The technopolitics of climate change: climate models, geopolitics, and governmentality

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Abstract

Based on an empirical study of climate modeling at Brazil's Instituto Nacional de Pesquisas Espaciais, the article explores how climate modeling represents a pragmatic government approach in the realm of climate change. The discussion begins with how this pragmatic approach serves the purposes of the geopolitical action of the State within the international framework of global climate knowledge production. It then shows how modeling engenders forms of interpretation of climate change phenomena and future impacts on the local scale and finds expression in governmental rationalities of a biopolitical nature. In short, the discussion is how the technoscience of climate modeling is constructed as a governmental technology and rationality (governmentality) of the State, a process I call the technopolitics of climate change.

Keywords: climate change; climate models; geopolitics; governmentality; Brazil.

Since the mid-1980s, definitions and responses to climate issues have been bound up both with a scientific basis for monitoring and forecasting the climate system as well as with a multilateral climate framework negotiated under the auspices of the United Nations (UN). Through research conducted by a growing scientific community in the climate sciences, anthropogenic climate change has been pinpointed as a global issue caused by the burning of fossil fuels and elevated emissions of greenhouse gases (GHG) into the atmosphere. In 1991, this global understanding gained expression in the first report issued by the Intergovernmental Panel on Climate Change (IPCC), which has become the body that defined the scientific parameters used in the discussions of global climate policies that are currently transpiring within the United Nations Framework Convention on Climate Change (UNFCCC).

International networks like the UNFCCC and IPCC were forged during a historical process that saw the joint construction of global climate science and climate policy (Miller, 2004). In this still unfolding process, the strategic action of nation-states has played a central role in laying the scientific foundations of climate change and negotiating multilateral political accords (Christoff, Eckersley, 2011; Harris, 2013). Geopolitical aspects of State commitment, or non-commitment, are currently palpable in the rounds of UNFCCC negotiations over proposals to assign distinct responsibilities to developed and developing nations in agreements over GHG emission reduction targets (Kartha, 2011).

In IPCC activities, geopolitics plays out in line with the organizational principle of a "balanced geographic representation," that is, the idea of including members from various countries on the panel (IPCC, 2013); geopolitics further manifests itself in the process of selecting and assessing scientific output from member countries for use in reports. While more researchers from developing nations have been incorporated into the institutional framework of the IPCC during the course of drafting these reports, this has not been accompanied by any substantial inclusion of scientific output from these countries (Vasileiadou, Heimeriks, Petersen, 2011). In IPCC reports, the overwhelming reliance on science produced in developed nations raises two questions: how do the governments of developing countries view, and value, their participation on the panel (Kandlikar, Sagar, 1997; Mahony, 2014) and what implications might this have on the correlation of forces among States within the political framework of climate change? These questions suggest that the geopolitics of climate change must be understood both within organized spaces for negotiating political accords and within spaces where global climate science is assessed and formulated (O'Lear, Dalby, 2015).

The geopolitical action of nation-states within the climate change framework entails political and scientific practices that flow globally through international networks like the UNFCCC and IPCC. Yet this global framework of practices wherein States act geopolitically is not detached from action on the local scale. For example, when the UNFCCC requires its signatories to conduct regional vulnerability studies (UNFCCC, 2006), its intent is to encourage States to take strategic action on the local scale. To produce such research, national technical apparatuses must be designed and new knowledge must be produced that will render the effects of climate change "legible" to the State (Scott, 1998) and thus susceptible to government practices on this scale (Taddei, 2013). The development of State technoscientific expertise is thus a prerequisite to geopolitical and governmental action in the realm of climate change. For social studies of climate change, understanding how these infrastructures and strategic knowledge are constructed is important to understanding how the State acts in these processes on different scales.

State production and usage of technical apparatuses and climate knowledge is what I call the technopolitics of climate change, a concept that encompasses the technical systems and knowledge that are central to the definition of government objectives and to the "action of the State"[1] within the climate change framework. I see State technopolitics as encompassing sets of processes of objectification, calculuses, codification, and strategy (Scott, 1998; Certeau, 1998; Miller, Rose, 2012). It is this pragmatic government approach that shapes the State as the central actor in the symbolic ordering of a given territory (Bourdieu, 1996). In this sense, technopolitics engenders spaces wherein government objectives are designed and where plans to implement them are legitimately conceived (Foucault, 2008b; Ferguson, Gupta, 2002). As a process of knowledge, calculus, and conceptualization of government actions, technopolitics can be understood to constitute forms of "governmentality" (Foucault, 2008b), that is, government rationalities (or mentalities) embodied as technical means directed at certain targets and government practices (Dean, 2010).

Recent studies have highlighted the growing importance of mathematical models, satellite images, and simulations by Brazilian research networks that seek to inform decision-making in the arena of climate and the environment while simultaneously seeking to modernize research infrastructure (Lahsen, 2002; Taddei, 2012, 2013; Rajão, Vurdubakis, 2013; Monteiro, 2014, 2015; Bailão, 2014). From the perspective of these processes of knowledge production, the question is whether new forms of scientific representation of climate and space constitute new government practices in contexts that differ from those in developed countries.

The present study offers a theoretical and empirical contribution to this discussion by exploring the development of computer models and simulations for forecasting climate change in Brazil. These projects have received public funding and incentives under national climate policies, justified on the basis of an express need to produce scientific knowledge to guide decision-making[2] (Brasil, 2007). One of the main Brazilian agencies involved in this process is the National Institute for Space Research (Instituto Nacional de Pesquisas Espaciais, INPE), a government agency that constructs climate models and projects climate futures. One of its current major projects is the Brazilian Earth System Model (BESM), a costly, complex tool for forecasting global climate futures that at present is only being developed by a select group of countries that participate in IPCC assessments.

