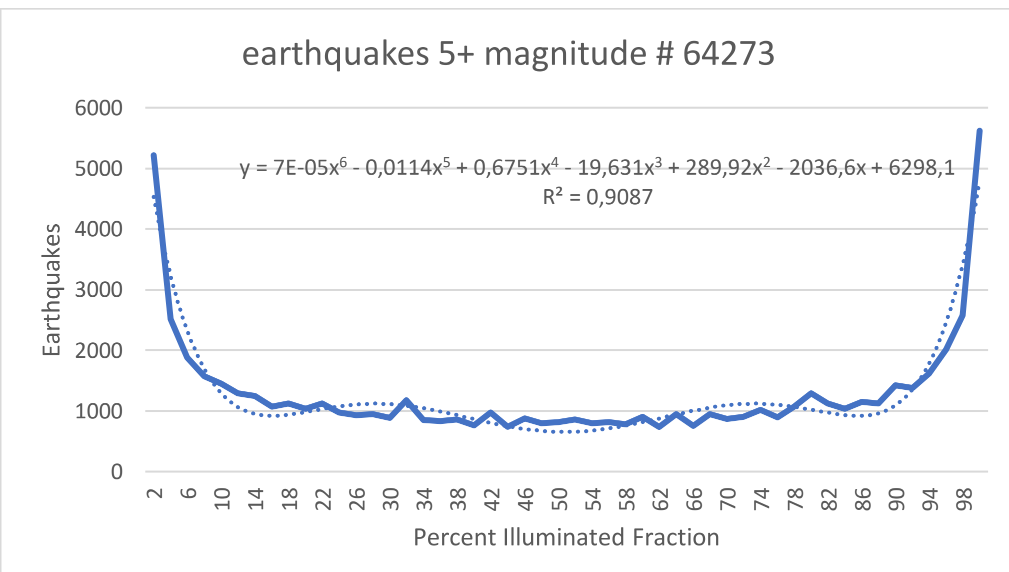
Lunatectonics: how the Moon and Sun continue to affect the Earth's lithosphere.

Abstract

There have been many explorations regarding a possible relationship between the many different types of tidal energy of our planet Earth, the Moon and the Sun and their relationships to the frequency of seismicity. All of the studies chose which tides, magnitudes and locations on the Earth to study. To date there has not been a review of all the earthquakes over the entire Earth for an extended period of time. This study compiled a list of all the earthquakes 4.5 magnitude and greater since 1 Jan 1973 through 31 December 2022 over the entire Earth, utilizing the United States Geological Survey's online database which includes all information of the database: magnitude, depth, longitude, latitude, etc. The study then interpolated all the lunar data for the same period of time according to universal time using lunar and solar data from Jurgen Giesen at http://www.jgiesen.de/moondistance/index.htm . Mr. Giesen also shared a spreadsheet which provided the data for lunar phases, orbit distance, lunar declination, lunar and sun tidal acceleration which were incorporated into the project.

By juxtaposing the two data sets of seismicity and lunar-solar data; the study permitted the data to speak for itself and the following relationship was evident:

Thus the data illustrates that the mean synodic month, from full moon to full moon, has a strong relationship to seismicity across the entire Earth. From 50 years of USGS data for magnitude 5 and greater earthquakes you see the following graph: 0% illumination is a new moon and 100% illumination being the full moon.



The R^2 of 0.9087 indicates a strong 90% relationship between seismicity and the mean synodic month period. The project also provides data analysis tools for any question one can ask regarding solar and lunar data contrasted with seismic data. The project then questions if the mean synodic month tide cycle may act as the clock which regulates seafloor spreading over the millennia, and also asks what accounts for the different rates of seafloor spreading for the different plates on Earth.

Introduction

For almost 100 years, all geophysicists have discounted the effects of the moon impacting the Earth's lithosphere. They have looked at short diurnal and some long term period tides in relation to frequency of earthquakes in specific areas of the earth but after a thorough review of the literature, nobody has yet to examine the relationship between the mean synodic month tide, from full moon to full moon, and its possible relationship to the frequency of earthquakes across the entire earth over an extended period of time. By looking at all the earthquakes 4.5 magnitude and greater, across the entire lithosphere for the past 50 years, the lunar – earthquake project examines this possible relationship.

The author, with the help of Biwiser Analytica based in Santiago, Chile has developed a python based project available for free on Github that demonstrates that the moon along with the sun continue to exert an effect upon the Earth's lithosphere by influencing the frequency of earthquakes in relation to the mean synodic month or 29.530 days, the cycle of new and full moon phases.

The author was granted access to the moon and sun data by Jurgen Giesen at http://www.jgiesen.de/moondistance/index.htm . Mr. Giesen also shared a spreadsheet which provided the data for lunar phases, orbit distance, lunar declination, lunar and sun tidal acceleration which were incorporated into the project.

50 years of earthquake data was derived from the United States Geological Survey (USGS) via their website, https://earthquake.usgs.gov/earthquakes/search . All earthquakes recorded 4.5 magnitude and greater over the entire earth for the 50 years, 1973 thru 2022, were incorporated into the database. It's important to use the USGS advanced settings tab to choose only earthquakes and not extraneous other activities such as mine explosions, volcano eruptions, nuclear blasts, etc. The earthquake data included all earthquake occurrences in universal time, their latitude, longitude, depth, magnitude along with everything else provided by the USGS database.

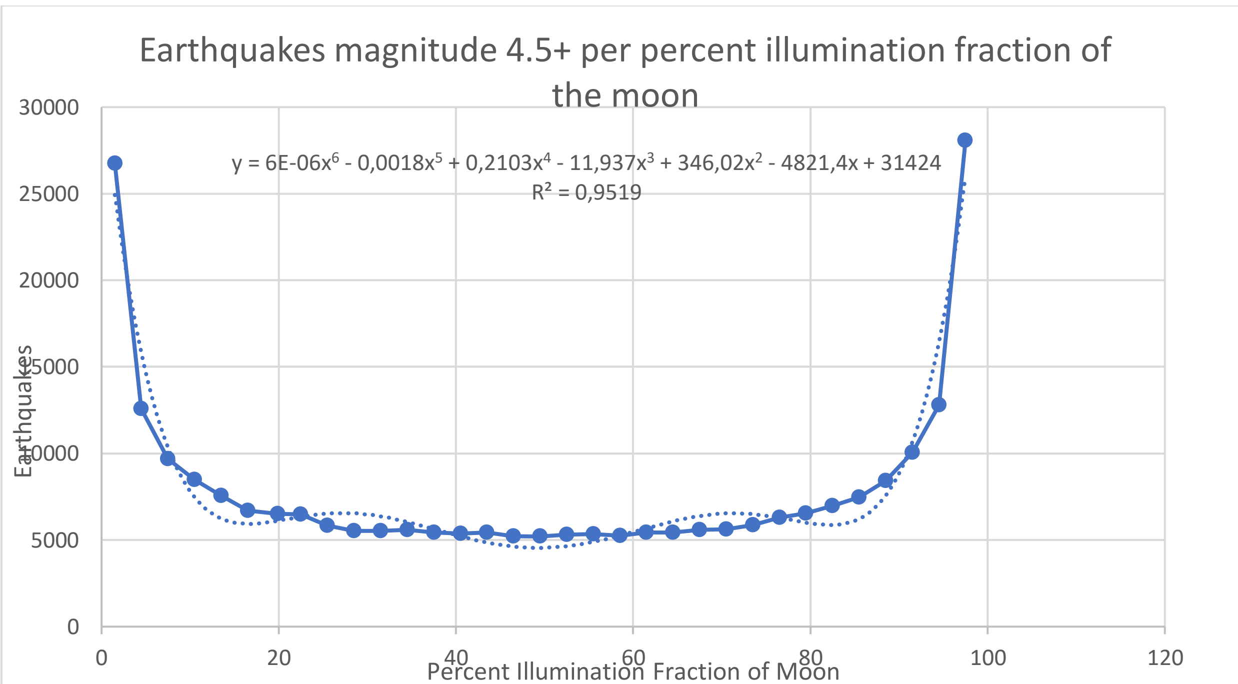
Biwiser Analytica in Santiago, Chile provided the data analyst, Nicolas Salgado, to create the python program available on Github at : …………………………

