A convention for Coordinated Universal Time

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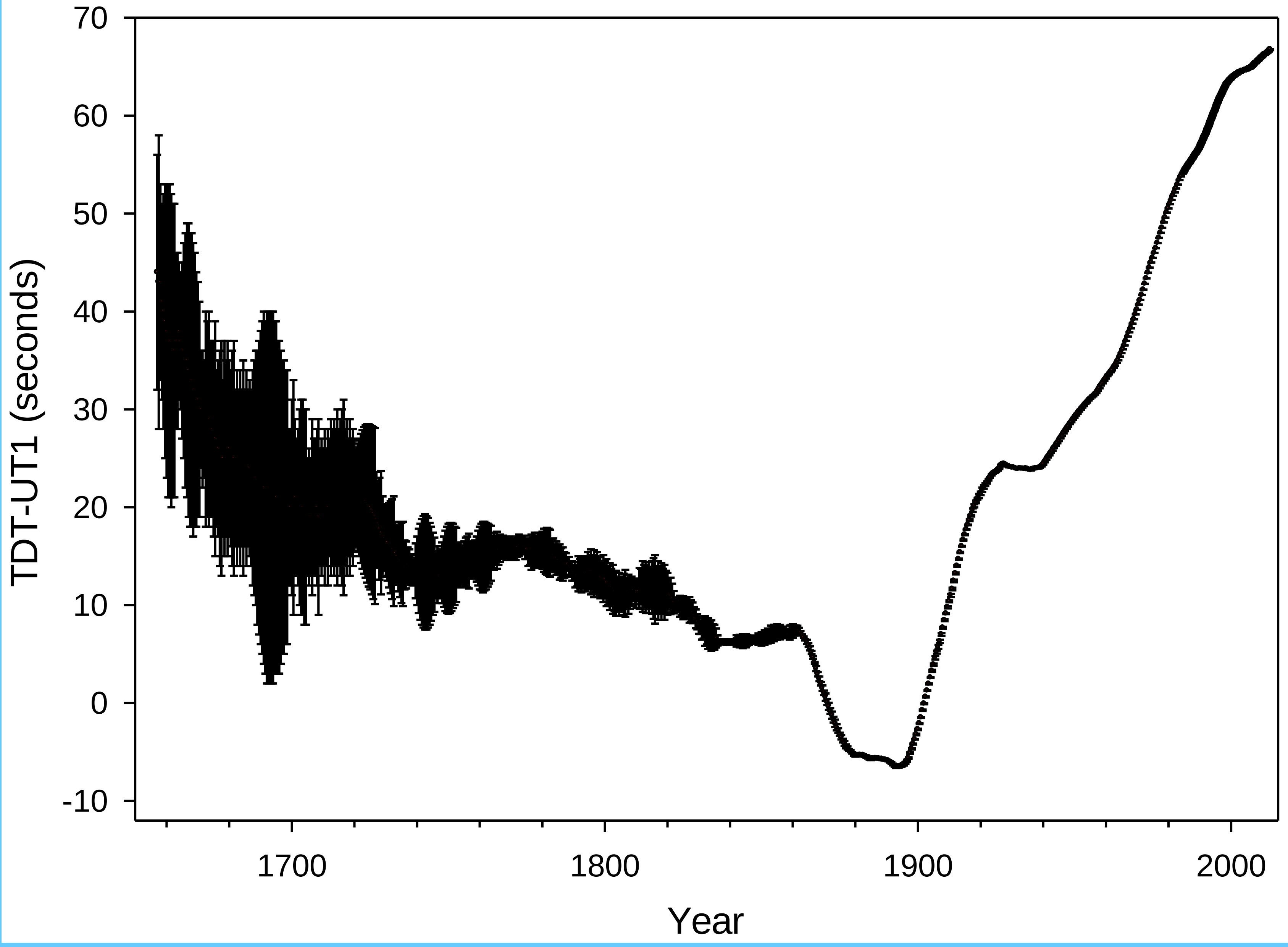
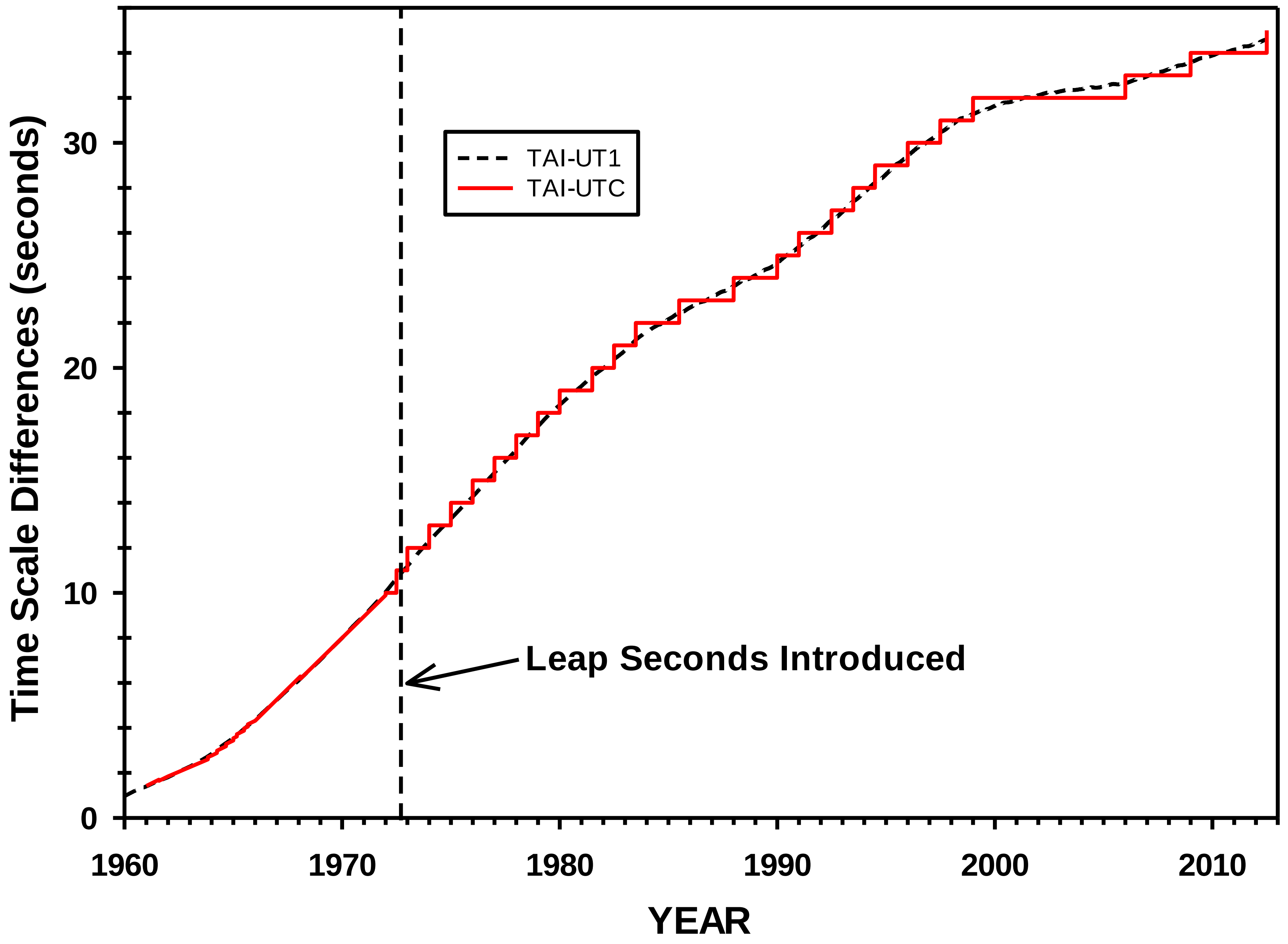
12-14th Century

