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THE EFFECT OF THE ORBIT OF THE SUN ON THE EARTH'S ATMOSPHERE

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1. Introduction

The Sun has an orbit about the center of gravity of the Solar System. This orbit holds on to all of the superior planets (Jupiter, Saturn, Uranus, Neptune and Pluto), but primarily Jupiter and Saturn. This orbit circles the center of gravity of the Solar System every 11.1 years on average. The radii of the orbits vary from a quarter of the Sun's radius to two times of the Sun's radius. Because the orbit depends primarily on just two planets (Jupiter and Saturn), the orbit nearly repeats itself every 178.7 years, and the pattern advances 30º in a clockwise direction during this time, due to the influence of the other superior planets.

The Earth-Moon system is in orbit about the Sun, not about the center of gravity of the solar system, so the Earth-Moon system shares the Sun's orbit just like the Moon shares the orbit of the Earth about the Sun. José (1965) has shown graphically the distance from the center of the Sun to the center of gravity of the Solar System, the instantaneous radius of curvature of the orbit, the time derivative of the angular momentum about the center of gravity, and the time derivative of the angular velocity of the angular momentum about the center of curvature.

A computer model was obtained from Standish (1993) which was modified by the authors to allow the computation of the three coordinates of the distance and the motion of all of the planets and the Sun, and the angular momentum of the orbit of the Sun. The computation obtained the same results given by José (1965). The Angular Momentum of the Sun's Orbit (AMSO) has a varying period of about 11.1 years. When the Sun and planets are considered as point masses, the angular momentum due to orbit is conserved for the planets. But when the planets are considered as balls of viscous fluid, the angular momentum can be transferred from the orbit to the planet.

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The maxima and minima in the angular momentum show a tendency to correspond to an El Niño or a La Niña in 95% of the cases since 1902. In 90% of the cases, an El Niño occurs with a maxima or minima in the AMSO. Since 1902 there have been twenty-two El Niños, and ten of those have occurred near a maximum or a minimum in the AMSO.

The orbit of the Earth-Moon system about the center of the Sun shows a maximum in angular velocity when the Sun is nearest the Earth at northern hemisphere winter solstice and a minimum in angular velocity at northern summer solstice. The length of day (LOD) shows larger values in the Northern Hemisphere's winter consistently year after year. At the Northern Hemisphere, winter solstice in most of the LOD records there is a local LOD minimum. This is interpreted as a local maximum in angular velocity, which is brought about by the increase in angular velocity of the Earth's orbit about the Sun. This is a case of the angular velocity of the Earth's orbit having an influence on the LOD. The occurrence above was used to validate our premise that the AMSO influence on the motion of the Earth has the same type of influence.

The LOD data was accurate enough to show up small local minima and maxima after 1955. The LOD was replaced by the angular velocity of the Earth (Omega), and there was a local maximum where AMSO had a maximum, and the same for an AMSO minimum. The 1991 minimum was not as pronounced as the other three but it was there. There were twenty local extrema in the record of Omega. The AMSO record shows angular velocity changes that are added to Omega, and the changes in Omega or LOD caused by El Niño/La Niña/Southern Oscillation (ENSO) and Quasi-biennial Oscillation (QBO) events.

2. History

The relation between sunspots and climate has been investigated for a long time. Certain investigators have departed from general wisdom and said it is not sunspots that cause the climate change but rather that sunspots on the sun are triggered by the same phenomena that affect the climate of Earth. Notable pioneers of this position are Bigelow (1901) and Sprung (1885). Modern serious sunspot investigators are Willet (1974) and Van Loon & Labitzke (1994). Willet made a 25-year forecast that verified and Van Loon & Labitzke tied the polar warming to sunspots.

There is a relationship that ties the orbit of the Sun about the center of gravity of the Solar System to a motion that is added to the motion of the Earth-Moon system that could serve as this common cause of sunspots and changes in the Earth's atmosphere.

1. Sun's Orbit

The orbits of Jupiter and Saturn are of sufficient size, and the planets are large enough that both of them are in orbit about the center of gravity of the Solar System, and the Sun is in orbit about this center as well. Newton proved this in Principia.[1]

One revolution of this orbit takes about 11 years and the one that follows could be larger or smaller in radius, so it is not periodic with an 11-year period. However, it does almost repeat itself in 178.7 years much more closely than in successive 11-year periods. José (1965) computed this orbit and related it to the sunspot cycle. This loop in the orbit varies in radius from an eighth of a million to a half million kilometers. The orbit does not remain in a plane because Jupiter and Saturn orbit the center of the solar system in different planes.

