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Research Notes

Time-Resolution of Climate Change Monitoring Volcanic Cycles, Stromboli, Ocean Floor Biota and Pandemics (?)

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Abstract: Climate change is an ongoing, poorly understood and disquieting challenge. The primary drivers are debated. Clear evidence is however suggestive of a time variation of the planetary release of endogenous energy. In fact, soil exhalation is an unprecedented challenge for humankind, as a phenomenon of this kind happens only every ~27.4±0.05 Ma, while human history spans only the last ~30,0000 years. Therefore, there is need for a quantitative and objective monitoring of climate change with high time resolution. It is here shown that Stromboli is a natural probe suited for such a purpose. More in detail, a general perception of phenomena clearly envisages an ever increasing climate variability, including more frequent extremes and catastrophic events. But no quantitative monitoring is available with some given time-resolution. In fact, no mean global temperature can be defined, even though it is unlikely that one index alone can be representative of a planetary phenomenon. Sea-level or glacier extension are affected by a huge number of drivers can be locally interpreted in several different ways, resulting into unreliable proxies. Planetary seasonal maps of atmospheric CO_2 concentration provided by the NASA satellite OCO-2 have shown that - in contrast with the often claimed paradigm - compared to soil exhalation the anthropic CO_2 plays a negligible role. In addition, based on evidence given by the Hawai'i volcanism, huge time-variations of release of endogenous heat certainly occurred several times with peaks at a pace of ~27.4±0.05 Ma, reminding about an electrocardiogram. On the occasion of every heartbeat, a great extinction struck the biosphere, often involving mainly oceanic biota. Hence, there is urgent need to monitor phenomena in better detail, in order to avoid that the humans are the subject of the next extinction. At present, the Earth is experiencing one peak of a heartbeat, even though we cannot know whether the maximum already occurred or not. The focus is here on volcanism, that however - owing to the highly uneven and inhomogeneous historical record - has always been underestimated. In contrast, it can be shown that volcanism is a significant proxy of the time-variation of the planetary release of endogenous energy. An important evidence is that the present variability of volcanic activity is found to be synchronous all over the globe. Therefore, even one volcano alone can be a reliable and objective gauge of the time-variation of planetary exhalation of endogenous energy. There is only need to assess the available time-resolution of a quantitative monitoring. It is here shown that Stromboli, owing to its peculiar morphology, can be likened to an effective natural probe that monitors the time-variation of endogenous energy supply with a time resolution of a few days. Hence, the systematic exploitation and use of Stromboli as a natural monitoring facility is recommended, being the present unique possible quantitative way to monitor, with a high time-resolution, the time-variation of the primary driver of climate change associated to endogenous energy. An additional gauge can be, maybe, represented by the microorganisms that are endemically generated at ocean floors that can perhaps justify the time evolution of pathogens maybe also some pandemics. In fact, the mutation of deep ocean biota can be, perhaps, related to the evolution of pathogens that since several decades are well-known to require the updating of all vaccines. In addition, these mutations could also be the possible cause of unprecedented pandemics, that perhaps might even impact at a possibly increasing frequency. An improved capability to detect environmental changes with a higher time-resolution is a prerequisite for understanding and managing also these disquieting and unprecedented threats.

Keywords: Monitoring Climate Change, Time Resolution, Earth's Heartbeat, Volcanic Cycles, Stromboli, Climate Proxies, Ocean Floor Biota, Pandemics

Introduction

Only objective observational evidence is here considered any reference is here avoided to computed models. The Earth is presently experiencing an unusual period of intense climate change, associated with a heartbeat of the Earth's electrocardiogram (Fig. 1). One heartbeat is repeated at a pace of ~ 27.4±0.05 Ma and it lasts a few Ma (Gregori, 2002; 2020; Gregori and Leybourne, 2021) and references therein, where several details of the physics of phenomena are extensively discussed). Humankind, having a documented history of, say, ~30,000 years, never experienced an Earth's heartbeat. This is therefore an unprecedented challenge and a real disquieting hazard. In fact, whole human history is being developed during the present heartbeat, although the ±50,000 year error-bar forbids to assess whether the peak already occurred, or is still going to happen. A higher-resolution gauge is urgently needed.

Unquestionable and documented information is available for heartbeats during at least 70 Ma, but clear indication is available also during at least 250 Ma or even longer. A recent investigation (Rampino *et al*., 2021) found-consistently with the more precise determination of Fig. 1 - a global geologic activity with pulses displaying an underlying ~ 27.5 Ma cycle, evidenced by a Fourier analysis of 89 major geological events during last 260 Ma. In general, on the occasion of every heartbeat, a large extinction event always occurred, mainly involving oceanic biota, resulting from anomalous fluid exhalation from the ocean floors. The challenge is therefore to avoid that the present climate change is going to cause the extinction of humankind. Moreover, all actions must be carried out that can prevent and mitigate catastrophes, causalities sufferance.

On the occasion of every heartbeat, a Large Igneous Province (LIP) always was generated. The present ongoing heartbeat is perhaps very close to a maximum. The associated LIP is the birth of Iceland that ~2 Ma ago did not exist.

The prime driver of climate change is an anomalous release of endogenous heat, that is manifested through an increase of soil exhalation of hot fluids on the planetary scale. The very often reported belief - that anthropic CO_2 is the leading cause of climate change - has been observationally proven to be untenable, on the basis of the records by the NASA satellite OCO-2 (Gregori, 2020; Gregori and Leybourne, 2021 references therein). The phenomenon is accompanied by a large variation of the viscosity at the base of the lithosphere, i.e., at the Asthenosphere-Lithosphere Boundary (ALB). The term "asthenosphere" denotes a weak and comparatively less rigid, layer characterized by large fracturing due to serpentinization and supercritical water (Gregori and Leybourne, 2021 and references therein).

Owing to the non-uniform distribution of the release of heat-flow over the globe, different regions experience a comparatively either higher or lower thermal expansion of the mantle. The formation of huge superswells - almost like huge hills - determines the sliding of the lithosphere and thrusting into megasynclines, maybe altogether with some crustal folding. This phenomenon causes orogeny and the formation of continents that are later destroyed by weathering and erosion, with a cycle of ~100-200 Ma (maybe ~180 Ma, i.e., Mortari cycle). Therefore, a heartbeat is associated to the enhancement altogether of geodynamic activity, of volcanism and of the exhalation of hot fluids into the ocean/atmosphere system The incompatibility ought to be pointed out of the best known and fashionable plate tectonic model, that is unsuited to explain several morphological features (e.g., Gregori, 2002; Gregori and Leybourne, 2021).

