COMPLEX EMERGENCIES. THE CALL.

«Human beings and the natural world are on a collision course. Human activities inflict harsh and often irreversible damage on the environment and on critical resources. If not checked, many of our current practices put at serious risk the future that we *wish for human society and the plant and animal kingdoms, and may* so *alter the living world that it will be unable to sustain life in the manner that* we *know. Fundamental changes are urgent if* we *are to avoid the collision our present course will bring about.* »[1]

«Where is the science, we *have asked ourselves, that will correctly analyse, explain and predict phenomena* as *complex and multivariate* as *global change? Where and when will the next human famine strike, and how can directions to avert it be set years or decades in advance?* »[2]

I

The statements transcribed above were made in 1992, and so, they should perhaps constitute no surprise, by now. But, as to the changes whose urgency was recognized, what have we seen since then?

And what about those two questions that they, somehow, motivated? Who was there, to take a stand in giving them a definite answer?

Undoubtedly, we have witnessed some progress, namely, on the sciences of complexity, but is it enough for the politicians to make their options and to deliver their power to the implementation of those fundamental changes, ecological, physical and economical that we globally urge?

Let us take a close look at this.

It is a matter of fact that, nowadays, throughout the world, countless many people all share a common fate. Their lives have been fundamentally disrupted and in most instances immediately threatened by the perverse interaction of politics and poverty. They are victims of what we now call 'complex emergencies'; a dreadful set of circumstances that are seen to occur more and more as a result of the breakdown of traditional state structures and the upsurge of ethnicity: trapped between conflicting factions, they have been thrown out of their traditional homelands and they have had to flee for their very survival (source: DHA NEWS, 1993 [3]).

Complex emergencies are concurrent with some extreme ambiental processes like windstorms, earthquakes, floods and other calamities of natural origin, in that the spatial interaction between populations highly sensitive as, for instance, refugees are and an hazardous environmental process, like one of these, is prone to result in severe losses, be they merely economical, or human. We call this sort of spatial interaction a 'natural disaster', although, we emphasize, the vulnerability of these populations to such losses is essentially determined by poverty [3-4].

It is also a matter of fact that a global analysis of recent trends of growth, and of sustainable development, reveal us that, while the later is being somewhat achieved, at least among some of the richest nations of the world, still, the former remains prevalent and scarcely controlled in most developing countries, with the consequence of bringing countless people to an increase in exposure to hazards (consider, for example, urbanization tendencies). It is important to acknowledge that such an increase goes coupled with an escalating potential for catastrophic loss [4].

These considerations enable us to comprehend the special attention given to the least developed countries in the United Nations General Assembly's resolution 42/169, adopted on 11 December 1987, and designating the 1990s the 'International Decade for Natural Disaster Reduction'. Let us proceed, then, in this way, by focusing our concern upon what can be thought of as a common denominator, both to complex emergencies and to natural disasters: the phenomenon of human famine. In fact, both sequences of processes and events can be viewed to reduce food availability and to cause widespread and substantially increased mortality [3]. Again, as it could be anticipated, it is usually only certain more vulnerable groups within communities that experience these effects in a significant way.

The strike of human famine can be interpreted as a critical point in one, or both of these sequences of processes and events. It is attained whenever those indicators that, somehow, parameterize the distribution of primary goods in a community, show some serious fluctuation. Surely, this can only happen at the expense of a scandalous violation of a pillar of justice, namely, the Difference Principle, according to which inequalities are tolerable only if they somehow benefit, or improve the expectations of the least advantaged members of society [5].

As human beings, we feel that a situation like this is an offence to our dignity, and we think that it calls to the immediate setting of a joint responsibility concerning the global effects of our economical, social and technological activities [6-7]. This is so because the kind of fluctuations that we denounce, in those systems that are the stage for complex emergencies or natural disasters to occur, these fluctuations are themselves the testimony of what we know as cooperative phenomena. Take, for instance, the case of the causal relation between economic recessions and consumer confidence (about the state of that economy in which they occur), as studies of the United States of America' s economy, during the last thirty years, reveal to be possible to reject the hypothesis that the later does not affect Gross National Product in the former [8].

