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## Trajectories and reconversions of the Center for Weather Forecasting and Climate Studies (CPTEC): forming the meteorological science elite in Brazil

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### Introduction

Elites do not arise simply and spontaneously; on the contrary, they are usually produced. They are subjected to different modalities of approximations, adjustments, recruitment measures, and competence negotiations. When a specific field, or an institution, decides to form a differentiated group of agents in a given area, it needs to establish new parameters and measures of competences that are different from those in force at the previous moment.<sup>1</sup>

In the book *The State Nobility*, Bourdieu highlights that people holding high positions in the functional hierarchy of modern social apparatuses inherit their prestige and cultural capital mainly from academic degrees obtained at elite schools. Passage through reference centers recognized and consecrated in the system of education and official research attests to essential differentiation that enables ascension to command positions.

According to Bourdieu, circulation through large schools is an element that allows the elite to reproduce itself and its distinctive symbols and control the functioning of other fields.

As large holders of cultural capital (they hold the most prestigious academic titles), symbolic capital (often noble, they enjoy *honors* both public, such as the Legion d'Honneur, and private, such as membership in the most exclusive clubs), and social capital (either inherited directly from their family or acquired through marriage, attendance at a top lycée or grande école, tenure in a ministerial cabinet, or service on the board of directors of a top-ranked company), the chief executives from the Parisian *bourgeoisie de robe* and *noblesse de robe*, from which the new state financial oligarchy is primarily recruited, are the *personification*, as it were, of a particular state of the structure of the field of economic power.<sup>2</sup>

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<sup>1</sup> Sheila Jasanoff, ed., *States of knowledge* (New York: Routledge, 2004).

<sup>2</sup> Pierre Bourdieu, Lauretta C. Clough, and Loïc Wacquant, *The state nobility: elite schools in the field of power* (Cambridge: Polity Press, 1996), 331.

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Knowledge on the functioning of large schools regarding their mechanisms of selection and evaluation of members and distribution of titles and distinctions assists with understanding how the transmission of intellectual inheritances and the continuation of some lines of research to the detriment of others occur. In reality, the importance of certain scientific agendas and the rise of new themes is not a process that is naturalized or endowed with unquestionable rationality. The dominant groups organize alliances and reconversions of interests to arbitrarily guide the movement of the scientific field on a large scale.

According to Saint Martin,<sup>3</sup> elite reconversion processes involve the use of strategies by which dominant social groups seek to guarantee privileged socioeconomic, cultural, and symbolic conditions amidst structural economic changes. Reconversions can occur in different directions, from economic capital to school capital, from bureaucratic-political capital to economic capital, among other senses. The notion of reconversion of elites is used to translate the changes that occur in the social field of science and that can occur when groups of scientists, in general, in situations of breaking the paradigm,<sup>4</sup> reach higher levels of notoriety and scientific excellence and, consequently, expand their scientific and symbolic capital. According to Bourdieu's grammar, the attributes of notoriety and excellence are conferred according to norms and passages through rites, which are proper to the scientific field, for which the education trajectory, the titles, as well as the ascension to positions in the academic and institutional bureaucracy matter.<sup>5</sup>

The formation and strengthening of a scientific nobility, constructed and consecrated from the circulation in the same and distinctive spaces of legitimation, represent the cohesion of groups of authority that assert their prerogatives and trajectories as those that define the current excellence.

In times of intense reorganization of the scientific field, the role played by authority groups is especially important. The rise and performance of low-capital members are a necessary impulse to establish new parameters of scientific activity. In this study, we advocate that the process that led to the implementation of the Numerical Weather Prediction (NWP) in Brazil favored the reconversion not only of a meteorological science elite at the national level, but also more broadly in the field of science. A similar process occurred a few years later, when the disciplinary field reorganization was driven by the emergence of studies in the field of climate change. These two transition phases were associated with external influences received by Brazilian scientists with greater circulation in international research environments. However, a series of historical aspects and conditions contributed to the transition undergone by this disciplinary scientific field.

Within a scientific space, structuring of a new group of excellence requires a set of agreements and adjustments to reputational principles that usually present a demand for differentiation and reconversion of previously present competences.

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<sup>3</sup> Monique Saint Martin, "Reconversões e reestruturações das elites: o caso da aristocracia francesa," *Análise Social* 30, no. 134, (1995), 1023-1039; Saint Martin, "Da reprodução às recomposições das elites," *Tomo* 13 (July-Dec. 2008).

<sup>4</sup> Thomas Kuhn, *A estrutura das revoluções científicas* (São Paulo: Perspectiva, 1998).

<sup>5</sup> Pierre Bourdieu, *Para uma sociologia da ciência*. (Lisboa: Edições 70, 2004).

Several authors from different theoretical backgrounds have discussed the interference of scientists' behavior in establishing the research agenda on climate change.<sup>6</sup> Undoubtedly, the role played by scientists in their professional and political articulations has promoted a set of arrangements for discussing climate science that need to be debated under new perspectives. Currently, there is need to analyze the dominant coalitions of this scientific agenda.

The present study aims to consider this aspect in the analysis of climate science in Brazil. The action of scientific elites in meteorological studies and their strategies for controlling this agenda are also important aspects, not only for the sociology of scientific knowledge, but also for environmental research. Beyond scientific controversies, reputational battles are also fought within the scientific field, producing transformations in established academic hierarchies and redirecting research on meteorology and climate change.

In this study, we selected and analyzed the trajectory of some researchers at CPTEC, as well as in the scientific field where they worked, based on public data and some interviews. Many other researchers were left out of this research, but we believe that the inclusion of more scientists and their trajectories would have very little influence on our analysis. Finally, we would like to highlight that it was not our intention to attribute personal value or judge positively or negatively the careers of these researchers, but rather to explore from a sociological standpoint how they overlap and correlate in a social field whose rules, norms, and rites are very specific, thus favoring and projecting scientific trajectories that hold certain characteristics over others.

### **Historical context of the meteorological science elite formation**

The conditions that enabled the process of reconversion of the Brazilian meteorological and climatic science elites between the 1970s and 80s emerged a few decades earlier. In the 1940s, military research institutes at the Aeronautics Technical Center (CTA) and, in particular, the engineering courses at the Aeronautics Institute of Technology (ITA) were forged under the model of the Massachusetts Institute of Technology (MIT). Richard Smith, who had been head of the Department of Aeronautical Engineering at the MIT, was hired as the first dean of that school of engineers, between 1946-1951, when the CTA and its research institutes were also being implemented.<sup>7</sup> The Brazilian Air Force was interested in establishing engineering courses to train highly specialized and qualified personnel to conceive and conduct large projects aiming to promote the country's scientific and technological autonomy in strategic areas.

In 1961, then-President Jânio Quadros, enthusiastic about the results of the space race<sup>8</sup>, created the Organizing Group of the National Commission for Space Activities (GOCNAE) through presidential decree no. 51.133. This group was led by brigadier and professor Aldo

<sup>6</sup> Naomi Oreskes, and Erik Conway, *Merchants of doubt: how a handful of scientists obscured the truth on issues from tobacco smoke to global warming* (New York: Bloomsbury, 2010); Mikaela Sundberg, *Making Meteorology: social relations and scientific practice. Stockholm Studies in Sociology* NS 25. Stockholm: Sweden, 2005); Steven Yearley, "Sociology and Climate Change after Kyoto: What Roles for Social Science in Understanding Climate Change?" *Current Sociology* 57, no.3 (May 2009), 389–405; and Paul Edwards, *A vast machine: computer models, climate data and the politics of global warming* (Cambridge: MIT Press, 2010).

<sup>7</sup> Paulo Escada, "Origem, institucionalização e desenvolvimento das atividades espaciais brasileiras (1940-1980)," (dissertation, UNICAMP, 2005).

