Nonlinear Processes in Geophysics (1995) 2: 107 - 108

Nonlinear Processes in Geophysics

20th international conference on mathematical geophysics "Complex space-time geophysical structures", June 19-24, 1994, La Citadelle, Villefranche sur mer, France

W. R. Peltier[1], D. Rothman[2], R. Snieder[3] and A. Sornette[4]

[1] CMG Chair, Department of Physics, University of Toronto, Toronto, Ontario M5S 1A7, Canada
[2] CMG Secretary, Department of Earth, Atmospheric and Planetary Sciences, MIT, Cambridge, MA 02139, USA
[3] CMG Vice-Chair, Department of Theoretical Geophysics, PO Box 80.021, Budapestlaan 4, 3508 TA Utrecht, The Netherlands
[4] Local Organizer, Chair Local Organizing Committee, Institute Geodynamique & Laboratoire de Physique de la Matière Condensée, Parc Valrose, Université de Nice-Sophia Antipolis, 06108 Nice Cedex 2, France

This conference focuses on the topics of Organization and complexity in the Earth Sciences on the one hand and on Interdisciplinarity on the other hand.

The Mathematical Geophysics Conferences have traditionally focused on the elaboration of new mathematical methods and ideas rather than on problems concerning the exploration of the earth by techniques already available. The adjective 'mathematical' in the name of these Conferences is taken very seriously. In mathematics, there is universality and thus real prospect for the development of interdisciplinary cooperation. It is now clear that strong notions of universality now underly much modern work in the physical sciences, for instance in the study of the few fundamental underlying physical mechanisms that underly a wide range of apparently distinct phenomena. By bringing together a group of internationally recognized scientists covering the full range of physical earth sciences, the conference aimed to foster interdisciplinary interaction in the broadest sense, on several of the most exciting problems in the field.

In particular, this conference was developed around a series of topics that placed a special emphasis on the physical mechanisms underlying geological, atmospheric, and oceanographic phenomena that are often characterized by spontaneous organization.

The first topic addressed in the conference was concerned with the mechanics of earthquakes (which appear to follow a stochastic spatio-temporal behaviors, albeit with some coherence at large scale) and the dynamics of faults (which are complex hierarchical spatial structures evolving slowly in time). A key question in this field is the origin of this geometrical and temporal complexity : does it emerge at a consequence of some organization process underlying a deterministic chaotic dynamics? Or is it rather the consequence of the intrinsic multiscale material heterogeneity of the earth? And what is the origin of crustal heterogeneity, if not partly a consequence of organization induced by cumulative (partly coseismic) deformation? Seismological analysis of recent earthquakes, geological investigations of faulting and physical modelling have significantly improved our understanding in these issues, even if this understanding remains largely incomplete and a subject of intense continuing research. A fundamental difficulty that remains is the problem of "scaling-up" from lab-based mechanical laws of rock friction and rupture to the scale of the earth.

The second subject addressed in the conference concerned modern issues in fluid dynamics, a field which has of course been instrumental in the development of the sciences of meteorology, oceanography and, to a lesser extent, astrophysics. The most easily observable of all astrophysical fluid systems are of course the liquid and gaseous envelopes of the Earth, which reveal a fascinating variety of coherent structures superimposed on the mean general circulation of wind and oceanic currents. Such coherent structures are associated with the collective motion of parts of a fluid medium and necessarily involves long-range interactions. Understanding the cause of such collective motion and exploiting it for the modelling and prediction of fluid behavior remains one of the most fascinating and challenging research goals in the earth sciences. In spite of the rapid progress in understanding weakly turbulent systems, it is the existence of these coherent structures in fluids that has made the theory of turbulence so difficult and elusive due to the fact that they largely control the statistical behavior of the fluid and thus the turbulence itself. This is certainly true for isotropic turbulence and all the more so for the considerably more anisotropic geophysical systems, in which the interactions between different regions of the fluid is generally stronger. Granular materials reveal yet another rich class of behaviors and modes of self-organization, that are in many ways different from those of other substances and cannot be easily classified as either solids or fluids. This has prompted the generation of analogies between the physics exhibited by a simple sandpile and that which underlies complicated microscopic systems, such as flux motion in superconductors or spin glasses.

The third area of focus at the Villefranche conference concerned the review of recent advances in understanding the mantle convection processes, which have been achieved through a close interplay between global seismological reconstructions of the three dimensional structure of the mantle, on the one hand, and a-priori fluid dynamical models of the mixing process on the other. A number of issues remain outstanding. Foremost among these concerns the pressure induced phase transitions that are observed (both seismologically and in high pressure laboratory experiments) to bracket the mantle transition zone. and the impact of these phase transitions on the deep circulation. Also of concern is the role of the plates in the style of convection and radial mixing, the role of different spatial scales in the connection between mantle convection and seismic tomography, and the extend to which existing tomographic reconstructions should be viewed as reliable.

More generally, considerable advances in the recent past have been achieved in the understanding, at an abstract mathematical level, of the behavior of complex nonlinear systems. The fourth subject of the conference was concerned with the planetary environment in the large, which is of course a particularly important example of such a complex system. and significant progress has recently been achieved in the application of novel theoretical methods to understanding the interactions among its component parts. Examples include the development of theories of the El-Nino Southern oscillation phenomenon that involves air-sea interaction, of the variability of the deep thermohaline circulation of the oceans that significantly influences mid-latitude climate, of the dynamics involved in volcanism and of the manner in which the trace element chemistry of the mantle of the earth may be employed to infer the detailled characteristics of internal mixing processes.

Our hope at the outset was that this conference would help drive the earth sciences further forward by providing a forum in which useful reviews of the most oustanding questions, concepts, methods, and mechanisms underlying the self-organization of complex spatio-temporal behavior in earthquake physics, in various geophysical "fluids" and environmentally related, complex dynamical systems might be presented. The organization of the meeting reflected our attempt to make accessible each field covered by the conference to the majority of non-experts (no one person attending could have been expert in all the four main fields and the many subfields covered). Oral presentations on the major questions were invited that were not only at the "state-of-the-art" but were also accessible to persons fro other sub-disciplines. Generally speaking, the oral presentations were highly successful. Each session continued in "poster mode", during which contributors were able to present their work for discussion and to focus on the latest discoveries. In each half-day of the meeting, this was followed by a panel discussion, under the direction of one or several chairpersons, during which the hightlights of the preceeding oral and poster presentations were amplified. The purpose in these discussions were to stress the most exciting remaining issues relevant to the subject of the session, and to make accessible to the general audience the different scientific trends and points of view, emphasizing possible commonalities. These discussions were generally fruitful and a very high level of participation was achieved.