Kepler's first law that says that each planet moves in an elliptical path with the Sun as one focus applies to the orbit of the Earth, so this orbit and the Earth-Moon system have the same motion as the Sun. Kepler's Law must be modified for the superior planets and for the orbit of the Moon about the Earth for the reasons discussed below.

A mechanism to transfer the motion of the Sun to the Earth needs to be found, then there will be shown that such a transfer is a simple result when the orbits are considered in detail.

There is a characteristic of orbits that can be illustrated if in the beginning one considers two bodies of equal mass orbiting about the center of gravity which is halfway between them. (Figure 1)

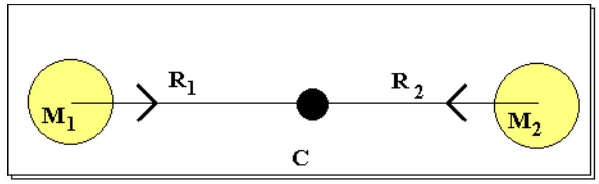

Figure 1. Two masses that are not rotating, the gravitational force pulls them together. The force on each mass is $\frac{GM_1M_2}{(R_1+R_2)^2}$ **M_1** and **M_2** will both move toward **C** unless a force on each one is introduced to keep them apart. This force is $\frac{V_1^2}{R_1}=\frac{V_1^2}{R_2}$ directed outward from **C**. **(Figure 2)**

$$\frac{GM_1M_2}{(R_1+R_2)^2}=\frac{V_1^2}{R_1} \qquad \frac{GM_1M_2}{(R_1+R_2)^2}=\frac{V_2^2}{R_2}$$

$$V_1=\sqrt{\frac{GM_1M_2}{(R_1+R_2)^2}R_1} \qquad V_2=\sqrt{\frac{GM_1M_2}{(R_1+R_2)}R_2}$$

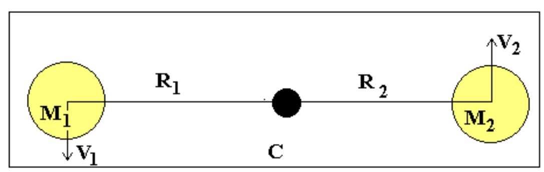

Figure 2. Two equal masses in orbit about the center of gravity that is halfway between them.

To simplify the study of orbits, contrary to popular usage, that **M_1** is not in orbit about about **M_2** (or vice versa) but both **M_1** and **M_2** are in orbit about **C**.

Now consider the two masses to be M_1 = Large Mass and M_2 = small mass.But $\frac{M_2}{M_1}>\frac{1}{5}$ where $\frac{1}{5}$ was chosen as an arbitrary number just to illustrate our next idea.

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1 Casori, F. 1934, "Newton's Principia" (University of California Press, San Francisco, Book III Preposition XIII)

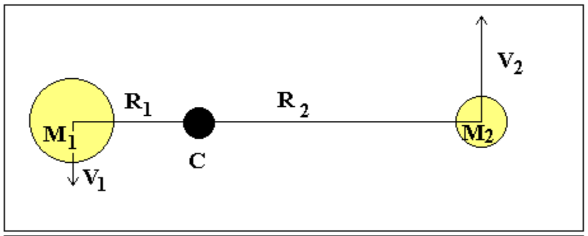

Figure 3. Two unequal masses in orbit about the center of gravity that is near the greater mass

The center of gravity is closer to M_1 than in the equal mass case. As long as **$R_1R_2 = M_1M_2$** the formulas still hold.

Notice that the large mass has a small velocity and the small mass has a large velocity, but the formulas are the same.

Notice also that the center of gravity of the masses is nearer the large mass, and one would likely say that the small mass is in orbit about the large mass. It is still however good policy to say that the two masses are in orbit about their center of gravity. Mass **M1 has** an orbit about the center of gravity and **M_2** has an orbit about the center of gravity just like the **$M_1 = M_2$** case. Now suppose we put a satellite about **M_1** with a mass **AM** that is tiny compared to **M_1** and **M_2**. **(Figure 4)**

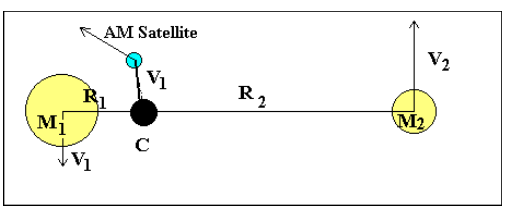

Figure 4. Same as figure 3, except that a satellite of M_2 is orbiting M_2 and shares it's motion.