In this paper, I investigate how INPE modeling constitutes a technopolitics of climate change. I describe the pragmatic approach found within this technopolitics as a way in which the Brazilian State acts within the climate change framework. I begin by discussing how the pragmatic approach serves the purpose of the State's desired geopolitical action in processes of global climate knowledge production – processes characterized by unequal conditions of production between developed and developing countries. I then show how modeling produces ways of interpreting the future impact of climate change on the local scale, thereby constituting governmental technology and rationality (governmentality) of a biopolitical nature.

These analyses are based on information collected during fieldwork at INPE, conducted from April 2013 to September 2015, including 28 in-person interviews with researchers, visits to climate modeling laboratories,[3] and participation at pertinent scientific events and work meetings.[4] Some important information employed in these analyses was gleaned by reading scientific output from INPE and other research institutions. INPE institutional records and official federal government plans on climate change were also analyzed.

In methodological terms, I consider this an interpretative study that sought to answer the proposed questions through personal experiences in the field, conversations and interviews with researchers, and the reading of written material collected in the course of the research. Furthermore, the analyses were guided by several papers published on climate modeling in the field of the Social Studies of Science and Technology, which add further information and shed light on field data.

Climate modeling at INPE as a pragmatic geopolitical approach

In Brazil, INPE plays a central role in assisting the federal government in addressing climate change issues. Some of its main duties include: coordinating work on the National Communication[5] for UNFCCC, managing satellite systems that detect deforestation in the Amazon,[6] and coordinating national climate change research networks, that is, the Brazilian Research Network on Global Climate Change, known as Rede Clima,[7] and the National Institute of Science and Technology for Climate change (INCT – Mudanças Climáticas).[8]

In 2007, INPE made the expansion of climate change modeling one of its strategic goals in order to "consolidate its position as a relevant actor on topics related to global environmental and climate change and strengthen Brazil's role in defining the global environmental agenda" (Inpe, 2007a, p.24). During my field work at the Center for Weather Forecast and Climatic Studies (Centro de Previsão do Tempo e Estudos Climáticos, or CPTEC), which is the main INPE modeling center, I endeavored to understand how the development of computer modeling could serve these ends.

The most straightforward definition of climate model that I heard in conversations with CPTEC researchers[9] was: "they are a type of computer tool applied to meteorology and climate sciences to conduct research and make predictions about atmospheric phenomena." These tools allow climatologists to simulate the global climate and conduct experiments that were formerly impossible. For example, they enable the simulation of climate futures that are based on high carbon emission rates and the subsequent investigation of what future global climate temperatures may bring.

Authors agree that these models are important because they are the main computer tools currently used by the atmospheric sciences to conduct research and make global climate forecasts (Shackley et al., 1998; Miller, 2004; Lahsen, 2005; Edwards, 2010). Models figure large in IPCC reports and decisively in the discussions surrounding anthropogenic changes to the atmosphere that underpin international political accords (Demeritt, 2001; Wynne, 2010). Modeling thus emerged as a vital organizational principle for the global epistemic community focused on climate issues (Sudenberg, 2007). Further, models have become key elements in international negotiations concerning climate policy, while they simultaneously reinforce the authority of policymakers and the epistemic hegemony of computer simulation as a way of producing global climate knowledge (Shackley, 1997; Hulme, 2013).

Right from its first report, the IPCC has derived its understanding of variations in average global temperature during the twentieth century on various simulations of global climate models. At present, the most important modeling project for the IPCC is the Coupled Model Intercomparison Project (CMIP), which compares simulations performed using the most complex global climate models available, called Earth System Models (ESMs).[10] Through a series of standardized simulation exercises using models at national climate centers, the CMIP updates the climate forecasts that ground IPCC reports (Edwards, 2010).

During my conversations with INPE modelers about the workings of the CMIP, I was told that only 11 countries worldwide took part in the project for the latest IPCC report (CMIP/AR5). They emphasized that the number of participants was so low because not all national climate centers have funds to purchase one or two supercomputers or to train the highly skilled human resources required to develop computer models as complex as ESMs, to give two examples. Since climate modeling demands steep government investments, few countries can afford to develop their own models for CMIP use. Ergo, IPCC climate updates use input from only a few climate centers worldwide.

Most climate centers that contributed to the CMIP5 were North American or European (Taylor, 2012). Specifically, the United States alone contributed 22 versions of models, representing a great capacity for climate modeling and also meaning that a larger number of its simulations were included in the CMIP5 database than from other countries (Taylor, 2012). Brazil, the only Latin American nation to take part (Taylor, 2012), was included in this edition because it recently began developing its own ESM at INPE.

The fact that few countries participate in the CMIP means that the main project for assessing the modeling knowledge that underpins IPCC reports concentrates its production at a few climate centers that are capable of developing increasingly complex models. The INPE modelers with whom I spoke emphasized that each CMIP phase demands new advances in modeling, which in their view fuels a “race” to achieve such advances among climate centers wishing to take part. In this race, whoever has more funds to invest in research infrastructure is able to produce more publications, which can then be assessed and included in the knowledge basis of IPCC Working Group 1 (WG 1), that is, the exact and natural sciences.

