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Indice

Supplementi ai Convegni

Palaeoclimate and archaeoclimate. The natural causes

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Riassunto. Le cause naturali che controllano il clima ben sembra possano venire spiegate in un contesto di relazioni Galassia – Sole – Terra, conformemente allo schema seguente. Gli incontri del sistema solare con materia interstellare controllano, tramite la fisica solare ed il vento solare, l'induzione e.m. nella Terra, la geodinamo e l'ammontare dell'energia endogena. La Terra si comporta come una batteria di automobile, con tempi diversi di scarica e ricarica. Le variazioni temporali del rilascio di energia endogena causano un corrispondente andamento nelle esalazioni dal suolo e dunque nella chimica atmosferica. Ne risulta una modulazione sull'effetto serra e sulla biosfera, come ultimi anelli della catena causa/effetto. Le anomalie climatiche degli ultimi due millenni per le quali si ha notizia indiretta sembrano accordarsi molto bene con questa via "interna" (le eccezioni molto sporadiche sono connesse ad eruzioni vulcaniche esplosive che hanno iniettato polvere in stratosfera). Questo schema interpretativo è stato costruito con induzione logica, con progressive aggiunte di dettagli derivanti da fatti osservazionali specifici, senza alcun modello fisico o matematico preconcetto. Per brevità solo pochi cenni sommari possono venire qui forniti. Una discussione più puntuale e dettagliata si trova in una monografia dell'autore apparsa nel *2002*, ed in un'opera in 8 tomi in avanzata fase di completamento (Gregori, 2012).

Acronyms

Afar SuSw = Afar superswell
ALB = asthenosphere-lithosphere boundary
Atl MOR SuSw = Atlantic mid-ocean ridge superswell
CMB = core-mantle boundary
E.S.I. = electric soldering iron
EastEIB = eastward Easter Island lithospheric belt or strip
EI SuSw = Easter Island superswell
IC = inner core
ICB = inner-core boundary
LIP = large igneous provinces
Ma = million years
MHD = magneto-hydro-dynamics
MOR = mid-ocean ridge
OC = outer core
SHE = spherical harmonic expansion
ss = spherical surface
SST = sea surface temperature
SuSw = superswell
SV = geomagnetic secular variation
TD = tide driven
WMT = warm mud tectonics

1. Introduction

Climatology, and to a much larger extent palaeoclimatology, includes almost every discipline of Earth's sciences. It appears almost impossible to give a definition of "climate". The term "environment" can be used for a wide variety of applications (e.g. one can refer to interstellar or interplanetary environment, etc.).

The term "climate" is here used as synonymous of "environment where the biosphere can develop and survive". "Climate" is therefore a concern dealing with some comparatively very thin layer between solid Earth and/or ocean and/or atmosphere (Figure 1). Unlike in laboratory science, in Earth's sciences we cannot separate physical, chemical, and biological effects. An Earth's scientist must deal, altogether, with all kinds of effects. He can only observe, and only very seldom he can carry out an active experiment aimed to modify the natural system. In terms of an expressive comparison, the investigation of "climate" appears *per se* as difficult as, or even more difficult than, the study of the human body. Medical sciences can rely on some huge number of potential case histories, unlike the climatologist who has available only one unique "patient", i.e. the Earth and its history.

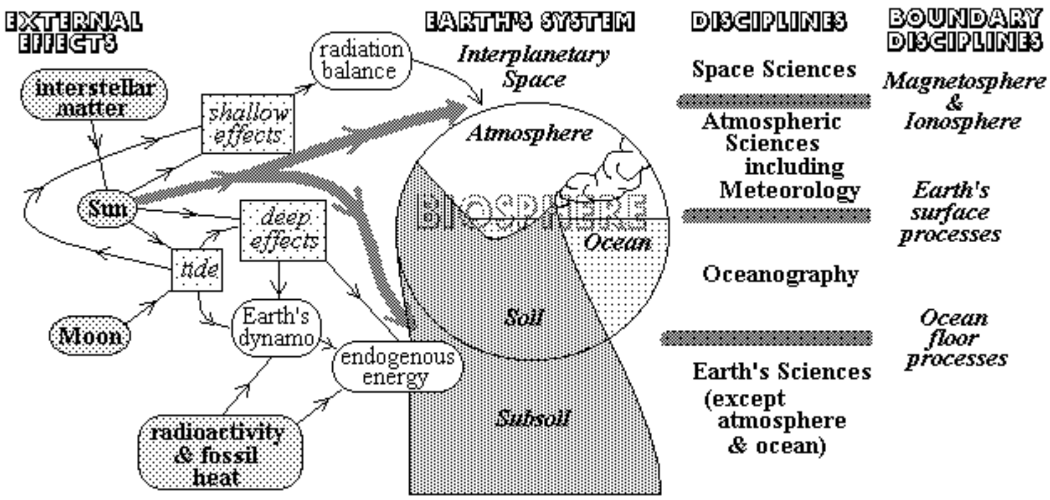

Fig. 1. Climate is the environment where the biosphere can live and survive. Climate is a typical boundary phenomenon between soil, ocean, and atmosphere. The separation of Earth's sciences into solid Earth's geophysics, oceanography, atmospheric sciences, and all respective sub-disciplines appears unrealistic and often misleading.

The time variations of climate can be well explained in terms of Galaxy – Sun – Earth relations. A concise account is here given, and, owing to brevity purposes, it is impossible to report and discuss the several evidences that support this interpretation. All presently known climatological evidences either on the geologic time scale, or during the last millennia, appear consistent with this proposal, upon considering also the leading role of humankind as a crucial and compulsory agent for climate control (Gregori and Gregori, 2003). Interstellar matter of every origin interacts with the Solar System and modulates the physics of the solar wind, which affects the deep Earth physics and its endogenous energy budget. The Earth operates like a car battery, with different temporal variations of its charging and discharging. A time varying soil exhalation causes a time varying atmospheric chemistry and greenhouse effect.

Such an entire multidisciplinary approach was derived by no preconceived idea, rather only in terms of the classical "logical induction" by progressive addition of details specifically suggested by different observations. Section 2 deals with a few basic methodological premises. Section 3 deals with the central item, i.e. with the rationale and prime cause of the origin of the magnetic field **B** of the Earth, in terms of a tide-driven (*TD*) dynamo, which generates a conspicuous amount of time varying endogenous energy, in terms of a specific mechanism, controlled by the variability of the long-period solar activity. Section 4 mentions the general perspective of Galaxy – Sun – Earth relations. Section 5 contains, for brevity purposes, only very few mentions of observational evidences of climate variations, which support the mechanism here envisaged.

Concerning the present much debated item of the anthropic responsibility in the so-called "global warming", the much authoritative and very wealthy study by Quinn (2010) ought to be considered. Upon carrying out a systematic and extensive investigation on the apparent correlations between every couple of the most complete data series available from the international data centres, he has clearly shown that the CO_2 concern is a false belief. Anthropic pollution is certainly a most relevant aspect of present climatology, but CO_2 is one of the several facets of the problem, and certainly it is not the most important concern.

Rather, Quinn (2010) has shown that the primary agent in solar-terrestrial relations is certainly manifested by geomagnetic effects, which seem to precede all other observed changes, thus supporting the hypothesis of a clear influence of the interaction with the solar wind.

2 . Methodological premises

We should refrain from relying either on an excessively strictly pragmatic viewpoint, or on mere abstraction or speculation. The Ockham's razor[1] is the most effective tool by which we should keep close to natural reality. *Exploratory* and *confirmatory* analyses are two fundamental steps of our cognitive process (Tuckey, 1977). Numerical modelling is an important part of the *confirmatory* stage, although it should be exploited only - and strictly only - whenever we already achieved, during the *exploratory* stage, some satisfactory qualitative interpretation about the structure and processes that govern the physical system. The exploratory and confirmatory stages remind, respectively, about the Aristotle's logical *induction* (i.e. from observations to laws and axioms) and *deduction* (viceversa). Or only whenever we presume to have achieved an adequate understanding of a given system, we should dare to implement a numerical model. In addition, whenever needed, we should dare to force this model in order to match as many observations as possible.

In the case, however, that our starting scheme is physically incomplete and/or inadequate or incorrect, we often forget about the eventual need for a critical re-thinking of our starting formulation, in terms of some improvement of our former *exploratory* stage. Instead, it is very common in science to shun every change of some former presumed (and eventually incorrect) interpretation, and to appeal, rather, to all mathematical facilities for *compelling* our preconceived model to

[1] Gregori and Gregori (1997), and references therein.

obey to our will and to fit observations. Mathematics is only one peculiar language by which we can write our guessed interpretation. Mathematics permits checking whether our guess is correct or not. But mathematics *per se* can give *no new* physical insight.

According to a feeling shared by several scientists, the present Earth's sciences are often biased by an excessive confidence in numerical models. For instance, a medical doctor shall never rely on a numerical model of the body of his patient, as he is realistically aware of the limits of his knowledge about the basic phenomena that control the physical, chemical and biological system of his patient. Several branches of science (not only climatology) should critically re-consider the basic foundations of their claimed understanding.

