Brazilian Network on Global Climate Change Research (Rede CLIMA): structure, scientific advances and future prospects

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RESULTADO DE PESQUISA

Resumo

A fim de criar o conhecimento científico necessário para o Brasil entender e lidar com as causas e consequências das mudanças climáticas, o governo federal criou, em 2007, a Rede Brasileira de Pesquisa em Mudanças Climáticas Globais (Rede CLIMA). A Rede CLIMA precisa discutir questões, fazer perguntas, desenvolver metodologias e produtos tecnológicos, encontrar respostas e sugerir soluções que sejam relevantes para a sociedade. Em sua primeira fase, a Rede concentrou-se em fornecer infraestrutura e consolidar suas sub-redes. Houve também vários avanços científicos, alguns dos quais são apresentados em seções focadas em modelagem climática, agricultura, energia e água, desenvolvimento e mobilidade humana, biodiversidade e serviços dos ecossistemas, e saúde humana. Agora, em sua segunda fase, o objetivo é estabelecer colaborações entre sub-redes por meio de projetos interdisciplinares. Argumenta-se que, para que tenha sucesso, a Rede precisa fomentar pesquisas de longo-prazo cujo mérito não seja medido apenas pela produção acadêmica.

Palavras-chave: mudanças climáticas; modelagem do clima; impactos, adaptação e vulnerabilidade; mitigação; ciência interdisciplinar.

Abstract

In order to create the necessary scientific knowledge for Brazil to understand and deal with the causes and consequences of climate change, the federal government created, in 2007, the Brazilian Network on Global Climate Change Research (Rede CLIMA). Rede CLIMA needs to discuss issues, pose questions, develop methodologies and technological products, find answers, and suggest solutions that are relevant to society. In its first phase, it focused mainly on providing infrastructure and consolidating the sub-networks. Several scientific advances were also achieved, a selection of which are presented in sections focusing on climate modelling, agriculture, energy and water, human development and mobility, biodiversity and ecosystem services, and human health. Now, in its second phase, the objective is to straighten collaboration between sub-networks by means of interdisciplinary projects. It is argued that in order to succeed the Network needs to foster research whose merit is measured not exclusively by academic production.

Keywords: climate change; climate modelling; impacts; adaptation and vulnerability; mitigation; interdisciplinarity science

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INTRODUCTION

In the last decade the issue of climate change has been progressivelyincorporated into Brazil's national, state and municipal policies and economic instruments. For example, the federal government instituted the National Climate Change Policy (Política NMC 2009), and, for it to be implemented, the National Climate Change Plan (Plano NMC 2007) and the Brazilian Network on Global Climate Change Research (hereafter Rede CLIMA, or the Network; 2007) were designed. States, such as São Paulo, Pernambuco, Paraná, Bahia and Rio de Janeiro, and cities, such as São Paulo and Rio de Janeiro, created similar instruments too.

Rede CLIMA, in particular, was conceived to become the country's main research and development pillar in the issue of climate change. It thus needs to discuss issues, pose questions, develop methodologies and technological products, find answers, and suggest solutions. Due to its focus on problems arising from society, the Network's fundamental nature is interdisciplinary.

More specifically, Rede CLIMA's aims[1] are to:

(i) generate and disseminate knowledge and technologies for Brazil to respond to the challenges imposed by the causes and consequences of climate change;

(ii) study the impacts of climate change upon Brazil and eventually elsewhere, focusing on the identification of the country's main vulnerabilities;

(iii) studyand suggest adaptation strategies for the social, economic, and natural systems;

(iv) study nutrient cycling and carry out Brazil's greenhouse gas emissions inventory;

(v) contribute to the design and implementation of Brazil's natural disaster monitoring and alert system;

(vi) contribute to the formulation of public policies on global climate change within the Brazilian territory;

(vii) support Brazil's diplomacy in international negotiations regarding climate change.

