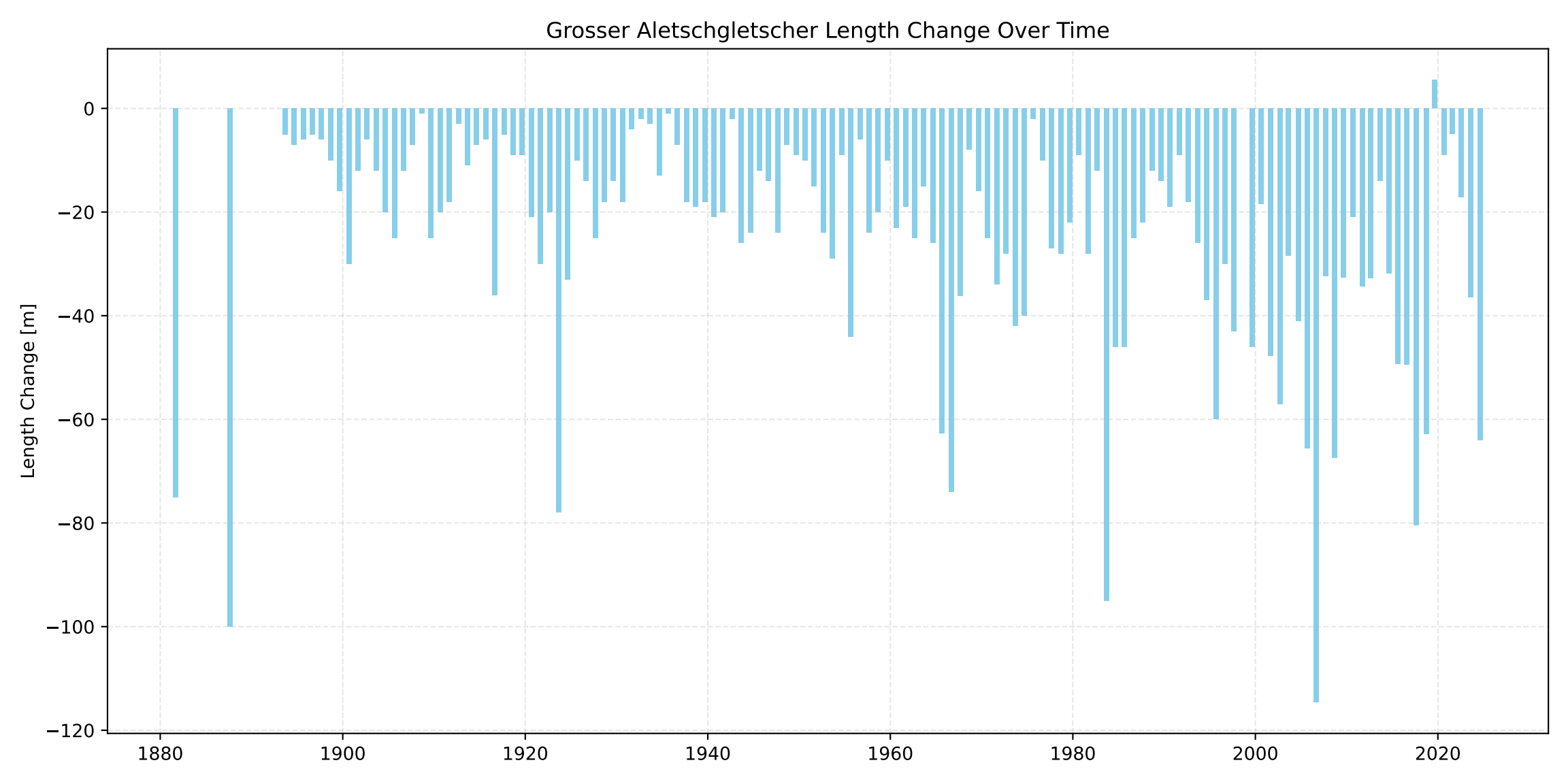
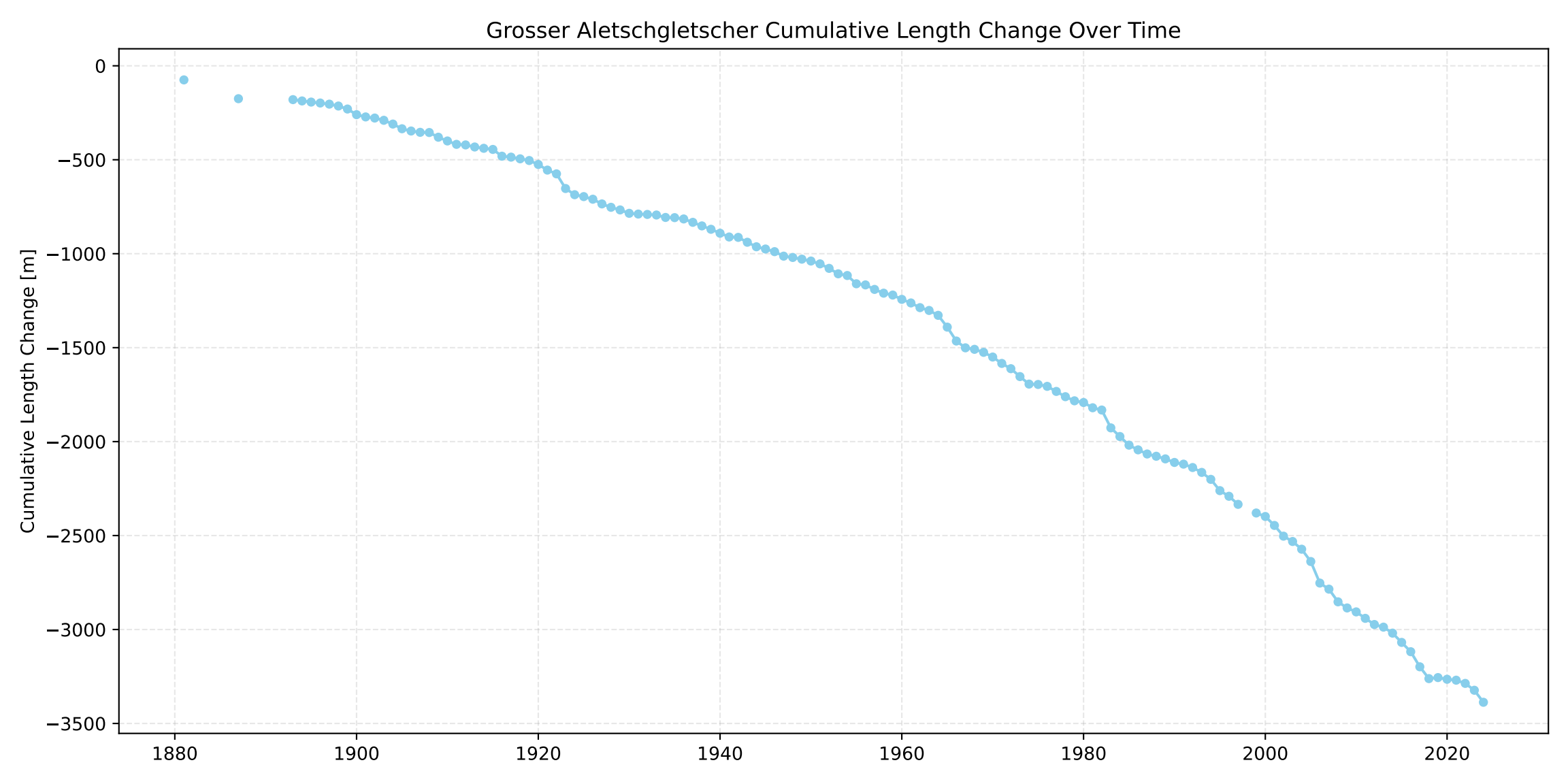