In general, it is a hazard to envisage some new physical law with no adequate observational test, because this shall unavoidably appear like an *ad hoc* hypothesis. For instance, Newton was certainly unhappy when he introduced universal gravitation, as he basically could rely on no direct observational support from any laboratory measurement. A few decades earlier, Kepler and Gilbert had desperately tried to interpret the orbit of the planets by means of an already known force, i.e. by magnetism. Today, the international scientific community would reject like nonsense every analogous proposal, based on some speculation about some totally new force for explaining some otherwise unexplained effect. In addition, consider that, until nowadays, gravitation apparently refused every direct observational link with other fundamental interactions. Maybe, the Newton concern is therefore still up-to-date.

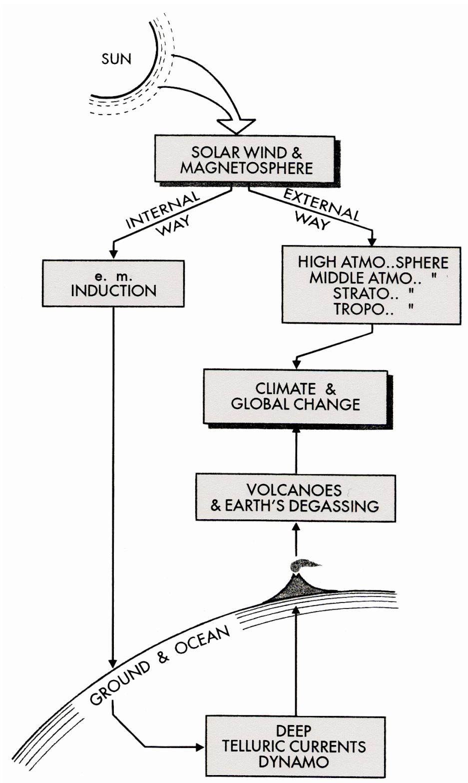

Fig. 2. The internal and external way.

While facing "climate", we must feel conscious of our cognitive limits and of the realistic content of our available observational information. Climatology and palaeoclimatology are here discussed in an attempt to show that a set of several presently available multidisciplinary observations fit into a specific interpretation. The mechanism here envisaged ought to be considered as a reasonable working hypothesis, viable for discussion, no matter how (sometimes unavoidably) speculative it may appear. The ultimate target of our understanding is the search for a progressive accumulation of finalised observational analyses aimed to confirm, to support, or to rebut some guessed interpretation.

The Sun is – and it has always been - the primary leading controller. Sun – Earth relations are the key concern. In this respect, we need to distinguish the "external" and the "internal" way (Figure 2). The literature is apparently concerned only with the external way. In contrast, according to the observational evidence, the internal way objectively seems to be much more effective. We must first assess the role of the endogenous energy of the Earth, and the eventual control on it by Sun – Earth relations. Such a target can be effectively investigated by means of the geomagnetic field **B** and of its origin.[2] The basic rationale for explaining climate begins therefore from consideration of the geodynamo, and its associated endogenous energy.

All this has relevant implications on almost every branch of Earth's sciences, and this whole topic is discussed in some detail in an 8-tome set that, at present, is being smoothed and revised (Gregori, 2012).

3. The geodynamo, the internal structure and the endogenous energy of the Earth

For brevity purposes, let us only remind about three dates and three authors, i.e. *1905* Einstein, *1919-1920* Larmor, and *1946* Elsasser.

In *1905* Einstein, shortly after his famous memoir on relativity, wrote that the origin of the magnetic field **B** of the Earth was one of the five unsolved problems of fundamental physics. For millennia, the cause that moves the needle of the compass remained mysterious, almost a nightmare, and the Einstein statement expressively stressed this point.

In *1919-1920* Larmor proposed a mechanism suited to explain the magnetic field **B** of the Sun and of the stars, in terms of an *MHD* dynamo supplied by the endogenous energy (thermonuclear reactions) that causes a violent convection, to be combined with *rapid* rotation and Coriolis forces. The term *MHD* was coined by Alfvén in ~ *1945*. A less frequently used term is "hydromagnetics".

In *1946* Elsasser, with his great personality and the prestige of Princeton University, proposed to apply the Larmor dynamo also to the Earth. He speculated about a suitable endogenous energy source, e.g. originated either by radioactivity, or by phase transformation (i.e. by a slowly decaying fossil energy), which generates convection within the outer core (*OC*) of the Earth.

The millennial nightmare had thus seemingly faded away. The Elsasser dynamo got rid of several previous unrealistic tentative proposals and models. Very soon it became an undisputed "theory" within the international community. This is generally referred to as the Elsasser-Bullard *MHD* geodynamo. During the subsequent years, however, an increasing number of experimental evidences were going to be collected, which could hardly fit with this model. The research strategy was therefore to search for some improved and progressively more

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[2] Only a very limited and much schematic presentation can be here given. The standard reference is the monograph Gregori (2002; brief presentations are Gregori, 2000, 2004). The basic critical discussion of previous models is given in (roughly) the first half of Gregori (2002). The "constructive" aspect of the new proposal, i.e. the detail of a new model capable to fit several observations much better compared to the previous standard geodynamo, can be found also in Gregori *et al.* (2001).

complicate numerical models, by adding some *ad hoc* corrections or speculations, based however only on mathematics, rather than on some deeper physical insight. The purpose was only to attempt to fit in some way the newly collected and apparently contrasting evidence.

In contrast, the geodynamo here envisaged is the result of a critical re-thinking of the basic *exploratory* analysis, beginning from the set of unexplained observational inferences. This logical and critical process culminated in Gregori (2002) to which the interested reader ought to refer. The final result is concerned with an *MHD* dynamo, just like Larmor's or Elsasser's. The prime energy source, however, is *the differential tidal torque* acting on different components of the body of the Earth. The result unexpectedly provided with an unprecedented explanation for the entire endogenous energy budget of the Earth, implying some substantial changes and rethinking of the general way of conceiving the Earth interior, its processes, and its evolution.

3.1. Some history

For clarity purposes, it appears worthwhile resuming a few historical points, which are, maybe, the best way for clarifying some crucial items.

For several millennia, the Earth was conceived as being crossed by caverns and channels, etc., much like some kind of a solid sponge or a blue cheese (refer to the accompanying paper by the author). This idea apparently dated back since the pre-classical civilisations of Sahara (Arnàiz Villena and Alonso Garcìa, 1998), and persisted until very recently, e.g. in *1864* in the Jules Verne's *Voyage au centre de la Terre*[3] and even later. For millennia magnetism had appeared disquieting and fascinating. The needle moved. Two needles attracted or repelled each other, etc. Nobody afforded to reproduce or modify this behaviour (unlike e.g. for electrostatics that could be reproduced by friction etc.). In *1600*, Gilbert published his *De Magnete*, based on an analogical model (i.e. a terrella of magnetite; the needed mathematical algorithms were formulated by Legendre only in *1785* and *1789*). Gilbert proved that the Earth appears just like a uniformly magnetized sphere. This was a most remarkable success. Descartes wrote a treatise on magnetism, which, in reality, was on geomagnetism. Kepler desperately tried to explain the orbits of the planets by the magnetic force,[4] until Newton proposed the

[3] Jules Verne (*1828-1905*) was a professional geographer, who had proposed a scientific exploration of Africa by balloons, thus anticipating the idea of airships, and of airborne remote sensing. But nobody apparently took him seriously, and he felt very frustrated. He was encouraged to write some novel etc. He was immediately very successful and acknowledged as a famous popular science and novel writer.

[4] Kepler, one of the most skilful and clever performers of the *exploratory* analysis, is sometimes reported as being a strange mixture of modern thinking and Aristotelian heritage. Actually, maybe, his logical approach is presently underestimated. Since Newton's time, we take for granted the concept of force, which, however, perhaps is not conceptually compatible with the finite speed for transmission of an e.m. signal (and very likely also of a gravitational signal, or of any other kind of interaction). Kepler was probably aware of our arbitrariness while deciding

universal gravitation, notwithstanding his aforementioned logical concern. A few years before *1700*, Halley made two research cruises in the Atlantic, and finally published the first magnetic maps of oceanic scale (this conspicuous investment in terms of funds, energies, and manpower was motivated by the fact that they were convinced that geomagnetism could help for a correct determination of the longitude). Halley thus discovered the westward drift of the geomagnetic secular variation (*SV*), and he envisaged the unique model that was possible at his time, i.e. based on permanent magnetised sources. He envisaged some thick concentric magnetised layers of the Earth, sliding with respect to each other, and he speculated about a possible cavity in between them, thus beginning the "hollow theory of the Earth" that was going to have some isolated supporters until the second half of the *XX century*. In any case, the origin of the **B** of the Earth and of the naturally magnetised bodies always appeared disquieting and mysterious. In the second half of the *XVIII century*, Buffon made experiments on the cooling of iron cannon balls, in order to seek information about the speculated cooling of the planet Earth, and on the decay of its fossil energy. In *1800*, Alessandro Volta discovered the Voltaic pile, and in *1820* Ampère first discovered the magnetic effects of an electric current **j**. By this, magnetism was finally born as a discipline of laboratory physics, independent of Earth's sciences.

