

Two Cultures, Multiple Theoretical Perspectives: The Problem of Integration of Natural and Social Sciences in Earth System Research

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1. Introduction

The integration of natural and social sciences has been recognized as a key aspect of Earth System (E.S.) research, a cross-disciplinary field involving the study of the geosphere, the biosphere, and society (IGBP, 2006; Leemans et al., 2009; Pfeiffer, 2008; Reid et al., 2010; Young, 2008). Because of societal and political correlates between environmental change and socio-economic development, the study of the Earth System has been increasingly ascribed social and political dimensions emphasizing the need for greater collaboration between the social and natural sciences (Beven, 2011; Kates et al., 2001; Leemans et al., 2009; Reid et al., 2010; Saloranta, 2001; Shackley et al., 1998).

The problem of inter-disciplinary articulation between the social and natural sciences is not specific to E.S. research, and its challenges can be traced back to the very origins of the notions of science and social science (e.g. Comte, 1830-1842; de Alvarenga et al., 2011; Latour, 2000, 2004). To a degree, these challenges could be explained in terms of the increasing gulf between two cultures - those of the sciences and the humanities - as suggested by C.P. Snow (1905-1980) in an instigating essay (Snow, 1990 [1959]), due to the high specialization in science and education, and, not less important, to a "tendency to let our social forms to crystallise" (Snow, 1990: 172). More to the point, the increasing importance attributed to the problem has motivated a growing number of analyses concerning the high level of specialization and fragmentation of science and university education (e.g. de Alvarenga et al., 2011; Moraes, 2005; Snow, 1990), but also the societal and political questions concerning research agendas (e.g. Alves, 2008; Kates et al., 2001; Latour, 2000, 2004; Schor, 2008), the disparities between developed and developing countries not just in affluence level, but also in research capacity (Kates et al. 2001; Pfeiffer, 2008; Schor, 2008), and, finally, from a more methodological point of view, the multiplicity of theoretico-methodological perspectives admitted by the social sciences (e.g. de Alvarenga et al., 2011; Floriani et al., 2011; Giddens, 2001; Leis, 2011; Moraes, 2005; Oliveira Filho, 1976; Raynaut & Zanoni, 2011; Weffort, 2006).

Yet, in the E.S. field the problem of bringing together social and natural sciences has been a permanent and still unresolved challenge (Alves et al., 2007; Alves, 2008; Geoghegan et al.,

1998; Hick et al., 2010; Liverman & Cuesta, 2008), despite its recognized central relevance for E.S. research programs (e.g. Hogan & Tolmasquim, 2001; IGBP, 2006; Leemans et al., 2009; Reid et al., 2010; Young, 2008). In this field, inter-disciplinary articulation is of great interest and importance specially due to the challenges of postulating societal responses to environmental changes attributed to society itself and addressing the considerable level of uncertainty in detecting and predicting E.S. changes as in the case of the Intergovernmental Panel on Climate Change (IPCC) (e.g. Beven, 2011; Bradshaw & Brochers, 2000; Houghton & Morel, 1984; Houghton, 1990; Houghton, 2008; IPCC, 1990, 1996, 2001, 2007; Saloranta, 2001; Shackley et al., 1998; Thatcher, 1990).

The study of the Earth System is the object of a number of research programs that has been generally defined as “the study of the Earth system, with an emphasis on observing, understanding and predicting global environmental changes involving interactions between land, atmosphere, water, ice, biosphere, societies, technologies and economies” (Leemans et al., 2009). It constitutes a cross-disciplinary field of research, including a broad array of disciplines and techniques, for which General Systems Theory (G.S.T.) plays a major role for inter-disciplinary articulation. G.S.T. offers the natural sciences a key, yet conceptually simple method to formulate and solve problems involving a variety of disciplines, and can serve, for the social sciences, as the basis for conceptualizing about social systems by taking into account their functions, reproduction and meaning behind social action (Buckley, 1976; Luhmann, 2010; Rhoads, 1991). At the same time, a number of critical issues concerning environmental change and societal responses to it, including the conditions for the stability of social order, the possibilities for social change, and the role of the knowing human agent (e.g. Giddens, 2001; Habermas, 2000 [1968]; Luhmann, 2010; Rhoads, 1991; Rosenberg, 2010) may need a broader theoretico-conceptual framework extending beyond G.S.T. to be answered.

The main objective of this chapter is to examine inter-disciplinary articulation in E.S. studies, investigating how General Systems Theory and the multiplicity of theoretico-methodological perspectives taken by the social sciences¹ can come together to explore both the “physical” problem of the changing E.S. and the social process of the emergence - for the social world - of the meaning of the changing E.S. problem². The example of the Intergovernmental Panel on Climate Change (IPCC) is taken to illustrate how the problem of climate change may have emerged for the social world. The aim of the chapter is to contribute to broaden the prevailing conceptual model of Earth System studies, in which the technical concepts of observing and modelling are usually better understood and studied, by attempting to complement it with a few reflections about the part played by society.

¹Before addressing the multiplicity of theoretico-methodological perspectives in the social sciences in more detail, it is possible to mention, as examples, the concepts of ideal type (Weber, 2005a [1904]), social fact (Durkheim, 1894), and structure and superstructure (Marx, 1859), which offer different approaches to conceptualize about the social world.