Hence, an ever greater scatter of climate is to be expected, that perhaps might occur in the next years with respect to a mild trend. However, during the next decade the greater solar activity, with an expected maximum in 2024±1 (Velasco Herrera *et al.*, 2021), ought to temperate a little bit the violence of phenomena. In fact, a higher solar activity implies a concentration of sunspots into one or very few areas. The Parker spiral pattern of the solar wind shifts from 4 sectors to 2 sectors. Thus, the electromagnetic (e.m.) induction in the Tide-Driven (TD) dynamo of the Earth is affected by a lower frequency e.m. signal (by a factor 1/2), hence by a deeper skin-depth of penetration (see Gregori, 2002; Gregori and Leybourne, 2021). The consequent modulation of the TD dynamo is more effective soil exhalation increases. Therefore, when the Sun is more active, climate is milder, consistently with available observations.

The primary energy source is the TD dynamo, supplied mainly by the lunar tide (Gregori, 2002; Gregori and Leybourne, 2021). Energy propagation occurs by the Hamilton's variation principle, generating several spikes that make the Earth's interior to look like a sea-urchin, where every spike is the conductor of intense DC electric currents, that decay by Joule heat at the very top of every spike. This explains, e.g., the double-eye pattern of the magnetic anomalies of the area around a volcanic edifice (Fig. 2).

In fact, the magnetic anomaly of every volcano has a typical "double-eye" structure, a pattern that is to be associated with DC currents flowing perpendicular to the axis joining the centres of such two "eyes". A usual data handling of magnetic anomalies in volcanic areas is concerned with the topographic reduction, by which it is guessed that the outpoured magma solidifies within an ambient **B**, hence the volcano is composed of material that is entirely uniformly magnetised along one and the same direction. Thus, a higher topographic elevation corresponds to a stronger geomagnetic anomaly. Hence, it is customary to subtract, from the observed anomaly, the contribution that is likely to be originated by the topographic elevation and by assuming some constant specific volume magnetisation. Even after applying such a correction the "double-eye" pattern remains. Moreover, to our knowledge, the geographic distribution of the orientation of the direction of such "double-eyes" is suggestive of no regular pattern and nobody ever gave an explanation for this seemingly ubiquitous "double-eye" morphological feature.

The double-eye feature is observed in every reported geomagnetic anomaly map, e.g., also all over the Tyrrhenian Sea floor, etc.

Detection by Volcanism of Climate Change – Volcanic Cycles (time Resolution 50,000 Years Through Several 10 Years)

There is urgent need to focus on some proxy capable of improving the time-resolution of climate change monitoring. Indeed, every action that ought to be taken is effective when phenomena are at an early stage, in order to prevent any larger-scale impact.

At present, the time resolution of climate change is very low, as we can only rely on some generalized almost subjective feeling of an increased scatter of meteorological parameters, or of a seemingly larger seismic activity, etc. As far as volcanoes are concerned, they operate like security valves of a pressure cooker, with a typical timing that can be even of several centuries. Therefore, in any case the time-resolution of monitoring of the primary energy supply is very poor.

As far as the output is concerned of the Hawai'i hotspot - that gives evidence of the heartbeats (Fig. 1) - it can permit only a time resolution of ~±50,0000 years, due to intrinsic error-bars (i.e., uncertainty of measurement both of volumes of submarine volcanic edifices and of the age of the earliest lava-emplacement).

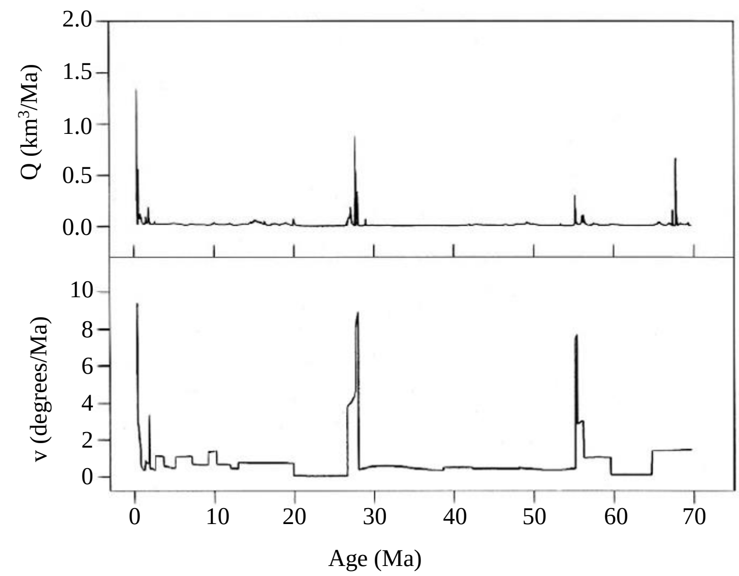

Fig. 1: Earth's electrocardiogram derived from the magma emplacement rate vs. time from the Hawai'i hotspot. The top plot refers to the time rate of the emplaced volume, the lower plot to the speed of the lithospheric drift on top the hotpot. The lower plot has smaller error-bars. For details refer e.g., to Gregori and Leybourne (2021) and references therein