The project utilizes the K-means grouping algorithm to create 60 clusters of earthquake loci on the Earth's surface. This allows for the investigation of earthquake occurrences over the entire earth as one complete unit as well as specific areas, throughout the 50 years of data while also providing filtering options for the earthquake data for depth, magnitude, longitude, latitude as well as lunar data of illuminated fraction, orbital distance, declination and tidal accelerations. By linking the lunar data with the earthquake data, the investigation permitted the data to speak for itself. Basically, if you can ask a data analytical question regarding the relationship between the lunar cycle and earthquakes, this program is able to answer it.

The Lunatectonics program

Initial Findings:

Looking at 50 years of earthquake data, brief in geological terms, one sees the relationship between the frequency of earthquakes and the lunar mean synodic month for earthquakes magnitude 4.5 magnitude and greater.

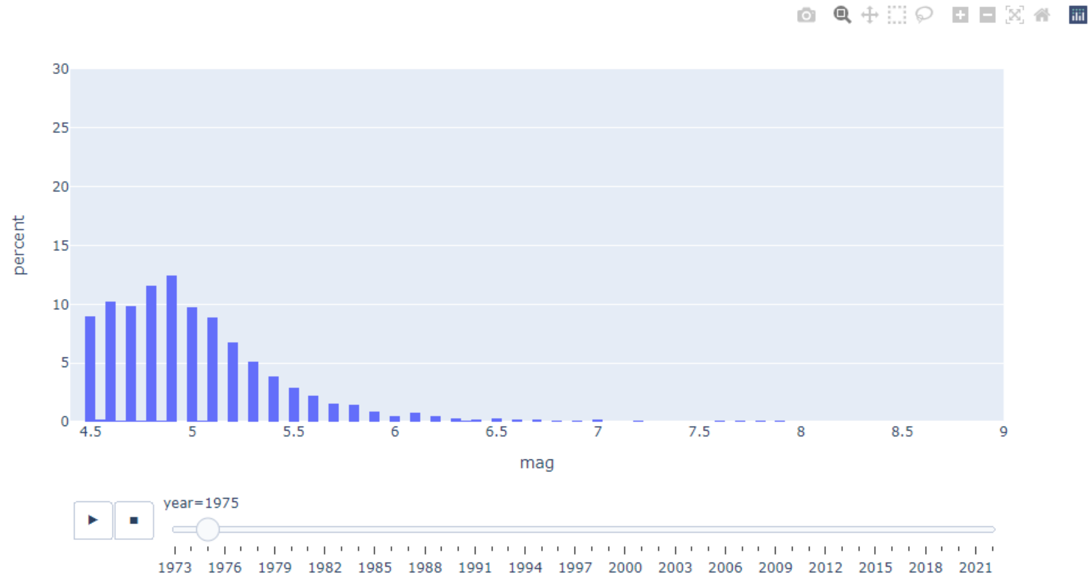


0% illumination fraction being a new moon and 100% ill_frac being a full moon representing the mean synodic month.

There was a problem in looking at the USGS data as earthquakes between the years 1973 and 1996. The USGS data for earthquakes did not completely capture all global earthquakes between 4.5 magnitude and 4.9 magnitude. This is evident in the Gutenberg-Richter graph of the USGS data of 1975, notice the decrease in earthquakes between 4.5 and 4.9 magnitudes:

In [282]:
```
histogram_animation(df1, var="mag", histnorm="percent",animation_frame="year", nbins=None,
                    range_x= [4.4,9], range_y=[0,30] )

# nbins if you want by default write None.
# range_x and range_y by default None, and will be like it was before, if you want to change set a list with two numbers
#animation_frame="MAG_SEG", "PERIOD", "YEAR"... any column name of categories
```



Compared with the data from 1997 and beyond:

