Chapter 11

Imagining Nations and Producing Climate-Change Knowledge in Brazil

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Anthropogenic climate change is represented in scientific narratives as a series of global phenomena studied and assessed through transnational scientific networks. While extreme events are observed locally, their causes and consequences are globally distributed in uneven and different ways. One side of this narrative pertains to a recurrent imagery of modern scientific knowledge as the production of universally valid laws and theories that transcend any given location of production or authorship (Shapin 1998). Another side of climate-change science relates to the 'global', through the use of General Circulation Models (GCMs), which simulate patterns of global atmospheric and ocean circulation using a combination of equations and data generated around the world (Edwards 2001, 2010). This 'global' imagery of climate change is a product of late twentieth-century science and follows the constitution of data-gathering networks around the planet, an international infrastructure of science and technologies to understand and visualize the global climate (Miller 2004). This climate-imaging process was related to and coeval with the production of images and imaginations of the planet understood as a 'whole' and as threatened by the perils of environmental change (Jasanoff 2001).

Fears of unpredictable and possibly catastrophic changes in climate patterns across the planet create the need for shared discourses and practices, for implementation and debate via international treaties and organizations, that transcend or even challenge national politics (Lahsen 2004; Mahony 2013). However, according to Whitehead, Jones and Jones (2007), even as debates on environmental change emphasize transnational issues, nation-states and national discourses continue to play a central role in knowing and ordering 'nature'. There is a recent literature in the social

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studies of science that tell us stories of how imaginations of the 'local' and the 'national' are still being produced by environmental-change science and how central the geopolitics of science are for understanding this production (see Mahony 2013, 2017).

To say that there are 'local' aspects being produced in climate-change knowledge, discourses and imaginations is insufficient, as 'local' can be framed and qualified in many different ways. Therefore, one question that will guide this chapter is: how can these different aspects of the 'local' in climate-change science be described? In my assessment, I draw from my own research between 2012 and 2014, an anthropological project aimed at describing the network formation of climate-change science in Brazil (Bailão 2014), and from the literature on climate-change science in the Global South (Lahsen 2004, 2009; Mahony 2014; Matthews 2015; Miguel 2017; Miguel, Escada and Monteiro 2016; Miguel and Monteiro 2015; Monteiro, Seixas and Vieira 2014; Monteiro and Rajão 2017).

This chapter discusses recent developments in Brazilian climate-change science and how national imaginations of the Brazilian territory were produced in relation to it. A second goal is to explore the difficulties and possibilities posed by the production of 'locality' in science and in its description by anthropologists, historians, geographers and sociologists (see Livingstone 2010). To this end, I present differences between two common idioms of Science and Technology Studies (STS) and their methodological treatment of 'locality' – the co-production idiom and actor-network theory (ANT) – as both of them have dealt with these issues in considerable detail.

The so-called 'co-production' idiom privileges descriptions of conflicts and associations between scientists and decision-makers, and highlights the way in which knowledge and power results from this (Jasanoff 2004a, 2004b). ANT, on the other hand, privileges thick descriptions of how facts are produced along material networks and focuses less on the disputed territorial and political imaginations of nation-states (Callon 1986; Latour 1983; Law 1986). I claim that these categories are also imagined and produced by scientists, not only in places where decision-making and knowledge production meet and clash, but also within the locations where scientists act: laboratories, fieldwork, conferences and reports. I start by shortly reviewing the problem of 'locality' in this literature.

Locality in Relation to Universality and Globalism

Actor-network theorists have focused on the specific locations where facts are produced, aiming to reconnect 'science in the making' with

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the immanent, material and local networks of relations between human and nonhuman agents – against a definition of science as abstract, transcendent and universal ideas (for a summary, see Law and Mol (2001)). Theories and objects circulate and become 'facts' after a great deal of effort and dispute, in order to maintain the stability and reproducibility of their production in other conditions. 'Universality' in science, constantly produced in the form of laws and facts, is always under threat whenever technoscientific networks spread into new settings, facing different frictions, tests and controversies. To describe 'locality', according to ANT, is to follow a narrow and unstable association of elements connecting what scientist do inside a laboratory to the connections they create with other people, things and settings.

Following the 'co-production' idiom, STS accounts describe how certain configurations of power and knowledge arise from associations of science and governmental sectors, and create policies, images, technologies and understandings concerning territories, which in turn produce 'sociotechnical imaginaries' (Jasanoff 2015). The enchantment with the globalization imagery in science and technology, especially regarding climate change, according to Myanna Lahsen (2004), obscures the geopolitics of science and the conflicts behind it. Specifically, in the Global South, in countries such as Brazil and India, there have been accounts describing how researchers and governmental agents frame global climate science as biased and as created in highly disputed international arenas, while simultaneously advocating for local knowledge on both global and local aspects of climate change (see Mahony 2014; Miguel 2017).