As mentioned earlier, Brazil first participated with its own model during the CMIP5. In conversations with modelers from the BESM team, I sought to understand the significance of Brazil’s participation. Paulo Nobre (13 jun. 2013), project modeler and coordinator, stressed that when the Brazilian State invested in the BESM, it “understood that Brazil needs to have autonomy in the development of this type of technology, that we need to build climate modeling expertise, that we have to generate a critical mass in this type of research.”

When I asked why it is important for the Brazilian State to gain this expertise, Nobre (13 jun. 2013) said:

> No other global model represents South America in detail, since the efforts of modeling groups worldwide are always concentrated on specifying the facets of climate that are of interest in their respective climate zones; therefore, if we want a suitable model for Brazil, we have to develop it ourselves.

In this conversation with the researcher, I observed that the term "autonomy" was related to the generation of a national basis of expertise in modeling, or critical mass, meant to build models without depending on foreign groups. I also noted in his comments a division between "their" interests – those of foreign groups – and "ours." From the perspective of Nobre and other INPE researchers who I interviewed, climate modeling is a kind of technoscience deemed strategic to the Brazilian State. They underscored that climate models are sensitive, not readily transferred technologies and that they should be developed as a matter of national security, since these models enable the prediction of climate futures, something that bears weight on State policy and that therefore should not depend entirely on foreign production.

Concern with Brazil's modeling expertise was a recurrent topic at the scientific events I attended, especially the National Conference on Global Climate Change (Conferência Nacional de Mudanças Climáticas Globais, or ConClima). INPE researchers at this event advocated the autonomous development of models and simulations as a precondition for advancing plans to adapt to climate change in Brazil. A desire to "devise a complete modeling and global and regional forecast system for South America," in the words of INPE researcher José Marengo, also became apparent at the event.[11] The "organizational core" of this system, according to Marengo, is the BESM, which might be able to bring Brazilian researchers together around this shared national project and provide other countries with climate change studies and futures.

The BESM was center stage at ConClima. The fact that Brazil, like the ten other countries currently building this technology, was developing its own ESM was highlighted repeatedly. Having a "latest-generation," "IPCC-class" model was cited as a source of prestige. When I interviewed the project coordinator, he said that, through the BESM, "we Brazilians have begun appearing on the international radar of climate science, showing that Brazil isn't just about soccer and coffee but innovation as well" (Nobre, 13 jun. 2013). It is thus evident that the fact that Brazil has its own ESM intimates that the country plays a larger role in "first-world climate science."[12] In pragmatic terms, building this type of technology is meant to signal a possible break with a past of complete dependence on the technoscience of developed countries. The ability to produce global models is thus seen as something that redefines Brazil's role in the geopolitical space of international climate science.

The high cost of advances in the technoscience of modeling presents a challenge when it comes to closing the gap between countries like the United States and Brazil in the development of this type of science. These differences in technoscientific ability make for distinct dynamics in the production of models and simulations. INPE modelers told me that the number of teams and personnel involved with modeling in the United States is much higher than in Brazil. One of them said that "there are very few professionals in Brazil devoted to modeling, which makes it hard for us to compete" (Nilo, 2 out. 2013). Another modeler stressed that "they are well ahead of us in historical terms, in number of teams, and in computer capabilities" (Chou, 3 out. 2014).

Consequently, both the pace and agenda of advances in modeling that are needed for a country to take part in international projects like the CMIP are dictated by centers in the United States and Europe. I observed these differences first-hand at international modeling events such as Environmental Modeling in Amazonia and the Atmospheric Modeling Seminar.

Discussions at these events explored how Brazilian modeling teams could achieve the progress required for the next CMIP phase. The Brazilian researchers with whom I spoke reported that sitting out the next CMIP would constitute a setback not in line with the "expectations nourished by the MCTI and federal government," which invested in modeling projects at INPE with the "intent of laying the foundations for scientific autonomy in climate issues."

The unequal conditions under which global climate models are produced and the aspirations for autonomy that were identified among INPE modeling teams are reflective of a process that renders more complex the painstaking historical description of the infrastructural globalism of climate sciences offered by Edwards (2010). When he analyzed the development of climate infrastructures, especially in the United States and Europe, Edwards (2010) argued that climate sciences engaged in an unprecedented drive to coordinate scientific efforts internationally in order to share information and develop broad infrastructures in global climate knowledge. These infrastructures have shaped the global character of climate and made it possible to speak today of the global governance of climate change.

The Brazilian case analyzed here exposes something not explored in any depth by Edwards: the reigning inequality in the national production and control of these infrastructures and their geopolitical dimension. As discussed elsewhere by other authors (Lahsen, 2002; O'Lear, Dalby, 2015), the process by which climate science has attained "globalism," in its effort to bridge political boundaries and establish itself as a global epistemic community, has been a nuanced one, revealing different agendas as well as conflicts of interest between epistemic groups from countries of the South and the developed North. These inequalities and possible conflicts of interest between epistemic groups in the production of global climate infrastructure represent processes that I call the "infrastructural geopolitics of climate knowledge."