The orbit of **AM** about **M_1** independent of **M_2** can be computed **M_2** does not have to be taken into consideration when the orbit of **AM** about **M_1** is computed. If the orbit of **AM** about **M_1** is measured it will be the same whether **M_2** is rotating about **C** or some other center of rotation.

However, if the total system involving **M_1**, **M_2** and **AM** is observed, **AM** has the motion of **M_1** (which is **V_1**) added to the orbital velocity of **AM**. In other words, **AM** moves with its orbital velocity about **M_1**, and added to that, the velocity **V_1** (the orbital velocity of **M_1**.)

The Earth and its orbit make the same motion that the Sun does, caused by the superior planets. This can be proven by showing that Jupiter does not exert enough direct force on the Earth to orbit about the center of gravity of the Jupiter–Sun system, even though that center of gravity is inside the Sun.

Thus, Jupiter, Earth and the Sun take on a configuration shown in **Figure 5.**

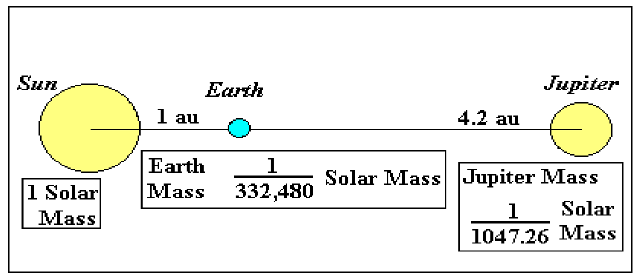

Figure 5. The force on the earth due to Jupiter is not enough to make it orbit the center of gravity of the solar system.

An astronomical unit (a.u.) is the distance from the Earth to the Sun (about 93,000,000 miles).

The force on the Earth due to Jupiter is

$$G\frac{\frac{1}{1047.36}x\frac{1}{332480}}{(4.2)^2}$$

The force on the Earth due to the Sun is

$$G\frac{1x\frac{1}{332480}}{(1)^2}$$

The forces are compared by dividing

$$\frac{Force\ caused\ by\ Jupiter}{Force\ caused\ by\ the\ Sun}=\frac{1}{(4.2)^2x1047.36}=1.8x10^{-4}$$

The force exerted by Jupiter on Earth is 1.8×10^{-4} times the force exerted by the Sun, and the distance between the Sun and the center of gravity of the Solar System is about $.2 \times 10^{-2}$ or 20×10^{-4} a.u. The force of Jupiter is a magnitude too small to change the Earth's orbit. Therefore, the Earth's orbit is about the center of the Sun. The Earth and its orbit move with the Sun like the Moon and its orbit moves with the Earth.

3. Details of the Sun's orbit

The Sun is in orbit about the center of gravity of the Solar System (barycenter). José (1965) drew the orbit of the Sun José shows that it makes 16 loops about the barycenter in 178.7 years and then almost repeats the same path again in the next 178.7 years. In addition to plotting the orbit, José (1965) drew some characteristics of it as a function of time and these appear in Figures 6-17. Figure 6 measures the projection of the distance from the center of gravity of the solar system to the sun on the elliptic. The actual distance in is in Figure 7., and the range that this radius makes is shown in Figure 8. The height of the planet above the limit is shown in Figure 9. The radius or curvature of the orbit of the son is in Figure 10, the velocity of the sun in its orbit is in Figure 11. The movement about the center of gravity of the solar system, L, is in Figure 12 and it's time derivative is in Figure 13. The movement, P, about the instantaneous center of rotation is in Figure 14, and it's time derivative appears in Figure 15. Due to size, these figures are best viewed at http://www.wxresearch.org/papers/sun.

The next consideration is the effect of Saturn and Jupiter. When Jupiter and Saturn are arranged as in Figure 16, the barycenter is far outside the Sun.

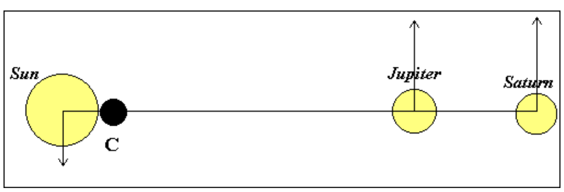

Figure 16. The center of gravity of the solar system is outside the sun when Jupiter and Saturn are on the same side of the sun.

But when they are on opposite sides of the Sun, the barycenter is inside the sun. Jupiter and Saturn determine the path of the Sun through the Sun's orbit according to José (1965). Uranus and Neptune have only the effect of moving the starting point of the 178.7-year cycle about 30 degrees counter-clockwise, and the other planets have hardly any effect.