There is nothing particularly new in stating that nation-building and science are co-produced, and co-produce one another. In the nineteenth century, meteorology and climatology, which were dependent on costly technology and infrastructure, were actively engaged with by nation-states, which funded, promoted and coordinated expensive research centres, and networks of data collecting and measurement in their territories (see Coen 2018; Edwards 2010; Jankovic, Coen and Fleming 2006). In this chapter I argue that, in a similar manner to weather and climate sciences in the nineteenth and twentieth centuries, climate-change knowledge is deeply connected to national sociotechnical imaginaries.

Climate-Change Science from, in and about Brazil

When I started my research project in 2012, my goal was to investigate Brazilian scientists working on the attribution of the causes and effects of climate change. Inspired by readings of ANT, especially Callon (1986),

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Edwards (2010) and Latour (1983), I wanted to understand what researchers defined as 'anthropogenic climate change' and what sorts of mixed narratives of nature-society were produced by them (Strathern 1996).

My investigation took me to oceanographers, atmospheric chemists and physicists who develop or work on computer simulations of the climate system, as recently described by STS analysts (Edwards 2010; Lahsen 2005; Shackley and Wynne 1996; Shackley et al. 1998; Sundberg 2007, 2009). In Brazil, the climate-modelling community largely works at the Instituto Nacional de Pesquisas Espaciais (National Institute for Space Research) (INPE), which has its headquarters in the city of São José dos Campos, 100 km from the city of São Paulo, and public federal and state universities, such as the University of São Paulo (USP), the leading research institution in the country (see Miguel (2017) for a summary in English).[1]

This community has been working on the different atmosphere-ocean coupled computer models that have been imported from the United States and Europe since the 1970s (see Miguel, Escada and Monteiro 2016). However, one of the most important events during my investigation was the creation of the first national GCM, called the Brazilian Earth-System Model (BESM). It is the first coupled atmospheric, oceanic and land-surface global (rather than regional) model produced entirely in Brazil and the Global South (Nobre et al. 2013). Some of the scientists I interviewed were involved in the development of the Brazilian model and those who were not involved worked on adaptations of imported models.[2] Due to budgetary and human-resource restrictions in Brazil, most researchers work in different projects simultaneously: collecting chemical, physical, oceanic and meteorological data in the field; analysing and re-analysing data; and simulating climate in the future, present and past (for example, in correlation to past El Niño events).

This aspect of 'locality', the production of imagery, discourses and knowledge on the 'nation-state' and the national territory, is relevant to the practices and discourses of these scientists. It is familiar for them, just as it is for governmental agents and decision-makers – it is not an external term imposed on them and what they do by the descriptions of social scientists.

As the historian of science and geography Charles Withers asked (2007: 6) concerning the Enlightenment in the eighteenth century, if science takes place in and over space, and sometimes also about it, what does thinking geographically, about these different aspects of locality, involve? In the following sections I describe different situations, drawing from public events, scientific conferences, interviews with scientists and analysis of scientific literature, in order to illuminate the recent history

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of production of different aspects of 'locality' and climate change knowledge – knowledge from, in and about Brazil.

Climate-Change Knowledge from the Nation: Creating a Brazilian Model, without Reinventing the Wheel

In 2013, I attended two scientific events held by the Brazilian climate-change scientific community.[3] The first was a workshop to launch the BESM. The second was the first national climate-change conference, which gathered researchers to present the results from the previous five years to the broader public. At both events, there were also journalists, policy-makers in the areas of science and technology and the environment, and even a few social scientists.

According to the scientists I interviewed, the situation changed completely after the mid-2000s, as Brazilian climate-change science moved to a more mature and modern stage, with more national and international visibility. During the second term of former President Luiz Inácio Lula da Silva, between 2007 and 2010, public funding directed towards research increased considerably. This was a moment of increased public control over the deforestation of the Amazon through the direct involvement of INPE (Monteiro and Rajão 2017).[4]

The approval in 2008 of the National Policy on Climate Change and the National Plan on Climate Change made possible the creation of several institutes and research programmes focused on climate-change science in Brazil (see Bailão 2014; Miguel 2017). At both the federal level and that of the state of São Paulo, there were new developments, which included the CLIMA Network (Rede CLIMA), the National Science and Technology Institute for Climate Change (INCT-MC) and the São Paulo Research Foundation Programme for Global Climate Change Research (PFPMCG). In order to concentrate and stimulate projects, grants and infrastructure, these programmes combined existing and new research groups at universities and public research institutions, such as INPE and others dedicated to agriculture research or studies of the Amazon. Also, in 2008, the Ministries of the Environment (MMA) and Science, Technology and Innovation (MCTI) called for the creation of the Brazilian Panel of Climate Change (PBMC), a national panel that mimics the Intergovernmental Panel on Climate Change (IPCC), in which researchers gather to review the scientific literature on climate change that either concerns Brazil or that is produced in the country.[5]

