18 A new concept of time and its applications: Natural time

18.1 The need for a different view on time

As explained in earlier chapters of this book (for example see Section 3.5), the preseismic electric signals of the VAN method (that is, the SES), are detected a few hours to several months before the earthquake. This information is obviously very important if one compares this relatively short time-window with the usual statistical estimates of the seismologists, for example that an earthquake will occur in an area after 30 years plus or minus 10 years, which in practice means that the earthquake might occur after 20 to 40 years. (Note that all these statistical seismologists’ estimates are based on the conventional concept of time, that means they count the time in years, days, hours, etc.)

Having thus confirmed the existence of SES after detailed measurements in the countryside in the 1980s, and largely understood the SES physical properties in the 1990s (that is, why one area is sensitive to SES while another is not, or why a sensitive station can record earthquakes from certain seismic areas only, which is the “selectivity” effect), during the next decade of 2000 all our research efforts were focused on the following: whether the above time-window (from a few hours to several months) could be made more precise. In other words, the question is as follows: If you say, for example, the earthquake will happen within the next three months, to avoid agonizing over this whole time period, could we somehow further identify just a few hours to a few days in advance that the earthquake is imminent? This is a very difficult question, because it is not only related to seismology, but is more general: in nature extreme (rare) phenomena occur in many disciplines, and hence the question turns to whether we can know when the occurrence of such a rare phenomenon is approaching. For example, let us mention such an important question in cardiology: while the electrocardiogram gives the doctor a picture of a healthy man, the man may suddenly die. Can we know in advance if this is going to happen? This is the case of the
so-called sudden cardiac death, which is a generally intractable problem, but widely known in the science of cardiology. For this reason there are several research groups working on this problem worldwide, and advanced research institutes abroad are exclusively devoted to this research.

In other words, the broader question could be raised as follows: Assume that we observe a complex system (for example, the Earth’s crust, the atmosphere, the heart of an individual, etc.) whose function at first glance is “normal” in the sense that our observations on its function show events that more or less occur frequently and maybe periodically. Is it possible from a series of “routine” measurements of such events to extract the information that an extreme (rare) event is going to occur shortly? The answer to this key question constitutes one of the objectives of a specific branch of science called “The Physics of Complex Systems” which has been developed during recent decades.

18.2 What is natural time?

To respond to this broader question, in 2001 Varotsos and his co-workers N. Sarlis and E. Skordas concluded that time should be measured in a way that is completely different from the conventional way we use it today. This new way of measuring time is called “natural time”, and is symbolized with the letter $\chi$, from the Greek word “χρόνος”, in contrast to conventional time which is usually denoted by $t$ (from the English word “time”).

To understand the difference, let us look at Figure 18.1, where the red lines plot what we measure in each one of five consecutive events 1, 2, 3, 4 and 5 observed at different times (as we measure them in the conventional way) marked on the horizontal axis. Consider, for example, that these events are earthquakes (in this case the symbol M in the vertical axis of Figure 18.1(a) stands for the earthquake magnitude) and suppose that earthquake 2 occurs one year after earthquake 1, earthquake 3 three months after earthquake 2, earthquake 4 two months after earthquake 3, and earthquake 5 two and half years after earthquake 4.

The situation in natural time (18.1(b)) is drastically different, since we now “forget” completely the different time intervals between these events. Here, we plot the energies (symbolized by the letter “E” in the vertical axis of Figure 18.1(b)) of the five events at equal distances from each other, because we believe that an observer in natural time is thinking as follows: The sequence (order) of the events is kept in the observer’s memory, i.e., which is the first event, which is the second, which is the third, etc., together with the relative energy released by each event compared to the total energy released by all the events (including the last one). In other words, imagine how a primitive man, who is not yet aware of the periodic phenomena that are happening around him (for example, the motion of the Earth around the Sun), remembers extreme events such as major earthquakes, severe storms, etc. The information that the (primitive) observer keeps in his memory are the following pairs of values: The first event emitted 40% of the total energy, the second 10%, the third 5%, the fourth 15% and the fifth 30%. (This is equivalent to what is expected to happen in practice: As each new event occurs, the observer compares its energy with that of the previous event or another earlier event which the observer remembers very well.)