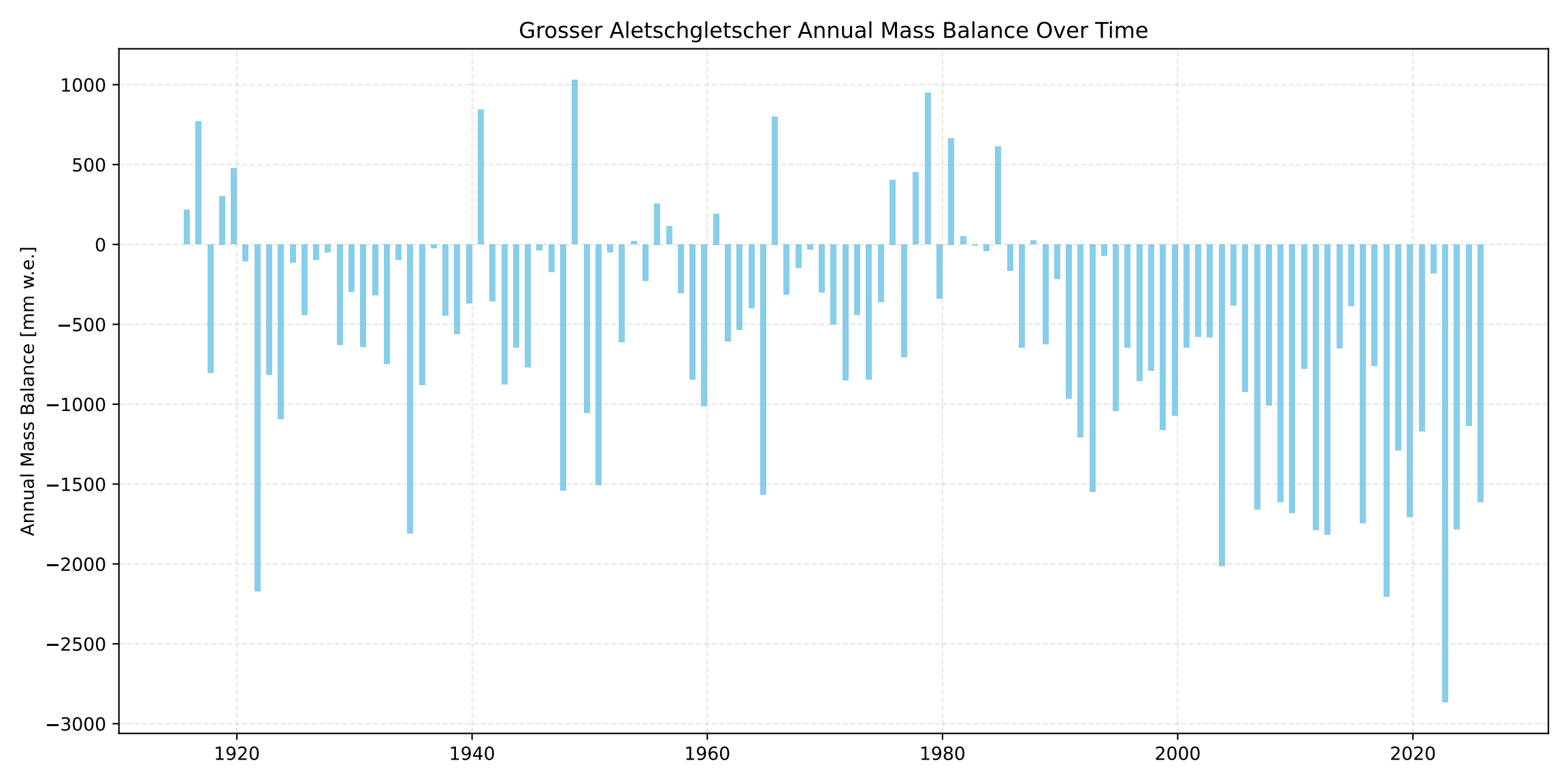