Attending both events were members of the leading climate-change scientific community in São Paulo, the focus of my investigation and

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the focal point of a large part of the Brazilian climate-change scientific networks. Both the state and the city of São Paulo, because of their economic power inside Brazil, centralize important research infrastructure and funding, including supercomputers and oceanographic ships. The BESM, for example, was the culmination of thirty to forty years of creating institutions and infrastructure, and training scientists, engineers and technicians in the state of São Paulo, after a long period of importing models from Europe and the United States, and developing local components at INPE and by research groups at other institutions.[6]

Producing their own simulations from GCMs is not a simple effort for most countries, as they demand high levels of state investment for a long time in order to purchase supercomputers and train scientists and technicians (Miguel 2017: 5). This is something that both researchers and policy-makers in countries such as Brazil, with limited science funding in comparison to the Global North, struggle to achieve. Therefore, the context of the BESM is different from that which Myanna Lahsen (2004) described for the late 1990s and early 2000s, when she investigated Brazilian scientists and policy-makers. Back then, national science was still poorly funded and the country could not afford, or was not inclined to invest in, expensive computer modelling of future scenarios. At that time, Brazilian researchers perceived that their position in international debates would change if only they had the resources to generate local contributions.

Between 2008 and 2014, for example, a new oceanographic ship, *Alpha Crucis*, was purchased for the University of São Paulo to conduct research in the South Atlantic Ocean, and *Tupã*, a R$50 million (US$30 million at 2011 rates) Cray supercomputer financed by the São Paulo Research Foundation and the Ministry of Science and Technology was installed at INPE in order to run data-heavy models (Marques 2012).[7]

Therefore, rhetoric at both events was abundant with celebratory discourse on the production of 'state-of-the-art technology' in climate modelling, which in turn inserts the country as one of the major players in international debates, including the IPCC, despite the enormous differences in budgets and human resources between Brazil and the European Union, Japan, the United States and the United Kingdom. Researchers celebrated a national achievement in a global setting that was perceived as unequal. This rhetoric is common among Global South researchers when they compare themselves with, or are compared to, their colleagues in the North, or when they perceive international scientific arena as biased (Lahsen 2004; Miguel 2017).[8]

Other than just chauvinist discourse, there are important processes involved in the creation of a national model, and thereby contributing in

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creating and training a national community of scientists. For example, at the workshop, different scientists said:

> Australia, for example, decided to aggregate its research to British models, which were already developed. Brazil could have done something similar, and there would be no problem with it, but the lack of national scientific structure guided the discussion towards developing a national model in order to create [and train] a national community, a national network of modellers and specialists. (Scientist A)
>
> We wanted to create a model for society to use as a tool, incorporating knowledge produced here in other projects on Brazil, such as the [Large-Scale Biosphere-Atmosphere Experiment in Amazonia], for example; providing scientific foundations for adaptation and public policy projects; in sum, creating a new generation of Brazilian scientists. (Scientist B) [9]

Models are produced from an association of institutions and older models, a process that requires vast financial, political and institutional efforts. Models in turn also create and aggregate different things and people, forming new specialized researchers and technicians, and creating new networks of technologies, infrastructure and research groups.

It is also important to scrutinize what these discourses at public events obscure. The public imagery of the peaceful and successful creation of scientific networks and technologies hides conflicts and problems that only appear through sociological and anthropological investigation. After his ethnographic research among climate modellers at INPE, the Brazilian STS researcher Jean Carlos Hochsprung Miguel showed how research institutions have been dismantling older climatological and meteorological research groups, relocating funds and human resources in order to concentrate them into new Earth-system modelling (see Miguel 2017; Miguel, Escada and Monteiro 2016; Miguel and Monteiro 2015). If networks of institution, funds, scientists and decision-making create models, models also create networks by cutting others out (Strathern 1996).[10]

The development of a model is not only associated with a nationalist self-image or the achievement of respect among international colleagues, but also with the material and symbolic production of knowledge over the territory. Brazilian scientists generate a kind of knowledge that is comparable to, and even better than, knowledge from the Global North, at least when it concerns the specific physical processes of the Brazilian territory, such as the role of the Amazon rainforest or the South Atlantic Ocean in both global and regional climate dynamics.

There is a clear production of 'national' imagery in climate-change science, coexisting with the more common rhetoric of 'globalism', as

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climate-change actors from the Global South try to impact and change intermediate international scientific debates by creating knowledge different from the Global North (Lahsen 2004; Mahony 2014). But when discussing the co-production of climate-change knowledge and narratives regarding the nation and the territory in relation to and in contrast with the 'global', STS description stops short in the places and spaces where decision-makers and researchers meet. I want to draw attention to how scientists themselves produce narratives on the nation.

