GEOPHYSICAL PHENOMENA AND PROCESSES

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Summary

The study of geophysical phenomena and processes requires the preliminary assessment of the leading forcing factors, because physics is often concerned with a way of describing effects originated by other prime causes. Anthropic and biological impacts often play a fundamental role, and chemistry is crucial mostly whenever the biosphere and/or the greenhouse effect are involved.

The physical description in itself can be based on the kind of coupling being involved (i.e., thermal, gravitational, electromagnetic, or by matter exchange). Gravitational coupling is related to celestial mechanics and tidal deformation. Thermal coupling is ultimately concerned with energy balance. Matter exchange is concerned with the interaction between contiguous systems, and particularly important when considering boundary phenomena, typical of the environment of the biosphere, that occur between atmosphere, ocean, and solid earth. Electromagnetic coupling is concerned with both short- and long-range interactions, from solar wind through to the deep earth, and including huge electric circuits through the sun–solar wind–magnetosphere–ionosphere; their coupling with deep telluric currents and earth's dynamo; and friction phenomena and the global atmospheric electric circuit, which should explain:

- the positive charge of the ionosphere with respect to the earth,
- the atmospheric potential gradient, and, perhaps,
- the processes that control the optical depth (hence, the greenhouse effect) and water precipitation in the atmosphere.

The efficient management of climate and the environment is needed for an adequate understanding of all such basic mechanisms.

1. Physical versus Nonphysical Forcing Factors

The definition of geophysics is biased by the impossibility of isolating within the natural—as compared with the human-made—laboratory, physical, chemical, biological, or anthropic factors on their own; for all of these are intrinsically intermingled with each other (see *Branches of Geophysics*). While investigating a natural phenomenon the first concern is twofold; it deals with the assessment of the leading forcing factors that either provide the largest energy budget, or exploit some crucial control. Concern with the energy contribution alone can be misleading, as energy exchange between different parts of the system can be controlled by minor components; this is critical for energy balance, no matter how negligible their mass may appear. Moreover, the environment is often concerned with phenomena occurring on space scales or timescales that are very much larger than either human or laboratory scales, so that their effective role becomes relevant only when integrating over huge spatial extensions, or over very long (e.g., geological) time intervals.

The biosphere is concerned with boundary phenomena between the earth's atmosphere and the ocean or the solid earth, so that it ultimately makes no sense to consider the sciences of the atmosphere, or of the ocean, or of solid earth, separately. Their concern is rather with a unique system where the biosphere plays an active—and not simply passive—role. It will be convenient to introduce here a specific term for such a small fraction of the environment—both in space and time—where the biosphere can develop and survive; let us call it "climate" rather than use the usual definition derived from meteorology (see *Branches of Geophysics*).

For the purpose of clarity, let us call "process" a direct cause-and-effect relationship, while "mechanism" will refers to a more-or-less complex cause-and-effect chain, resulting in an ensemble of several steps, each defined by one or several "processes."

In a general discussion of geophysical phenomena and processes, a preliminary concern is whether, when, and how we must deal with nonphysical effects. In general, the rationale is to consider as "natural" forcing or control factors the merely physical, chemical, and biological aspects, and to deal separately with the "anthropic" action, which mainly occurred after the Industrial Revolution. Humans are generally supposed to have adapted themselves to the whims of nature. On the other hand, the belt where civilization was developed (i.e., the Sahel, the Sahara, western Europe, the Middle East, Mesopotamia, the Indus Valley, China, and the Silk Route) was formerly covered by forest and dense vegetation, which was almost totally destroyed by humankind owing to overgrazing, the systematic destruction of forest or irrigation plants during wars, the improper use of land for agriculture, and so on. In truth there is no sound reason why we should exclude anthropic impact as a determinant prime role, compared to other "natural" factors. And this holds true not only after the Industrial Revolution, but also since the earliest appearance of humankind on the earth. Any realistic approach to the extremely difficult study of geophysical phenomena and processes cannot overlook the key role played by the most likely leading prime cause of all observed phenomenon. Humans had to invent agriculture as soon as they found that had an inadequate food supply to allow for demographic expansion; they also implemented infrastructures for communications, irrigation, commerce, territory management, and so on. Their impact was sometimes rational, sometimes not. The result was certainly impressively devastating and it makes no sense to neglect it.

Neither is the problem merely academic. Rather, it has dramatic and even tragic contemporary concerns. For instance, even in one of the most recent instances, the great Sahel drought of 1983–1985, the catastrophe seems to have been mostly determined by an improper interaction between Western civilization and aborigine societies. Another well-known example is the construction of cement banks along rivers; an intervention in the natural environment justified from the viewpoint of engineering alone (i.e., to solve problems locally, supposing that its eventual drawback elsewhere will be mitigated by Mother Nature), but which cannot be justified in terms of pedology. Such cement banks have caused serious problems all over the world. This is a typical (mainly, though not exclusively) physical catastrophe triggered by anthropic intervention. Conforming to the present standard subdivision of science into disciplines, and restricting consideration to its mere geophysical aspects is, therefore, definitely a blind way of tackling problems.