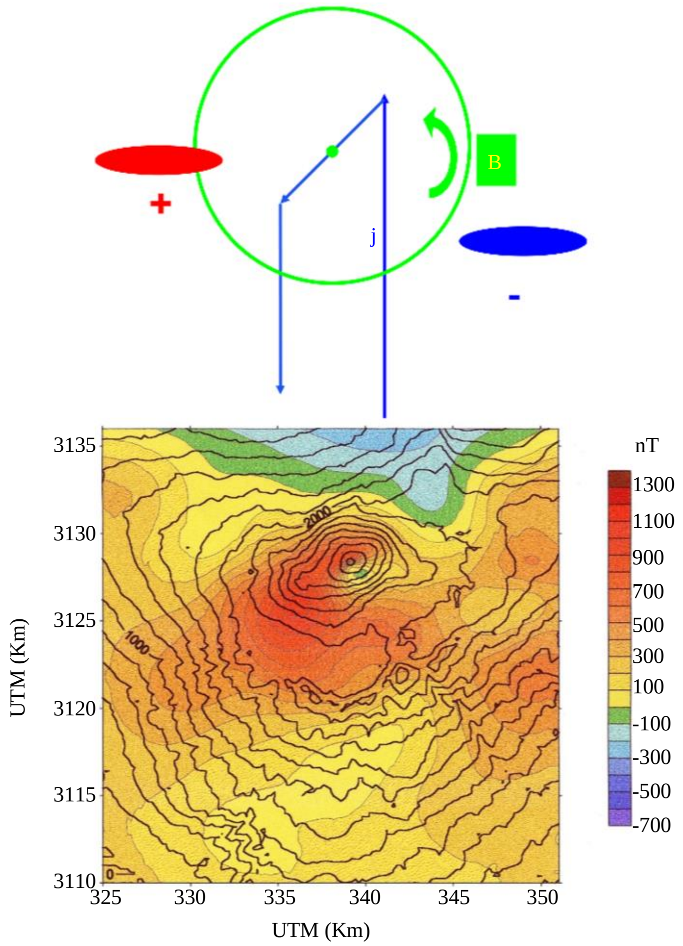

Fig. 2: (a) -Cartoon showing the scheme of the shallowest extension of a DC circuit supplying the top point of a sea-urchin spike. The magnetic field **B**, that is generated (green), causes a local geomagnetic anomaly of opposite sign (red and blue) on either side of the "horizontal" segment of such a circuit. The positive or negative sign depends on whether one considers either one hemisphere, as the conventional definition of positive and negative sign can have a different meaning, although with no ambiguity. (b) -Topography-corrected geomagnetic anomalies of Pico de Teide (Tenerife) (after García *et al*., 1997; units are kilometres; the colour version of the figure is a courtesy by A. Garcìa, I. Blanco and M. Torta)

Concerning the so-called and generally reported “climatic parameters”, it is well-known that no “mean” global temperature can be defined. Rather, it is evident that the scatter of “climate” with respect to a mean trend is more significant compared to every “smooth” and “mild” trend (Pavese and Gregori, 1985). But, the availability of historical information is in any case very limited, inhomogeneous and concerned with very restricted regions.

The often mentioned proxies of glacier retreat and/or of sea-level change are of very little help - if any - as these phenomena are controlled by a large number of drivers and mechanisms that are not understood. Hence, every reported trend can be explained by several competing and contradictory models and no reliable information can be attained. In this respect, a false though very often mentioned concern refers to icebergs that are claimed to be associated to the increase of atmospheric temperature. Ice (and also lava) have a very low thermal conductivity. Glaciers flow like huge ice-rivers at a speed even of a few hundred meter per year. Icebergs are formed when an ice sheet is overloaded by an excess precipitation at high altitude. Thus, the glacier is pushed downslope, until it floats on ocean water like some kind of “ice-tongue”- this is called “outlet glacier”. When it abruptly breaks, a large number of icebergs is released. That is, the phenomenon depends on atmospheric precipitation upstream, not on atmospheric temperature.

In any case, it should be emphasized that a crucial drawback is the impossibility to estimate the total water content that is stored in the four natural reservoirs, i.e., either in the atmosphere, or in the oceans, or in ice sheets, or underground. In fact, the water storage in every such a reservoir can change vs. time by some even very large amount.

For instance, an enhancement of endogenous heat-flow causes rock dehydration and favors subsequent serpentinization, that reduces friction at the ALB, increasing geodynamic phenomena and seismicity. But, owing to serpentinization, the asthenosphere increases thickness and total volume, hence the total amount is larger of supercritical water that is stored inside it.

At the same time, the enhanced hot fluid exhalation from soil originates a greater evaporation of water into the atmosphere, while ocean floors and sea bottoms are largely affected by tectonism, that dramatically influences the local sea-level change.

In addition, it should be considered that even the interannual variation of the total cloud cover cannot be monitored, due to the instrumental drift of satellite infrared measurements.

Therefore, there is urgent need for alternative and more reliable gauges of climate change.

Unlike what has been generally believed, volcanism can provide with significant information. However, as a premise there is need the get rid of the conventional way to look at volcanoes, that - as reported also in the most recent literature - according to some generally agreed and unconscious feeling are believed to be supplied by some network of pipelines for lava flow, reminding about the water-pipes in a building. Thus, reference is often found to “magma chambers” and to the eventual connection between different magma chambers.

That is, the ancient unproven and naïve myth survives of the Earth conceived like a hot fluid-ball that cools in space. This is a basically unconscious belief, reminding about the famous naturalist George-Louis Leclerc Comte de Buffon (1707-1788) who studied the cooling of bronze cannon-balls. The Buffon model seems to be still fashionable, although undeclared, in the literature.

Observational evidence is in contrast with such a naïve concept. A volcano is just a restricted area (for simplicity identify it with a “point”) of anomalous high local release of endogenous heat. The energy supply can be either (i) by Joule heat on top of a bunch of sea-urchin spikes (Fig. 2), or (ii) by friction heat consequent to the geodynamic activity and to the sliding of the lithosphere on the ALB. For instance, the largest number of volcanoes of the Pacific ring of fire is supplied by friction heat. In any case, a magma chamber is always a strictly local feature, specific of every given volcano, related to the endogenous heat source, of any kind.

The propagation of volcanic heat through the shallowest crustal layers occurs by fluid advection (i.e., water, oil, geogas others), although only as far as a sufficient amount of fluid is available. When the available fluids are insufficient for energy balance, the local temperature increases, hence also the local electrical conductivity. The currents of the sea-urchin spike can thus expand upward according to Hamilton’s principle, etc. That is, spikes further penetrate upward, when they reach a sufficiently shallow depth, the reduced lithostatic pressure permits melting. A new fluid is thus formed - i.e., magma - that eventually outpours like lava effusion. That is, the system obviates to the deficit of standard fluids and creates a new fluid.

This lava generation mechanism - related to the lithostatic pressure - applies for both primary energy source (i.e., either Joule or friction). Lava effusion is a spectacular seldom-occurring manifestation, much like a rainbow is an occasional although seldom-occurring event. That is, volcanism is a much more general phenomenon than lava effusion. Huge volcanic eruptions eventually imply no lava effusion (e.g., no lava effusion is reported from the famous Pompeii AD 79 eruption).

