"Binary Calendar" and Global Warming

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Abstract. The "binary calendar" is "Years divisible by 4 but not by 128 are leap years." I point out this suggestion would be a factor>10 more accurate than the "Gregorian calendar." We also look at the idea of using precise measurements of sidereal day length (Earth's rotation period≈86164.1 SI seconds) as a tool to help assess "climate change." We find it could be helpful but is not trivial to assess.

The Gregorian calendar (so-called since introduced by Pope Gregory XIII in October 1582) is an international standard solar calendar designed to maintain synchrony with the mean tropical year. Its rule:

Every year divisible by four is a leap year, except for years divisible by 100, except in turn for years also divisible by 400.

For example, 1600, 2000, and 2004 were leap years, but 1800, 1900, and 2001 were not. Leap years add February 29 to the calendar. This cycles every 400 Gregorian years, i.e. every 146097 solar days. Each cycle repeats the months, dates, and weekdays. The average length of a Gregorian year is exactly

$$146097/400 = 365+1/4-1/100+1/400 = 365+97/400 = \mathbf{365.2425}$$

solar days.

However, the Gregorians were incorrect in the sense that the mean tropical year as of 1 January 2000, instead was **365.2421897** solar days. The mean solar day length was pretty exactly 86400 SI seconds (to within less than 10 microseconds) during the year 2019 AD. SI seconds are based on a standard Caesium atomic clock frequency.

Both the mean tropical year and the mean length of the solar day, as measured in SI seconds, vary. The year-length would remain constant according to the Kepler-Newton solution of the sun-earth 2-body problem, but changes because the solar system involves *more* than two bodies. The day length would remain constant if the earth were a rigid rotating body not subject to any externally applied torques. But in fact, tidal friction from the moon and sun both cause torques, while temperature changes, volcanos, earthquakes, and weather cause expansion and contraction and mass-redistribution of the earth's outer layers (e.g. atmosphere, ocean, ice caps), plus winds and ocean currents and internal-earth convection currents all alter the earth's angular momentum, all changing the length of the solar day. These effects are complicated and nonuniform, and the more precisely you try to model them, the more complicated they become.

According to solar system modeling by Jacques Laskar, an expression suitable between 8000 BC and 12000 AD for calculating the length of a tropical year in "SI days" is

$$\text{Year} = 365.2421896698 - 6.15359\times10^{-6}T - 7.29\times10^{-10}T^2 + 2.64\times10^{-10}T^3$$

where T is measured in "Julian centuries" with T=0 on 1 January 2000. (Definitions: an "SI day" is 86400=24×60×60 SI seconds, and a "Julian century" is 36525 SI days. Laskar's expression is valid for $|T|\le100$.) According to this formula in 8000 BC the year length was 365.2425337 and in 12000 AD will be 365.2418310 SI days, in between averaging to 365.24218724. That is, the mean value of Laskar's expression when integrated for $-100\le T\le+100$ is **365.24218724**.

During the 66 years [1960, 2025] AD, the solar day *shortened* by about 1.3 SI milliseconds from 86400.00125 to 86399.99995 SI seconds. That averages out to about -20 SI microseconds per year solar day shrinkage. However over the long term, the solar day should be gradually *lengthening* due to tidal friction from the moon slowing the Earth's rotation and pushing the moon's orbit outward. E.g. daily and annual growth-feature evidence from ancient coral fossils (first measured by John W. Wells in 1963) clearly indicate that about 350 Myr ago the solar day was a bit less than 23 SI hours long, and 430 Myr ago was a bit less than 21 SI hours. Analysis by M.L.Lantink et al in 2022 of "Milankovitch-cycle" features in banded iron formations in sedimentary rocks in Western Australia suggest, less clearly, that when those geological formations formed 2.46 Gyr ago, days were only 17 hours long. Those indicate the long term trend that the solar day lengthened about +26 SI microseconds per year on average during the last 430 Myr (but +10 SI microseconds per year on average during the last 2460 Myr, if we trust the banded iron Milankovitch work). At least naively, this does not make sense: Naively, the ancient earth had bigger oceans, thinner crust, rotated faster, and was closer to the moon, all suggesting that day length should have been increasing *faster* on the ancient earth than on the modern earth. Also (even without Lantink) why did the solar day length increase about twice as much during 430-350 Myr BC, than it did during 350-0? The explanation presumably is either: Lantink et al were wrong; different configurations of the continents back then altered tides, climates, ocean currents, and prevailing winds; and/or some other important effects we do not understand intervened. Over Laskar's 20000-year period the -20 and +26 μsec/year opposed-sign trends would extrapolate to total changes in solar day length of ±0.5 SI seconds; and ±20000×365.25×0.25 seconds amounts to ±21 extra or missing solar days!