This concept encompasses the geopolitical processes associated with the technoscientific capabilities of the State, capabilities that allow governments to act technopolitically within the international climate change framework by building "infrastructures"[13] for the production of climate knowledge. I believe that the case of Brazilian climate modeling exemplifies the infrastructural geopolitics of climate knowledge as administrated by scientific groups from an emerging nation that, in climate negotiations, has traditionally positioned itself in diplomatic terms as a leader of developing countries, with a sharply "sovereigntist" discourse (Viola, 2002; Viola, Franchini, 2013). Yet how would it be possible to act sovereignly in these matters if the Brazilian State continued to depend on climate futures predicted by developed countries, or if Brazil did not have its own supercomputer, global model, and research teams to produce the climate knowledge needed to substantiate these actions? These troubling questions, made apparent during my field work, indicate that a "normative convergence in geopolitics and science" is produced during Brazilian climate research (Lahsen, 2002, p.8).

During my field work, the geopolitical aspect of climate science and especially of modeling became clear when Brazil's place in the IPCC was discussed. Brazil's key scientific contributions (i.e., INPE) were presented at an event organized by the IPCC, held at INPE in 2015, where discussions explored what would be needed for the Brazilian scientific community to play a bigger part in the panel's working groups. The scientific contributions that were presented came solely from the area of climate modeling, including advances with the BESM and the production of regionalized Latin American climate scenarios. During discussions between Brazilian researchers and members of the IPCC secretariat, I noted that one of the chief concerns was how to bring more Latin American scientific output to IPCC Working Group 1. The cited challenges have to do with these countries' lack of modeling expertise, since most of this scientific output is grounded in simulations. During discussions, it was argued that both the demand for strong technical expertise in modeling and the use of criteria of excellence based on high-impact publications erect an obstacle to entrance in the WG 1, so that scientific groups from developed countries end up a majority. The presence of INPE modeling teams at the event, conveying their contributions to global climate science, provided those in attendance with evidence of these teams' intense efforts to have their output included in the WG 1 of the IPCC's Fifth Assessment Report (AR5). It became obvious at the event that inequalities in the science of global climate modeling reflect a broader state of conflicts within the IPCC, which do not at first appear to be geopolitical in nature, but which figure decisively in the makeup of the global climate change framework.

At the same time, even in negotiation spaces generally deemed to be eminently geopolitical in nature, like BRICS summits (Brazil, Russia, India, China, and South Africa), the infrastructural geopolitics of climate knowledge likewise gains expression in discussions of environmental issues. In this regard, some insight can be gained from the workshop held in Brazil prior to the BRICS summit in 2014 (see Guerra, 2014). On this occasion, Brazilian climatologist Carlos Nobre, then in his capacity as MCTI secretary, stated that "the generation of researchers to which [he] belonged trained in an environment where everything went through the United States and Europe." He stressed that "we, from developing countries, have always looked to the North in search of scientific exchange," but that now "the world is made not of one hemisphere alone, and BRICS nations have clearly shown that there are other arrangements, vital to the sustainable development of the planet as a whole" (Guerra, 7 maio 2014). The workshop ended with the drafting and approval of a document providing for cooperation between BRICS nations in the fields of oceanographic research, climate modeling, and natural disaster prevention (Rocha, 8 maio 2014). In what is a process of scientific cooperation, developing countries endeavor to form new arrangements for scientific exchange, distinct from those to which countries of the North belong. With the intention of building new political and scientific alignments, specific technoscientific knowledge is selected and serves the purpose of these goals and political arrangements for the countries of the South. In this regard, one month prior to the workshop, the BESM model was presented in China as part of an initiative to bring the forces of BRICS modeling teams together (Shimizu, 22 abr. 2014). Here again we see climate modeling appearing as a strategic science, that is, as one of the areas of scientific cooperation to which countries of the South should assign priority.

In summary, this section has argued that global climate modeling involves a type of technoscience that is central to defining the causes and impacts of global warming. It was shown that countries of the North are the biggest developers and depositories of this type of knowledge within the CMIP/IPCC. Therefore, the national production of this type of technoscience is an important pragmatic geopolitical approach for countries of the South wishing to occupy positions within the international climate change framework. In the case of Brazil, it was suggested that INPE climate modeling research projects are part of broader geopolitical negotiation processes that involve countries of the South. Pragmatically, these projects serve as ways of rearranging certain correlations of forces within global climate science and policy that historically have been administrated by developed countries. This process, which I have called the infrastructural geopolitics of climate knowledge, shows how nation-states would like to enjoy sovereignty in managing their internal and foreign affairs, grounded in their own foundation of climate knowledge production. As noted, however, the geopolitics of climate change entails other means, in addition to political negotiations over GHG emissions, commonly seen as the major source of disagreements and controversies among decision-makers. The very creation of the infrastructural means to produce climate knowledge constitutes a pragmatic geopolitical approach, as a way for the State to negotiate its international space and have a technopolitical voice in climate issues.

The technopolitical action of the State on the local scale: climate scenarios, governmentality, and biopolitics

The development of INPE climate models and simulations also involves the technopolitical action of the Brazilian State on a local scale. In the guidance of Brazil's climate policy, the National Climate Change Plan (Plano Nacional sobre Mudanças do Clima, or PNMC) states that, through the design of climate futures for Brazil, "the country will be better qualified to identify the regions and sectors that are more vulnerable with a greater degree of confidence than that afforded through the IPCC's global models" (Brasil, 2007, p.87). To reach this goal, and as a prerequisite for government action on a local scale, government officials have placed an emphasis on incentives for the regional modeling of climate change at INPE. The discourse of certain government officials signals that by conducting these simulations, "INPE is looking at Brazil through a magnifying glass,"[14] allowing the State to "see" the impacts of climate change on human life at a level of great detail.