²Here it is postulated that in order to recognize and respond to the problem of the changing E.S., the social world needs both to understand the „physical“ nature of the environmental changes and to elucidate to itself what such changes might mean. Although natural and social sciences take part in both processes, the emergence for the social world of the meaning of the problem would be seen as the result of social interaction leading to the elucidation of the extent and the consequences of the problem, as well as of possibilities of responding to it. The assumption of the double hermeneutic (Giddens, 2001) described in section 3.1 will help further explore these ideas for the case of the IPCC.

The chapter is organized in three major sections: the first presents an introductory, brief review of the problem of inter-disciplinary articulation and the importance of G.S.T. as a tool for it, the second reassesses the concept of method in the natural and the social sciences, and postulates how the problem of the emergence of meaning of environmental change can be explained within the G.S.T. framework, and the last section examines the workings of the IPCC, postulating the emergence of the ideas of detection and attribution of climate change, and of emission scenarios as shared concepts between the social world and science, that helped the social world to elucidate to itself what climate change might mean.

2. On inter-disciplinary articulation and general systems theory

2.1 A brief account of inter-disciplinary articulation

The question concerning the articulation of scientific knowledge produced by different disciplines has relevance not only for E.S. studies, and includes many different aspects such as the question about the unity of science, the processes leading to disciplinary fragmentation, epistemological differences among sciences, and the varied understandings of the concept of inter-disciplinarity (e.g. Aubin & Dalmedico, 2002; de Alvarenga et al, 2011; Jollivet & Legay, 2005; Jordi, 2010; Leis, 2011; Nowotny et al, 2003; Poincaré, 1968 [1902]; Raynaut & Zanoni, 2011; Schor, 2008; von Bertalanffy, 1950).

The growing importance of this question can be perceived, in particular, following the great achievements of science in the late XVIII and early XIX centuries, and the multiplication of scientific disciplines that started at that time, including the foundation of what would become sociology. In addition to the question of understanding how scientific knowledge could be achieved – which would include enquiries on the nature of scientific knowledge and method - it would be proposed that such knowledge would provide a basis to make society more just and, not less important, to evade social crises such as those of the time of the French Revolution.

One of the key conceptions at that time, one that followed the Galilean tradition, but also reflected new scientific advances in the domains of physics and chemistry, postulated a unifying, analytical view of the world provided by mathematics, as illustrated by the proposition made by the mathematician Marquis de Laplace (1749-1827):

"We ought [...] to look at the present state of universe as the effect of its previous state, and as the cause of the following one. An intelligence which, for a given moment, would know all the forces animating nature, and the conditions of the beings composing it, if furthermore it would be as immense as to analyze these data, would hold together in the same one formula the movements of the largest bodies in the universe, and those of the lightest atom: nothing would be uncertain for it, and the future as the past, would be before its eyes"³ (Laplace, 1825: 3-4; my translation)

At about the same time, Auguste Comte (1798-1857) saw the construction of scientific knowledge as needing a more complex logico-theoretical framework. For him, Laplace's

³"Nous devons [...] envisager l'état présent de l'univers, comme l'effet de son état antérieur, et comme la cause de celui qui va lui suivre. Une intelligence qui pour un instant donné, connaîtrait toutes les forces dont la nature est animée, et la situation respective des êtres qui la composent, si d'ailleurs elle était assez vaste pour soumettre ces données à l'analyse, embrasserait dans la même formule les mouvements des plus grands corps de l'univers et ceux du plus léger atome: rien ne serait incertain pour elle, et l'avenir comme le passé, serait présent à ses yeux." (Laplace, 1825: 3-4)

ideas would have been presented as a “simple philosophical game” without real consequences not even for the progress of chemistry, and offering no way to achieve a “scientific unity” which might comprehend, for example, “physiological phenomena” (Comte, 1830-1842: 58). Comte envisaged a conceptual interconnection for all scientific knowledge including the new discipline of “social physics” or “sociology”, whereas

“[to determine] the actual dependence of various scientific studies [...] it is possible to organize them among a small number of categories [...] arranged in such fashion that the rational study of each category is founded on the knowledge of the laws [...] of the previous category, and become the foundation for the study of the next one [...] from what follows [the] successive dependency [of observable phenomena]” (Comte, 1830-1842: 77; my translation).⁴

In this conception, the understanding of social phenomena was to contribute to the greatest good of humanity, as a result of “social physics” achieving the same positive stage of the study of astronomical, physical, chemical and physiological phenomena. Such views would not necessarily search for unique, unifying laws encompassing all branches of knowledge, and would leave room for the admission of limits to scientific knowledge at any given moment, but they would nonetheless think of an entire unified scientific building as the result of the juxtaposition of knowledge from the different branches of science.

Throughout the XIX century and early 1900s, a series of developments in physics, mathematics, biology, as well as in the social sciences, motivated lively debates about the nature of science and the construction of scientific knowledge, and, also, about the methods and the role of the social sciences. These debates would have a long list of protagonists, including John Stuart Mill (1806-1873), Charles Darwin (1809-1882), Claude Bernard (1813-1878), Karl Marx (1818-1883), Herbert Spencer (1820-1903), Ludwig Boltzmann (1844-1906), Vilfredo Pareto (1848-1923), Emile Durkheim (1858-1917), Max Planck (1858-1947), Alfred Whitehead (1861-1947), David Hilbert (1862-1943), Max Weber (1864-1920), Bertrand Russell (1872-1970), Albert Einstein (1879-1955), Werner Heisenberg (1901-1976), Kurt Gödel (1906-1978), and many others. These developments would mark the debate on inter-disciplinary articulation, reflecting many different, sometimes opposing, views of the possibilities and methods of science, and producing a long lasting effect on the conception of the inter-relationships among different disciplinary knowledge.