The Sun and the five superior planets orbit about the barycenter (the center of gravity of the Solar System). They move the barycenter as much as 0.0100 astronomical units (a.u.) from the center of the Sun (Stacy 1965). The Sun's radius is .0044 a.u., so when this occurs the barycenter is well outside the Sun, but when Jupiter is on the opposite side of the Sun from Saturn, the barycenter is inside the Sun. The Sun's orbit was computed by modifying the program KEPPOS (Standish 1993). The program was modified by accounting for the computation of the Sun's orbit as well as the computation of the orbits of the planets.

Detailed study of the Sun's orbit was carried out by José (1965). At first glance, the orbit seems to be irregular and have no periodicity. Closer investigation of the long record shows that the orbit almost repeats itself every 178.7 years and that it forms 16 loops in that time. Fifteen of the loops are around the barycenter; the loop that was made in 1992 misses looping around the barycenter.

The motions of the Sun about the barycenter will result in corresponding motions of the earth because the Earth is close to the Sun, with Jupiter and Saturn having an effect on the Earth's atmosphere as that on the Sun. When the angular momentum is changing greatly, it is expected that the gases that make up the atmosphere of the orbiting bodies will respond with greater changes than at other times. One might conclude a more turbulent atmosphere on the Earth when this occurs.

4. Transfer of angular momentum from the orbit to the planet

When the Sun and planets are considered as point masses, then angular momentum is conserved for each mass. When the planets and the Sun are considered as balls of viscous fluid, which the Sun is and the interior of the Earth is and Earth's atmosphere and oceans are to a lesser extent as regards viscosity, then angular momentum can be transferred from the orbit to the Sun or the planet. This transfer is so very very small it is insignificant in the study of orbits, but it is measurable for the study of sunspots and the effect on LOD.

This works in the following way. If we take Jupiter and the Sun (Figure 17), then the tidal bulge goes along with Jupiter and the Sun

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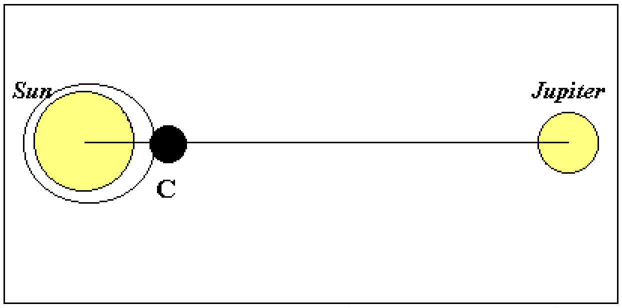

Figure 17. The tidal bulge follows the orbit of Jupiter around the sun.

Taking 11 years to make one revolution, the Sun rotates in 27 days and Jupiter rotates in about 10 hours. So this bulge acts as a stationary barrier in the fluid and the fluid streams through it. The barrier transforms some of its velocity to the Sun or Jupiter through viscous flow. This is a very fast flow, supersonic near the equator of the planet, so the transfer is larger because of that.

Two items in the previous discussion are related to this phenomenon. This is probably what caused the sunspots to have a period near Jupiter's period; also, this effect is probably the cause of the northern winter local minimum in LOD.

5. Earth-Moon System Orbit

The Sun is orbiting the center of gravity of the Solar System, and the Moon is orbiting the center of gravity of the Earth-Moon system, as is the Earth. Meanwhile, the center of gravity of the Earth-Moon system is orbiting a point that is very near the center of the Sun, not the center of gravity of the Solar System. This is a vital difference; it means that the center of gravity of the Earth-Moon system experiences the same motion as the Sun as it goes through its orbit, just like the Moon follows the orbit of the Earth. This could have a measurable effect on the weather of the Earth.

6. Evidence that the affects the LOD

The first place that an influence of AMSO should show up is in Omega, if it exists and it can be measured accurately enough. Since the invention of the atomic clock, the accuracy of measurement of Omega has greatly increased. This accuracy influenced the measurement of Omega starting in 1955. Figure 18 illustrates AMSO and Omega plots. The values of Omega show maxima or minima within two years of most of the corresponding maxima or minima in AMSO. This is taken as direct evidence of influence of the Sun's orbit on the Earth's rotation.

Höfpner (2000) has determined that LOD is affected by El Niño, La Niña and the Quasi-biennial Oscillation (QBO), so the effect on the atmosphere of the Earth and the weather has been demonstrated.

The angular momentum of the sun and the angular velocity of the earth are plotted together in Figure 18.

