to 1.01] °C)*".
According to the NASA database, the average temperature change for the ocean only in 2011–2020 was 0.58°C above the 1951-1980 baseline.

According to Berkeley Earth (LBL) [4] [5] "*the ocean surface temperature, excluding sea ice regions, has increased in 2021 0.83 ± 0.05* °C" above the average temperature from 1850 to 1900.
According to the NASA database, the temperature change of the ocean only in 2021 was 0.56°C above the 1951-1980 baseline.

Table 24 - Database for ocean only

	NASA
Reference	[1] [2]
Units	°C
Records	annual
from	1880
to	2021
years	142
Baseline (BL)	1951-1980
BL years	30
Decimal places	2
Ave in BL	+0.0007

Table 25 - Baselines and reference periods

	IPCC	LBL	NASA
Reference	[8]	[4] [5]	[1] [2]
1850-1900	+0.00	+0.00	
1901-2000			-0.06
1951-1980			+0.00
2011-2020	+0.88		+0.58
2021		+0.83	+0.56

Table 26 - Estimation of conversion factor from 1951-1980 to 1850-1900 baseline according to reference [8] (IPCC) and NASA database [°C]

Ref	from	to	°C
[8]	1850-1900	2011-2020	+0.88
NASA	1951-1980	2011-2020	+0.58
Δ	1850-1900	1951-1980	+0.31
CF	1951-1980	1850-1900	+0.31

Table 27 - Estimation of conversion factor from 1951-1980 to 1850-1900 baseline according to reference [4] [5] (LBL) and NASA database [°C]

Ref	from	to	°C
[4] [5]	1850-1900	2021	+0.83
NASA	1951-1980	2021	+0.56
Δ	1850-1900	1951-1980	+0.27
CF	1951-1980	1850-1900	+0.27

Table 28 - All estimations of the conversion factor from 1951-1980 to 1850-1900 baseline for ocean only [°C]

Ref	[8]	[4] [5]	Ave *
	°C	°C	°C
CF	+0.31	+0.27	**+0.29**

* selected conversion factor

Both options apply two sources of information. The selected conversion factor is an average of both options.

Table 29 - Estimation of conversion factor from **1901-2000** to 1850-1900 baseline according to NASA database [°C]

Ref	from	to	°C
CF	1951-1980	1850-1900	+0.29
NASA	1951-1980	1901-2000	-0.06
CF	1901-2000	1850-1900	+0.23

Table 30 - Conversion factors to 1850-1900 baseline for ocean only [°C]

from BL:	Ocean
1850-1900	+0.00
1901-2000	+0.23
1951-1980	+0.29

All Conversion Factors of Global Surface Temperature Changes Baselines

Table 31 - Conversion factors to 1850-1900 baseline [°C]

from BL:	Land+Ocean	Land	Ocean
1850-1900	+0.00	+0.00	+0.00
1901-2000	+0.28	+0.49	+0.23
1951-1980	+0.31	+0.49	+0.29

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