As Brazil has had a multitude of scientific enterprises aiming at helping the country to deal with climate change related issues, such as the National Institute of Science and Technology for Climate Change (INCT-MC), the FAPESP Program on Global Climate Change Research (PFPMCG), among others, Rede CLIMA is slowly moving to become the initiative where all such knowledge is being progressively aggregated and synthesized.

ORGANIZATIONAL STRUCTRE

The Network was established by Ordinance MCT No. 728 of 20 November 2007 and amended by Ordinance MCT No. 262 of 2 May 2011. There is a Board of Directors (BD; MCT Ordinance No. 171 of 27/03/2008), a Scientific Body (SB) that is led by a Science Coordinator (SC), and an Executive Secretariat (ES), which is based at the National Institute for Space Research (INPE).
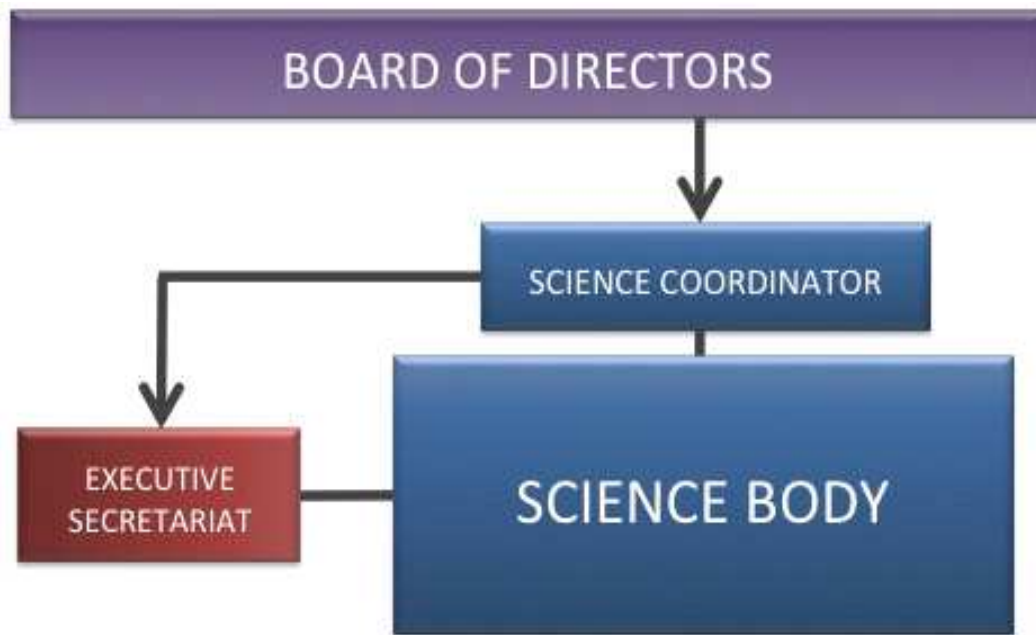

Figure 1: Rede CLIMA's organization structure. The Science Coordinator and the Executive Secretariat are both based at INPE; the science body is comprised within the 13 sub-networks distributed throughout Brazil.

The Board of Directors is responsible for defining Rede CLIMA's scientific agenda, overseeing and evaluating its activities, obtaining and allocating financial resources for it, establishing data exchange policy, integrating and articulating it, establishing new sub-networks, and bridging the gap between science and public policies. It is comprised of one representative from each of the following institutions: The Ministries of: Science, Technology and Innovation (which presides it); Environment; Foreign Affairs; Agriculture, Livestock and Supply; Health; Cities; Mines and Energy; National Integration; along with the Brazilian Academy of Sciences; Brazilian Society for the Advancement of Science; Brazilian Climate Change Forum; National Forum of the State Secretaries for Science, Technology and Innovation; and the National Forum of the State Research Funding Agencies.