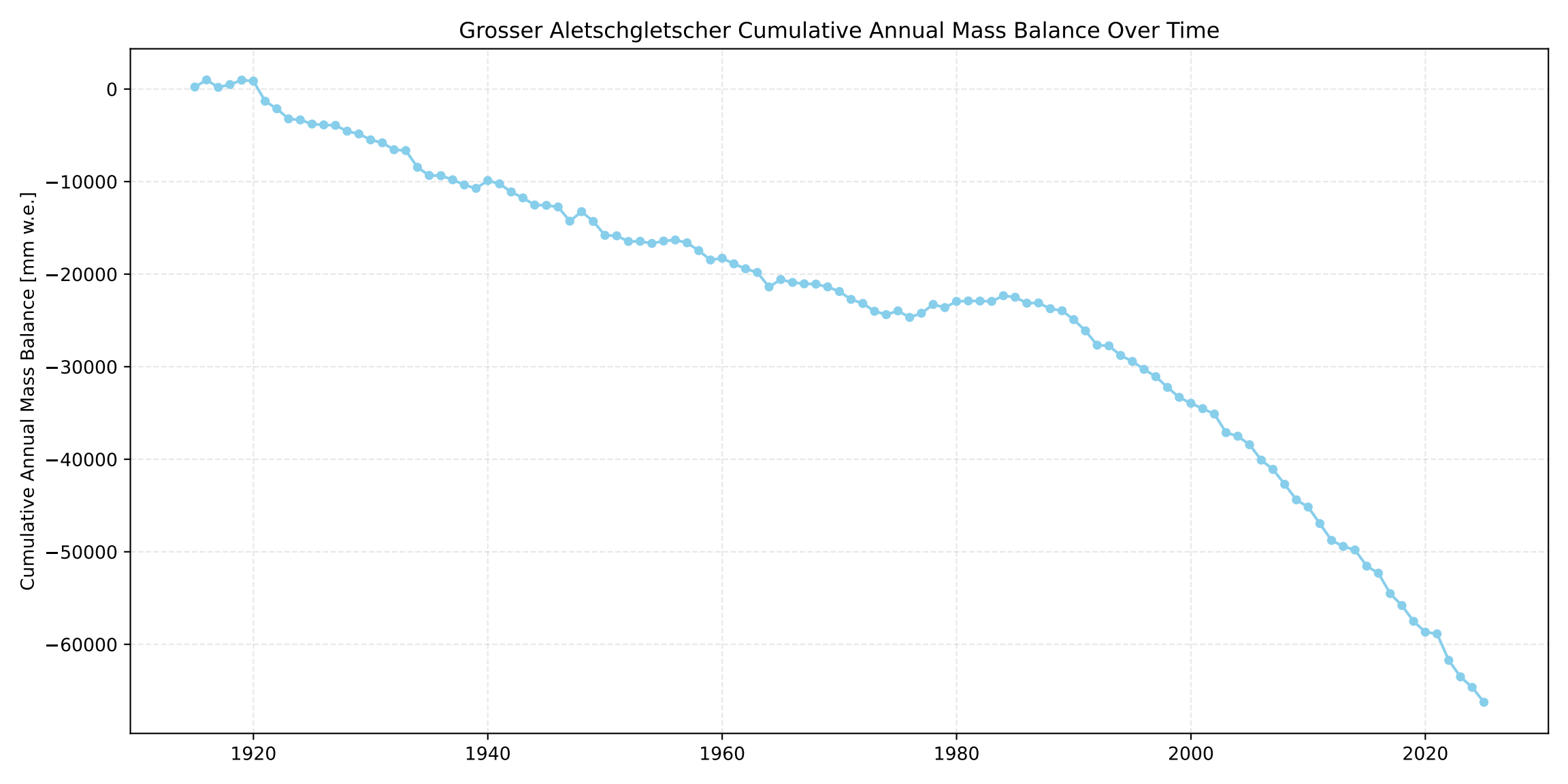
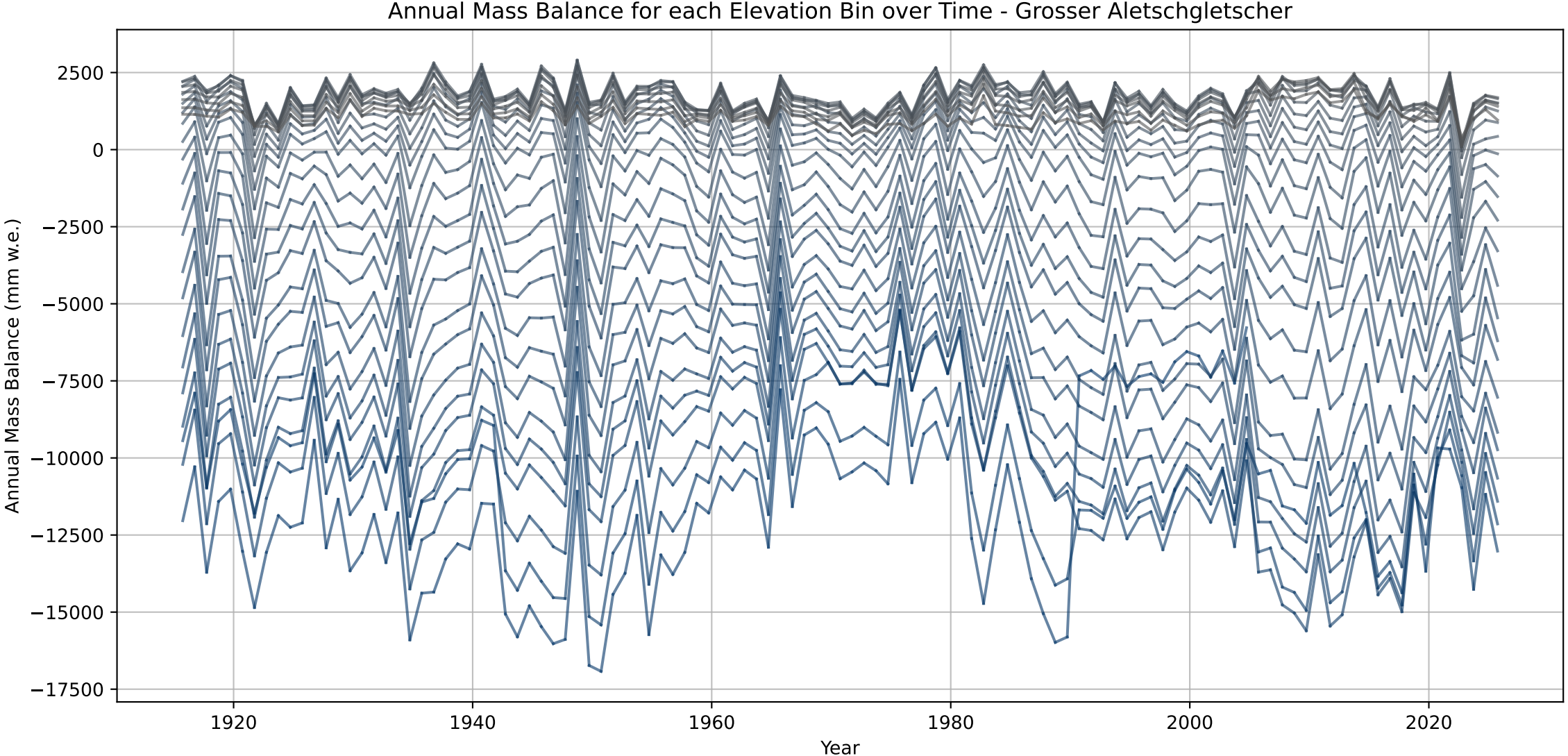