The nation is a charged category, collectively imagined by people to exist as a bordered unit spanning towards the past and into the future. According to Benedict Anderson (1991), this imagination, rather than a mental state, is materially produced through museum displays, monuments, educational systems, censuses and maps, which provide efficient ways to visualize and manage the territory. Science has intensively created means to visualize and understand nation-states, what they are comprised of and their desired (or undesired and to be resisted) futures. These are what Sheila Jasanoff (2015) has called 'sociotechnical imaginaries', the ideas, politics and the materiality of science and technology that shape and frame our collective lives. The researchers in my study deal with both global and local aspects when producing models, scenarios and analyses, and by doing so create new ways of visualizing the nation and of imagining what the future holds for its territory. When scientists discuss the importance of national research, not only is this knowledge produced from Brazil, by Brazilians rather than researchers from the Global North, but it is also knowledge intimately related to the way in which the territory is understood, one that is produced in and about Brazil.

Why spend large sums of taxpayers' money in order to produce another climate model when North America and Europe already produce them? One researcher involved at the creation of the BESM gave an answer to this question that went beyond the formation of local human resources mentioned above:

> FAPESP [the São Paulo Research Foundation] and the Ministry of Science and Technology bought the supercomputer to support and improve environmental research in Brazil. By that time, we started to think about creating a Brazilian model, but not to reinvent the wheel, but rather to stimulate the development of Brazilian research, with emphasis in local concerns and local issues. (Scientist A)

The rationale is not the reproduction of work done by researchers elsewhere, nor is it in the rhetoric about the geopolitics of science or the development of national science, but it is the production of knowledge

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that is relevant to material dimensions of locality as exhibited in local physical processes, which is the subject of the next section.

Creating Knowledge in and about the Nation: 'Tropical Rain Isn't the Same Thing as British Rain'

The Amazon is a key area for climate-change science. As the world's largest rainforest, it plays an important role in global and regional climates, and meteorological and biological processes, all of which are directly affected by deforestation and anthropogenic changes (Monteiro and Rajão 2017; Monteiro, Seixas and Vieira 2014). This argument has motivated many of the major research projects conducted in the region, such as the Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) (see Lahsen 2004). On the relevance of a Brazilian climate model to international debate and simulation of the Earth system, Brazilian researchers usually highlight the important role the Amazon rainforest plays in global and regional climate dynamics, and the local research on natural processes and human influences in the environment of the region.[11] As one researcher stated during one of the conferences:

> There are many local issues in environmental and climate change research with which Brazil could contribute to global science: issues concerning deforestation of the Amazon forest, natural fires in the Amazon and the savannah, cloud and aerosol formation in the Amazon, megacities, tropical rivers, South Atlantic Ocean dynamics, El Niño and La Niña oscillations – local issues, particularities from here. (Scientist C, conference presentation, 2013)

Being a country the size of a continent, there is a perceived need for more detailed knowledge of the physical processes in Brazil in order to improve both regional and global climate models. For example, one of my interlocutors, Scientist D, works both as a modeller in an institution in the state of São Paulo and as a field researcher in the Amazon with a research group studying rainforest atmospheric physics and chemistry. His research is conducted as part of an international collaborative project in the Amazon, funded by Brazilian, European and American institutions, aimed at understanding and modelling the relationship between the forest and the atmosphere, regional and global climate, and anthropogenic environmental change. His group also collects and generates data related to urban pollution in the Amazon, natural and anthropogenic aerosols, dust and fires in order to understand how clouds and rain are formed, as well as the ways in which natural and anthropogenic processes impact them.

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Back in the state of São Paulo, Scientist D and his colleagues also work on programming, developing parameterizations of these processes for improving GCMs, including the BESM and regional climate models, and simulating medium- and small-scale physical processes of the region. According to him, one of the major sources of uncertainty comes from the fact that physical processes in the Amazon rainforest and the South Atlantic Ocean are poorly represented in current models due to insufficient long-term research or rarefied networks of data, with few measuring stations and buoys in the region and not so robust sets of climatological and oceanographic data.

Scientist D says that the global models, equations, global datasets that Brazilian researchers work with, and the instruments responsible for producing and measuring them are developed mostly in and for the Global North, and are better suited for temperate phenomena. However, 'tropical rain isn't the same thing as British rain', as he once told me. Rain, cloud and river processes are phenomena that can hardly be universalized in any simplistic way, even as their names refer to similar things. How they are formed, how they perform and how they interact with other phenomena is different for different locations, and has a direct impact on how climate is modelled and the way that simulations perform.[12]

Problems multiply in the field and in data and modelling centres when researchers deal with the tropical world – the so-called 'frictions', following the definition used by Paul Edwards (2010), meaning the struggles encountered by scientists and engineers in transforming raw data into computational data. Many scientists I interviewed mentioned satellite sensors as problematic because, being developed in the North, they cannot properly visualize or represent tropical rain or the rainforest, with its particular physical, chemical and biological characteristics. They also tell stories of measurement instruments deployed in the field malfunctioning when soaked in tropical rain because they were built for temperate climates. Climate theories, models, equations and instruments have to overcome countless frictions, trials, struggles and resistances.[13]