At present, it is believed that the Earth is composed of a "solid" *malicrust*, a fluid *OC*, and a "solid" *IC*, this last statement relying on the evidence of S wave propagation. It appears however perplexing to reconcile the very high temperature with the presence of the crystal bonds that characterize a "solid". Indeed, *mutatis mutandis* consider the analogy with the "metallic" state envisaged by planetologists for the interior of the large external planets. By a thorough discussion (not here given) it appears very reasonable to guess that the *IC* is not "solid", rather it results from a strong magnetic coupling between the magnetic moments of nuclei largely spoiled of their electron shells. This "magnetic polarization" state justifies the transmission of S waves etc. (refer to Gregori, 2012 for detailed discussion).

But the origin of the **B** of the Earth became even more intriguing. Seismology progressively got rid of the former idea of an Earth conceived much like the Buffon cannon balls with a hot fluid inside a thin solid layer. The existence of a thick solid mantle was assessed, and of a fluid core, while the discovery of the solid inner core (*IC*) had to wait for the availability of some more accurate observational database.

The Larmor and Elsasser-Bullard dynamo were proposed within this historical scenario, while at present, paradoxically, the Buffon experiments appear to be,

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to introduce the present generally agreed concept of "force", which, after Newton, was going to be considered almost like an innate concept, while in reality it is not. Kepler's discussion was perhaps related to his deep concern about this fundamental aspect of our cognitive process, which only very recently was (indirectly and implicitly) re-discussed after the second quantisation and the Feynman graphs. This topic should require a much longer analysis. Refer e.g. to Gregori (2005, 2010) and references therein.

maybe, the unique surviving direct observational support for the prime idea of isostasy (and of plate tectonics), and of a primordial cooling Earth progressively releasing its fossil heat.[5]

3.2. The tide driven (*TD*) dynamo, the Earth structure, and its internal coupling

Concerning the internal structure of the Earth, *tout court* let us call *malicrust* the ensemble of mantle plus lithosphere plus crust. *Malicrust* will be here considered like one approximately unique solid body. It is well known that the tide generates a torque that slows down the spin rate of the Earth and accelerates the orbital motion of the Moon. Consider the Earth as being similar to an onion, and compute the tidal torque that acts on every onion layer. It results much larger on the *malicrust* than on the *IC*. In addition, this difference is further largely strengthened by the loading tide (Figure 3), i.e. the major effect on the spin rate of the Earth results by the tidal influence by oceanic tides, rather than by direct tidal action on the Earth body: oceans load continental shelves and push on continental masses. At present, as a standard, the literature reports about studies by two schools of thought, ultimately depending on whether the background of their respective authors is the theory of the dynamics of solid bodies (recalling Euler's) or hydrodynamics.

The first school considers some solid Earth's components, such as the solid *malicrust*, plus the solid *IC*, which is immersed inside the *OC*. From the anomalies of the spin rate of the Earth, they afford to estimate the viscosity η of the fluid *OC*. Their evidences unanimously agree on a definitely negligible η. Colloquially, they claim that the fluid *OC* appears less viscous than water at standard temperature. In contrast, a different authoritative and leading school, inspired by hydrodynamics, begins by considering the electrically conducting *OC* fluid. Moreover, in order to avoid every concern about the primary energy supply to the dynamo, since the beginning they speculate about some very high electrical conductivity σ of the medium. It is usual to rely on a $\sigma \to \infty$ assumption. This implies that the energy dispersion is null, or almost null. This crucial point results into a physically strong constraint.

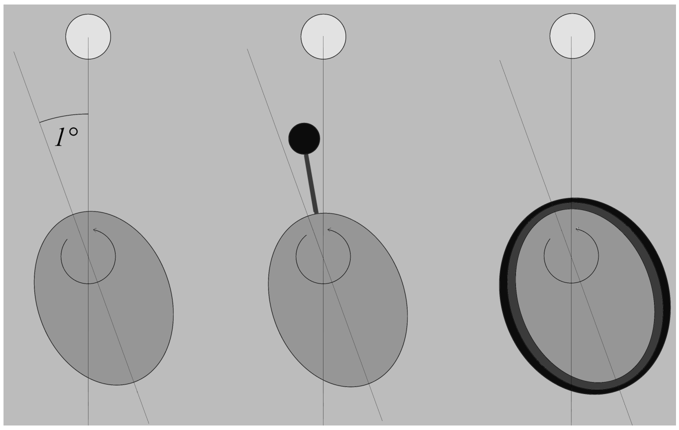

Fig. 3. The loading tide (*right*) plays the leading role in slowing down the spin rate of the Earth, almost like an additional handle (*centre*) added to the tide directly acting on the Earth's body (*left*).

[5] Close to the end of the *II World War* this idea was finally "consecrated" by the first Walt Disney movie *Fantasy* (with the pictorial representation for the *Sacre du Printemps* by Igor Stravinsky).

For clarity purposes, consider a hydroelectric plant, where the operator regulates the water input to the turbine in order to keep approximately steady the output to the user network. By night-time, owing to the reduced user absorption, the water flow has to be correspondingly reduced. Suppose that the coil of the dynamo (Figure 4) has an almost $\sigma \to \infty$ and that the water flow is never reduced, or even that no user network takes off energy from the coil. The electric current **j** induced into the coil continuously increases, in principle up to infinity. In reality, the magnetic force between coil and static magnet rapidly increases, and with it also the opposing torque. Finally, the entire system shall soon become totally blocked. The magnetic forces shall thus become even more intense than the chemical bonds within the hardest solid object. An ever increasing water flow shall never succeed to move the turbine: it shall rather lead to a complete disruption of the hydroelectric plant.

Such a paradoxical degeneracy of a system dominated by magnetic forces was in fact envisaged by Biermann in *1941*, when he stressed that, within a sunspot, the magnetic energy density largely overwhelms the kinetic energy density, by which sunspots can never cool. Owing to this, Gregori (2002) calls *Biermann's blocking* this phenomenon, which obviously must occur in every physical system whenever σ is very large and no adequate sink can be envisaged for the generated e.m. energy.

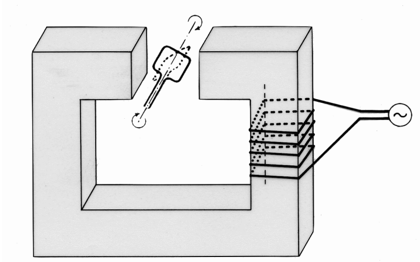

Fig. 4. A general dynamo. The static magnet can be modulated for mimicking the solar control via deep e.m. induced **j**'s. After Gregori (2000).

In contrast with the Biermann argument, the school inspired by hydrodynamics considers a fluid *OC*, where some generally non-specified heat source is guessed to cause some primary *very strong* convection. They also *specifically* mention that they *must* assume some *rapid* rotation of the fluid, in order to generate congruent effects by Coriolis etc. But they use the $\sigma \to \infty$ assumption. Indeed, they write formal equations, and attempt to solve them. The result appears frustrating, because the solution is found to be fully blocked (as it had to be expected due to Biermann's blocking). Therefore, they envisage some weakening of the starting hypotheses, in order to get some equations that do allow for some solution. Depending on the kind of such a speculated weakening, they find different solutions. Several very clever applied mathematicians challenged this very difficult problem by using computers of an ever increasing power. During several decades a huge amount of literature appeared. One ultimate physical and crucial point, however, deals with the internal coupling between different parts of Earth's interior, i.e. between *malicrust* and *IC*.

At present, according to all standard geodynamo theories, it is unanimously concluded (in agreement with the aforementioned Biermann blocking) that every numerical model implies an almost perfect coupling. There is an apparent agreement on the fact that the Earth results to rotate like an almost unique solid object (i.e. the tidal torques applied to all the "onion" layers must be summed up altogether, in order to give the total torque that operates over one unique practically perfectly solid Earth). Until the middle of the *1990*'s, authors appealed to an e.m. coupling. More recently, it is being claimed that density inhomogeneities within deep Earth ought to ensure some very strong and efficient gravitational (i.e. not simply e.m.) coupling.

Indeed, the $\sigma \rightarrow \infty$ hypothesis necessarily implies that every computed model *must* display *per se* a perfect and ideal total e.m. coupling between *malicrust* and *IC*. That is, this e.m. coupling is *not* a finding of their theories; rather it is a starting assumption implicit within the equations. Only a few authoritative scientists appear concerned with the need for "self-limitation" of the system, or for "quenching", etc. in order to avoid such a destructive drawback. Moreover, concerning the speculated gravitational coupling between *malicrust* and *IC*, it should be suitably shown by observational inferences, and not just speculated. In any case, if it exists, it is in strong contradiction with the inferences of the scientists who claim that the *IC* can move inside the fluid *OC*, being immersed in an apparently totally inviscid fluid. How can it move within an environment, which is *totally* blocked either by e.m. or by gravitational coupling? In addition, such a coupling should strictly forbid any kind of fluid motion *including convection* within the *OC*, because such a speculated "total" coupling is *per se* incompatible with the original starting hypothesis, which they must assume to trigger the geodynamo, about *MHD* motions supported through Coriolis etc. The millennial "mysterious" aspects of the magnetic field of the Earth seem to survive!