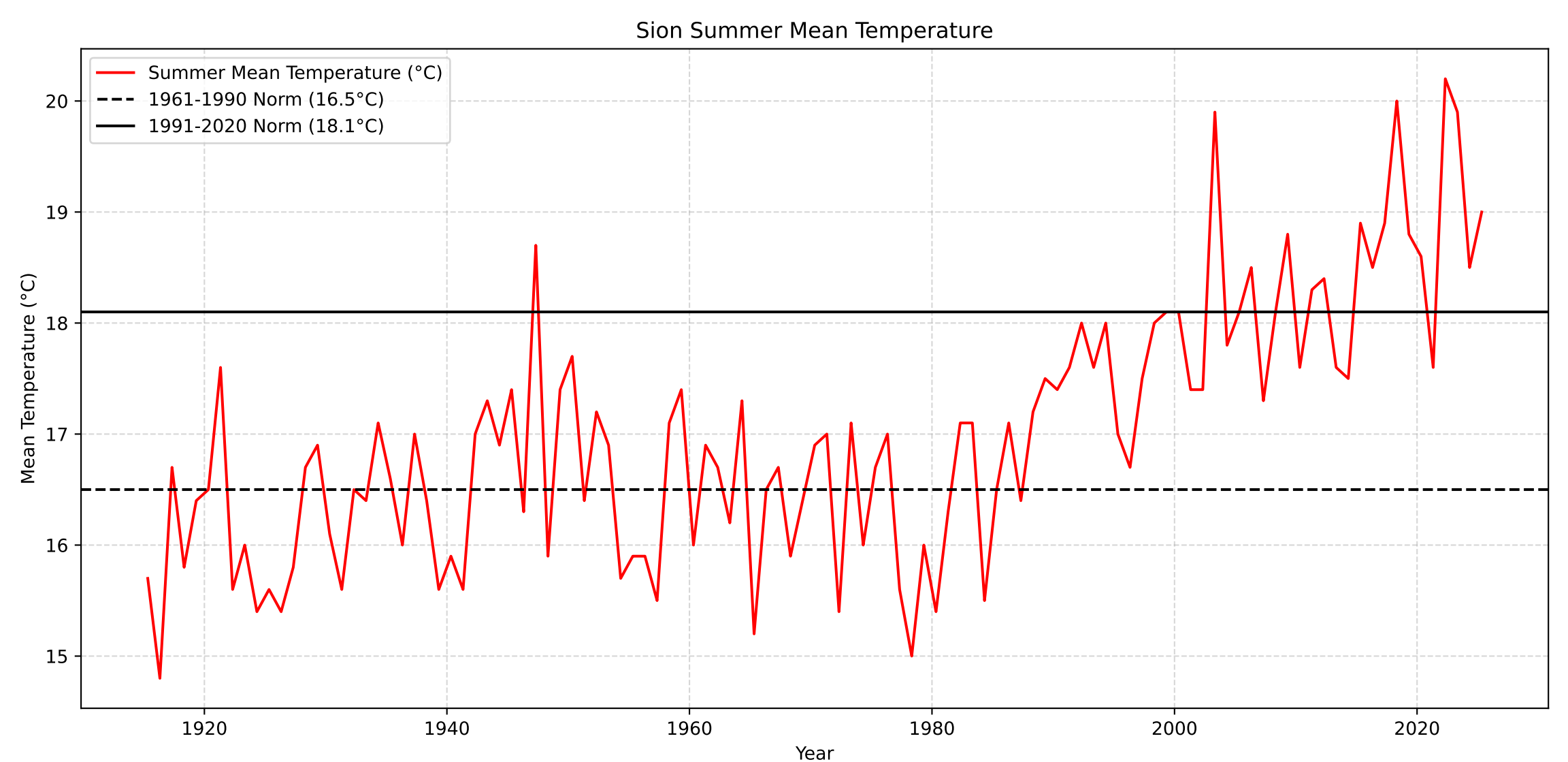

