In a Climate of Mobilization

Researchers from various disciplines, from the natural sciences to the humanities, are joining together to advance knowledge of global change

Fabrício Marques

In the largest and most concentrated multidisciplinary effort ever undertaken in Brazil to advance knowledge of global climate change, São Paulo state scientists from multiple disciplines – from the physical and natural sciences to the humanities – are participating in FAPESP's Global Climate Change Research Program (PFPMCG). Begun in August 2008, the initiative anticipates investments of R$100 million over a period of ten years – or approximately R$ 10 million annually – for ongoing basic and applied studies on global climate change and its impact on human life. This amount is likely to increase, since R$ 40 million has already been disbursed in the first three years alone.

The balance of the first three years of the program is made up of research projects on a wide range of topics involving the natural, biological and social sciences. Several studies involve understanding the effects of human activity on changing rainfall patterns and on the increased concentration of gases in the atmosphere. The impact of fires on the sugarcane harvest and the influence of agricultural management practices on emissions of carbon dioxide from soil are also being studied. Other important subjects, such as the vulnerability of the coastal areas north of São Paulo to climate change and alternatives to introducing the so-called "green economy" are also being studied. PFPMCG has 18 research

Flooding in the cities of Navegantes and Itajaí, Santa Catarina, in November 2008: the urban population will be hardest hit by the effects of global climate change.

projects and is aiming for more than a hundred. At least two dozen projects are currently being incorporated into the program under agreements established with the Research Foundations of Rio de Janeiro (Faperj) and Pernambuco (Facepe).

One of the most ambitious goals of the program is to create a Brazilian Model of the Global Climate System, a system capable of doing sophisticated simulations of global climate phenomena. The need to develop national competency in this field is explained by the fact that today, computational tools that are still limited and do not take into account key processes of Brazilian climate are being used to forecast the effects of climate change. "In order for science to provide society with reliable information, it is essential that we have a model that is not based on those of other countries, but includes regionalized characteristics and data," says Reynaldo Victoria, the executive coordinator of the program and a professor at the Center for Nuclear Energy in Agriculture (Cena), on the University of São Paulo (USP) campus in the city of Piracicaba.

In order to use and refine this modeling program, a US Cray supercomputer was purchased for R$50 million (R$15 from FAPESP and R$35 from the Ministry of Science, Technology and Innovation), which is able to perform 224 trillion operations per second. Christened the Tupã, it was installed at the Center for Weather Forecast and Climatic Studies (CPTEC) of Brazil's National Institute for Space Research (Inpe) and launched in early 2012. "Tupã put Brazilian meteorology on a par with major world centers," says Osvaldo Moraes, CPTEC's general coordinator. "It will be used for our work on climate predictions, but will also be available to all research groups of the FAPESP program." In 2011, Tupã ranked as number 29 on the list of the 500 most powerful computers in the world.

EFFECTS ON NATURAL SYSTEMS

The projects linked to the program will use supercomputer simulations and apply them to subjects from various disciplines, studying the impact of global changes and the most efficient ways of mitigating their effects. Part of the studies approved in the first call for projects, carried out in 2009, seeks to understand the effects of climate change on natural systems. Reynaldo Victoria, for example, leads a group of researchers analyzing the role of rivers on regional carbon cycles. His project interfaces with another, coordinated by Humberto Ribeiro da Rocha, a professor at the Institute of Astronomy, Geophysics and Atmospheric Sciences (IAG) of USP, designed to quantify carbon and water cycles in the Amazon Rainforest, in the Cerrado and Atlantic Forest, and in two agro ecosystems, sugarcane and eucalyptus plantations. "In previous projects, we made local

FILIPE ARAÚJO/AE

field measurements at experimental sites in Amazonia. We now want to do them on a larger scale and include the entire watershed," says Rocha. "We are analyzing what enters, what stays or leaves carbon in Amazonia, through a variety of approaches, such as measurements of the concentrations of greenhouse gases with sensors on aircraft, in river areas, on dry land, using a combination of calibrated models assimilating field data," he said.