The Larmor *MHD* dynamo applies very well inside a star or inside the Sun, where the Biermann blocking occurs. However, the overwhelming endogenous thermonuclear reactions violently disrupt any blocking. Owing to this reason the **B** of the Sun or of a star shall never appear like a dipolar field, which *per se* should require some reasonably steady configuration. Rather, it must always display some erratic pattern. It can be shown that the Larmor *MHD* dynamo also applies for the explanation of the magnetic field of galaxies. It is not possible to summarize here this entire argument. The well known classical concern about the Cowling theorem (dating to the early *1930*'s) ought to be recalled. It states that in a system with perfect cylindrical system no Larmor's dynamo can be self-sustained. A generalization can be shown by which it is proven that every Larmor's dynamo must fit in either one of two topological classes (Figure 5). One class (with poloidal **B** and toroidal **E**; Figure 5a) represent a state of unstable equilibrium. The other class (with poloidal **E** and toroidal **B**; Figure 5b) represents a state of stable equilibrium, which, however, for a system that displays an ideally perfect cylindrical symmetry, has a null equilibrium energy (which gives justice to Cowling).No galaxy, however, has an ideal equilibrium symmetry. Concerning the geomagnetic field, the Elsasser geodynamo, when it was formerly proposed,

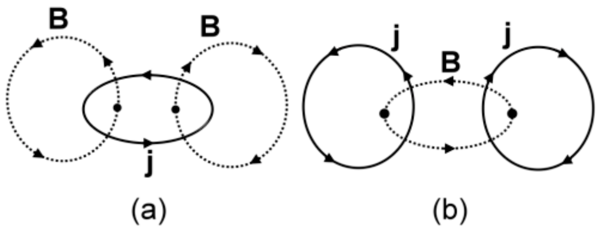

Fig. 5. The generalized Cowling theorem. Se text.

appeared very promising (the physically astute Elsasser papers are indeed still very pleasant and physically intriguing). But at present we do know on a sound logical basis that such a geodynamo shall never work.

3.2. Electrical conductivity, Hamilton's principle, and current sheets

College textbooks claim that every electric current **j** must attempt to expand through space as much as possible. In the formal language of theoretical dynamics, this is known to be due to the Hamilton variational principle. Hence, every **j** generated inside the Earth by whatever mechanism must expand as much as possible, until the **j**'s meet some abrupt relative drop of σ (Figure 6). Consider the spatial spectrum of **B** (Figure 7), where E_n is proportional to the average magnetic energy density at Earth's surface, as it results from its evaluation by means of the only terms of degree *n* in the spherical harmonic expansion (*SHE*) of the geomagnetic potential. This spatial spectrum gives evidence of *3* different shells of **j**'s. Every one generates one line in Figure 7, and every one corresponds to a σ discontinuity in Figure 6. The *SHE* models computed for different epochs give lines with different tilt, although they always cross either one the three points denoted by X. Let us apply the well known algorithm by Chapman and Bartels (1940), and consider the **B** associated with only one such a line or **j**-shell at a time. Let us *arbitrarily* choose a radius *R* for every one of such a **j**-shell, and compute the **j**-distribution over the spherical shell (*ss*) that approximates one **j**-shell, and that justifies the corresponding **B** observed at Earth's surface. Evaluate the magnetic energy *U(R)* of every such a *ss* or **j**-shell. By some simple algebra, it is found that *U(R)* has an asymptote for $R = \overline{R}$, such that if $R < \overline{R}$ the **j**-sheet ought to be generated by an infinite *U(R)*. Call $\overline{R}^{(0)}$, $\overline{R}^{(1)}$, and $\overline{R}^{(2)}$ these asymptotic radii.

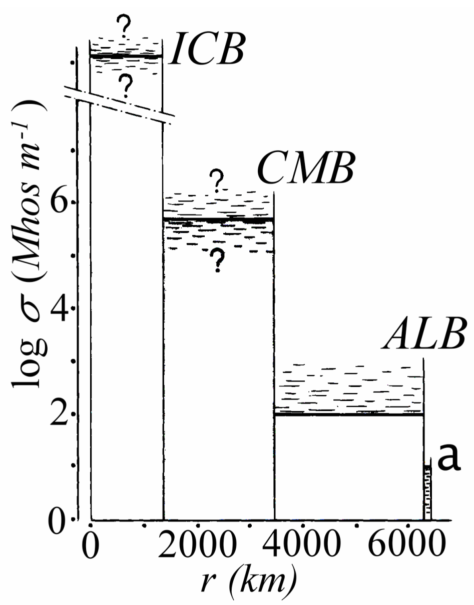

Fig. 6. Order of magnitude of σ in deep Earth characterised by three main step-wise drops. After Gregori (1999).

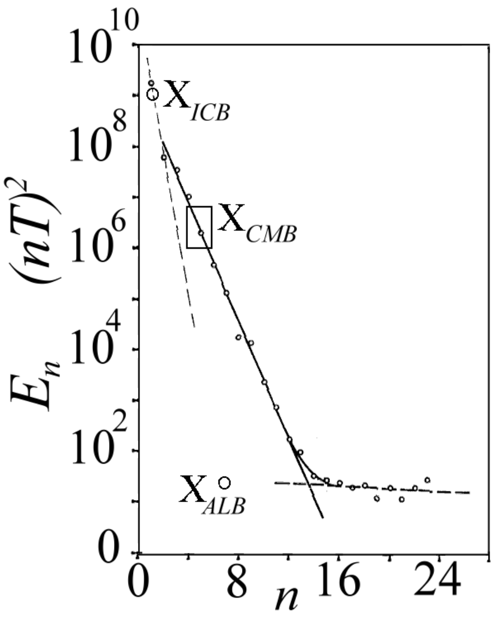

Fig.7. Spatial spectrum of the geomagnetic field. See text. After Gregori *et al.* (1999).

It is thus realised that $\overline{R}^{(0)}$, $\overline{R}^{(1)}$, and $\overline{R}^{(2)}$ are slightly (say *~ 5%*) less than, respectively, the seismologically determined radii R_{seism}^{ICB}, R_{seism}^{CMB}, and R_{seism}^{ALB} of the *ICB*, *CMB*, and *ALB*, respectively. That is, in this way we have computed, by means of an energy argument applied to **B** records, a lower limit for the radii of the *3 ss* that originate the *3* lines in the spatial spectrum of Figure 7. We can thus give (apart a few percent) a geomagnetic evaluation of the seismic radii R_{seism}^{ICB}, R_{seism}^{CMB}, and R_{seism}^{ALB} .

3.3. The *TD* geodynamo

The relative sliding of the two uncoupled bodies, *malicrust* and *IC*, pulled by a differential tidal torque, operates like a poorly efficient, although enormously energetic dynamo. Only *<<1%* goes into magnetic energy, while the remaining energy goes into Joule's loss, which supplies the Earth endogenous energy budget. A detailed energy balance shows that this mechanism is sufficient *per se* to justify all Earth's endogenous phenomena. Eventual additional sources are optional.

According to a rough and much approximate order-of-magnitude evaluation, to be eventually suitable improved, the present *TD* geodynamo is supplied by $\sim 4 \div 5\ 10^{12}\ W$, while during the last few million years (*Ma*) the Earth has been, and is still, releasing a power of. $\sim 7.54\ 10^{13}\ W$. Moreover, *~ 60%* of this (observed) power is presently released like geothermal flow (thus playing a fundamental role for climate control). Error-bars are conspicuous. The ratio *~ 19* (rough estimate) for release/recharge is discussed below, resulting consistent with other independent inferences on climate.

In detail, the *TD* geodynamo generates *2* major **j**-sheets, on the *ICB* and on the *CMB*, respectively. Owing to the action-reaction principle, they must have an identical energy. An unknown percent of this energy decays on the *ICB*, and it supplies some violent convection within the fluid *OC*. The same percent decays on the *CMB*, and, in addition to it, ~ *99 %* of the e.m. power that affords to reach it. That is, this *TD* geodynamo has a performance *<< 1%* in term of magnetic energy. Only a tiny fraction ($\sim 10^{-8}$) of the **j**'s of the *CMB* can leak off through the mantle. These **j**'s expand and decay by Joule's heating on the *ALB*, where they cause the partial melt of the asthenosphere, resulting into a lubrication, which makes possible the drift of the lithosphere. The lithosphere/mantle coupling is found to be ~ *96%* viscous, and ~ *4%* elastic, although it experiences very large fluctuations depending on the Earth "heartbeat" (see below).