In the field of the physical sciences, in particular, the debate would include a number of issues that have relevance for the field of Earth System research, as can be illustrated by the writings of Henri Poincaré (1854-1912), a prominent French mathematician, physicist and philosopher of science. He was among the several scientists that contemplated the problem of the nature of different sciences and the construction of knowledge in mathematics, mechanics, gas dynamics and other domains. For him, physics would be mainly an experimental science conditioned by the scale of observation; his understanding of an experimental science was based on the idea that every “experimental law is always subjected to revision [and that] we should always expect to see it replaced by another, more precise one”. Attuned to the great doubts afflicting his time, Poincaré proposed that neither

⁴ “[pour déterminer] la dépendance réelle des diverses études scientifiques [...] il est possible de les classer en un petit nombre de catégories [...] disposées d’une telle manière, que l’étude rationnelle de chaque catégorie soit fondée sur la connaissance des lois [...] de la catégorie précédente, et devienne le fondement de l’étude de la suivante. [...] d’où résulte [la] dépendance successive [des phénomènes observables]” (Comte, 1830-1842: 77)

space nor time had any absolute sense (1968 [1902]: 116), and that the “science of the numbers” would be “synthetic *a priori*”, questioning the validity of the program asserting that mathematics could provide analytical means to “apprehend every truth” of the world (: 32); he also conjectured that Euclidian geometry would be “provisory”, while non-Euclidian geometries – like those of Lobatchevsky and Riemann – might prove to be adequate for problems involving “very large triangles or highly precise measurements” (: 74). A very precocious investigator who faced the challenge of “chaotic” behaviour in his studies of the stability of the Solar System, Poincaré would state that:

“The simplicity of [Johannes] Kepler’s [1571-1630] laws [of planetary motion] [...] is nothing but apparent. That should not forbid that they shall be applied [...] to all systems similar to the solar system, yet that should prevent that they’d be rigorously exact” (Poincaré 1968 [1902]: 165; my translation)⁵

These ideas reveal a series of difficulties and impasses verified in the natural sciences at the time, including those that would lead to the relativity and quantum theories, and challenge the efforts of linking atomic theory and the kinetic theory of gases, and the postulates about the foundation of mathematics. This would significantly impact the understanding of what science is, justifying, for example, the proposition of the convention of falsifiability by Karl Popper (1902-1994), the increased perception of incommensurability of scientific knowledge from different disciplines, and the questions concerning the possibilities and the limits of both observation and formal inference.

In this context, the prospect of *a priori* interdependence among scientific disciplines based on shared categories, as conceived by Comte, would fail to provide a consensual, universal framework for scientific articulation, just as Laplace’s model would do. At the same time, the natural and social sciences would continue to interact, exploring and borrowing ideas one from another, and investigating problems involving multiple disciplines. This interaction would include, most particularly, the use of analogies, as in the case of V. Pareto, whose concept of social equilibrium was analogue to mechanical equilibrium, and H. Spencer, who extended Darwin’s ideas of natural selection to society and thought of society as a social organism formed by different organs, borrowing ideas from mechanics and biology (Buckley, 1971; Rosenberg, 2000). Not less importantly, General Systems Theory ideas of exchange of matter and energy among several elements or systems, as well as the concepts of system reproduction and evolution would provide a valuable investigative framework for a number of problems requiring inter-disciplinary articulation, as examined in the next section.

2.2 General systems theory in the uncertain inter-disciplinary E.S. field

General Systems Theory (G.S.T.) – defined by von Bertalanffy (1950) as a “logico-mathematical discipline [...] applicable to all sciences concerned with systems” – has played a central role in integrating a variety of disciplines in many fields of research (e.g. von Bertalanffy, 1950, 1972; Alves, 2008; Almeida Júnior et al, 2011), and, not less importantly, has been applied to the domain of social systems (Buckley, 1971; Luhmann, 2010; Rhoads, 1991). It has evolved from a series of methods aiming at the representation, simulation

⁵ “La simplicité des lois de Képler [...] n'est qu'apparente. Cela n'empêche pas qu'elles s'appliqueront[...] à tous les systèmes analogues au système solaire, mais cela empêche qu'elles soient rigoureusement exactes.” (Poincaré 1968 [1902]: 165)

and/or control of a broad variety of processes ranging from control theory to biological, ecological and social systems. In Earth System studies, the use of G.S.T. is of key importance as it provides the basic instrumental means to join together the different Earth "sub-systems" for which numerical modelling and simulations are performed.

Here, a system will be understood as an entity formed by interacting elements, whose evolution presupposes exchange of energy and matter with its surrounding environment, at the same time as such entity is capable of maintaining or reproducing itself in this environment. This definition is similar to other system definitions (e.g. Buckey, 1971; Gell-Mann, 1994; Luhmann, 2010), although it could be noticed that it attempts to put as much emphasis on the ideas of system reproduction and evolution as on that of system maintenance. Examples of such entities may be the atmosphere, the oceans and terrestrial ecosystems, that during their entire histories have evolved by continually exchanging energy and matter among themselves.