In regard to these regional climate modeling projects, what is of interest to the present analysis is how climate modeling becomes an expression of technopolitics when it furnishes the State with a specific way of seeing and interpreting climate change. When climate models "invite" other mathematical and econometric models to work with them, they allow the State to identify certain sectors of the economy as well as vulnerable populations. Models thus produce forecasts, which are performative in nature, making climate part of totalizing representations and narratives (Taddei, 2013). These processes can be interpreted as a kind of "governmentality" of climate change which transforms life-sustaining conditions into objects of the "biopolitics" of the State (Foucault, 2008a, 2008b).

Foucault (2008a, 2008b, 2010) introduced the concepts of "governmentality" and "biopolitics" to capture a historic number of specific rationalities linked to the modern State. The term "governmentality" is a neologism that combines two aspects of government: (a) the representation and knowledge of the phenomenon to be governed; (b) the means of action toward this phenomenon (Miller, Rose, 2012, p.72). The former aspect refers to "governmental rationalities" and the latter to "technologies of government." These rationalities and technologies identify the nature of the phenomena to be governed and provide officials with goals. The term "biopower," or "biopolitics," designates forms of power wielded over subjects as members of populations whose way of life has been threatened. Foucault (2008a, 2008b) observed that maintaining the lives of populations is a prerequisite to the sovereignty of the modern State. The State can gain knowledge of endangered populations through a gamut of statistical studies, scientific predictions, and other risk measurement techniques. Based on this pragmatic approach, which objectifies vulnerable populations, the State can effectively "govern life" technopolitically.

Authors have argued that when environmental issues are translated into threats to human and other forms of life, this affords an opportunity for nation-states to demonstrate their ability to "make people live," laying out strategies that centralize knowledge and power (Agrawal, 2005; Taddei, 2013; Braun, 2014; Turhan, Zografos, Kallis, 2015). Therefore, the presence of future climate threats must be construed as an object of governmental practices. In this section, I would like to call attention to this type of pragmatic approach by analyzing the projection of climate futures for Brazil.

In 2007, INPE undertook the first project to produce climate scenarios for Brazil, which in these pages I will call the PROBIO Climate Scenarios (Inpe, 2007b).[15] Regionalized climate futures for Brazil were simulated for the first time and published in the form of maps that convey rainfall and temperature anomalies for the 2071-2100 period. This atlas of climate futures focuses on each of Brazil's five macro-regions and projects seasonal averages and anomalies for temperature and rainfall (see Figure 1).

Figure 1 reflects the fact that cartographic representations of climate are one of the main forms for conveying modeling results. Contour lines and color gradations are used to separate regions of distinct rainfall and temperatures. This representation shows the territorial divisions of South American nation-states and Brazilian macro-regions. Climate change is therefore visualized within a political space, that is, within specific regions of government, territory, and borders – geopolitical markings that are susceptible to the centralizing and authoritarian strategy of the State[16] (Certeau, 1998; Scott, 1998; Paterson, Stripple, 2007; Bourdieu, 1996).

According to Mahony (2014), the authority of climate change modeling has been legitimated at a time when the technical ability to discover what will happen to a territory in the future is of growing importance. Like other maps, climate maps represent power and are valued because they offer projections useful in planning and ordering a territory (Carey, 2012). In this sense, cartographic patterns provide frameworks of intelligibility for climate phenomena, affording the State a certain way of interpreting these phenomena (Scott, 1998). Based on these coded, interpretable spaces, new forecasts can be made, enabling the definition of specific government objectives (Taddei, 2013).

PROBIO Climate Scenarios gave birth to a series of further modeling studies, conducted by other Brazilian institutions in partnership with INPE. In the following paragraphs, I analyze one project conducted at the Federal University of Minas Gerais (Universidade Federal de Minas Gerais, or UFMG) and the Oswaldo Cruz Foundation (Fiocruz) and another conducted by the Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária, or Embrapa), both in partnership with INPE. These studies were entitled, respectively, "Climate change, migration, and health: scenarios for the Brazilian Northeast, 2000-2050" ("Mudanças climáticas, migrações e saúde: cenários para o Nordeste brasileiro 2000-2050") and "Global warming and the new geography of agricultural production in Brazil"