3.4. The propagation of the endogenous energy through the Earth body

Heat propagation through the Earth body occurs in two ways. The aforementioned violent convection through the *OC* (Figure 8) seems recognisable even at Earth's surface (although this item is much more complicate and cannot be here discussed in the needed detail). In contrast, concerning the *malicrust*, the propagation occurs through "spikes" of the **j**'s. Every such a "spike" is pushed outward through *malicrust* by the Hamilton variation principle. The details are as follows. An eventual minor deviation, of the *ss* of the *CMB*, from perfect spherical symmetry, implies a locally larger **j** concentration and Joule's heating, an increase both of the local temperature and of σ, thus favouring an outward propagation of **j**. That is, the "spike" is pushed upward by Hamilton's, resulting into a process that recalls an electric soldering iron (*E.S.I.*) pushed into a block of ice. This process generates a "spike" that crosses the whole *malicrust*, at a speed of the order of ~ 10 $cm\ year^{-1}$. By **B** observations, its speed can be shown to increase, while the spike penetrates upward and shrinks, from ~ 0 to ~ 20 $cm\ year^{-1}$. It should be stressed that the upward propagation occurs by implying no transport of matter, other than simple motion of electrons.

The Earth internal pattern reminds about an onion, as far as its density and rheological properties are concerned, while as far as σ is concerned, it recalls a sea-urchin. A miniature model of this process (scaled $\sim 10^8$ times) is represented by a field of kimberlites (up to *100* kimberlites occur within ~ 40 *km* linear range). Several "spikes" rise from the *CMB* (Figure 9). Whenever one spike approaches the Earth surface and it encounters some fluids, the heated fluids transport by advection the endogenous energy off the Earth surface. The former mere electrodynamics has thus shifted to thermodynamics. Whenever these fluids are insufficient, heat accumulates and the *E.S.I.* mechanism goes on. When a spike attains some shallow depth, where the reduced lithostatic pressure permits melt, a new fluid, i.e. magma, is thus eventually generated. Compared to water, oil, gases, etc. it has a much larger η, and a much smaller mobility. However, it is an effective carrier of heat, and it is eventually manifested as a lava effusion. Differently stated, there is no physical discontinuity between a "cold" and rocky area and a volcano. There is just a continuum of different amounts of endogenous energy. Even the isotopic chemism of the ocean floor basalts can be justified by such a rationale (the outpouring lava is a sample the depth where melt first occurred, etc.).

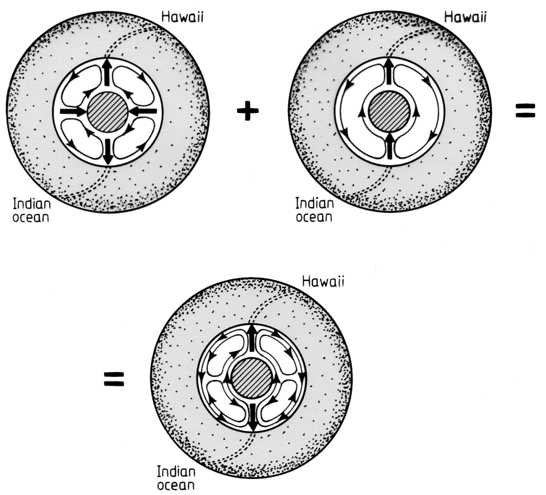

Fig. 8. Convection pattern within the fluid *OC*, dominated by a "quatrefoil" structure, over which a minor contribution is to be added having the shape of a "beam". The uprising plumes are roughly located underneath the Hawaii's and antipodal to them. After Gregori (2002).

3.5. Some key observational support

Let us recall only a few key observational evidences, which support the *TD* model, and which have been its first motivation.

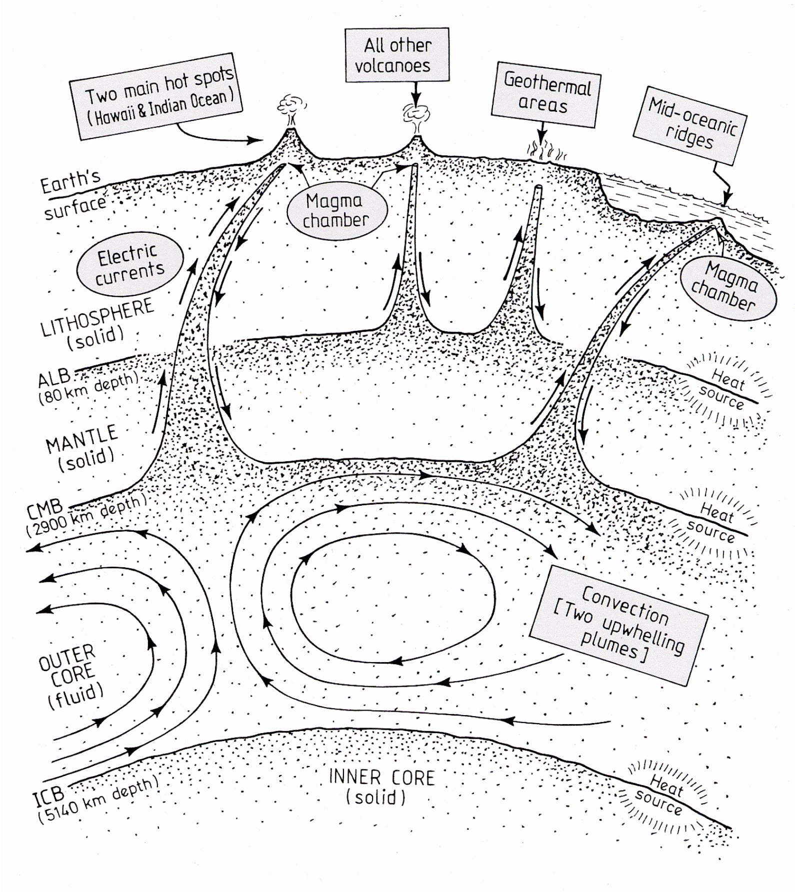

Fig.9. "Spikes" rise from the *CMB*. Violent convection occurs within the fluid *OC*. The electric currents **j**'s attempt to expand as much as possible. A former minor deviation from spherical symmetry of any given *ss* causes an excess local concentration of **j**, which produces local heating and increases *σ*. This favours an upward propagation and formation of a spike, which progressively shrinks. This effect can be specifically recognised by some peculiar features of ground based geomagnetic records. These spikes supply volcanism, and more generally and mainly the geothermal heat flow. See text. After Gregori (1994).

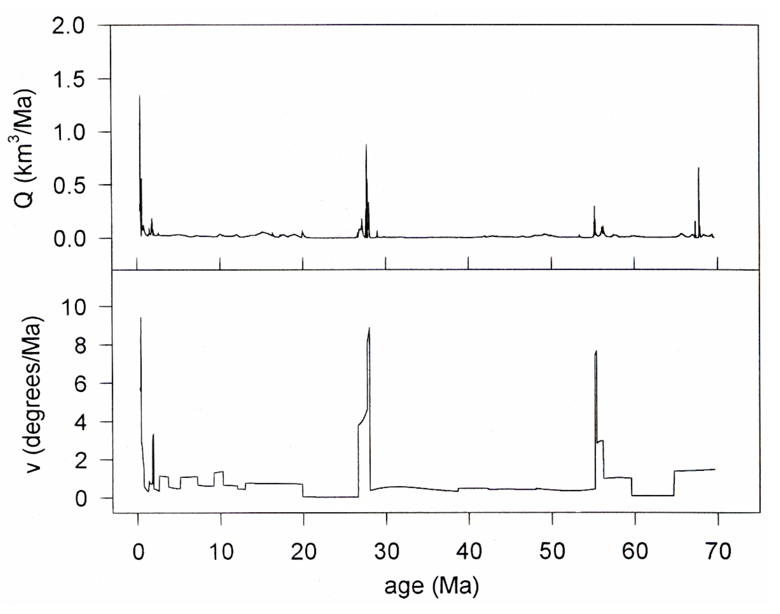

Fig. 10. The electrocardiogram of the Earth is shown by the magma emplacement rate [*upper plot*] from the Hawaii hot spot during the last ~ *70 Ma*. The *lower plot* shows the speed of the lithosphere while it slides down from the superswell, showing a maximum recorded speed of the order of ~ *3 mm day*$^{-1}$. This kinetic energy is shown to transform into friction energy that supplies volcanism after ~ *50 ÷ 100 ka*. One heartbeat occurs every ~ *27.4 Ma*, and it corresponds to the birth of a *LIP*. After Gregori and Dong (1996).

1) Upon investigating the time variation of the magma volumetric output from the Hawaii hot spot, the Earth reveals a behaviour much like an *electrocardiogram* (Figure 10), with one heartbeat lasting a few *Ma*. Subsequent heartbeats occur

every ~ *27.4 Ma*. This timing can be shown to depend on the *E.S.I.* mechanism. On the occasion of every heartbeat, a *Large Igneous Province* (*LIP*) is generated. The human civilisation developed during one such heartbeat, and its *LIP* was the birth of Iceland.