Paulo Artaxo, a professor at the USP Physics Institute, is now intensifying a line of research on which he has spent a considerable amount of time: the effects on regional and global climate of the aerosol particles emitted in Brazil. Aerosols can be formed naturally through forest emissions or generated by human activity, such as burning fossil fuels or deforestation, which has a strong influence on climate and on phenomena such as cloud formation and development. The project focuses on the Amazon and Pantanal regions. "We are studying the physical and chemical properties of particles and their effects on atmospheric radiation balance, the change in the mechanisms of cloud formation and development and their impact on the hydrologic cycle," says Artaxo. According to him, data are being collected using satellite measurements, atmospheric modeling and through monitoring stations in different locations: one near Manaus, another in Porto Velho, which is impacted by burning emissions, and a third in the Pantanal. "We are going to measure with unprecedented detail the radioactive and optical properties of aerosol particles and their effects on cloud formation and development," says the researcher.

Data collected in the South Atlantic will supply the Brazilian climate model and support the exploration of pre-salt.

THE HUMAN DIMENSION

The call to researchers to study the human dimensions of climate change yielded excellent results. Three of the intended projects fit this profile. One of them, presented by Daniel Hogan

The Alpha Crucis oceanographic vessel, purchased with support from FAPESP: impetus for research on the relationship between the ocean and climate.

PHOTO NEIL RABINOWITZ/WWW.NEILRABINOWITZ.COM

(1942-2010), a pioneer in the study of sociodemographic and environmental dynamics at the State University of Campinas (Unicamp) and in Brazil, and subsequently led by Lúcia da Costa Ferreira, an ecologist and sociologist of the Center for Environmental Studies and Research at Unicamp, is facing one of the more troubling dilemmas posed by climate change in Brazil and in the world. Since coastal areas will be the first and hardest hit by extreme weather events, as was the case of Hurricane Catarina, which hit the coast of Santa Catarina in 2004, Hogan decided to focus on medium-sized coastal cities of São Paulo, "because they are less prepared than large cities to deal with the problem," he told *Pesquisa FAPESP* magazine in May 2009. According to Costa Ferreira, after a number of years of research, a question arises. "If surveys indicate the widespread perception that the influence of human activity on climate change is a fact; that the public is aware that coastal cities are vulnerable to extreme events and environmental disasters, in particular well-known risk areas; if there is a minimum institutional/political structure to address these challenges, then why do the social choices, whether made individually or collectively, always depend on human activities sustained by oil and gas, or occupying areas at risk, especially in protected areas of biodiversity? And why is there still so much hope placed on regional development plans based on high carbon emissions, in addition to other greenhouse gases?"

According to Costa Ferreira, ever since the project began it was assumed that these answers would only be found through categories related to problems of scale – time and space – and to multiple levels of human organization in decision-making processes of the area. So there was a large investment in acquiring and processing high and medium resolution images and terrain surveys in the early years of the project. "We already have data on biomass, demographic and forest transition, on the minimum institutional structure already present in the region, in addition to surveying and characterizing the actors and the local, regional and national decision-making arenas."

Professor Ricardo Abramovay, of the School of Economics, Business Administration and Accounting (FEA) at USP, is also examining the human dimension by coordinating a project that attempts to survey the socioeconomic impact of climate change, whose additional goal is to help formulate consistent public policies. The initiative has several fronts. One of them is the search for tools to help improve the capacity to predict the social and economic effects of climate change. A second focus is analyzing the private sector's willingness to respond to climate change. "Many companies have expressed their intention to reduce carbon emissions in their production processes. We want to know if these intentions are real and what their specific plans are," says Abramovay. Another front is analyzing the negotiation processes leading to the formation of carbon credit markets, which today are unstable. "We are also examining critical issues, such as sustainable consumption. Our intention is to map out how the production and consumption model will be affected by climate change."

A project led by Inpe researcher Gilberto Câmara aims to identify the institutional actors linked to Amazonian deforestation and study their behavior, to build scenarios with more efficient public policy impacts. "We call on institutional actors, the organized groups of society that have influence on the occupation and use of land in Amazonia. These actors include groups such as large planters of soybeans and other commodities, livestock breeders, small farmers, predatory loggers, loggers that follow management rules, wood industry workers, environmentalists, scientists and settlers." says Câmara. "Each seeks to influence the federal, state and municipal governments for its own benefit, adopting policies in its interest." The assumption is that all are represented in the political struggle. Therefore, drafting laws to define land use in Amazonia and enforcing them depends on the relative strength of each group. The change in the Forestry Code in 1994, which, in a victory for environmentalists, increased the protected area on private properties in Amazonia from 50% to 80%, was caused by a rate of deforestation which that year had reached 29,000 square kilometers. But the ruralists, who were politically organized, prevented the law from being applied," says Câmara. According to him, the annual variation in deforestation rates is not well explained by statistical models, which attempt to correlate the price of goods with deforested areas. "We are looking for a socio-anthropological understanding of the institutional actors in Amazonia and to develop models using that knowledge to build realistic scenarios."

