WHY THE SUN IS SOMETIMES FAST AND SOMETIMES SLOW

Dec 16, 2005

As the earth orbits the sun in an ellipse, it goes faster approaching the sun and slower when receding, just like when you throw a ball up in the air and it slows at the top of its travels. The earth has two segments; leaving the sun when it slows down, and turning back when it picks up speed. The earth takes more days on one half, less days on the other. When the earth is leaving the sun and moving slower, days are shorter as the earth doesn't need to rotate as long on it's axis to have Greenwich point to the sun at Greenwich noon (or any other standard place). This gives the sun an apparent variation of plus or minus about 7.64 minutes between clock and solar time in one full annual sine wave which has an upper and a lower half.

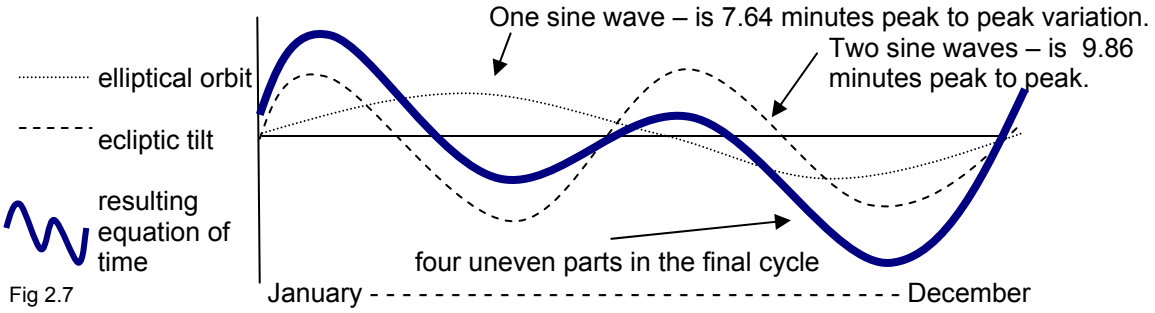


Fig 2.7

Also, the earth is tilted by about 23.5 degrees to it's orbit around the sun creating the two solstices and equinoxes. At the solstices the sun moves neither north nor south but reverses its north/south direction, and moves from increasing latitudes to decreasing ones. At the equinoxes the sun is on the equator and moves from decreasing latitudes to increasing ones. When the sun is moving south or north, some angular movement shifts from the north-south travel to the sun's east-west travel, or vice versa. This means the sun moves westward slower or faster which in turns makes the sun appear slower or faster. Between the equinox and solstice points, solar and clock time differ by about plus or minus 9.86 minutes in two full annual sine waves.

These two variations added together give the equation of time curve, or EOT, which varies by plus or minus about 16 minutes. The equation of time corrects apparent sun time so it matches a virtual perfect sun, or mean sun, which flows at the same rate as a clock. The graph above was built by summing both waves, slewing their start days of the year, and applying a few other refinements. Appendix 8 has several formulae for the equation of time, and a pictorial showing how the day varies in length.

USING THE EQUATION OF TIME ~ EOT

There are three uses for the equation of time.

- To correct a sundial reading
- To build a sundial using the sun's shadow to mark hour points
- To locate true north by solar noon

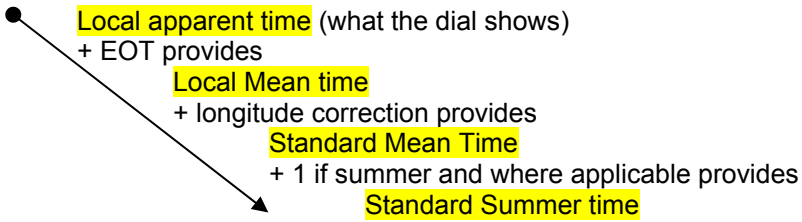
There are four days when the EOT is effectively zero, they are roughly April 15, June 15, September 1, and December 25.

	Feb	Apr	Jun	Sep	Nov	Dec
1	13:34	3:49	-2:09	**0:02**	-16:21	-10:52
3	13:48	3:14	-1:50	-0:41	-16:22	-10:06
11	14:12	1:01	-0:20	-3:24	-15:54	-6:39
13	14:10	0:30	**0:04**	-4:07	-15:38	-5:43
15	14:05	**0:00**	0:29	-4:49	-15:19	-4:46
25	13:00	-2:03	2:39	-8:21	-12:55	**0:08**

Fig 2.8

The extreme values of the EOT are around February 11th when the sun is slow and the EOT is +14 minutes 12 seconds, and early November when it is fast and the EOT is then – 16 minutes 22 seconds. Other peak values are May 13th and 14th when the sun is fast, so the EOT is –3 minutes 39 seconds, and July 25th and 26th when the sun is slow with an EOT of +6 minutes 30 seconds. Those dates are approximate.