The Science body is, at present, composed of the following 13 sub-networks: Climate Modelling, Agriculture, Economics, Biodiversity, Environmental and Ecosystem Services, Energy, Hydric Resources, Regional Development, Cities, Coastal Zones, the Oceans, Natural Disasters, and Health (Figure 2).

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Figure 2: Sub-networks of Rede CLIMA. The headquarters of the sub-networks are based in each of Brazil's five regions. Each sub-network is a network in itself, with links connecting the headquarters to other Brazilian and foreign institutions, so that, in practice, Rede CLIMA's reach and interconnectedness are much greater than what can be perceived here.

Financial resources

Rede CLIMA's funding comes from the Cross Actions (CA) of the National Fund for Scientific and Technological Development (FNDCT). The FNDCT funds, in turn, come from portions of the royalties derived from oil or natural gas production, percentage of net operating revenues of electric utilities, contracts of assignment of rights of use of road infrastructure for the purpose of operating communication and telecommunication systems, financial compensation for using hydric resources for electric power generation, revenue activity aimed at promoting scientific research and technological development of the space sector, loans from financial institutions or other entities, contributions and donations from public and private entities, and other sources. In 2011, approximately 40% of the funds came from oil royalties alone (FIESP 2011).

Progress up to now

Research infrastructure

In its initial phase, one of Rede CLIMA's main accomplishments was to provide its sub-networks with research infrastructure. For this matter, it has spent, to date, R$

17.5 million. Of these, R$ 15million corresponded to 1/3 of the amount required to buy INPE's new supercomputer (29th most powerful civilian computer in the world, ranked 8th amongst those that are devoted to climate modelling). R$ 2.45 million were to buy computational and furniture items, all of which were distributed to its sub-networks and central node.

Science

The scientific challenges facing Rede CLIMA are related to producing scientific knowledge to cope with climate change impacts, mitigation and adaptation, in addition to providing means to promote regional development within a developing country. The strategy adopted from start was to strengthen the individual sub-networks, aiming at a future interdisciplinary synergic development of the Programme. The main results obtained so far by Rede Clima are divided into thematic areas presented below:

Climate Modelling

The development of the Brazilian Earth System Model (BESM) is the central pillar to achieve the goals of Rede Clima. Eventually, BESM will have counterparts of all sub-networks, at the same time that it will generate climate change scenarios for all the Network expert activities.

Figure 3 – Financial Resources paths from the origin within the Federal Government to the Sub-Networks of Rede CLIMA.

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The first release of BESM is based on the global coupled ocean-atmosphere model of the Centre for Weather Forecasting and Climate Studies (CPTEC) (Nobre et al. 2012). The results generated by this model were submitted to the Coupled Model Intercomparison Project Phase 5 (CMIP5) and constitute Brazil's contribution to the Fifth Assessment Report of the Intergovernmental Panel on Global Climate Change (IPCC AR5).

Agriculture

Brazil's economy is strongly dependent on natural resources, such as crops, livestock and hydroelectric plants. The close relationship between these and the climate makes the country particularly vulnerable to predicted future climate changes (Andrade et al. 2012).

Regarding agriculture, the effect of the increase in atmospheric CO_2 concentration on the health of plants of commercial interest for the country is being investigated. This is being done via Free-air Concentration Enrichment (FACE) experiments that have been installed in six sites in four regions of the Brazilian territory. Numerical simulations that aim at investigating the effects of climate change on plant pathogens are also being used. One result indicates that *Hemileia vastatrix*, a pathogen that commonly attacks Coffee (*Coffea arabica)*, might have its incubation period reduced if either A2 or B1 IPCC AR 4 scenarios are considered (Ghini et al. 2011a). A detailed review on the relationship between global warming and plant diseases in different species was published. It was reported that under the IPCC future climate scenarios a great variety of tropical crops including banana, cassava, pineapple and sugarcane will be at an increased risk of infection (Ghini et al. 2011b). Finally, a numerical simulation system to evaluate the impacts of climate change on agricultural production in Brazil was concluded, and assessments of soil carbon stock to support the Sectorial Plan for Brazil's Low Carbon Agriculture are being conducted. It is important to highlight that Brazilian economy is highly dependent on the export of primary commodities, several of which are derived from agricultural production, so such studies are of major importance from the perspective of planning adaptation strategies aiming at food security.