IMPACT ON AGRICULTURE AND FAUNA

Some projects follow a more applied direction, seeking to understand how biological systems in cultivated areas, such as sugarcane, soybeans and eucalyptus, disrupt carbon dioxide emission patterns. Sui Mui Tsai, a Cena-USP researcher, manages a project that seeks to monitor the diversity and functional activities of microorganisms impacted by deforestation and land use changes on soybean and sugarcane crops. The impact on the atmosphere of the Southeast region from the release of particulate material – very fine particles of suspended solids and liquids in the air – is being investigat-

ed by project researcher Arnaldo Alves Cardoso, a professor at the Araraquara Chemistry Institute of São Paulo State University (Unesp). "Our region is very impacted by cane burning, but there are still no studies that map the release of particulate matter in the atmosphere coming from different sources, such as cities, industries and other stages of the agro-industrial process, and what the potential consequences for the environment are," says Cardoso.

Investments in people and infrastructure in the 1990s trained leaders in the study of climate change.

The group headed by Professor Newton La Scala Junior of the School of Agrarian and Veterinary Sciences of UNESP at Jaboticabal is analyzing the impact of agricultural management practices on CO_2 emissions from soil in sugarcane production in interior areas of São Paulo. "There are distinctive aspects to CO_2 emissions from soil, especially in agricultural systems. This emission varies in time and space, and is affected by management, especially by soil preparation. The goal is to map the role of different management practices on carbon dioxide emission from soil," says La Scala. The project is part of a series that La Scala's group has conducted over the last ten years. Soils used for farming in the period in which they were devoid of vegetation are analyzed. In this stage, soil becomes a CO_2 transmitter because there is no vegetation present and photosynthesis does not occur. "The goal is to advance our understanding of greenhouse gas emissions from soil used in agricultural practices. Several management systems interfere with carbon loss, and we are attempting to more thoroughly classify the emissions," said La Scala.

To what extent is wildlife able to adjust to temperature and rainfall patterns altered by climate change? Professor Carlos Arturo Navas of the USP Biosciences Institute is coordinating a project that seeks to identify this limit, particularly from the perspective of extreme weather events. Navas sometimes investigates the plasticity of fauna physiology, that is, their ability to adjust and adapt to environmental gradients -- to understand, for example, how a typical population at the base of a mountain can lead to populations in areas of higher altitude. Last year, Navas completed a thematic project on this subject. "About four years ago I realized that this research know-how would also be useful in relation to climate change. And I also noticed that I was not alone, since there are researchers from the United States and Europe poring over the same challenge. Animal physiology developed tools that have much to contribute to conservation and climate change research," said Navas. "Our goal is to study animal physiology in the context of climate extremes, temperature for example, to understand and even anticipate how animal populations would respond to climate change."

Tupã, the supercomputer: simulations to store the Brazilian climate model and more accurate weather forecasts.

CRITICAL MASS FOR CLIMATE RESEARCH

Creating PFPMCG was made possible by the critical mass of climate research developed in Brazil over the past decades – and FAPESP played an important role in this effort. In the 1990s, the Foundation's support enabled the training of human resources and the creation of an advanced research infrastructure, which helped to create national leadership in the study of global climate change at a time when the subject was gaining importance and momentum. Carlos Nobre, an Inpe climatologist and member of PFPMCG's executive coordination, cites two examples of that contribution. The first investment was in 1996, in Inpe's Meteorological Instrumentation Laboratory (LIM) in the city of Cachoeira Paulista, which became a reference for researchers in environmental sciences and meteorology in Brazil. The second investment, in 1999, was the creation of a data and information system for the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA), one of the world's largest scientific experiments in the environmental area: a total of 156 research projects, developed by 281 national and foreign institutions. "It was the first time it was possible to gather data from a multidisciplinary experiment. I have no doubt that the program would not have been as successful without this system," says Carlos Nobre, who

Homes hit by a landslide in Teresopolis (Rio de Janeiro state) in January 2011: researchers investigate the vulnerability of cities to propose public policies.

was the first executive coordinator of PFPMCG and is currently the Secretary of Research and Development Policies and Programs for the Ministry of Science, Technology and Innovation (MCTI). "Its success was so great that it inspired databases for other programs, such as FAPESP's Biota and PFPMCG," he said. FAPESP, says Noble, was also a major source of funding for LBA, by sponsoring research projects for São Paulo scientists linked to the program, which is managed by the Ministry and coordinated by Inpe and the National Institute for Amazonian Research (Inpa). It has partnerships with the US National Aeronautics and Space Administration (NASA) and many other institutions in the United States and Europe.

