TITLE

Temporal correspondences in the period 1905-2023 between the bradyseismic trend at Campi Flegrei, the periods of lunar Culminations with Altitude above 75° and the New Moons in Perigee orbiting on the boreal segment delimited by the meridians +1° and +25°

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ABSTRACT

The Campi Flegrei are an extensive volcanic area west of Naples subject to slow vertical deformation of the ground.

The accelerations of the phenomenon which occurred in the periods 1950-1952, 1969-1972, 1982-1984 resulted in an overall uplift of just under 4 metres.

It is shown how in the period 1905-2023 the most relevant ascending phases of phlegraean bradyseism, except two, took place during the periods of lunar Culminations with a Altitude greater than 75 degrees (**Fig. 1B**) after which the ground has decreased or more in general it has not undergone considerable changes: from 1905 to 2023, excluding the 1982-1984 and 2010-2021 windows, every period of lunar Culminations with a Altitude lower than 75 degrees can be aligned with an subsidence (**Fig. 2**).

Two ascending phases do not align with the periods of highest Moons, but the first (1982-1984) was anticipated and accompanied by a peculiar sequence of 3 New Moons High in Super and Extreme Perigee orbiting at the peak of the sygytial phase over the Central Europe and the second took place during an configuration (extensive and unique) of some Elevated New Moons in Perigee over Italy (**Fig. 3**) in the central period (2013-2018) intermediate (2010-2021) to the two periods 2003-2009 and 2022-2028 with maximum Culminations (**Fig. 1B**). It is highlighted how the distribution over time of the 24 most relevant Moons, in gravitational and geometric terms (**Fig. 3**), corresponds to concomitant bradyseismic phases of proportionate importance.

By far the most intense bradyseismic phase, that of 1982-1984, corresponds to the largest concentration of Major Moons and the most moderate and prolonged uplift phase (2005-2023) corresponds to an extensive distribution of "Central European" High New Moons in Perigee only Minimum.

It is shown how these 24 Moons (which will be called Major Moons here as they are simultaneously the highest New Moons in the local celestial vault, the closest to the Earth and the most attractive because combined with the gravitational force of the Sun) are not to be considered isolated but always accompanied, before and after, by a harmonica of Elevate Moons in Super and Extreme Perigee.

INTRODUCTION

The Campi Flegrei are an extensive volcanic area west of Naples subject to slow vertical deformation of the ground. The accelerations of the phenomenon which occurred in the periods 1950-1952, 1969-1972, 1982-1984 resulted in an overall uplift of just under 4 metres. The ground uplift, between the years 1970 and 1972, led to the total eviction of Rione Terra. The phase between the summer of 1982 and the very first days of 1985 was characterized by a high rate of ascent of 3 mm per day and by 16,000 total earthquakes of magnitude 0.4 - 4.2 which forced the authorities to order the evacuation of approximately 40,000 people. After 20 years of general subsidence, a constant and gradual ground uplift followed which began in 2005 in the absence of frequent and strong tremors until the years 2016/2018 when the frequency of earthquakes progressively increased, in particular from 2022 (**Fig. 15**).

Observing the trend of the vertical deformation of the ground at the Campi Flegrei from 1905 to today, if the serious crisis of 1982-84 had taken place a few years later (3 - 4) it would have been possible to find an evident periodicity of the most relevant bradyseisms with frequency average close to 19 years (**Fig. 1A**). Given that, 1) each daily lunar passage at the local meridian is capable of raising the ground by several centimeters for an extension equal to several nations combined, 2) the lunar nutation cycle is equal to 18.6 years, 3) the role of Earth tides is widely debated as a relevant controlling factor of a variety of geological processes, including seismicity, volcanism[2] and the dynamics of tectonic plates[3], it is reasonable to assume that the cause of the vertical deformation of the Phlegraean soil is the Moon. Over the course of a month, the Moon in Pozzuoli exceeds the Height of 75 degrees in the celestial vault, or not. Over time, periods of lunar culminations above 75 degrees (with an average duration of 6-7 years) alternate with periods of lunar culminations below 75 degrees (with an average duration of 11-12 years). These periods appear to be concomitant with the phases of uplift and subsidence of the Phlegraean soil. The apparent discrepancy of the 1982-84 period can be coherently interpreted.

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1   The Scientific Council of the Raffaele Bendandi Municipal Geophysical Observatory of Faenza is made up of University Professors, Senior Researchers and Research Directors (CNR, INAF, INFN, INGV, OV) (https://www.osservatoriobendandi.it/wp-content/uploads/2021/04/Consiglio-Scientifico-1.pdf)
2   Sottili G, Palladino DM (2012) "*Tidal modulation of eruptive activity at open-vent volcanoes: evidence from Stromboli*" Terra Nova
3   Zaccagnino D, Vespe F, Doglioni C (2020) "*Tidal modulation of plate motions*" Earth Science Reviews
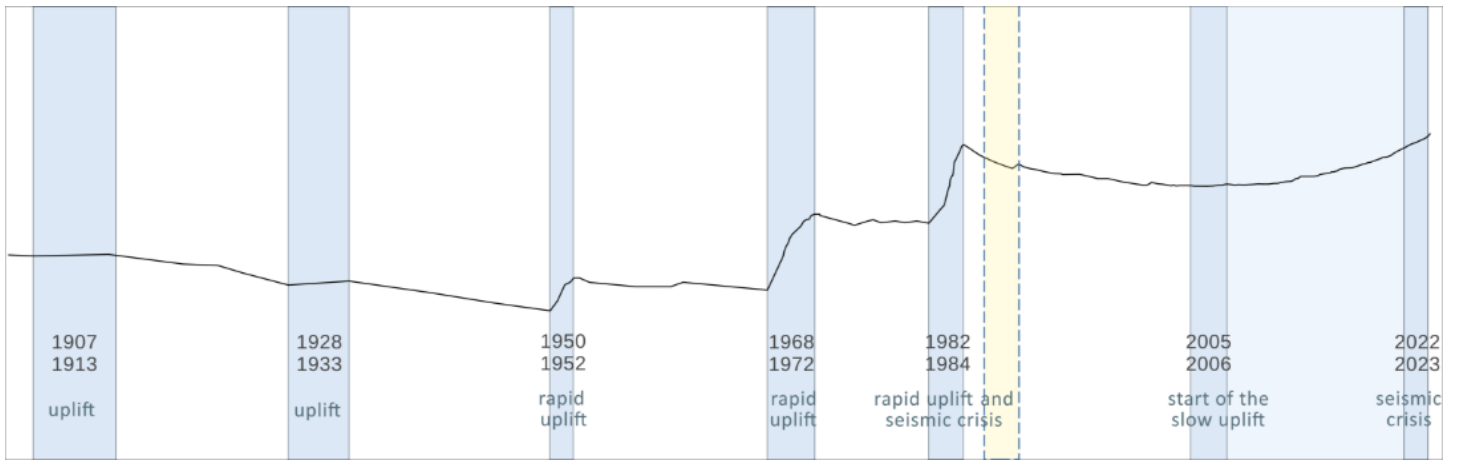
Figure 1A *Postponing the 1982-84 crisis, it is possible to detect on the graph an average periodicity of the most relevant phases close to 19 years*
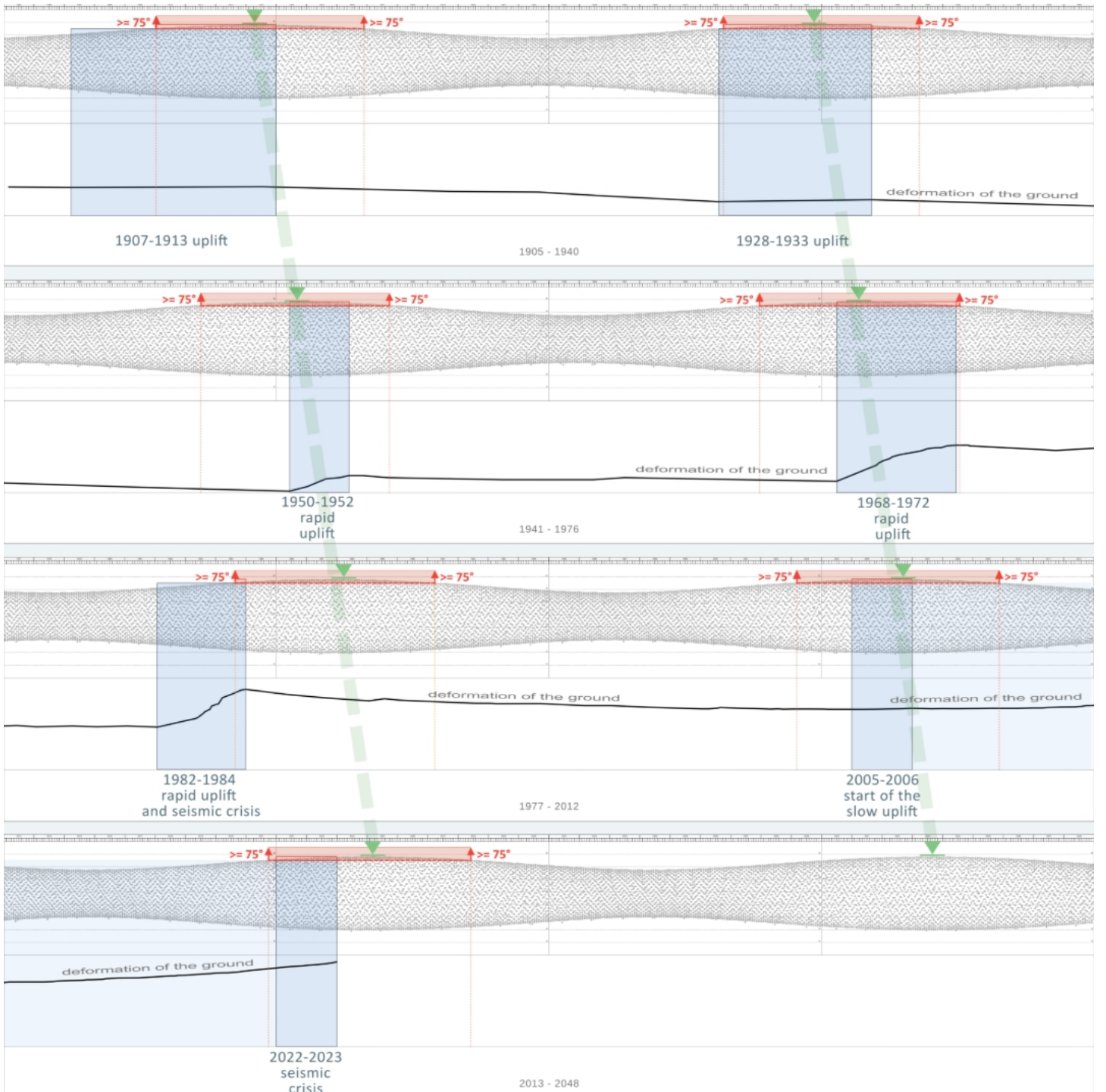
Figure 1B *Daily lunar Culminations at the Pozzuoli meridian in the period 1905-2048 and bradyseismic phases at Campi Flegrei from 1905 to 2023*

Figure 2 *Daily lunar Culminations at the Pozzuoli meridian in the period 1905-2048 and intervals (in green) of general subsidence at the Campi Flegrei concomitant with the phases of lunar Culminations with a Altitude lower than 75 degrees in the years 1905-2023 Excluding the 1982-1984 phase, we can note a certain periodicity of the most relevant bradyseismic phases which can be matched to that of the lunar nutations, of the nodal cycle, equivalent to 18.6 years*
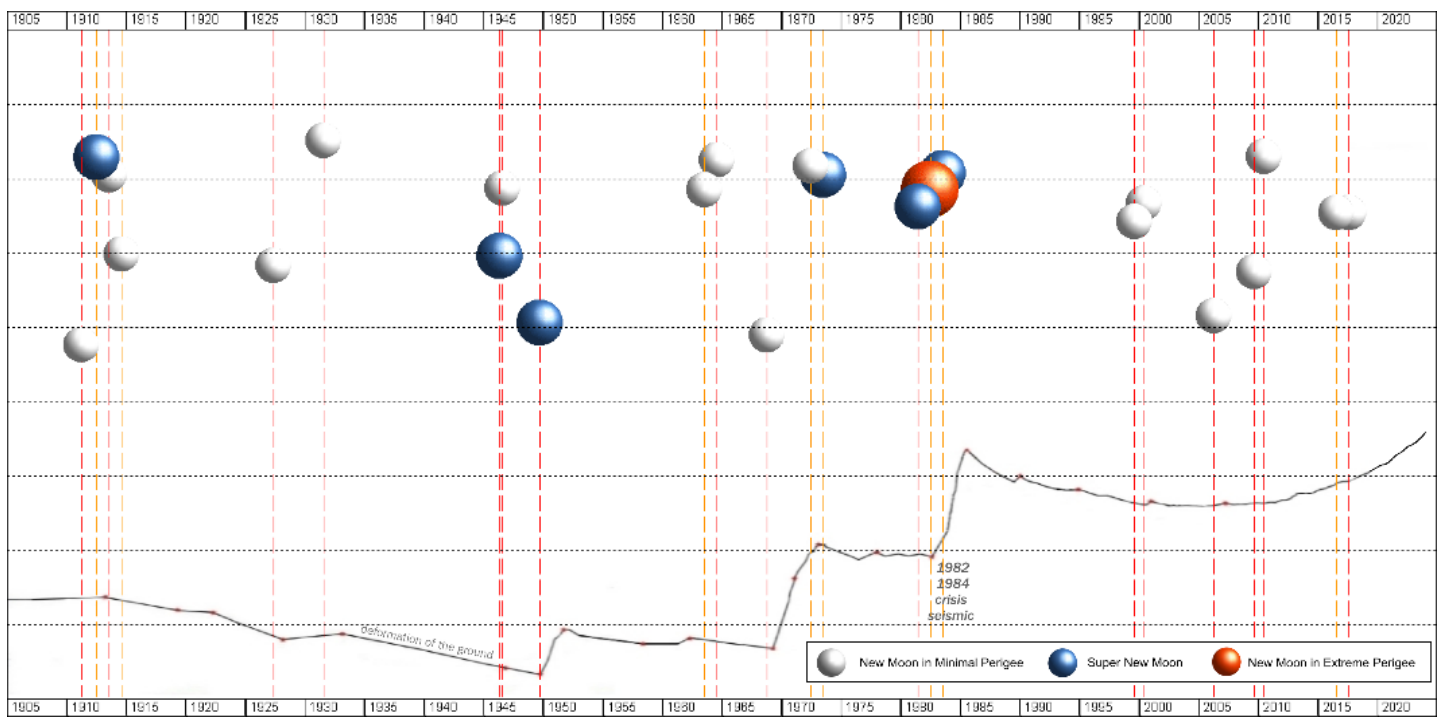
Figure 3 *"Majors" New Moons in the period 1905-2024 and bradyseismic trend at the Campi Flegrei between 1905 and 2023*

DISCUSSION AND RESULTS

The Moon crosses the local meridian every day when its elevation is maximum compared to the horizon. In Observational Astronomy, lunar Culmination is the Altitude (the angle of elevation above the local horizon) reached when the Moon transits the meridian passing through the observer (**Box 1**). The graph in **Fig. 1** shows how generally in the period 1905-2023 the most significant phases of phlegraean bradyseism correspond to the periods of lunar culminations of Altitudes above 75 degrees, how the ground slowly decreases, or more generally does not undergo significant changes, during the transits of the Moon to the local meridian with an Altitude lower than 75 degrees (**Fig. 2**).

The analysis will be gradual and structured in 3 steps: **A**, **B**, **C**.

(A) The four tapered shapes in **Fig. 1B** refer to the 4 periods 1905-1940, 1941-1976, 1977-2012, 2013-2048. They are made up of 52,596 Moons in daily transit, a number equivalent to the days contained between the years 1905 and 2048 inclusive. Each Moon for each day is positioned in the graph at the maximum Altitude reached, the upper limit which is reached when the Moon passes over the local meridian of Pozzuoli. The absolute maximum values reached during the periods (lasting 6-7 years) of lunar Altitudes above 75 degrees are indicated by the eight inverted green triangles while the two oblique dotted lines highlight the periodicity of the lunar nodal cycle equivalent to 18.6 years. The four boxes below them contain the trend of the ground level, its rise and fall; the periods of bradyseismic phases are indicated by the rectangles arranged vertically in grey-blue colour, as in the box below containing the trace of the complete bradyseismic trend and not divided as in the boxes.

The periods of lunar Culminations with Altitudes above 75 degrees, lasting on average 6-7 years (equivalent to the portions of the tapered shapes with concave upper parts), will be abbreviated here to [**MoonA>75P**], while the complementary periods of the average duration of 11-12 years to [**MoonA<75P**] (graphically these equate to the portions of the tapered shapes with the convex upper profile).