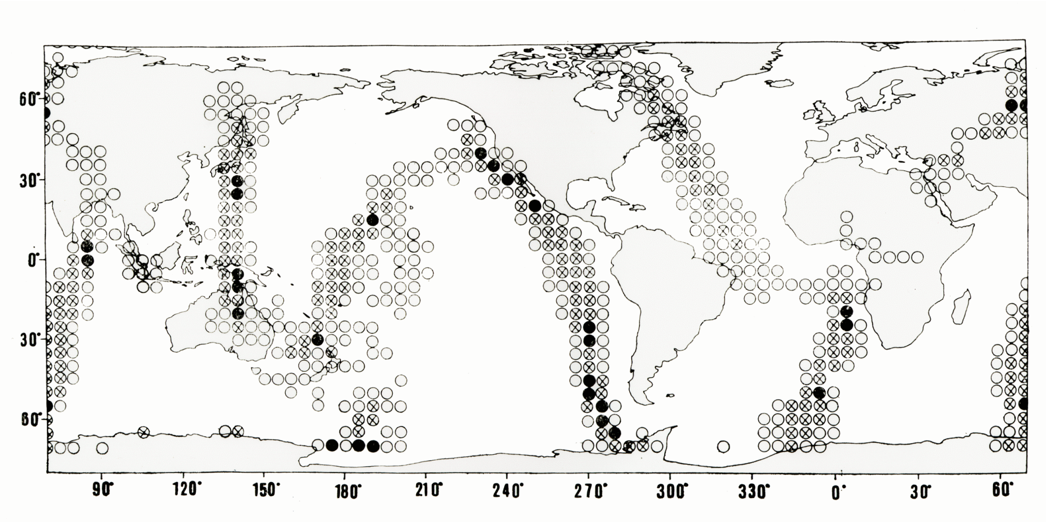

Fig. 11. Geometrical locus of the points on the Earth's surface where the *SV* displays neither a westward nor an eastward drift. After Urban and Janackova (1990). Such feature can apparently be understood (Gregori, 1993) only in terms of some kind of an elongated cleft of **j**'s uprising from the *CMB* until some comparatively much shallow depth underneath the *MOR* network.

2) The westward drift of the *SV* was analysed by seeking, at Earth's surface, the geometrical locus where the drift results neither westward nor eastward. The result resembles the distribution of mid-ocean ridges (*MOR*). This feature can be explained only by assuming that the **j**'s that generate **B** flow at some much shallow depth underneath the *MOR*'s.
3) The primary heat supply to every volcano of the world seems to be originated (Gregori *et al*., 1994) by one unique common fire, modulated by the long period variations of solar activity, with no time delay, i.e. the process appears to occur by an almost immediate energy propagation towards Earth's surface from the *CMB*. Up to the author knowledge, such an "instant" propagation can be explained *only* by means of the *E.S.I.* mechanism (Figure 9). On the other hand, one should also consider that several volcanoes, e.g. the island arc volcanism, are *not* supplied in this way, rather they appear to be a consequence of friction heating, derived from kinetic energy. Just one comment appears crucial. It is normally believed that the solar wind and the deep Earth interior cannot be e.m. coupled, due to the Faraday screening by the high σ of the mantle. However, the sea-urchin structure is such that every spike operates like some kind of "antenna" pushed towards Earth's surface, and almost reaching it. That is, a substantial amount of e.m. coupling is possible through these spikes-antennas of the sea-urchin, which link the e.m. solar activity and the deep Earth interior. This sea-urchin antenna explains the impressive correlation between solar activity and the primary heat supply to volcanoes (Figure 12).

3.6. The history of the Earth interior, and the battery charging and discharging

We can compute $\overline{R}^{(0)}$, $\overline{R}^{(1)}$, and $\overline{R}^{(2)}$ for every available historical model of **B**, by means of the *SHE* of the **B** potential for every given epoch. $\overline{R}^{(0)}$ is computed by the *SHE* terms of degree $n = 1, 2$, $\overline{R}^{(1)}$ by terms of degree $n = 3, \ldots 13$, and $\overline{R}^{(2)}$ by terms of degree $n = 14, \ldots$ In this way, Figure 13 was computed. Upon a thorough discussion (not here reported) of this entire item, it can be concluded that the Earth behaves much like a car battery. It re-charges during ~ *27.4 Ma*, while some "spikes" propagate upward by the *E.S.I.* mechanism. During this process, the system is much more efficient in generating than in releasing energy. Energy is stored within Earth's interior by transforming solid into fluid matter, while the volume of the Earth remains constant, and it experiences a conspicuous time variation of its internal pressure. When the spikes reach Earth's surface, the discharging efficiency gets much better, and the Earth battery rapidly looses energy.

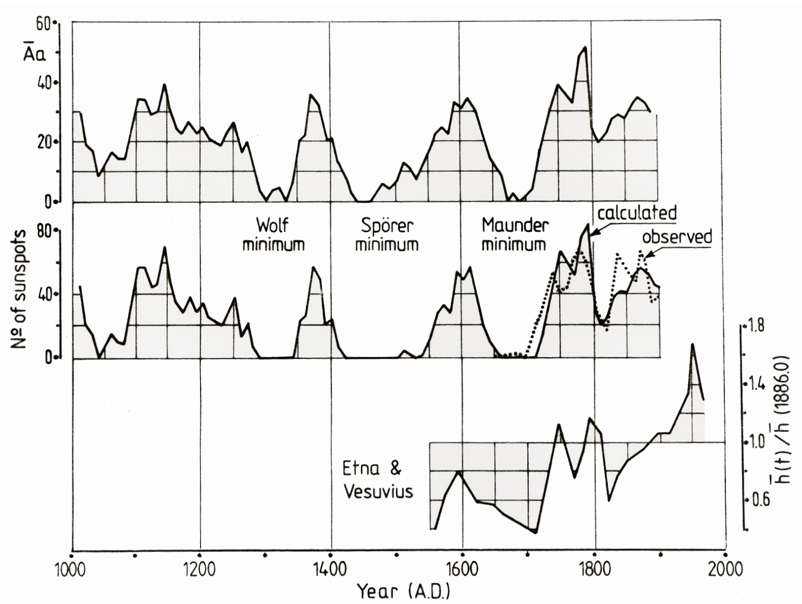

Fig. 12. The historical eruption logs for Etna and Vesuvius permitted the computation of the guessed time variation of their respective prime heat supply (lower plot). The ^{14}C content within historical wood permitted the evaluation of the long-period solar and geomagnetic activity (upper two plots). The correlation appears striking between these inferences that rely on completely independent databases. After Gregori *et al.* (1992).

Humankind was developed close to the time of a maximum release of endogenous energy, as shown in Figure 13. Upon a closer analysis, it was possible to infer that an increase of solar activity slows down the Earth cooling rate, and, with no such solar recharging, the Earth should decay with a time constant of ~ *110 ± 1 years*.

Let us also only mention that the observed **B** of all planetary objects of the Solar System fits very well with a speculated role of a *TD* dynamo inside a given object, which is also manifested by its surface features associated with a likely tectonic activity etc. (see also here below).

3.7. Superswells, geodynamics, and warm mud tectonics (*WMT*) and climate control

Whenever a bunch of spikes approaches Earth's surface, the surrounding medium is warmed within the *malicrust*, which suffers thermal expansion. Some huge area on Earth's surface is uplifted. This is a *superswell*. The lithosphere posed on top of the mantle (Figure 14) slides down the slopes of this superswell, moving on the *ALB*, i.e. the aforementioned asthenosphere, which is gently lubricated by the **j**'s that leak off the *CMB*. A few examples of presently occurring superswells is as follows.

- One superswell is located roughly in the Indian Ocean, Kerguelen Islands until the Afar triangle. Let us call it the *Afar superswell* or *Afar SuSw.*
- Another superswell is elongated underneath the Atlantic *MOR*. Let us call it the *Atl MOR SuSw*. According to *GPS* measurements, western Europe slides eastward on its slope. The time variation of sea level (during *1993-2000*) observed in the Mediterranean by *TOPEX/POSEIDON*, clearly envisages a sea floor uplifting in the western Mediterranean and sinking of its eastern side, consistently with the upheaval of *Atl MOR SuSw*.
- A third and apparently the presently hottest superswell seems to be located roughly around the Easter Island, where the thermal lithosphere seems to be comparatively thinner than all over the world. Let us call it the *Easter Island SuSw*, or *EI SuSw*.