The atmospheric and the oceanic systems can be considered to be the two central components of Earth System research investigating climate change (e.g. McGuffie & Henderson-Sellers, 2001; Randall et al, 2007), as they are the major entities responsible for heat storage and transport across the globe in climate models. At the same time, the atmospheric-oceanic climate system is connected to other systems, including the terrestrial ecosystems - which can act as a sources or sinks of greenhouse gases, and, not less importantly, transform themselves due to ecological succession in face of climate change. Similarly, social systems - the source of "dangerous anthropogenic interference with the climate system" (United Nations, 1992) - are also expected to evolve, transforming themselves to both mitigate and adapt to climate change.

In the case of the Earth System research, G.S.T. offers a very valuable and unifying framework to join together several different disciplines. Yet, a conceptual understanding of such a system does not imply that the study of the changing Earth System would assure that accurate predictions of climate and environmental change can be achieved, a fact that has had important implications for both seeking legitimacy for E.S. research and for conceiving of how social systems will respond to climate change (e.g. Bevin, 2011; Houghton, 2008; Le Treut et al, 2007; Saloranta, 2001; Verosub, 2010). This state of affairs justifies the need for understanding the different sources of uncertainties⁶ in E.S. studies, and here four different uncertainty categories are highlighted:

- uncertainties that are intrinsic to the chaotic nature of some Earth-System processes, significantly affecting the feasibility of long-term prediction of atmospheric and oceanic fluid dynamics (e.g. Lorenz, 1963; Houghton & Morel, 1984);
- uncertainties due to insufficient and incomplete knowledge about key atmospheric, oceanic, and ecosystem processes (e.g. Kesselmeier et al, 2009; Longo et al, 2009; Randall et al, 2007);
- uncertainties resulting from the choices made in implementing numerical models of the Earth System, due to limited computational resources and observational data, and to parameterization in coupling the various E.S. sub-systems (e.g. McGuffie & Henderson-Sellers, 2001; Randall et al, 2007);
- uncertainties arising from the impossibility of actually predicting changes and the evolution in social systems (e.g. Rosenberg, 2000).

⁶For further analyses of uncertainty relevant to this context see also Brown (2010), Lahsen (2005) and Shackley et al (1998).

The first three categories can be attributed to the characteristics of the natural sciences objects and methods in Earth System research, which have been the focus of continuous efforts of model improvement and data collection (e.g. Forster et al, 2007; Houghton & Morel, 1984; IPCC, 1990, 1996, 2001; Le Treut et al, 2007; Randall et al, 2007; Solomon et al, 2007). They might be assumed not to be directly relevant to the problem of articulation between natural and social sciences, even though the reader shall keep in mind their potential effects on the reception of E.S. research by the social world (e.g. Beven, 2011; Houghton, 2008; Le Treut et al, 2007; Verosub, 2010).

The assumption of the impossibility of predicting changes in social systems seems to be of greater relevance to analyze the problem of inter-disciplinary articulation involving the social sciences. To address this problem it might be useful to highlight a few perspectives from the social sciences which are relevant to the question concerning environmental change, as attempted below.

2.3 Articulation with the social sciences and environmental change studies

Despite the recognition of existing difficulties in articulation between the natural and the social sciences, environmental change has been the focus of several social science programs and projects with varying degrees of inter-disciplinary articulation with the natural sciences (e.g. Lambin & Geist, 2006; Moran & Ostrom, 2005; Pfeiffer, 2008; Young, 2008). Moreover, the establishment of environmental change as a field of research has contributed to systematizing a number of ideas and perspectives that are helpful to advance the discussions of inter-disciplinary articulation.

First of all, environmental change is frequently assimilated - from a theoretical perspective - to the problem of scarcity or distribution of resources in face of a growing population, usually taking as reference some of the postulates of Thomas Malthus (1766-1834). This theoretical perspective has received attention from several commentators, who discussed the role of technology to answer to population pressure and scarcity of resources (Boserup, 1995 [1965]; Floriani et al, 2011; Hardin, 1968; Mortimore, 1993; VanWey et al, 2005), and its political-economic, ideological and political-philosophic roots (Harvey, 1974; Montibeller, 2008; Walker, 1988). Not less importantly, a number of analyses contributed to refer this debate to questions of inequality among nations and to the development agenda (e.g. Cardoso, 1972; Furtado, 1998 [1974]; Martins, 1976).

More recently, two new fields of study - environmental sociology and political ecology - have offered valuable contributions to the problem of articulation of the natural and social sciences in the context of environmental change, in particular, by systematically reviewing a number of classical issues in the social sciences (e.g. Alimonda, 2002; Alonso & Costa, 2002; Hannigan, 2006).

In these fields, K. Marx (1818-1883), E. Durkheim (1858-1917) and M. Weber (1864-1920) are usually recognized as key references from classical, XIX-century, social theory (e.g. Hannigan, 2006) offering critically relevant, but frequently opposing views to the problem of scarcity and distribution of resources and its relation to social stratification and order. For example, Marx's concepts of structure and superstructure, his attribution of changes in the former to the transformation of the latter, and the assertion that nature is as much a source of value and wealth as labour (Marx, 1859, 1875), assume the pre-eminence of economic relations of production and appropriation of surplus value as sources of both societal contradictions and transformation. Durkheim's definition of social fact, and his distinction

between normal and pathological social phenomena (Durkheim, 1894), his understanding of solidarity (Durkheim, 1893), and anomie (Durkheim, 1897), presuppose the existence of social facts as “things” external to individuals and analyze the role of social norms and practices as something that could help to evade or to understand dysfunctional states and crises in society. Weber’s concept of ideal type and his analyses of the nature of the social sciences (Weber 2005a [1904]), the distinction among class, status group and party (Weber 2004 [1922, posthumous]), and his analyses of the German national question (Weber 2005b [1895]) take into account the influence of scientist’s values for developing theories and abstractions, and allow to examine social differentiation and stratification beyond the strict limits of economic relations.