During an interview, Scientist D opened on his computer a high-resolution satellite image of the Amazon forest and zoomed in on a region where he does his research. In this image, only the rainforest could be seen, divided by large serpentine rivers and covered by clouds:

> Rivers in the Amazon, for example, complicate things too much. Look how clouds gather above the forest, but not above rivers … Rivers in the Amazon are so large they produce breeze, because of the temperature difference – because the radiation absorption is different between the forest and the river,

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> just as it happens in the coast between the land and the sea. Radiation is altered, because clouds above the forest reflect solar radiation with different intensity than rivers, as rivers are dark and absorb more radiation [than trees]. In low-resolution models, grid cells do not represent rivers when plotting the Amazon. They are too small for the grid and only the forest is represented. But they are too important for the climate. And this generates a huge difference in simulated results [in relation to observation] … Models have to bridge between many different scales and you can't advance if you don't have good information from the small scale. (Scientist D, interview, December 2012)

Therefore, scientists have to develop new parameterizations and improve climate models if they want to account for the physical processes of Amazonian rivers, clouds and wind patterns. Otherwise, simulations of the future climate will be deficient with regard to the Amazon, either unreliably representing the impacts of climate change on this biome or underplaying the effects of local physical processes and environmental change in other regions.

Researchers, for example, have recently pointed to intimate connections between the Amazon rainforest and rain patterns in the densely populated areas in southeastern Brazil and the Southern Cone, more than 3,000 km away, a region with more than 130 million inhabitants, where the largest South American metropolitan areas are located, such as São Paulo, Rio de Janeiro, Buenos Aires and Montevideo (for a summary, see Nobre (2014)). According to current climate theories, simulations and observations, the disruption of Amazon physical processes due to deforestation could impact and disrupt not only rain patterns within the forest, but also those in these distant places.

It is important to state that while the 'local' is central to climate-change debates, the framing of them as 'universal' or 'global' is not a false interpretation created by Northern scientists. Brazilian scientists aim at creating universally valid science as much as their colleagues on the other side of the equator. As they told me, even though they only trust their models if they have enough reliable information from the local scale, their models function with 'the same physics' as those developed in the North, and their aim is to make the physics and data of local issues as 'global' as the representations of their 'Northern' colleagues.

Better understandings and descriptions of local phenomena can be achieved regardless of scientists' institutional origins or places of birth. Foreigners also wish to improve their models, instruments and data measurements of regions such as the Amazon as much as Brazilian researchers.[14] To frame what my interlocutors do as simply 'nationalistic' is to reduce its complexity. Transnational networks are desired

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as much as the strengthening of national research centres. Brazilian climate-change researchers circulate in international arenas; many of them are trained overseas and constantly generate knowledge by sharing and coworking with foreigners (see Lahsen 2004).

Far from being antagonists, 'universality', 'globalism' and 'locality' are interconnected and show the geographical complexity of climate-change knowledge production (Mahony 2014). That said, we might still ask how national imaginations are created in relation to global and local climate-change research. To answer this, we have to ask what they do with this knowledge and for whom they do it.

Concepts of the Nation and the Conflicts of Trying to Guide Public Policy with Them in Brazil

There has been increasing production of global and regional climate scenarios for the Brazilian territory since the mid-2000s (e.g. Ambrizzi et al. 2007; Marengo 2006, 2007; Nobre et al. 2013; PBMC 2014). The aim of the researchers is to influence public debate and policy-making on climate change, acting as 'concerned citizens', as Monteiro and Rajão (2017) have described for scientists at INPE researching deforestation.[15]

Generally, scenarios are produced according to multiple 'narrative storylines' that imagine different patterns of technological, natural and societal change for the future – often called 'optimistic' or 'pessimist', according to whether they predict higher or lower increases in greenhouse-gas concentration. Each narrative reduces the complexity of social-technical-natural interrelations and factors to a limited number of indicators in order to be deemed operational.[16] Researchers involved in the production of these scenarios run atmosphere-ocean (and sometimes atmosphere-ocean-land) coupled models that extrapolate increases in greenhouse-gas concentrations, using, for example, the IPCC's special scenarios for the twenty-first century, the so-called Special Reports on Emission Scenarios (IPCC 2001; see Hulme 2009). The resulting simulations, physical-mathematical outputs of models, are then translated into other 'stories' in the form of analyses, reports, maps, graphs and images, all of which are to be read by other scientists, policy-makers and the general public, following the international practice of producing reports summarizing analyses and results for a broader audience.