To correct a sundial reading to find legal time, add the EOT (equation of time) to the indicated or local apparent time (LAT). If the EOT is +5, then add 5 minutes to the dial's indication because the sun is slow . If the EOT were –3, you would subtract 3 minutes (add the minus 3 means subtract 3) from the reading because the sun is fast.



A caution: some almanacs show the equation of time with opposite signs to those used here. To a dialist, a minus means the sun is running fast and needs the minus to "slow it down". To an astronomer, a minus means the sun is "slow" or "minus" and thus needs a plus to correct it. Neither is right, neither is wrong, it is just that astronomers and dialists have different perspectives.

Many sundials have a single table that is both the equation of time and the longitude correction combined.

EQUATION OF TIME [extracted from appendix 8]

A formula derived from Frans Maes from data by Savoie producing the EOT in minutes and using two sine waves is used for some spreadsheets, e.g. A2.1b, A2.1c. The values in the sin(...) function result in radians, so the formula is spreadsheet ready as-is. Value d = 1 to 365

E = -7.36*sin(2*3.1416*(d-4.21)/365) + -9.92*sin(4*3.1416*(d-9.9)/365)

A8.29a

Another formula using the sum of three sine waves is used for some spreadsheets, e.g. A2.1d, A2.1e. The sin(...) values result in degrees hence the required indicated radian conversion.

E = -1*(9.84*SIN(RADIANS(2*(360*(mm1+dd-81)/365))) -7.53*COS(RADIANS(360*(mm1+dd-81)/365)) -1.5*SIN(RADIANS(360*(mm1+dd-81)/365)))-0.3

A8.29b

where: mm1 is the number of days prior to this month's day 1, So Jan is 0, Feb is 31, Mar is 59, April is 90, etc, assuming a non leap year. For leap years add 1 for March to December.

Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec
0	31	59	90	120	151	181	212	243	273	304	334

dd is the day of the month, being 1 to 31

Another formula derived from the work of Frank Cousins uses the sum of seven sine waves, produces the EOT in seconds, however this book does not use it in any spreadsheets-

E=-(-97.8*SIN(SL)-431.3*COS(SL)+596.6*SIN(2*SL)-1.9*COS(2*SL)+4*SIN(3*SL)+19.3*COS(3*SL)-12.7*SIN(4*SL))

A8.29c

where "SL" is the solar longitude, being SL=(-1*((356/365.2422)*360-270)) + julian day of year
the values in sin(...) result in degrees, so the RADIANS( ) function (not shown) is required for a spreadsheet.

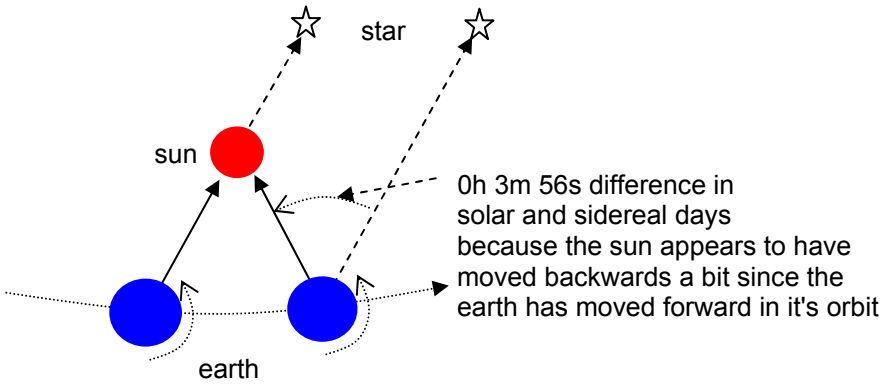
Every approximation is just that, and this book uses several methods for the EOT to demonstrate the real world of approximations, with their benefits as well as drawbacks.

Even established published tables vary by almost a minute. Part of this is explained by the year within a leap year cycle, part by the decade the table was printed, and so on.

The most accurate formulae use the astronomical Julian day. The book, "Astronomical Algorithms" by Jean Meeus has such a formula should further research be desired. The astronomical Julian day is first calculated (in one chapter), and then other chapters are used to build up to a highly generalized EOT formula.