One general concern deals, therefore, with ecology. For instance, the problem is well known of introducing some unprecedented animal, plant, or bacterium into the environment, such as an island. This will eventually begin to severely unsettle the local ecological equilibrium, and may trigger dramatic effects. A realistic model of an oasis must account for all its different forms of life, which ultimately support each other in overcoming environmental severity. If some apparently negligible component of the system is destroyed, the entire equilibrium can eventually break down, and the whole oasis die.

Ecology is concerned with the global behavior of a system, considered as a whole in terms of some macro-model with no detailed consideration of its basic micro-processes. However, it would be misleading to rely on a mere hierarchy of control factors, either “natural” or “anthropic,” which in reality are closely intermingled with each other.

The prime available energy supply must be taken into account appropriately, a component that is often poorly understood. Basically, two main energy sources need to be considered. One is the sun. The earth receives solar radiation, keeps a fraction of it, and reflects the remaining part into space. The percentage of energy that is reflected is called the “albedo,” and is controlled by the greenhouse effect, which itself is controlled by atmospheric chemistry (see below). The second source is endogenous energy, which is manifested almost exclusively as thermal energy; the gentle heat flow from the ground, a ubiquitous feature, provides about 60% of the entire endogenous energy supply. Sometimes the heat is so great that it cannot be transported by conventional fluids (water, gas, oil, and so on). Subsoil, however, can be heated and, hence, expanded; through which action a real bump occurs on the globe (a superswell), almost like a hill of 1000 km diameter. Tectonic plates slide down their slope. The equation of state is basically very poorly known. However, when the lithostatic pressure (i.e. the weight of the overlying layer of ground) is sufficiently small, melt occurs and magma is formed. The thermal processes are, therefore, clear, although the prime energy source, and the space-and time-pattern of its propagation through the earth’s body (which has a very low thermal conductivity) remain more a matter for mere speculation than for sound scientific understanding. The prime source is generally reported to be fossil (deriving from the heat reservoir, and from compositional transformations, of the deep earth since the time of its formation as a planet about 4.6 billion years ago). This, however, is largely a matter of lack of alternative proposals, while several endogenous phenomena do reveal a temporal trend that is in clear contradiction to such speculation. Several, very authoritative scientists have manifest their unhappiness in having to relying on such ideas. Other sources of heat, particularly in the crust, are radioactive compounds. Energy transport phenomena through the earth's body are closely intermingled with the investigations of the deep structure of the earth, which is a real challenge to present science (it is often claimed that it is much easier to study other planets than the earth's interior).

As far as the geophysical phenomena and processes are concerned, the focus ought to be on the microprocesses that govern the occurrences of the observed events in every given case history, in every specific scale- and time-range, that responds to the prime energy source of concern. Then, every specific agent can eventually originate a feedback, always in terms of such prime mechanisms and processes.

Having such a target in mind, a discussion is given here in some detail, in terms of different kinds of coupling, including thermal, gravitational, by matter exchange, and electromagnetic. This seems to be a convenient way of organizing the discussion, and can be equally applied either to anthropic action, or to the influence of the biosphere on climate, or to phenomena that govern geodynamics, earthquakes, or volcanoes, and so on. The reader should be warned, however, that there is no scheme capable of fully separating different processes, mechanisms, and phenomena that are very closely connected with each other within natural reality. Moreover, in general, there are several as yet unexplained processes and mechanisms, and climatology often appears to be one of the major interdisciplinary challenges of the entire present science.

2. Couplings

Let us call "coupling" a process or mechanism that characterizes the reciprocal influence of different parts of a system. Coupling can occur either through electromagnetic, thermal, or gravitational processes, or by matter exchange.

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Biographical Sketch

Professor Giovanni P. Gregori ,is currently at the Institute of Acoustics, O.M. Corbino of CNR, located in Rome, Italy, where he studies the application of acoustic emissions to environmental and climatic studies. During the period 1963–2001 he was at the Institute for the Physics of the Atmosphere of CNR, in Rome, his main concern being solar–terrestrial relations and climate. He obtained a "laurea in Physics" in 1961 from the University of Milan, and a "libera docenza" in Terrestrial Physics in 1971. His academic and other appointments have included: member of the panel on the earth's electrical environment of the National Research Council of the United States of America (1982); co-chairman of the Interdivisional Commission of the IAGA for External/Internal (E/I) Geomagnetic Relations (1983–1987); chairman of the WG V-3 of the IAGA on the E/I Geomagnetic Relations (1987–1991); in 1991, "associate" of the Royal Astronomical Society (1991); member of the executive committee of the IAGA (1991–1995); chairman of the Interdivisional Commission on History of the IAGA (1995–1999); foreign member and later honorary member of the Deutsche Geophysikalische Gesellschaft e. V., Arbeitskreis Geschichte der Geophysik (1999); and in 2000 he was invited to contribute to a volume of autobiographical notes in *Wege zur Wissenshaft, Gelehrte erzählen aus ihren Leben* (ed. W. Schröder). Arbeitskreis Geschichte der Geophysik und Kosmischen Physik, Bremen, Germany. His main research interests deal with the mechanisms of climate, including the role of humankind since its earliest appearance. The "more traditionally known" factors are, perhaps, highlighted in his recent monograph "Galaxy–Sun–Earth relations" (see Bibliography).