In [282]:
```
histogram_animation(df1, var="mag", histnorm="percent",animation_frame="year", nbins=None,
                    range_x= [4.4,9], range_y=[0,30] )

# nbins if you want by default write None.
# range_x and range_y by default None, and will be like it was before, if you want to change set a list with two numbers
#animation_frame="MAG_SEG", "PERIOD", "YEAR"... any column name of categories
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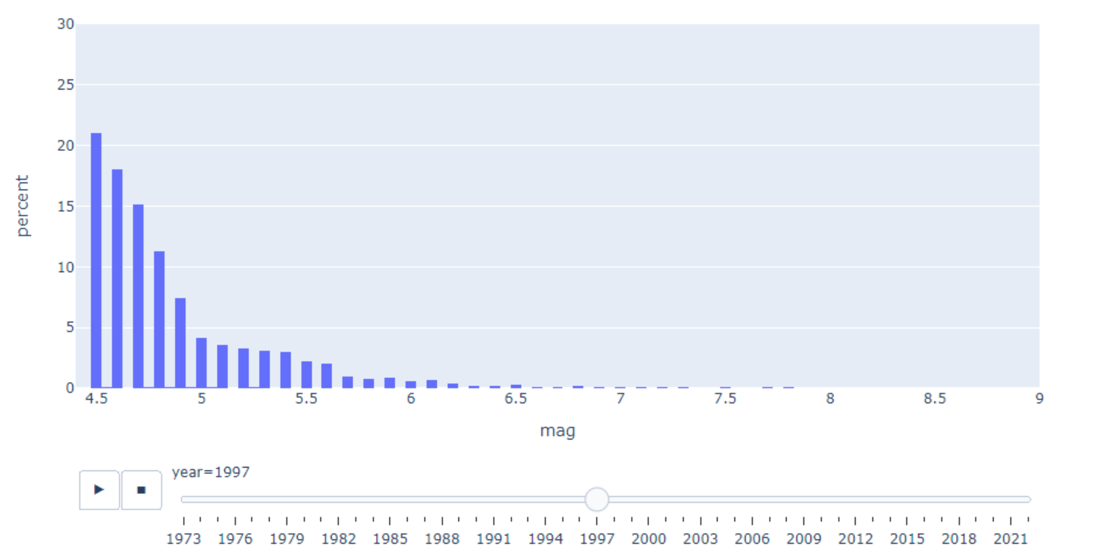
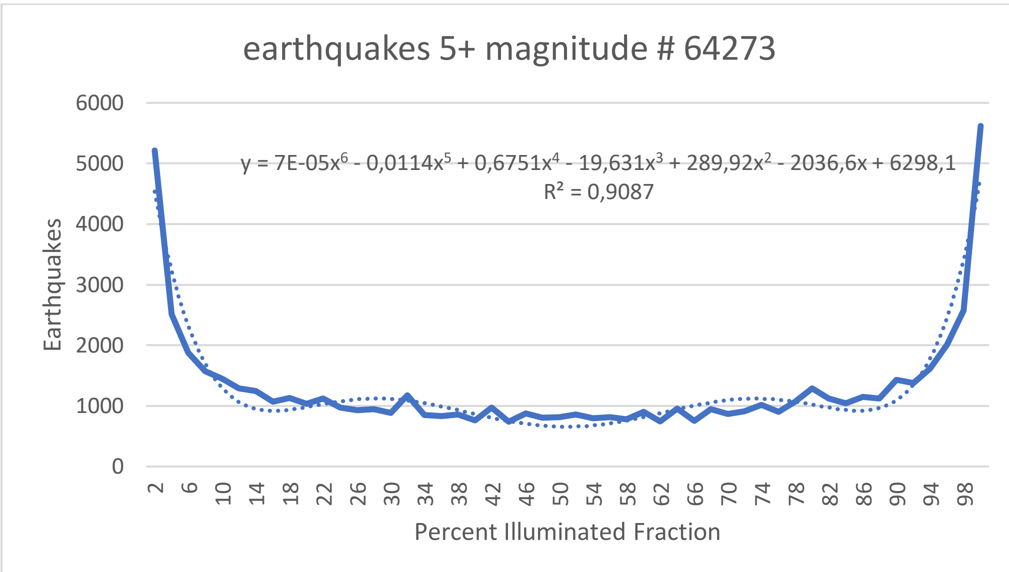
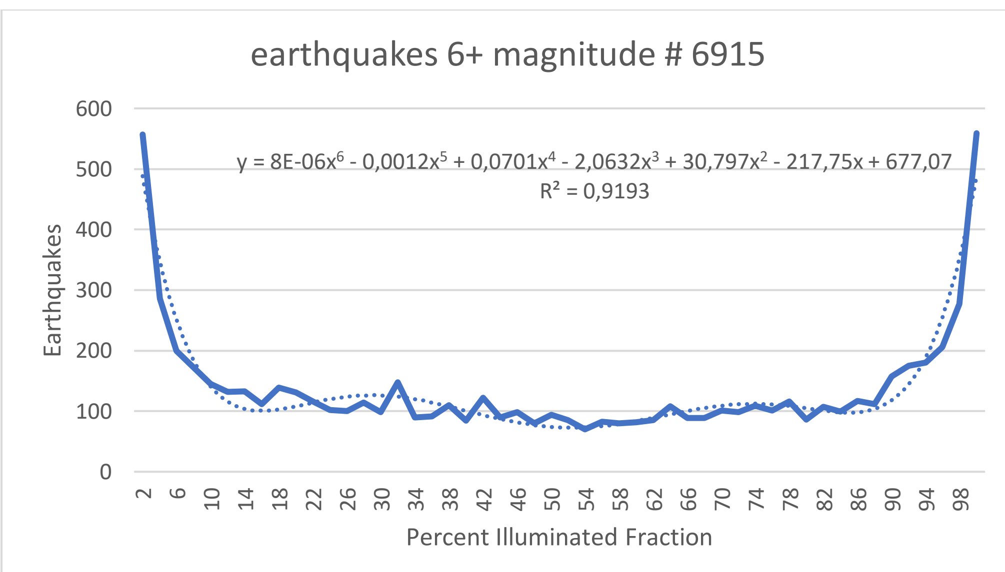


By 1997 it is now evident that the earthquakes between 4.5 and 4.8 magnitude are being captured worldwide by the USGS data system and this is easily visualized in the time sequence animation available when using the project.

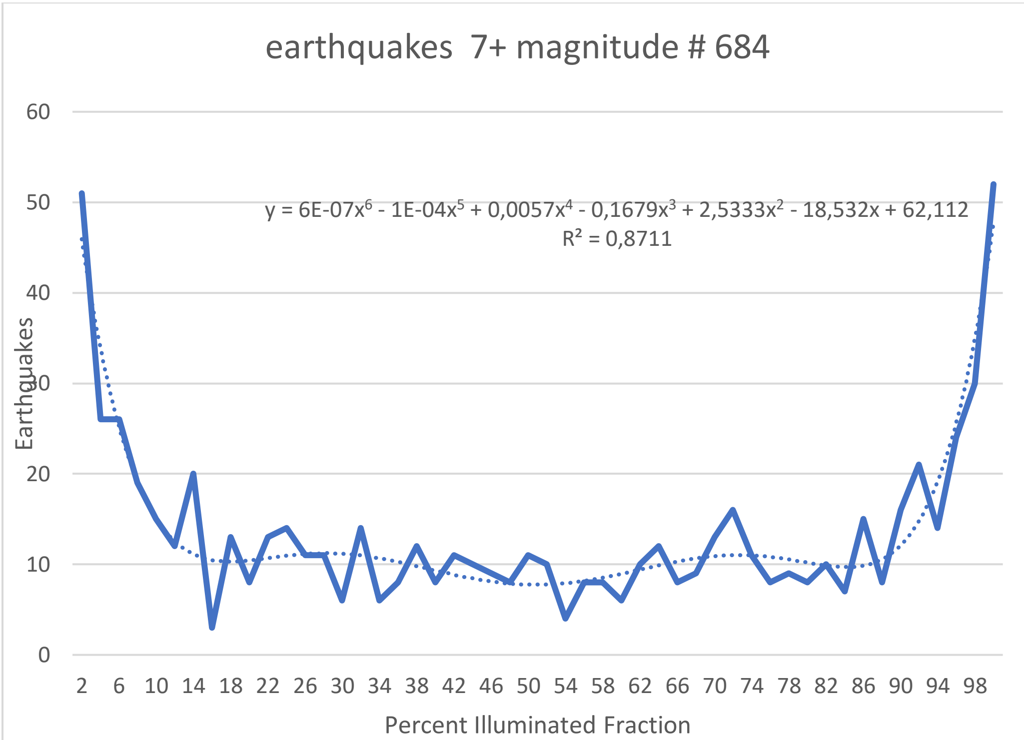
Thus in looking at the mean synodic month for the 50 years of USGS for just magnitude 5 and greater you see the following graph:



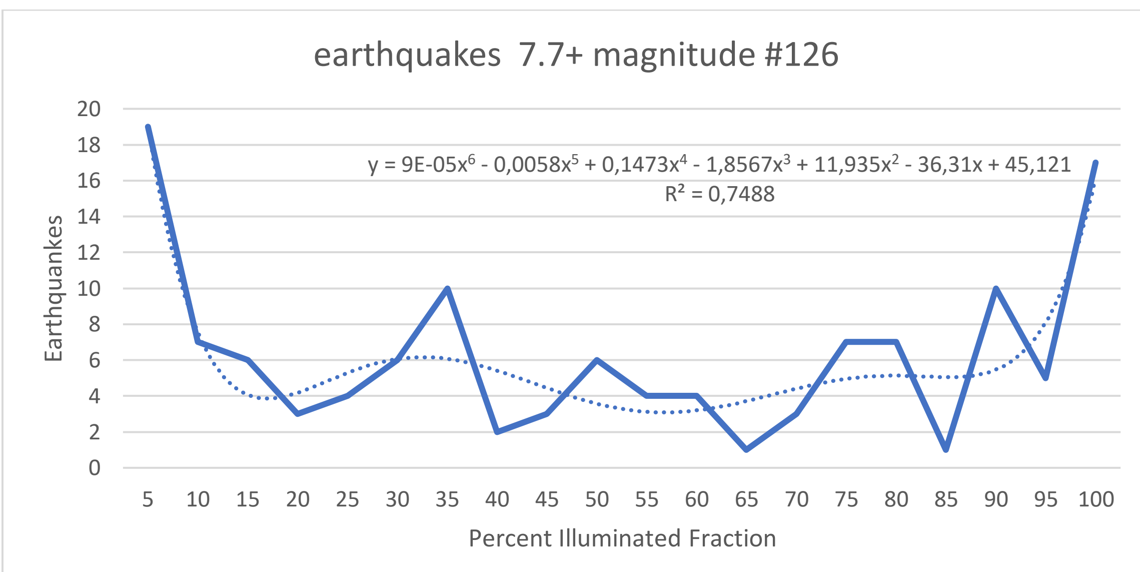
As well as for earthquakes magnitude 6+ for the 50 years:



As well as for earthquakes magnitude 7+ for the 50 years:



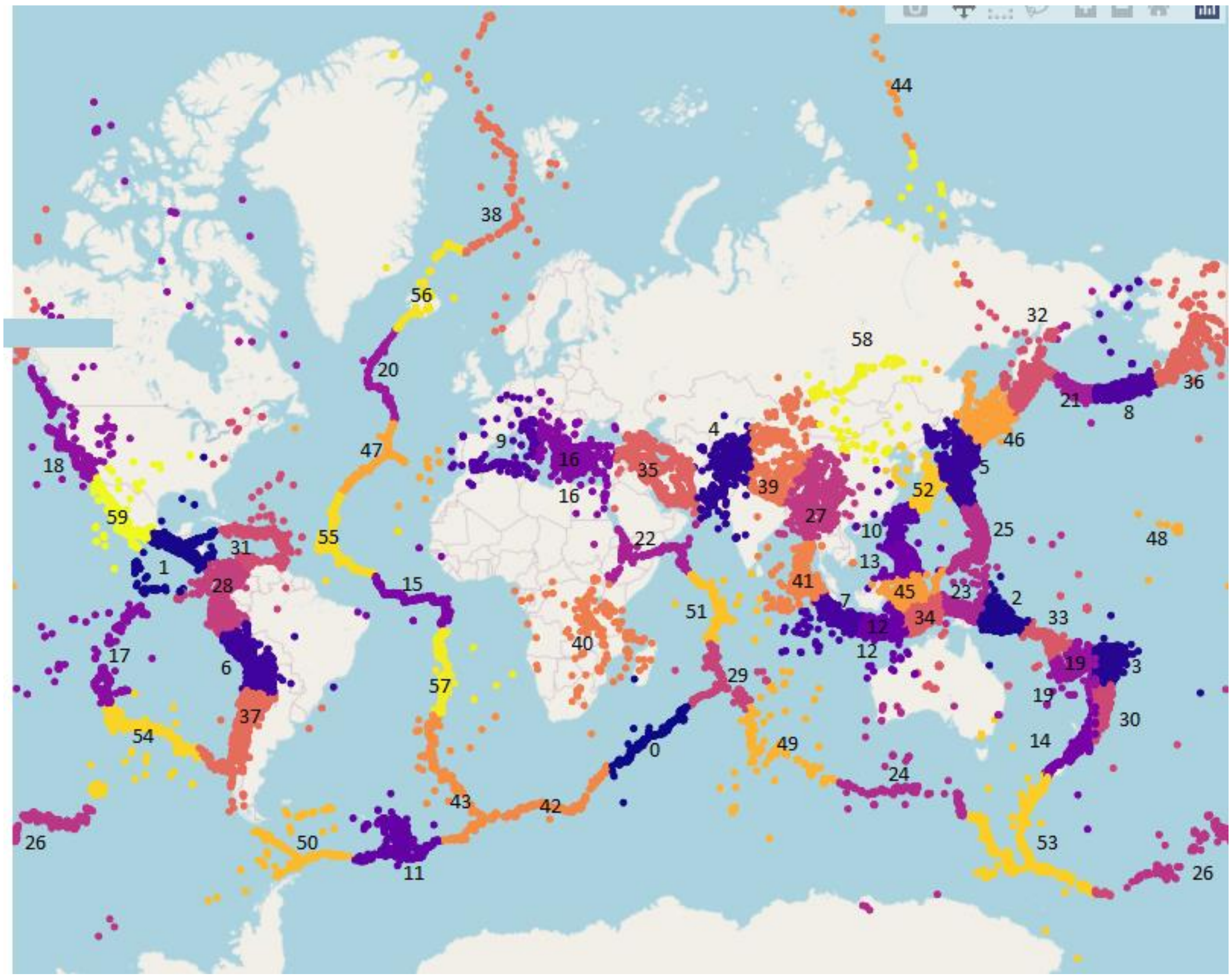
And even for earthquakes greater than 7.7 + magnitude, there is a strong relationship between the synodic lunar phase and the number of earthquakes:



Because of the fewer earthquakes at the greater magnitudes over 7.5 magnitude, one earthquake can greatly sway the data as evident of the peak when the illuminated fraction of the moon was 33 % during the great Tohoku-Oki earthquake on 11 March 2011. Once there is 300-400 years of data , one might see a smoother curve relationship similar to those above with the peaks remaining at the new and full moon periods.