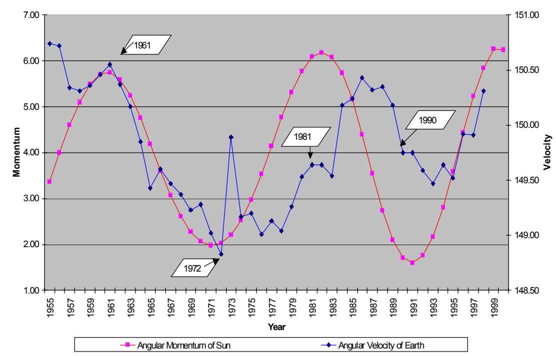

Figure 18. Angular Momentum of the Sun and Angular Velocity of the Earth, 1955 to 2000

The angular momentum is the smooth curve. The angular velocity of the earth has many local maxima and minima because it is affected by the yearly changes in atmosphere and oceanic circulation. The figure shows that there is a local maxima or minima in the angular velocity of the earth corresponding to each maxima or minima of the angular momentum of the sun.

The Maunder minimum in sunspot number occurred during the period 1645-1715 (Herman 1978). As can be seen in Table 1, the absolute minimum in AMSO over the last 505 years occurred in 1671. This is one event in the record of AMSO that corresponds to a cold period on the Earth. The longest day in the last 100 years occurred in 1912, and the second lowest minimum in AMSO in the last 100 years occurred in 1911. The shortest day occurred in the summer of 2001 and the second highest maximum occurred late in 1988. These are two phenomena that occurred in a record of phenomena on the Earth that correspond to phenomena that happens to the Sun.

There have been eleven maxima or minima AMSO since 1900. Eight of these have been within the year of a warm or cold episode of an ENSO event, one has been within two years and two within three years of a significant ENSO event. See Appendix. This is a very good example of an occurrence on the Earth that is related to an extremum in AMSO. The ENSO events in this study were those selected by the National Center for Environmental Prediction (NCEP) and listed by Ropelewski (1996).

Quinn, et al (1985) listed all years that a strong or very strong El Niño occurred during the period 1516 to 1983. See Appendix. There were 47 extrema in the record of AMSO, and strong or very strong El Niños occurred within zero years six times, one year sixteen times, two years five times and three years one time. The total is 27 times out of 47 that a strong or a very strong El Niño occurred near an extremum of AMSO.

Quinn (1984) also listed all moderate to weak El Niños from 1803 to 1983. This period had nineteen extrema in AMSO. Six of those had an El Niño in the same year, nine had an El Niño or La Niña within one year and three had an El Niño within two years. The 1960 maximum had an El Niño in 1957.

A complete record of El Niños showed that El Niños occurred within two years on seventeen of nineteen extrema in AMSO, and a La Niña occurred on one. This is another piece of evidence that AMSO affects the weather on the Earth.

For the period 1962 to 1999 with the LOD with a constant decrease with the time for the earth and for the same period. In Figure 18, the curves show that a relationship of some kind exists between these two curves and thus a relationship between the orbit of the sun and the rate of rotation of the earth is established. Höpfner (1998) showed there is a relationship between El Niño, La Niña, and to QBO, and the rotation of the Earth so we have established a relationship between the orbit of the sun and ENSO.

The length of day (LOD) has been related to QBO and El Niño Southern Oscillation (ENSO) by Joachim Höpfner in a paper presented the 22nd General Assembly, International Union of Geodesy and Geophysics, Birmingham, UK 1999

As stated by José (1965), Isaac Newton showed that the Sun has an orbit. José computed this orbit and found the orbit had a repeatable period of 178.7 years and a quasi-period of 11.1 years. The 11.1-year period is related to sunspots. José computed the angular momentum and Figure 7 shows its time derivative. The authors of this paper wish to demonstrate that the angular momentum of the sun's orbit (AMSO) has an effect on the angular velocity of the earth's rotation (Omega), IERS (2002) that is reflected in the length of day (LOD), Munk (1960).

Höpfner (1999) showed that the LOD measurements have become more accurate since 1961, and the estimate of the wind has improved since the Reanalysis Project (Salstein 1997). This accuracy has allowed him to carefully filter the LOD data to show that LOD is related to ENSO and the quasi-biennial oscillation.

7. Conclusion

The study of the effect of sunspots on the atmosphere and oceanic flow has traditionally been hampered by lack of a basis for a significant connection.

There is such a connection described in this paper. It is the motion of the earth caused by following the motion of the sun in its orbit about the center of gravity of the solar system. The angular momentum of the sun in its orbit is followed by the earth. This is an fundamental motion of the earth itself and there is no question about it causing atmospheric and oceanic changes.

Therefore it is no surprise that one feature of this motion, the angular momentum, has maxima and minima that seem to relate to El Niños and La Niñas.

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