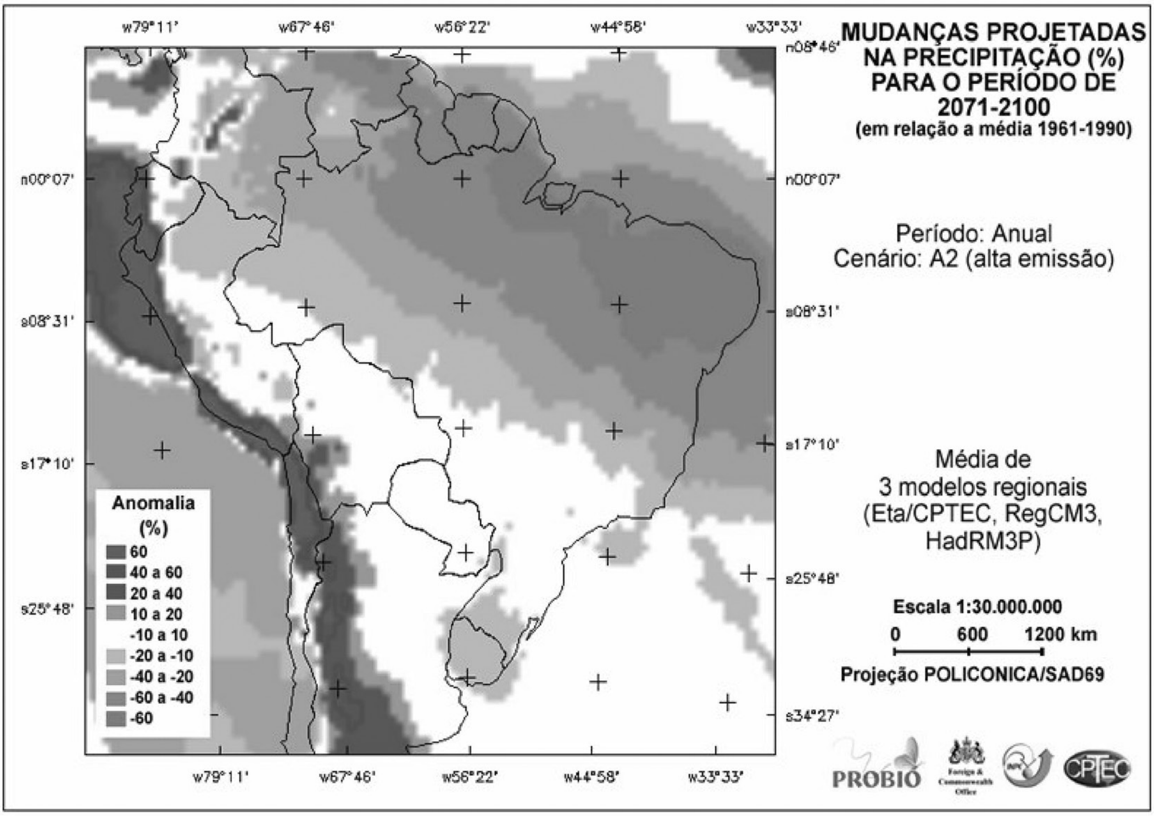

Figure 1: Regionalized climate scenarios for Brazil (INPE, 2007b)

("Aquecimento global e a nova geografia da produção agrícola no Brasil"). My analysis of these studies will be based on their publication in the form of science communication materials, which is the format in which modeling findings are often conveyed to decision-makers and the general public.[17]

The UFMG/Fiocruz study (Cedeplar/UFMG, Fiocruz, 2008) used projections of temperature and precipitation anomalies for the Northeast region, drawn up by the PROBIO Climate Scenarios project, to study impacts on economic growth and public health in this region. Data from PROBIO projections were incorporated into economic and demographic models that were then used to arrive at vulnerability indexes for health and migration, allowing the study to produce complex correlations between factors impacted by these events, that is, increased temperature, falling regional GDP, population growth, malnutrition, insufficient water resources, rising disease rates, population migration, and increased public spending. Based on these projections, in-depth inferences were then drawn about local populations considered at risk, for example:

> [Based on the models,] the population residing in the northern Northeast is expected to migrate toward the forest, given the proximity and migratory history of these regions. One of the hardships that Northeastern migrants are expected to face in the

> municipalities where they arrive is limited access to water and sewer services. This inference can be drawn based on the observation that some of the areas that may come to receive the largest contingents of migrants did not, in 2000, display the infrastructure required to supply treated water and to collect and treat waste water (Cedeplar/UFMG, Fiocruz, 2008, p.33).

In this excerpt, the association between rising temperatures and population migration in the Northeast is identified in specific trajectories in the region and measured in terms of infrastructural needs for water and sanitation. Migration, the lack of sanitation, and the possibility of increased diseases are factors that can be linked based on modeling and the projection of a warmer climate future for the region.

In terms of the migration of people in the Northeast, it is interesting to note how the movement of these populations within the territory appears as a matter of security in the study. It is informed that "climatic migrants" (*retirantes*) may leave their lands in the next fifty years, heading into cities and other states (Cedeplar/UFMG, Fiocruz, 2008, p.29). The text addresses this question as if the movement of these populations represented a danger, public health risk, or something socially and politically undesired. In this regard, climate change projections bring to the surface the old biopolitical problem of the circulation of people and things as something that must be managed by the State, especially when public health matters and the scarcity of natural resources are at play. As a way of managing these threats, biopolitical projects seek to maximize "the good circulation by diminishing the bad" circulation of people and things" (Foucault, 2008a). The fact that the study acquires a biopolitical nature is evident when the authors suggest a specific government measure for administrating the effects of climate change in the region: the State should create certain conditions so that the "climate migrant" will remain in the region, that is, it should build one million cisterns, increase government incentives for the development of new agricultural techniques, put in new sanitation and healthcare infrastructure, and maintain social programs like Bolsa Família (Cedeplar/UFMG, Fiocruz, 2008). The target of these administrative measures are the lives rendered vulnerable when climate change threatens the systems and infrastructures on which they depend for survival (Collier, Lakoff, 2014). As a pragmatic approach, climate modeling forges a space where biopolitics can play out, because it identifies infrastructures critical to sustaining life and characterizes "vulnerable populations" as objects of government open to calculated State interventions.

The study by Embrapa and the Center for Meteorological and Climate Research Applied to Agriculture, at the University of Campinas (Cepagri/Unicamp) used the scenarios modeled by PROBIO to arrive at estimates of agricultural losses for different crops in Brazil. As announced in its title (Embrapa, 2008), the study lays out and analyzes the "new geography of agricultural production in Brazil." In other words, it looks at which agricultural crops will need to be relocated to other areas in the coming century due to increased warming and also estimates losses for the agricultural sector. This calls attention to the weight placed on both the territorial factor and economic losses related to rising temperatures.