The New Moons, between Earth and Sun, which during the peak of the sygytial phase in an equatorial geocentric perspective orbit over Italy (with France and Greece partially included), on the northern geographical segment delimited by the Equator and by the semi-meridians of Longitude +1° (that cross Rouen , FR) and +25° (that cross Central Romania), will be defined here as **Central European Moons**.

Box 1 The first graph shows the lunar Culminations during the month of September of the year 1984 (chosen as a generic example), i.e. the maximum Altitudes reached each day by the Moon when transiting the local meridian of Pozzuoli. The second and third graphs show the compression of the same content which allows entire years to be graphed in less space as in the fourth image representing the lunar culminations in Pozzuoli in the period 1977-1989.
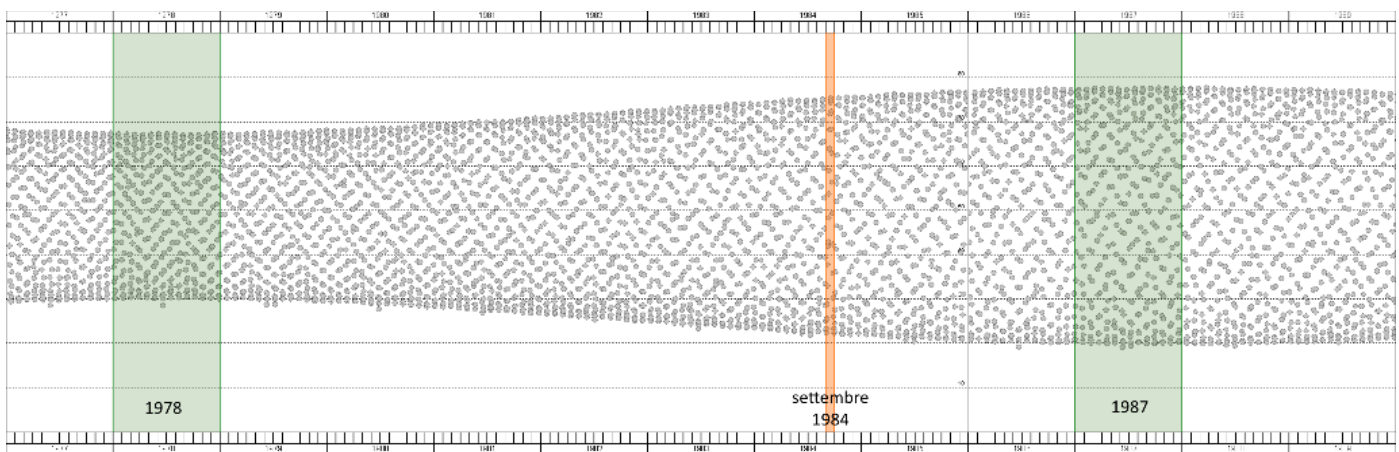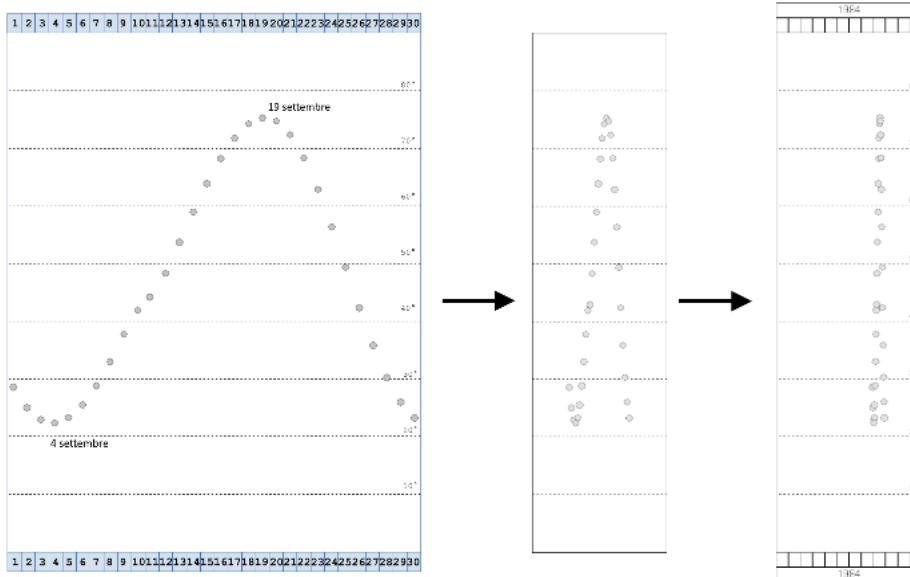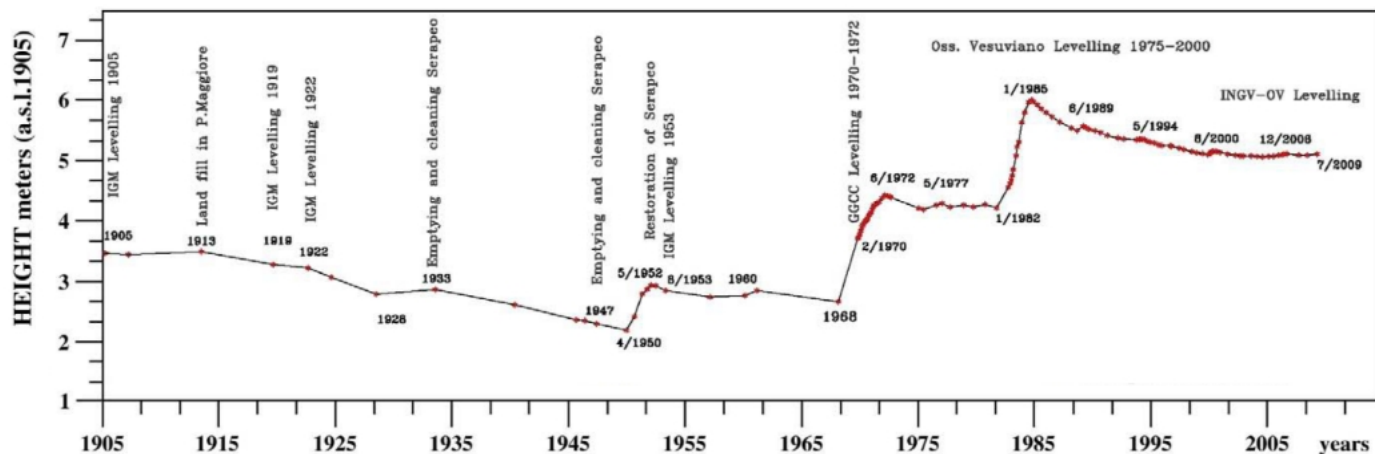
Box 2 *Soil deformation at the Campi Flegrei between the years 1905 and 2009*
(Vesuvian Observatory , National Institute of Geophysics and Volcanology, Naples section)

Box 3 From the year 1905 the most consistent phases of Phlegraean bradyseism, with the exception of the crisis of 1982-1984 and the slow uplift of 2005-2023, are concomitant with the periods with lunar Altitudes above 75 degrees, but every period with the highest Moons (for example example the interval 1986-1989) differs from its predecessors (for example the interval 1976-1980) due to a difference in maximum Altitudes of around only 10 degrees. A difference in lunar Altitude of around only 10 degrees, despite being physically modest, is instead decisive, as shown by the close concomitances between the various ascending phases and the highest Moons.

The next two graphs show, with respect to the local horizon, the lunar positions for each hour of the years 1978 and 1987 highlighted by two vertical boxes in the fourth graph of **Box 1**. The periods with extreme Altitudes are characterized by a greater distribution of the Moon, represented from each yellow point, in the local celestial vault. The years 1978 and 1987 are distinguished from each other by the different extreme lunar Altitudes reached, both lower and higher and by the percentage of local celestial space occupied by the Moon. They are similar in terms of lunar permanence at positive Altitude: in 1978 the total minutes were 260,612 (an average of 11.9 hours per day) while in 1987 they were 262,346 (equal to an average of 11.98 hours per day).
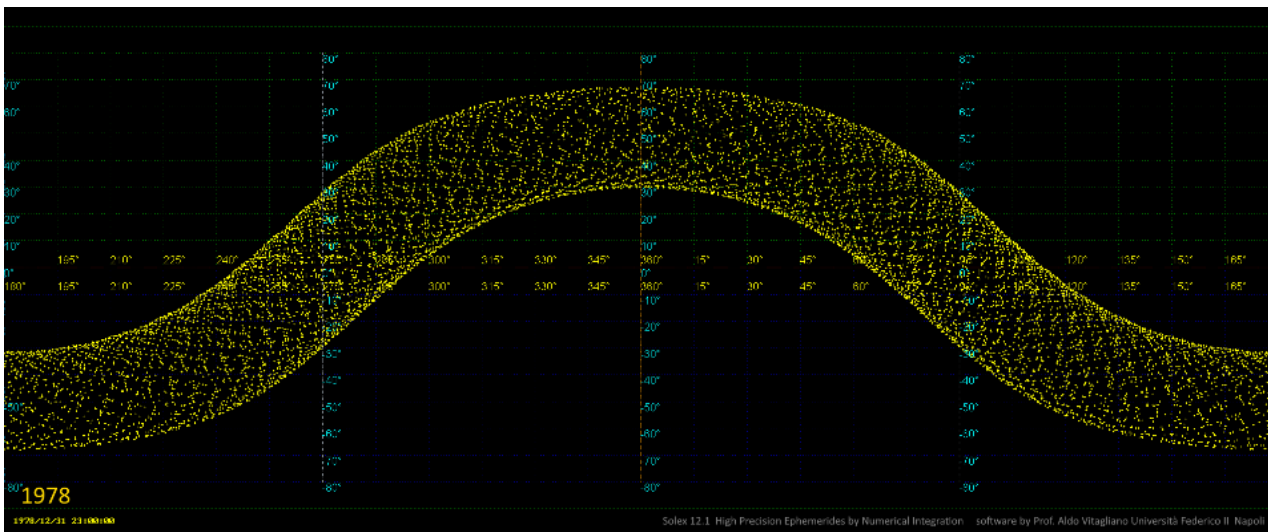
Box 3a *Positions at each hour of the Moon relative to the local horizon horizon of Pozzuoli (central horizontal red line) during the year 1978 (graph produced using the Solex 12.1 software www.solexorb.it)*
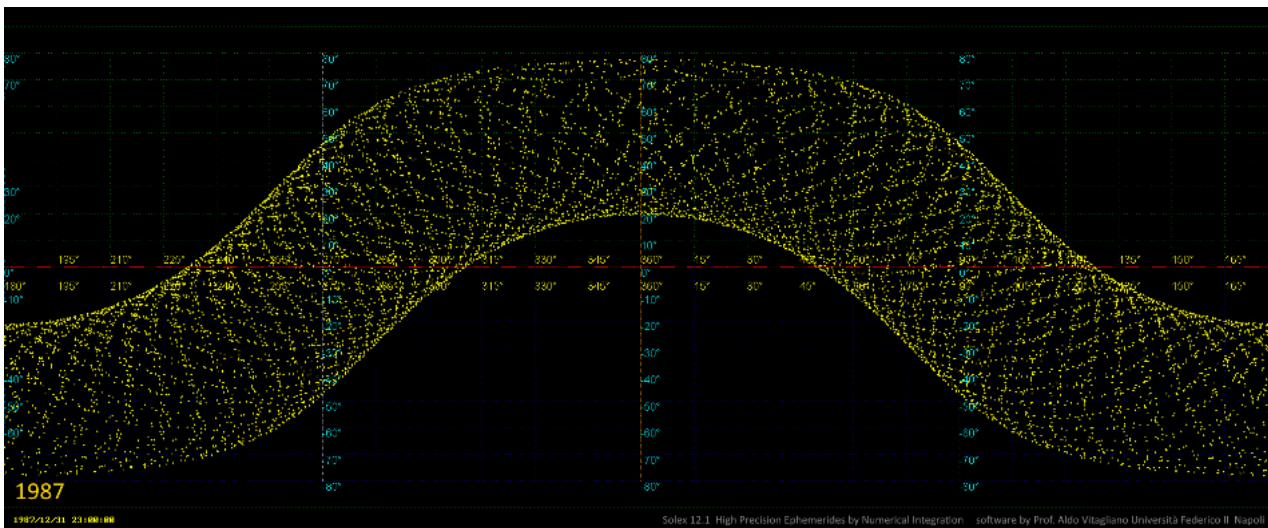
Box 3b *Positions at each hour of the Moon relative to the local horizon of Pozzuoli (central horizontal red line) during the year 1987 (graph produced using the Solex 12.1 software www.solexorb.it)*
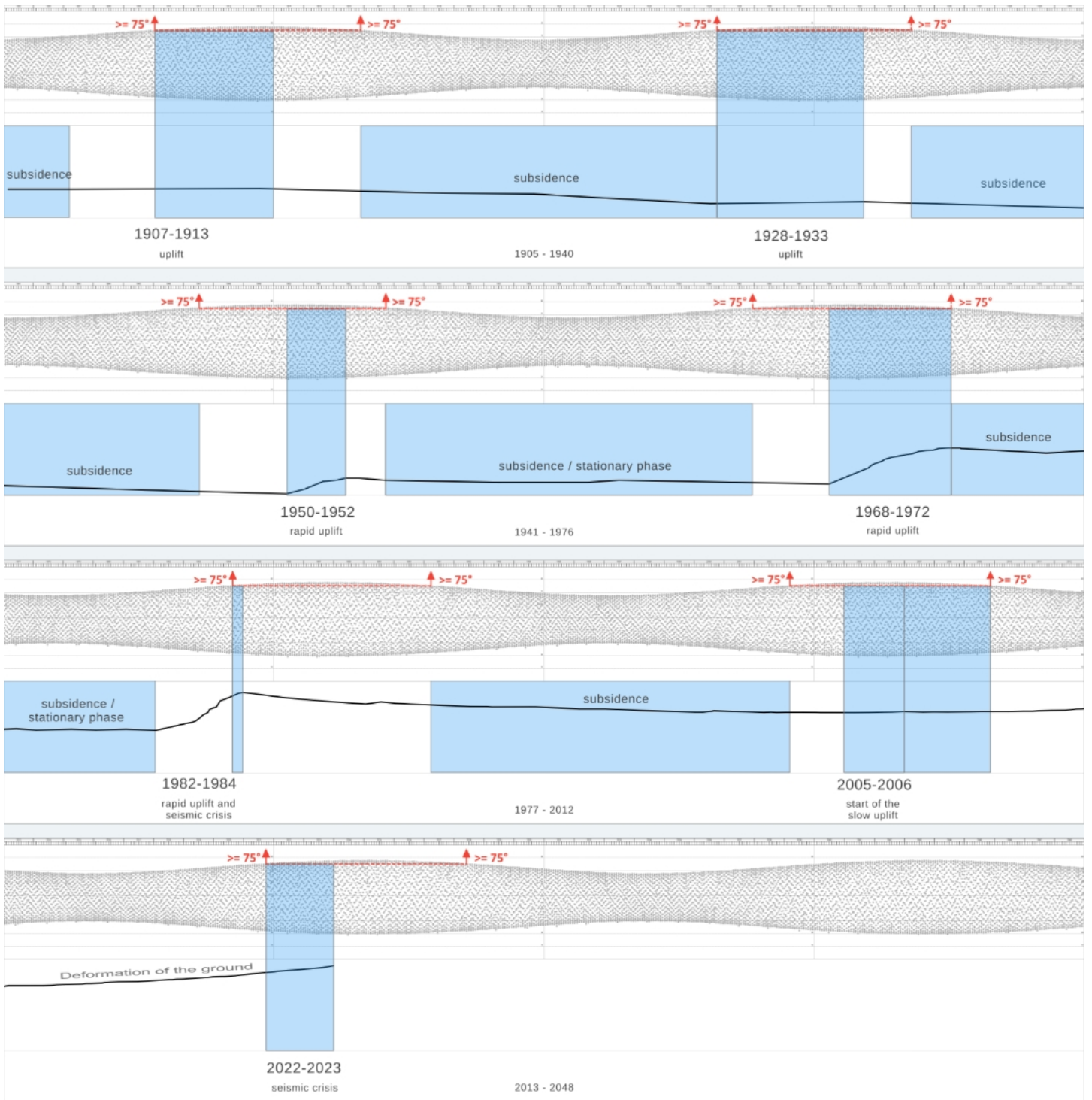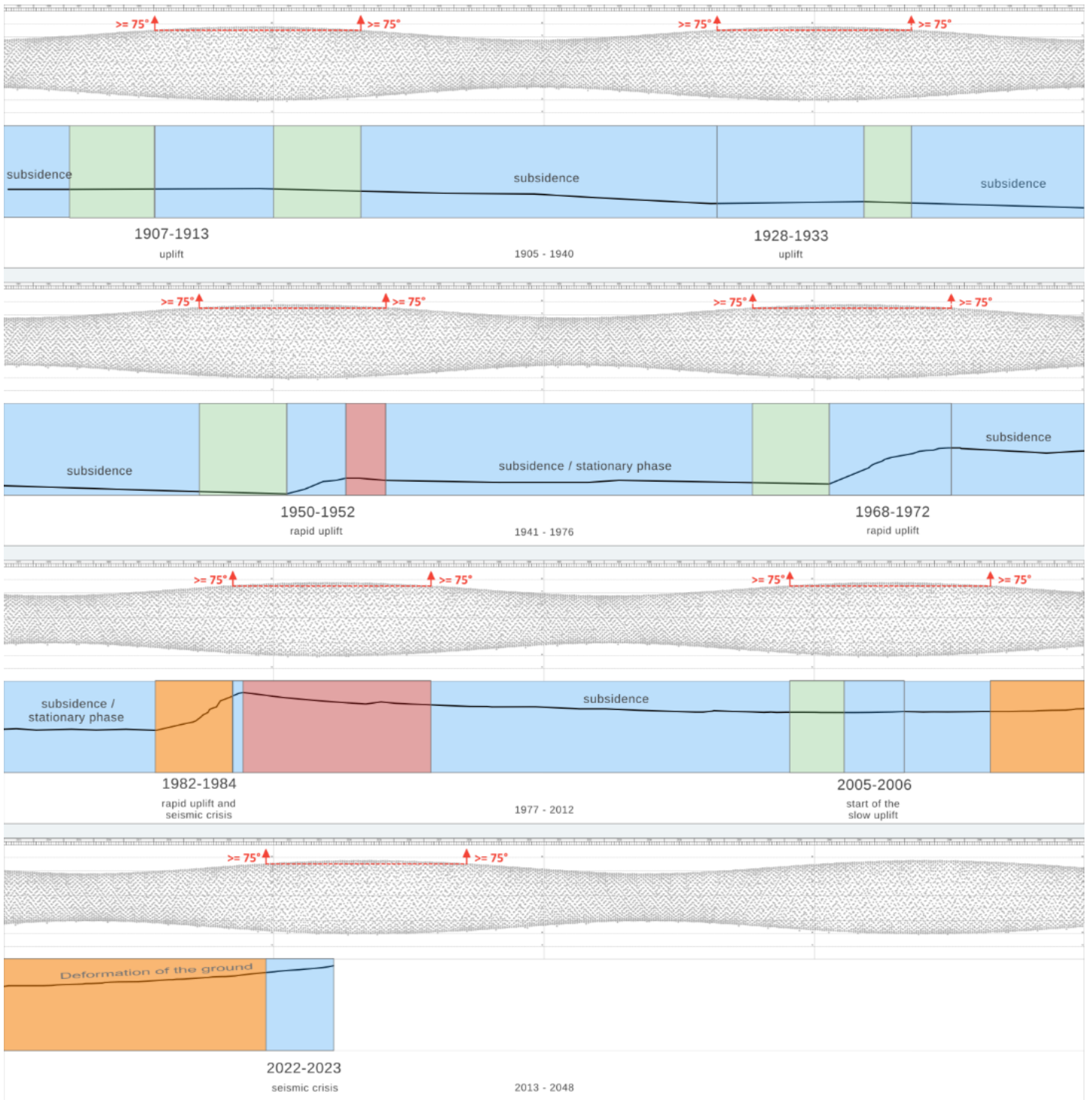
Figure 4a *Daily Culminations of the period 1905-2048 and highlighting the correspondences detected [MoonA>75P] / [Uplift] and [MoonA<75P] / [Subsidences]*