In Brazil, these scenarios project and narrate dangerous futures, with the possibility of parts of the Amazon turning into savannah or even disappearing altogether, and other future disruptions of nature and society in the rest of the country. As one modeller said, 'it is already possible

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to witness the future we are modelling', downplaying the uncertainty factor present at every simulation (see Bailão 2015; Lahsen 2005; Shackley and Wynne 1996; Taddei 2012). Nevertheless, the number of extreme climate events has increased considerably in the country, The Amazon had record droughts in 2005 and 2010, the state of Rio de Janeiro was hit by severe storms in 2011, producing the worst weather-related catastrophe in the history of the country, with over 900 deaths, and the state of São Paulo suffered with a water crisis after a long drought in 2013–15, and Hurricane Catarina hit the southern coast of Brazil in 2004.[17]

On the last day of the national conference in 2013, one of the presenters, in the presence of representatives of federal agencies, commented on how important public investment in national science had been for the co-production of knowledge and policy in the previous years, in comparison with the situation before 2008, when Brazilian climate-change science was underfunded:

> We had reached the conclusion that climate change is a major problem, but we didn't have enough detail to inform decision makers of what would happen at the local scale. Now the results we are showing are relevant to this country's sovereignty. We are producing knowledge for the national scale … With the knowledge we have, we have the responsibility to think about how we can change the future of our nation. … This is something that bothers me, how can we influence policy-making? … You cannot imagine the treasure that Brazilian climate-change science has presented us with, these concepts of Brazil, knowledge that is comparable to what is being produced in developed countries. But how can we guide policy with this knowledge? (Scientist E, conference talk, September 2013)

Engaged researchers such as Scientist E justify what their work is in terms of what the government and society can do with its results, framing their knowledge production as a powerful tool for social action. Scenarios turn these climate modellers into spokespersons of past, present and future imaginations of Brazil, turning climate change into a new way to comprehend what the territory is, what it is comprised of and what it may become. Extreme climate events, through the narratives of climate modellers, are connected to rainforest and land management, forest-fire control, and the ensuing major economic, social and political choices in a country driven by commodity exploration and agribusiness. For them, the country cannot continue devastating the Amazon, overexploiting oil resources and not investing enough in renewable energy sources when their models show the connections of global and local climate change to increases in the number and severity of disasters. How we represent the world is connected to the ways we choose to live in it (Jasanoff

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2015), and climate models play a role in national knowledge making by producing new ways of seeing the country (Mahony 2014: 125).

When these imaginaries circulate, these 'concepts of Brazil', in Scientists E's words, are tested against, and have friction with, competing and counter-imaginaries that these researchers are not capable of controlling. Celebratory rhetoric about the recent success of national climate-change research often fades away into one of outcry that their efforts are not producing the desired results in the face of the competing policies of land management dominated by the agribusiness sector.

As successful as they have been in building their networks, drawing governmental interest and funds to their research, that has not precluded important failures, such as in their participation in congressional hearings in 2013, for example, when the National Congress approved a new, less conservationist, forest protection code under pressure from the agriculture lobby (*Reuters* 2018). For these scientists, according to the global and regional models they use, as well as observations and field research in the Amazon, this new forest code seems likely to worsen climate and environmental change in Brazil (for a summary of this, see Nobre (2014)).

The executive branch of the Brazilian federal government has increased investment in oil production and thermoelectric power since the mid-2000s, with low investment in renewable energy sources, such as wind and solar power, and weakened environmental protection, with deforestation levels increasing since 2016. As this chapter was being revised, former President Michel Temer, in office after the impeachment of Dilma Rousseff in 2016, and current President Jair Bolsonaro, elected in 2018, have vastly decreased public funding in education, science, technology and environmental protection (see Watts 2017). President Bolsonaro has appointed several climate change deniers to his cabinet and reduced INPE's power in monitoring and controlling deforestation in the Amazon region, which became a diplomatic crisis in 2019 (see Sandy 2019).

Conclusion

Brazilian climate modellers have recently been producing knowledge from, in and about Brazil, revealing how 'local' aspects of sociotechnical imaginaries of climate change are as important as the more common globalizing and universalizing ones.

In recent years, they celebrated the advancement of national research and knowledge produced from Brazil, as they perceive the international

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scientific arena to be deeply biased. This happened after an intense state-led investment in the creation of different infrastructures and institutions, the training of human resources after 2008 and the development of a Brazilian climate model, the first GCM of the Global South. Beyond its use in nationalist rhetoric, researchers' defence of the need for a national GCM is based on the importance they give to research done in and about Brazil, as current models produced in the Global North do not account for specific tropical physical processes and phenomena as well as they do for 'Northern' ones. They only trust their own models to take account of knowledge concerning the specificities of the local scale, though their models work with the 'same physics' as their counterparts in the other side of the equator. Their goal is to make their 'local issues' – such as creating a national community of science, and producing reliable and sound science in and about local physical phenomena – 'global', meaning that there is an interplay between 'global', 'universal' and 'local' aspects of science rather than only a contraposition.