Not just time but place also responds to the mean synodic month cycle.

It is not just an average over the entire Earth that there is an effect of the lunar and solar synodic month phases. Everywhere on Earth, all the 60 different individual groupings, earthquake frequency responds to the mean synodic month cycle.



This map shows the 60 different cluster locations as defined by the K-means algorithm. Here you can see each of the mean synodic month graphs of earthquakes magnitude 5 and greater for each different cluster:

https://drive.google.com/drive/folders/1lD9HS0F_0NQbFMOA3-m7Hm0D58mUc0p1?usp=drive_link

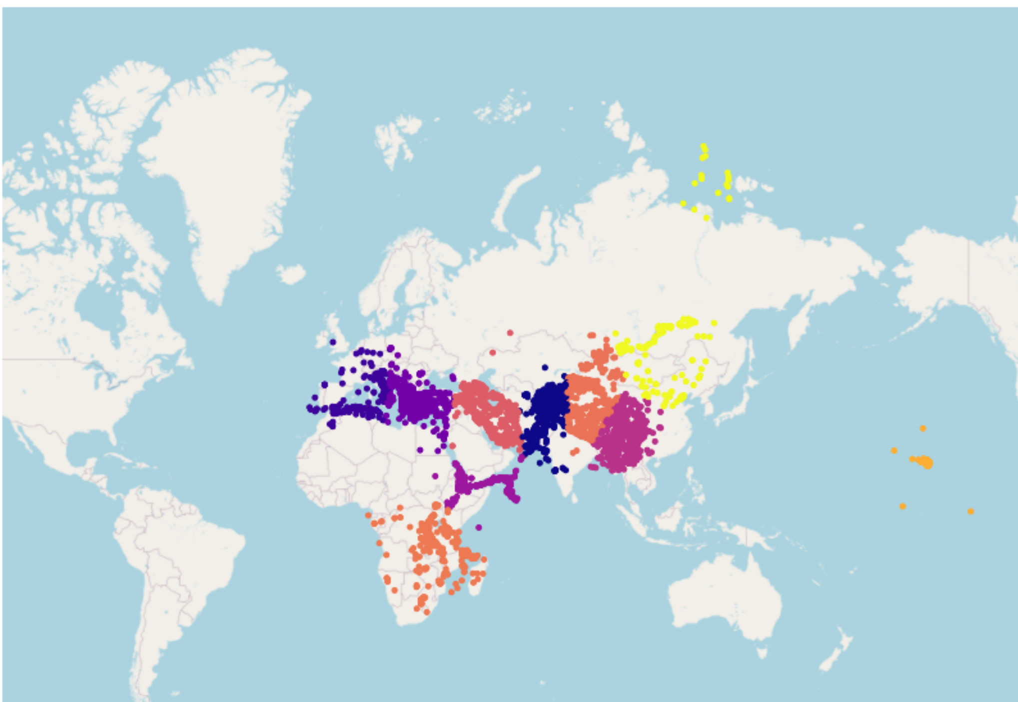
All the graphs include all the earthquakes from 1973 thru 2022 at magnitude 5 and greater. You can see the list or click to see the icons in a grid form. Smaller earthquakes below 5 magnitude were discarded due to the known lack of complete data from 1973-1996. Also notice group cluster # 5, Japan, as it again highlights how one large earthquake can drastically alter the graph.

The magnitude 9 earthquake in Aceh, Indonesia occurred on the full moon, cluster graph # 41 as well as the 8.8 magnitude Bio Bio earthquake in Chile , cluster graph # 37.

A case study from the project:

Dr Doglioni in Polarized Plate Tectonics, http://www.mantleplumes.org/WebDocuments/Doglioni2015.pdf, writes that, "The tidal forces are too small to generate earthquakes within continental areas, and for this reason they have been disregarded for long time." Dr. Doglioni is writing about the diurnal effects of the lunar tides, not the mean synodic month of lunar phases. Here is the map of the earthquake group clusters located on the continents:

```
In [168]: # Plot map on negative trendline cluster
          ######## you must want to change these piece of code ########
          clusters_toplot = list(negative_trend.keys()) # [48,8,46,18] for example
          clusters_toplot = [9,16,35,4,39,27,58,40,22,48]
          ##############################################################
          plot_map(df, clusters=True, specific_clusters=clusters_toplot)
```



As you can see in the following graphs, there is a relationship between the mean synodic month and the frequency of earthquakes on the continental lithosphere:

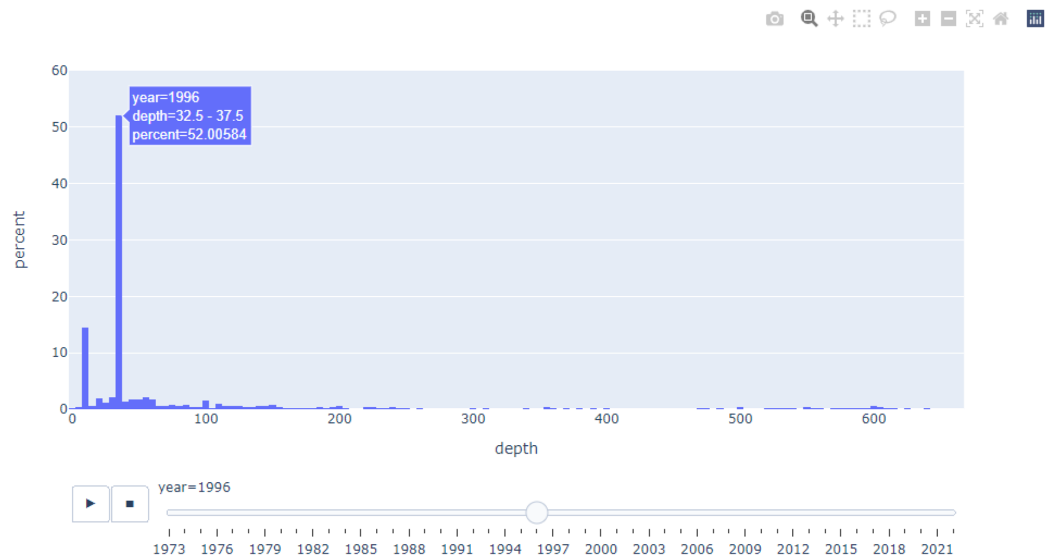
https://drive.google.com/drive/folders/1qGBmM5t3gIiqXV4ebstwHa2_rCj2HgHf?usp=sharing

Another case study of the project reveals the changing depth of earthquakes over the most recent 50 years:

Up until 1996, the animated data shows that for earthquakes magnitude 5 and greater, more than 50% occurred at within the average depth of 32-37 km.