History

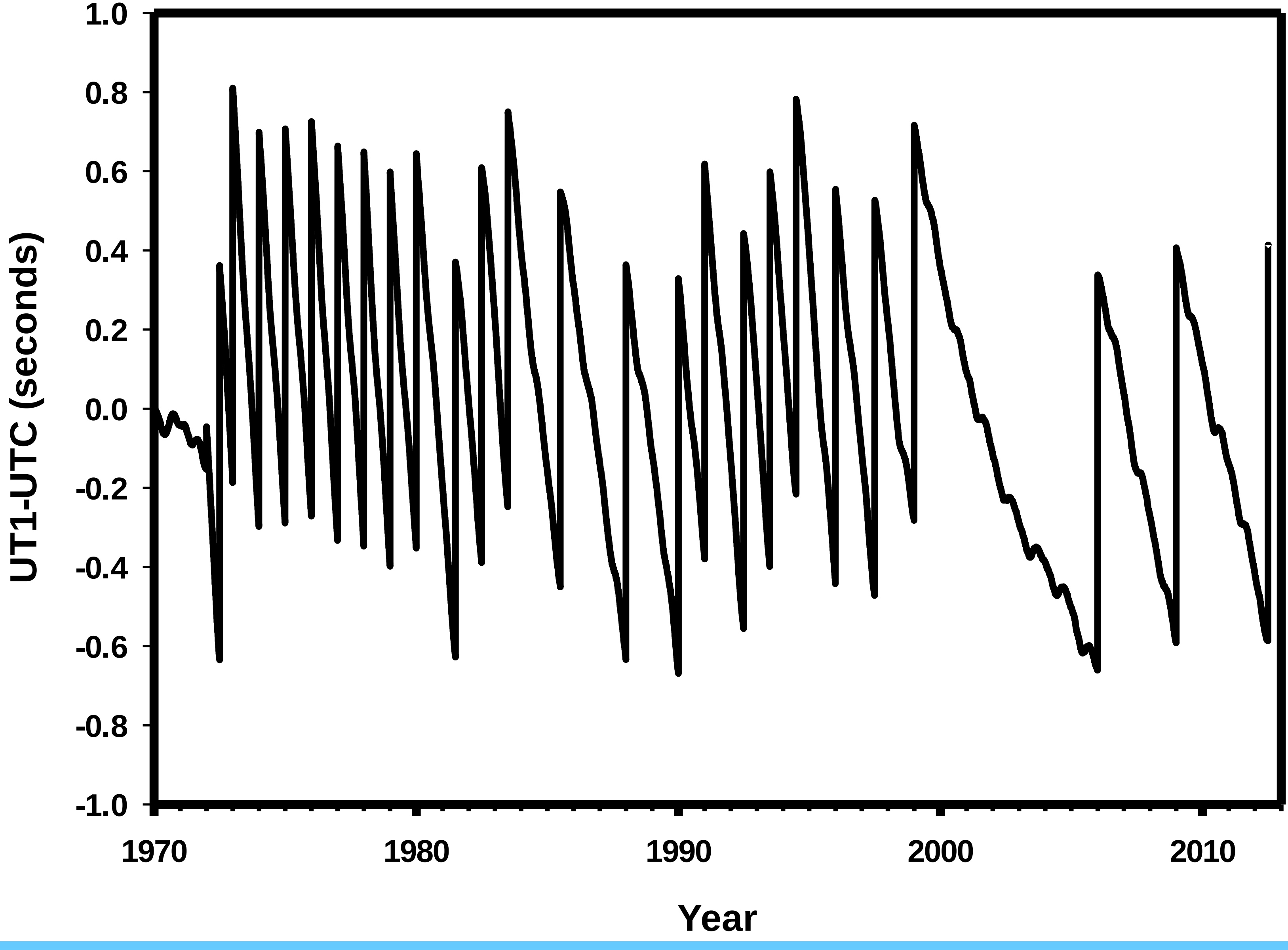
- **Clocks have long ago surpassed the Earth's rotation as a source for accurate time.**
- **Celestial navigators need to know Earth's rotation angle (provided by a function of UT1) to compute accurate directions.**
- **Coordinated Universal Time redefined in1970 to provide knowledge of the Earth's rotation angle by time signals to an accuracy of ~1 second for navigators.**
- **GPS has made celestial navigation virtually obsolete.**
- **But UTC is still used to provide Earth rotation to low accuracy (~1 second) users. (This information is routinely available to accuracy of 0.000 010 seconds for high-accuracy users.)**



70
60
50
40
30
20
10
0
-10
TDT-UT1 (seconds)
1700
1800
1900
2000
Year



Time Scale Differences (seconds)
30
20
10
0
1960
1970
1980
1990
2000
2010
YEAR
TAI-UT1
TAI-UTC
Leap Seconds Introduced



1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
UT1-UTC (seconds)
1970
1980
1990
2000
2010
Year