This quick, certainly far from comprehensive, recollection of Marx’s, Durkheim’s, and Weber’s ideas is indicative of the different methodological and theoretical perspectives taken by these authors, as well as of their differing logical and philosophical approaches to social phenomena. A number of other classical authors and theories can contribute new perspectives to the context of the problem of the changing Earth System, among which V. Pareto and H. Spencer, for their views of social stratification and competition, and the references to them in the study of social systems (Buckley, 1971); and the XIX-century theories of geographic and biological determinism that have been recognized as being of interest in our context (Bresciani, 2005; Hannigan, 2006).

This multiplicity of methodological and theoretical approaches recognized since the “classical” 1800s has been the cause of continuous and lively debates, in which theories can be tentatively or effectively falsified, and questions concerning the scale and context of their validity can be raised (e.g. Browder et al, 2008; Giddens, 2001; Lambin et al, 2001; VanWey et al, 2005). At the same time, it also represents a critical element of the philosophy, the theory, and the methods of the social sciences, as it is related to the capacity of judgment and intent of the social agent, and to the very question about the possibility of predicting changes in social world (e.g. Arendt, 2010; Giddens, 2001; Rosenberg, 2000).

Here, it is suggested that such multiplicity of approaches is one of the major sources of tension in attempts to articulate the natural and the social sciences in the study of the changing Earth System. Taking into account or ignoring the fact of this multiplicity ends up having important consequences to the very conceptualization of inter-disciplinary articulation, most particularly, in efforts to explore new possibilities of enquiry on how the meaning of environmental change can emerge for the social world, and on the possibilities of articulation with the political field. It is also suggested that exploring the differences in the understanding of the concept of method in the natural and the social sciences can help to better recognize this multiplicity and some of its implications for the study of the changing Earth System.

3. Methodological issues in studies of the Earth System

3.1 Postulating different understandings of the concept of method

By assuming that the study of the changing Earth System requires the articulation between the natural and the social sciences (e.g. IGBP, 2006; Reid et al, 2010), crucial questions about **how** to actually achieve such an articulation will arise, concerning both how to conceive of the investigative process involving multiple disciplines and how to consider the different logical, epistemological, ontological and political perspectives in relation to the problem of changing Earth System (e.g. Alimonda, 2002; Alves, 2008; Geoghegan et al., 1998; Hick et al.,

2010; Liverman & Cuesta, 2008; Moraes, 2005; Oliveira Filho, 1976; Schor, 2008; Shackley et al., 1998). Although these questions have not impeded close collaborative work between natural and social scientists (e.g. Alves, 2008; Lambin & Geist, 2006; Moran & Ostrom, 2005), they can justify a broader examination of the persistent difficulties in approaching the articulation problem (e.g. Alimonda, 2002; Alonso & Costa, 2002; Liverman & Cuesta, 2008; Moraes, 2005; Schor, 2008).

This section’s departing point is the different understandings of the concept of method as presented by Moraes (2005), who proposed that methods, in the natural sciences, are understood just as the “technical-instrumental means” of investigation, while, in the social sciences, they in fact represent “logico-theoretical frameworks” for scientific enquiry. This differentiation is summarized in Table 1.

	Techniques	Methods	Theories
Natural sciences	Technical-instrumental means of investigation		Hypothetico-deductive or inferential systems allowing for interpretation of natural and social phenomena
Social sciences	Technical-instrumental means of investigation	Logico-theoretical frameworks for enquiry	

Table 1. Schematization of the different concepts of method in the natural and the social sciences, based on Moraes (2005) and Audi (2005).

In addition to these differences in the concept of method, it is useful to distinguish two different aspects of the methodologico-theoretical problem according to Oliveira Filho (1976): the conception of the process of social investigation and the different logical, epistemological and ontological perspectives that can be found in the field of study. For this author, the process of social investigation can include, for example, functionalism, ethnomethodology, and structuralism, to which it seems appropriate to add possibly different frameworks for data collection, systematization and analysis (e.g Moran & Ostrom, 2005); different logical, epistemological and ontological perspectives can be exemplified by the dialectical, hermeneutical, and pluralistic methods. Here it will be suggested that conceiving of the process of investigation may represent not the largest of the obstacles to collaborative work, provided that the multi-disciplinary team be capable to work towards common investigative problems and questions (see, for example, Alves, 2008; Keller et al., 2009; Moran & Ostrom, 2005; Schor, 2008). On the other hand, different logical, epistemological, and ontological views may be at the origin of a challenge of different nature, in particular, as they can be intertwined with the attribution of different meanings to social phenomena not only by scientists, but also in the social world. Further discussion of the nature of this challenge and its implications can easily expand into the domains of political science, philosophy of science and philosophy of the social sciences (e.g. Arendt, 2010; Latour 2000, 2004; Rosenberg, 2000), possibly creating further barriers for understanding what to expect of inter-disciplinary articulation. Here, this discussion will quickly refer to the concept of double hermeneutics proposed by Anthony Giddens (1938-, e.g. Giddens 2001), which can provide an instrumental reference to conceive of how the meaning of environmental change emerges in the social world, considering, at the same time, the nature of the contribution of science to this process.