Summarizing, a volcano operates like the security valve of a pressure cocker cyclic features can be effectively monitored as follows. Consider the sequence of the time-lags Δt between two subsequent eruptions of one given volcano plot Δt vs. order number in the sequence (this is called “Imbò histogram”). Vesuvius and Etna are the historically best documented volcanoes (Fig. 3 and 4), even though the bias is evident due to the incompleteness of the historical data series. The data sources of Fig. 3 and 4 are the volcanic catalogue of the Smithsonian Institution (Simkin *et al*., 1981) and Gasparini and Musella (1991). But, also the assessment of a new eruption, with respect to the continuation of previous event, is to be critically considered. No detail can be here given. Use is made of the “atl-line” explained in the captions of Fig. 3.

Concerning Stromboli, only recently a complete historical data set was published by Bevilacqua *et al*. (2020). The corresponding Imbò histogram (Fig.5) is not very expressive, while the Imbò cycles plotted vs. date - instead of vs. order number - is indicative of a cyclic feature. The great lack of data is evident after 1950. This deficit of information is a clear indication of a lack of any interest by the scientific community for the physical significance of Stromboli as a proxy.

Apart the obvious “prediction” of a possible future sub-Plinian eruption of Vesuvius on the basis of the bi-millennial historical eruption series (Gregori, 1993; 1996a, 1996b), one can recognize a cycle in every volcanic data series. In order to minimize errors, conventionally define that a cycle begins (or ends) corresponding to a minimum of Δt. Consider the mean energy supply per unit time during one cycle of the volcano. This mean energy supply is inversely proportional to Δt. This argument is briefly called “calorimetric criterion”. Then, plot the mean energy supply vs. time.

When such an algorithm is applied to Vesuvius and Etna (Fig. 6), it is surprisingly found that solar activity modulates the volcanic supply. In addition, it is of paramount importance the fact that, compatibly with the available historical information, the same trend of heat supply is *synchronous* for every historical volcano all over the world (Gregori *et al*., 1992). The data source is the aforementioned catalogue by Simkin *et al*. (1981).

Figure 6 was formerly drawn in the early 1990s, in order to check the physical significance and reliability of the time variation of the primary energy supply to Vesuvius and Etna, as it is inferred from the Imbò cycle analysis of Fig. 3 and 4. The purpose was to compare the result with other known climate proxies. At that time, the available data were the DVI (Dust Veil Index) that refers to dust in the atmosphere that reduces solar radiation at Earth's surface. In addition, a well-known Eddy curve was available, plus a tree ring analysis of ^{14}C that is indicative of a variation of sunspot cycle. Finally, a statistical curve was available of global volcanic activity vs. time, based on the whole Smithsonian Institution catalogue, upon "normalizing" the reported eruption number to the total world population. That is, world population was likened to a "detector" that reported eruptions.

The result displayed in Fig. 6 was surprising and was one of the several hunches that formerly triggered Gregori (2002). Gregori (2002) later generated other investigations, including the three engines that control climate evolution, as reminded in Gregori and Leybourne (2021). It should be pointed out, however, that volcanic cycles have never been fashionable in the volcanological community. In fact, the study of volcanic cycles was started in 1928 by the late Giuseppe Imbò, who later became a renowned Director of the Osservatorio Vesuviano. But volcanic cycles were later unduly abandoned due to an incorrect use (and subsequent debate) made by other authors referring to the Hawai'i volcanism, on the basis of an unsuited data base. This caused an oblivion of this algorithm. Owing to brevity purpose, no detail can be here given. See e.g., a historical account in Bullard (1984). This explains, however, the lack of more recent literature on these topics.

A more detailed description of Fig. 6 is as follows. The top diagram in Fig. 6 is the old classical Dust Veil Index (DVI) that denotes the volcanic dust injected into the stratosphere by explosive eruptions. These events also caused famous famines. The DVI is derived by means of several proxies. See Lamb (1983) and references therein. That is, DVI refers to the so-called "nuclear winter scenario", which is the object of several climate models. Therefore, Fig. 6 shows that this phenomenon is occasional and local, although implying a planetary catastrophe, in contrast with the long-range trend deriving from the planetary endogenous heat release that affects volcanic cycles. Differently stated, the lack of any apparent correlation of DVI with other indices shows that independent phenomena are the volcanic cycles the explosive eruptions that cause a "nuclear winter scenario".

The 2nd diagram (top to bottom) in Fig. 6 shows a conventional, classical well known (Eddy, 1976) trend of the historical climate. The 3rd and 4th plots were derived by (Stuiver and Braziunas, 1988; 1989 references therein) upon considering that a comparatively higher solar activity implies a lower cosmic ray flux impinging on the Earth (Forbush decrease), hence a smaller ^{14}C production rate. Two related regression lines are needed (not here shown) that refer to ^{14}C content vs. – respectively - either sunspot number or some indices of geomagnetic activity. These curves were calibrated by Minze Stuiver *et al*. by means of available historical observations. Then, the ^{14}C content in tree rings (of a given age) was used to infer - through the previously determined calibration - either the solar or the magnetic activity index during previous and non-documented epochs.

These data are plotted in the 3rd and 4th plots, where the dotted line shows, for comparison purpose, the curve derived from direct sunspot observation. Note that the tree-ring-derived curve is physically more objective and significant than the subjective standard astronomical definition of sunspot numbers. To our knowledge, the most recent aforementioned reconstruction of past sunspot cycles (Velasco Herrera *et al*., 2021) was not yet correlated with tree rings series. Such a very recent reconstruction was derived from Artificial Intelligence (AI) algorithms applied to sunspot data series. In this respect, AI application to astronomical and astrophysical phenomena recently experienced a relevant expansion (see e.g., Fluke and Jacobs, 2019), more specifically, the Deep Learning (DL) and Machine Learning (ML) algorithms, that are particularly suited for time series analysis (e.g., Lewis, 2016; Nielsen, 2019). In any case, as far as the application is concerned to volcanic series, a warning is that the observational data base is particularly scant and inhomogeneous the effectiveness of any kind of algorithm can be seriously hampered and considered with great care.

The 5th plot in Fig. 6 shows the time variation of the primary energy supply to Etna and Vesuvius in terms of the aforementioned "calorimetric criterion", applied to the Imbò histograms of Fig. 3 and 4. The plot conventionally reports the computed ratio relative to the heat supply occurred in AD 1886. The choice of this year was only determined in order to minimize error bars. The trend is found to increase by ~500-600% during the last ~5-6 centuries. This effect can well justify the transition from the Little Ice Age to present climate.