Grosser Aletschgletscher Length Change Over Time
Length Change [m]
0
−20
−40
−60
−80
−100
−120
1880
1900
1920
1940
1960
1980
2000
2020

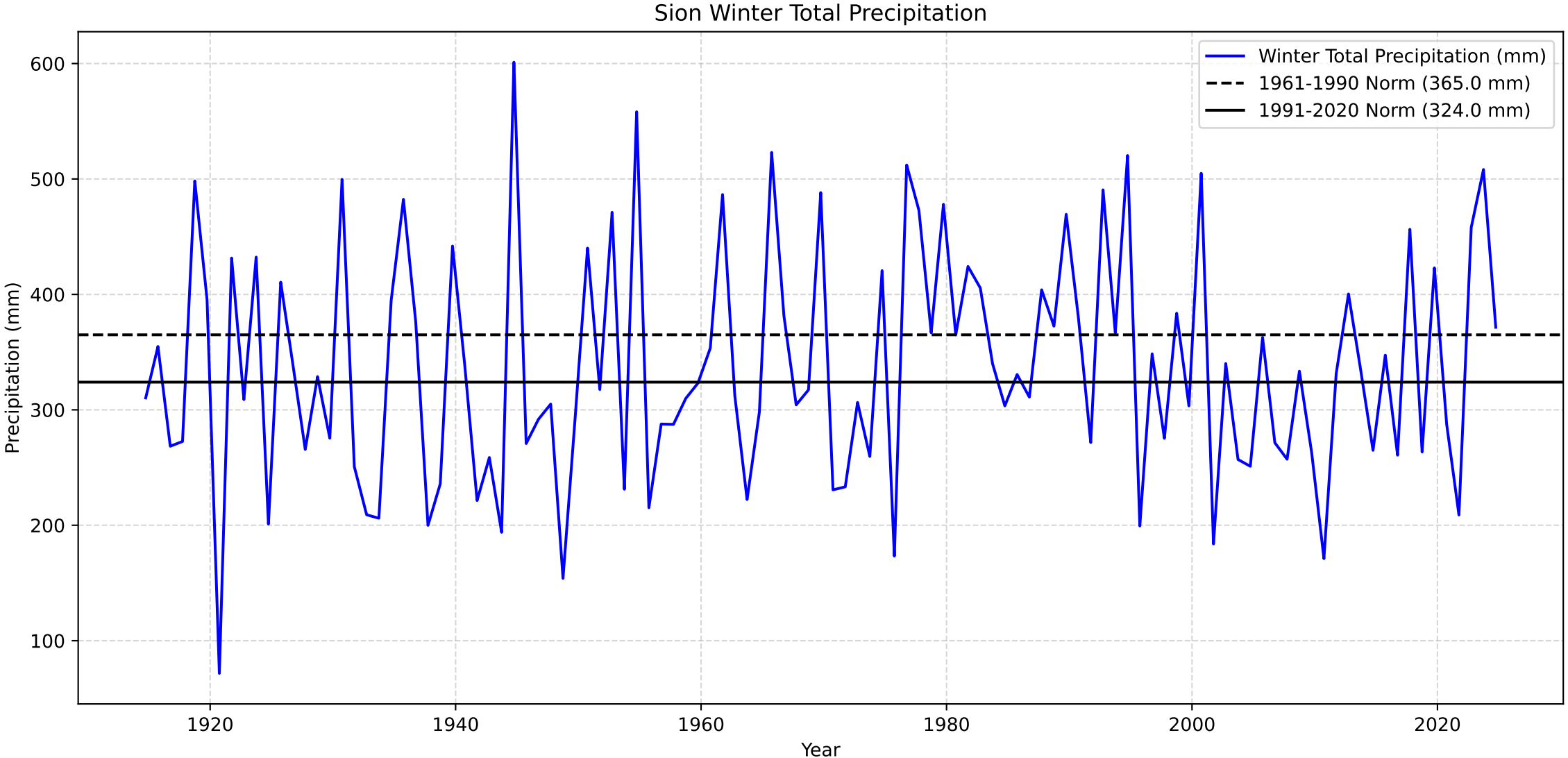

Grosser Aletschgletscher Cumulative Length Change Over Time
Cumulative Length Change [m]
0
−500
−1000
−1500
−2000
−2500
−3000
−3500
1880
1900
1920
1940
1960
1980
2000
2020