The concept of double hermeneutic posits that the social sciences are distinguished from the natural sciences by the fact that the latter “consist of hermeneutic or interpretive efforts [...] [where the interpretation of the natural-science laws] must occur in the domain of theoretical systems” (Giddens, 2001: 101; my translation from the Brazilian edition), while the former are concerned by “[knowing] agents [imbued of intent] that generate and invent concepts, theorize about what they do, as well as about the conditions under which they perform their acts [...] In contrast to the natural science [...] the social sciences entail a double hermeneutic, since the concepts and theories developed in their domain are applied to a world which is constituted of activities performed by individuals who conceptualize and theorize [about their world]” (Giddens, 2001: 111; my translation from the Brazilian edition). Getting back to the distinction between the process of investigation in itself and the different logical, epistemological and ontological ideas permeating different methodological approaches (as in Oliveira Filho, 1976), it can be suggested that the assumption of the double hermeneutics helps further scrutinize the problem of different, frequently opposing logical-philosophical-political views behind the methodological question. In fact, by admitting a “knowing human agent” capable of attributing meaning to the findings of science and to respond to these because he/she is instilled with intent, it also assumes that it is not up to the “social scientist to interpret the meaning of the social world for the social actors therein inserted” (Giddens, 2001: 101; my translation from the Brazilian edition). While stating that, Giddens also proposes that the practical impact of the social science will be found in the social world actually absorbing social sciences concepts, without abdicating from its own capacity of judgment and intent. The concept of the double hermeneutic has been considered in a number of social analyses, ranging from the field of education, to cultural and political-philosophical problems (e.g. Aguiar, 2009; Botelho & Lahuerta (2009); Domingues, 1998, 1999; Magalhães & Stoer, 2002; Rodrigues, ND). As suggested in section 4, it can open new perspectives to assess the role of science by analysing the work of the IPCC. Before concluding this section, it seems appropriate to raise the question about what possible places can be attributed to social systems and to the knowing human agent, in the study of the changing Earth System, where General System Theory plays a central role. This will be explored next.

3.2 The place of social systems in the study of the changing Earth System

The question concerning the effective role of the social sciences in the Earth System field is far from being a consensual one, including different views ranging from the indication that the social sciences “have been reluctant to respond to global-change science” to the proposition that they are “critical in shaping the public discourse on the changing socio-environmental condition”. Although this lack of consensus has not prevented collaborative work involving the natural and the social sciences (e.g. Alves, 2008; Lambin & Geist, 2006; Moran & Ostrom, 2005), a fundamental question can be raised about the place of the “social system” in E.S. research, most particularly, if the interest of investigation is how the meaning of environmental change can emerge in the social world, and a “knowing human agent”, capable of judgement and intent, is to be recognized.

Here, three aspects of this problem will be referred to, a first one related to the sceptical views about G.S.T. in some domains of the social sciences, a second one pondering the addition of a social component to Earth System models, and a last one discussing how the concept of social systems can be of interest in studies of the changing Earth System.

The sceptical views concerning G.S.T. have their roots in the association of this method with technocratic inclinations, including the postulate that social and economic problems can be resolved based on “objective” knowledge provided by the technocracy, and a tendency to dispense with political constituency and representativeness (see, for example, Habermas, 2000; Leff, 2002; Martins, 1976; Mirowski, 2003; Schwartzman, 1980; Whiteside, 1998). Although this scepticism will not be examined in detail here, it seems pertinent to notice, on one hand, that E.S. researchers should be aware of it, and, on another, that the problem of environmental change is involved in multi-faceted processes that makes the analysis of its political dimensions particularly complex, extending beyond the questions about the technocracy (e.g. Alonso & Costa, 2002; Latour, 2004; Leis, 2011; Raynaut & Zanoni, 2011; Santos & Alves, 2008).

The idea of adding a social sub-system to fully-coupled Earth System models seems to have its roots in the Galilean-Laplacian mathematico-analytical views, in the foundation of cybernetics and modern G.S.T., and, more recently, on agent based models (e.g. Gell-Mann, 1994; Grimm et al, 2005; Holland, 2006; Mirowski, 2003; Parker et al, 2006; von Bertalanffy, 1950, 1972; Whiteside, 1998). Although a complete analysis of this proposal is still to be done, it can be observed that conceiving of a social sub-system as part of a broader system can be instrumental to exercise inter-disciplinary collaboration by taking into consideration social structure and processes. However, reducing the social world to just one element of a larger system may elude key socio-logical and political aspects of the process of emergence of the meaning of environmental change, and contribute to some form of technocratic predisposition concerning the issue of societal responses to the changing E.S. (Mirowski, 2003; Shackley et al, 1998; Whiteside, 1998).

In contrast, the question whether and how the concept of social system could be adopted in Earth System research is suggested to potentially contribute to the approximation of the natural and the social sciences on more conceptual ground. In fact, despite some scepticism concerning the relationship between G.S.T. and the social sciences, a number of authors have examined how different logico-theoretical frameworks can be combined with the concept of social system (e.g. Buckley, 1971; Luhmann, 2010; Rhoads, 1991), pointing to the possibility of taking into account the role of the knowing human agent. Most notably, the contributions by Talcott Parsons (1902-1971), George Homans (1910-1989), and Niklas Luhmann (1927-1998) offer a variety of conceptual frameworks allowing consider the changing, “live” nature of social structure and action, and, in varying degrees, the meanings and intents present in the social world. Although such work does not seem to contribute to the conceptualization and construction of more powerful Earth System models or simulators, it is suggested that they offer important perspectives to bridge the gap between the “two cultures” as they can help to incorporate some key social science issues and categories into the Earth System field debates. Furthermore, it is suggested that by recognizing a “living” social system, it may be possible to re-position some of the questions about the interface between the social world and science.