<sup>8</sup>Former President Jânio Quadros received and honored Soviet cosmonaut Yuri Gagarin, recognized as the first human to journey into outer space, a few months after his orbital flight of the Earth.

Vieira da Rosa, who also participated in the creation of the CTA, and installed in the municipality of São José dos Campos, state of São Paulo. The space race, disputed between the great powers, USA and USSR, boosted the scientific and technological frontiers while stimulated the new national scientific leaders organized around the military sector—some of them trained in courses at ITA—to create new scientific and technological research initiatives.

A former ITA student and military aviator, Fernando de Mendonça, during his doctorate at Stanford University, in contact with NASA directors and researchers, was invited to collaborate with the work of GOCNAE. From the United States, he sent reports describing the model, structure, and scientific areas that this new space research institution should operate. A few years later, Mendonça became one of the first and longest-serving directors of the Brazilian National Commission for Space Activities (CNAE), which years later would be named the National Institute for Space Research (INPE).

According to Harvey, et al., the participation of this researcher was essential to promote an articulation with NASA in the first space research projects in Brazil.

Fernando de Mendonça, at that time a lieutenant of the Brazilian Air Force studying in the Stanford University in California, played an important role in these contacts. After finishing his Ph.D. in radio sciences, he brought back equipment, compliments from NASA, with which a complete station for receiving signals from ionospheric satellites was assembled.<sup>9</sup>

On the occasion of the 50<sup>th</sup> anniversary of the creation of INPE, its then-director Gilberto Câmara said:

The original assignments of the CNAE were typical of a space agency like NASA. They included proposing a Brazilian space policy in collaboration with the Itamaraty [Ministry of Foreign Affairs], developing technical-scientific exchange and international cooperation, promoting the training of specialists, and coordinating space activities with the Brazilian industry.<sup>10</sup>

It makes sense to compare the CNAE with NASA. Space research in Brazil was established within an institutional framework in aeronautical research imported from the USA since the 1940s, combining civil and military scientific knowledge. According to Schwartzmann,<sup>11</sup> the action of the CTA, a military institution, solidified the exchange of Brazilian scientists with American institutions and served as a model to constitute these international scientific partnerships. In the case of the CNAE (INPE as of 1971), a civil institution created under the influence of the military personnel of the Air Force and CTA, international cooperation since its first activities was fundamental and strategic to expand research and technological development in the space area. The experience and knowledge acquired by the CNAE from international scientific cooperation were considered essential even for military research institutions, which presented restrictions on establishing partnerships with developed countries.

Another aspect emphasized by CNAE in its first years of activity was the training of specialized personnel. Under the leadership of Fernando de Mendonça, the CNAE endeavored

<sup>9</sup> Brian Harvey, Henk H. F. Smid, and Théo Pirard, *Emerging Space Powers: the New Space Programs of Asia, the Middle East, and South America* (New York, 2010.: Praxis), 313.

<sup>10</sup> Gilberto Câmara, A pesquisa espacial no Brasil: 50 anos de INPE (1961-2011). *Revista USP*, n.89, março/maio 2011, 234-243.

<sup>11</sup> Schwartzmann. *Um espaço para a ciência - a formação da comunidade científica no Brasil*, (Campinas: Unicamp, 2015)

to set up a structure on bases similar to those of other countries operating in the space area. Aiming to provide the country with qualified labor for space research, the first graduate courses in the scope of the CNAE were created in 1968, within the PORVIR project. Through this project, short-term goals for training Brazilian scientists were established to organize projects and guide new researchers. The initial proposal of PORVIR was to form PhDs and Masters by sending young researchers mainly to the USA, France, and the UK.<sup>12</sup>

It is worth noting how the criteria of quality and distinction were used on a large scale to format these courses. The selection of candidates and recruitment of students at the most reputable universities in the country was based on indicators of excellence, with a view to forming a research elite in emerging areas. According to the analysis of Moreira and Velho on the creation and importance of these courses,

...candidates for these programs were chosen based on their ranking in universities, with those at the top third of their classes being selected. Thus, the institute sought to ensure the level of excellence in academic and research work, since students were dedicated to the studies and work in the institute.<sup>13</sup>

The development of these graduate programs was important to train qualified personnel in the country, as well as to enrich the staff of INPE, given that several graduates were hired by the Institute. In addition, in the early 1970s, young qualified teachers from other countries, such as India, were invited to work in the graduate and research courses at INPE to form a base of scientists at the Institute. The Brazilian space science elite was forged under this new arrangement, in terms of institutional function. Following the American model, these graduate courses were created at research institutes, and not at universities, as had occurred in Brazil until then.

Outside the purview of the Brazilian Ministry of Education, these non-university research institutes were allowed to establish graduate education and began to have a regime for hiring and remunerating teachers outside the standards imposed by conventional academic research. Space and atmospheric sciences was the first research area of the CNAE in this period of implementation.

The first years of space activities were devoted to Space and Atmospheric Sciences at a time when the international scientific community intensified research in the areas of Geophysics, Aeronomy, and Magnetism because of the lesser solar activity in the International Years of the Quiet Sun (1964-1965). Foreign researchers were interested in studying the equatorial belt and, as a result, the CNAE was included in international research.<sup>14</sup>

In 1966, following this line of interest in studies that allowed international projection and exchange, the Remote Sensing (SERE) and Satellite Meteorology (MESA) projects were created. These projects consisted in receiving images from remote sensing and meteorological satellites, mainly those developed by the USA, and involved both technological and scientific development activities in specific areas of application: installation of image reception stations and processing, treatment, analysis and interpretation of images. New graduates from

<sup>12</sup> Guilherme Reis Pereira. *Política espacial brasileira e a trajetória do INPE (1961-2007)*. 2008. 210 p. Doctoral dissertation - Universidade Estadual de Campinas, Instituto de Geociências, Campinas, SP, <http://www.repositorio.unicamp.br/handle/REPOSIP/286896>, (last accessed 17/05/2021).

<sup>13</sup> Moreira and Velho. Pós graduação no INPE: a aliança pesquisa-desenvolvimento e ensino. *Cadernos de Pesquisa*, 39(136), 2009, 243-268.

<sup>14</sup> Pereira, op. cit., 20.

traditional fields of knowledge (physics, chemistry, geology, biology, mathematics, forestry, engineering, oceanography, etc.) were encouraged to work and specialize in the use of space technologies based on the possibilities created by graduate courses at INPE or at recognized foreign centers and universities.

The emphasis given to the development of applications in the areas of remote sensing and meteorology was also important in this initial period of space research as a means of fundraising. Meteorology, for instance, sought to meet the needs of the agricultural and transportation sectors, which made knowledge about this area strategic for the country's internal demands.

Formation of a meteorological science elite at INPE thus occurred from the activities of the MESA project, in a stimulating scientific environment, with resources, and a certain autonomy, despite the period of military governments (1964-1985) in Brazil. Some INPE researchers underwent preparation prior to enrolling in graduate programs at internationally recognized universities and research centers. When these researchers returned from their doctoral studies, they had already established important contacts and partnerships with scientific groups and leaders who would be fundamental to their participation in international research projects.

In this context, some scientists at INPE, in the 1970s, following the evolution of new techniques and knowledge on weather and climate prediction using supercomputers, started to advocate the creation of a center similar to those already operating in developed countries.

### **Meteorological science elite forged in the CPTEC/INPE creation**

Our case study was carried out at CPTEC, which was created within INPE – a scientific institution linked to the Brazilian government, with the aim of structuring a department focused on operational meteorological, weather forecasting, and climate research activities, based on the trajectory of its main exponents.

Initially, we discuss the preconditions for the structuring of CPTEC based on the trajectory of its direct predecessors and main exponents. This analysis will enable us to identify the transformations that occurred within INPE in relation to the strategies negotiated by its agents in the formation of the new elite.