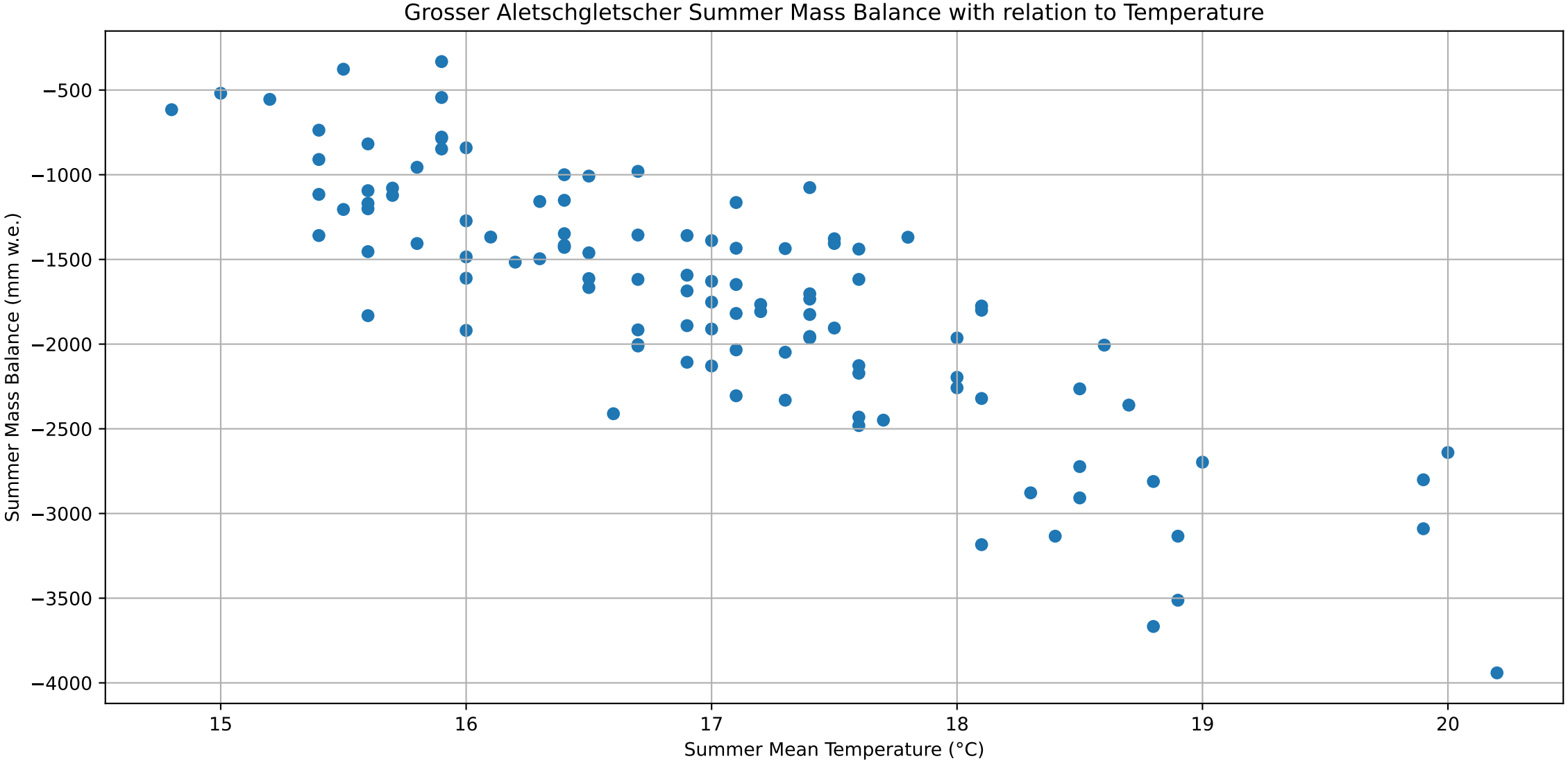

Grosser Aletschgletscher Annual Mass Balance Over Time
Annual Mass Balance [mm w.e.]
1000
500
0
−500
−1000
−1500
−2000
−2500
−3000
1920
1940
1960
1980
2000
2020


Grosser Aletschgletscher Cumulative Annual Mass Balance Over Time
Cumulative Annual Mass Balance [mm w.e.]
0
−10000
−20000
−30000
−40000
−50000
−60000
1920
1940
1960
1980
2000
2020


Annual Mass Balance for each Elevation Bin over Time - Grosser Aletschgletscher
Annual Mass Balance (mm w.e.)
2500
0
−2500
−5000
−7500
−10000
−12500
−15000
−17500
1920
1940
1960
1980
2000
2020
Year


Sion Summer Mean Temperature
Summer Mean Temperature (°C)
1961-1990 Norm (16.5°C)
1991-2020 Norm (18.1°C)
Mean Temperature (°C)
Year
15
16
17
18
19
20
1920
1940
1960
1980
2000
2020


Sion Winter Total Precipitation
Winter Total Precipitation (mm)
1961-1990 Norm (365.0 mm)
1991-2020 Norm (324.0 mm)
Precipitation (mm)
600
500
400
300
200
100
1920
1940
1960
1980
2000
2020
Year


Grosser Aletschgletscher Summer Mass Balance with relation to Temperature
Summer Mass Balance (mm w.e.)
−500
−1000
−1500
−2000
−2500
−3000
−3500
−4000
15
16
17
18
19
20
Summer Mean Temperature (°C)

Regression: Monthly 1961-1990

```
================================================================================
MONTHLY DEVIATIONS ANALYSIS USING 1961-1990 CLIMATE NORMS
================================================================================

================================================================================
MONTHLY DEVIATIONS for Grosser Aletschgletscher (1961-1990 norms)
================================================================================

Correlation Analysis with Significance Testing:
        Variable  Correlation Coefficient       P-value  Significant (p < 0.05)
6     october_pd                 0.257259  6.415710e-03                    True
10   february_pd                 0.185586  5.116320e-02                   False
9     january_pd                 0.171998  7.106367e-02                   False
7    november_pd                 0.140863  1.403069e-01                   False
8    december_pd                 0.106127  2.676038e-01                   False
11      march_pd                 0.067017  4.846355e-01                   False
12      april_pd                -0.018161  8.499417e-01                   False
5   september_td                -0.386431  2.800089e-05                    True
1         may_td                -0.476302  1.264350e-07                    True
2        june_td                -0.601370  2.966760e-12                    True
4      august_td                -0.601941  2.795118e-12                    True
3        july_td                -0.658611  3.951726e-15                    True
0          const                      NaN           NaN                   False

Number of observations: 111

Regression Summary:
                                OLS Regression Results
==============================================================================================
Dep. Variable:     annual mass balance (mm w.e.)   R-squared:                       0.760
Model:                                       OLS   Adj. R-squared:                  0.731
Method:                            Least Squares   F-statistic:                     25.86
Date:                           Mon, 08 Dec 2025   Prob (F-statistic):           3.55e-25
Time:                                   12:08:21   Log-Likelihood:                -810.49
No. Observations:                            111   AIC:                             1647.
Df Residuals:                                 98   BIC:                             1682.
Df Model:                                     12
Covariance Type:                       nonrobust
==============================================================================
                   coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const         1.615e+04   1101.005     14.665      0.000     1.4e+04    1.83e+04
may_td        -112.0230     26.694     -4.197      0.000    -164.996     -59.050
june_td        -98.1723     25.746     -3.813      0.000    -149.264     -47.081
july_td       -140.9470     26.832     -5.253      0.000    -194.194     -87.700
august_td      -94.1784     29.398     -3.204      0.002    -152.519     -35.838
september_td   -43.2964     26.343     -1.644      0.103     -95.573       8.980
october_pd       4.1218      1.144      3.604      0.000       1.852       6.391
november_pd      2.5133      0.864      2.910      0.004       0.799       4.227
december_pd      1.9253      0.778      2.475      0.015       0.381       3.469
january_pd       3.5573      1.036      3.433      0.001       1.501       5.614
february_pd      1.2807      0.816      1.570      0.120      -0.338       2.899
march_pd         0.7875      1.203      0.654      0.514      -1.601       3.176
april_pd        -0.7447      1.477     -0.504      0.615      -3.675       2.186
==============================================================================
Omnibus:                        0.127   Durbin-Watson:                   1.760
Prob(Omnibus):                  0.939   Jarque-Bera (JB):                0.216
Skew:                          -0.077   Prob(JB):                        0.898
Kurtosis:                       2.848   Cond. No.                     2.36e+03
```