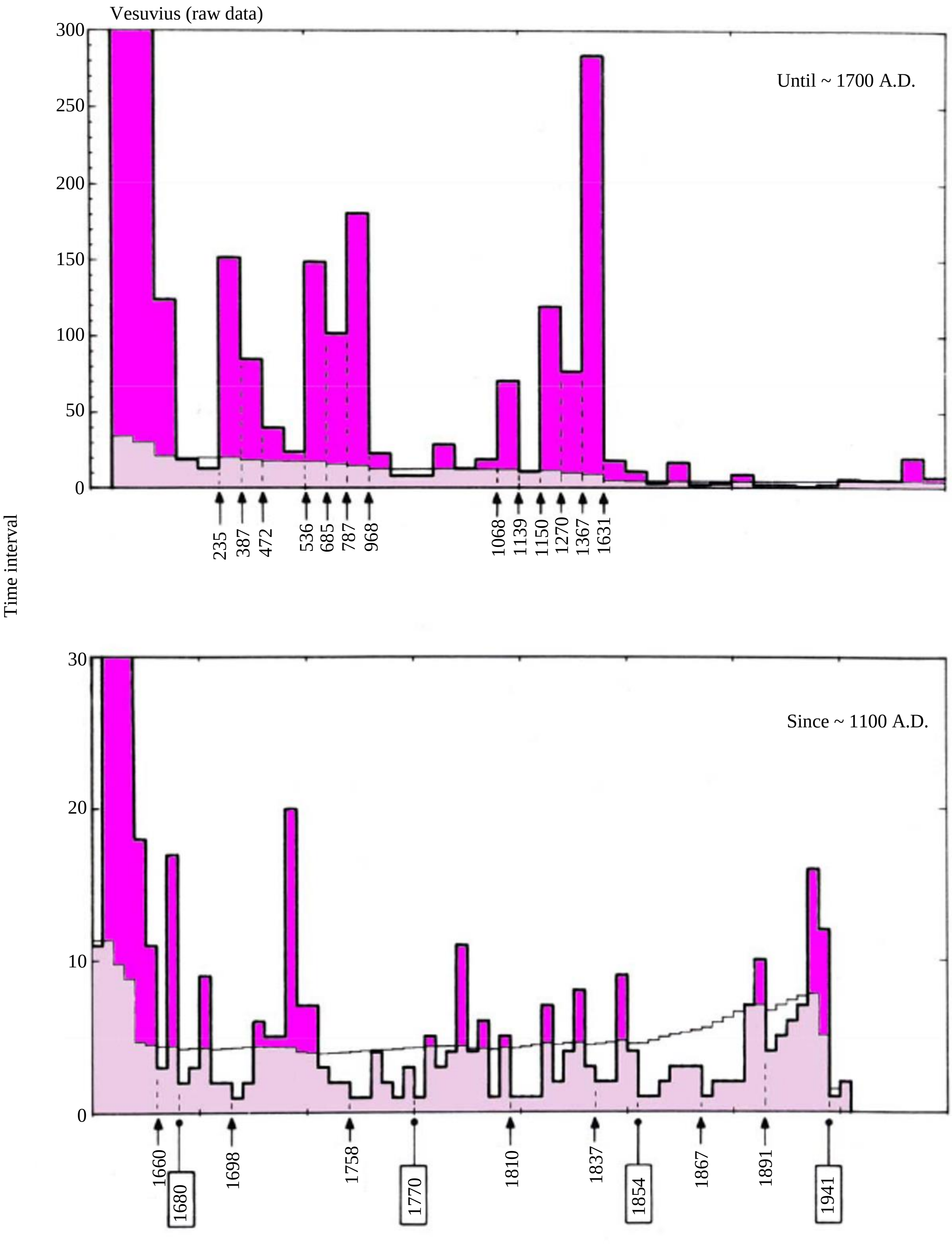

Fig. 3: Imbò histogram both for the bi-millennial and for more recent historical eruption series of Vesuvius. The smooth line is the mean of all values of the histogram at the right of every respective point (called "average-time-lag-line" or "atl" line) used to give an objective definition of cycle boundaries. After Gregori (1996a)

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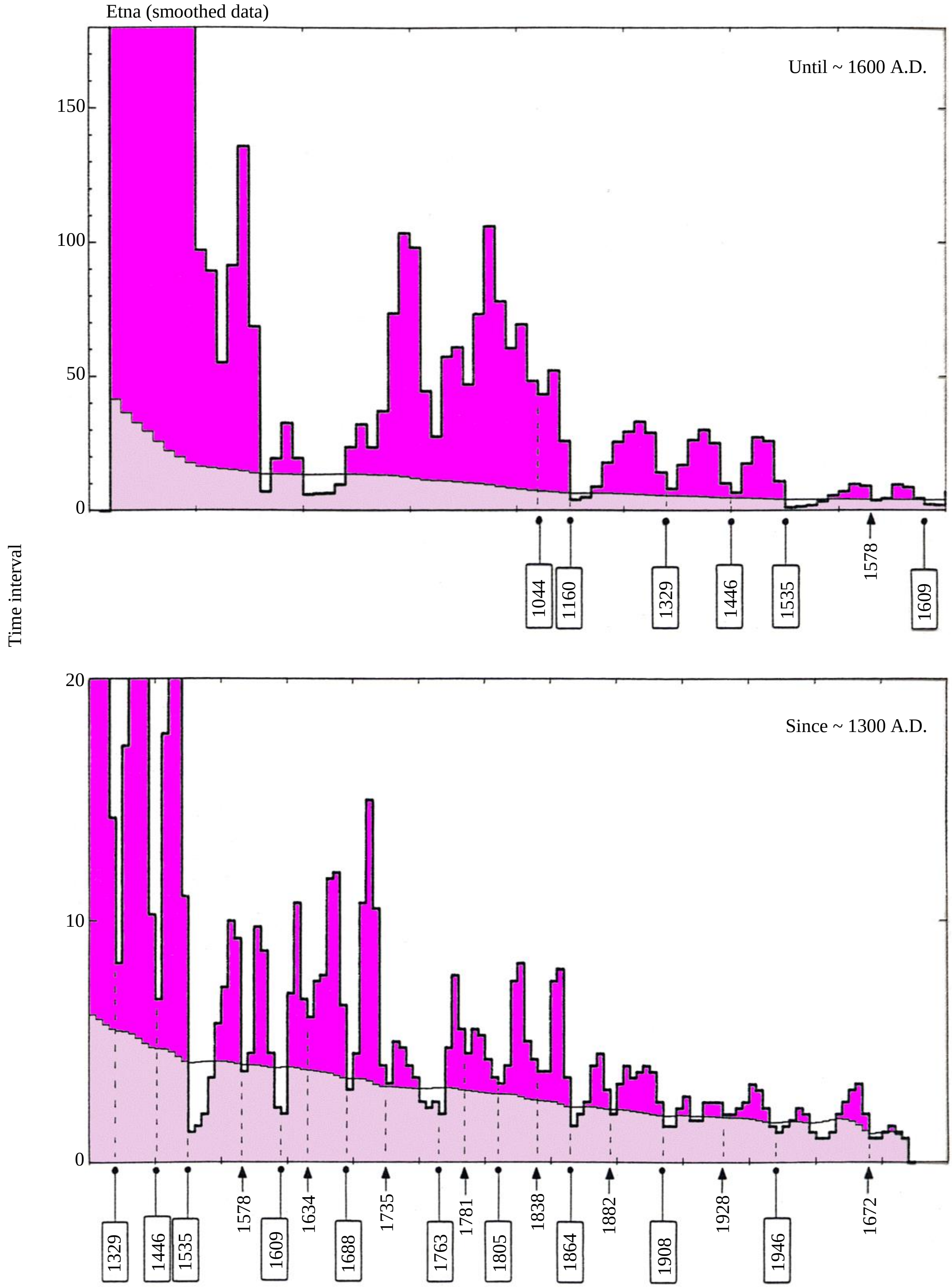