Energy and water

In relation to renewable energy, studies focused mainly on greenhouse gas mitigation strategies at the national level, considering IPCC scenarios in which the participation of these sources are more significant. The discussion about the energy issue within the National Climate Change Plan is noteworthy, with proposals to expand biofuels production in the Southeast and Midwest, hydroelectricity in the watersheds of the Amazon and La Plata basins, and wind and solar power in urban areas (water heating) and isolated areas (photovoltaic electricity).

Water is a resource of major concern in Brazil. Hydropower is the main source of energy in the country and it is often considered as a good alternative for the development of a 'greener' economy. However, recent data shows that CO_2 emissions

from hydroelectric dams can be higher than that of energy sources driven by fossil fuel, particularly when dams are built in the Amazon Basin (Fearnside & Pueyo 2012).

Furthermore, preliminary results indicate that there has been an increase in the frequency and magnitude of droughts in the Madeira, Tapajós and Xingu rivers within the Amazon Basin (Paiva et al. 2011). Such reduction should be increased as the climate in the region becomes drier, and this should compromise the region's hydropower generation and navigation potentials, and well as alter ecosystems - and hence its services - in ways that are still unknown. Thus, results to date question strongly the medium and long-term adequacy of the Amazon Basin as a hydropower-generating region.

Human development and mobility

Most large Brazilian cities, where a considerable part of the country's human population lives, are located close to the coast. Because almost 50% of the country's coastal zone is vulnerable to rising sea levels, there is obvious concern with the impacts of climate change on the population, as well as with finding adaptations strategies. In the metropolitan centre of the city of Recife in the State of Pernambuco, for example, 40% to 80% of the buildings are situated in areas that are at sea level and at less than 30m from the coastline (Faveri et al. 2010), making the risks of sea level rise obvious. Moreover, there is erosion in large part of the Brazilian coast, which will be enhanced by the increased frequency of extreme weather events. Such processes are particularly intense in southern Brazil, where in the last 30 years there have been 40 storm waves (Machado et al. 2010).

With respect to the part of the human population that still lives in the countryside it has been shown that smallholder farmers in the NE Brazil are already feeling the effects of extreme droughts (Lindoso et al. 2012). The necessity to create a system of indicators to identify similarities and differences in the vulnerability and adaptation of communities of farmers living in different environmental and socioeconomic contexts thus emerged. The indicators created are part of a framework composed of the universal attributes of vulnerability (adaptive capacity, sensitivity and exposure), as well as specific sensitivity indicators weighted by exposure type (drought, floods, landslide slopes, agriculture burning). Within this context, up to June 2012 approximately 900 questionnaires were applied to people living in the N, NE and CW regions of the country

In light of the probable local-scale impacts of climate change on human populations, studies have also focused on assessing possible migratory flows across the country. These have used a general equilibrium model of the Brazilian economy and considered scenarios A2 (until 2020) and B2 (until 2070) of the IPCC AR 4. Of particular interest were the regional changes in labour demand, as well as the changes in the population distribution patterns. The results point to a reversal of the current migratory flows, suggesting a new wave of migration originating in Northeast region of Brazil, but also in MatoGrosso do Sul, and directed mainly to the Southeast and South regions of

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Brazil, as well as a new flow to the North region. The study found out, however, that absolute numbers of new migrants should not be very high (Reilly et.al.2012).