When meteorological research started at INPE, in the late 1960s and early 1970s, there was only one meteorology undergraduate course in Brazil, created in the 1960s at the Federal University of Rio de Janeiro, and the National Institute of Meteorology (INMET), linked to the Federal Government, was the institution responsible for generating and disseminating weather forecasts. However, the forecasts were synoptic and, at the time, several meteorological centers in the world were making, or had already made, the transition to NWP models using supercomputers.<sup>15</sup> Although INMET is the most traditional national institution in Meteorology, established in the early 20<sup>th</sup> century,<sup>16</sup> the modern NWP techniques and methodologies were

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<sup>15</sup> Kristine C. Harper, "Research from the Boundary Layer: Civilian Leadership, Military Funding and the Development of Numerical Weather Prediction (1946-55)." *Social Studies of Science* 33, no. 5 (2003): 667-96.

<sup>16</sup> Christina Helena Barboza, "História da meteorologia no Brasil (1887-1917)," in *Congresso Brasileiro de Meteorologia* (2006), 1-6.

implemented by scientists at INPE in a process that, in our view, simultaneously produced the reconversion of the meteorological science elites and, a few years later, the climate change elites.

In the next sections, we resume the trajectories of the researchers who founded CPTEC, between 1986 and 1994, presenting their background and the differentiation process, as well as its implications in relation to the activities established at INPE previously. In the end, we expect to understand the tensions and disputes used by agents in the area to form the new national meteorological science elite.

### **Researchers and knowledge that enable CPTEC – scientific capital and reconversions**

It is interesting to observe the trajectory of some INPE researchers who joined the institution in the 1970s, in the area of meteorology, to verify the scientific capital relevant at the time of creation of CPTEC and the corresponding institutional and scientific reconversion and adaptation formulas. The analysis of this process is useful for the understanding of which were the main defining elements in the creation process of this new scientific elite organized within CPTEC.

#### ***Vadlamudi Rao – scientific and formation capital***

In 1971, researcher Vadlamudi Brahmananda Rao, a physicist with a doctorate in Meteorology from the University of Andhra in India, was hired by INPE. He had defended his doctoral dissertation in 1968, and had important participation as a researcher and adviser of master's and doctoral students at the Graduate Studies Program in Meteorology (PGMet) at INPE. He retired from INPE in 1998, but continued working at PGMet.

With over 110 articles published in leading international journals, such as *Journal of the Atmospheric Sciences*, *Tellus*, *Journal of Climate*, *Journal of Geophysical Research*, *Geophysical Research Letters*, *Monthly Weather Review*, and *Agricultural and Forest Meteorology*, Rao is an important academic reference at INPE in the field of Meteorology since the 1970s. For many years, he was in charge of the Dynamic Climatology and Tropical Meteorology disciplines, important themes in the curriculum of the graduate studies course in Meteorology.

The first master's defense under Rao's supervision dates back to 1974, with the thesis by Yoshihiro Yamazaki. In 1980, he supervised the doctoral dissertation of Rubens Leite Vianello, one of the first Brazilians to receive a doctorate in Meteorology. Between 1974 and 2011, Vadlamudi Rao supervised 26 master's theses and 19 doctoral dissertations, an extremely solid performance for a graduate studies adviser in an area of research still under consolidation in Brazil.

In 2009, Rao became the first professor to be awarded the title of Professor Emeritus, both by INPE and PGMet, in gratitude for "his exceptional contribution to teaching, research, and human resources training at the institution,"<sup>17</sup> that is, the merit established within the metric of conventional academic production. The recognition of this successful trajectory by the

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<sup>17</sup> INPE (2009). Dr. Rao recebe título de Pesquisador Emérito do INPE, [http://www.inpe.br/noticias/noticia.php?Cod\\_Noticia=1906](http://www.inpe.br/noticias/noticia.php?Cod_Noticia=1906)

institution indicates that the field of Meteorology identified in this researcher a differentiated and well-adjusted contribution to the demands of the area in its consolidation project.

An aspect stands out in Rao's résumé on the Lattes platform.<sup>18</sup> He mentions that he supervised, at PGMet/INPE, the first professionals (researchers and technologists)<sup>19</sup> who worked at CPTEC. "He supervised 17 doctors (including one of the first doctors in Brazil, in 1980) and 26 masters in Meteorology."<sup>20</sup>

The main researchers who founded CPTEC obtained their degrees abroad, and most of the first researchers and technologists who started the activities in CPTEC in the 1990s, received their master's or doctoral degrees from PGMet at INPE, many of them under the supervision of Rao. However, Prof. Rao never worked at CPTEC, despite all intellectual reference exercised as a supervisor of theses and dissertations. There is no institutional contribution to the organization of CPTEC and its subsequent guidelines in his history.<sup>21</sup>

The possession of academic recognition in the area of Meteorology, the extensive production of scientific papers, and the supervision of masters and doctors did not guarantee Rao participation and leadership in the conduct of INPE new scientific enterprise, although he defined himself as an indirect collaborator to CPTEC structuring through his alumni.

Mastery of pure scientific capital is not sufficient to determine the directions that agents will follow in the field. The new institutional trends and scientific arrangements on an international scale in the area of meteorological and climate sciences between the 1980s and 90s overwhelmed the preferences of researchers established in the field. CPTEC started operating in 1994, at the INPE unit located in the municipality of Cachoeira Paulista, state of Sao Paulo, to where INPE was planning to transfer all its facilities. Before CPTEC, PGMet began its activities at INPE headquarters in São José dos Campos, also in the state of Sao Paulo, in the late 1970s, where the Meteorology Department was located.

Why was CPTEC moved to another INPE unit, more distant from PGMet, as well as from a good part of its body of researchers? It is known that the choice of the place where CPTEC would be installed was surrounded by controversies and conflicts, more related to the way this process occurred (many employees resisted change due to family and personal motivations) than to a non-adherence to a new model of knowledge production.

However, the conflicts occurred during this transition were amplified by the discontinuity between the endogenous academic training and the recognition rules of PGMet on the one hand, and the structuring of a reference center in the field of Meteorology in more operational terms on the other hand, precisely at a time of reconversion of the elites in the field of national Meteorology, operated within INPE. It is worth remembering that the creation of CPTEC is associated with a worldwide paradigm shift in the area of Meteorology and weather

<sup>18</sup> CNPq Plataforma Lattes database on the career of Brazilian scientists used to support Research and Development policies. Vladamundi Brahmananda Rao's CV. <http://lattes.cnpq.br/7733149898220234>.

<sup>19</sup> As of the 1990s, the staff of civil servants for Research and Development (R&D) activities in the Federal Government relied on the careers of researchers and technologists, the latter focused on development activities.

<sup>20</sup> CNPq Plataforma Lattes database. Vladamundi Brahmananda Rao's CV. <http://lattes.cnpq.br/7733149898220234>.

<sup>21</sup> In part, this is explained by the fact that CPTEC was created as a center linked to the meteorological area of INPE. Subsequently, the institutional status of CPTEC rose, incorporating the entire meteorological area of INPE.



and climate forecasting, a process that began at the end of World War II in the United States and Sweden.<sup>22</sup>

The new agents of the field did not feel fully restricted in relation to their career perspectives then that were consolidated. They could reconstruct their trajectories in other ways, according to new sets of actions. From the 1980s, scientific careers began to face problems related to meeting the forms of recruitment and “realignment” of organizations, which became even more competitive and standardized. This process was linked a change in the guidelines of Brazilian scientific policies, which began to associate more strongly the distribution of resources with certain quality criteria, themes, and research productivity.

In this sense, scientists established in their professions and areas of knowledge are no longer able to lead the institutions and impose hierarchical and authoritative interests.<sup>23</sup> This new dynamic is associated, to a large extent, with a gradual transfer of a good part of research funding from scientific institutions to development agencies.<sup>24</sup>

Young researchers who graduated at INPE in the 1980s could ask themselves: Should I remain faithful to an intellectual orientation of academic research and supervision of theses and dissertations, following the line drawn by researchers such as Prof. Vadlamudi Rao, or seek other forms of positioning in the field of meteorological sciences? To continue in this perspective of analysis, from now on we will discuss another important exponent of INPE meteorological research at that time, Prof. Luiz Gylvan Meira Filho.