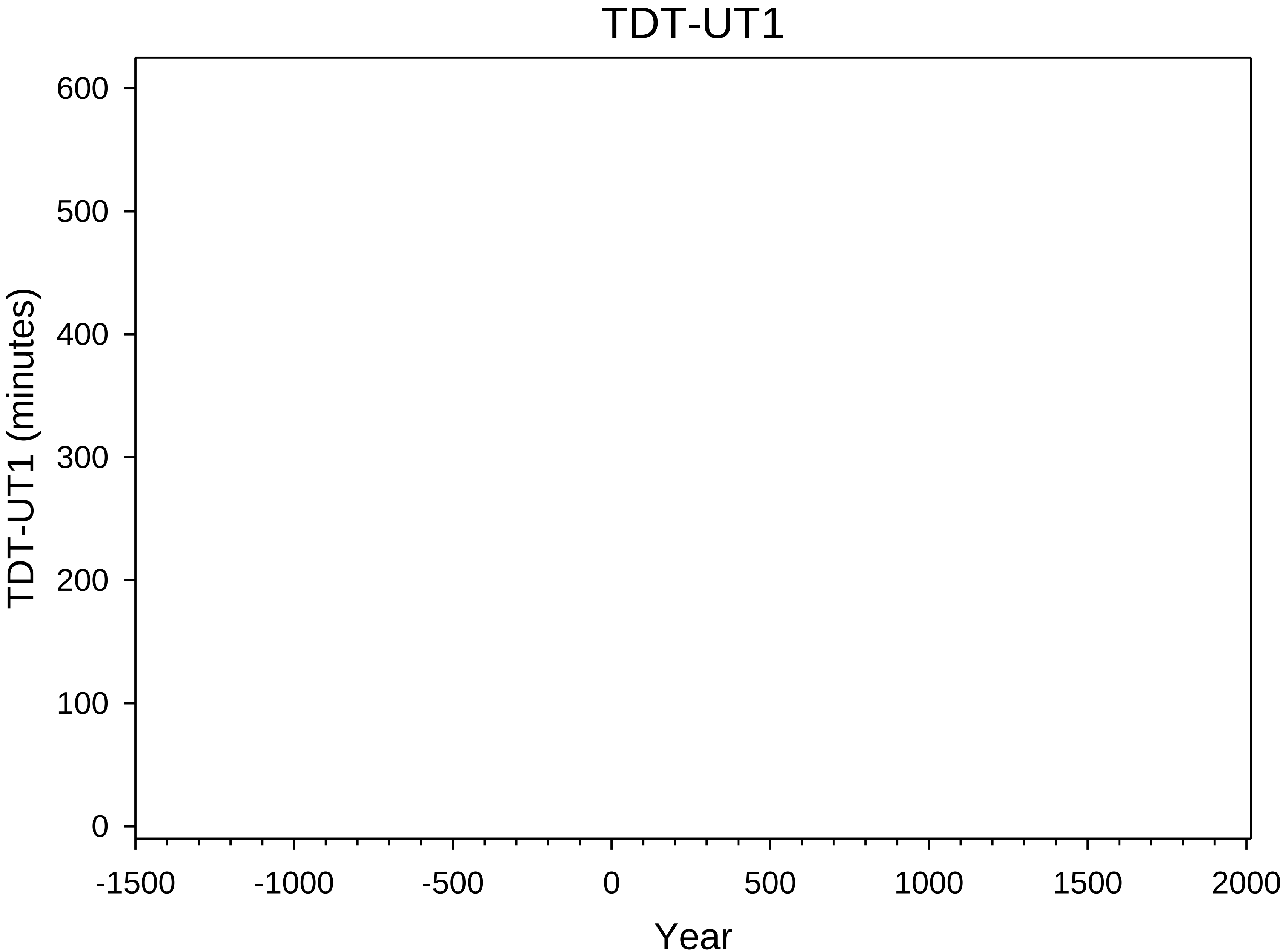
Why do we still have leap seconds?

1. Provides low-accuracy knowledge of Earth rotation for specialists.
    - Telescope pointing software
    - Some legacy orbit analysis software users
2. Provides loose connection between civil time and time historically determined from the solar hour angle. (Those can differ now by up to 5 hours because of time zones, daylight savings time, *etc*.)

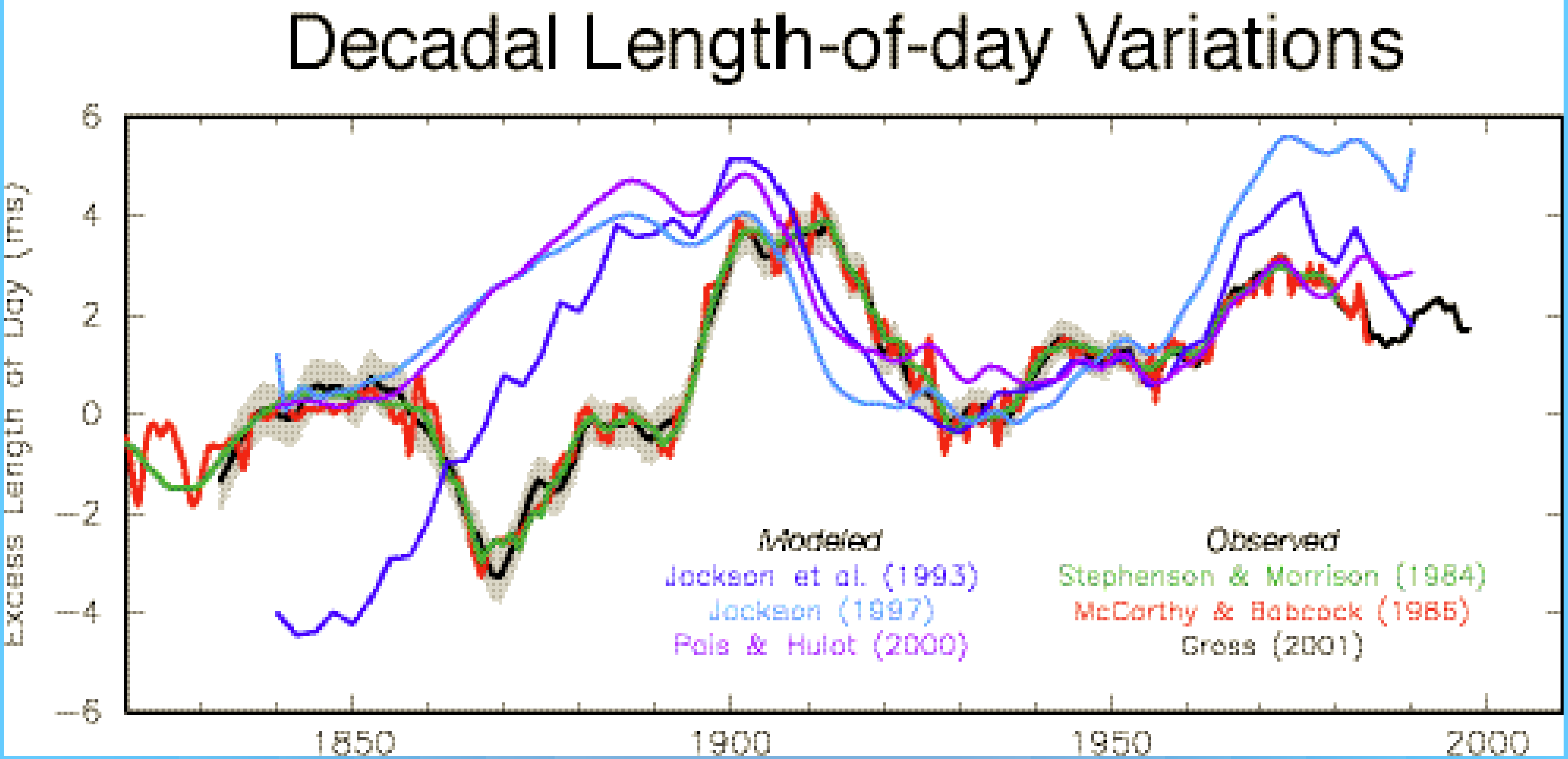
Can we know when we will need to stop all the clocks in the world?