CONSTANTS AND VARIABLES OF THE SOLAR SYSTEM

Earth tilt:	23.5 degrees or more exactly 23 degrees 47 minutes
Moon tilt	the moon's orbit is tilted by 5 degrees from the earth's orbit
Object size	both the sun and the moon, as observed from earth, are about 0.5 degrees wide
Precession	the earth wobbles and it's axis rotates once every 25800 years
Sidereal day:	on rotation of the earth compared to a star, 23h 56m 4s of a mean solar day
Solar day:	one rotation of the earth plus a bit because the earth moves in relation to the sun compared to a sidereal day

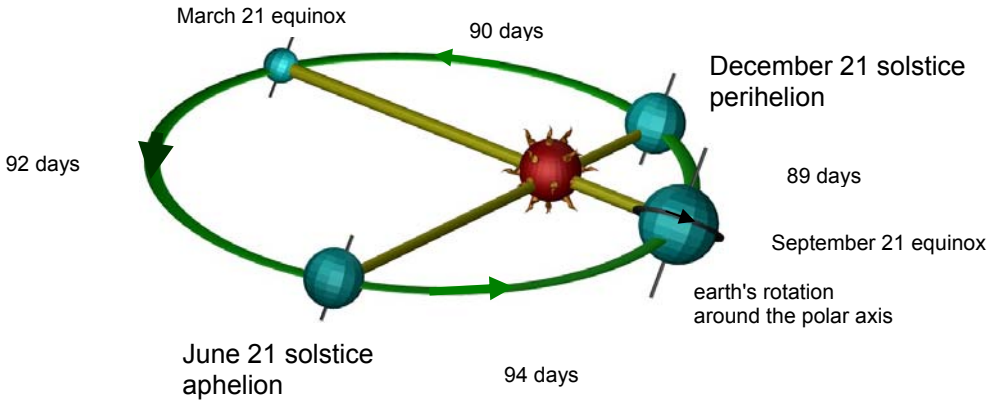


While sun is a long way away, the earth moves enough so that each day the sun has moved "back a bit" compared to a star which is much further away, thus the solar day is a bit longer than the sidereal day based on the stars.

Sidereal year	366.25 rotations of the earth
Solar year	365.25 rotations of the earth
Days EOT=0:	There are four days when the EOT is effectively zero, they are roughly April 15, June 15, September 1, and December 25.
Solstice	Shortest and longest days, December 21 and June 21 approximately
Equinox	Daytime equals night time. March 21 and September 21 approximately except on the equator when every day is an equinox

Solstice to solstice EOT sine wave: because the earth orbit slows and speeds on the solstices, solar apparent time varies in one full wave which is 7.64 minutes peak to peak

Intra-solstice-equinox EOT sine wave: because the sun appears to move north and south, then except for the equinoxes and the solstices, the sun's eastward travel appears to go faster of slower in two waves which are 9.86 minutes peak to peak



EQUATION OF TIME ~ EOT

[extracted from appendix 2]