### ***Gylvan Meira Filho – institutional capital and autonomy in the field***

Luiz Gylvan Meira Filho majored in electronic engineering at ITA in 1964 and got a doctorate in Astro-geophysics from the University of Colorado, USA, in 1970. At that time, he had contact at the same university with Danish researcher Aksel Win-Nielsen, who would become the first director of the European Centre for Medium-range Weather Forecasts (ECMWF), which started operating in late 1979.<sup>25</sup>

Gylvan Meira Filho was one of the first INPE researchers, brought there in the early 1960s by Fernando de Mendonça, who would have identified that he presented scientific qualifications and the profile to take actions aimed at INPE establishment and academic and organizational strengthening. However, unlike Vadlamudi Rao, Meira Filho was not intellectually involved with PGMet and supervision of theses and dissertations. Because his scientific and intellectual attributes were vastly recognized, upon returning from his doctoral studies, he was requested to lead the restructuring of Meteorology at INPE, with a view to implementing the NWP model. In the early 1970s, he trained researchers in Fluid Mechanics for eight months with the aim of preparing them for their doctoral studies abroad. This initiative was coordinated with the pursuit of Indian researchers, including Rao, to work at INPE—a mission entrusted to Meira Filho by the director of INPE at the time.<sup>26</sup>

<sup>22</sup> Harper, op. cit.

<sup>23</sup> João Batista Oliveira, *Ilhas de competência – carreiras científicas no Brasil* (São Paulo: Brasiliense, 1985).

<sup>24</sup> Shozo Motoyama, *Prelúdio para uma história: ciência e tecnologia no Brasil* (São Paulo: Edusp, 2004).

<sup>25</sup> L.G. Meira Filho, interview by Paulo Escada, February 12, 2012, São Paulo.

<sup>26</sup> Ibid.

Meira Filho's trajectory evidences that the institutional dynamic was extremely effective for his good positioning in the field of Meteorology and Climate Sciences. In the following decades, he occupied relevant positions at INPE, as head and coordinator of the Meteorology area between 1975 and 1978. He also held important scientific positions, both domestically and internationally, having actively participated in the establishment of the contours of climate discussion on a global scale as early as in the 1990s. Between 1981 and 1984, before the establishment of CPTEC, Meira Filho served with the World Meteorological Organization (WMO) as Regional Director for the Americas, in Asunción, Paraguay. In addition, he was in charge of the long-range weather forecasting research program in Geneva, Switzerland. Decades later, this organization was essential to give CPTEC credibility as part of the global meteorological science elite. In 2010, the WMO certified CPTEC as a Global Producing Center for long-range weather forecasting, a recognition that allowed CPTEC to be aligned with the main world centers for seasonal climate prediction.<sup>27</sup>

In 1985, when the Brazilian Ministry of Science and Technology (MCT) was created, Renato Archer, its first minister, gave great impetus to the creation of new research centers in Brazil, including CPTEC, a modern center for climate studies at INPE.<sup>28</sup> During this period, INPE, which was previously linked to the National Council for Scientific and Technological Development (CNPq), became subordinate to the MCT. New organizational models in the area of Science and Technology were brought to Brazil at that time. With strong support from CNPq, the first Innovation Centers and Technology Parks were implemented in Brazil,<sup>29</sup> which included the importation of international research practices, especially within the North American models. This process did not occur without conflicts, as university research rules had to adapt to these new formats.<sup>30</sup>

At this time, between 1986 and 1994, Meira Filho was one of the main creators of CPTEC in its formation phase, with institutional articulation between INPE, MCT, INMET, and the Ministry of Agriculture to accomplish it. After leading the work that defined the structure of Meteorology at INPE and CPTEC—the latter conceived as a part of the meteorological area of the former—and its relations with other meteorological institutions in the country, Meira Filho was appointed the first head of CPTEC.<sup>31</sup>

It is worth noting that, after this period of institutional structuring of CPTEC, Meira Filho also served as co-president of the Working Group I (scientific aspects) of the Intergovernmental Panel on Climate Change (IPCC) from 1990 to 1995. In 1992, Meira Filho retired from INPE, and assumed another extremely relevant position in 1994, becoming the first president of the Brazilian Space Agency (AEB), where he remained until 2001. Between 1996 and 2002, he was vice-president for IPCC, accumulating this position with the presidency of AEB. He actively participated in the Kyoto Protocol negotiations between 1996 and 1997,

<sup>27</sup> Agência FAPESP, *CPTEC é reconhecido como referência em previsões climáticas pela OMM*, São Paulo, March 30, 2010. <https://namidia.fapesp.br/cptec-e-reconhecido-como-referencia-em-previsoes-climaticas-pela-omm/36021>.

<sup>28</sup> Miguel, et al. Políticas da meteorologia no Brasil: trajetórias e disputas na criação do CPTEC. *Revista Brasileira de História da Ciência*, v. 9, n. 1, 2016, 36-50.

<sup>29</sup> J.A. Medeiros, A.P. Mattedi, M.M. De Marchi, "Polos tecnológicos e núcleos de inovação: lições do caso brasileiro," *Revista de Administração* 25, no 4 (Oct.-Dec. 1990), 3-12. <http://www.spell.org.br/documentos/ver/18742/polos-tecnologicos-e-nucleos-de-inovacao—licos-do-caso-brasileiro/i/pt-br/>.

<sup>30</sup> Andrade & Silva Filho. Elites Locais de ciência e tecnologia no Brasil: o caso do Parqtec de São Carlos (SP). *Lua Nova*, São Paulo, v. 94, 2015, 295-327.

<sup>31</sup> Meira, op. cit.

especially in relation to Articles 3 (carbon emission reduction targets for industrialized countries) and 12 (Clean Development Mechanism). During the government of President Fernando Henrique Cardoso, he also served as special adviser to the Science and Technology Policy Secretary of the MCT, being responsible for important international negotiations within the principles of Clean Development Mechanism at the Rio+10 Conference. In 2002, he was awarded the Grand Cross medal of the National Order of Scientific Merit.

Since 2004, Meira Filho has been a visiting researcher at the Institute for Advanced Studies at the University of Sao Paulo (USP) and, in 2012, started working in the area of climate change at Vale Institute of Technology.

As it can be observed, in this period Meira Filho accumulated considerable and diversified scientific capital, becoming a qualified representative of a community peripheral to the established climate sciences. His international transit and work in national agencies and bodies, recognized universities, and contacts with politics and research bureaucracy made him a spokesman for a still incipient community that sought to be better established in the globalized scenario of climate sciences.

It should be highlighted that his participation in international research organizations did not occur through strictly university means established by academic exchange modalities, such as postdoctoral positions or occupation of special chairs. The importance of his institutional action in this context should also be considered. According to Bourdieu,<sup>32</sup> the formation of an autonomous scientific discipline marked by its own rules depends on a large investment of scientific capital in the formulation of guidelines and spaces for recognition, the so-called institutional capital. The presence of agents in different instances of deliberation, such as assessment commissions for research projects in development agencies, is also essential for the establishment of recognized and agreed theories and methods.

During the 1980s and 90s, the presence of Meira Filho in prominent positions in different spaces and research institutions shows that, to a certain extent, at the time of CPTEC structuring, he already had a considerable institutional scientific capital in the field of Meteorology.

It is also noteworthy that only in the following decade, after a relevant institutional trajectory, did Meira Filho join USP, a renowned university that recognized his scientific attributes, which were constituted outside a conventional academic career and without recognition symbols of the public university. He availed himself more of the institutional scientific capital with which he built significant positions in the field of climate science.