Since 2000, research on climate change in Brazil has increased and become more in-depth, which led to a set of original contributions and significant international exposure. Several São Paulo groups have stood out in this effort, with support from FAPESP. Progress was made, for example, in determining the role of fire as a factor in disrupting the balance between ecosystems and the atmosphere, in projects led by names such as Paul Artaxo, USP, Alberto Setzer and Karla Longo, Inpe researchers. "There have been enormous developments in the field," says Carlos Nobre. Modeling how vegetation and climate are integrated has also advanced. Under the leadership of researchers such as Carlos Nobre and Gilvan Sampaio, Inpe, and Humberto Ribeiro da Rocha, IAG-USP, it demonstrates the risks posed by climate change to maintaining Brazil's major biomes such as Amazonia and the Cerrado. Understanding the environmental impacts on biogeochemical cycles of sugarcane plantations, especially on aquatic systems, under the

PHOTO 1. EDUARDO CESAR **2.** FABIO MOTTA/AE

Drought in the Rio Negro region of the city of Iranduba (Amazonas state), near Manaus, in October 2010: extreme weather events become more frequent.

leadership of Luiz Martinelli, Cena-USP, and the detailed balance of carbon emissions through the use of biofuels, especially ethanol, under the leadership of Isaias Macedo of Unicamp were also original contributions. In oceanography, research led by Paulo Nobre, of Inpe, and Edmo Campos, of the USP Oceanographic Institute, has advanced the understanding of how ocean currents circulate in the South Atlantic, with emphasis on the interaction between the Brazil and Malvinas (Falklands) Currents.

FAPESP and USP funded the purchase of a new oceanographic vessel for São Paulo state researchers, which has also been recently added to the program. Christened the Alpha Crucis, the vessel will be a seagoing research platform, and will emphasize oceanographic, marine biodiversity and, of course, climate change studies. "Use of the ship on several research projects will enable us to explore the role of the South Atlantic on Brazilian and global climate," says Reynaldo Victoria. Up until recently the Alpha Crucis belonged to the University of Hawaii, but was completely rebuilt at a shipyard in Seattle after its acquisition. It can carry 40 people aboard, 25 researchers and a crew of 15. A thematic PFPMCG-linked project, coordinated by Tércio Ambrizzi, IAG-USP, will even use the ship this year. The objective is to analyze the impact of the Atlantic on the climate of South America in the twentieth and twenty-first centuries.

GLOBAL DEBATE

Brazil's consistent scientific output has guaranteed it a prominent role in the global scientific debate on climate change. At the Planet Under Pressure conference held at the end of March in London in preparation for Rio+20, a memorandum of understanding was signed for collaborative research on global climate change by the research funding agencies of the signatory countries known as the Belmont Forum. One of the goals of the group, comprising FAPESP and other major research funding agencies for projects on climate change in the world, is trying to change the course of international collaborative research on the topic through joint calls for interdisciplina-

Drafting of environmental laws depends on the relative strength of farmers, workers, scientists and environmentalists.

RICARDO AZOURY / PULSAR IMAGENS

ry research. Launched in April, the first call for proposals has approximately €20 million in funding, of which €2.5 million will be invested by FAPESP, including €1.5 million for research projects on water security and €1 million for research on coastal vulnerability. The projects will be undertaken by Sao Paulo researchers in these areas, in partnership with scientists from at least two other of the forum's participating countries.

Coordinated by the International Group of Funding Agencies for Global Change Research (IGFA), the Belmont Forum was created in 2009 at a conference organized by the National Science Foundation (NSF), of the United States, and by the Natural Environment Research Council (NERC), of the United Kingdom, in the U.S. city of Belmont. Representatives of research funding agencies from the countries that make up the G8 (Group of Seven most developed countries plus Russia) attended the first meeting. Since the second meeting in London in 2010, the group now has representatives from agencies of emerging countries such as Brazil (represented by FAPESP), China, India and South Africa. "PFPMCG is an important milestone to incentivize interdisciplinary research in a strategic area for Brazil," says Paulo Artaxo. "National and international partnerships are being formed under the program, which encourages the internationalization of research in São Paulo. Working together with FAPESP's Biota and Bioen programs is also critical to structuring public policy and establishing strategies to mitigate climate change, to be implemented in our country. Such strategies require a solid scientific basis, and FAPESP's role is to promote them," he said. ■