That makes it clear that it is not really possible, given today's (lack of) predictive understanding of solar-day-length variation, to design a calendar system that will remain valid to within ±2 solar days for 20000 years.

Binary calendar

However, I want to point out the rather stunning fact that

$$365 + 1/4 - 1/128 = 365 + 31/128 = \mathbf{365.2421875}$$

happens to equal (up to error 1 in the final decimal place!) Laskar's estimate 365.2421874 of the length of the mean tropical year in SI days between 8000 BC and 12000 AD. And as we said, during 2019 AD, the SI and mean solar days were equal to within a few microseconds. This suggests this "**binary calendar**" as a better-than-Gregorian calendar system:

Years divisible by 4 but not by 128 are leap years.

This should be a factor>10 more accurate than the Gregorian calendar, plus arguably is simpler. The reason I call this "binary" is that $4=2^2$ and $128=2^7$.

Global warming assessment from day length?

In this section I want to explore the effects of climate change on the Earth's rotation period. Earth's rotation period can be measured very precisely by atomic clocks and astronomical observations of, e.g, distant quasars. The "event horizon telescope" claimed an angular resolution of 19 micro-arcseconds, from which we infer that it ought to be feasible to measure the earth's rotation period (each day) accurate to ±1.26 microseconds. Converted to a distance along the Earth's equator, this accuracy is equivalent to ±0.47 millimeters.

If we could deduce the **mean temperature** of earth's atmosphere from earth's rotation period (possibly combined with tidal energy-loss models) then we would have a very easy way to measure that temperature and thus track climate change – without needing even a single thermometer!

Earth's moment of inertia is $I_{earth}=8.0358\times10^{37}$ meter^{2}kg. The moment of inertia of the atmosphere alone is about $I_{atm}=(2/3)M_{atm}R_{atm}^2\approx1.3955\times10^{26}$ meter^{2}kg. where $M_{atm}\approx5.1441\times10^{18}$ kg is the mass of the atmosphere, while $R_{atm}=6379$ km is the solid+liquid Earth's radius plus an extra 8000 meters to get us up to about the mean height above sea level of a molecule in the atmosphere.

So if the atmosphere's **mean temperature** increases by 1°C, expanding it by a factor of 1/288, that should increase I_{atm} by a factor of about 1.00000871, i.e. 8.71 parts per million, thus increasing I_{earth} by a factor of $1+1.5126\times10^{-17}$, thus increasing the day length by 1.31 picoseconds.

Due to **ice cap melting**, Antarctica is losing ice at an average rate of about 135 billion tons per year (about 1 cm in average ice cap height per year), while Greenland is losing about 266 billion tons per year. That mass is not "lost," but rather "mixed into Earth's oceans," thus moving it radially outward from the earth's rotation axis from about 2000 to about 5200 km (RMS). This increases I_{earth} about 9×10^{27} meter^{2}kg annually, which is a nearly-2-orders-of-magnitude greater |effect| on I_{earth} each year than completely eliminating the entire atmosphere would have had! Fractionally this is about 1.15×10^{-10} annual increase in I_{earth}, which corresponds to an annual increase in day length by about 9.9 microseconds, which should be quite feasible to measure.

However, the day length instead *shrank* between 1960 and 2025 AD by about 20 microseconds per year. So even assessing ice cap melting is not so easy via day-length measurements, because other effects (such as winds) evidently are larger.

If the entire atmosphere had **prevailing winds** parallel to the equator at, say, 10 km/hour mean windspeed, then that would decrease the rotational angular momentum 5.8598×10^{33} Joule-sec of the earth by a factor$\approx1+1.27\times10^{-8}$ versus if there were no winds, thereby decreasing the day length by 1 millisecond, which would be a 2-orders-of-magnitude greater effect than ice cap melting!

If all seawater were flowing at 1 km/hour on average in a direction parallel to the equator (due to

prevailing ocean currents) then that would decrease the rotational angular momentum of the earth enough to decrease the day length by 29 milliseconds versus an earth with no ocean currents. That would be a nearly-2-orders-of-magnitude greater effect than winds!

We conclude that the day-length method of measuring earth's atmosphere's temperature will not work, i.e. the noise will greatly exceed the signal; but it nevertheless could be a valid way to assess climate change by measuring combined effects from ice cap melting, prevailing wind and ocean current changes, etc provided we were capable of modeling all the main effects, which, unlike all our analysis in this paper, certainly is not trivial.

References

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