EQUATION OF TIME TABLE

minutes:seconds **mm.ss**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3.11	13.30	12.31	4.06	-2.48	-2.18	3.41	6.22	0.17	-10.03	-16.26	-11.16
2	3.40	13.38	12.19	3.49	-2.56	-2.09	3.53	6.19	-0.02	-10.22	-16.27	-10.54
3	4.08	13.45	12.07	3.31	-3.02	-1.60	4.04	6.15	-0.21	-10.41	-16.28	-10.31
4	4.35	13.52	11.54	3.13	-3.09	-1.50	4.15	6.10	-0.41	-11.00	-16.28	-10.07
5	5.03	13.58	11.41	2.56	-3.14	-1.40	4.26	6.05	-1.01	-11.19	-16.28	-9.43
6	5.29	14.03	11.28	2.39	-3.19	-1.29	4.36	5.59	-1.21	-11.37	-16.26	-9.18
7	5.56	14.07	11.14	2.22	-3.24	-1.18	4.46	5.52	-1.41	-11.55	-16.24	-8.53
8	6.22	14.10	10.59	2.05	-3.28	-1.07	4.56	5.45	-2.01	-12.12	-16.21	-8.27
9	6.47	14.13	10.44	1.48	-3.31	-0.56	5.06	5.37	-2.22	-12.30	-16.17	-8.01
10	7.12	14.15	10.29	1.32	-3.34	-0.44	5.15	5.29	-2.42	-12.46	-16.12	-7.34
11	7.36	14.16	10.14	1.16	-3.36	-0.32	5.23	5.20	-3.03	-13.02	-16.06	-7.07
12	8.00	14.16	9.58	0.60	-3.38	-0.20	5.31	5.10	-3.24	-13.18	-15.59	-6.40
13	8.23	14.15	9.42	0.44	-3.39	-0.08	5.39	5.00	-3.45	-13.33	-15.52	-6.12
14	8.46	14.14	9.26	0.29	-3.40	0.05	5.46	4.50	-4.07	-13.48	-15.43	-5.44
15	9.08	14.12	9.09	0.14	-3.40	0.17	5.53	4.39	-4.28	-14.02	-15.34	-5.15
16	9.29	14.09	8.52	0.00	-3.39	0.30	5.59	4.27	-4.49	-14.16	-15.24	-4.46
17	9.50	14.05	8.35	-0.15	-3.38	0.43	6.05	4.15	-5.11	-14.29	-15.13	-4.17
18	10.10	14.01	8.18	-0.28	-3.37	0.56	6.10	4.02	-5.32	-14.41	-15.01	-3.48
19	10.29	13.56	8.00	-0.42	-3.34	1.09	6.14	3.49	-5.53	-14.53	-14.49	-3.19
20	10.48	13.50	7.43	-0.55	-3.32	1.22	6.18	3.35	-6.15	-15.05	-14.35	-2.49
21	11.06	13.44	7.25	-1.07	-3.28	1.35	6.22	3.21	-6.36	-15.15	-14.21	-2.19
22	11.23	13.37	7.07	-1.20	-3.24	1.48	6.25	3.06	-6.57	-15.25	-14.06	-1.50
23	11.39	13.29	6.49	-1.31	-3.20	2.01	6.27	2.51	-7.19	-15.35	-13.50	-1.20
24	11.54	13.21	6.31	-1.43	-3.15	2.14	6.29	2.35	-7.40	-15.43	-13.34	-0.50
25	12.09	13.12	6.13	-1.54	-3.10	2.27	6.30	2.19	-8.01	-15.51	-13.16	-0.20
26	12.23	13.03	5.55	-2.04	-3.04	2.40	6.31	2.03	-8.21	-15.58	-12.58	0.09
27	12.36	12.52	5.37	-2.14	-2.57	2.52	6.31	1.46	-8.42	-16.05	-12.39	0.39
28	12.49	12.42	5.19	-2.23	-2.50	3.05	6.31	1.29	-9.02	-16.10	-12.19	1.08
29	13.00		5.00	-2.32	-2.43	3.17	6.30	1.11	-9.23	-16.15	-11.59	1.38
30	13.11		4.42	-2.40	-2.35	3.29	6.28	0.53	-9.43	-16.20	-11.38	2.07
31	13.21		4.24		-2.27		6.25	0.35		-16.23		2.36

If "+" then add to solar time to get mean time as the sun is slow. If " –" then subtract from solar time to get mean time as the sun is fast. Some tables have a plus for our minus and vice versa. If in doubt look at the figure of eight equation of time. This table is based on the astronomical formulae discussed in the supplements, it used 2007 as it's basis. **Formulae involving dates** use approximations thus these tables may disagree with other sources using other formulae. This and other publications have figures that are well within drafting tolerances.

EOT (decimal mm.ss) AVERAGE FOR MONTH (2 sine wave formula)

A2.1b

mm.ss	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec
avg	8.49	13.46	8.37	0.10	-3.26	0.30	5.46	4.11	-5.08	-14.21	-14.25	-3.47

EOT (decimal mm.ss) AVERAGE FOR MONTH WITH LONGITUDE CORRECTIONS FOR DIAL PORTABILITY

A2.1c

Month	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec
Long Diff					EAST	OF	TIME	ZONE				
-8	-23.11	-18.14	-23.23	-31.50	-35.26	-31.30	-26.14	-27.49	-37.08	-46.21	-46.25	-35.47
-7	-19.11	-14.14	-19.23	-27.50	-31.26	-27.30	-22.14	-23.49	-33.08	-42.21	-42.25	-31.47
-6	-15.11	-10.14	-15.23	-23.50	-27.26	-23.30	-18.14	-19.49	-29.08	-38.21	-38.25	-27.47
-5	-11.11	-6.14	-11.23	-19.50	-23.26	-19.30	-14.14	-15.49	-25.08	-34.21	-34.25	-23.47
-4	-7.11	-2.14	-7.23	-15.50	-19.26	-15.30	-10.14	-11.49	-21.08	-30.21	-30.25	-19.47
-3	-3.11	1.46	-3.23	-11.50	-15.26	-11.30	-6.14	-7.49	-17.08	-26.21	-26.25	-15.47
-2	0.49	5.46	0.37	-7.50	-11.26	-7.30	-2.14	-3.49	-13.08	-22.21	-22.25	-11.47
-1	4.49	9.46	4.37	-3.50	-7.26	-3.30	1.46	0.11	-9.08	-18.21	-18.25	-7.47
0	8.49	13.46	8.37	0.10	-3.26	0.30	5.46	4.11	-5.08	-14.21	-14.25	-3.47
1	12.49	17.46	12.37	4.10	0.34	4.30	9.46	8.11	-1.08	-10.21	-10.25	0.13
2	16.49	21.46	16.37	8.10	4.34	8.30	13.46	12.11	2.52	-6.21	-6.25	4.13
3	20.49	25.46	20.37	12.10	8.34	12.30	17.46	16.11	6.52	-2.21	-2.25	8.13
4	24.49	29.46	24.37	16.10	12.34	16.30	21.46	20.11	10.52	1.39	1.35	12.13
5	28.49	33.46	28.37	20.10	16.34	20.30	25.46	24.11	14.52	5.39	5.35	16.13
6	32.49	37.46	32.37	24.10	20.34	24.30	29.46	28.11	18.52	9.39	9.35	20.13
7	36.49	41.46	36.37	28.10	24.34	28.30	33.46	32.11	22.52	13.39	13.35	24.13
8	40.49	45.46	40.37	32.10	28.34	32.30	37.46	36.11	26.52	17.39	17.35	28.13
					WEST	OF	TIME	ZONE				