Just as we declared above to be offended with this state of affairs, so we, thereby, manifest ourselves willing to grow up human. Turning to the communities where we belong, their receptiveness to the call that we make will, in turn, testify their disposition to grow up, in humanity. This growth is not an optional matter, to be decided at one's wish! [9].

II

What is that we must do?

III

The serious situations that we have denounced above are complex. They arise, or emerge during an evolution of their physical or social support systems that seems oriented toward critical regions in their, respective, phase spaces. We would like to be precise about the sense of this likeness, but we have no acceptation concerning the terms on which to parameterize such an evolution.

However, it is possible to clearly identify some general characteristics, common to all these mentioned processes and systems, the most obvious being, perhaps, that they all demand the setting of infinite dimensional phase spaces in order for the parameterization that we ask for to take place. This is indeed the case with the atmosphere, the earth' s crust, the global economy, or with the various ecosystems.

Another property, also common to these systems, but whose formulation raises delicate questions, is that they all turn turbulent sometimes, somehow; they all have the power to realize turbulence. But, what is turbulence? We don't have no rigorous theory available and, in fact, we don't even dispose of a definition, gathering universal consensus, for its concept. Nevertheless, let us proceed with a provisory one, as a working hypothesis: we shall understand turbulence as that dynamical regime that is typical of systems whose effective degrees of freedom are not limited above and change in time.

Note that this tentative definition is general enough to include so-called fully developed turbulence, in that experimental evidence for the emergence of coherent structures (another not-so-well defined concept), in flows that attain this last, extreme regime make proof that the effective degrees of freedom (of the support systems involved) do change in time, at least locally.

The awareness of the emergent complexity in systems like the global economy, or human social networks, can be seen as an outcome of the trends toward global communication systems, but it is not new [10]. In general, the novelty, if any, goes to the recognition that it is becoming urgent to develop know-how to consistently manage the challenges thereby raised.

Meanwhile, as we stand, we acknowledge that all systems of our concern interact with each other on a variety of scales of space and time. We recognize that financial speculation can induce some erratic economic fluctuations which, in turn, change patterns of land and energy use in a given ecosystem [11]; we recognize that a peak in seismic activity in Japan (Kobe) can cause such a disturbance to futures markets that a financial institution in Great Britain

(Barings) is compelled to declare bankruptcy; and we recognize that injection of waste fluids underground at high pressure may cause the onset of seismic activity (Denver, 1966) [12-13].

Such coupling multiplicity does not make our problem intractable, but it do invites prudence and humbleness in dealing with it. Accordingly, we shall adopt the strategy to ignore it, at least for start: we shall isolate one of this systems and we shall try to emulate it with a model whose usefulness may be extended to the others. Observe that this setting apart does not reduce the complexity of the problem, as the system keeps its power to develop turbulence.

Consider, then, the flow of those stress fields whose drainage along fault systems is induced by the ongoing plate tectonics. The seismic activity thus sustained amounts to a regime of brittle fracture of rock material that can be interpreted as turbulence of solids [14-15], but it has also been described as self-organized criticality. [16-18].

This last concept is another ill-defined one, just like turbulence: everybody knows what it is, as long as one is not asked to give a rigorous definition. Notwithstanding, it is used here to acknowledge that stress fields obeying the rupture criterion almost everywhere are attracting states for plate tectonics, and that it happens to be so without the need of no external tuning of parameters: the system that exhibits such a dynamics evolves spontaneously to the neighbourhood of a critical point in its phase space [19].

Consequently, we must assume the earth's crust, as a whole, to be an infinite dimensional dynamical system, but we wish to combine this with the reported evidence that, locally, some fault systems have been observed to produce time series with deterministic chaos characteristics (in California, Greece, Japan and Ireland) [20-22].