Biodiversity and ecosystems

Analysis of molecular phylogenies have shown that most speciation events in the *Psophia spp.* (Psophiidae) occurred before the Pleistocene glaciations, which started approximately 900,000 years ago, indicating that periods of drier climate associated with a possible fragmentation of Amazon forests did not promote speciation in this lineage; these findings, the authors stress, do not support the 'Pleistocenic refuge hypothesis' (Ribas et al. 2012). Moreover, results of species distribution models considering future climate scenarios suggest a large reduction in the richness of birds species in the Atlantic Forest, with 44 species suffering a reduction in their geographic range and six reaching the extinction threat threshold due to habitat loss (Souza et al. 2011).

Coastal ecosystems such as mangroves, seagrasses and tidal marshes are able to uptake huge amounts of CO_2 due to their high photosynthetic rates - they release high concentrations of O_2 and stock CO_2 in the biomass (Copertino 2011). However, there has been a 30% bleaching of inshore coral reefs (>5km from coastline) due to rising sea temperatures (Zelinda et al. 2010).

Human Health

With regard to human health issues, studies conducted in the Amazon region during the rainy season, when natural aerosol emissions predominate, show that the concentration of these particles in the air is in the order of 10 to 15 ìg.m-3. In the dry season, due to emissions from forest fires, concentrations rise to about 300-600 mg m-3 (Yamasde 1999). This increase in aerosol concentration during the dry-season has been correlated with an increase in the incidence of airborne diseases in humans. In 2007, in the state of Mato Grosso, respiratory diseases were the leading causes of hospitalization in children less than five years old, accounting for 70% of the cases in the region of Alta Floresta (Barcellos et al. 2012; Sisenando et al. 2012). Among the major categories of hospitalizations due to diseases of the respiratory system in this age group were: pneumonia (73% of admissions) followed by asthma (14% of hospitalizations) (Mourão et al 2007). In Rio Branco, human mortality rate has been found to be 21% greater in the dry season, with evidence showing that this is mainly due to pollution from forest burning (Barcellos et al. 2012). These studies show clearly that the negative effects of forest fires act not only to degrade our biodiversity and ecosystems, but also are prejudicial to human health.

AFFINITIES WITH RESPECT TO IDEAS AND POTENTIAL TOPICS BETWEEN SUB-NETWORKS

Three main broad-scale situations have recently been identified: 1) urgent demands from the federal government which need to be tackled, 2) sub-networks that have been carrying out research that has strong similarities with respect to questions

being asked, data collection and/or analyses methods, and that thus collaboration seems to be more straightforward; and 3) areas in which sub-networks' scientific results differ in fundamental ways with respect to the policies that they would recommend and, therefore, collaboration should require a greater scientific enterprise.

National government's more urgent demands

The government's more urgent demands are for Rede CLIMA to: 1) carry out the 3rd National Green House Gas Emissions Inventory, 2) create a nation-wide system to observe and collect data about the impacts of climate change and 3) to develop the Brazilian Model of the Global Climate System.

Areas where collaboration between sub-networks is more straightforward

Collaboration with the Climate Modelling sub-network develops by means of the usage of the climate change scenarios generated. In particular, the Agriculture sub-network has been using the Climate Modelling's future climate scenarios as input in an agri-meteorological model to predict the impacts of climate change in Brazil's agriculture, and to propose a new National agri-economic planning system. In its turn, the Economy sub-network has been using the results of the agri-meteorological model as input into its economic model to predict the impact of climate change on the economy of the State of Minas Gerais. There thus exists a sequential relation between the models used in each of these three sub-networks.

The sub-networks Cities, Regional Development, Health and Natural Disasters identified common grounds, on the matter of people's perception of and vulnerability to climate change. From the methodological point of view, Cities Sub-network is developing an interactive electronic questionnaire on top of a tablet platform; meanwhile, Regional Development has been applying traditional printed questionnaires to rural families, and Health has been studying people's health in contexts of forest burning in the Amazon and of disasters such as flooding. The Natural Disasters sub-network is in the process of defining its research focus and it found clear possibilities of interacting with the other three.