Rather than make hour lines and their angles conform to the dial's location, it may be wiser to have an equation of time incorporating the longitude difference. This facilitates dial portability. Since time zones tend to be 7.5 degrees wide, a table is provided to cover that longitude span.

LAT (local apparent time) or solar time as shown on the dial	+ EOT eg: Nov –15 Feb +12	+ longitude correction – if E of legal meridian + if west of it	+ 1 if it is summer	➔ LEGAL STANDARD MEAN TIME
is what you see	gets local mean time	gets legal standard time		

Tables A2.1b and A2.1c use a two sine wave formula A8.29a which differs from table A2.1 and tables A2.1d and A2.1e, which is why their figures differ.

When using any EOT values, always know what they indicate, their sign, and what assumptions have been made.

EOT (decimal mm.ss) AVERAGE FOR MONTH (3 sine wave formula)

A2.1d

mm.ss	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec
avg	8.38	13.39	9.04	0.14	-3.35	0.00	4.54	3.22	-5.51	-14.39	-14.31	-4.16

EOT (decimal mm.ss) AVERAGE FOR MONTH WITH LONGITUDE CORRECTIONS FOR DIAL PORTABILITY

A2.1e

Month	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec
Long Diff					EAST	OF	TIME	ZONE				
-8	-23.22	-18.21	-22.56	-31.46	-35.35	-31.60	-27.06	-28.38	-37.51	-46.39	-46.31	-36.16
-7	-19.22	-14.21	-18.56	-27.46	-31.35	-27.60	-23.06	-24.38	-33.51	-42.39	-42.31	-32.16
-6	-15.22	-10.21	-14.56	-23.46	-27.35	-23.60	-19.06	-20.38	-29.51	-38.39	-38.31	-28.16
-5	-11.22	-6.21	-10.56	-19.46	-23.35	-19.60	-15.06	-16.38	-25.51	-34.39	-34.31	-24.16
-4	-7.22	-2.21	-6.56	-15.46	-19.35	-15.60	-11.06	-12.38	-21.51	-30.39	-30.31	-20.16
-3	-3.22	1.39	-2.56	-11.46	-15.35	-11.60	-7.06	-8.38	-17.51	-26.39	-26.31	-16.16
-2	0.38	5.39	1.04	-7.46	-11.35	-7.60	-3.06	-4.38	-13.51	-22.39	-22.31	-12.16
-1	4.38	9.39	5.04	-3.46	-7.35	-3.60	0.54	-0.38	-9.51	-18.39	-18.31	-8.16
0	8.38	13.39	9.04	0.14	-3.35	0.00	4.54	3.22	-5.51	-14.39	-14.31	-4.16
1	12.38	17.39	13.04	4.14	0.25	4.00	8.54	7.22	-1.51	-10.39	-10.31	-0.16
2	16.38	21.39	17.04	8.14	4.25	8.00	12.54	11.22	2.09	-6.39	-6.31	3.44
3	20.38	25.39	21.04	12.14	8.25	12.00	16.54	15.22	6.09	-2.39	-2.31	7.44
4	24.38	29.39	25.04	16.14	12.25	16.00	20.54	19.22	10.09	1.21	1.29	11.44
5	28.38	33.39	29.04	20.14	16.25	20.00	24.54	23.22	14.09	5.21	5.29	15.44
6	32.38	37.39	33.04	24.14	20.25	24.00	28.54	27.22	18.09	9.21	9.29	19.44
7	36.38	41.39	37.04	28.14	24.25	28.00	32.54	31.22	22.09	13.21	13.29	23.44
8	40.38	45.39	41.04	32.14	28.25	32.00	36.54	35.22	26.09	17.21	17.29	27.44
					WEST	OF	TIME	ZONE				

Rather than make hour lines and their angles conform to the dial's location, it may be wiser to have an equation of time incorporating the longitude difference. This facilitates dial portability. Since time zones tend to be 7.5 degrees wide, a table is provided to cover that longitude span.