At the global scale, the complexity of our system can thus be thought as resulting, either from the coupling that plate tectonics induces between local, chaotic dynamics, or from the interaction that the propagation of seismic waves induces between fault systems [23-24]. It is important to note that the physical support for this network of communications, so established, can be considered as a nonlinear active medium containing internal sources of accumulated elastic energy whose release can be triggered by small, external stimulation, natural or man made [25-26].

Now, if, considering plate tectonics, one has to deal with a time scale such that it is reasonable to model the coupling induced as a constant, at least during one life's span, nevertheless, the same is not true when it comes to modelling the interaction, either between fault systems, or between fault systems and human activities such as mining, oil or gas extraction, and reservoir water impoundment [27-30]. One has, then, to admit that the relevant channels, for communication between these diverse systems to occur, are not always activated. Consequently, the emergence of those cooperative effects that concern us here, arising as spatial-temporal coherent structures in the form of intelligible changes in seismic activity, and that are, somehow, modulated in accordance with the kind of information that flows in those channels, such emergence, one has to recognize, is rather erratic in time. But the point is that this is the same as saying that, at least locally, the effective degrees of freedom of the systems involved do change in time.

Such a wealth of phenomena can be classified by yet another fundamental concept, namely, that of spatial-temporal chaos [31]. Concerning the objectives that we prosecute, the importance of this new concept relies on the fact that it has been used with reference to the behaviour of globally coupled map lattices (more properly, networks, whose elements follow some specific deterministic chaos dynamics and share an all-to-all coupling).

These models have been intensively studied in the last few years, both numerically and analytically. Among the results thereby obtained, we want to emphasize the discovery that, in their so-called partially ordered phase, they develop a regime denoted as chaotic itinerancy, whose features match, in an essential way, those of the complex systems upon which we centred our attention. In fact, when this phase is attained, these lattices exhibit an intermittent evolution between stages of high dimensional chaos and a multiplicity of low dimensional attractor ruins. It is reported that the switching among these ruins (crisis phenomena), although spontaneous, can also be induced externally by means of small local inputs which have, nonetheless, some remote or global effects (as jumps between phase subspaces with different dimensions are) [32-33].

Thus, we can infer that both the earth' s crust and globally coupled map lattices are included in a same equivalence class, with respect to their common properties of having the dimension of their phase spaces as a dynamic variable, and of being accessible to global modulation by means of small, local perturbations [23-26,34-35]. This is a first step toward an engineering of complex systems. Next, we must determine the modalities for these local inputs to be made, in order that some specific phase trajectories be induced, through particular phase subspaces, by opposition to others that we may classify as inconvenient or even disastrous. This is much like a chaos control problem.

Meanwhile, and because the dynamic regime modulation strategy that we are anticipating is meant to be effective in relaxing certain undesirable, critical fluctuations in complex systems other than the earth's crust, let us now argue on the relevance that the ideas exposed until now may have on them.

Concentrating on the global economy, we acknowledge that the task we propose ourselves has been facilitated to the extent of the effectiveness with which economists have been promoting the migration of concepts, from statistical physics and nonlinear dynamic systems theory onto their own fields of research.

Subsequently, it was reported that the time series generated by economies and financial markets exhibit nonlinearities and deterministic chaos [36-37]. Of course that, with respect to nonlinearities, this is no surprise at all, but as to deterministic chaos, the case is different. In fact, the announcement of evidence for chaos in these time series has been received with caution, as there is no general agreement on its conclusiveness [38-39].

There are two reasons to justify such reserve. First, the scarcity of experimental data available, which makes it hard, if not impossible to apply the proper inversion algorithms [40]. Second, the fact that, for deterministic chaos to be safely detected, in economic or financial time series, it must be associated with a process in some phase space with dimension, say, lesser then ten. If this is not the case, then, it is generally undecidable whether the data at hand was generated by some stochastic process or by higher dimensional chaos [39,41].