```
In [30]: histogram_animation(df, var="depth", histnorm="percent",animation_frame="year", nbins=300,
                             range_x=None, range_y=[0,60] )

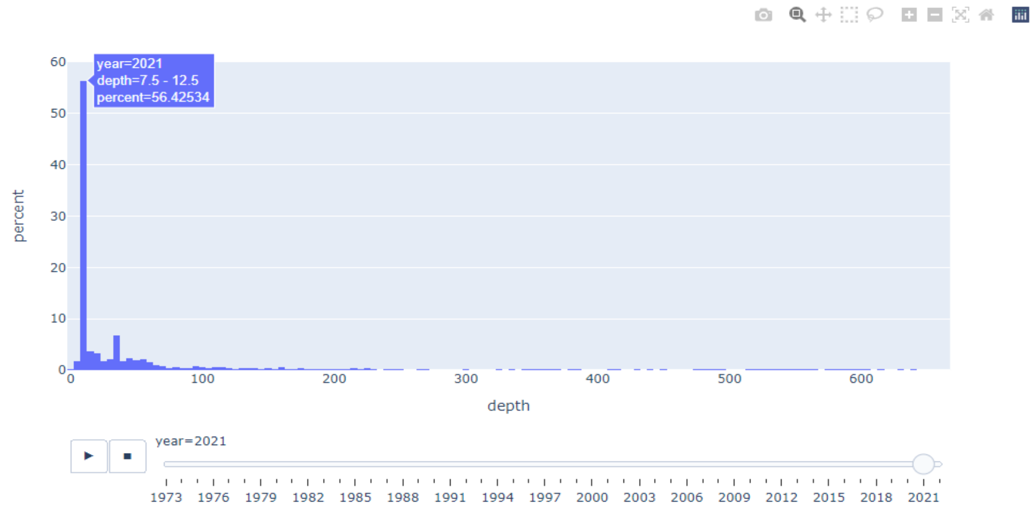
         # nbins if you want by default write None.
         # range_x and range_y by default None, and will be like it was before, if you want to change set a list with two numbers
         #animation_frame="MAG_SEG", "PERIOD", "YEAR"... any column name of categories
```



Between 1973 and the mid 1990's the majority of earthquakes occurred between 30-40 km, but then in the early 2000's something changed as the program illustrates how 56% of earthquakes now occur at the shallower depth of 7-12 km, the example being 2021 but also for the past 15 years when viewed by the project's animated histogram.

```
In [30]: histogram_animation(df, var="depth", histnorm="percent",animation_frame="year", nbins=300,
                            range_x=None, range_y=[0,60] )