Based on PROBIO simulations for 2100, the study made statistical deductions for the years 2010, 2020, 2050, and 2070. This reduction in temporal scale indicates that the Embrapa study sought to produce temporal coordinates that bring climate change into a temporal scale of human proportions, thus more easily instilling a sense of urgency in actors from the business and political communities (Taddei, 2012, 2013). Working with spatial scales and territorial aspects, the study territorialized the impact of rising temperatures on agriculture in Brazilian states and on their respective crops.

The impact of warming within the Brazilian territory is expressed through maps accompanied by texts that address the subject directly in terms of estimated monetary losses. The figures mentioned for agricultural sector losses in 2020 and 2070 are BRL 7.4 billion and BRL 14 billion; the most heavily affected crop is soybeans, which is projected to lose roughly 40% of its output in 2070. It is warned that a number of crops are threatened. In addition to soybeans, which account for the greatest part of Brazil's agricultural trade balance, manioc – the main food staple in Northeast Brazil – is cited as a case where climate change threatens "food security."

According to Foucault (2008b, p.51), as a problem related to rising food costs, the question of food security is a biopolitical issue, since it involves the non-availability of supplies that are vital to the population. Foucault contends that the problem requires the State to devise a set of governmental techniques that address food circulation in order to regulate scarcity. The key feature of this kind of governmentality is the need to understand the circulation of foodstuffs in order to impose certain constraints while also allowing certain liberties.

In the context of climate change, however, food security becomes a profoundly technical issue that transcends the matter of availability and circulation on the market. A new set of problems presents itself, requiring the State to act pragmatically to foster advances in production technology, for example, techniques to lower emission levels and adapt crops to warmer temperatures. In this sense, the matter of food circulation as a matter of guaranteeing populations that this resource will be available is linked to the need to "guarantee the life" of agricultural crops in a warmer future. Biopolitics thus comes to target security issues that require an examination of "the systems that sustain the 'lives' of food crops," which in turn sustain human life (Cavanagh, 2014).

In exploring the future geography of Brazilian agriculture, the Embrapa modeling study states that:

> The future scenarios projected for Brazilian agriculture in this study may appear frightening and even discouraging at first glance, but it is important to stress that they will only be this intense if the country's production methods remain the same as they are today. Some losses should prove inevitable, given that Brazil has only now begun to understand its vulnerability in this sector (Embrapa, 2008, p.75).

These measures, which are suggested at the close of the study, consist of a sequence of technological packages that the State should provide for implementation by the agricultural sector. The techniques include: integrated crop and pasture production to reduce carbon emissions by the agricultural and livestock raising industry; the adoption of forestry systems that avoid burnoffs when clearing land for cropping; direct planting to avoid releasing carbon from the soil; and genetic improvement and transgenics to adapt plants to a new rainfall regime and to future temperatures.

"Narratives about warmer futures" (Bailão, 2014) and proposals for government measures to adequately ensure agricultural crop safety are drawn from the anticipation of climate futures based on mathematical modeling, through their power to forecast and to socially construct temporality (Taddei, 2013), thus endowing them with the technopolitical feature of being able to create spaces for the State's biopolitical planning.

Final considerations

The article has discussed how the science of climate modeling constructs objects of government and enables certain kinds of governmental action by the State within the climate change framework. It sought to understand what type of technoscientific knowledge is produced for the administration of the State and who develops it. Furthermore, it also explored what the centrality of this type of knowledge can mean in terms of government practices in the realm of climate change, and it therefore turned an eye to the processes and actors generally not included in analyses of climate policy.

In examining the political dimension of processes of climate knowledge production, the article identified initiatives that have been taken by scientific groups linked to the Brazilian State and that have the intention of moving beyond inequalities in the international science system and laying down conditions for the State to undertake governmental practices on a local scale. The conclusion was reached that the choices made by these groups in the field of science are imbued with important geopolitical and governmental significance, for they reflect a pragmatic approach through which certain visions for State action are stipulated. This does not, however, lead to the conclusion that relations between science and climate policy in Brazil are deterministic or utilitarian. It must be recognized that technologies like modeling, which seek to intervene in activities and processes, give rise to their own challenges, do not work perfectly, and at times fall short of the purposes they were designed to serve in the realm of rationalities. In fact, as noted by Miller and Rose (2012, p.53), "governing is not the 'realization' of a programmer's dream."

This article has endeavored to shed light on the pragmatic approach, which reflects certain idealized schemes (always uncertain and incomplete) that are meant to plan, produce, and attain certain objectives of government. I observed aspects of this approach while investigating climate modeling and learning how this field produces knowledge while it concomitantly crafts certain visions for governmental practices and State action. In doing so, a certain type of governmentality became apparent, a certain way of planning and acting in the realm of climate change, where the centrality of the State and certain kinds of knowledge are deemed indispensable.

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NOTES

[1] In employing the term "action of the State," I am thinking of the proposal by Callon and Latour (1981) that the macropolitical level of the State is constructed from a complex network of actors and material practices that perpetuate a given social and material order. This processual conception of the State – similarities and dissimilarities notwithstanding – has been discussed by a number of scholars, such as Foucault (2008b), Bourdieu (1996), Scott (1998), Certeau (1998), and Ferguson, Gupta, (2002).