LAT (local apparent time) or solar time as shown on the dial	+ EOT eg: Nov –15 Feb +12	+ longitude correction – if E of legal meridian + if west of it	+ 1 if it is summer	➔ LEGAL STANDARD MEAN TIME
is what you see	gets local mean time	gets legal standard time		

Tables A2.1d and A2.1e use a three sine wave formula A8.29b which differs from table A2.1 and tables A2.1b and A2.1c, which is why their figures differ.

When using any EOT values, always know what they indicate, their sign, and what assumptions have been made.

SUPPLEMENT – EQUATION OF TIME

ASTRONOMICAL FORMULAE FOR EOT

The most accurate formulae use astronomical elements. The astronomical Julian day is first calculated, and then other elements build up to a highly generalized EOT formula. "Astronomical Formulae for Calculators" by Jean Meeus is referred to below, fourth edition, ISBN 0-943396-02-6. It's page 24 derives the Julian Day, page 90 derives the equinoxes and solstices for a given year. Do not mix formulae among different books, they may use different baseline epochs, these formulae use Jan 1, 1900 as their epoch, however the formulae work back a couple of thousand years and well into the future. The Julian day discussed here is noon at Greenwich, England.

Julian Day
=INT(365.25*(4716+(IF((IF(MM>2,1,0))=0,YYYY-1,YYYY)))
+INT(30.6001*((IF((IF(MM>2,1,0))=0,MM+12,MM))+1))) +DD -1524.5
+(2-INT((IF((IF(MM>2,1,0))=0,YYYY- 1,YYYY))/100)
+INT(INT((IF((IF(MM>2,1,0))=0,YYYY-1,YYYY))/100)/4))
where: yyyy = eg 2005, mm=01 to 12, and dd=01 to 31

March equinox: =1721139.2855+365.2421376*YYYY+0.0679190*ZZ*ZZ-0.0027879*ZZ*ZZ*ZZ
June solstice: =1721233.2486+365.2417284*YYYY-0.053018*ZZ*ZZ+0.009332*ZZ*ZZ*ZZ
September equinox: =1721325.6978+365.2425055*YYYY-0.126689*ZZ*ZZ+0.0019401*ZZ*ZZ*ZZ
December solstice: =1721414.392+365.2428898*YYYY-0.010965*ZZ*ZZ-0.0084885*ZZ*ZZ*ZZ
where yyyy = eq 2005, and zz = yyyy/1000

Page 79 provides four ingredients, T, L, M, e. Page 81 provides another two, Obliq and "y". Page 91 deriving the final EOT which is the astronomically accurate EOT in radians, which you convert to degrees, then hours and minutes.

T =(jd-2415020)/36525 A date conversion for the Jan 1, 1900 epoch

L =279.69668+(36000.76892*T)+(0.0003025*T*T)
Geometric mean longitude of the sun

M =358.47583+(35999.04975*T)-(0.00015*T*T)+(0.0000033*T*T*T)
Sun mean anomaly

E =0.01675104-(0.0000418*T)-(0.000000126*T*T)
Earth eccentricity

Obliq =23.452294-(0.0130125*T)-(0.00000164*T*T)+(0.000000503*T*T*T)
Ecliptic obliquity

Y =TAN(RADIANS(OBLIQ/2))*TAN(RADIANS(OBLIQ/2))

EOT =(Y*SIN(RADIANS(2*L))) - (2*E*SIN(RADIANS(M)))+
(4*E*Y*SIN(RADIANS(M))*COS(RADIANS(2*L)))-
(0.5*Y*Y*SIN(RADIANS(4*L))) - ((5/4)*E*E*SIN(RADIANS(2*M)))

mm.mm EOT is the EOT above in radians converted to degrees, divided by 15, and multiplied by – 60 (to get from astronomical EOT to sundial EOT).

The above are employed in the EOT spreadsheet used for table A2.1 which has a number of different worksheets and all that is needed is for the year to be entered once. The spreadsheet then provides the EOT for that year, the year's Julian day for the solstices and equinoxes, the high and low peak values, as well as a five year review of the EOT for the 15th of the month, and finally a highly detailed daily EOT listing.

Comparisons of mid month EOT values for five year spans in the last, this, and the next century..