Such conceptions of the social system presuppose that it is only in the process of social reproduction - including the processes of social interaction and mobilization mediated by social institutions and stratification - that the meaning of environmental change can emerge for the social world. There are two aspects of this proposition that need to be further stressed. First, it does not assume any definite need of incorporating a social sub-model in a single fully-coupled model of the changing Earth System as part of an integrated simulation

effort; yet, it still corroborates to the assumption that system theory concepts can serve as a common ground for interaction between natural and social scientists (e.g. Buckley, 1971; Luhmann, 2010). Second, and perhaps most importantly, it re-positions inter-disciplinary research so that it becomes possible to look for questions for scientific investigation outside the strict dynamics of the scientific field, i.e. in the very process of social reproduction, when the meaning of environmental change emerges and evolves continually for the knowing human agent. It is this emergence of questions shared by both the scientific field and the social world that will be postulated and discussed for the case of the IPCC in section 4.

By leaving aside the assumption of the definite need of implementing fully-coupled simulation models including the social world, it is not suggested that there are no relationships between this world and the “physical” Earth System. Rather, it is proposed that the social world may need different concepts and logics than those of the physical system to be elucidated. Thus, it is suggested that social systems can be conceptualized about by recognizing in it a symbolic dimension, in which socially mediated information can be valued by the knowing human agent, and a reproductive-evolutionary dimension in which the meaning of environmental change can emerge and evolve in the process of social reproduction.

Figure 1 illustrates these ideas in the form of a 3-dimensional conceptual space in which physical, ecological, and social systems are represented with the purpose of interdisciplinary articulation in Earth System studies. The “physico-chemical” axis corresponds to the conceptual dimension of atmospheric-oceanic-biogeochemical “physical-climate” systems, for which the question of exchanging energy and matter, and the idea of positive and negative feedbacks constitute the main elements for conceptualizing and modelling. The figure also suggests that the emergent/reproductive-evolutionary axis together with the physico-chemical one define a 2-dimensional “*conceptual plane*” where the reproduction and evolution of ecological systems can be conceptualized about by taking into account both physical processes and ecological succession; in this case, the long term result of ecological succession might be, for example, the emergence of new ecosystems as the product of climate change.

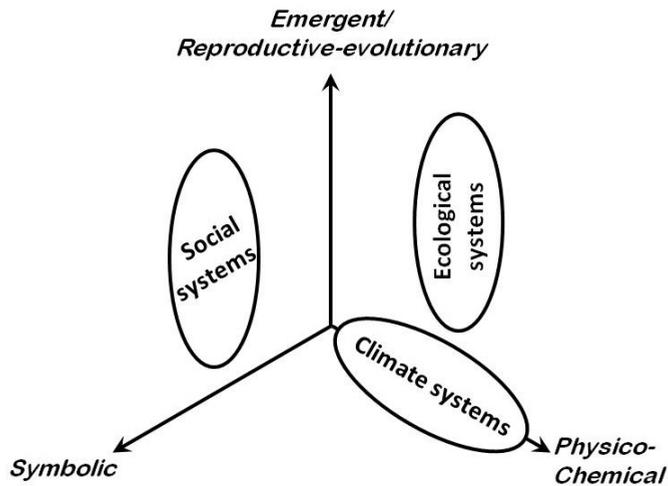


Fig. 1. Schematic representation of three conceptual dimensions for Earth System studies.

Finally, the figure shows a second “*conceptual plane*” defined by the symbolic and the emergent/reproductive-evolutionary axes, which is suggested to be the place for conceptualizing about social systems. It should be noticed that the emergent/reproductive-evolutionary dimension is proposed to highlight the idea of evolution of both the social and the ecological systems, which incorporates both *inheritance* and *random elements*, making the long-term prediction of such systems daring. As noted before, the impossibility of prediction in social systems is also related to the nature of the knowing human agent.

4. An assessment of the Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change (IPCC) defines itself as an “international body for the assessment of climate change [...] established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts”. Its constitution assures that it is both “a scientific body [which] reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change” and intergovernmental, in the sense that “governments participate in the review process and the plenary Sessions” (IPCC, ND). The Panel was the recipient of the 2007 Nobel Peace Prize “for [its] efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change” (Nobel Foundation, ND).

The Panel’s dual constitution as a scientific body in which governments take part has been suggested to offer a new model for the science-policy interface stressing extensive public reviews (e.g. Saloranta, 2001). Yet, the socio-political nature of its procedures seems to be easily eluded when its achievements are seen as the result of the objectivity of its scientific results alone (e.g. Houghton, 2008). The IPCC workings are not immune to the debate involving the problem of making political choices, most notably suggestions of a “technocratic policy orientation to [the] climate change [problem]” (e.g. Shackley et al, 1998). Despite disputes involving the Panel, it is considered a very respectable body since its foundation, as demonstrated by it being awarded the Nobel Peace Prize, the testimonies of several public persons (e.g. Thatcher, 1990), and appraisals of the effectiveness of its contribution to the climate change debate (e.g. Saloranta, 2001).