[2] Brazil's National Climate Change Plan (Plano Nacional sobre Mudanças Climáticas, or PNMC) states: "When one considers the matter of climate change in Brazil, one runs into the problem of an absence of reliable scenarios for the country's possible climate future. ... To undertake these studies, there is a need to develop climate change models ... from which specific adaptation projects can be drawn up, based on an appropriate scientific foundation and enabling a more rational allocation of public resources" (Brasil, 2007, p.87).

[3] These visits took place over the course of a week, while I was at the INPE facility in Cachoeira Paulista, São Paulo, where I became familiar with routine practices at the Center for Weather Forecast and Climatic Studies (Centro de Previsão do Tempo e Estudos Climáticos, or CPTEC). During this time, I visited a number of CPTEC divisions whose work entails different parts of the process of numerical prediction of weather and climate, including the Modeling and Development Division (Divisão de Modelagem e Desenvolvimento, or DMD).

[4] These include: ConClima (the first National Conference on Global Climate Change), held at the São Paulo Research Agency (FAPESP), in São Paulo, on September 9-13, 2013; Environmental Modeling in Amazonia, held at the National Institute for Research on the Amazon (Instituto Nacional de Pesquisas da Amazônia, or INPA), in Manaus, on November 25-27, 2013; the Atmospheric Modeling Seminar, held at CPTEC/INPE, in Cachoeira Paulista, on October 6-8, 2014; and the IPCC Meeting for the Brazilian scientific community, held at INPE, in São José dos Campos, on September 14, 2015.

[5] A national communication is an UNFCCC document presenting an inventory of a country's GHG emissions and a summary of its main government initiatives for mitigating and adapting to climate change. In Brazil, the Ministry of Science, Technology, and Innovation (MCTI) is assigned to coordinate work on the document; the ministry entrusts INPE with a large part of this task. See http://www.mct.gov.br/index.php/content/view/4004/Comunicacao_Nacional.html (accessed February 27, 2015).

[6] Controlling deforestation through the Real-Time System for Detection of Deforestation (Detecção de Desmatamento em Tempo Real, or DETER) and the Amazon Deforestation Satellite Monitoring Project in the Legal Amazon (Programa de Cálculo do Desflorestamento da Amazônia por Satélite, or PRODES) are some of the main technologies for cutting Brazilian carbon emissions. The surveillance and control activities carried out under these programs have been vital to reducing deforestation, the main culprit behind Brazil's carbon emissions (Rajão, Vurdubakis, 2013; Monteiro, 2015).

[7] See http://redeclima.ccst.inpe.br/index.php/sem-categoria/instituicoes/ (accessed February 23, 2015).

[8] See http://inct.ccst.inpe.br/ (accessed March 23, 2015).

[9] While I have used the term "researchers" to identify those who I interviewed at INPE, they might better be identified as "State scientists" since their activities are not exclusively academic; many of them simultaneously hold, or have held, administrative posts in major areas within the MCTI and the Ministry of the Environment (MMA). Their research often aims to produce official scientific reports and other output in response to federal government requests. Some help draw up IPCC reports and make national climate change policy.

[10] ESMs are complex climate models that simulate interactions between the atmosphere and the oceans, land surface, and sea ice, along with other biophysical and chemical processes deemed important to understanding and predicting the global climate (Edwards, 2010). On the CMIP, see http://cmip-pcmdi.llnl.gov/cmip5/ and http://www.climatechange2013.org/ (accessed September 29, 2014).

[11] For a video of Marengo's talk, see https://www.youtube.com/watch?v=UOz1-2qyZIU (accessed January 29, 2016).

[12] This speech was featured in major Brazilian media outlets. See Carvalho (20 fev. 2013) and Escobar (20 fev. 2013).

[13] The term "infrastructure," used here in the same sense as Edwards (2010), does not refer merely to a material background that is naturalized by our actions, but rather to a variety of relations between technical objects, teams, laws, and institutions that are related to and interact with each other.

[14] Statement by Sérgio Margulis, under-secretary of the Department of Strategic Affairs of the Office of the Presidency (Secretaria de Assuntos Estratégicos da Presidência da República, or SAE/PR), in which he justified SAE investments of BRL two million in the BESM and underscored the importance of modeling to government planning (see Silveira, 25 abr. 2014).

[15] The Project for the Conservation and Sustainable Use of Brazilian Biological Diversity (Projeto de Conservação e Utilização Sustentável da Diversidade Biológica Brasileira, or PROBIO) was a research program led by the MMA in conjunction with the National Council for Scientific and Technological Development (CNPq/MCTI). The program encompassed research on topics related to sustainable development, including climate change modeling. The title of the INPE modeling study is "Global climate change and its effects on biodiversity: characterization of the current climate and definition of climate change for the Brazilian territory during the twenty-first century" ("Mudanças climáticas globais e seus efeitos sobre a biodiversidade: caracterização do clima atual e definição das alterações climáticas para o território brasileiro ao longo do século XXI") (INPE, 2007b). I use the shorthand PROBIO Climate Scenarios in these pages.

[16] Certeau (1998) and Scott (1998) explore resistance to centralizing strategies through tactics deployed by agents engaged in diffuse guerilla actions. Territories thus constitute a form of power relations subject to constant change.

[17] I did not have access to the original research reports. However, I believe it is important to analyze science communication material since this is how specific technical knowledge and findings are translated into a language more "palatable" to decision-makers, policymakers, and the general public. Science communication thus constitutes an important link in the broad chain of circulation and translation of information (maps, graphs etc.) produced by these models.

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