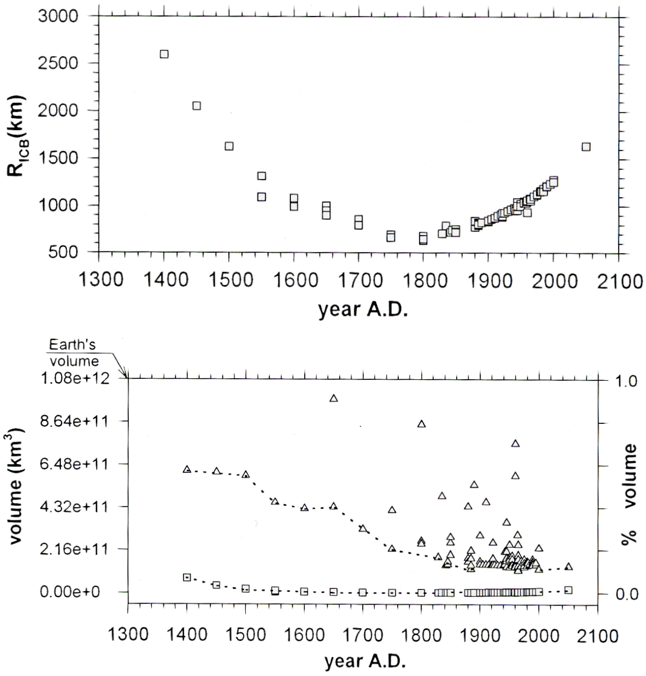

Fig. 13. Upper plot: time variation of $\overline{R}^{(0)}$ showing the great jerk of *AD 1790 ± 1*. Lower plot: time variation of the volume enclosed by the *CMB* and by the *ICB*. The plateaus are associated with period or greater solar activity. The scattered points depend on the error of the *SHE* models. After Gregori (1997).

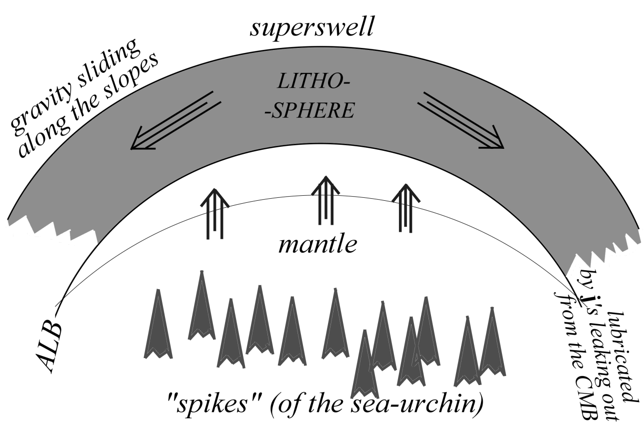

Fig. 14. The lithosphere slides down the slopes of a superswell, sliding over *ALB*, which is lubricated by the partial melt generated by **j**'s that leak out from the *CMB*.

Both North and South America slide westward, down the slope of the *Atl MOR SuSw*. The *EI SuSw*, however, apparently generates a band of lithosphere, which is probably comparatively less dense than its surrounding lithospheric slab, resulting into the longitudinal strip comprised between the two transform faults that strike, respectively, one through the Easter Island – Sala y Gomez – Islas Desventuradas, and the other through the Juan Fernandez Islands. This lithospheric slab appears likely to be comparatively warmer, associated with a positive gravity anomaly. Let us call it the "eastward Easter-Island band" (*EastEIB*). It crosses the Andes along their latitudinal segment comprised between a northern terminal, which is close to the huge volcanic complex of Ojos del Salado, and a southern terminal close to the Aconcagua.

South America, while sliding westward, overrides this *EasEIB*, while the *EastEIB* apparently cannot sink, due to its smaller density. Opposite to what occurs for both segments of the Andes that are located north and south of the *EastIEB*, this phenomenon causes the so-called *flat subduction*, e.g. it intuitively reminds about a knife used for detaching a pie from its cooking floor. This peculiar tectonic scenario seems to be supported by the morphology of the topography of the entire area. A nice confirmation seems to be given by the Precordillera folding, and by the general comparatively higher topography of South America with no active volcanoes.

In general, crustal stress propagation can be very effectively monitored by recording acoustic emissions (*AE*), which, in addition, provide information on the temporal variation of soil porosity. Geochemical data of soil exhalation (e.g. in wells), display a comparable advance-time for diagnosing the incipient evolution of the physical system towards a "catastrophe". Moreover soil exhalations play a crucial role in the long range control of climate. Only a global array of *AE* recorders could effectively monitor the propagation of crustal stress on the planetary scale.

Summarising, the *Afar SuSw*, the *Atl MOR SuSw*, and the *EI SuSw* appear consistent with the geodynamo model here envisaged, and with the aforementioned model for endogenous energy generation, and have important implications for climatology. In contrast, the well known interpretation in terms of plate tectonics seems to have great difficulties to explain this general macro-morphological scenario, and particularly the aforementioned sea level variation in the Mediterranean. The floatation concept should imply a much different rationale, compared to the case history of a lithospheric slab that slides on top of an inclined solid surface. There is no need to consider any lithospheric plate. Rather, the entire lithosphere is one unique non-uniform layer, much like a mud layer heated underneath, continuously re-shaping while sliding over a lubricated surface that continuously changes shape, under the action of a time varying flow of endogenous heat. Compared to *plate tectonics*, this model can be called *warm mud tectonics* (*WMT*) . See Gregori (2001, 2002).

WMT envisages an Earth permanently searching for some final equilibrium, which, however, is never attained, due to the continuous regeneration of internal spikes, which transport endogenous heat, and reshape continuously the *ALB*. Mountain folding and continental drift are therefore the obvious consequence (mainly by an overthrusting mechanism) of a time varying endogenous heat release. The case histories of the several planetary objects (such as the Moon, Mars, Io, Ganymede, and others) nicely support this entire interpretation, combining the magnetic and surface topography. Up to the author understanding, it appears very awkward, if possible at all, to interpret these features according to the present conventional models.

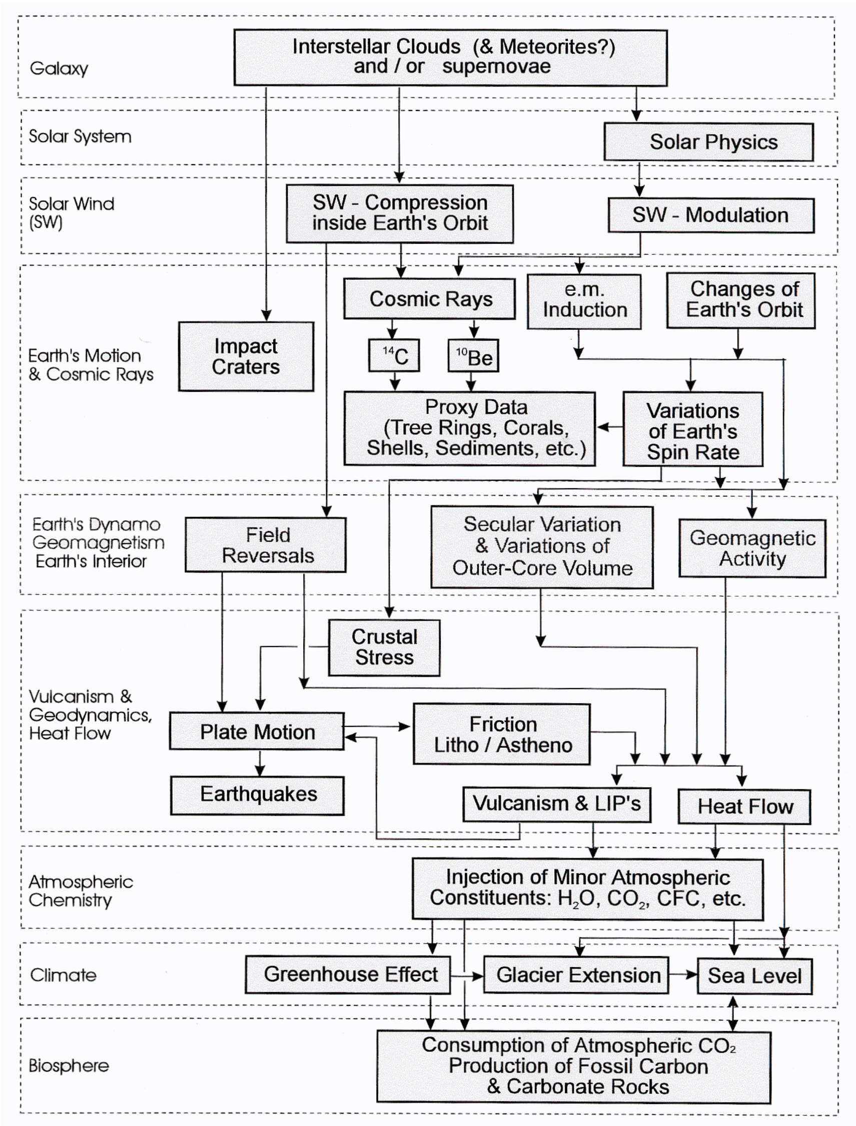

Fig. 15. Flow diagram for Galaxy-Sun-Earth relations. The encounters of the solar system with dense clouds of interstellar matter of any origin control the solar physics, and the solar wind, which influences the Earth dynamo, and its endogenous heat. This controls geodynamics, fluid exhalation from soil, hence climate and the biosphere. Upon considering the tiny size of the Earth compared to the expanding solar corona, and the tiny size of the solar system compared to the Galaxy, all terrestrial phenomena appear erratic. After Gregori (2000).