Meira Filho's résumé on the Lattes platform does not include publication of studies—although his articles and reports can be found in other databases and collections—or supervisions of graduate students, but his strong institutional links and awards stand out.

Probably, the absence of this accumulation of links and prominent positions with the WMO, MCT, and INPE, in addition to the constant circulation in universities and meteorological and climate centers in developed countries, would hinder the establishment of a weather prediction center within the rules of the modern scientific reputational system.

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<sup>32</sup> Bourdieu (2004), *op. cit.*

According to Jeorges & Shinn, transversalist science operates in the exchange of experiences between universities, research centers, intergovernmental arenas, and companies.<sup>33</sup> Since the 1970s, strategies for assessing scientific research in central countries have considered the interaction flows between these differentiated arenas.

The fact that Meira Filho circulated in the WMO, and later in the IPCC, enabled him—along with a few other INPE scientists with very similar scientific attributes and capital—to provide CPTEC with international expertise attuned to the parameters of the transversal spheres, beyond university research excellence measured by supervision of theses and dissertations, publication in specialized journals, and conventional internationalization practices (post-doctorates or visiting professor positions).

Meira Filho's trajectory expands, in INPE and in Brazilian climate science, a scientific practice that is not only internationalized, but also transversal, and marked by interconnection between institutions of variable hierarchies and designs. Intergovernmental panels and research organizations work through durability and specific organizational charts that force their leaders to occupy spaces in a flexible way and through responses to both academic and political demands. His trajectory represents a non-university trend in contrast to the traditional institution trend, such as the University of São Paulo (USP).

It is important to emphasize that the capital at stake and the distribution of rewards now follow different patterns in relation to the compositions of traditional forces of the Brazilian academy. There is neither the previous dynamic of peer reviews, which was marked by accommodations and adjustments between specialties, nor the typical corporativism of exchanging favors between the research community and the managers of the State bureaucracy. As it has mentioned before, there has been an important transition during the 1980's related to the national scientific and technology policy that would change all the relationships among researchers, academia and scientific institutions. The scientific field would become more ruled by specific norms managed by scientific fostering agencies that adopted criteria based on international models of financing and research assessment. The scientific institution and the academic hierarchy have become less influential than before to manage the scientific and research fields.

Scientists at INPE, in general, were already acting according to the internationalized science model when this transition began in the Brazilian research institutions and universities, which would provide one of the main bases for the reconversion of scientific elites. In the area of Meteorology, this process was amplified when the scientists at INPE criticized, in the late 1970s, the use of statistical methodologies for climate predictions and artificial rain nucleation techniques for the Northeast region of the country, both promoted by the Institute of Aeronautics and Space (IAE), linked to the CTA—a military institution.

The controversy reverberated in the media and the National Congress at different times in the early 1980s.<sup>34</sup> In these episodes, the scientists at INPE emphasized the need to implement

<sup>33</sup> Bernward Joerges, and Terry Shinn, *Instrumentation between science, state and industry* (Dordrecht: Kluwer, 2001).

<sup>34</sup> "Meteorologista acha inviável a mudança do clima," *O Globo*, February 28, 1982; "Procura-se uma explicação. Os cientistas não chegam a um acordo," *Revista Isto É*, August 10, 1983, 34-35; "A Antártida pode estar influenciando na seca do NE," *O Estado de S.Paulo*, October 9, 1983; "Atuação do CTA no Nordeste é refutada e as chuvas artificiais são negadas pelo INPE," *Jornal Valeparaibano*, January 14, 1984, 3; "Programa de chuvas provoca debate entre cientistas," *Jornal do Brasil*, February 19, 1984; Brasil, *Anais do Senado, 154ª a 167ª, Sessões*, vol. 7, book 12, (Brasília: Congresso Nacional,

methodologies already used in the main meteorological centers in developed countries, which used modeling and approaches that associated correlations between distant meteorological events, such as the occurrence of anomaly patterns of surface temperature in the eastern tropical Pacific (which would be known as El Niño) and of drought in the semi-arid region of northern Brazil. They also advocated the creation of a modern numerical weather and climate forecasting center in the country.<sup>35</sup>

According to Whitley, the reputational system started in the 1970s and 80s required that modern scientific leadership have the flexible ability to adjust to changes in political circumstances and in the crossing of data and materials between different academic areas.<sup>36</sup> The interdisciplinary dynamic and the capacity to respond rapidly to demands established by different social agents make these scientific elites manage flows of open and uncertain themes that go far beyond the safety of hierarchical and centralizing academic spaces.

Compared to the traditional university-based science, the growth of different forms of financing and contracting made available by the increasing presence of multilateral agencies in climate research forced the academic hierarchies to operate according to the new rules brought by the international reputational system operated by agencies such as the WMO, IPCC, and the International Research Institute for Climate and Society (IRI) among others. In this sense, as previously highlighted, the trajectory of science developed within INPE Meteorology Department was already being shaped and generated in this new model of scientific practice.

The importance Meira Filho's contribution to the formation of the new meteorological science elite based at CPTEC is measured not only by the accumulation of his institutional scientific capital, but also by the mobility and differentiation of transversal attributes spread in the different spaces he circulated. In addition to a conventional academic internationalization, his presence in non-academic scientific organizations has assisted with attuning the demands of INPE emerging groups to the new parameters of action in the climate area. Other young researchers with a doctorate in Meteorology from INPE also began to circulate in recognized foreign research centers and institutions. The individual participation of these INPE researchers was crucial to form and intensify the scientific capital of INPE Meteorology Department within the broader scientific field of Brazilian Meteorology.

It is worth highlighting the links and scientific affiliations that Gylvan Meira Filho established throughout his career, which will link him, in some way, to exponents of international Meteorology. His proximity to researcher Joseph Smagorinsky was public, with whom he shared, in the early 1980s, the idealization of a NWP center for Latin America. In the 1940s, Smagorinsky participated in the experiment that would make NWP operational, having worked at Princeton under the leadership of Jule Charney in the processing of the first forecast using ENIAC, the supercomputer under development and testing at the time.<sup>37</sup> In the 1960s, Smagorinsky was one of the precursors to the first climate model, known as the General Circulation Model (GCM), and of ideas about climate change. He chaired the Geophysical Fluid

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September 16-30, 1983), 4276.

[http://www.senado.gov.br/publicacoes/anais/pdf/Anais\\_Republica/1983/1983%20Livro%202012.pdf](http://www.senado.gov.br/publicacoes/anais/pdf/Anais_Republica/1983/1983%20Livro%202012.pdf).

<sup>35</sup> Neiva, E. "Situação da Previsão do Tempo no Brasil – Relatório – III Congresso Brasileiro de Meteorologia," *Boletim Informativo*, Sociedade brasileira de meteorologia (Belo Horizonte) 9, no. 3(1985), 47-59.

<sup>36</sup> Richard Whitley, *The intellectual and social organization of the sciences* (New York: Oxford UP, 2009).

<sup>37</sup> F. Shuman, "History of Numerical Weather Prediction at the National Meteorological Center," *Weather and Forecasting* 4, (September 1989), 286-296.

Dynamics Laboratory (GDFL) at the National Oceanic and Atmospheric Administration (NOAA) for several years.

The trajectory of another INPE researcher, Antonio Divino Moura, is largely similar to that of Meira Filho and assists with corroborating the impressions about the reconversion carried out by these agents who incorporated this transversal dynamic in the practice of research in the climate area. Divino Moura completed his doctorate at MIT, worked at PGMet, circulated in prominent international agencies such as the WMO and NOAA, was the first director of the International Research Institute for Climate and Society (IRI), and received international awards for his scientific excellence. He was president of the Brazilian Society of Meteorology (SBMet) and head of INPE Meteorology Department, in a time when CPTEC was only a department of this larger area.

In the next section we discuss how the Meira Filho's scientific actions favored and enabled the formation of a new reputational group within INPE, and how the new generations of climate scientists responded to these new activity contours in the area.