Scenarios generated from national research produce (and are produced for) intense imaginaries of the national territory and its future. These scientists are engaged in circulating their research to, and debating it with, broader audiences, aiming at influencing public debate concerning climate patterns and environmental change, especially with regard to the Amazon rainforest and its deforestation. But sociotechnical imaginaries of the Brazilian territory are still a matter of controversy in the face of recent political changes in Brazil, and the question remains as to whether climate-change researchers will be able to compete with opposing political forces, such as the agribusiness sector.

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Acronyms

ANT:	Actor-Network Theory
AR4:	The IPCC's Fourth Assessment Report
BESM:	Brazilian Earth-System Model
CAPES:	Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Coordination for the Improvement of Higher Education Personnel)
CNPq:	Conselho Nacional de Desenvolvimento Científico e Tecnológico (Brazilian National Council for Scientific and Technological Development)
COP15:	2009 United Nations Climate Change Conference in Copenhagen
FAPESP:	Fundação de Amparo à Pesquisa do Estado de São Paulo (São Paulo Research Foundation)
GCM:	General Circulation Model
INCT-MC:	Instituto Nacional de Ciência e Tecnologia para Mudanças Climáticas (National Science and Technology Institute for Climate Change)
INPE:	Instituto Nacional de Pesquisas Espaciais (National Institute for Space Research)
IPCC:	Intergovernmental Panel on Climate Change
LBA:	Large-Scale Biosphere-Atmosphere Experiment in Amazonia
MCTI:	Ministério da Ciência, Tecnologia e Inovação (Ministry of Science, Technology and Innovation)

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MMA: Ministério do Meio Ambiente (Ministry of the Environment)
PBMC: Painel Brasileiro de Mudanças Climáticas (Brazilian Panel of Climate Change)
PFPMCG: Programa FAPESP para Pesquisa em Mudanças Climáticas Globais (São Paulo Research Foundation Programme for Global Climate Change Research)
STS: Science and Technology Studies
USP: University of São Paulo

Notes

1. I obscure researchers' identities, gender and institutional affiliations, as the climate-change community in Brazil is small. I have interviewed researchers who develop or work on global and regional GCMs at public institutions in the state of São Paulo, attended workshops and conferences and read their research projects and articles. The limited time period for my Master's studies (2012–14) and the sheer size of Brazil did not allow me to do research in the rest of the country. See note 6 below.
2. The differences between 'imported'/'produced' or 'users'/'developers' can hide agency in knowledge production (Lahsen 2005; Sundberg 2007, 2009). Models are complex ensembles of equations, parameters and methodologies, and 'users' take decisions as what to include and exclude in them, changing the original model and developing specific parameterizations of processes that are relevant to their research. Parameterizations are equations that represent physical phenomena that are not resolved by models, being too small for the model's resolution, unknown or not well represented by current knowledge. While core equations are the same in every model, modellers chose parameterizations that seem to best fit the simulation they want to perform or the specific region they want to model. Parameterizations are one of the main sources of dispute among climate modellers and pose challenges to any attempt to create 'global' or 'universal' knowledge (see Edwards 2010; Sundberg 2007).
3. They were both organized by FAPESP, the second-largest research foundation in Brazil, an agency that funds research in the state of São Paulo. The largest was at that time the CNPq, an institution associated with the Ministry of Science and Technology that provides funding for research at the federal level. FAPESP is the oldest and largest of all the state research foundations in the country, and since São Paulo is the wealthiest state in the country, its budget in 2013 was almost the same size as those of all the other state foundations combined and almost half of the national research budget. A third of all research in Brazil is generated in São Paulo. See http://www.fapesp.br/en/about, http://cnpq.br (retrieved 17 March 2021). See also note 6 below.
4. The Brazilian government also took a more aggressive position in climate-change policy internationally. President Lula's diplomatic and scientific mission at the 2009 United Nations Climate Change Conference (COP15) in Copenhagen set a historical precedent by presenting carbon emission reduction goals and results from a Global South nation (see Barros-Platiau 2010).