It is quite reasonable, however, that, independently of the final result of such a dispute (if any), one assumes the global economy to be a complex, spatially distributed system. Then, besides the erratic fluctuations exhibited, the fact that it manifests itself capable of endogenous phase changes, altering its own dynamics qualitatively, invites the recognition that it develops itself, or that it flows through phase subspaces with not necessarily constant dimension. Observe that such transitions between subspaces can be the result of some new technology penetrating a local market, for example, and turning dominant (and global) afterwards [39,42]. But, if this is so, then, it follows that only from time to time can we expect to witness the emergence of a determined, low dimensional chaotic behaviour. Still, the potential remains for this to occur.

We also realize that these last considerations could have been the logical step to infer from numerical studies with a panoply of models, irrespective of the type, or the aspect of the economy being simulated (socialist versus market, for example, or the diverse macroeconomic modes) [43-47]. Consequently, we feel authorized to include our complex system 'global economy' in that same equivalence class that we established first, with the earth's crust and the globally coupled map lattice (such equivalence, we conceive, under isomorphism that is relative to the species of structure that are responsible for the common dynamic phenomenology observed) [48-49].

So far, so good, we next concentrate on the diversity of ecosystems around the world. Their inclusion in this equivalence class can be motivated by the following considerations:

Take Internet, as an example of a computational network that turned out global. It is possible to think the multiplicity of computer programs running on it as a community of agents operating in an economy. Then, the problem of resource allocation (time in central processing unit) translates to a problem of assignment of resources to production, which is to say that, somehow, the global computational network can be thought of as a market economy. Alternatively, one can think of Internet as a community of concurrent processes, thereby giving it the configuration of a true computational ecosystem [50-52].

Whatever should turn out to be the case, the important point is that both computational ecosystems and computational markets demonstrate the ability to generate oscillatory and chaotic dynamics. Moreover, specifically, in the Internet, it was already reported [53], one measures so-called l/f noise, which is to say that one observes one of the hallmarks of self organized criticality. Conspicuously, the same can be said about some simple ecosystem models [54-55].

Certainly, as we argue by analogy, we do not make proof of the possibility to include ecosystems in our equivalence class. But we do manage to accept as natural that many independent studies can be invoked to point in this direction.

Ecosystems are, indeed, complex systems that spontaneously evolve toward critical points, in their phase space, and that somehow manage to maintain themselves in their respective neighbourhoods. Moreover, this is accomplished without loss of potential for them to switch between high and low dimensional phase subspaces, respectively, either undergoing evolutionary branching, or collapsing through extinction of species [54-61].

Note that our argument on computational networks could have been used, instead, *mutatis mutandis*, to motivate what we said earlier, concerning the global economy: each argument corroborates the other, as both the economy and the ecosystem stand in the same analogy with computational networks.

IV

We now recall the situation that was our starting point. Our reflections were triggered by an acute consciousness of some pervasive human suffering caused by phenomena that we called complex emergencies. Subsequently, the remark that such disastrous events have the fingerprint of generic, collective phenomena lead us to call for the setting of a joint responsibility concerning the global effects of our participant observation of these processes. Because we do act like participant observers, and, as such, we do have the power to control the degree, the quality and the intentionality of our participation [62] .

We have just made plausible the construction of an equivalence class of complex systems. Now, assume this as a working hypothesis and let a certain globally coupled map lattice be the representative of the class.

Assume a community of participant observers and let them be connected to the lattice by as many communication channels as convenient.

The information that flows through these channels (coming from the lattice) can be classified as symbolic dynamics [63-64]. Consequently, the observers do possess an inversion algorithm that enables them to recover the abstract thermodynamics of the local maps that are responsible for each such flow [65]. Indeed, they can even so detect any eventual switch made by one of them (and consequently, by the lattice) between different phase subspaces [66] .

Finally, assume that the existent communication channels allow information to flow in both directions, and thereby, that they permit the participant observers to stimulate, at their wish, the local dynamics in the lattice. Thus, it becomes feasible to determine the phase trajectory of the lattice, and to do it in a selective way. In fact, the techniques for the control of chaos, developed since 1990, are by now validated by an enormous amount of evidence, both numerical and experimental [67]. As to the theoretical work that drove their development, some consequences are worth to be mentioned: the effectiveness of control (whether in the suppression or in the maintenance of chaos) does not depend, neither on the strength of chaos, nor on the dimension of the underlying attractors. Moreover, it is robust against external noise impinging on the local map to be controlled [68-72].