The correspondences detected [MoonA>75P] → [Ascending phases] and [MoonA<75P] → [Subsidences], both represented by the light blue squares in **Fig. 4a**, cover 69% of the period examined 1905-2023. The short intervals lasting no more than 3 years incompatible with the two types of correspondence, observable in **Fig. 4a** and represented in **Fig. 4b** by the light green colored squares, can reasonably be attributed to a non-immediate geological response of the subsoil and also , until the post-war period, to an insufficient frequency of measurements.

The discordance of the intervals following the two fast uplifts of 1950-1952 and 1982-1984 (represented by the amaranth colored squares in **Fig. 4b**), here is presumed to be attributable to a greater response of the soil, due to geological settlement.

Two other discrepancies in the correspondences of the type [MoonA>75P] → [Uplift] and [MoonA<75P] → [Subsidence], represented in **Fig. 4b** by two orange-colored squares, are observed: the seismic crisis of 1982-1984 and the slow uplift 2009-2021 (started in 2005 and still ongoing) are not aligned with periods of lunar Culminations with Altitudes above 75 degrees (See step **B**).

Figure 4b *Daily Culminations of the period 1905-2048 and highlighting the incompatible periods*
with the correspondences [MoonA>75P] → [Ground Uplift] and [MoonA<75P] → [Ground Subsidence]

(B) But up to this point the eccentricity of the lunar orbit has been overlooked, as if the Moon periodically did not move away and moved closer to the Earth (the Moons at the meridian in every previous graph have been uniformly represented by means of gray disks equal to each other). By distinguishing each daily Moon at the meridian by Earth-Moon distance, according to the 5 classes of the following table (**Fig. 5**), it is possible to differentiate MoonA>75P from each other. After the year 1930, only from the year 2008 (**Fig. 7f**) did they orbit Moons with Culminations with a Altitude greater than 75 degrees and lunar distances in Super and Extreme Perigee (the maximum expression of this kind of configuration can be observed in **Fig. 6a,** in the years 2043-2044 and 2062). Each box in **Fig. 6a** is bordered according to the color of the Moons inside. The red-edged boxes contain centered Extreme and Super perigee Moons, while in the amber boxes the latter are decentralized and in smaller quantities. In the boxes with Moons predominantly at apogee or at an intermediate distance, the border is light blue, while the frame is yellow in the case of a prevalence of Moons at minimum perigee compared to those at apogee and at an intermediate distance (the distinction between different types of boxes are more understandable by observing **Figs. 7a-7i**).

		Daily Moon (at the meridian) in Extreme Perigee	<= 357 400 km
●		Daily Moon (at the meridian) in Super Perigee	> 357 400 km and <= 359 600 km
●		Daily Moon (at the meridian) in Minimum Perigee	> 359 600 km and <= 373 500 km
○		Daily Moon (at the meridian) at intermediate distance	> 373 500 km and < 390 000 km
○		Daily Moon (at the meridian) in Apogee	>= 390 000 km

Figure 5 *Representation in disks of the lunar Culminations according to the Earth-Moon distance*
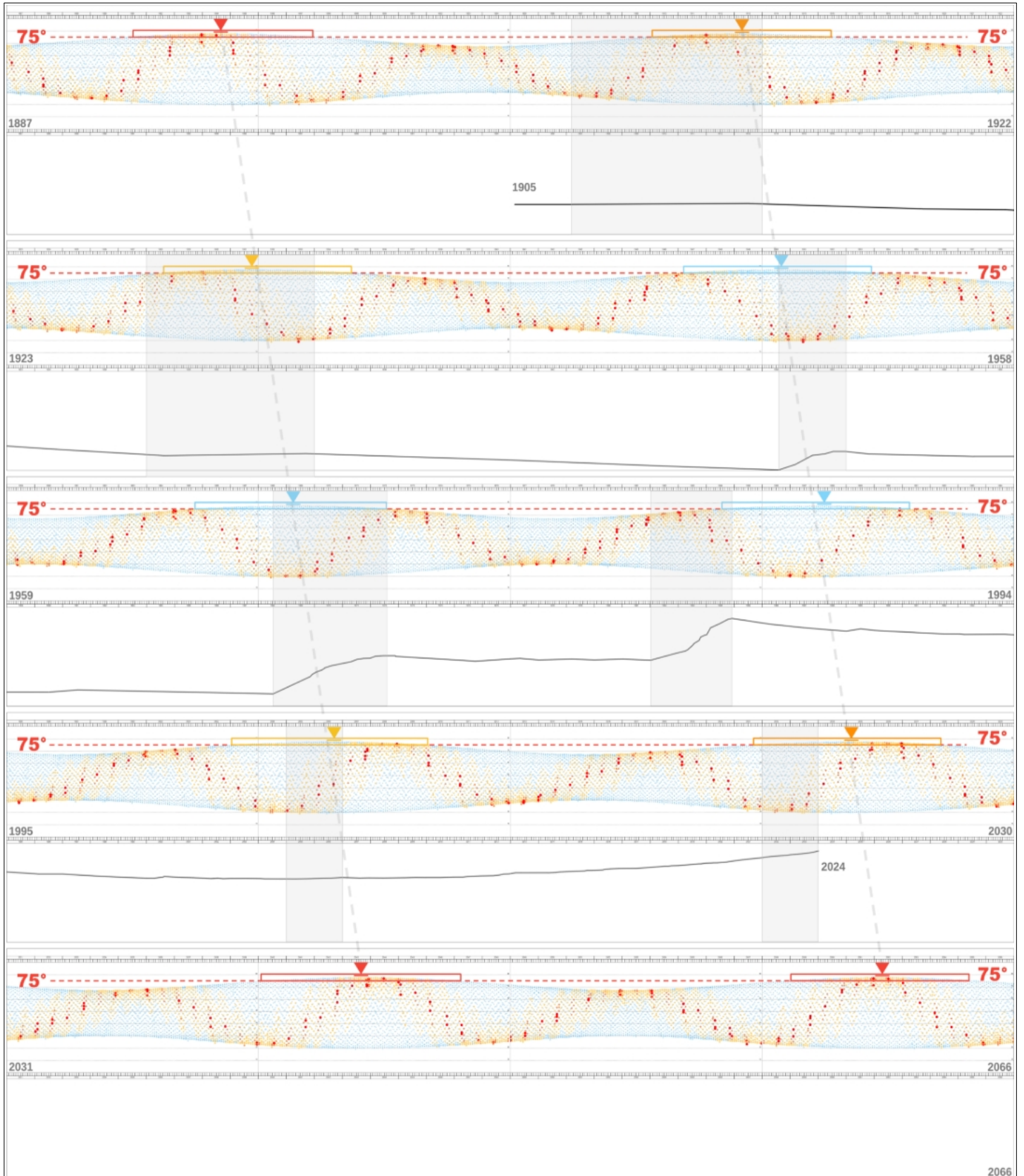

Figure 6a *Lunar Culminations differentiated by Earth-Moon distance in the period 1887–2066; periods of Culminations higher than 75 degrees highlighted by horizontal rectangles centered by the culmination (details in **Figs. 7a-7i**) and uplifts represented by light gray vertical squares*

The periods, here called **intermediate**, with the Culminations of Altitudes lower than 75 degrees (**Fig. 2**), to which the subsidences corresponded up to the year 2009 excluding the interval of 1982-1984, respond to the same periodicity of the time spans with the Altitudes above 75 degrees, centered at the peaks by the inverted triangles. This periodicity of the cycle of the lunar node line (equivalent to 18.6 years) is different from that, halved, of the apexes of the harmonic of the Culminations in Super and Extreme Perigee (**Fig. 6b**). The representation of the most central intermediate periods in **Fig. 6b**, limited to Altitudes between 60 and 70 degrees to improve readability, shows a greater presence of daily Culminations in Super and Extreme Perigee in the intermediate intervals up to the year 1921 and only at starting from 2016 (the maximum will be reached between the years 2052 and 2053). Here it is assumed that this gravitational reinforcement explains the inconsistency between the slow uplift and the period of Culminations with Altitude below 75 degrees from 2010 to 2021 inclusive. The period of subsidence, between the years 1985-1990 inclusive, concomitant with a phase with Altitudes above 75 degrees, is presumed to be caused by the very strong seismic crisis of 1982-1984 but also by the descending phase (1984-1986) of the harmonic of the Moons in Super and Extreme perigee (orange and red disks).
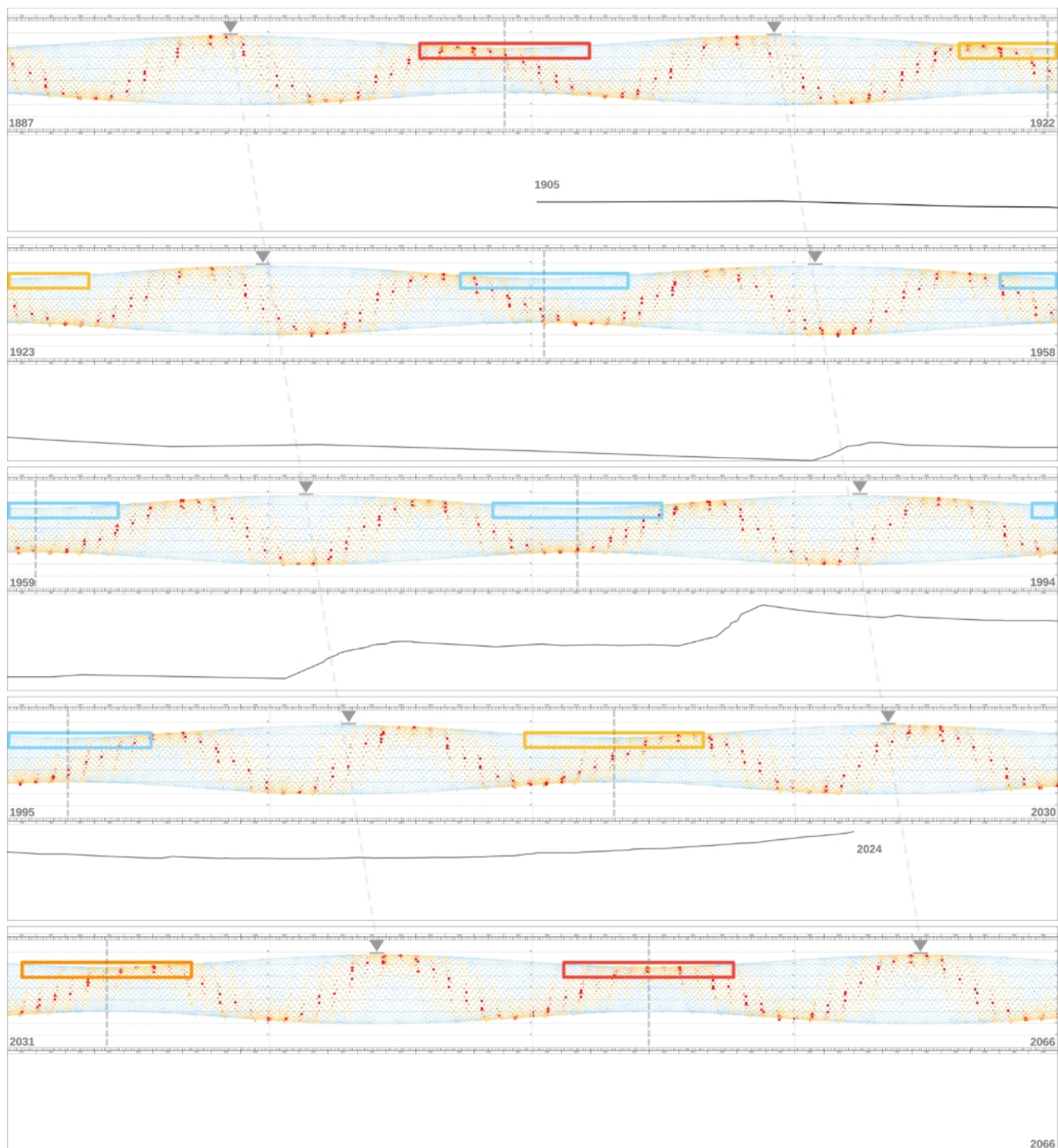
Figure 6b *Lunar Culminations differentiated by Earth-Moon distance in the period 1887 – 2066 and intermediate periods of Culminations with Altitude below 75 degrees*
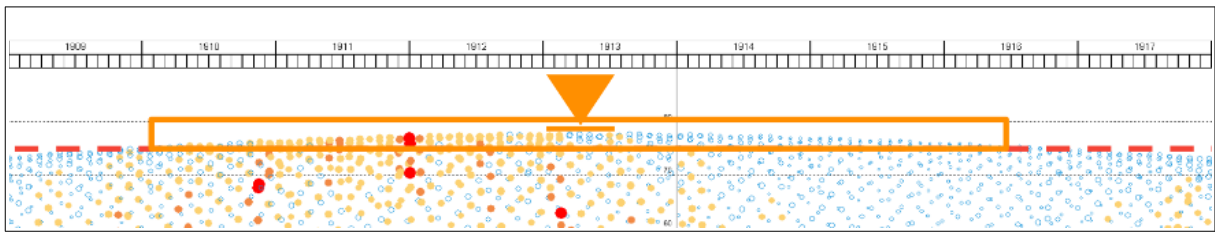
Figure 7a *Lunar Culminations of Altitude >= 75 ° framed and classified by Earth-Moon distance in the period **1909 – 1917***
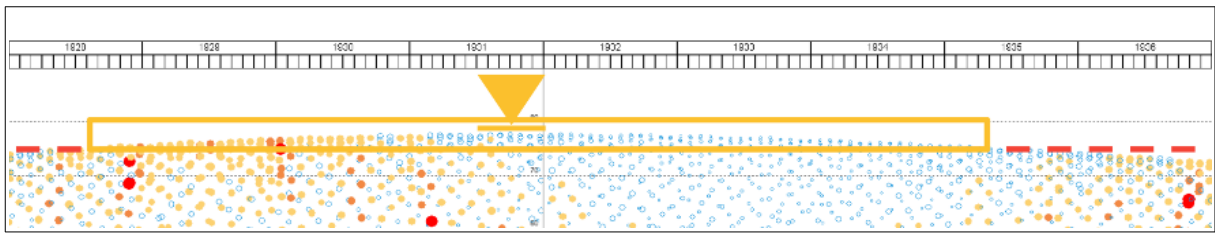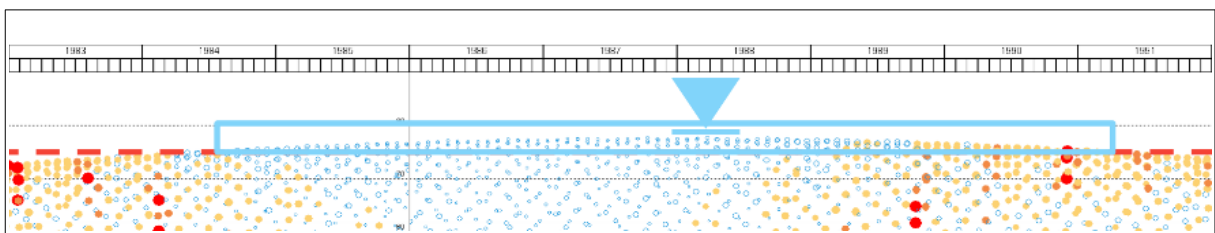