The Oceans, Coastal Zones and Climate Modelling sub-networks also found common ground on which to work. The first two are involved in observational activities in different parts of the western and southern Atlantic Ocean, while the third will better the BMGCS development with the knowledge from the time-series produced by the first two.

Areas where collaboration between sub-networks will impose greater challenges

From the activities reported by the sub-networks during these first three years of existence of Rede CLIMA, conflicting points of view about some areas emerged.

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For example, the cases of Renewable Energy, Ecosystem Services, Biodiversity and Regional Development. The first argues that, due to the nearly exhausted hydroelectric potential in other regions of the country, the Amazon basin should be the new "hydroelectricity barn" or "new hydroelectric frontier" (Souto & Freitas 2011). The second presented evidence that hydroelectric dams act as 'carbon pumps' that convert CO_2 into CH_4 in short time-scales in significant quantities, particularly in the floodplains around the reservoirs (Fearnside & Pueyo, 2012). The valuation of nature emerged as a theme that can contribute to this discussion. In a shorter-term practical perspective, when the outputs of economic models are being influenced by parameters that are related to ecosystem functioning nature will become a bit more part of the solution than of the problem. This will probably make it be better understood, as well as considered more important, by decision-makers.

The areas where conflict is apparent can be thought of as light beams that illuminate themes were the exercise of interdisciplinarity is useful. Resolving these conflicts will probably require greater effort and more resources, but it is by solving them that, arguably, the more important and unexpected advances in knowledge will be obtained. Hence we have termed them constructive conflicts.

Future Prospects

Integration by means of interdisciplinary projects

As mentioned earlier, the first phase of Rede CLIMA has had the main aim of providing research infrastructure and consolidating its sub-networks. Now, in its second phase, the overarching objective is the integration of the sub-networks around transdisciplinary themes via interdisciplinary[2] projects.

Among the issues raised in the discussion, the following deserve notice: 1) the universalization of adaptation to climate change, 2) the valuation of nature in its various aspects, based on biodiversity itself (e.g. bioprospecting) and ecosystem services, 3) food security related issues, and 4) problems related to the increased frequency of extreme climate events in Brazil (Figure 4).

Finally, from combining information from all above studies, plus additional data from interviews and questionnaires, it is possible to make a comprehensive assessment of the vulnerabilities of local inhabitants (Regional Development, Health, Cities and Natural Disasters) to climate change. Thus, in this figure, connecting lines represent not only the relatedness between each sub-network and the main theme, but also between sub-networks, which interact via the main theme (Figure inspired on Moraes, in press).