- Earth rotation is difficult to predict far in advance
  - Tides slow it down but geophysical decadal variations have significant effects.

What would happen if we adopted a rule like we do for leap years?



TDT-UT1
600
500
400
300
200
100
0
TDT-UT1 (minutes)
-1500
-1000
-500
0
500
1000
1500
2000
Year



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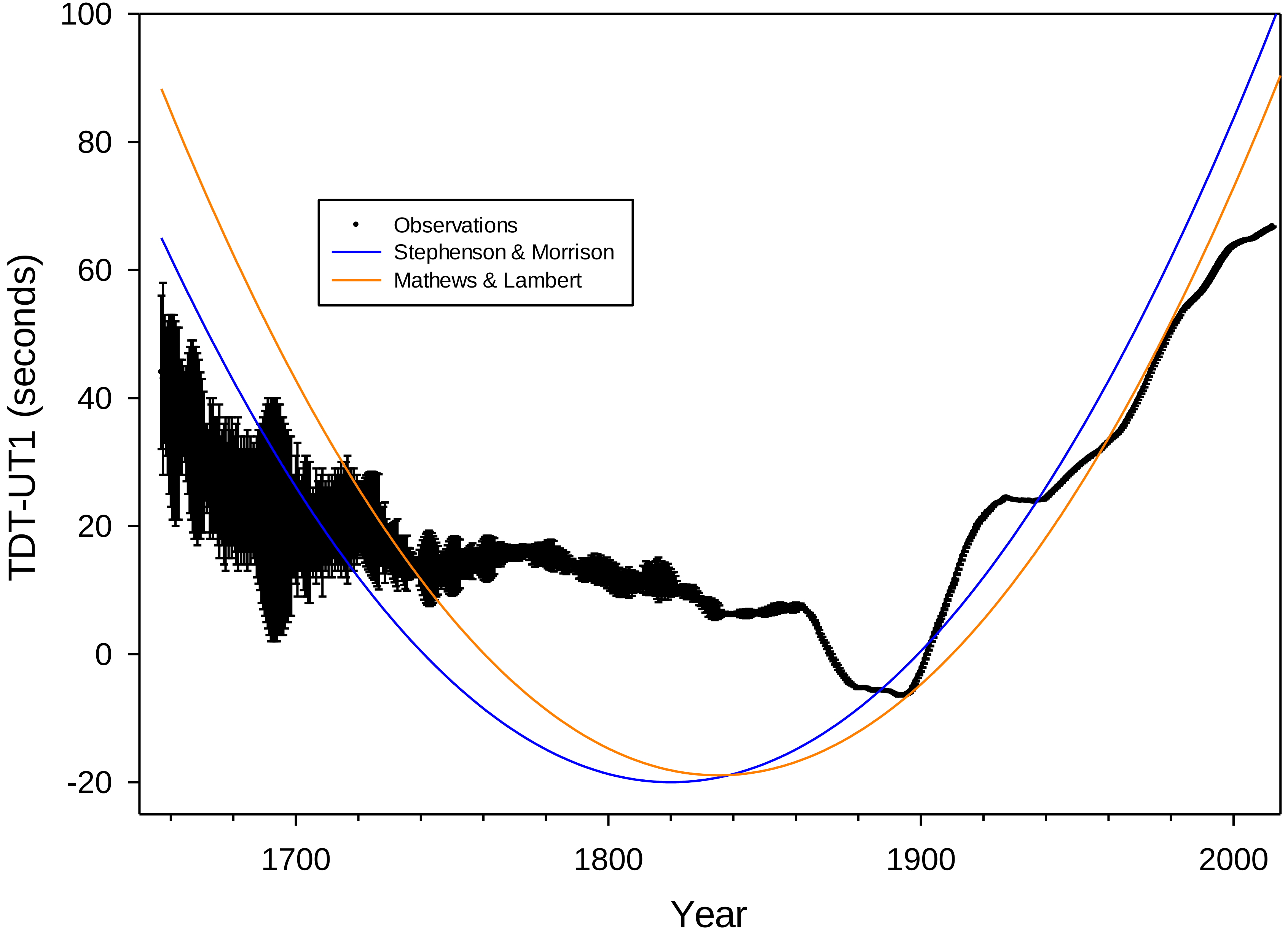
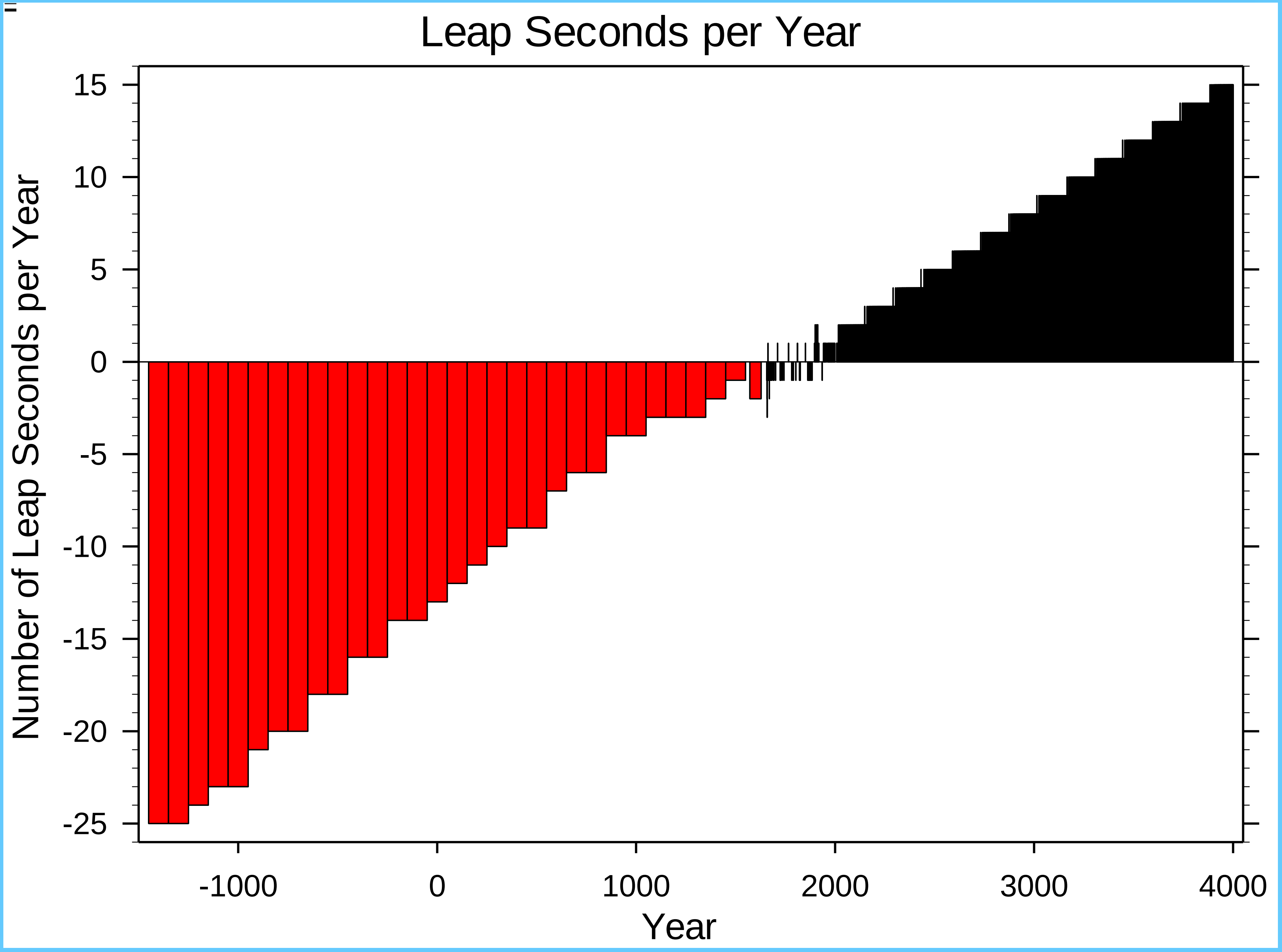
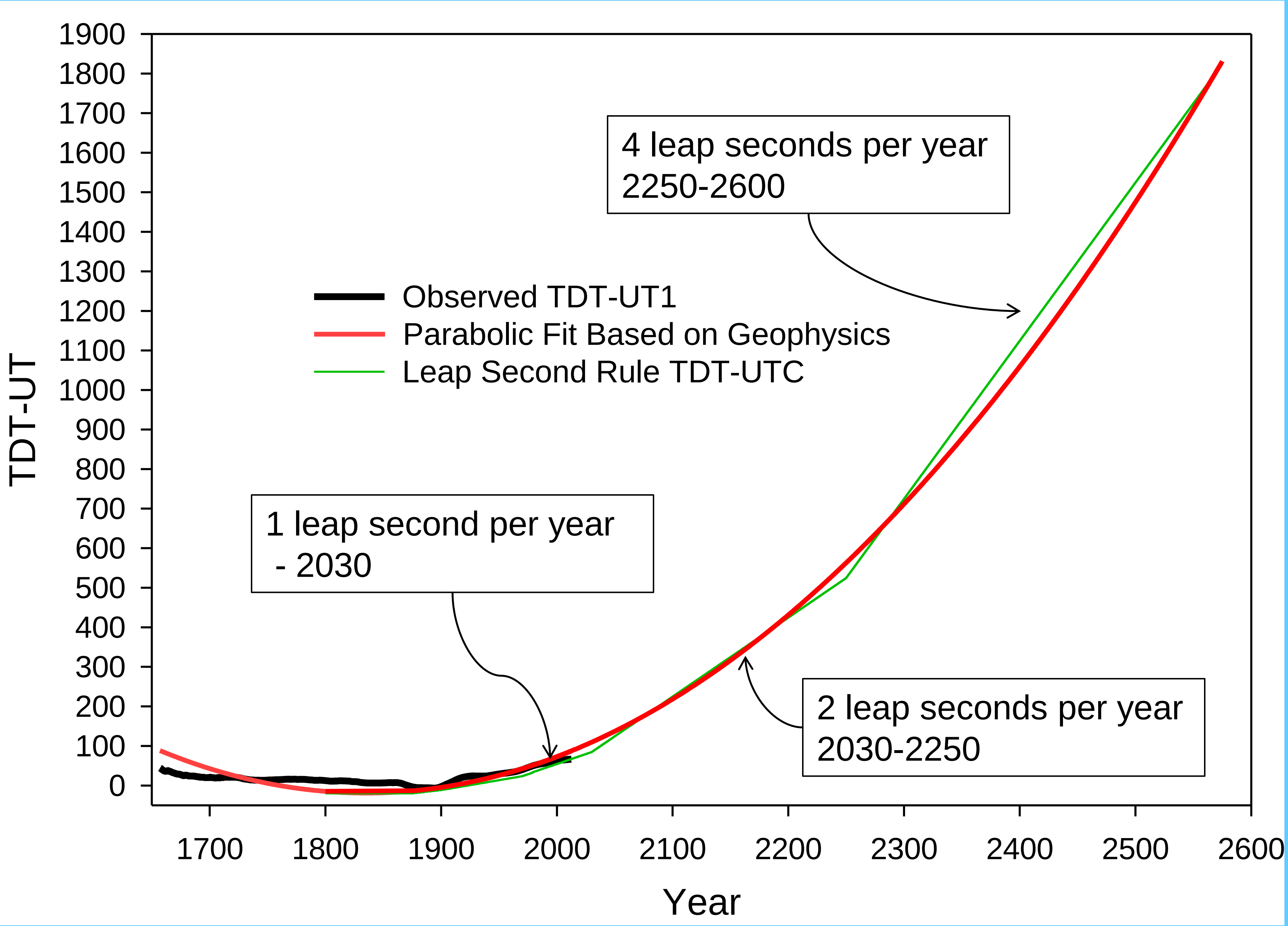
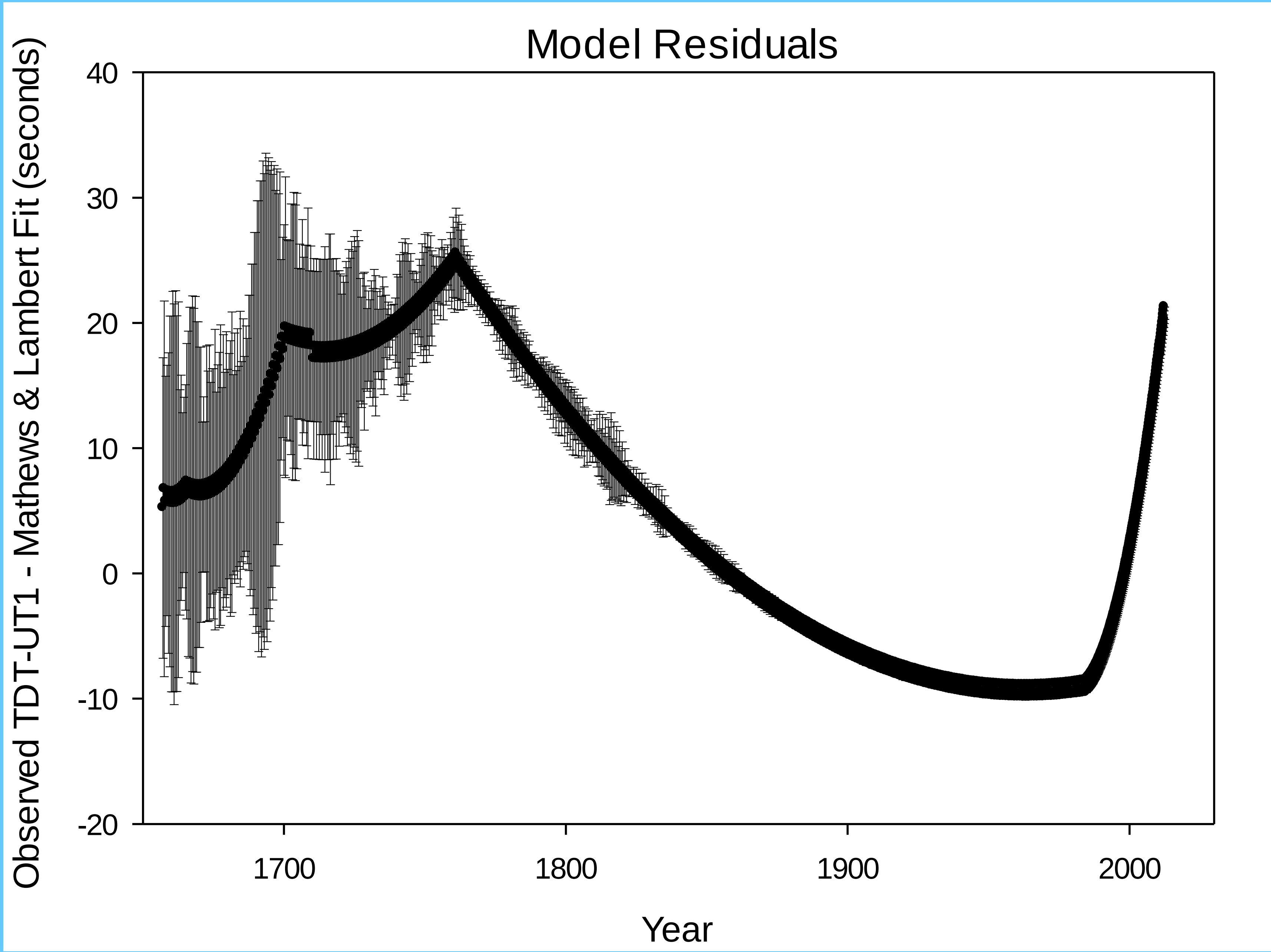