It may well happen to be the case that, by studying the time series generated by some number of local maps, one of the observers detects the slow development of a symbolic dynamics associated with the setting of a huge fluctuation in the underlying abstract thermodynamics. Such a detection amounts to the recognition of the emergence of a coherent structure, thus, to the occurrence of a localized reduction of the number of effective degrees of freedom, and thereby, to a switch between different phase subspaces.

Our team of observers may be interested in such an emergence, or it may be not. Suppose it is not. Suppose that, instead, they would rather prefer the switch to a different phase subspace, in that, this way, the fluctuation whose growth was detected may relax and its eventual inconvenient effects be cancelled. To drive the local maps in a phase trajectory that best suits their preference amounts, then, to the induction of those symbolic orbits whose underlying thermodynamical process drives the relaxation of the initial fluctuation. Now, the feasibility of such fine control of chaos is already established and supported by experimental evidence [73-75].

Proceeding, let us now see the incidence that our discussion can have upon still another complex system, namely, the human social network.

In this case, also, we are pleased to acknowledge an important migration of concepts and ideas, imported from nonlinear systems theory and statistical physics. The progress that, subsequently, was made, has driven us to a reasonable comprehension of the mechanisms for the social impact that politicians may have on society. These mechanisms are the same ones that underlie the emergence of collective processes, like self-organization and chaos in social networks, whenever adaptive decision sequences run by leaders, or leading coalitions, result in a continuous change of the coupling between forecast adjustment and policy implementation [76- 79].

From this point of view, one recognizes that a new light is shed upon the way that polls to public opinion may be conducted, as some sort of driven input to the underlying social network, slowly altering the image of those institutional frames that give the reference for an electorate to express its sentiment toward different politics. Afterwards, such a smooth transformation will result in a change of the relevant preference profile, in policy space, with the due consequences on the outcome of an eventual election, or referendum [80]. Indeed, such an induction of an agenda path can proceed under rather general conditions and have, as a consequence, that the configuration of voter preferences emerge as a chaotic dynamic variable, exhibiting sensitivity to small changes and the potential for outcomes anywhere in the policy space [81].

Thus, the variety of behaviour accessible to a chaotic system acts as a guaranty that all sets of alternatives in policy space, which is to say, all policy subspaces, will eventually be visited, as different options will be favoured by the voters sentiment. Once that this state of affairs is realized, we are faced with a system to which the techniques for the control of chaos can be applied. It will be possible to make it wander through the different sets of alternatives in the policy space, and it will also be possible to make it explore systematically the outcomes of each such set (by phase locking it to the relevant subspace).

But, is it really so? Who knows? Maybe not.

Maybe these scientific developments that we reported here still have not arose the greed of politicians and financials. Concerning this particular question, we reserve ourselves from judging, although we feel conscious of the multiple technical (and conceptual) problems yet to be solved in order that some consistent strategy for the control of complex systems may be implemented (consider, for instance, the extreme sensitive dependence on parameters that they exhibit [82]).

Be as it may, we firmly assert that these problems are minor, when confronted with the seriousness of the situations that motivated our call.

We think that their solution will be the corollary of the theoretical establishment of those laws that govern the dynamics of species of structure in our equivalence class (the composition of morphisms in a category having such species of structure as objects [83]), throughout their respective scales of space and time, but this is conjectural in character, as it corresponds to a step that we do not want to make here, and now.

Let us reflect.

The disposition of spirit that drove us, from the beginning, along the lines of this essay, prevails unshaken.

Suppose that the aforementioned problems are solved. Then, our relation to the complex adaptive system that we are part of is a relation with a world whose trajectory of phase we can control. But, in what direction should we manage to implement that control?

Such wisdom is not to be found on these lines whose writing we now put to an end. From these lines, what we get is just the frame that lead us to a call. Yet, we do believe that the value of the answer that we seek-for shall be calibrated by the generosity we put in our response to such an appeal.

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