Moreover, it was agreed that the following themes should be incorporated into projects of all sub-networks: economics, education regarding climate related issues, and ecosystem services.
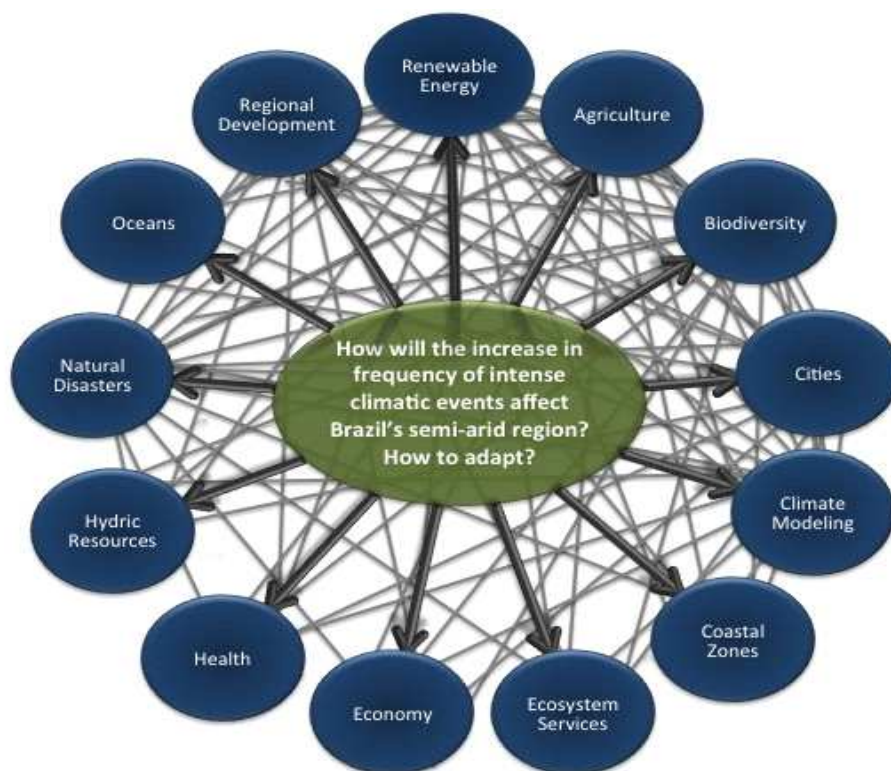
Figure 4 –Scientific integration of Rede CLIMA by means of thematic interdisciplinary projects that aim at helping society to respond to the causes and consequences of climate change. This is a schematic illustration of how all sub-networks shall work in collaboration to help solve the problems regarding the increase in frequency of strong droughts or floods in the semi-arid region, Northeastern Brazil. For example, it is possible to produce future climate scenarios (Climate Modeling) and assess the impacts of such climatic changes to the cultivars (Agriculture), and, from this, assess the impacts of such changes to the country's economy (Economy). Moreover, the changes in climate can be used to predict changes to the species composition of the ecosystems (Biodiversity), which in turn influence the goods and benefits that humans derive from healthy ecosystems on a local and national scale (Ecosystem Services, Hydric Resources, Renewable Energy).

With respect to Rede CLIMA's interaction with society, it is now consensual that there is need to create a communication strategy aiming at enlightening the population's perception of climate change. This strategy shall be aimed at issues that Brazilian society is currently facing, so that it captures the public's interest on topics that already impact their lives. For example, it was mentioned that it is necessary to better discuss Brazil's strategy to expand its energy offer, which includes a plan to dam several of the largest Amazon rivers in order to produce hydroelectricity. However, as shown above, emissions from tropical hydropower are often underestimated and can exceed those of fossil fuel for decades (Fearnside & Pueyo, 2012), so it is necessary that such issue be discussed in depth and that Rede CLI-MA produces one coordinated opinion on the matter.

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External and Internal Assessment

Due to the complexity of its constitution and goals, creating an evaluation criterion for Rede CLIMA is a challenge itself. How can a multidisciplinary network that encompasses natural and social sciences, as well as technological areas, which have the objective of influencing public policies and participating in the process of communicating with society and profiting from such experience, be evaluated with respect to its contribution to the progress of science, in particular, and society, in general? The answer to this question is yet to be discovered, but some ideas emerged from the 3rd Meeting of the Science Coordinators that are worth mentioning.

The purpose of creating an evaluation method for Rede CLIMA has three main reasons: 1) provide accountability to government and society in general, 2) identify and support (with funding and other actions) the best initiatives regarding research, dissemination of knowledge, formulation of public policy, and education, and 3) serve as the guiding force of the Network's scientific advances.

This issue requires looking a bit more into the complexity of the challenge. It is known that a great portion of research increases knowledge modestly, while radical breakthroughs are rare (Kuhn 1962). Moreover, it is known that these great breakthroughs may take time to be accepted by the scientific community and, indeed, society in general.