4. Galaxy – Sun – Earth relations, and the cause of geomagnetic reversals

The interpretation here suggested relies on an *exploratory* analysis of some large and multidisciplinary observational database. It includes a wide perspective Galaxy–Sun–Earth relations, as briefly synthesised in Figure 15. For brevity purposes, no details can be here given of the evidence about an influence on the Sun by the encounters of the solar system with clouds of interstellar matter. In particular, the *TD* geodynamo explains fairly well the geomagnetic field reversals, which should result from an external trigger, i.e. from the apparent disappearance of the solar wind, which follows the compression of the heliosphere inside the Earth orbit, by the interaction with a dense cloud of interstellar matter (e.g. following the blast of interstellar matter from a nova or supernova; Figure 16). The solar wind modulates the efficiency of the geodynamo through e.m. induction within the Earth (via the spikes of the *E.S.I.*), according to the aforementioned battery mechanism.

When the charge of the battery is reduced below some threshold, the deep Earth σ is lowered, and the *E.S.I.* mechanism is finally stopped. Some small fraction, however, remains of the liquid phase, and this is sufficient to permit the *TD* dynamo to recharge the battery. A new ~ *27.4 Ma* period is thus started, while the system is going to prepare the next heartbeat. In contrast, the Moon and Mars are much smaller than - though originally much similar to - the Earth. When their former battery discharged for the first time, they kept no sufficient remaining fluid fraction, by which no subsequent dynamo recharging could be restarted. Thus, their dynamo, altogether with their volcanism, endogenous heat, gas exhalation, atmosphere, and magnetosphere, faded away. That is, they "died", keeping however the relics of their former history. Summarising, the Larmor-Elsasser dynamo (with all its clever and remarkable additional details exploited during over *80 years* of computations) fits very well for stars and other large celestial bodies. In contrast, it is intrinsically unviable for the Earth, for planets, and for satellites

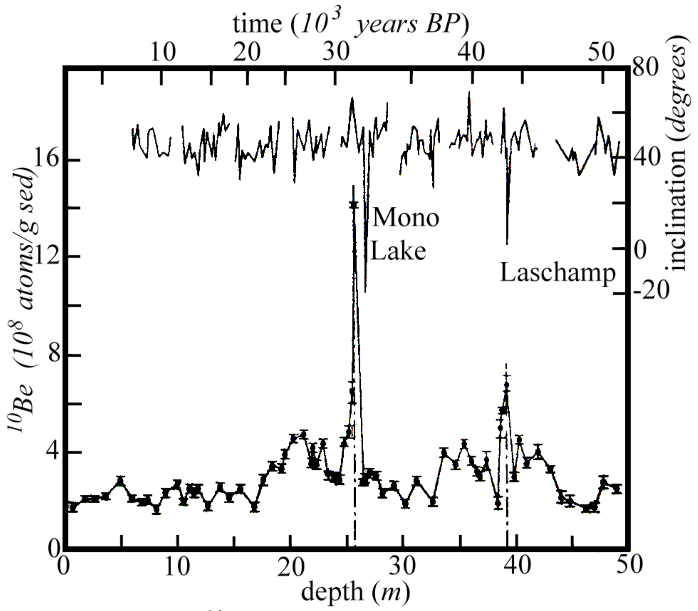

Fig. 16. The ^{10}Be content within sediments on the East Pacific Rise show two peaks interpreted in terms of stellar events that produced large fluxes of cosmic rays. In striking correlation with them, two geomagnetic excursions (i.e. the field reversed during < *150,000 years*) were observed. The Elsasser-Bullard dynamo cannot explain this correlation. In contrast, this appears to be a crucial experimental test for the *TD* geodynamo. Redrawn after McHargue *et al.* (1995).

(such as Io and Ganymede), where no sufficient endogenous energy is available capable to break the Biermann blocking.

5. Climatic inferences and conclusion

Every exceptionally cold period during the last ~ *2 millennia* (their information deriving from different sources, proxy data, etc.) very closely fits with the aforementioned interpretation. During the last ~ *5 centuries*, the global supply to volcanism increased by ~ *5 ÷ 6* times (Figure 12), thus explaining the transition from the *Little Ice Age* to present climate. The anomalous increase of climate temperature that apparently occurred during the last several decades could be associated with this phenomenon. At present, owing to Figure 13b, the maximum of the heartbeat ought to be attained by a matter of a few to several decades, although one should allow for some long subsequent relaxation time. The battery seems to become soon exhausted. The climate trend should therefore go toward a trend reversal.

All these phenomena deal with an essentially planetary-scale perspective. Some phenomena however, seem to imply some continental scale patterns. Several evidences are suggestive of a steady increase of release of endogenous heat underneath the northern polar cap, which also explains several climate anomalies of the recent years. This phenomenon seems to be in progress since a long time, even on the geological time scale.

The anomalous heat wave that stroke Europe during summer *2003* (associated with anomalously high *SST* around Europe), the reversals of water circulation in the Adriatic Sea (during a few weeks in summer *2003*, and in *January 2004*), the anomalous energy supply to Stromboli in *December 2002* and in *April 2003*, the upheaval of sea floor (up to ~ *6 m* depth, or less) at the site in the Sicily Channel where the Ferdinandea (or Giulia, or Graham) Island was born in *1831*, denote that some anomalous release of endogenous energy is presently occurring in southern Europe.

El Niño is a seasonal climatic oscillation involving (at least) the Pacific and Indian Ocean areas. Its prime trigger is presently unknown, although it could be associated (perhaps) with some anomalous heat flow that ought to be expected to occur sometimes and somewhere through the Pacific Ocean floor (maybe in the Banda Sea, or consider that the *EI SuSw* is likely to be the presently the most active *SuSw*).

Also phenomena on a much smaller scale can be explained in terms of some "miniature-scale" sea-urchin structures. The aforementioned fields of kimberlites recall a miniature model of the sea-urchin pattern of the *CMB*, with a scale factor ~ 10^{-8} . On an elongated spatial scale, in *December 2003* several wild fires hit California, striking along the inland prolongation of the East-Pacific rise, which, owing to the argument of Figure 11, should produce an anomalous coupling with the ionosphere, possibly originating sparks on the occasion of some abrupt perturbation in the ionosphere (study in progress). Since ancient Roman times, they reported that lightning stroke occurred preferentially at some specific sites, which can be interpreted as being the likely location of the "point" of a spike. In addition, beginning in *January 2004*, some wild fires occurred in Sicily and they could be related to the same phenomenon (analysis in progress).

The conclusion is that, concerning climate control, a distinction ought to be made between the "external" and "internal" way in solar-terrestrial relations (Figure 2). Short period e.m. phenomena involve e.m. induction by the solar wind into the Earth, although the induced telluric currents rapidly damp off within some shallow layers, which have a low σ. In contrast, the longer period e.m. induction affects the geodynamo and the endogenous energy budget of the Earth, eventually through the antenna role played by the sea-urchin. The battery is charged. The increased budget is eventually discharged through processes and mechanisms that can determine a time delay even by ~ *27.4 Ma* (or less). The entire literature largely privileges the "external" way, while several observational evidences appear to be definitely in favour of the "internal" way. Both ways are effective, although the "external" way causes some comparatively immediate and totally negligible Joule's heating release within some very shallow layers of the crust and lithosphere. In contrast, it appears much more likely that climate is controlled by long period e.m. induction, through the "internal" way.

It is well known that the heat capacity of the atmosphere is ~ 10^{-3} times the heat capacity of the oceans. Hence, in general the oceans warm the atmosphere, rather than viceversa. Depending on the greenhouse effect, however, the atmosphere changes its transparency for infrared radiation, influencing both *(i)* the amount of solar radiation captured (rather than being reflected into space like albedo), and *(ii)* the radiation outgoing from Earth's surface towards space. That is it operates like a sweater. The prime energy source is always the Sun, also in terms of its control on the geodynamo battery. But, according to the *TD* geodynamo, an additional (and leading) energy source derives from the tidal interaction (~ *5/6* by the Moon, and ~ *1/6* by the Sun). In addition, on the proto-historical time scale, the role *must* be considered of humankind as an *active* agent for climate control, as stressed elsewhere (Gregori and Gregori, 2003). All climatic effects originated after the Industrial Revolution are a comparatively minor episode, and the role of CO_2 is certainly a secondary aspect of the problem (Quinn, 2010).

The history of science, and of the way humankind challenged the understanding of natural reality, are a fundamental aspect of environmental research in a twofold way. On the one hand, humankind is a reliable recorder of natural events. On the other hand, the birth of several unproven paradigms, which unconsciously bias our present science, can be discovered only by investigating the history and evolution of scientific knowledge.

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