Figure 7b *Lunar Culminations of Altitude >= 75 ° framed and classified by Earth-Moon distance in the period **1928 – 1936***
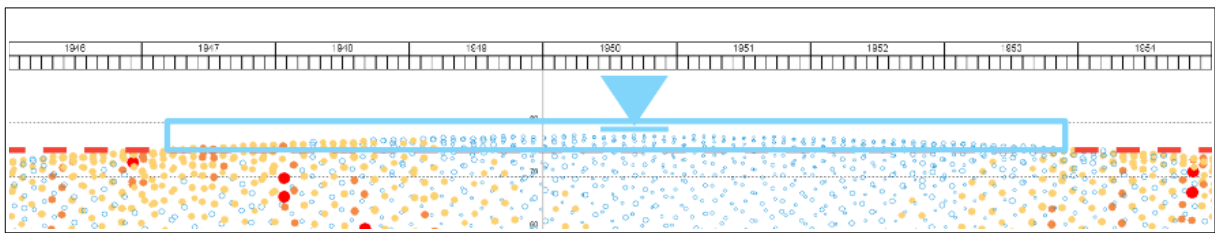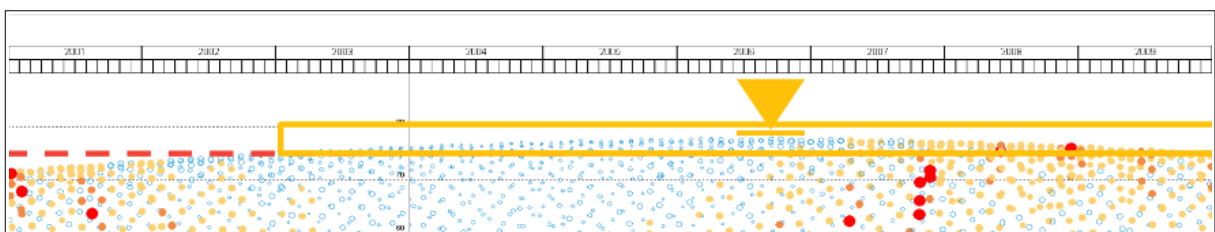

Figure 7c *Lunar Culminations of Altitude >= 75 ° framed and classified by Earth-Moon distance in the period **1946 – 1954***
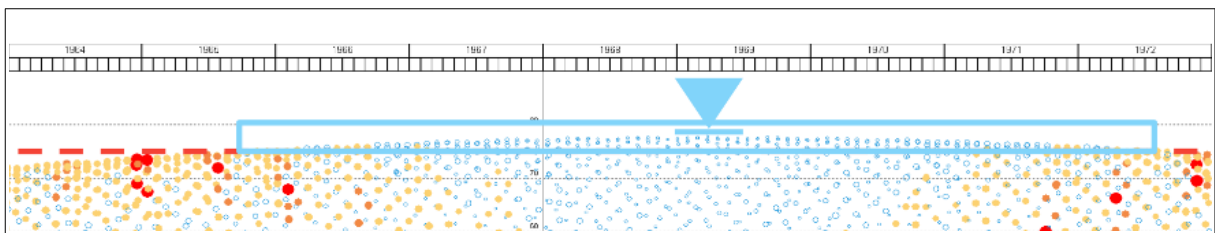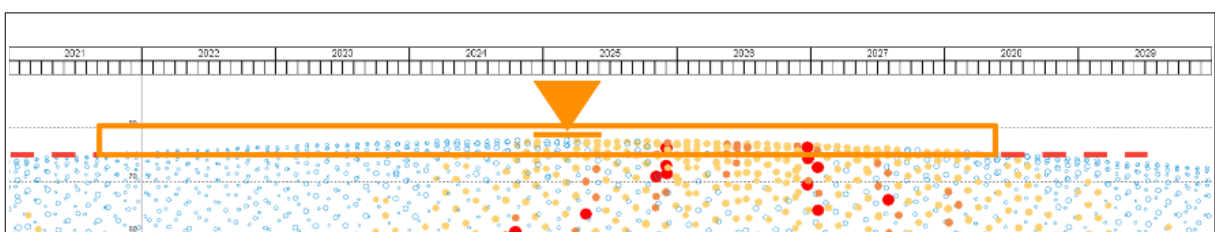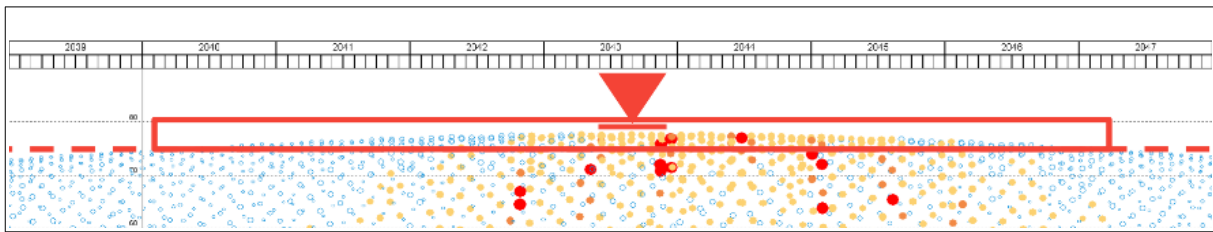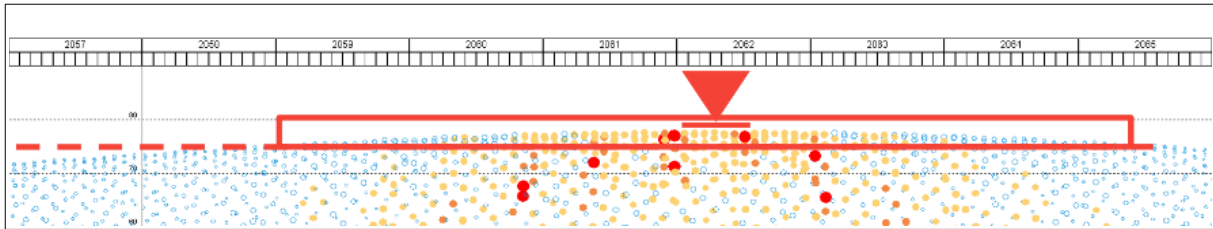

Figure 7d *Lunar Culminations of Altitude >= 75 ° framed and classified by Earth-Moon distance in the period **1964 – 1972***

Figure 7e *Lunar Culminations of Altitude >= 75 ° framed and classified by Earth-Moon distance in the period **1983 – 1991***

Figure 7f *Lunar Culminations of Altitude >= 75 ° framed and classified by Earth-Moon distance in the period **2001 – 2009***

Figure 7g *Lunar Culminations of Altitude >= 75 ° framed and classified by Earth-Moon distance in the period **2021 – 2029***

Figure 7h *Lunar Culminations of Altitude >= 75 ° framed and classified by Earth-Moon distance in the period **2039 – 2047***

Figure 7i *Lunar Culminations of Altitude >= 75 ° framed and classified by Earth-Moon distance in the period **2057 – 2065***

(C) But up until now the superior lunisolar conjunctions have been overlooked, as if the gravitational attraction forces at play did not increase when the Moon periodically interposes itself between the Sun and planet Earth.

We proceeded by isolating the New Moons (between Earth and Sun) simultaneously in Perigee, with a High Altitude on the local horizon of Pozzuoli and with a minimum angular distance with respect to the meridian that crosses the phlegraean area. The peaks of these New Moons, here called Major, were calculated in an equatorial geocentric perspective (i.e. calculated according to the Earth's rotation axis and not just with respect to the center of the Earth).

Over the course of a year the Moon positions itself between the Earth and the Sun 12 times, sometimes 13, every 29 and a half days during the New Moon phases: between the years 1905 and 2023 inclusive, 1472 New Moons were configured or Black Moons (not Full).

During the peak of sygytial phases (relative to the Earth's axis and not only with respect to the Earth's center), in these approximately fifteen hundred New Moon phases, the lunar satellite orbited at a distance of less than 373,500 kilometers (the limit that here defines the Moons in Perigee) exclusively over the course of 558 occurrences. Among the latter, only 24 Moons orbited above 49 degrees of local Altitude during the peak of the sygytial phase and above the Central European meridians of Longitude between +1° (which cross Rouen, FR) and +25° (which cross Central Romania) (**Fig. 16 and Box 6c**).

The Moons here called Major have been divided into 3 Perigee classes: Minimum, Super and Extreme corresponding to the distance bands <= 357,400 km, <= 359,600 km, <= 373,500 km, represented by the colors cadmium orange, electric blue and ash (although the New Moons they should have been represented as black and each paired with a Sun (**Fig. 8**)).

🔴	**New** Moon in Extreme Perigee	<= 357 400 km
🔵	Super **New** Moon	> 357 400 km and <= 359 600 km
⚪	**New** Moon in Minimum Perigee	> 359 600 km and <= 373 500 km

🟡	**New** Moon at intermediate distance	> 373 500 km and < 390 000 km
🟢	**New** Moon at Apogee	>= 390 000 km

Figure 8 *Representation in spheres of the New Moons according to the Earth-Moon distance*
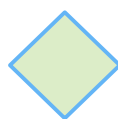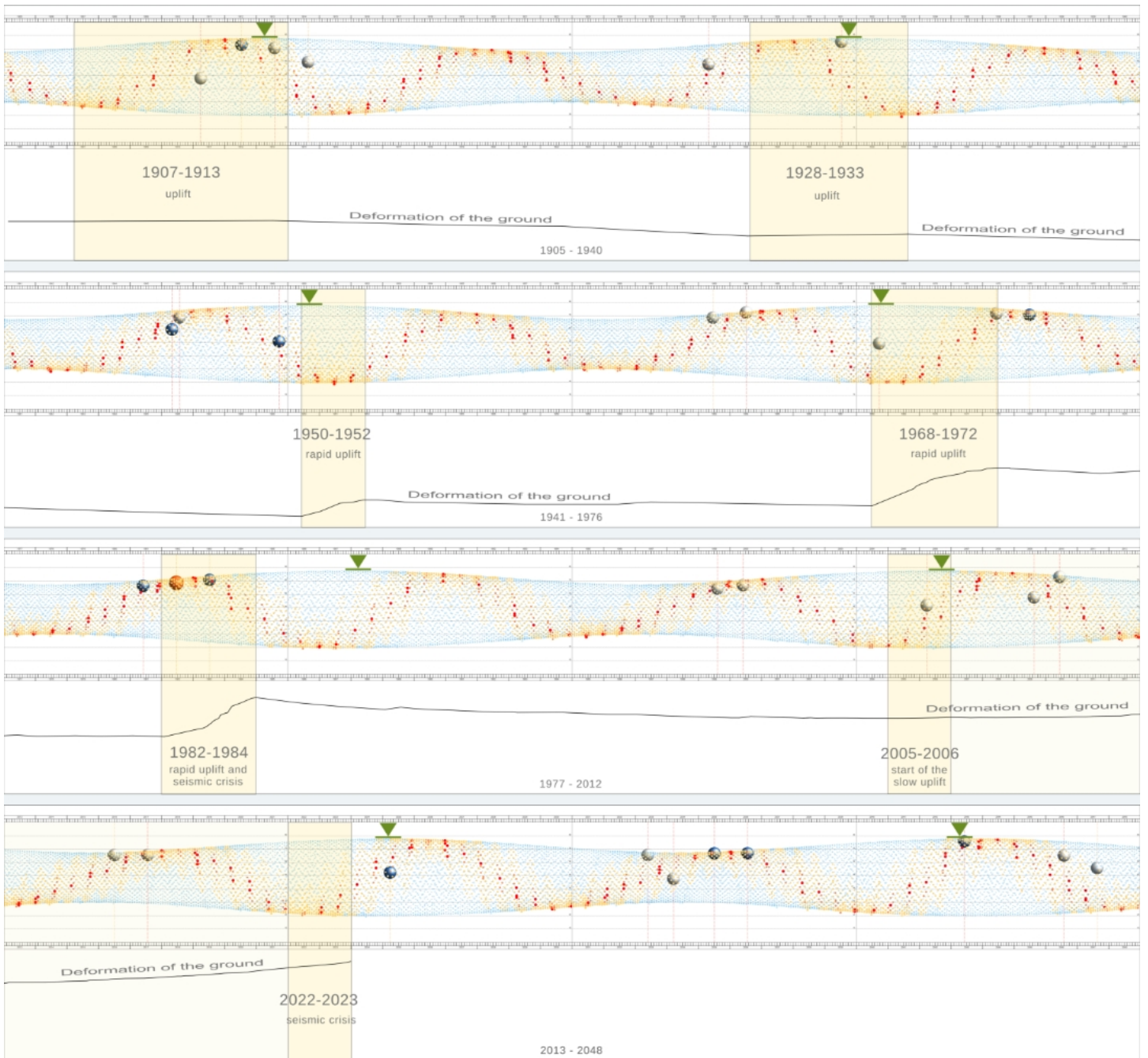
Figure 9 *Lunar Culminations at the Pozzuoli meridian differentiated by Moon-Earth distance (red, orange, yellow, light blue disks), Major Moons (spheres) in the period 1905-2048 and bradyseismic trend at the Campi Flegrei 1905-2023*

By inserting the 24 dates into a representation of the bradyseismic trend of the Phlegraean caldera between the years 1905 and 2023 inclusive (**Figs. 3 and 9**), it is shown how these particular and relatively rare Moons frame the bradyseismic phases of uplifting and lowering and in their absence the ground decreases slowly or more generally the trend is not significantly altered:

- According to the surveys reported (**Fig. 10b**) by Aster and Meyer carried out at the port of Pozzuoli, the uplift that led to the most serious bradyseismic crisis since the times following the 1538 eruption began almost simultaneously with the formation in the celestial vault of 21 June 1982 of a rare New Moon in Extreme Perigee orbiting in Extreme Perigee at 357,353 km from Earth and at 69° degrees of Altitude on the Pozzuoli meridian. The seismic swarm of April 1st '84 which developed during the night until the morning for about 8 hours with over 500 events and the first slowdown recorded in the first days of May, occurred close to a group of Moons in Extreme Perigee with the Altitude decrease. The stopping was preceded by a relatively low New Moon in Super Perigee (and a shock of magnitude Md 3.8 +- 0.3 on December 8, 1984).

- The bradyseismic crisis of 1970-1972, with an uplift similar to the ascending phase of the following phase (1982-1984), was not accompanied by Central European Elevated New Moons in Super Perigee, nor was it characterized by strong and frequent tremors (the seismicity recorded was weak, especially instrumental).