Regression: Optimal 1961-1990

```
================================================================================
OPTIMAL SEASONAL DEVIATIONS ANALYSIS USING 1961-1990 CLIMATE NORMS
================================================================================

================================================================================
OPTIMAL SEASONAL DEVIATIONS for Grosser Aletschgletscher (1961-1990 norms)
================================================================================

Correlation Analysis with Significance Testing:
        Variable  Correlation Coefficient       P-value  Significant (p < 0.05)
2  opt_season_pd                 0.369735  6.502864e-05                    True
1  opt_season_td                -0.797619  1.110407e-25                    True
0          const                      NaN           NaN                   False

Number of observations: 111

Regression Summary:
                                OLS Regression Results
==============================================================================================
Dep. Variable:     annual mass balance (mm w.e.)   R-squared:                       0.729
Model:                                       OLS   Adj. R-squared:                  0.724
Method:                            Least Squares   F-statistic:                     145.1
Date:                           Mon, 08 Dec 2025   Prob (F-statistic):           2.51e-31
Time:                                   12:08:21   Log-Likelihood:                -817.27
No. Observations:                            111   AIC:                             1641.
Df Residuals:                                108   BIC:                             1649.
Df Model:                                      2
Covariance Type:                       nonrobust
================================================================================================
                     coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------------------------
const          1.552e+04   1047.094     14.826      0.000    1.34e+04    1.76e+04
opt_season_td  -466.8954     30.408    -15.355      0.000    -527.168    -406.622
opt_season_pd     2.4006      0.395      6.072      0.000       1.617       3.184
==============================================================================
Omnibus:                        0.176   Durbin-Watson:                   1.812
Prob(Omnibus):                  0.916   Jarque-Bera (JB):                0.306
Skew:                           0.082   Prob(JB):                        0.858
Kurtosis:                       2.802   Cond. No.                     2.72e+03
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
[2] The condition number is large, 2.72e+03. This might indicate that there are
strong multicollinearity or other numerical problems.

Coefficient Interpretation:
Intercept (normal mass balance): 15523.97 (p=0.0000)
opt_season_td: -466.90 (p=0.0000)
opt_season_pd: 2.40 (p=0.0000)

Variance Inflation Factors (VIF):
        Variable         VIF
0          const  814.025785
1  opt_season_td    1.007004
2  opt_season_pd    1.007004

R-squared: 0.7288
Adjusted R-squared: 0.7238
```

Regression: Seasonal 1961-1990

```
================================================================================
SUMMER/WINTER SEASONAL DEVIATIONS ANALYSIS USING 1961-1990 CLIMATE NORMS
================================================================================

================================================================================
SUMMER/WINTER SEASONAL DEVIATIONS for Grosser Aletschgletscher (1961-1990 norms)
================================================================================

Correlation Analysis with Significance Testing:
    Variable  Correlation Coefficient       P-value  Significant (p < 0.05)
2  winter_pd                 0.356799  1.211095e-04                    True
1  summer_td                -0.792813  3.468709e-25                    True
0      const                      NaN           NaN                   False

Number of observations: 111

Regression Summary:
                                OLS Regression Results
==============================================================================================
Dep. Variable:     annual mass balance (mm w.e.)   R-squared:                       0.713
Model:                                       OLS   Adj. R-squared:                  0.707
Method:                            Least Squares   F-statistic:                     134.0
Date:                           Mon, 08 Dec 2025   Prob (F-statistic):           5.61e-30
Time:                                   12:08:21   Log-Likelihood:                -820.46
No. Observations:                            111   AIC:                             1647.
Df Residuals:                                108   BIC:                             1655.
Df Model:                                      2
Covariance Type:                       nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const       1.596e+04   1111.970     14.355      0.000    1.38e+04    1.82e+04
summer_td   -493.1045     33.239    -14.835      0.000    -558.990    -427.219
winter_pd      2.1107      0.375      5.625      0.000       1.367       2.855
==============================================================================
Omnibus:                        0.457   Durbin-Watson:                   1.765
Prob(Omnibus):                  0.796   Jarque-Bera (JB):                0.146
Skew:                          -0.042   Prob(JB):                        0.930
Kurtosis:                       3.157   Cond. No.                     3.10e+03
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
[2] The condition number is large, 3.1e+03. This might indicate that there are
strong multicollinearity or other numerical problems.

Coefficient Interpretation:
Intercept (normal mass balance): 15962.71 (p=0.0000)
summer_td: -493.10 (p=0.0000)
winter_pd: 2.11 (p=0.0000)

Variance Inflation Factors (VIF):
    Variable         VIF
0      const  866.702229
1  summer_td    1.007355
2  winter_pd    1.007355

R-squared: 0.7127
Adjusted R-squared: 0.7074
```