Fig. 4: Imbò histogram for Etna (see captions of Fig. 3). After Gregori *et al.* (1992)

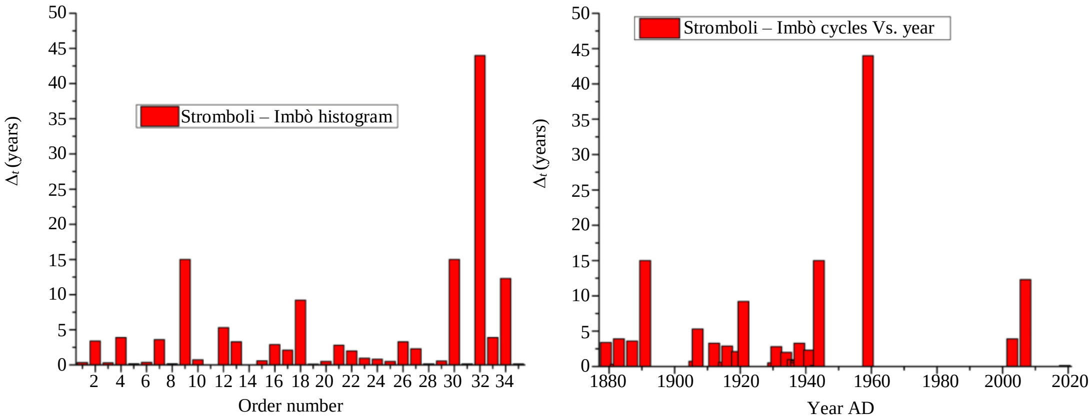

Fig. 5: Imbò histogram for Stromboli Imbò cycles Vs. year. Unpublished figure based on data after Bevilacqua *et al*. (2020)

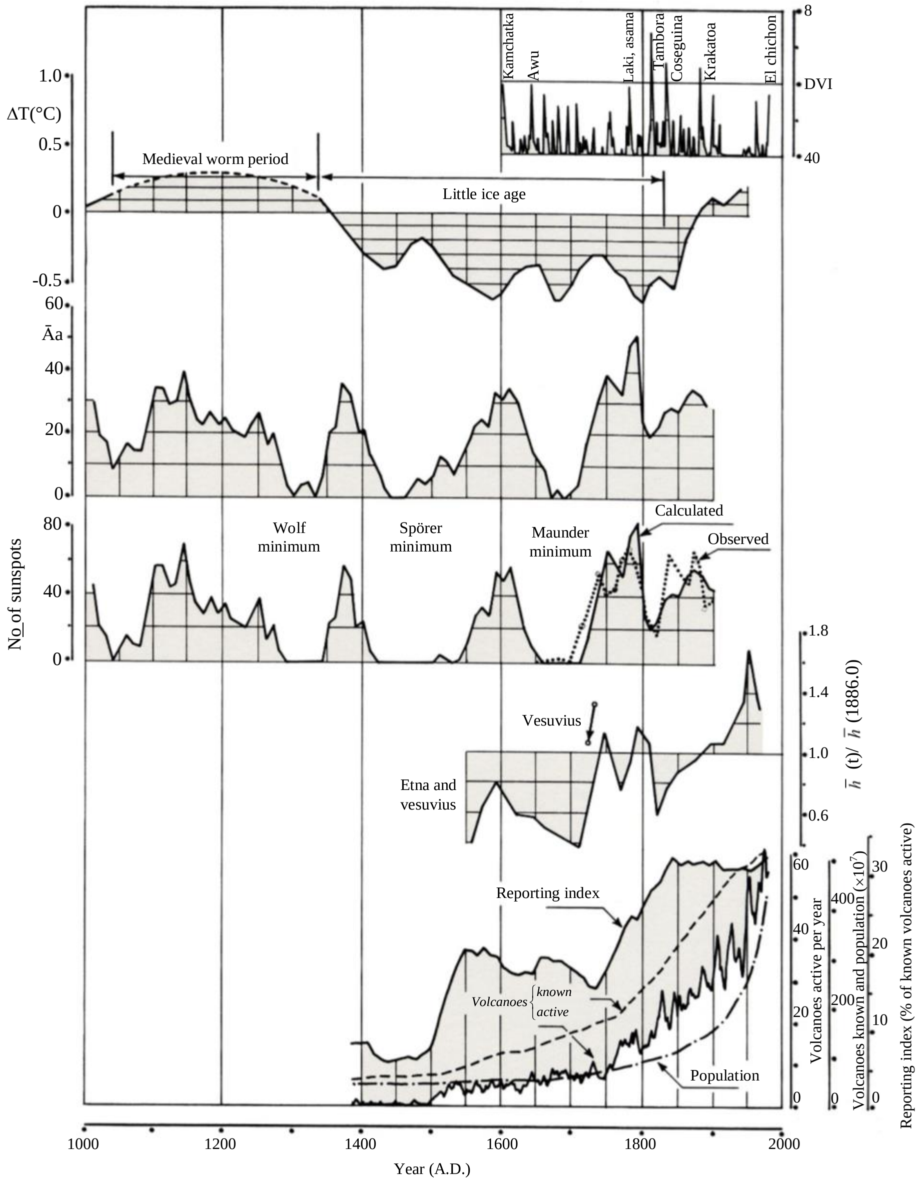

Fig. 6: Comparison of volcanic cycle evidence and climate proxies. See text. Figure after Gregori *et al.* (1992) and Gregori (2002)

In addition, as already mentioned, such a time variation of the primary supply to volcanoes is found to be synchronous for every historical volcano from all over the globe. This is important. In fact, only one volcano is thus suited to act as a planetary gauge.