The New Moons in Super and Extreme Perigee over time can only be configured by their very definition in the same times and at the same celestial coordinates as the daily Culminations in Super and Extreme Perigee (and in the following elaborations of **Figs. 10a, 10b, 10c, 10d, 10e** could only have been found on the graphic harmonica of red discs). Just as a Lunar Culmination in Super Perigee

does not appear in the celestial vault suddenly but is preceded and followed by more than one Moon Culmination in Minimum Perigee, just as a New Moon in Extreme Perigee can be preceded and/or followed by a New Moon in Super Perigee and, as in the case contemporary with the eruption of Monte Nuovo, by other New Moons in Extreme Perigee, between the years 1533 and 1541 (**Fig. 10d**), a unique case since 1419, the initial year of the elaborations of **Fig. 14**.
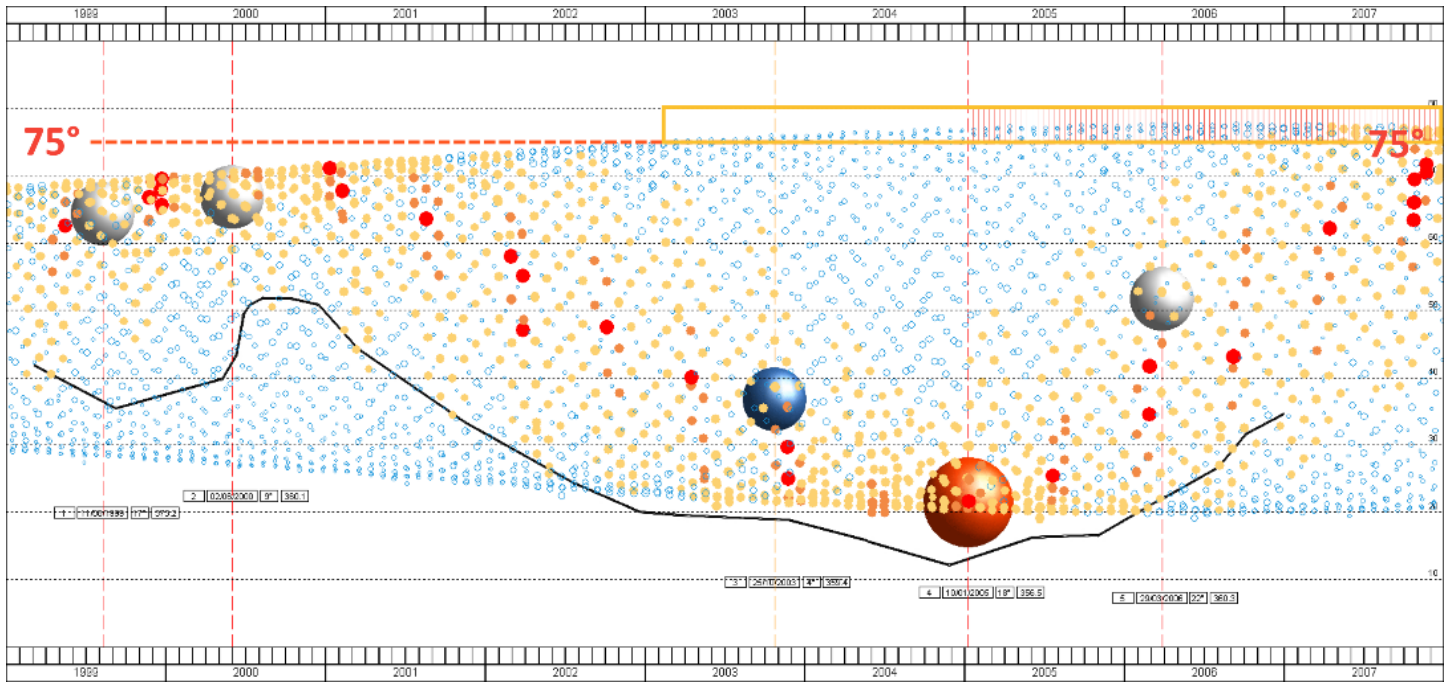

Figure 10a *The inversion between the years 2004 and 2005 parallels the harmonic of (Daily and New) Moons in Super and Extreme Perigee. The trace of bradyseism from Ricco C, Aquino I, Del Gaudio C (2007) "Study of the tiltmetric inversion recorded from July to October 2006 at the Campi Flegrei"*
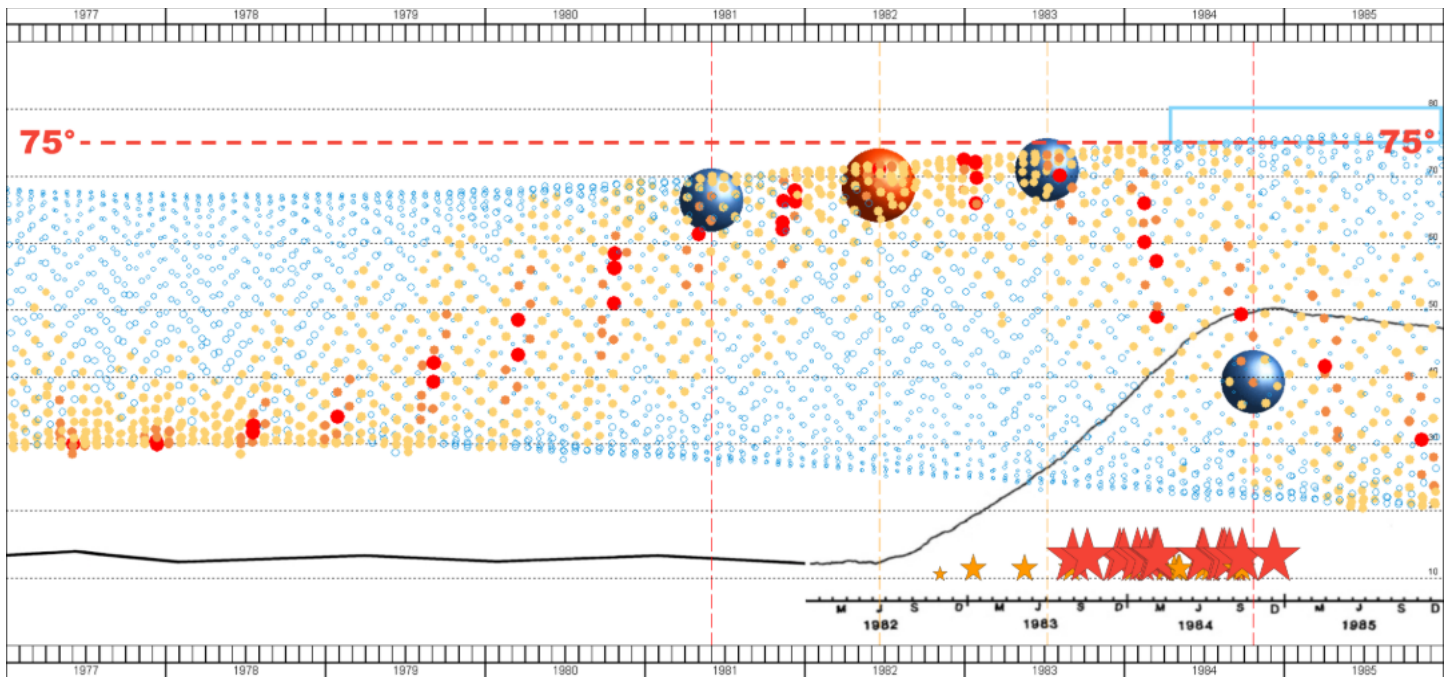
Figure 10b *Culminations, Central European (Elevated and non-Elevated) New Moons in Perigee in the period 1977-1985, the INGV-OV track of the trend of soil lifting between the years 1977-1981 and 1982-1985 according to Aster and Meyer (1988). The red stars represent earthquakes with magnitude M>=3.0 (https://terremoti.ov.ingv.it/gossip/flegrei/1984/index.html)*
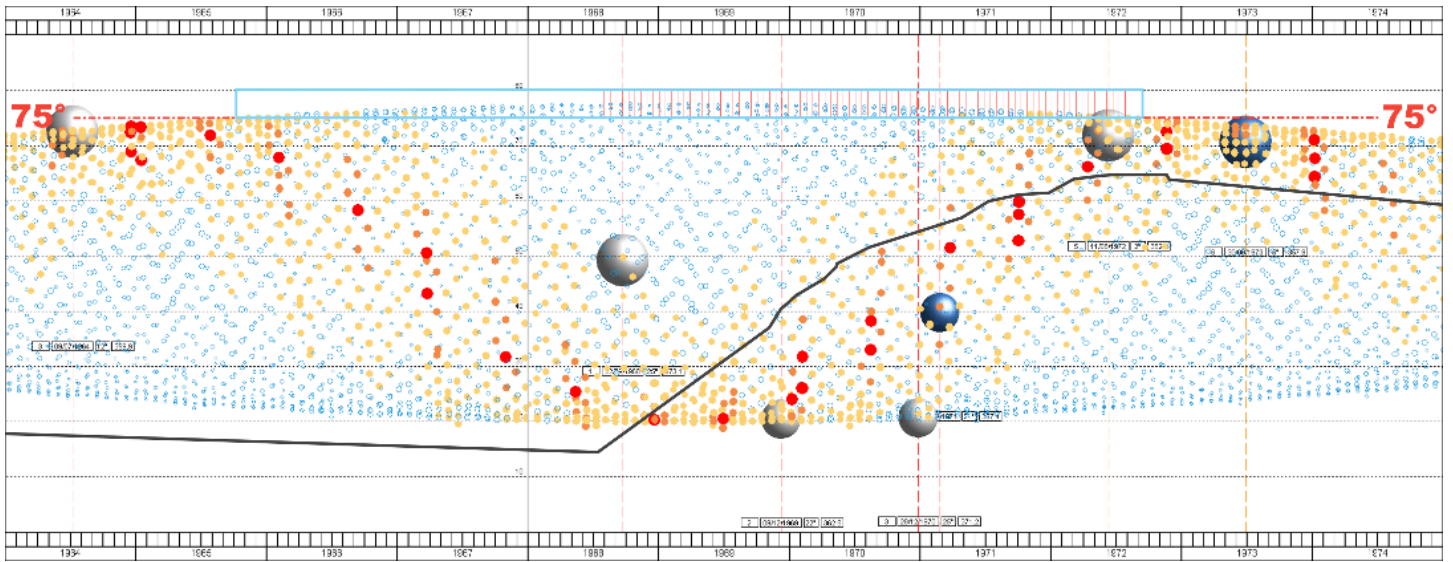
Figure 10c *Culminations, Central European (Elevated and Non-Elevated) New Moons in Perigee and soil deformation in the period 1964-1974.*
The seismicity of the bradyseismic crisis from 1969 to 1972 was weak; the tremors were mainly instrumental (not felt by the population)
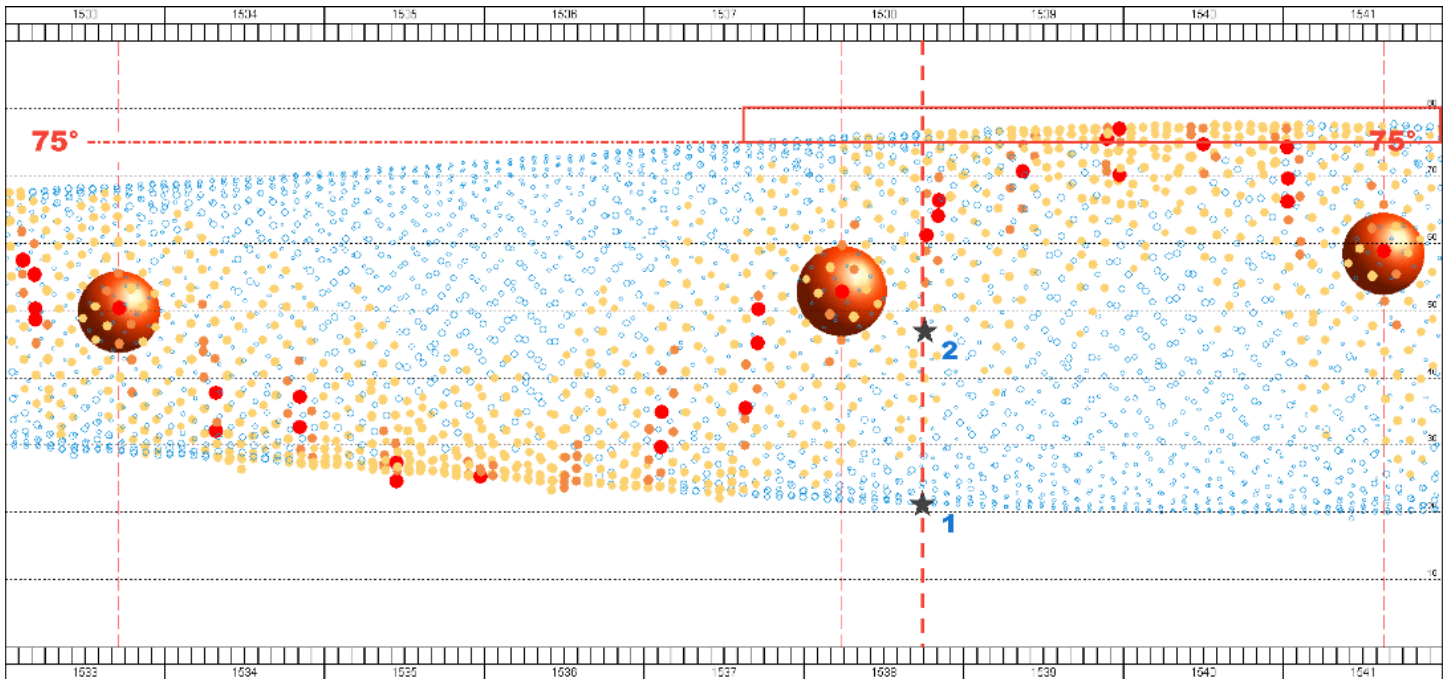
Figure 10d *(1)* Montenuovo eruption of 30 September 1538. *(2)* Explosion of 6 October 1538 (24 victims).
Culminations and (Elevated and Non-Elevated) Central European New Moons in Minimal, Super, Extreme Perigee in the period 1533-1541
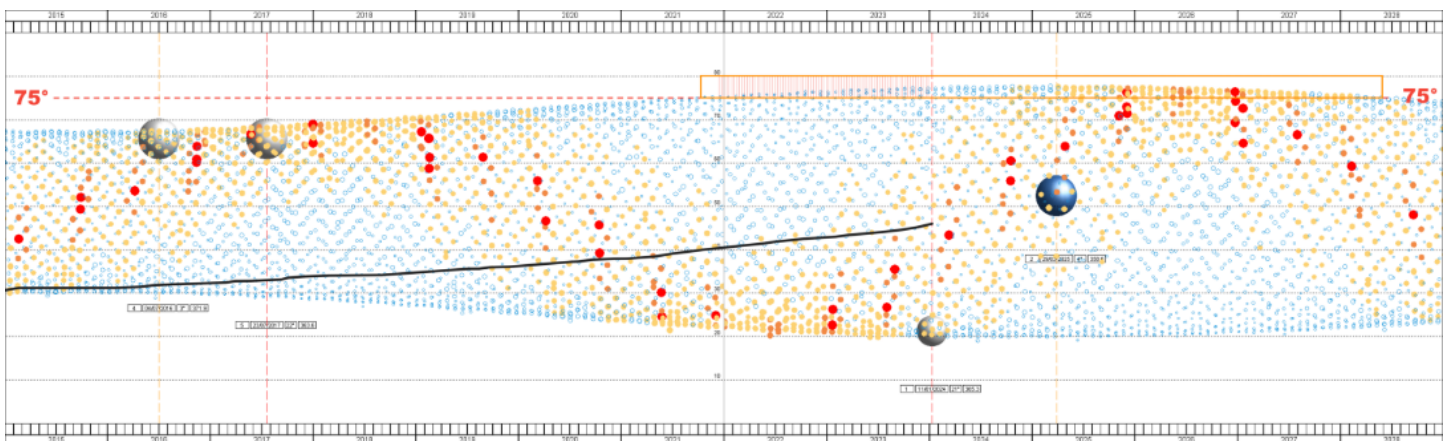
Figure 10e *Culminations, Central European New Moons (Elevated and Non-Elevated) in Minimal, Super, Extreme Perigee in the period 2015-2028*

Each Central European Elevated New Moon in Minimum, Super and Extreme Perigee of the 24 Moons here called Major of **Fig. 3** was configured in the celestial vault anticipated and followed by highestdaily Culminations and by other similar New Moons at a synodic temporal distance, so their this supposed action should not be considered isolated but always supported, day by day, previously and subsequently, by a harmonic of Moons in Minimum, Super and Extreme Perigee.