### **A generational climate project**

According to Bourdieu,<sup>38</sup> within the French university system, the search for homology with the dominant agents of the field and respect for the consecrated symbols of prestige constitute the necessary means for young people to share the intellectual and institutional heritage of the academy. Completion of a doctorate under the supervision of a prestigious professor, publication in recognized journals, and participation in academic events are requirements for a safe trajectory. Hierarchical and concentrated capital systems require obedience to the capital credits established by the dominant pole at the risk of curtailment of future career opportunities.

However, what occurs when the scientific field is changing? Is it necessary to remain true to these requirements in order to obtain secure credits, or is it necessary to carry out a reconversion of objects and positioning strategies in the field?

Resuming the discussion on scientific careers and influences, it is worth pointing out how Oliveira perceives the dilemmas of the choices made by technicians and scientists in Brazilian research centers in the 1980s. According to Oliveira, there was an increasing imposition of organizational demands on the daily practice of technicians and scientists who worked in this professional field.

Isolated and self-sufficient scientists were no longer on the main stage of the contemporary scientific world. Once closed within the limits of the organizations, scientists had to try to ensure, within them, the conditions they considered essential to intellectual and scientific work. Such conditions (...) referred fundamentally to the social and organizational structures where the nature of the work to be carried out was defined, where the competence of the different members to conduct it was established, and where the progress made was assessed.<sup>39</sup>

Bringing this discussion to the formation of CPTEC, it was necessary to meet the organization's expectation in order to seek an adaptation to the new contours of climate research

<sup>38</sup> Bourdieu. *Homo academicus*. (Florianópolis: Ed. UFSC, 2011).

<sup>39</sup> Oliveira, op. cit., 163.

in transformation. The trajectory model of the main leaders who composed the scene at INPE in the 1980s presents the manifestation of Meira Filho as the most seductive, in tune with the world-renowned centers and with easy transit in the Brazilian government spheres.

It is not possible to understand the formation of the group of researchers at CPTEC without considering the type of capital that made it institutionally viable and its forms of distribution. The strategies adopted by the young scientists at INPE at that time, the behavior of its leaders, and the context of the scientific institutions of the 1980s and 90s are fundamental to understanding scientific investments.

The different trajectories followed by researchers Rao and Meira Filho provide elements to understand the directions that climate research was taking in that period in Brazil. The types of direct and indirect collaboration of these agents to CPTEC structuring point to the symbolic divergences and disputes that have occurred in the Brazilian climate field. INPE is a stage for confrontation between pure scientific capital, which is organized around academic research, and institutional capital, which circulates between international organizations of different modalities.

The new generations of researchers in the field of Meteorology at INPE sought an intellectual and institutional reconversion aiming to stand out in the field and thereby establish an independent dialogue with the international climatic organizations that were formed since the 1960s. Next, we discuss the recruitment methods established by INPE for the selection of researchers focused on the leadership of activities at CPTEC and the implications for reconfiguration of the field of Meteorology.

#### *Scientific recruitment and concentration of symbolic capital*

The process of recruitment and selection is essential for the formation of a dominant group in any area. It is not possible to understand the constitution of a business organization, a political party, or the formation of a high bureaucratic body without considering the trajectory and circulation of its prominent members. At some point in the trajectory of an agent, belonging to a *grand corps* defines their potential for future growth. In the words of Saint Martin,

The socialization and training of members of future elites depend closely on educational institutions (elite schools, private or public, large high schools, *grandes écoles*, etc.) that favor the structuring of groups, the constitution of networks, and the learning of methods to manage relations and exercise of authority. Research on the *grandes écoles* - scientific, administrative, or of management ... in the late 1960s and early 1970s, enabled the explanation and understanding of how social boundaries are established between students of *grandes écoles* and those of universities, as well as between students of different schools, more or less important, farther or closer to the intellectual or economic pole, and these borders have an effect on their lives as a whole.<sup>40</sup>

Specifically within the scientific field, graduating from a recognized institution and incorporating its reference values and symbols is essential for integration with the high levels of qualification.

The analytical perspective centered on the study of preparatory *grandes écoles* presents problems and controversies, but even so it has been important to understand the symbols of

<sup>40</sup> Saint Martin (2008), op. cit., 52.

distinction used by certain groups of knowledge to recruit their staff. From the perspective of Bourdieu and Saint-Martin, the concentration of intellectual capital in the same institution generates a set of premises and expectations that are exported to the set of subsidiary spaces forming new coalitions of ideas and perspectives.

The current model of relations in the scientific field, established internationally, has been redefining the modalities of circulation of traditional knowledge and methods. The intersection between areas of education, departmental activity, research groups, and funding sources shows that the contemporary scientific scenario creates a complex network of areas and subareas of specialization in which conventional boundaries cannot explain how hegemonic groups are articulated and reproduced.

In its turn, the filters established by the Brazilian research centers, to a large extent, introduced selection mechanisms that favored a previous acceptance by renowned institutions. In the 1980s, during the structuring of CPTEC, the members of its staff were recruited based on their passage by prestigious academic institutions, publication in recognized journals, and participation in relevant scientific associations in the area of meteorology, such as SBMet.

The agents who formed the leadership of CPTEC in its initial moments were not necessarily individuals with newly obtained doctorates who sought initial positions in their research career, subjected to the impositions of string-pullers and field dominators. On the contrary, the effort to bring scientific leaders to CPTEC conducted by INPE favored in part researchers who were already established in important institutions and had come from renowned research centers and universities. This is the case of researchers with doctorates completed at prestigious institutions in the USA who, in the passage from the 1980s to the 1990s, had already accumulated relevant scientific positions, such as Pedro Leite da Silva Dias, Eugenio Neiva, Carlos Afonso Nobre, and Maria Assunção da Silva Dias.

One of the persons involved with the first initiatives for the creation of an NWP center was Marco Antonio Maringolo Lemes, who joined INPE in 1968. He did not complete a doctorate, which prevented him from occupying a more visible institutional position for CPTEC establishment; however, he was the first INPE researcher to develop studies, reports, and articles on NWP.<sup>41</sup>

Meira Filho was the first head of CPTEC (1987-8), followed by Pedro Dias (1988-90), from USP; Eugenio Neiva (1990-1), from the Brazilian Navy; Carlos Nobre (1992-2003), from INPE; and Maria Assunção Dias (2003-9), from USP. In 1995, shortly after the institutional creation of CPTEC, Lemes retired from INPE, and later joined the Federal University of Alagoas (UFAL).

Analysis of the trajectories of the other researchers mentioned shows how the implementation of CPTEC followed a strict and judicious formula for optimizing scientific opportunities through INPE. All heads of CPTEC, linked to traditional scientific institutions, had trajectories of training and research abroad.

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<sup>41</sup> Miguel, et al., 2016, op. cit.; M.A.M. Lemes, *Relatório Preliminar sobre a Implantação de Previsão Numérica do Tempo no Brasil* (São José dos Campos: INPE (CNPq), 1973).



Pedro Dias and Maria Assunção Dias completed their doctorates at the University of Colorado (USA), when they already had a strong connection with USP as teachers at the Institute of Astronomy, Geophysics and Atmospheric Sciences (IAG-USP) since the 1970s. Their doctorates abroad were conditioned to their return to assist with implementing the graduate studies program in Meteorology at IAG/USP (DIAS, 2012).<sup>42</sup>

Carlos Nobre graduated from ITA, completed his doctorate at MIT in 1983, worked at the National Amazon Research Institute (INPA) before joining INPE, and returned to MIT to do a postdoctoral research in the late 1980s. Eugenio Neiva graduated in Naval Sciences at the Brazilian Navy and received a new bachelor's degree, followed by a master's degree and a doctorate in Meteorology at an institution of the United States Navy in Monterey. Antonio Divino Moura, who was coordinator of INPE Meteorology Department in the early 1990s and deeply involved in the creation of CPTEC, also completed his doctorate at MIT, and a postdoctorate under the supervision of Prof. J. Shukla at the Goddard Laboratory for Atmospheric Sciences at the National Aeronautics and Space Administration (NASA) in 1980. He was also director general of INMET in the mid-1980s.