The bottom diagram in Fig. 6 - redrawn after the Smithsonian Institution Simkin *et al*. (1981) volcanic catalogue - shows several parameters, namely a suitably smoothed trend (i) of the total world population, (ii) of the total number of known volcanoes, (iii) of the total number of reported active volcanoes (iv) of the "reporting index", i.e., of the ratio of reported active volcanoes with respect to the total number of known volcanoes.

It is worth noting that this same diagram was not reported in the second edition of the volcanic catalogue of the Smithsonian Institution (Simkin and Siebert, 1994), evidently believing that it is not physically significant. This is clearly suggestive of the underestimation of volcanism as a proxy suited to monitor endogenous heat release. Such a prevention and drawback derives from an improper concept of the prime drivers of volcanism, related to the aforementioned Buffon's concept of an Earth considered like a hot ball that is cooling in space. The completely unprecedented perspective, that is highlighted e.g., in Gregori (2002) on in Gregori and Leybourne (2021), envisages an Earth that behaves like a battery that stores and releases energy at different times. Thus, a plot, like the bottom diagram in Fig. 6 - that was formerly considered physically unreliable - is found to be significant, even though the historical data base is largely uneven and discontinuous.

Summarizing, if one relies on the duration of volcanic cycles, one can infer a time resolution – for monitoring the endogenous heat that controls climate change - that is compatible with the duration of a volcanic cycle, such as in Fig. 6. On the other hand, the time resolution is in the order of magnitude of at least several decades, or even of a few centuries. In addition, the historical information is scant - in the ultimate analysis - this proxy is therefore of little practical use.

Stromboli (Time Resolution a Few Days)

Stromboli is peculiar, as it displays a unique and classical well-known morphology. The size of Stromboli is comparable to Etna's - unlike Vesuvius that has a linear size three times smaller. But, unlike Etna (which is up to 3326 m high, although the height is increasing), Stromboli is almost entirely immersed in water, with peak elevation at 926 m above sea level. Hence, unlike Etna, Stromboli has a huge availability of water that, by advection, periodically releases the energy that is accumulated during a time-lag of, say, $\Delta t \approx$ 20 min. Instead, Etna accumulates the internal heat until the stored energy is sufficient to generate an adequate amount of lava. Thus, a lava effusion can occur the phenomenon is repeated at a pace of the order of, say, ~2-3 years.

On 28-30 December 2002, Stromboli had an unusual great paroxysm, that also caused a small tsunami. Gregori and Paparo (2006) reported the interpretation of this phenomenon in terms of the records of Acoustic Emission (AE), i.e., passive ultrasound monitoring, that measures the response of the solid materials of the volcanic edifice to the time-varying impact of the pressure by endogenous hot fluids (see details of methods e.g., in Gregori, 2020 and references therein). To our knowledge AE monitoring resulted to be the unique specific available instrumental monitoring of the paroxysm-except seismic records. Two frequencies were monitored, i.e., a Low-Frequency AE (LF AE) at 25 kH a High Frequency AE (HF AE) at 200 kH. Unlike LF AE that reflect the mechanical yield of the solid structures of the volcanic edifice, the HF AE are indicative to the time-varying supply of the primary endogenous energy. These AE techniques and methods are quite general suited to monitor the performance and security of every either natural or manmade structure (e.g., Gregori, 2020 references therein).

The different information is to be stressed between the amplitude of the recorded HF AE signal (Fig. 7) and the fractal dimension D_t of the signal (Fig. 8). In fact, the fractal dimension denotes how the crystalline bonds of the solid materials respond to the increasing stress originated by the endogenous hot fluids. That is, D_t monitors the performance of the solid structure of the volcanic edifice, rather than the intensity of the applied stress.

A similar phenomenon - displaying the typical difference between raw AE records and D_t - was observed in the laboratory by stressing by a mechanical press - until final rupture - concrete cubes of 15 cm side, getting plots analogous to Figs. 7 and 8 (Gregori and Paparo, 2006 and references therein).

It is thus found in Fig. 8 that D_t steadily increased during several months. The records were interrupted on September 23rd, 2002, due to a bad functioning of the recording device. Consider the unfriendly environmental conditions where instruments are operated. It is therefore very reasonable to infer that when the threshold $D_t = 1$ was attained, the volcanic edifice yielded and new boas were opened on the flank of the volcano, causing also a small tsunami.

Some fluctuations in Fig. 8 are associated to the erratic changes of the endogenous fluid pressure, that are shown in Fig. 7. The ~4-5 day periodical variation in Fig. 8 is probably associated to the meteorological circulation, by which the weight exerted on the volcanic edifice by the atmospheric pressure modulates the response of the stress applied to the materials.

When the rupture threshold is attained, the paroxysm occurs the volcano is reset. That is, Stromboli - through the fractal dimension of cyclic activity - is an effective natural probe suited to monitor in real time the time-variations of endogenous heat supply.

The interpretation was also checked with CO_2 exhalation recorded in several wells that other authors independently monitored on the island. However, soil exhalation of fluids is sensitive to the enormous local space-gradient of soil porosity, by which measurements are greatly scattered and affected by large error-bars. In any case, the mean trend was found to be consistent with the AE records, although upon allowing for a conspicuous scatter.

It is therefore concluded that the peculiar nature of Stromboli permits to monitor in real time the trend of the time-variation of the endogenous heat supply, with the time-resolution permitted by the variations of the atmospheric baric pressure, i.e., with a time-resolution of the order of magnitude of, say, one or a few days, as the performance of the volcanic edifice responds to the mean trend of the endogenous time-varying stress.

The Stromboli monitoring looks therefore precise, objective sensitive to minor changes.