Regression: Monthly 1991-2020

```
================================================================================
MONTHLY DEVIATIONS ANALYSIS USING 1991-2020 CLIMATE NORMS
================================================================================

================================================================================
MONTHLY DEVIATIONS for Grosser Aletschgletscher (1991-2020 norms)
================================================================================

Correlation Analysis with Significance Testing:
        Variable  Correlation Coefficient       P-value  Significant (p < 0.05)
6     october_pd                 0.257259  6.415710e-03                    True
10   february_pd                 0.185586  5.116320e-02                   False
9     january_pd                 0.171998  7.106367e-02                   False
7    november_pd                 0.140863  1.403069e-01                   False
8    december_pd                 0.106127  2.676038e-01                   False
11      march_pd                 0.067017  4.846355e-01                   False
12      april_pd                -0.018161  8.499417e-01                   False
5   september_td                -0.386431  2.800089e-05                    True
1         may_td                -0.476302  1.264350e-07                    True
2        june_td                -0.601370  2.966760e-12                    True
4      august_td                -0.601941  2.795118e-12                    True
3        july_td                -0.658611  3.951726e-15                    True
0          const                      NaN           NaN                   False

Number of observations: 111

Regression Summary:
                                OLS Regression Results
================================================================================================
Dep. Variable:     annual mass balance (mm w.e.)   R-squared:                       0.760
Model:                                       OLS   Adj. R-squared:                  0.731
Method:                            Least Squares   F-statistic:                     25.86
Date:                           Mon, 08 Dec 2025   Prob (F-statistic):           3.55e-25
Time:                                   12:08:21   Log-Likelihood:                -810.49
No. Observations:                            111   AIC:                             1647.
Df Residuals:                                 98   BIC:                             1682.
Df Model:                                     12
Covariance Type:                       nonrobust
================================================================================
                   coef    std err          t      P>|t|      [0.025      0.975]
--------------------------------------------------------------------------------
const        -1177.4733     51.689    -22.780      0.000   -1280.048   -1074.899
may_td        -112.0230     26.694     -4.197      0.000    -164.996     -59.050
june_td        -98.1723     25.746     -3.813      0.000    -149.264     -47.081
july_td       -140.9470     26.832     -5.253      0.000    -194.194     -87.700
august_td      -94.1784     29.398     -3.204      0.002    -152.519     -35.838
september_td   -43.2964     26.343     -1.644      0.103     -95.573       8.980
october_pd       4.1218      1.144      3.604      0.000       1.852       6.391
november_pd      2.5133      0.864      2.910      0.004       0.799       4.227
december_pd      1.9253      0.778      2.475      0.015       0.381       3.469
january_pd       3.5573      1.036      3.433      0.001       1.501       5.614
february_pd      1.2807      0.816      1.570      0.120      -0.338       2.899
march_pd         0.7875      1.203      0.654      0.514      -1.601       3.176
april_pd        -0.7447      1.477     -0.504      0.615      -3.675       2.186
==============================================================================
Omnibus:                        0.127   Durbin-Watson:                   1.760
Prob(Omnibus):                  0.939   Jarque-Bera (JB):                0.216
Skew:                          -0.077   Prob(JB):                        0.898
Kurtosis:                       2.848   Cond. No.                         70.6
```

Regression: Optimal 1991-2020

```
================================================================================
OPTIMAL SEASONAL DEVIATIONS ANALYSIS USING 1991-2020 CLIMATE NORMS
================================================================================

================================================================================
OPTIMAL SEASONAL DEVIATIONS for Grosser Aletschgletscher (1991-2020 norms)
================================================================================

Correlation Analysis with Significance Testing:
        Variable  Correlation Coefficient       P-value  Significant (p < 0.05)
2  opt_season_pd                 0.369735  6.502864e-05                    True
1  opt_season_td                -0.797374  1.177630e-25                    True
0          const                      NaN           NaN                   False

Number of observations: 111

Regression Summary:
                                OLS Regression Results
==============================================================================================
Dep. Variable:     annual mass balance (mm w.e.)   R-squared:                       0.727
Model:                                       OLS   Adj. R-squared:                  0.722
Method:                            Least Squares   F-statistic:                     143.8
Date:                           Mon, 08 Dec 2025   Prob (F-statistic):           3.55e-31
Time:                                   12:08:21   Log-Likelihood:                -817.63
No. Observations:                            111   AIC:                             1641.
Df Residuals:                                108   BIC:                             1649.
Df Model:                                      2
Covariance Type:                       nonrobust
==============================================================================
                     coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const         -1174.4716     51.607    -22.758      0.000   -1276.765   -1072.178
opt_season_td  -466.7401     30.540    -15.283      0.000    -527.276    -406.204
opt_season_pd     2.3835      0.397      6.008      0.000       1.597       3.170
==============================================================================
Omnibus:                        0.086   Durbin-Watson:                   1.805
Prob(Omnibus):                  0.958   Jarque-Bera (JB):                0.082
Skew:                           0.057   Prob(JB):                        0.960
Kurtosis:                       2.929   Cond. No.                         144.
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

Coefficient Interpretation:
Intercept (normal mass balance): -1174.47 (p=0.0000)
opt_season_td: -466.74 (p=0.0000)
opt_season_pd: 2.38 (p=0.0000)

Variance Inflation Factors (VIF):
        Variable       VIF
0          const  1.964658
1  opt_season_td  1.007507
2  opt_season_pd  1.007507

R-squared: 0.7270
Adjusted R-squared: 0.7220
```

Regression: Seasonal 1991-2020

```
================================================================================
SUMMER/WINTER SEASONAL DEVIATIONS ANALYSIS USING 1991-2020 CLIMATE NORMS
================================================================================

================================================================================
SUMMER/WINTER SEASONAL DEVIATIONS for Grosser Aletschgletscher (1991-2020 norms)
================================================================================

Correlation Analysis with Significance Testing:
    Variable  Correlation Coefficient       P-value  Significant (p < 0.05)
2  winter_pd                 0.356799  1.211095e-04                    True
1  summer_td                -0.790691  5.681560e-25                    True
0      const                      NaN           NaN                   False

Number of observations: 111

Regression Summary:
                                OLS Regression Results
==============================================================================================
Dep. Variable:     annual mass balance (mm w.e.)   R-squared:                       0.710
Model:                                       OLS   Adj. R-squared:                  0.705
Method:                            Least Squares   F-statistic:                     132.3
Date:                           Mon, 08 Dec 2025   Prob (F-statistic):           9.16e-30
Time:                                   12:08:21   Log-Likelihood:                -820.97
No. Observations:                            111   AIC:                             1648.
Df Residuals:                                108   BIC:                             1656.
Df Model:                                      2
Covariance Type:                       nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const      -1170.9339     53.040    -22.076      0.000   -1276.069   -1065.799
summer_td   -492.1145     33.399    -14.735      0.000    -558.316    -425.913
winter_pd      2.1197      0.377      5.624      0.000       1.373       2.867
==============================================================================
Omnibus:                        0.462   Durbin-Watson:                   1.778
Prob(Omnibus):                  0.794   Jarque-Bera (JB):                0.137
Skew:                          -0.004   Prob(JB):                        0.934
Kurtosis:                       3.172   Cond. No.                         158.
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

Coefficient Interpretation:
Intercept (normal mass balance): -1170.93 (p=0.0000)
summer_td: -492.11 (p=0.0000)
winter_pd: 2.12 (p=0.0000)

Variance Inflation Factors (VIF):
    Variable       VIF
0      const  1.954085
1  summer_td  1.007113
2  winter_pd  1.007113

R-squared: 0.7101
Adjusted R-squared: 0.7047
```