Until 1994, when CPTEC was implemented, these scientists had already accumulated supervisions of theses and dissertations in graduate studies programs in the area of Meteorology, in addition to postdoctoral studies at prestigious North American universities and research centers. INPE Meteorology Department, the Research Center for Environmental Modeling and Application (CEMA), had already implemented in 1982 a laboratory that would be attended by both master's and doctoral researchers, where the first modeling research experiments were developed at INPE.

When these researchers converged to structure CPTEC at that moment, they were willing to invest in their careers using strategies that would involve new scientific approaches in the field of Meteorology with operational perspectives, adding even more scientific capital to their previous trajectories. These researchers have also always been associated with international projects to which INPE was invited to collaborate in the climate area, such as the Anglo-Brazilian Climate Observations Study (ABRACOS) and the Tropical Ocean and Global Atmosphere Project (TOGA) between 1985 and 1994, whose results represented a new era for climate predictions and the Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA).

In addition, in terms of international insertion, the aforementioned researchers acted in the structuring and leadership of CPTEC, while participating in the main international scientific organizations in the area of Meteorology, namely, WMO, IPCC, NOAA, IRI, ECMWF, and the National Center for Atmospheric Research (NCAR) among others through agreements, occupying positions in management, as visiting professors, and in councils and coordination of the writing of reports.

A standard of scientific excellence, combined with a non-university insertion in renowned research centers in the global and transversal scope, legitimized the groups of agents that assumed qualified positions in the Brazilian climate science. They were, therefore, relatively young members of the elite of researchers in the field of Meteorology who circulated

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<sup>42</sup> Pedro Leite Dias, interview by Paulo Escada, April 2, 2012, São Paulo.

outside the borders of INPE and its institutions, widening the margins of reputational positioning.

In the following decade, three of them (Pedro Leite, Maria Assunção Leite, and Carlos Nobre) became members of the Brazilian Academy of Sciences (ABC), reaching a prominent position in the national scientific field. The political field also recognized the excellence of this small group, through the awarding of medals of honor from the Brazilian State, such as the Order of Scientific Merit, granted by the Ministry of Science and Technology (MCT).

According to Bourdieu, every scientific field tends to give more capital to those more familiar with its distribution procedures and formulas. The best positioned scientists benefit from the credits made available by the field in their favor, increasing the benefits received despite of a general aspect of collective gains.

Symbolic capital attracts symbolic capital: the scientific field gives credit to those who already have it; the best known are those that most benefit (or benefit themselves) from the symbolic gains apparently distributed equally among the signatories, in the case of multiple authorship or multiple discoveries by people of unequal fame – even when the best known do not occupy the foreground, which gives them an even greater benefit, that is, to seem disinterested from the point of view of the norms of the field.<sup>43</sup>

The rise of CPTEC in the scenario of Brazilian meteorological and climate sciences occurred through a specific recruitment system, rewarding in part researchers who combined international academic trajectories, especially in North America, with a strong insertion in the set of institutions that comprised the modern framework of computational and informational models of weather and climate forecasting.

Good positioning in the academic field, and movement in the prominent university centers, are necessary components, but insufficient for a more noticeable recognition in the climate sector, because the reputation system triggered by these agents values scientific excellence, training, and experience in the modern meteorological institutions that form the new global climate elite.

#### *Reconversion and adjustment of competences*

Formation of a scientific elite within a given field of knowledge is a process that involves capital redistribution, consecration of new symbols of knowledge and power, changes in the criteria for scientific certification, and reconversion of academic investments.<sup>44</sup>

When new agents join a field of knowledge, they open space for new alliances and revision of strategies, aiming to change the current scientific excellence parameters and the competition rules.

To maintain their positions or accumulate more scientific capital, agents often need to redirect their strategies within the field. Reconversions of agents frequently occur in the scientific field. In the field of meteorological sciences in Brazil, two reconversion moments are worth highlighting in the past decades: in the NWP implementation process, which culminated

<sup>43</sup> Bourdieu, 2004, op. cit., 81.

<sup>44</sup> Terry Shinn, “Formes de division du travail scientifique et convergence intellectuelle,” *Revue Française de Sociologie* 41, no. 03(2000), 447-473.

in the creation of CPTEC, between the 1980s and 90s, and in the adherence of researchers from meteorological sciences to the theme of climate change, a process that occurred between the 1990s and 2000s. Changes in strategy occur especially when a given discipline and its subfields face turbulence and demands for updating, as it was the case with climate sciences in the 1980s and 90s, when this demand became more urgent.

The modeling techniques and informational frameworks of weather forecasting began to occupy a central position in meteorological research techniques in the 1980s, demanding a more incisive adaptation effort from researchers in the area. Conventional academic training and the analogical knowledge available could lead young researchers to an impermeable labor market.

Fidelity to academic training and to the type of knowledge transmitted by advisers of theses and dissertations could no longer be the exclusive definer of future trajectories. Therefore, there was need to reconvert scientific competences and practices in order to keep up with the changes that INPE had been undergoing, initially, with the experiences of CEMA and, later, strongly substantiated by the creation of CPTEC.

The structuring of CPTEC implied the promise of other professional rewards that younger researchers began to crave for. An important characteristic of the younger researchers who entered a less centralized and hierarchical field was the dynamic of identifying available opportunities and safe investment in promising trajectories.

Agents with smaller scientific capital are the most predisposed to operate reconversions that, presumably, at least will produce a repositioning of their qualified insertion possibilities; however, reconversion can also be carried out by those who already have considerable scientific capital and are favorably positioned in their scientific field. This could be observed in the 1990s, when researchers at CPTEC with works focused on deforestation and impacts on climatic and biogeochemical cycles in the Amazon rainforest, and who occupied a privileged position in the institutional hierarchy and scientific field got involved in research associated with climate change.

Nevertheless, not all of the researchers who collaborated to the rise of CPTEC in the Brazilian climate community held the same symbols of scientific recognition as those in the group previously mentioned. Many of them completed a master's or doctoral degree in Meteorology at INPE and remained identified with that institution. INPE researchers, such as José Paulo Bonatti, Sergio Henrique Franchitto, and Yoshihiro Yamazaki, who worked at CEMA, and Prakki Satyamurti, Marley Moscatti, and Magda Abreu participated prominently in the acquisition of material and signing of agreements and contacts with international meteorological centers during the structuring period of CPTEC.<sup>45</sup>

It should be emphasized that, during this period, some of these researchers already had a certain connection with prestigious scientists and meteorological centers abroad, with representative participation of INPE in meetings at meteorological organizations of excellence. However, the scientific capital available to these agents was restricted and fundamentally defined by the professional and scientific conditions provided by INPE, which included the Department of Meteorology and PGMet. Better positioning in the field of meteorological and

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<sup>45</sup> Miguel, et al., 2016, op. cit.

climate sciences would only occur after CPTEC was in place in 1994, when some of these agents began to occupy positions in other Brazilian centers and universities as researchers or teachers. Analysis of the trajectory of these five researchers reveal that:

- In 1994, José Paulo Bonatti completed a postdoctoral degree at the Center for Ocean-Land-Atmosphere Studies (COLA) in the USA, with the mission of bringing and adapting the model of global atmospheric circulation of that center to be run operationally at CPTEC.
- In 1994, Sérgio Franchitto started collaborating with the graduate studies program in Geography at the Sao Paulo State University (UNESP), teaching classes on geographic simulation, but maintaining his link with INPE.
- In 1996, Magda Abreu became a professor in the Department of Geography at the Federal University of Minas Gerais (UFMG), teaching in the area of Climatology.
- In 1996, Marley Moscati completed her doctorate, and in the following year became a researcher at INPE; in the following decade she became a member of the board of directors of SBMet.
- In 1998, Yoshihiro Yamazaki became a professor in the Meteorology Department at the Federal University of Pelotas (UFPEl).
- In 2001, Prakki Satyamurty became the president of SBMet and later worked as a professor at the State University of Amazonas (UEA).