100
80
60
40
20
0
-20
TDT-UT1 (seconds)
1700
1800
1900
2000
Year
Observations
Stephenson & Morrison
Mathews & Lambert



Leap Seconds per Year
Number of Leap Seconds per Year
15
10
5
0
-5
-10
-15
-20
-25
-1000
0
1000
2000
3000
4000
Year

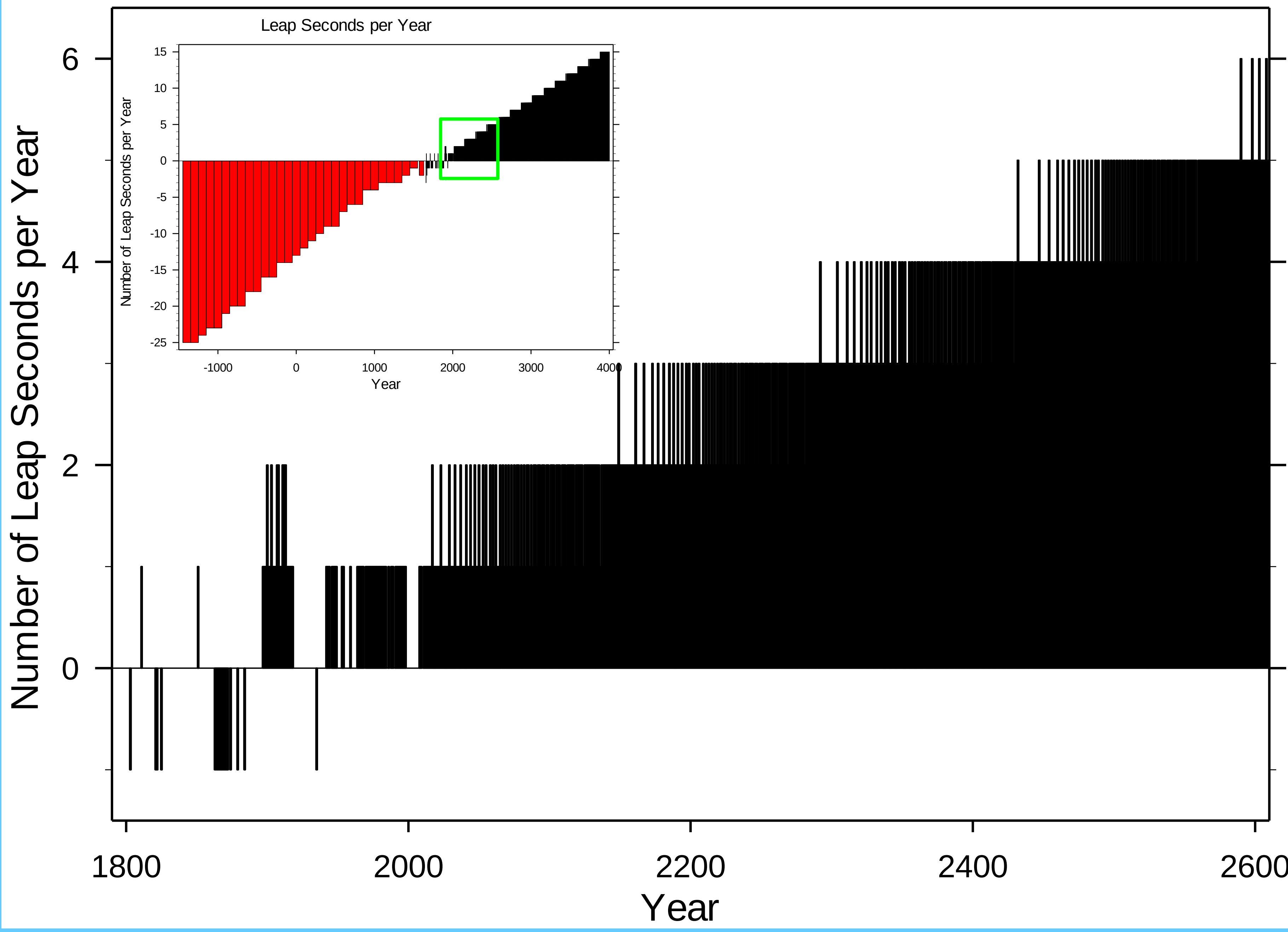


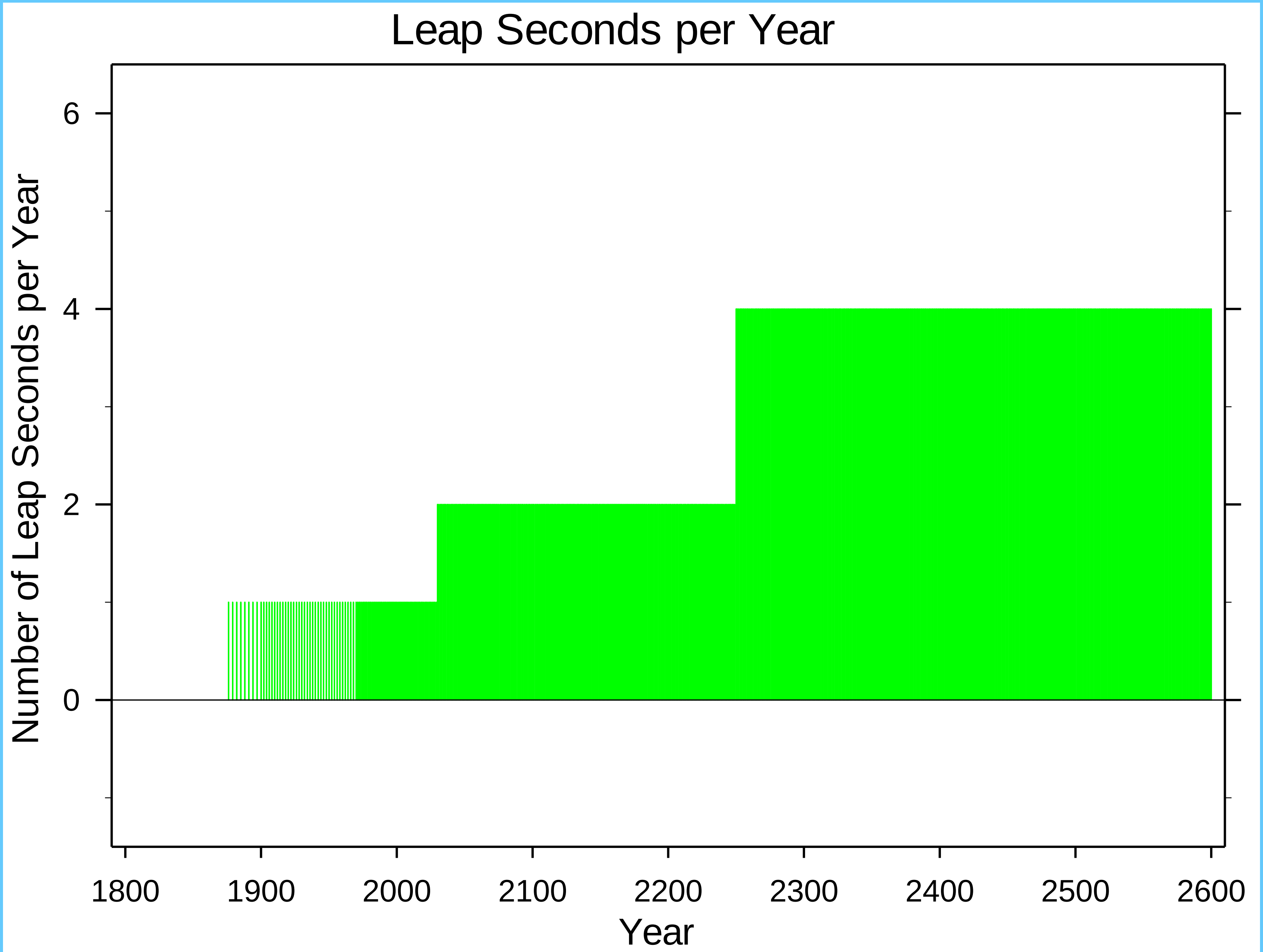
TDT-UT
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
Year
Observed TDT-UT1
Parabolic Fit Based on Geophysics
Leap Second Rule TDT-UTC
4 leap seconds per year
2250-2600
1 leap second per year
- 2030
2 leap seconds per year
2030-2250