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5. This is different from what Mahony (2013: 117) has described for India, where an 'Indian IPCC' was created to offer independent research from northern ones. In Brazil, geopolitics plays a lesser role and the existence of the PBMC is not to counteract foreign research, but rather to congregate state-of-the-art research produced in and about Brazil in order to influence national decision-making on climate change.
6. There is a strong rhetoric among Paulistas on their leading role in Brazilian science and technology – invoking the narrative of 'the nation's locomotive', as many people from São Paulo call their state. Quoting scientists on the role of São Paulo in Brazilian climate-change science at both events: 'Environmental science has advanced in Brazil, we are at a more mature and modern stage in national science, with national and international visibility … São Paulo's scientific community is part of this milestone. It is a well-established and recognized scientific community' (Scientist A); 'FAPESP is a watershed in Brazilian science. In 2006, before the famous [IPCC's AR4], FAPESP was already organizing itself, and its scientific director gathered a small but relevant number of climate change researchers in São Paulo … Brazil is now amongst the major players of scientific research' (Scientist B). These statements were selected to show how researchers from São Paulo easily equate their state with the whole nation, overlooking historical structural and financial inequalities inside the country. It is important to keep this in mind when reading the rest of this chapter. I thank Renzo Taddei for his remarks and comments on this issue. For his research among meteorologists in northeastern Brazil, see Taddei (2012, 2013). The IPCC's AR4 was the Fourth Assessment Report written in 2007, providing the physical science basis of climate change and based on scientific literature on the subject, including datasets, analysis and modelling. See: http://ipcc.ch/report/ar4/wg1 (retrieved 17 March 2021).
7. The supercomputer was named after the native Tupi nation's god of thunder, following a tradition starting in the nineteenth century of silencing indigenous populations, while simultaneously creating official nationalist memory from stereotypical indigenous elements and names from certain nations, especially the Tupi-Guarani (Schwarcz 2004: 132–50). Climate-change science, as with the majority of modern scientific endeavours, does not consider indigenous peoples as a source of knowledge. To mention one example during my research, during a debate on the PBMC at the national conference in 2013, someone in the audience asked about the place of traditional and local knowledge in climate-change science, which prompted the memory of a controversy surrounding the IPCC's AR4 report, which contained erroneous predictions on melting of Himalayan glaciers (see Mahony (2013) for details on how the case impacted the climate change debate in India). One of the scientists reacted to the idea of 'local knowledge: 'There is no such thing. It is either scientific knowledge or it's not … Climategate happened because non-scientific data was used to discuss the Himalayas and that gave the IPCC a huge headache. Cultural traditions don't have scientific tradition, so they were excluded from the PBMC Report, so we wouldn't get attacked.' A second debater intervened and tried to relativize, but went on to justify the first: 'We are not questioning traditional knowledge, especially given its importance regarding local changes of soil and forest and ecosystem management. The CNPq even called for a group to work on this. For this time, however, the PBMC excluded [traditional knowledge], but maybe it will change in the future. The goal was to revise scientific peer-reviewed literature.'
8. The perception of a North-South divide is not exclusive to the natural sciences. As a student in the Global South, I constantly heard from professors how Northern anthropologists treated Brazilians as suppliers of ethnographic data, while they actually produced theories – just as the IPCC is sometimes perceived as an arena where scientists from the North provided models and theories, while scientists from the South provided data (at best).

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9. The Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) is an international multidisciplinary research project conducted by Brazilian, North American and European institutions. One of its aims is to understand how the Amazon rainforest functions as a regional integrated unity (see Lahsen 2009).
10. According to Scientist F (interview, August 2013), one week prior to the national conference on climate change, 'even with the increase in science funding, there is a major lack of planning. The older prediction centre is being dismantled to relocate researchers to the new earth-system and natural disaster centres, because there are just not enough people to be specialist in climate science in Brazil. Doing science in Brazil is still very difficult'.
11. It is important to notice how the Brazilian savannah (the 'Cerrado'), covering over 20 per cent of Brazil, has been historically understudied, underprotected, undervalued and over-exploited, especially in comparison to the Amazon (see Lahsen, Bustamante and Dalla-Nora 2016).
12. There was no implication that Northern scientists did not understand this, especially given that an international consortium funds his project. International scientific networks spend a great amount of human, material and financial resources in the Amazon, as it is considered a key area to earth-system science and natural sciences in general.
13. According to Edwards, every effort in producing climate knowledge involves friction: 'Climatology requires long-term data from many locations, consistent across both space and time. This requirement implies a lengthy chain of operations, including observation, recording, collection, transmission, quality control, reconciliation, storage, cataloguing, and access. Every link in this chain represents an information interface subject to data friction' (2010: 84). What scientists in Brazil are saying is that the production of climate knowledge in the tropical rainforest or more generally in the Global South involves extra layers of friction, which I explored above.
14. There is a long history of connections between Brazilian natural and human sciences, and foreign research missions in the country, going back to the nineteenth century, when several foreign naturalists travelled around the territory and some of them occupied important positions at public institutions, and well into the twentieth century during the foundation of public universities.
15. See Monteiro and Rajão (2017) for a discussion on how the Brazilian researchers at INPE that are detecting and monitoring deforestation of the Amazon have been involved in broader controversies, and policies towards environmental change and protection during the last three decades. Monteiro and Rajão describe how scientists, in their practice, were concerned with technicalities of interest to the scientific community as well as the way in which other social actors would read their results and analyses on deforestation.
16. What counts is a matter of great controversy and dispute. 'Human dimensions' in these stories are metonyms, referring to activities related to industrial-urban-agricultural processes that can be translated into chemical concentration rates and their variations (for more on this, see Malm and Hornborg (2014)).
17. Hurricane Catarina was the first of its kind in the South Atlantic Ocean, as climatological factors do not favour the formation of tropical storm systems in this region.

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