By expanding the limit distance defining the Moon in Minimum Perigee from 373,500 km to 390,000 km, the correspondence [Elevated Moons] / [Bradyseism] is maintained (**Fig. 11a**) (more evidently before 1945 when the lower frequency in the celestial vault of Major Moons corresponds to a generalized subsidence; and also as after the brady-seismic crisis of 1982-1984). In the same way the [Moons] - [Bradyseism] correspondence is maintained, also considering every Central European New Moon Elevated in Apogee (**Fig. 11b**). Therefore the 24 Moons, here called Major (**Fig. 3**), represent the essence of lunar periodicity (not perfectly regular). This configuration of 24 Major Moons is consistent with the bradyseismic phases of the Campi Flegrei volcanic system between the years 1905 and 2023.
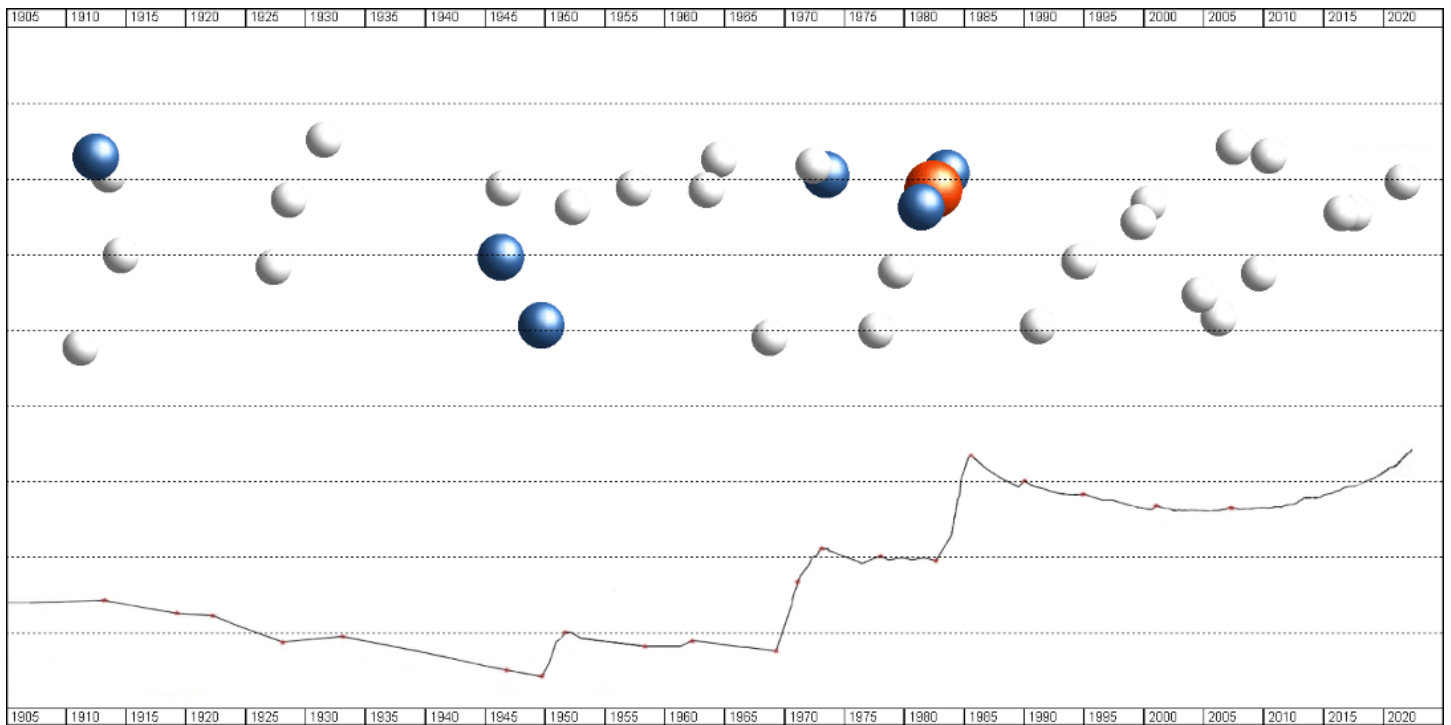
Figure 11a *Major Moons on Pozzuoli in the period 1905-2024 with expanded Moon-Earth distance limit*
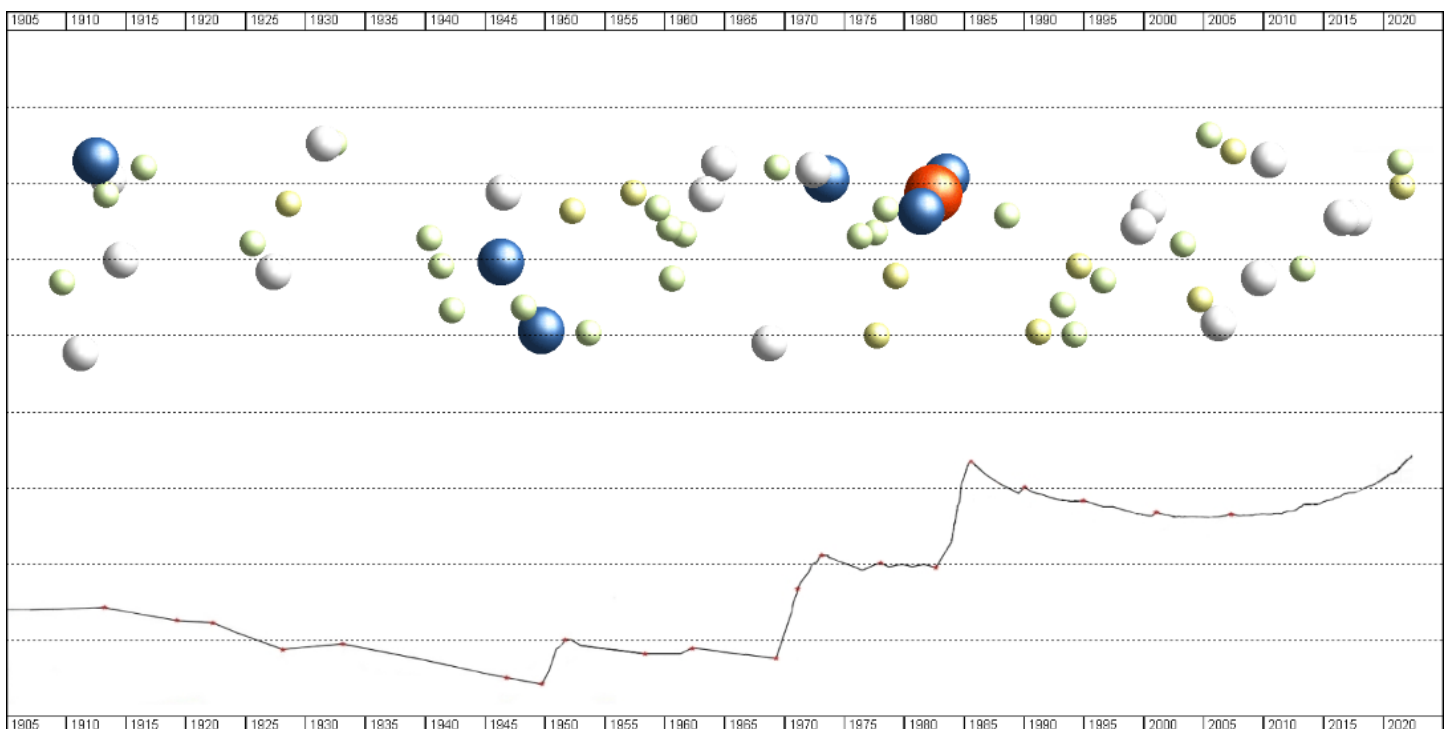
Figure 11b *Major New Moons on Pozzuoli in the period 1905-2024 and Central European High New Moons in Apogee*

TOOLS AND CALCULATION METHOD

The graphics are based on the scan of the alphanumeric file MINDIST.DAT (**Fig. 12**) created by the calculation of the Moon-Sun Right Ascension conjunctions in equatorial geocentric perspective performed using Solex 12.1.01 High Precision Ephemerides by Numerical Integration, a software application of Celestial Mechanics with precision equivalent to the NASA/JPL Horizons online ephemeris system, developed by Prof. Aldo Vitagliano of the Federico II University of Naples (www.solexorb.it).

The 24 Moon-Sun conjunctions, here called Major New Moons (**Fig. 3**), that occurred between the years 1905 and 2023 derive from the line-by-line scan of the 1472 Moon-Sun conjunctions in R.A. formed in the same period listed in MINDIST.DAT, filtered according to the 3 conditions: Lunar Distance (**r2**) <= 373 500 km (according to the definition of Lunar Perigee), Lunar Declination (**Dec2**) >= 0 (equal to the lunar angular elevation positive with respect to the Earth's equatorial plane) and Earth Time 10:20:00 <= (**TT**) <= 11:56:00 (criterion, based on the close relationship between universal times and geographical longitudes, equivalent to the delimitation of the segment of the Earth's surface limited by the meridians of Longitude +1° and +25°) (**Fig. 16**).

Among the totality of Moons in solar conjunction orbiting at the peak of the phase in correspondence with Italy, we selected those which are both closest to the Earth and above the equatorial plane as they are more attractive due respectively to the shorter distance and the greater force distributed on the component vertical. These Major Moons orbiting over the Northern Hemisphere have been replaced in the graphs by the Central European Major Moons of with Altitude >= 49° (they are coincident): in this way they are graphically homogeneous, that is, they can be represented together with the daily Culminations transiting on the meridians of Pozzuoli.

If the Earth-Moon-Sun conjunctions were always calculated according to a geocentric but not equatorial perspective, i.e. only according to the center of the Earth (not inserting the **/C** option among the parameters of the Solex software rel. 12.1.01), the correspondence [Moons] / [Bradyseism] would not emerge: the difference between the times of the two types of sygytial peaks can reach up to 4 hours, equivalent to approximately 60 degrees of longitudinal geographical difference.

UNIVERSAL TIMES AND GEOGRAPHICAL LONGITUDES

(The meridian segment between Longitudes +1 and +25 and the TT time interval 10:20 – 11:56)

Our lives and days are regulated by the Sun, but the solar day does not have a constant length as the apparent motion of the Sun in the celestial sphere is not uniform due to the ellipticity of the Earth's orbit in its motion around the Sun and the fact that the equatorial plane and the ecliptic plane do not coincide.

For this reason, the concept of the average Sun was introduced which by definition moves at a uniform speed (along the celestial equator) and passes the meridian exactly every 24 hours.

Mean Solar Time refers to the fictitious observation of the **Mean Sun**, **True Solar Time** refers to the actual observation of the **True Sun**, and **Sidereal Time** refers to the actual observation of a star or the fictitious observation of the Vernal Point or Aries Point.

Greenwich Mean Time (**GMT**) is a time based on the hour angle of the **Mean Sun** at the Greenwich meridian, used until 1972 as the reference for civil time around the world. Midday GMT (**12:00**) coincides with the transit of the **Mean Sun** over the Greenwich meridian.

The meridian passing through the English Royal Observatory has been conventionally designated as **meridian 0** (initial or fundamental meridian). The zero hour (date line) was decided at the other end of the Earth, on the antimeridian, in the middle of the Pacific Ocean, where the implications would be more easily managed.

Following the improvement of atomic clocks and accurate measurements of the Earth's rotation, **GMT** was replaced in 1972 with the definition of the current universal time scales: the Coordinated Universal Time or **UTC**. Terrestrial Time **TT**, used in the MINDIST.DAT file of the Solex software and in Astronomy in the calculation of orbits and ephemeris which imply geocentric calculations, differs from **UTC** by only a few seconds.

The longitude of a place is the spherical angle between the local meridian and the 0 reference meridian passing through Greenwich. The time, in which the Sun is on the meridian of the place (conjunct the Moon in the specific case of this document), is calculated through the distance in longitude from the 0 meridian.

Each difference in longitude of the place with respect to the 0 meridian is worth 4 minutes for each degree. It follows that the meridian of longitude +14 passing through the island of Procida, west of the Campi Flegrei, corresponds to 11.04:00.

The Sun transits (together with the Moon, in the specific case of this document) from 10:20:00 to 11:56:00 on the central european meridians between the 25° and 1° longitudes (here the solar ephemeris are considered only to identify the positions and times of the Moon which necessarily coincide with those of the Sun, the latter being in this case united with the satellite during the peaks of the New Moons).

The Moon-Sun conjunctions in R.A. belonging to the TT time interval 10:20:00 – 11:56:00 are isolated to obtain the New Moons (Moon+Sun) orbiting over Italy (with France and Greece partially included).

The passage of the **True Sun** over the local meridian does not occur exactly every 24 hours but varies due to the different speed of the Earth around the Sun and the obliquity of the ecliptic plane. Combining the two phenomena, they give rise to a complex variation which is called the **Equation of time** (**e**).
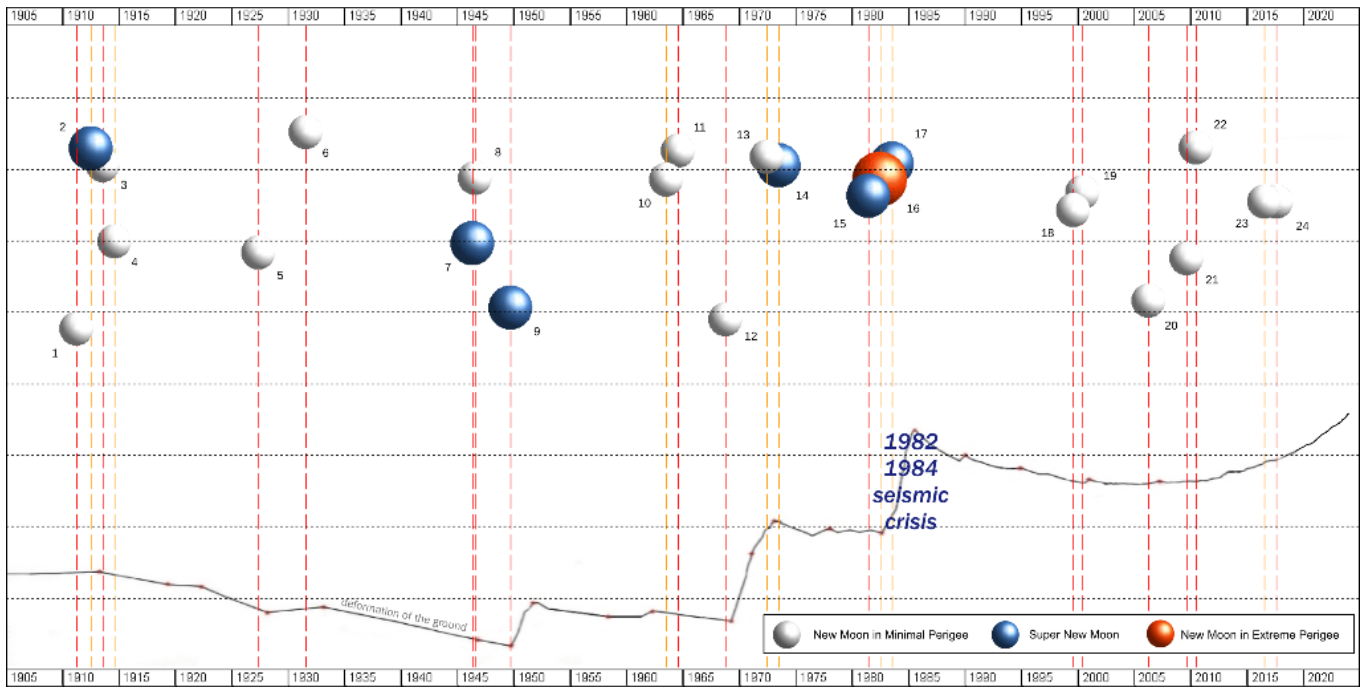
The difference in time in the meridian passages between the **True Sun** and the **Mean Sun** is expressed by the **Equation of Time**: positive when the **True Sun** is ahead and negative when the **True Sun** is late, which can be calculated as a function of longitude average of the Sun, that is, theoretically.

The real time of the passage of the Sun at the local meridian is obtained from the variation **e**: True solar time = Mean solar time + **e** . It would therefore be necessary to adjust the times of the 24 Moon-Sun conjunctions, here called Major Moons, by applying the Equation of Time but its + - 16 maximum corrective minutes would not substantially affect the results represented in the graphs of this document.