Notwithstanding the wide public recognition of its “technical” contribution to the climate change debate, it is suggested here that seeing it as a predominantly technical-scientific body can elude the nature of its dual constituency and can be misleading. Indeed, the Panel’s mission statement asserting that it “reviews and assesses the most recent scientific, technical and socio-economic information”, and the analyses focussing on the nature of its “reviewing” procedure (e.g. Saloranta, 2001) may conceal the fact that it has been built on a privileged relationship with the socio-political world based on sharing the meanings of a number of concepts between the scientific field and the social world. It is proposed that these shared concepts – those of detection and attribution of climate change, and emissions scenarios – played a crucial role in the very institution of IPCC, as well as on the success of public mobilization around the climate change issue. It is further postulated that this can be apprehended based on the double hermeneutic concept of Giddens (2001) summarized in section 3.1.

Indeed, the concepts of detection and attribution⁷ – have clear shared meanings for both the political world and the scientific field, following the dialectics assumed by Giddens, in which the impact of the social sciences appears when “socio-scientific concepts [end up being selectively absorbed] by the social world, to which such concepts [become] a constitutive part” (2001: 112; my translation from the Brazilian edition). In addition, it can be observed that attribution of climate change to human action depends on the shared understanding of the uncertainties intrinsic to climate modelling. This dialectics is manifested in the importance attributed to detection and attribution in both the technical and the political discourses, which can be documented by the generalized and continuing use of these concepts, as central elements of both scientific investigation and political deliberation as can be found, for example, in Houghton & Morel (1984), Thatcher (1990), and in the scientific reports of IPCC WG1 (IPCC, 1990, 1996, 2001, 2007).

The role of the concept of emissions scenarios⁸ (i.e. scenarios of emissions of greenhouse gases as defined, for example, in IPCC, 2000), can be understood in similar terms. In this case, it also presents particular interest because it offers the prospect of descriptions of the future which would be immediately shared with the social world, but manifestly have not the status of predictions, since the result of the reproduction and evolution of the social world is admittedly uncertain for anyone. Emissions scenarios, more particularly, serve to at least two purposes – as qualitative narratives that can be associated to reference ranges of emissions necessary to parameterize GCM models, and as an idea reflecting the unpredictability of emissions produced by social systems for both the scientific field and the social world itself.

In comparison to other analyses, which put emphasis on the IPCC review procedures, for example, those assuming an “‘Extended Peer Community’ [where] various stakeholders with various perspectives [...] are brought into the dialogue assessing the input from science to decision-making” (Saloranta, 2001: 492), the double hermeneutic framework may consider that some core issues pertaining to IPCC work are not *a posteriori* deliberated by society. On the contrary, here it is assumed that shared concepts have emerged in a social world in which the scientists are embedded. The success in arriving at some shared concepts does not presupposes consensual, definite and comprehensive responses as a result of the production of “objective” knowledge by science, and the dialectics assumed by the double hermeneutics can potentially recognize situations of conflict, contradictions, and the result of different mobilizations in relation to the environmental change issue (e.g. Alves, 2008; Alves, 2010; Schor, 2008; Shackley et al, 1998).

5. Conclusion

The societal and political aspects of the problem of the changing Earth System have represented a major challenge for both the development of Earth System studies and to consider the question about the societal responses to climate change. In such a context, the articulation between the natural and the social sciences is also seen as a significant challenge

⁷Here, detection will be understood as detection of climate change, in particular, temperature, and attribution as attributing climate change to specific causes, in particular, to anthropogenic greenhouse gas emissions (Houghton & Morel 1984; IPCC, 1990).

⁸“Scenario is a plausible description of how the future may develop, based on a coherent and internally consistent set of assumptions about key relationships and driving forces. Note that scenarios are neither predictions nor forecasts.” (IPCC, 1995: 33)

involving multiple dimensions, whose solution may be expected to be provided by instrumental means – methods - which would allow to carry Earth Systems studies to a new level, and to formulate new strategies and solutions to face issues like the climate change.

This chapter attempted to examine a few basic differences between that the natural and the social sciences, whose understanding is expected to contribute to the goal of responding to societal and political aspects of the changing E.S. problem by taking into account, in particular, the different understandings of the concept of method. It attempted to show to the reader a variety of perspectives concerning how the social world can be understood, from the point of view of the process of investigation, but, also, admitting that different logical, epistemological, ontological and political perspectives are part of the “logic” of the social world for which the meanings of environmental change have ultimately to emerge.

In conclusion, there are three final points that might be stressed here. First, the proposed approach to analyze the workings of the Intergovernmental Panel on Climate Change attempted to put in evidence that climate change is something relevant for both science and the social world, suggesting that more than just providing assessments of climate change, scientists have been engaged in some kind of dialectical exercise in which the scientists and the social world have ended up sharing a small number of key concepts, and have been similarly conscious of the huge uncertainties facing both science and society in relation to climate change. Second, it is necessary to make it clear that the admission of a variety of perspectives concerning the social world does not attempt to demonstrate that “truth is a relative concept” (e.g. Verosub, 2010), or that political aspects of responding to climate change can be reduced to a matter of supposedly objective cost-benefit analysis (e.g. Beven, 2011). In contrast, it is proposed that the social world is capable of attributing meaning and is imbued of intent, and the more this capacity is recognized and exercised, the greater the likelihood that the social world will respond to the climate change issue, although not without its own contradictions, its own inequities, its own aspirations and intents. Finally, it is suggested that this proposition is part of what the two cultures can attempt to develop as some kind of strategy shared with society towards the problem of the changing Earth System, and understanding the nature of this challenge is one of the key contributions that might be expected from the social sciences and their multiple methods.

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