         # nbins if you want by default write None.
         # range_x and range_y by default None, and will be like it was before, if you want to change set a list with two numbers
         #animation_frame="MAG_SEG", "PERIOD", "YEAR"... any column name of categories
```



Discussion

This lunar-solar-earthquake relationship project demonstrates there continues to be an interaction between the moon, the sun and the lithosphere regarding the frequency of earthquakes despite what the geophysical literature might say otherwise. An R^2 of > 0.9 indicates a strong relationship between earthquakes occurring more frequently during the new and full moon periods.

Since the 1990's many geophysicists have described the earth's lithosphere is a Self organizing system in a complex state of which the original concept was first described in 1987 by Per Bak , Chao Tang , and Kurt Wiesenfeld .
https://archive.ph/20130704122906/http://papercore.org/Bak1987

The recent thinking regarding the Earth's lithosphere is that it is a Self-organized system in a critical state. However;

"The critical point of a self-organized system is also known as the "edge of chaos," which implies that at this point, any external change can push the system toward either deterministic or chaotic behavior." Self-Organized Criticality in Earth Systems STEFAN HERGARTEN 2002 Springer, New York; ISBN 3-540-43452-6

The "edge of chaos" cannot endure for 200,000,000 years as is the current empirical evidence of the earth's rate of seafloor spreading or possibly for the more than 2-3 billion years of plate tectonics, depending on when one thinks plate tectonics initiated within the lithosphere. Only some form of a clock can regulate such a measured response of seafloor spreading for 200 million years and possibly for billions of years. This lunar-earthquake project shows that the

"mean synodic month" has a relationship with the sun, the moon and the earth and the frequency of earthquakes which could possibly be such a timing mechanism. (It is interesting to note that the "mean synodic month" tide is not even considered a major harmonic tide component even though it is responsible for spring tides twice monthly and perigean or king tides several times a year. The king tide project began in Australia in 2009 and has been expanded throughout the world by organizations now alerting coastal areas to king tides and educating those interested in the fact that king tides will become the new normal with sea level rise.)
https://coastadapt.com.au/sites/default/files/case_studies/SS28_The_Witness_King_Tides_project.pdf

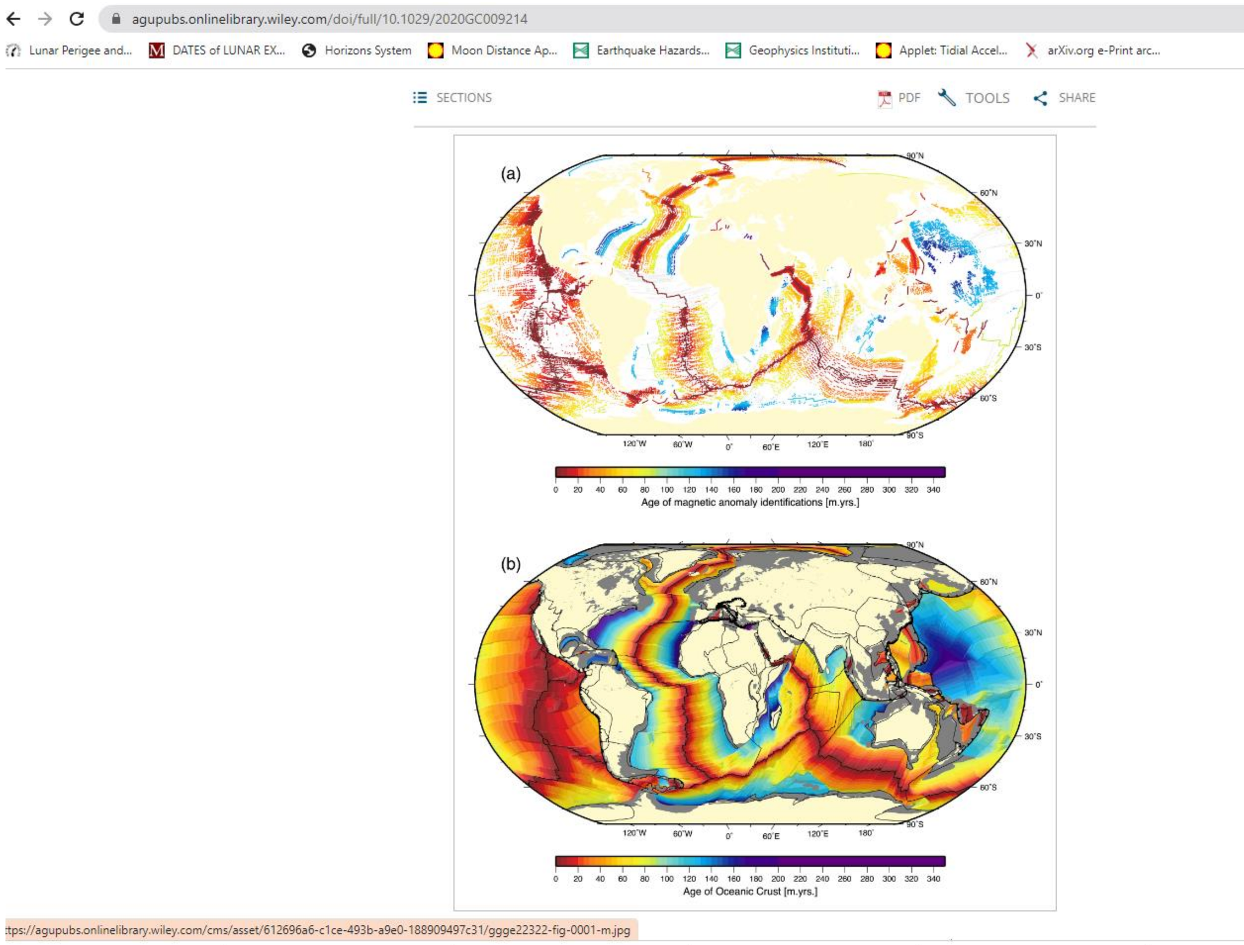
Seafloor spreading: Is Lunatectonics the clock regulating seafloor spreading ?

The wonderful work below, https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020GC009214, clearly illustrates that seafloor spreading occurs over 100's of millions of years in a precise, regulated and controlled manner. Geophysicists have yet to postulate what governs this consistent process. In other words, what is the clock that synchronizes the rate of seafloor spreading over 100's of millions of years ?

Free Access

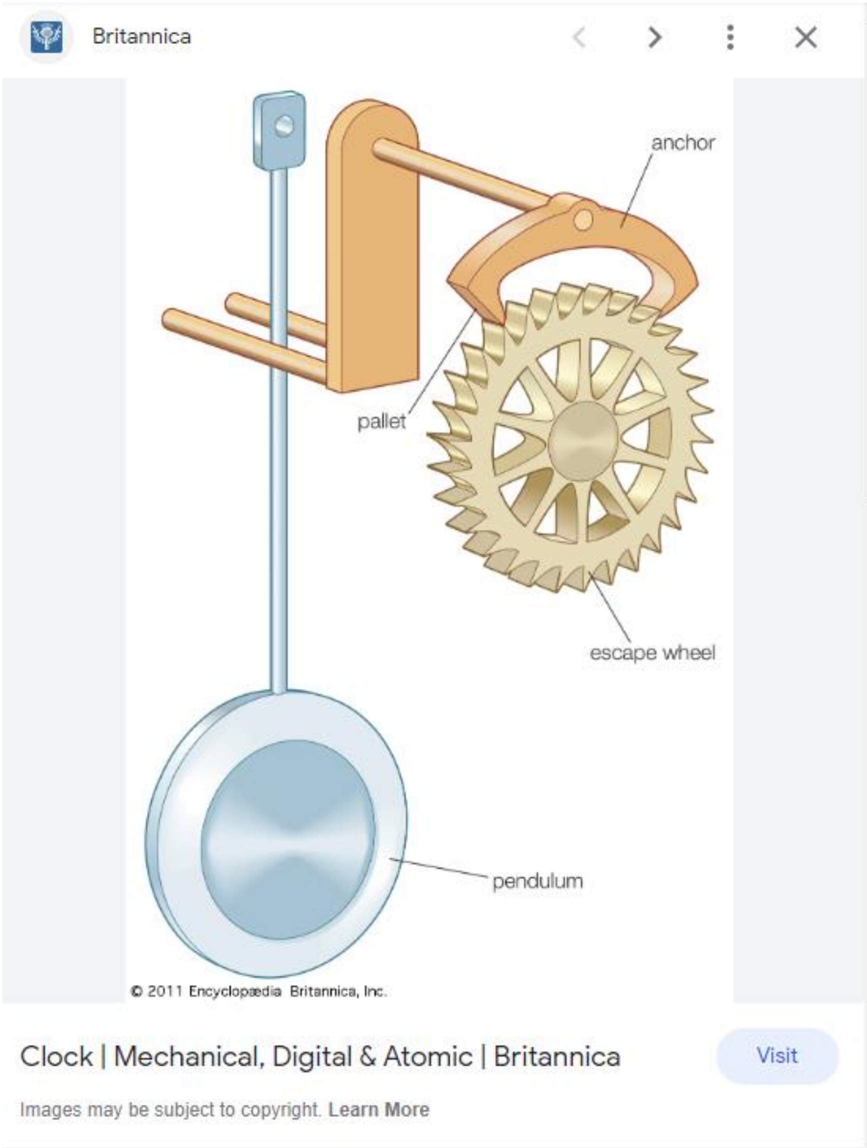
A Global Data Set of Present-Day Oceanic Crustal Age and Seafloor Spreading Parameters

Maria Seton, R. Dietmar Müller, Sabin Zahirovic, Simon Williams, Nicky M. Wright, John Cannon, Joanne M. Whittaker, Kara J. Matthews, Rebecca McGirr
First published: 17 September 2020
https://doi.org/10.1029/2020GC009214
Citations: 81



Mechanism:

The mean synodic month of lunar phases would be such a clock. The New and Full Moon cycles act as a pendulum anchor mechanism squeezing the earth biweekly in a stronger and stronger grip culminating in spring tides. But the mean synodic month cycle lasts for 3-5 days at a time surrounding each new and full moon, not hourly as in diurnally, and has not been investigated until now.



https://www.britannica.com/technology/clock

The mean synodic month of new and full moons acts as the pendulum, squeezing the earth over an ever changing cycle of roughly 18.6 years. This squeezing action will be better illustrated further through an application developed by Ingo Berg at his website: https://beltoforion.de/en/contact/

Further evidence of the squeezing action of the mean synodic month is noted in the relationship of the equatorial bulges of the planets within our solar system .

unf.edu/~n00006757/astronomylectures/equatorial%20bulges.htm

planet	% bulge	rotation period (Earth days)
Jupiter	6.5	0.42
Saturn	9.8	0.45
Neptune	1.7	0.67
Uranus	2.3	0.72
Earth	0.3	1
Mars	0.6	1.03
Pluto	0	6.4
Mercury	0	59
Venus	0	244

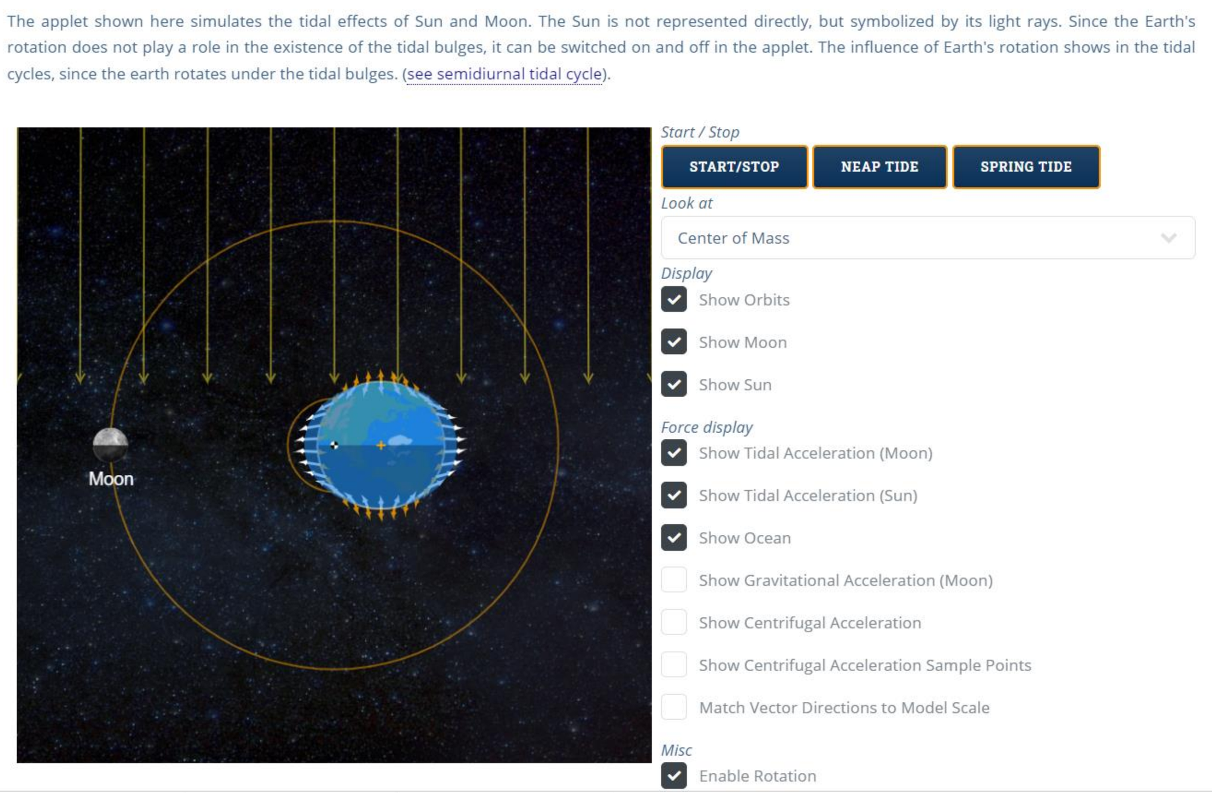
https://www.unf.edu/~n00006757/astronomylectures/equatorial%20bulges.htm

The percentage of equatorial bulge is due to the rate of spin of the planet, those that rotate faster have a larger equatorial bulge. Notice how Venus of all the planets barely rotates and has no equatorial bulge, remaining a completely perfect spheroid. Mars and Earth rotate at approximately the same rate yet Mars's equatorial bulge is double that of Earth's. Mars has two very small moons, the Earth has one significantly larger one which has been squeezing Earth's equator continuously for billions of years. Thus, is this why Earth's equatorial bulge is just half of that as seen on Mars ? Since Earth's lithosphere is very thin and fractured compared to Mars, shouldn't it have an even larger equatorial bulge than Mars if the equatorial bulge is due solely to the planet's speed of rotation ?   Can the squeezing of the earth by all the different tidal actions as well as by the mean synodic monthly tidal force explain the smaller Earth equatorial bulge as well as possibly how plate tectonics function on Earth? As tidal forces are proportional to the distance between the objects, the squeezing of the earth would be greater when the moon was closer. What would have been Earth's equatorial bulge 500 mya when our Moon was just one half its current distance ? Would the equatorial bulge have been even smaller than it is today and how would that squeezing of magma up into the mid-ocean spreading centers affect the lateral movements of the plates ?

An excellent visualization of the synodic monthly tidal cycle is available here: https://beltoforion.de/en/tides/simulation.php#idMixed

During the Neap tides, the tidal forces of the sun and moon are perpendicular to each other, cancelling out the effects of the other to the point that the combined tidal acceleration can actually be less than the effects of the sun alone.

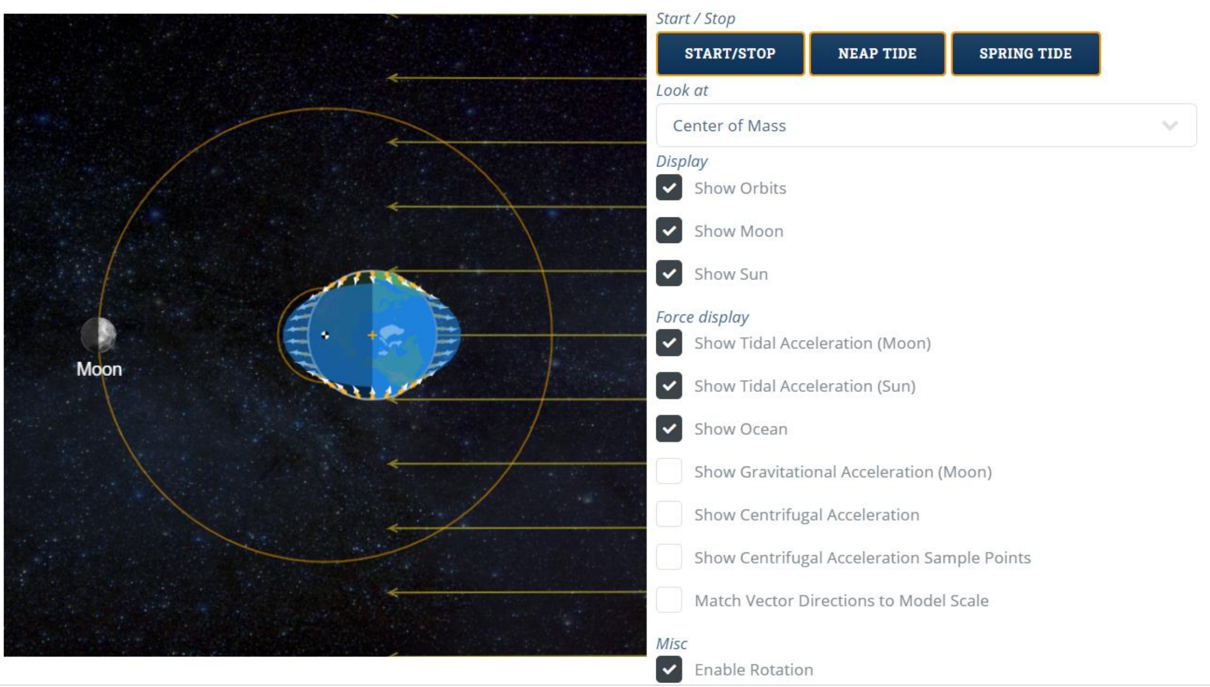
This application beautifully illustrates a Neap tide alignment of the moon and the sun:



When the moon is at first and last quarter, its illuminated fraction being 50%, is when the combined tidal acceleration force is at its nadir, when the tidal forces are perpendicular to each other. It is interesting to note that of the 39 magnitude 8 and greater earthquakes in the USGS catalog since 1973, none have occurred during the first or third quarter phase.