Figure 12 *First lines of the MINDIST.DAT file generated by the SOLEX 12.1.01 software (credits: http://www.solexorb.it/) containing the Moon-Sun conjunctions in Right Ascension between 1905 and 2044*

Figure 13 *The 24 filtered lines of the MINDIST.DAT file generated by the SOLEX 12.1.01 software (credits: http://www.solexorb.it/) containing the Moon-Sun conjunctions in Right Ascension between 1905 and 2024*

Box 4a *Major New Moons on Pozzuoli in the period 1905-2024 and bradyseismic trend 1905-2023*

|	Date of initial phase of the New Moon	Now to the climax of the phase sigicial (TT)	Longitude East of geographic correspondence (°)	Lunar distance (Giga Meters)	Lunar declination during the peak of the phase (°)	Lunar Altitude during peak phase (°)	Lunar Altitude during transit to the meridian (°)
1	1911/03/30	10:25:57	24	0,370577	0.83	47,720	49,068
2	1912/07/14	11:53:16	2	0,357764	26.56	72,947	75,765
3	1913/08/02	11:11:40	13	0,362222	21.42	70,580	70,590
4	1914/08/21	11:55:40	2	0,369784	12.75	59,838	62,084
5	1927/05/01	10:26:12	24	0,360656	11.02	58,394	59,495
6	1931/07/15	10:54:11	17	0,371215	26.46	75,202	75,516
7	1946/05/01	11:20:43	10	0,358582	11.56	59,653	59,903
8	1946/07/28	10:20:17	25	0,367371	22.58	68,770	71,525
9	1949/09/22	11:08:46	13	0,358308	1.88	50,582	50,751
10	1963/06/21	11:45:55	4	0,366355	21.55	68,514	70,351
11	1964/07/09	11:13:47	12	0,359984	23.65	72,546	72,582
12	1968/09/22	10:22:45	25	0.373132	1.09	49.075	49.642
13	1972/06/11	11:53:14	2	0.362251	26.16	71.703	75.050
14	1973/06/30	11:40:30	5	0.357998	23.06	70.582	72.000
15	1981/06/02	10:37:50	21	0.359134	18.20	66.369	66.988
16	1982/06/21	11:52:56	2	0.357323	22.20	68.454	70.993
17	1983/07/10	11:52:55	2	0.359489	24.26	70.734	73.193
18	1999/08/11	10:52:49	17	0.373285	15.83	64.342	64.551
19	2000/06/02	11:27:16	9	0.360138	18.67	66.772	67.402
20	2006/03/29	10:34:57	22	0.360342	3.82	51.647	52.593
21	2009/08/20	11:37:31	6	0.361074	9.70	57.550	58.426
22	2010/06/12	11:29:16	8	0.371746	24.99	72.996	73.908
23	2016/07/04	11:49:51	3	0.371991	18.37	65.389	67.160
24	2017/07/23	10:35:02	22	0.363631	17.93	65.425	66.598

Box 4b

1419

1538

1905

2138
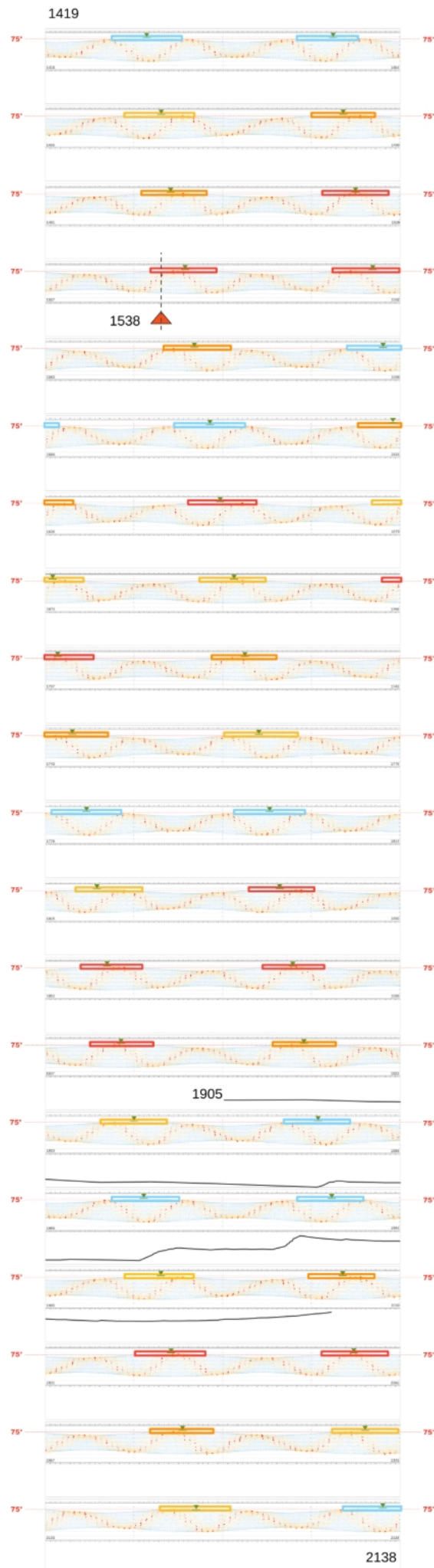
Figure 14
Si presume che, tra gli anni 1840 e 1930 successivamente all'eruzione del 1538, la presunta azione dell'armonica di Culminazioni in perigeo Super ed Estremo con Altezza >=75°, abbia sortito effetti esclusivamente nelle profondità del sottosuolo
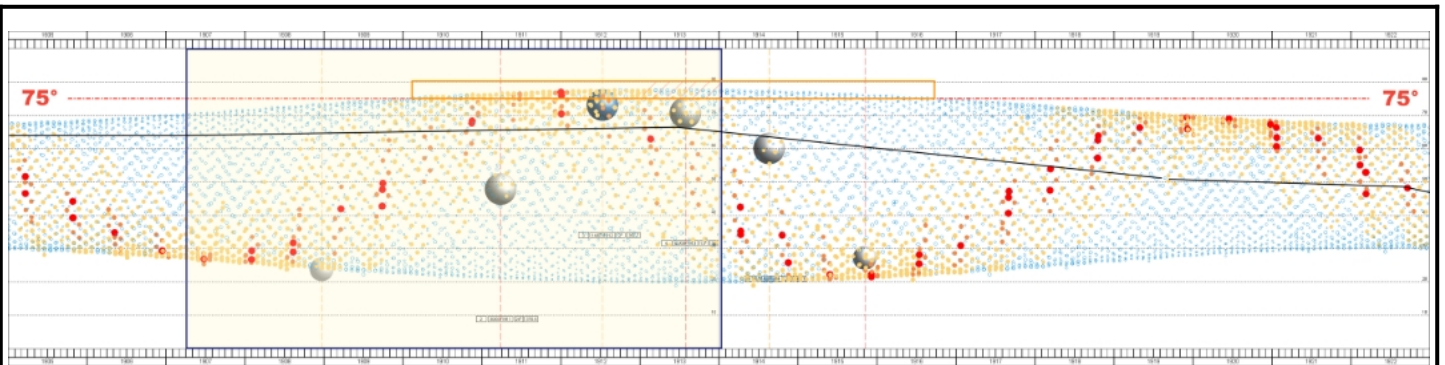
Box 5a *Lunar culminations, Central European Moons in Minimum, Super and Extreme Perigee of the period **1905-1922** and the lifting of the soil in the years **1907-1913** (framed)*

Since the surveys were carried out many years apart (IGM 1905, 1913, 1919), it cannot be ruled out that the ascending phase may have begun with Altitudes >75° around 1910 and the descending phase around 1916 with Altitudes <75°
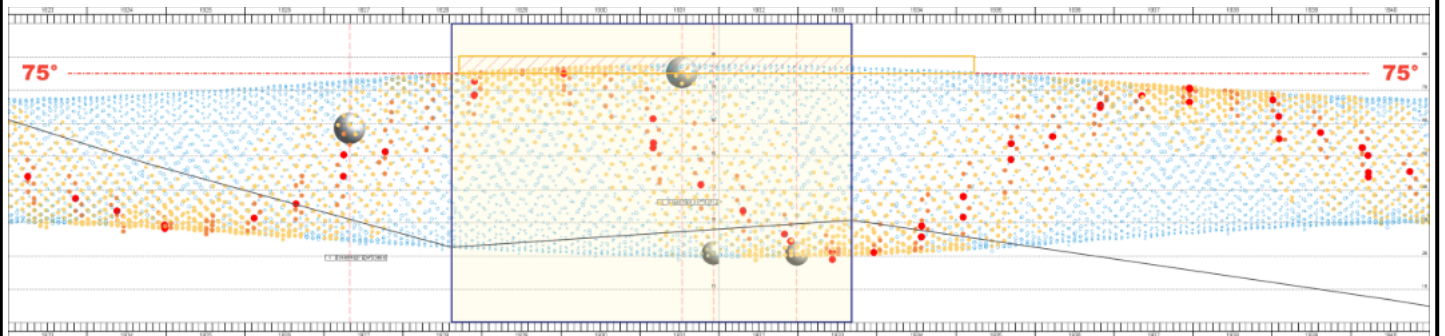
Box 5b *Lunar culminations, Central European Moons in Minimum, Super and Extreme Perigee of the period **1923-1940** and the lifting of the soil between the years **1928 and 1933** (framed)*

According to the measurements (IGM 1922, (?) 1928, Maio 1933 and Ranieri 1945) the ascending phase began during the period of lunar Culminations with Altitudes above 75 degrees. It cannot be ruled out that the descending phase began with Altitudes lower than 75 degrees around 1935.

Box 5c *Lunar culminations, Central European Moons in Minimum, Super and Extreme Perigee of the period **1941-1958** and the lifting of the soil between the years **1950-1952** (framed)*

The ground uplift phase was concomitant with the period of lunar culminations with Altitudes above 75 degrees and the subsidence was concomitant with phase with lunar Altitudes tending to decrease.
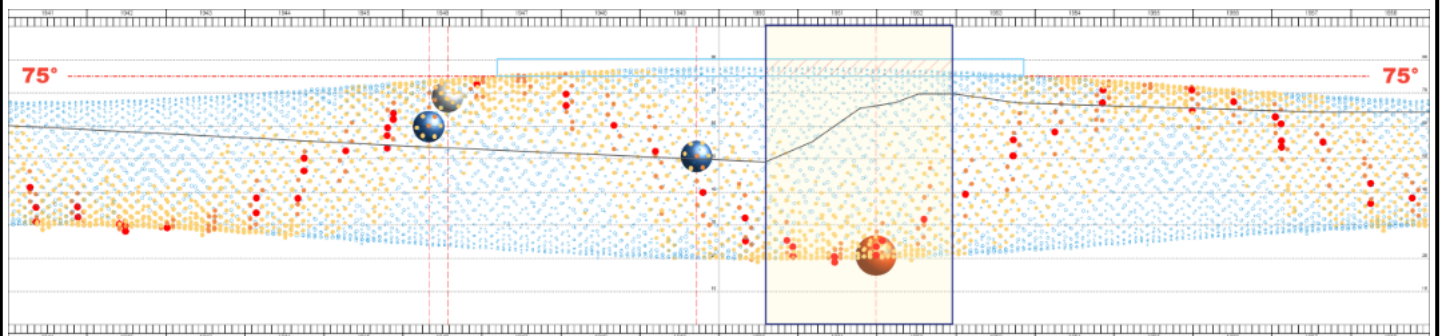

Box 5d *Lunar culminations, Central European Moons in Minimum, Super and Extreme Perigee of the period **1959-1976** and the lifting of the soil between the years **1968-1972** (framed)*

The bradyseismic phase of 1969-1972 ended as soon as maximum lunar Altitudes decreased below 75 degrees. The ground uplift followed the trend of the lunar Altitudes of the Moons in Super and Extreme Perigee.
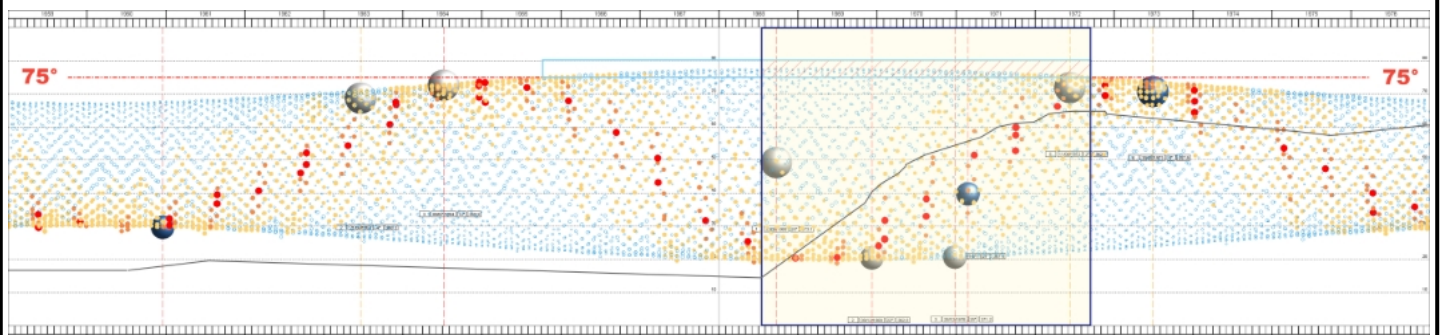
Box 5e *Lunar culminations, Central European Moons in Minimum, Super and Extreme Perigee of the period **1977-1994**
and the lifting of the soil between the years **1982-1984** (framed)*

The concentration of major shocks during the crisis of 82-84 began between 74 and 75 degrees of lunar Altitude (**Fig. 10a**). The seismic swarm of April 1st '84 which developed during the night until the morning for about 8 hours with over 500 events (and the first slowdown recorded in the first days of May) occurred close to a group of Moons in Extreme Perigee with Altitude decreasing. The ground uplift in the first phase followed the trend of the lunar Altitudes of the Daily and New Moons in Super and Extreme Perigee. The descending phase followed the decreasing trend of the Altitudes of the daily and New Moons Non-Elevated in Super and Extreme Perigee.
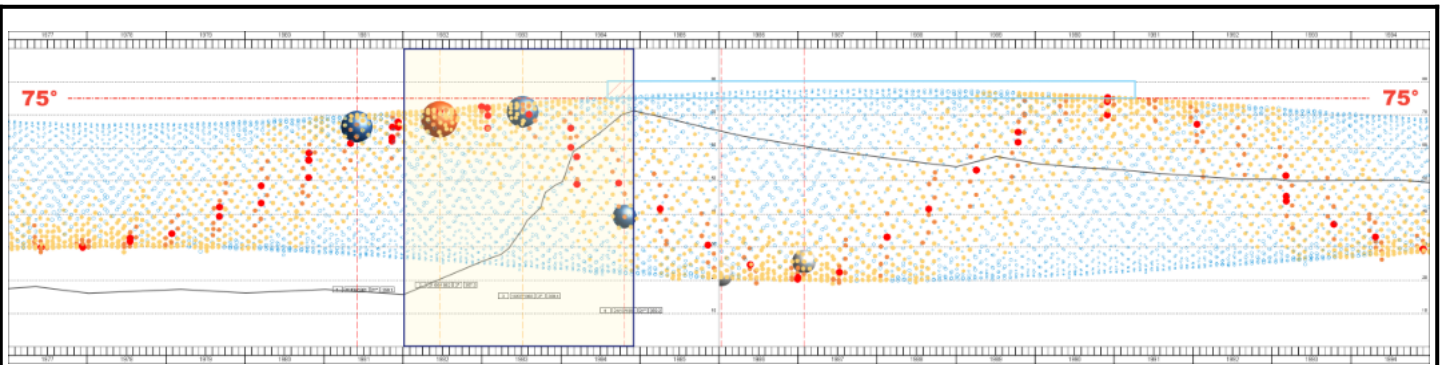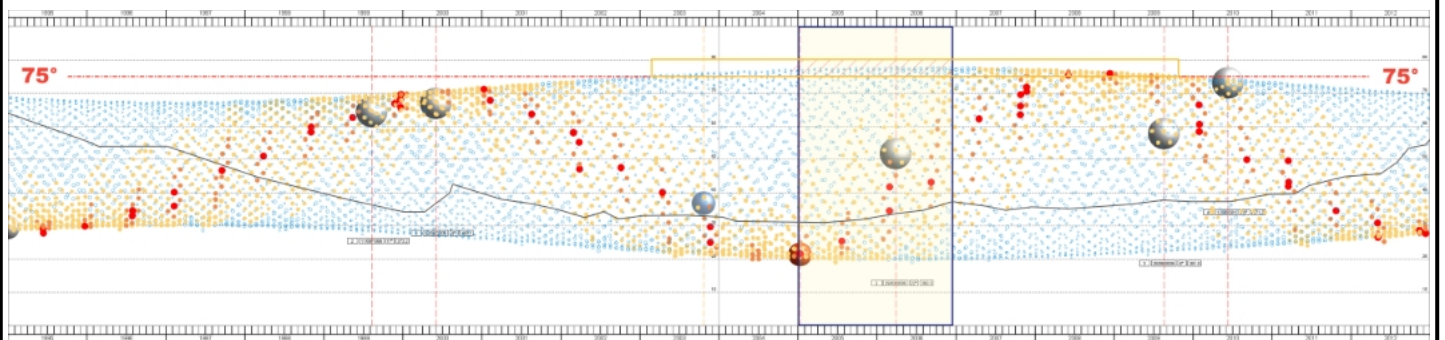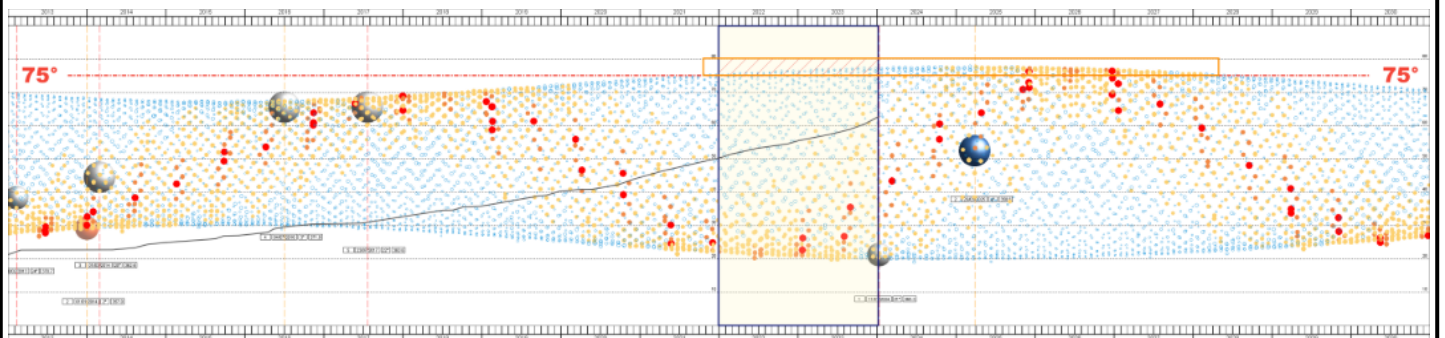

Box 5f *Lunar culminations, Central European Moons in Minimum, Super and Extreme Perigee of the period **1995-2012**
and the lifting of the soil between the years **2005-2006** (framed)*

The uplift and lowering of the ground followed the trend of the Altitudes of the Daily and New Moons in Super and Extreme Perigee. The rapid increase in the rate of uplift detected in 2012 (magma intrusion) is assumed to be due to the New Moon itself on May 20, 2012.