Summarized annual comparison

20th century
19xx

mm	dd	1904	1905	1906	1907	1908
1	15	9.01	9.17	9.12	9.06	9.01
2	15	14.26	14.24	14.24	14.25	14.25
3	15	9.15	9.19	9.23	9.27	9.15
4	15	0.13	0.17	0.20	0.24	0.13
5	15	-3.49	-3.49	-3.49	-3.49	-3.49
6	15	0.03	0.00	-0.03	-0.06	0.04
7	15	5.38	5.37	5.35	5.34	5.39
8	15	4.29	4.31	4.34	4.37	4.29
9	15	-4.32	-4.27	-4.22	-4.16	-4.32
10	15	-14.01	-13.57	-13.54	-13.51	-14.01
11	15	-15.27	-15.29	-15.32	-15.34	-15.27
12	15	-5.02	-5.09	-5.17	-5.24	-5.02

Summarized annual comparison

21st century
20xx

mm	dd	2004	2005	2006	2007	2008
1	15	9.02	9.19	9.13	9.08	9.03
2	15	14.13	14.11	14.11	14.12	14.12
3	15	8.57	9.01	9.05	9.09	8.56
4	15	0.04	0.07	0.11	0.14	0.03
5	15	-3.40	-3.40	-3.40	-3.40	-3.39
6	15	0.26	0.23	0.20	0.17	0.27
7	15	5.57	5.55	5.54	5.53	5.58
8	15	4.30	4.33	4.36	4.39	4.30
9	15	-4.44	-4.38	-4.33	-4.28	-4.44
10	15	-14.12	-14.09	-14.06	-14.02	-14.13
11	15	-15.27	-15.29	-15.32	-15.34	-15.27
12	15	-4.54	-5.01	-5.08	-5.15	-4.53

Summarized annual comparison

22nd century
21xx

mm	dd	2104	2105	2106	2107	2108
1	15	8.42	8.59	8.53	8.48	8.42
2	15	14.01	13.60	14.00	14.01	14.01
3	15	8.55	8.59	9.03	9.07	8.54
4	15	0.09	0.12	0.16	0.19	0.08
5	15	-3.31	-3.31	-3.31	-3.31	-3.31
6	15	0.37	0.34	0.31	0.28	0.38
7	15	6.09	6.08	6.07	6.05	6.10
8	15	4.43	4.46	4.49	4.51	4.43
9	15	-4.34	-4.28	-4.23	-4.18	-4.34
10	15	-14.10	-14.06	-14.03	-13.59	-14.10
11	15	-15.37	-15.39	-15.41	-15.44	-15.37
12	15	-5.14	-5.21	-5.28	-5.35	-5.13

ASTRONOMICAL Julian and EOT, equinox & solstice data, peak EOT values for: 2004

EQUATION OF TIME (EOT) FOR YEAR:	2004	LEAP YEAR

	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec
1	3.04	13.28	12.11	3.36	-3.01	-2.03	4.01	6.16	-0.16	-10.36	-16.28	-10.37
2	3.32	13.36	11.58	3.18	-3.07	-1.53	4.12	6.11	-0.36	-10.55	-16.28	-10.13
3	4.01	13.44	11.45	3.01	-3.13	-1.43	4.23	6.06	-0.55	-11.14	-16.28	-9.49
4	4.28	13.51	11.32	2.43	-3.18	-1.32	4.33	5.60	-1.15	-11.32	-16.27	-9.25
5	4.56	13.57	11.18	2.26	-3.23	-1.22	4.43	5.54	-1.35	-11.50	-16.24	-8.60
6	5.23	14.02	11.03	2.09	-3.27	-1.11	4.53	5.47	-1.56	-12.08	-16.22	-8.34
7	5.49	14.06	10.49	1.53	-3.31	-0.59	5.03	5.39	-2.16	-12.25	-16.18	-8.08
8	6.15	14.10	10.34	1.36	-3.34	-0.48	5.12	5.31	-2.37	-12.42	-16.13	-7.41
9	6.41	14.13	10.18	1.20	-3.36	-0.36	5.20	5.22	-2.58	-12.58	-16.07	-7.14
10	7.06	14.15	10.03	1.04	-3.38	-0.24	5.29	5.13	-3.19	-13.14	-16.01	-6.47
11	7.30	14.16	9.47	0.49	-3.39	-0.12	5.36	5.03	-3.40	-13.29	-15.54	-6.19
12	7.54	14.16	9.30	0.33	-3.40	0.01	5.44	4.52	-4.01	-13.44	-15.46	-5.51
13	8.18	14.16	9.14	0.18	-3.40	0.14	5.50	4.41	-4.22	-13.58	-15.37	-5.22
14	8.40	14.15	8.57	0.04	-3.40	0.26	5.57	4.30	-4.44	-14.12	-15.27	-4.54
15	9.02	14.13	8.40	-0.11	-3.39	0.39	6.03	4.18	-5.05	-14.25	-15.16	-4.25
16	9.24	14.10	8.23	-0.25	-3.37	0.52	6.08	4.05	-5.26	-14.38	-15.05	-3.56
17	9.45	14.07	8.05	-0.38	-3.35	1.05	6.13	3.52	-5.48	-14.50	-14.52	-3.26
18	10.05	14.02	7.48	-0.51	-3.33	1.18	6.17	3.38	-6.09	-15.02	-14.39	-2.57
19	10.24	13.58	7.30	-1.04	-3.29	1.31	6.21	3.24	-6.30	-15.12	-14.25	-2.27
20	10.43	13.52	7.12	-1.16	-3.26	1.44	6.24	3.10	-6.52	-15.23	-14.10	-1.57
21	11.01	13.46	6.54	-1.28	-3.21	1.57	6.26	2.55	-7.13	-15.32	-13.54	-1.28
22	11.18	13.39	6.36	-1.40	-3.17	2.10	6.28	2.39	-7.34	-15.41	-13.38	-0.58
23	11.35	13.32	6.18	-1.51	-3.11	2.23	6.30	2.24	-7.55	-15.49	-13.21	-0.28
24	11.51	13.24	5.60	-2.01	-3.06	2.36	6.31	2.07	-8.16	-15.56	-13.03	0.02
25	12.06	13.15	5.42	-2.11	-2.59	2.48	6.31	1.51	-8.36	-16.03	-12.44	0.31
26	12.20	13.05	5.24	-2.21	-2.53	3.01	6.31	1.33	-8.57	-16.09	-12.25	1.01
27	12.33	12.56	5.05	-2.30	-2.45	3.13	6.30	1.16	-9.17	-16.14	-12.04	1.30
28	12.46	12.45	4.47	-2.38	-2.38	3.25	6.28	0.58	-9.37	-16.18	-11.44	1.59
29	12.57	12.23	4.29	-2.46	-2.30	3.37	6.26	0.40	-9.57	-16.22	-11.22	2.28
30	13.08		4.11	-2.54	-2.21	3.49	6.23	0.22	-10.17	-16.25	-10.60	2.57
31	13.19		3.53		-2.12		6.20	0.03		-16.27		3.25