The training and experience in Meteorology that these researchers gathered at INPE quite possibly symbolically accredited them to occupy these positions in national and international universities in this area, spreading the expertise obtained at INPE to other teaching and research centers, and forming a model of scientific practice.

These researchers have another aspect in common: except for Magda Abreu, all of them completed their graduate studies at INPE. This shows that INPE already had a mature group of researchers with endogenous training in order to be able to build new forms of insertion in the meteorological agenda, not completely depending on professionals with doctorates obtained abroad or linked to other universities.

Another aspect that strongly marks this group of professionals, graduated at PGMet, is the fact that they were all supervised by the same professor, Vadlamudi Rao, between 1974 and 1996. It is worth highlighting how these researchers were present in the field in relation to their research areas of interest. An INPE catalog of 1993 brings a list of professors who worked in graduate studies programs in Meteorology and their respective areas of interest.

Researchers José Paulo Bonatti, Sergio Henrique Franchitto, Yoshihiro Yamazaki and Magda Abreu had Numerical Modeling as their research area of interest, a specialty that was not of interest to Vadlamudi Rao.<sup>46</sup>

This mismatch between the areas of interest of the adviser and of the young doctors indicates the occurrence of a reconversion of research agendas, very strongly induced by the institutional environment, which starts to invest in modeling - also a methodological requirement for research and development related to weather and climate forecasting.

<sup>46</sup> Instituto Nacional de Pesquisas Espaciais, *A Meteorologia no INPE* (São José dos Campos, 1993).

As previously underscored, the influence of Rao in the training of the aforementioned researchers is extremely important, which qualifies him as an indirect collaborator for the consolidation of CPTEC. In addition to his supervision, Rao also published more than one article co-authored with each of his graduate students in prestigious international journals, which undoubtedly strengthened their academic curricula. The researcher Magda Abreu, in her turn, did not produce articles co-authored with Rao, but with her supervisor at the American university where she completed her doctorate, Peter R. Bannon, following the logic of that during or finishing the doctoral degree, researchers use to publish articles co-authored with their supervisors.

The involvement of some of these researchers with missions and participation in research and routines at CPTEC shows that the figure of the graduate studies adviser as a supporter that holds the essential credits for professional development was not an exclusive prerogative.

The career trajectory of the young PhDs and partners of Rao points to a diversity of influences exerted by the field on its entrants. The supervision and publication in co-authorship on the one hand, and the investment and use of CPTEC computational infrastructure on the other hand, comprised a set of stimuli and opportunities that needed to be balanced. These young graduates trained at INPE invested their time and initial scientific capital in an institutional project with characteristics qualitatively different from the directions then in force in academic meteorological research.

It is also interesting to note the awards and honors received by this group of researchers in their trajectories:

- In 1996, José Paulo Bonatti received a distinguished service award from INPE.
- In 2008, Sérgio Franchitto had an award-winning work at the SBMet Meeting and an article featured in the journal *Nature*. In 2010 and 2015, he received awards for services rendered to INPE.
- In 2004, Magda Abreu received a CPTEC/INPE award for rendered services.
- In 2008, Marley Moscati received an award from SBMet for her participation in its board of directors.
- In 1998, Prakki Satyamurty received an SBMet award for best published paper. In 2002 and 2003, he received distinguished service awards from INPE and obtained another award from SBMet in 2018.
- Yoshihiro Yamazaki has received no awards.

As it can be observed, this group of researchers with a more endogenous background has received more outstanding recognition mainly from national organizations: INPE and SBMet. Unlike the more internationalized group linked to more prestigious universities, such as USP, the researchers trained in PGMet at INPE have been awarded symbols more restricted in terms of importance in the field of climate science.

According to Bourdieu,<sup>47</sup> the distribution of awards and honors is an essential moment in which the scientific field makes its preferences public in terms of practices and institutions that receive the magic of consecration. This means that members linked to INPE receive credits

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<sup>47</sup> Bourdieu (2004), op. cit.

and recognition from the meteorological field, but with limitations. None of them was ready to receive a more distinctive honor such as, for instance, access to the ABC.

In this sense, it is not possible to follow the trajectory of these researchers without noticing the formation of hierarchies within this field. Graduating in Meteorology from PGMet/INPE with the prestigious stamp of CPTEC represented an important addition of scientific capital for these agents that entered the field of meteorology and climate; however, the distribution of prestige beyond the borders of INPE represented a structural limitation for the accumulation of subsequent scientific capital for these local entrants.

The leadership most strongly present between the 1980s and 90s was exercised by Gylvan Meira Filho, who had not strongly aligned with PGMet, or to journals in the area, and did not have such close contacts with strictly academic research institutions. Or the leadership exercised by Carlos Afonso Nobre, in his trajectory in ITA, INPA and MIT, who followed a conventional academic career and, in addition, held leadership and coordination positions at CPTEC and as secretary at the Ministry of Science, Technology and Innovation (MCTI), and presented a strong interface with institutions such as WMO and IPCC, as well as being a coordinator of major international projects and scientific organizations such as the LBA, executive secretary of the Brazilian Network for Research on Global Climate Change, head of the Scientific Committee of the International Geosphere Biosphere Programme, high scientific adviser of the United Nation's Panel on Global Sustainability, and one of the 26 members of the United Nation's Secretary-General's Scientific Advisory Board (UNSAB). Carlos Nobre follows the model of a new type of climate scientist, operating a second reconversion, considering that he also emerges as scientific leadership in the field of climate change, and increasingly attuned to the intergovernmental agenda and the parameters of assessment of hegemonic organizations in the field on a national and global scale. He has also received several national and international awards, such as the 2007 Nobel Peace Prize, along with other members of the IPCC.

It can be stated that participation in CPTEC provides its members with a possibility of ascension within the field of climate science, but in such a way that the differentiation symbols established by the dominant players of the field overwhelm all others and define the general redistribution of scientific capital.

### **Final considerations**

It seems clear, throughout this analysis, that CPTEC not only represented an institutional investment to drive meteorological and climate research, but also to form prestigious groups responsible for the supply and redistribution of scientific capital.

The transformations undergone by climate research in Brazil between the 1970s and 90s,<sup>48</sup> and on a global scale between 1990 and 2000, reconfigured the possibilities for the rise and consolidation of centers focused on climate, weather forecasting, and climate change. Conventional university research activities, marked by the production of theses and dissertations, supervision and co-authorship of articles in journals, and receiving of prizes, had to be adjusted to the gain in importance of the role played by intergovernmental agencies in the

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<sup>48</sup> The first World Climate Conference organized by the WMO and held in Geneva, Switzerland, in 1979, is considered the first major international meeting that discussed global warming and climate change.

scientific field, which started influencing the international decision-making and recognition spheres.

However, this initiative did not occur without the formation of new tensions and hierarchies. The forms of accreditation and transmission of prestige operated formulas of exclusion and symbolic distance in the face of the new standards of excellence established by the climate field. The researchers already established and certified by this new order of transversal research conducted and selected, by means of their different signs, the operational parameters for forming routines, choosing equipment, and conducting daily analyses.

INPE was responsible for a large part of the institutional pioneering spirit that organized the technical and political systems for the operationalization of this new phase of meteorological research, defining leaderships, recognizing scientific practices, providing possibilities for ascension and replacement in the academic system in order to form new elites in the climate field, and constricting differentiated criteria. However, it is also clear that CPTEC, as a space for a rising scientific elite, is subordinated to the more general principles of international recognition in the field of meteorology.