Box 5g *Lunar culminations, Central European Moons in Minimum, Super and Extreme Perigee of the period **2013-2030**
and the seismic crisis between the years **2022-2023** (framed)*

The slow uplift that started in 2005 and is still underway, more precisely the one between the end of 2009 and August 2021, did not correspond to Culminations above 75 degrees. However, the ascending phase was accompanied by lunar Culminations and Central European New Moons in Minimum, Super and Extreme Perigee. The next intermediate phases will be characterized by this type of Moon (**Fig. 6b**). The current seismic crisis, an evolution of the slow uplift that began in 2005, has undergone a substantial increase starting from the last months of 2021, after the culmination Altitudes exceeded 75 degrees.

(N.B. The traces of the bradyseismic trend within the documents have been stretched and vertically positioned to a different extent from graph to graph, in such a way as to show more clearly the hypothesized close relationship between ascending/descending phases and the lunar orbit)
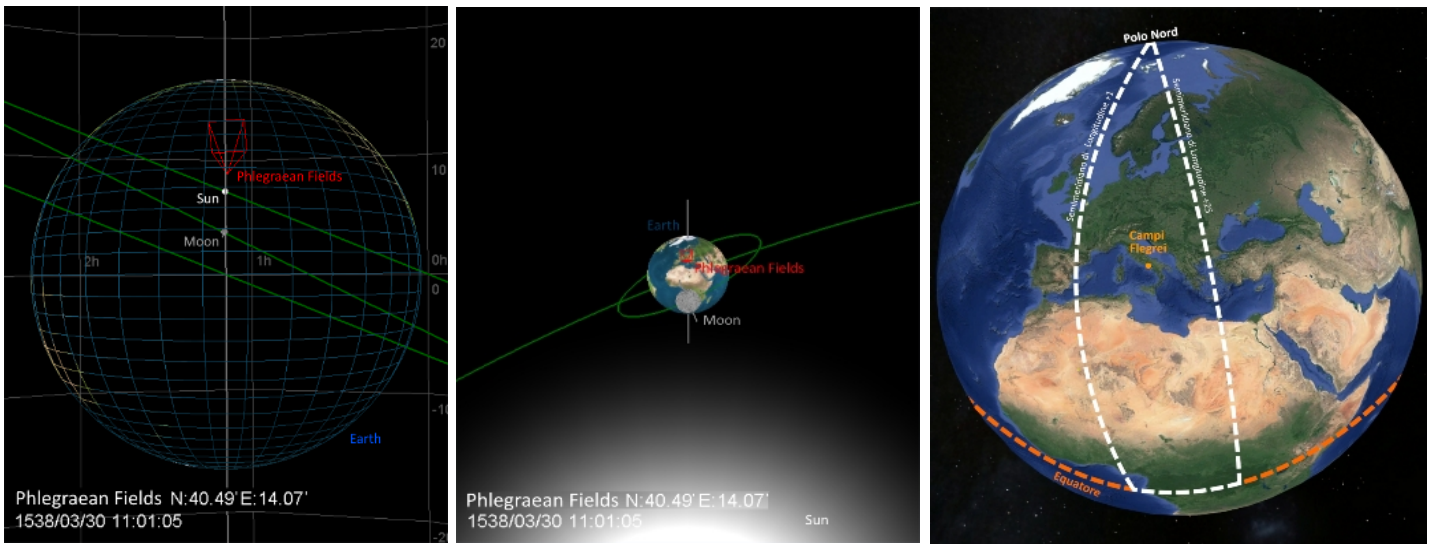
Box 6a, 6b *The rare boreal New Moon orbiting in Extreme Perigee and in an equatorial geocentric perspective on the Salerno meridian on 30 March 1538, which anticipated the Monte Nuovo eruption of 30 September by 6 months (credits: http://www.sssim.com/)*

Box 6c *The northern geographical segment delimited by the Equator and the semi-meridians of Longitude +1° and +25°*

Figure 15 Shocks with a magnitude >= 1.0 in the period 2020-2023 with an epicenter less than 25 km away from Pozzuoli (Naples). (credits: INGV-Osservatorio Vesuviano). With an orange background the shocks M>= 2.6. Earthquakes with magnitude M>= 3.2 are marked with a star

Figure 16 *Longitudes and corresponding UTC times of solar transit to the meridian (credits: Google Earth)*
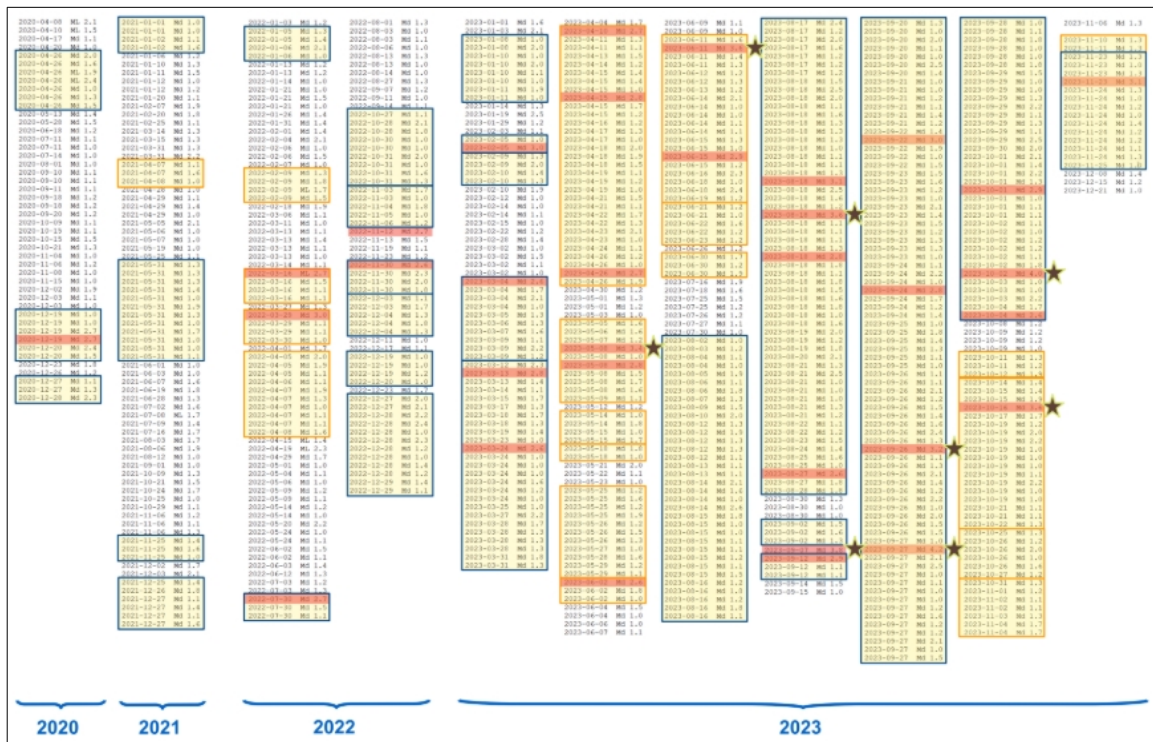
CONCLUSIONS

Excluding the 1982-1984 and 2010-2021 windows, from 1905 to 2023, every 11-12 year period of Lunar Culminations with an Altitude below 75 degrees coincided with a deflationary phase at Campi Flegrei, while every significant uplift, except two, it occurred during a period of lunar Culminations with an Altitude above 75 degrees.

Each phase imperfectly followed the lunar nutation cycle equivalent to 18.6 years. The latter are distinguished from each other by the configuration over time of Moons at a variable distance from the Earth and more or less attractive New Moons (between the Earth and the Sun).

Two incompatibilities are observed with respect to the correspondences of the type [Periods with Altitude Culminations above 75 degrees] → [Uplift] and [Periods with Altitude Culminations below 75 degrees] → [Subsidences] but at the same time there have been configured a peculiar sequence in the celestial vault of 3 High New Moons orbiting in Super and Extreme Perigee over the European meridians of Longitude between +1° and +25° and of the periods with maximum daily lunar culminations in Super and Extreme Perigee together with an extensive distribution of Highest New Moons in Perigee Minimum orbiting over Central Europe (during their sygytial peak).

The subsidence between the years 1985 and 1990 is presumed to have been affected by the serious bradyseismic crisis of 1982-1984 but also by the 1984-1987 descending phase of the harmonic of the Moons in Minimum, Super and Extreme Perigee. The remaining incompatibilities, lasting no more than 3 years, are presumed to be attributable to a non-immediate geological response of the subsoil and, until the post-war period, to an insufficient frequency of measurements.

SCIENTIFIC LITERATURE AND REFERENCES

1. Sottili G, Lambert S, Palladino DM (2021) "*Tides and Volcanoes: A Historical Perspective*" Frontiers in Earth Sciences - ISSN 2296-6463-9

2. Zaccagnino D, Vespe F, Doglioni C (2020) "*Tidal modulation of plate motions*" Earth Science Reviews

3. Di Luccio F, Chiodini G, Caliro S, Cardellini C, Convertito V, Pino NA, Tolomei C, Ventura G (2018) "*Seismic signature of active intrusions in mountain chains*" Science Advances

4. Ide S, Yabe S & Tanaka Y (2016) "Earthquake potential revealed by tidal influence on earthquake size–frequency statistics" Nature Geoscience

5. Sottili G, Palladino DM (2012) "*Tidal modulation of eruptive activity at open-vent volcanoes: evidence from Stromboli*" Terra Nova

   ----

6. Del Gaudio C, Aquino I, Ricciardi GP, Ricco C, Scandone R (2010) "*Unrest episodes at Campi Flegrei: A reconstruction of vertical ground movements during 1905–2009*" Journal of Volcanology and Geothermal Research 195, 48–56

7. Ricco C, Aquino I, Del Gaudio C (2007) "*Studio dell'inversione tiltmetrica registrata da luglio ad ottobre 2006 ai Campi Flegrei*" Open File Report n° 1 – 2007 Osservatorio Vesuviano – Istituto di Geofisica e Vulcanologia INGV

8. Rydelek P, Sacks I, Scarpa R (1992) "*On tidal triggering of earthquakes at Campi Flegrei, Italy*" *Geophysical Journal International*, Volume 109, Issue 1, April 1992

9. Berrino G, Corrado G (1991) "*Tidal signal in the recent dynamics of Campi Flegrei caldera (Italy)*" Journal of Volcanology and Geothermal Research Volume 48, Issues 1–2, Pages 93-101, August 1991

10. Palumbo A (1985) "*Influence of external tidal and meteorological forces on the bradyseismic phenomenon in the Phlegraean Fields*" Il Nuovo Cimento, Volume 8, pages 538–551 1985

DATA SOURCE

- Solex 12.1.01 High Precision Ephemerides by Numerical Integration by Prof. Aldo Vitagliano, Federico II University of Naples (www.solexorb.it)

- Osservatorio Vesuviano – Istituto di Geofisica e Vulcanologia INGV (https://terremoti.ov.ingv.it/gossip/) (https://www.ov.ingv.it/) (https://www.ingv.it/)

- Solar System Simulator Studio vers. 1.1.6 2004-2006 (http://www.sssim.com/)

KEYWORDS

Campi Flegrei, Phlegraean Fields caldera, tidal modulation, tidal tilting, crustal response to earth tides, seismic and volcanic activity

EXTENDED TITLE

Temporal correspondences in the period 1905-2023 between the bradyseismic trend at the Campi Flegrei, the periods of lunar Culminations with a Altitude greater than 75 degrees and the New Moons between the Earth and the Sun orbiting in Perigee on the northern geographical segment delimited by the Equator and the semi-meridians of Longitude +1° and +25° during the peak, in an equatorial geocentric perspective, of the syzygial phase.

PRELIMINARY OBSERVATIONS

(posts published on the HTML page *cruscottobendandiano.it and the Facebook page "Cruscotto Bendandiano software/studio su cause/previsione terremoti")*

http://www.cruscottobendandiano.it/testi_e_documenti.html

https://www.facebook.com/profile.php?id=100080263935830

- Ballabene A (2021,10,14) *"The eruptions of Vesuvius in the year 79 AD (Pompeii) and 1538 in the caldera of the Campi Flegrei supervolcano (Monte Nuovo) (i.e. the two most significant eruptions that occurred in the Neapolitan area starting from the year 1 AD) were preceded (5 and 6 months earlier respectively) by a New Maximum Supermoon Local Boreal, i.e. from a Moon between the Earth and the Sun in strong perigee at a distance of less than 357,350 kilometers on the Italian meridians (*) during the peak (with respect to the Earth's rotation axis and not only to its center) of the sygytial phase"*
  FB link : https://www.facebook.com/permalink.php?story_fbid=pfbid09zbP4vsramQ4tcf1zdbw1c7AZpkkWeBDEJn4xiyL5sRD5XPUEtfzS8YHtCP6cUYfl&id=1541025452819752

- Ballabene A (2022,05,22) *"Apical Moons and trend of bradyseism from 1905 to 2022 at the Campi Flegrei"*
  FB link : https://www.facebook.com/permalink.php?story_fbid=pfbid0b8so6PVYwjqxqwwv3PokcSMTAiZYHLZm2rBiaGyEvGDXSEokFEcSixc1cjufuwnkl&id=1541025452819752

- Ballabene A (2022,05,09) "*Temporal correspondences between semi-periodic lunisolar apical configurations and paroxysmal phases in the Campi Flegrei-Vesuvius volcanic system (part one)*"
  FB link : https://www.facebook.com/permalink.php?story_fbid=pfbid02LhnCRiYsZJ8rawNw1SNhvUGfQceuuB25cb7tSDLKwQ4KEBimBaQDU3YTcJLEZzYzl&id=1541025452819752

- Ballabene A (2022,06,25) "*The 'convergence' of two centuries-old cyclicalities. Temporal correspondences between semi-periodic lunisolar apical configurations and geophysical phenomena in the Campi-Flegrei-Vesuvius volcanic systems and in the city of Rabaul. Some initial evaluations (which do not allow any type of conclusion or prediction) according to a hypothesis contextual to peer-reviewed studies*"
  FB link : https://www.facebook.com/permalink.php?story_fbid=pfbid0271vzpXP7EoJ9LurMxq5yn5nYsTxCfWj2TonKt6JPGaH37uVPjakoT4R8tXcePGHDl&id=1541025452819752

DATA FILES (allow the verification of the graphic-numerical documents contained in this document)

1905 - 2023 (New Moons) Moon-Sun Conjunctions in equatorial geocentric perspective, therefore according to the Earth's rotation axis and not only with respect to the center of the Earth, i.e. by setting the /C option using the Solex software

https://drive.google.com/file/d/1Fs8Mli_zs54Jd-qSGzlYU8jdiq_i-sRd/view?usp=drive_link

https://drive.google.com/file/d/10RVwpBTK5-opIKwPsxUl_TCwqVBIFGv4/view?usp=drive_link

1905 - 2023 'Major' Moons

https://drive.google.com/file/d/11ZujK9dXBvo0_XgTawteZ50CDwsS6r9h/view?usp=drive_link

1905 - 2102 Lunar Culminations at Pozzuoli

https://drive.google.com/file/d/1FoW-9ZG8fIPCy2NTUIrfEKaAKAY6Sm3u/view?usp=drive_link

(my algorithm, that treated the data produced by Solex 12.1, can be improved)

Instructions for calculating New Moons in equatorial geocentric perspective using Solex 12.1 software

https://drive.google.com/file/d/1BeCe0S3yCLkYpJMeyrPdqlfQocAAXcM9/view?usp=drive_link

HD VERSION

PDF High Definition Document in English

"Temporal correspondences in the period 1905-2023 between the bradyseismic trend at Campi Flegrei, the periods of lunar Culminations with Altitude above 75° and the New Moons in Perigee orbiting on the boreal segment delimited by the meridians +1° and +25°"

https://drive.google.com/file/d/1UxFnoSv0gOBCuuhGPWuNXz4N3RHc1roN/view?usp=drive_link

PDF in Italiano e in Alta Definizione

"Corrispondenze temporali nel periodo 1905-2023 tra l'andamento bradisismico ai Campi Flegrei, i periodi di Culminazioni lunari di Altezza superiore a 75° e le Lune Nuove in Perigeo orbitanti sullo spicchio boreale delimitato dai meridiani +1° e +25°"

https://drive.google.com/file/d/1YhT36qS4bJ8niaht2BhipZ4fteLuk3el/view?usp=drive_link