EOT 2004

MAJOR PEAKS		MINOR PEAKS	
MAX	MIN	MAX	MIN
14.16	-16.28	6.31	-3.40

Solstice and Equinox for this year

yyyy	mm	dd	Astronomical Julian Day	
2004	1	1	- - >	2453005.5
2.004				

Julian day and day of year for the event

March equinox:	2453084.8	79.28
June Solstice:	2453177.5	172.03
September equinox:	2453271.2	265.69
December solstice:	2453361	276.25

Some comparisons of peaks and valleys, and solstice and equinox data.

2004 – see prior page

EOT 2005

MAJOR PEAKS		MINOR PEAKS	
MAX	MIN	MAX	MIN
14.16	-16.28	6.31	-3.40

Solstice and Equinox for this year

yyyy	mm	dd	Astronomical Julian Day	
2005	1	1	- - >	2453371.5
2.005				

Julian day and day of year for the event

March equinox:	2453450	78.52
June Solstice:	2453542.8	171.28
September equinox:	2453636.4	264.93
December solstice:	2453726.3	276.25

EOT 2006

MAJOR PEAKS		MINOR PEAKS	
MAX	MIN	MAX	MIN
14.16	-16.28	6.31	-3.40

Solstice and Equinox for this year

yyyy	mm	dd	Astronomical Julian Day	
2006	1	1	- - >	2453736.5
2.006				

Julian day and day of year for the event

March equinox:	2453815.3	78.76
June Solstice:	2453908	171.52
September equinox:	2454001.7	265.17
December solstice:	2454091.5	276.25

EOT 2007

MAJOR PEAKS		MINOR PEAKS	
MAX	MIN	MAX	MIN
14.16	-16.28	6.31	-3.40

Solstice and Equinox for this year

yyyy	mm	dd	Astronomical Julian Day	
2007	1	1	- - >	2454101.5
2.007				

Julian day and day of year for the event

March equinox:	2454180.5	79.01
June Solstice:	2454273.3	171.76
September equinox:	2454366.9	265.41
December solstice:	2454456.8	276.25

2008 as for 2004,2009 as for 2005, etc

EOT 2104

MAJOR PEAKS		MINOR PEAKS	
MAX	MIN	MAX	MIN
14.04	-16.33	6.44	-3.32

Solstice and Equinox for this year

yyyy	mm	dd	Astronomical Julian Day	
2104	1	1	- - >	2489529.5
2.104				

Julian day and day of year for the event

March equinox:	2489609	79.52
June Solstice:	2489701.7	172.20
September equinox:	2489795.4	265.89
December solstice:	2489885.3	276.29