And here the same application illustrates Spring tides of the new and full moon:

The applet shown here simulates the tidal effects of Sun and Moon. The Sun is not represented directly, but symbolized by its light rays. Since the Earth's rotation does not play a role in the existence of the tidal bulges, it can be switched on and off in the applet. The influence of Earth's rotation shows in the tidal cycles, since the earth rotates under the tidal bulges. (see semidiurnal tidal cycle).



As one can see, the tidal forces producing the larger effect of the Spring tides are parallel and exert a stronger squeeze on the earth, not just of the oceans, but on the physical earth itself. This squeezing on the lithosphere of the earth has gone on for billions of years, and continues to occur to this day. When the moon and sun are in alignment in the new and full moon phase of the mean synodic month, the mantle magma at the mid-ocean spreading ridges is squeezed up into the space between the lithospheric plates pushing them apart by microns at a time as illustrated by the horizontal heat flow at the mid-ocean spreading centers. It has been well documented that the sheeted dikes formed in the section within the spreading ridge cool faster on the side furthest from the spreading center. Spreading at the mid-ocean ridges occurs in different places and different rates on the earth as the earth rotates through these periods of greater tides. But over the perigean cycle, currently 18.6 years, this would be averaged over the entire Earth. Things that affect or regulate the perigean cycle are the changing declination of the moon, from -28° to +28° latitude as well as its variable orbital distance between 356,000 kilometers and 406,000 kilometers. As if to complicate things further there is also a cycle within the moon's declination that changes from -28° and 28° latitude, to -18° and 18° latitude called the Major and Minor Lunar standstill.

Once every 18.66 years, the ascending node coincides with the vernal equinox, and the Moon will reach declinations of about +28° and -28° (more than the Sun, which reaches ±23°, (the angle of the earth's axis to the ecliptic); this is called a 'major lunar standstill'. In the major lunar standstill the moon changes declination from -28° to +28° latitude on earth every two weeks, while in minor lunar standstill, approximately 9 years between the Major lunar standstills, the declination only changes from -18° to +18° latitude every two weeks. The changes from Major to Minor lunar declination standstill can be easily visualized in this project available on Github.

Thus the moon and the sun continue to play a role in the horizontal movement of the lithospheric plates. The approximately biweekly alternation of the squeezing force of the mean synodic month acts on the earth as the pendulum of a clock and thus regulates the rate of seafloor expansion. This also explains why the seafloor spreads at faster rates in some plates on Earth rather than with other plates. As is evident with the rate of seafloor spreading, the fastest moving plates are those that are subducting, (inducting would actually be a preferable word). As the mid-ocean ridge associated with these subducting , (inducting) locations do not have continents to push against, the squeezing of the tides produce more seafloor faster and push it faster across the surface of the earth as there is only the earth's mantle density pushing back as the seafloor is pushed in to the mantle. It's curious how subducting slabs have been described as one of the main driving mechanism of plate tectonics, yet many descending slabs have been shown to be actually descending at a slower rate than the plate that it is supposedly pulling. Thus, how can the engine of the system be going slower than the train being pulled behind it ?

Conclusions

The analyses of this python data analysis project illustrating the relationship between the mean synodic month and earthquake seismicity indicate that there remains a connection between the sun, the moon and our lithosphere across the entire lithosphere for the duration of the 50 years of USGS data.

In private emails, Chris Hawkesworth said that geophysicists would consider the effects of the moon if there was any evidence of such an effect. The author hopes this current project presents enough evidence of a current effect between the sun, the moon and the earth that geophysicists will reconsider the prior work of Darwin, Joly, Wegerer et al.

For almost 100 years the moon's affects upon the present lithosphere have been discounted and discredited whenever addressed. George Darwin noted in 1879 that, "In the "remote past," were the Earth and Moon to have been in closer proximity, because the screwing actions varies as the sixth power of the Moon's distance, and the rotation rate of the Earth was then greater, the deformation might by now be prominent." Thus when the moon was just $1/10^{th}$ its current orbital radius, the screwing action of the moon would have been 1,000,000 times stronger than today; when the moon's orbit was just half its current radius approximately 0.5 billion years ago, the screwing action of the Moon would have been 64 times greater than today. This quote has been included in many books from The Earth by Sir Harold Jeffreys to Polarized Plate Tectonics by Carlos Doglioni et al. To date no one has detailed when the screwing actions nor tidal effects of the moon and sun supposedly ceased as the evidence presented by this project continues to indicate a strong relationship still persists between our moon, the sun and Earth.

Further research: Are the mid-ocean ridge elevated spreading centers the anti-roots of the continental roots ? How did cratons become continents ?

Acknowledgments: To Jurgen Giesen for sharing his wonderful lunar and solar data, to the United States Geological Survey for making their seismic database available online. To Biwiser Analytica; particularly to Nicolas Salgado, Olivia Tamboryn and Andres Erlandsen for their time, patience and support in bringing this project forward. To Carmen Lorena Guerrero for her support and kindness listening to my thinking out loud. To Jayne Zimmerman and Cher Franklin-Owen, two geologists whose support and encouragement more than 15 years ago and since have sustained the project when everyone else said leave it to the experts, an expert of which the author has yet to find and continues in the quest.

Conflicts of Interest: The author reports no conflicts of interest .

Video class on the Moon-Earthquake python project :

Conflicts of Ideas in Geophysica :

References: Further Reading

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Treatise de Geofisica: Voluma 6

“ We must know the law satisfied by the rate of change we are using as our standard. “ Jeffreys