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Projects of FAPESP's Global Climate Change Research Program

PROJECT	COORDINATION	INVESTMENT
Effects of emissions on current and future rainfall patterns in Southeast Brazil – No. 2008/58073-5 (2009-2013)	Arnaldo Alves Cardoso IG/Unesp	R$772.087,94
Effects of global climate change of the Brazilian fauna: a conservation physiology approach – No. 2008/57687-0 (2009-2013)	Carlos Arturo Navas Iannini IB/USP	R$1.092.786,44
Urban growth, vulnerability and adaptation: social and ecological dimensions of climate change on the coast of São Paulo – No. 2008/58159-7 (2009-2013)	Lúcia da Costa Ferreira Nepam/Unicamp	R$1.181.736,80
Land use change in Amazonia: institutional analysis and modeling at multiple temporal and spatial scales – No. 2008/58112-0 (2010-2014)	Gilberto Camara Neto Inpe/MCTI	R$1.194.720,00
Carbon tracker and water availability: controls of land use and climate changes – No. 2008/58120-3 (2009-2013)	Humberto Ribeiro da Rocha IAG/USP	R$1.884.704,99
Impact of management practices on soil CO_2 emission in sugarcane production areas, Southern Brazil – No. 2008/58187-0 (2009-2012)	Newton La Scala Junior FCAV/Unesp	R$528.986,32
Aeroclima – direct and indirect effects of aerosols on climate in Amazonia and Pantanal – No. 2008/58100-2 (2009-2013)	Paulo Eduardo Artaxo Netto IF/USP	R$2.535.758,04
The role of rivers on the regional carbon cycle – No. 2008/58089-9 (2009-2013)	Reynaldo Luiz Victoria Cena/USP	R$1.073.273,97
Socio-economic impacts of climate change in Brazil: quantitative inputs for the design of public policies. No. 2008/58107-7 (2009-2013)	Ricardo Abramovay FEA/USP	R$115.089,90
Monitoring the microbial diversity and functional activities in response to land-use changes and deforestation under soybean and sugarcane cultivations – No. 2008/58114-3 (2009-2013)	Siu Mui Tsai Cena/USP	R$1.017.172,18
Generation of alcohol production scenarios to support the formulation of public policies that could be applied to the national sugar and alcohol industry in adapting to climate change – No. 2008/58160-5 (2010-2014)	Jurandir Zullo Junior Cepagri/Unicamp	R$547.722,00
Early Warning System for Emerging Infectious Diseases in Western Amazonia: technological innovation in order to adapt to the adverse effects of global climate change on human health – No. 2008/58156-8 (2010-2014)	Manuel J. C. M. Paiva Ferreira Unifran	R$654.654,00
Assessment of impacts and vulnerability to climate change in Brazil and strategies for adaptation option – No. 2008/58161-1 (2010-2014)	José Antonio Marengo Orsini Inpe/MCTI	R$1.021.109,52
The evaluation of energy efficiency and CO_2 equivalent abatement potentials according to different technology dissemination policies: guidelines to policy-makers – No. 2008/58076-4 (2011-2013)	Gilberto De Martino Jannuzzi Cocen/Unicamp	R$40.710,00
Narrowing the uncertainties on aerosol and climate changes in São Paulo State - nuances-SPS 2008/58104-8 (2011-2015)	Maria de Fatima Andrade IAG/USP	R$1.646.883,47
The evaluation of energy efficiency and CO_2 equivalent abatement potentials according to different technology dissemination policies: guidelines to policy-makers – No. 2008/58104-8 (2011-2015)	Maria de Fátima Andrade IAG/USP	R$1.646.883,47
Brazilian Model of the Global Climate System No. 2009/50528-6 (2011-2015)	Carlos Afonso Nobre CPTEC/INPE	R$571.200,00
Miniface climate-change impact experiment to analyze the effects of elevated CO_2 and warming on photosynthesis, gene expression, biochemistry, growth, nutrient dynamics and yield of two contrasting tropical forage species – No. 2008/58075-8 (2011-2015)	Carlos A. Martinez y Huaman FFCLRP/USP	R$1.154.426,05
Impact of the Southwestern Atlantic ocean on South American climate for the 20th and 21st centuries – No. 2008/58101-9 (2011-2015)	Tercio Ambrizzi IAG/USP	R$3.034.727,23