On May 19th, 2021, Stromboli had a new violent paroxysm, reported by all mass media, with no consequences. This is consistent with the several other reported proxies that indicate an ongoing climate change. Unfortunately, no AE recording station is presently operated on the island.

It can be stated that every eventual volcano with a similarity to Stromboli - even though with a different timing of cycles - can be considered an efficient natural gauge of the time-variation of the planetary primary endogenous heat supply. Every such a volcano operates almost like a dedicated probe, aimed to monitor - on the time-scale of the cycle - the variations all over the globe of the release of endogenous heat by the TD dynamo.

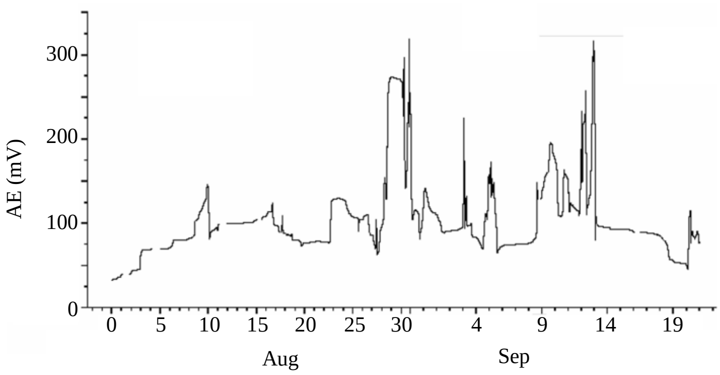

Fig. 7: "The result of applying the triangular weigh function of width t = ±12 h to the August and September raw data set (every raw datum is a 15 min average*)*. Figure after Paparo *et al.* (2004)." Figure and captions after Gregori and Paparo (2006)

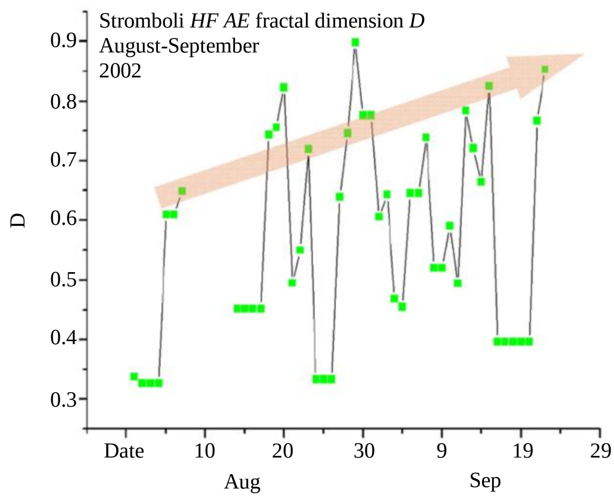

Fig. 8: "Fractal dimension D_t computed on the point-like process that results after subtracting the ±12 h running-average, shown in Fig. 7, from the unsmoothed raw data set (i.e., every raw datum is an average over 15 min). The point-like process is defined by choosing only 'YES' events that result above some given threshold. Every D_t value was computed for one day. Whenever the number of 'YES' events available for one given day resulted insufficient, several subsequent days were considered altogether and they are here plotted like several days with the same D_t. We stress the significant circumstance by which, when the volcanic edifice is 'deflating' and D_t results comparatively low, the AE events in the point-like process seldom occur, due to a temporary reduction, or lack, of any prime energy breeding to the volcano. Figure after Paparo *et al.* (2004)." The added orange arrow shows the increasing trend that presumably continued until reaching on December 28th a value D_t = 1. See text. Figure (modified) and captions after Gregori and Paparo (2006)

Ocean Floor Biota

Even though we have no competence in microbiology, another possible and important gauge of the time variation of the endogenous heat supply - with a time resolution of, say, a few months - can be provided by the time variations of deep ocean floor biota.

In fact, it is now well-assessed that life (microorganisms) are steadily and endemically regenerated of the deep ocean floors, being supplied by endogenous exhalation of hot CH_4 (Judd and Hovland, 2009). It is therefore reasonable to expect that, maybe, a relevant change of the release of endogenous heat flow can produce a possible mutation of the generated microorganisms.

In this respect, since several decades it is well-known that vaccines have to be continuously updated, due to the mutations of the pathogens. This means that, maybe, also pandemic phenomena can be originated by changes of the microorganisms that are spontaneously generated at deep ocean floors.

That is, if this tentative hypothesis is correct, biota could be a reliable proxy aimed to monitor the effect of some forthcoming impact of the biosphere on climate, including some expected pathogens that might eventually imply a pandemic hazard.

Therefore, a reasonable recommendation is that samples of matter (sand) from deep ocean floors ought to be systematically collected every few months by Autonomous Underwater - or Unmanned - Vehicles (AUV) in order to monitor the ongoing mutations of micro-biota. This could be a way to monitor the role of endogenous heat exhalation on life evolution and also a way to know - in advance - the eventual possible trigger of any new unpredictable pandemics. This is speculative, although realistic.

The time resolution that can be attained depends on the AUV operation costs, but mainly on the unknown sensitivity of the biological sensor to changes of endogenous heat flow. If successful, this would result to be a highly reliable and precise monitoring of the mutations of the global environment, while whole Earth is a unique natural system, including the biosphere.

Conclusion

Climate change is an unprecedented challenge for humankind and must be monitored objectively and with high time-resolution in order to be able to plan timely actions aimed either to prevent catastrophes or to mitigate the hazard.

Climate change can be indicatively monitored by means of several proxies that give a quantitative and objective gauge, however with various time-resolution. The focus is here on volcanic cycles - that are a generally underestimated proxy - and, more specifically the focus is on Stromboli that gives information with a precise highly valuable time-resolution of a few days.

Also deep ocean-floor biota is a possible proxy, with a time-resolution defined by the frequency of deep ocean sampling and by the sensitivity of biota to changes of endogenous soil exhalation. Monitoring the mutation of deep ocean-floor biota, depending on the change of endogenous geothermal flux, is an important proxy for understanding the role of the biosphere in the Earth evolution and, maybe, even a way to know in advance the eventual birth of new pathogens that can even trigger unprecedented diseases or pandemics.

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Author's Contributions

Giovanni Pietro Gregori: Data analysis and writing the paper.

Gabriele Paparo: Instrument instalment and operation in the field, data acquisition, relevant physical contribution to discussion and interpretation.

Ethics

This article is original and contains unpublished material. Authors declare that there are not ethical issues and no conflict of interest that may arise after the publication of this manuscript.

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