An example of such happening in the history of scientific knowledge, and indeed of our society, is the story of Galileo Galilei's abjuration. Galileu, with the consent of Pope Urban VIII, published a book in which he defended and strengthened the arguments presented by Nicholas Copernicus, that the Sun, not the Earth, was the centre of the known universe (Galilei1632). After reading the manuscript, however, Pope Urban VIII became dissatisfied with the implications of the thesis presented in it. As a result, he ordered a string of public humiliations and accusations that ended with, Galileo, age 70,being forced to refute his own ideas and discoveries before an inquisitive ecclesiastical court, pronouncing the following words:

> "I held, as I still hold, as most true and indisputable, the opinion of Ptolemy, that is to say, the stability of the Earth and the motion of the Sun… I affirm, therefore, on my conscience, that I do not now hold the condemned opinion and have not held it since the decision of authorities... I am here in your hands - do with me what you please… I, Galileo Galilei, have abjured as above with my own hand." (Linder, 2002)

These two examples illustrate what, according to Jung (1964), is a common psychological phenomenon in human societies, both 'primitive' and 'evolved': misoneism - fear, hatred or intolerance for the new.

It can be seen that, faced with the challenges of creating an interdisciplinary science that can help society deal with the causes and consequences of climate change,

Rede CLIMA needs to create the fertile and safe institutional atmosphere that will allow new discoveries to flourish at their own pace, while at the same time promoting the bettering of previous discoveries and knowledge.

In this context, in the 3rd Annual Meeting of the Science Coordinators of Rede CLIMA, held in São José dos Campos, 29-31 November 2012, it was decided that the Network shall develop its own evaluation method. Such method will involve: 1) A committee formed by external researchers and members of other careers, Brazilian and foreign, 2) monitoring, by means of indicators, scientific production in the form of articles, books and chapters, educational activities, the emergence of public policies that were influenced by the knowledge generated within it, and 3) a measure of people's awareness, comprehension and use of climate information. The indicators will take into account aspects such as quantity of publications and citations, papers published as a result of collaboration between sub-networks, patents, activities for the non-scientific audience, production of educational materials, establishment of new fields of research, all of which will be weighted by the number of researchers linked to each sub-network, the amount of funding each sub-network and the whole Network received, and other criteria. The creation of an evaluation process for Rede CLIMA will be a process in itself, but in a short time-scale this set of indicators will better portray the actual role that the Network will be playing in society's transformation process, and, as importantly, will guarantee that its actions will be directed by society's needs.

Within the fragmented structure of present institutions (science, policies, markets, others), the need for an institution such as Rede CLIMA is a proof that transdisciplinary problems are presented to science by society. Other current examples of such problems are poverty, habitat and land degradation, loss of biodiversity and economic instabilities, all of which have received much attention from national and international communities. Fortunately, in Brazil, such a problem-solving integrated view of knowledge is one of the main guidelines of the country's National Curriculum Parameters (NCP 1997), which establish the quality-guiding references for primary education. The teaching, in school and universities, of interdisciplinarity by focusing on thematic projects (e.g. Kleiman & Moraes 1999; Moraes 2005; Pereira et al 2010) will, in the medium - and long - run, contribute to the formation of more integrative scientists, professionals, and, as importantly, citizens. This will benefit research initiatives like Rede CLIMA, which in turn can contribute to the educational system by means of disseminating the knowledge it generates. This possibility for a stronger feedback mechanism between research and education in Brazil can help the country deal with climate change, and indeed with many other problems it faces.

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Notas

[1]Decree MCT nº 728 of 20 November 2007, Decree No. 7390 of 9 December 2010, and Decree MCT nº 262 of 2 May 2011.

[2]**Interdisciplinarity** happens when research involves "two or more academic, scientific, or artistic disciplines", while **transdisciplinarity** was defined by Jean Piaget in the following phrase: "Finally, at the stage of interdisciplinary relations, we can hope to see succession to one upper stage, which would be "transdisciplinary"; this would not only achieve interactions or reciprocities between specialized research, but its routes would be situated within a total system without stable boundaries between disciplines" (Piaget 1972, *apud* Nicolescu 2006).Thus, here, transdisciplinarity refers to the theme that is under investigation, while interdisciplinarity refers to the approach of bringing knowledge from two or more different disciplines to try to solve a transdisciplinar problem.