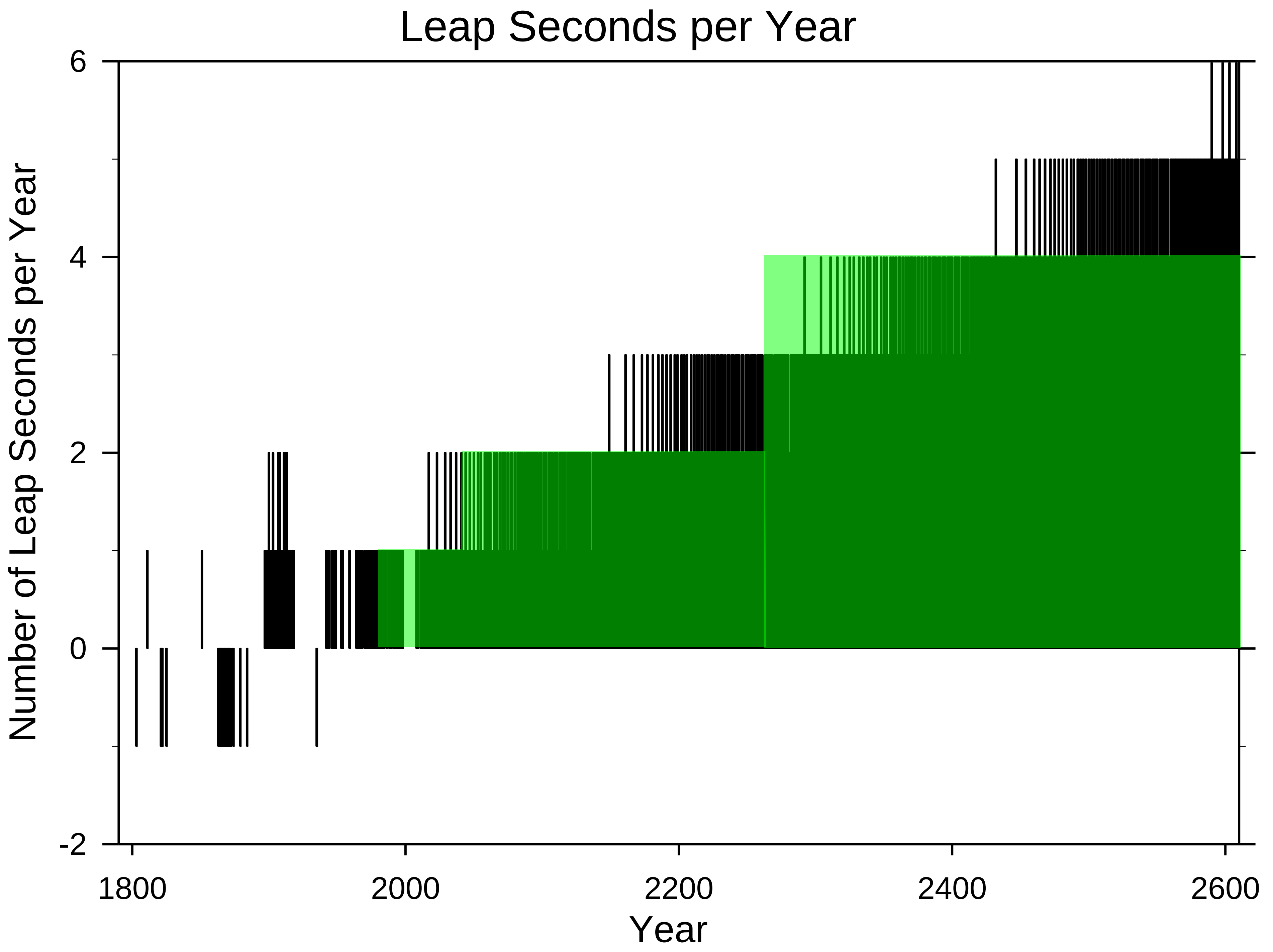
Model Residuals
Observed TDT-UT1 - Mathews & Lambert Fit (seconds)
40
30
20
10
0
-10
-20
1700
1800
1900
2000
Year

Leap Seconds per Year

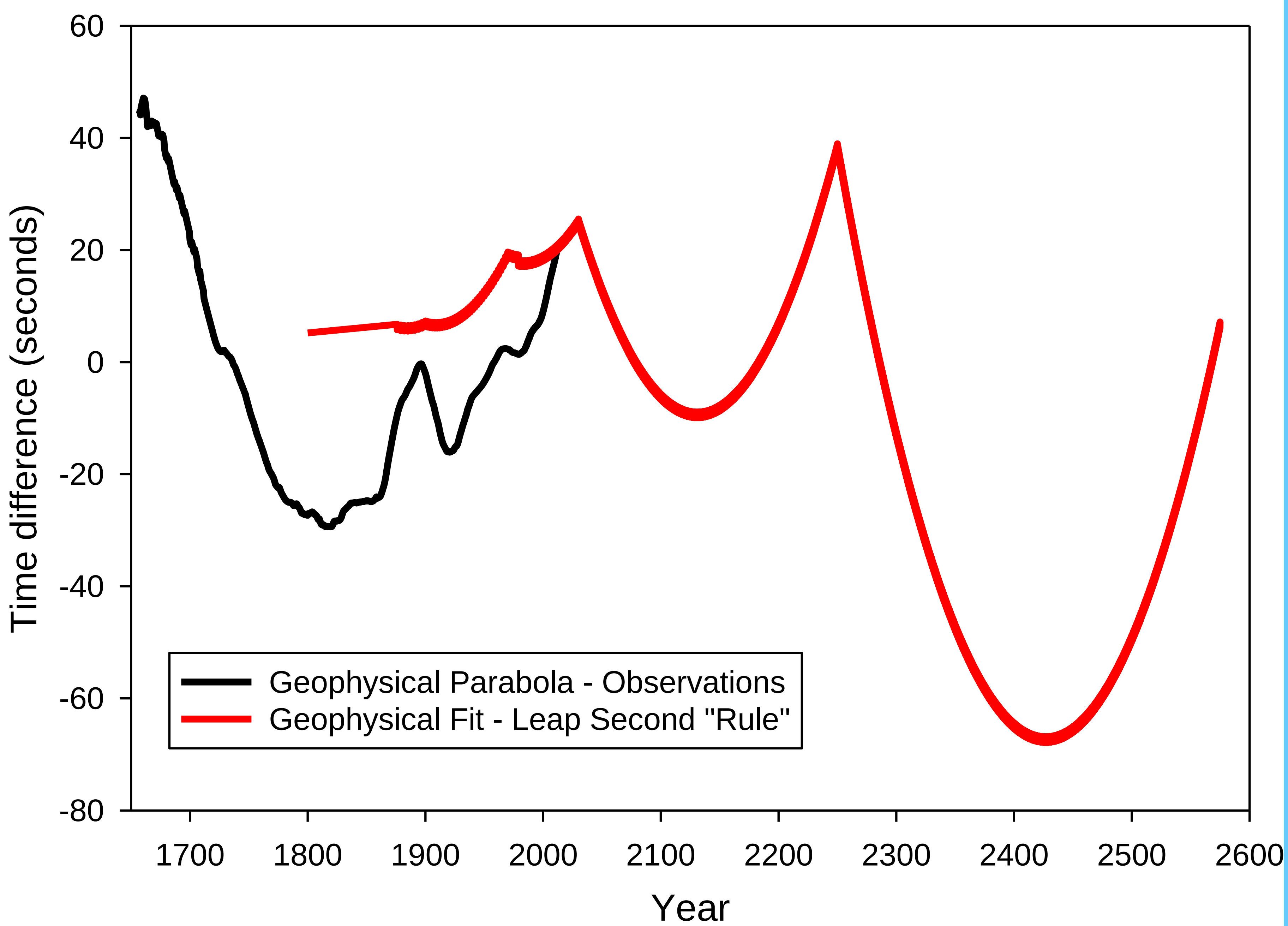




Leap Seconds per Year
Number of Leap Seconds per Year
Year
0
2
4
6
1800
1900
2000
2100
2200
2300
2400
2500
2600



Leap Seconds per Year
6
4
2
0
-2
Number of Leap Seconds per Year
1800
2000
2200
2400
2600
Year



60
40
20
0
-20
-40
-60
-80
Time difference (seconds)
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
Year
Geophysical Parabola - Observations
Geophysical Fit - Leap Second "Rule"

Conclusions

- Conventional rule will result in UT1-UTC of the order of a few minutes
- Conventional rule will require leap seconds
  - twice per year beginning in 2030
  - every quarter beginning in 2250
  - every month after 2600
- Do we want to stop every clock in the world every month for 1 second?