CHARLES UNIVERSITY

FACULTY OF SOCIAL SCIENCES

Institute of Political Studies

Department of Security Studies

Master's Thesis

2022 **Zuzana Boháčová**

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Big Data and governing climate change: opportunities and challenges

Master's Thesis

Author: Zuzana Boháčová

Study programme: Bezpečnostní studia (BS)

Supervisor: PhDr. Vít Střítecký, M.Phil., Ph.D.

Year of the defence: 2022

Declaration

1. I hereby declare that I have compiled this thesis using the listed literature and resources only.

2. I hereby declare that my thesis has not been used to gain any other academic title.

3. I fully agree to my work being used for study and scientific purposes.

In Prague on 28th July Zuzana Boháčová

References

BOHÁČOVÁ, Zuzana. *Big Data and governing climate change: opportunities and challenges.* Praha, 2022. 63 pages, Master´s thesis (Mgr.). Charles University, Faculty of Social Sciences, Institute of Political Studies. Department of Security Studies. Supervisor PhDr. Vít Střítecký, M.Phil., Ph.D.

Length of the thesis: 114 529 (spaces included)

Abstract

Climate change is one of the most significant global challenges that need to be managed; however, the current governance of climate change is not bearing the desired results. This thesis thus examines the opportunities Big Data-based tools offer for more efficient climate change governance. It provides an overview of the current state of play regarding climate governance and the way climate change is entering the realm of security. The study then introduces the concept of Big Data and, through two case studies, offers specific examples of Big Data applications in the context of climate change. It identifies several categories of Big Climate Data applications i) monitoring behaviour, perceptions and social attitudes, ii) monitoring markets and supply chains, iii) smart buildings, energy and smart cities, and iv) carbon monitoring and monitoring of natural conditions and changes. The thesis also highlights the main critiques and barriers these applications face, which include i) the lack of theoretical and methodological framework, ii) the issues of opacity, accountability, lack of transparency, iii) missing efficient governance system to employ the technology, iv) the complexity of climate and climate data, v) the environmental consequences of AI. It concludes that the trend of public-private partnerships, which is evident also on a general level in global governance, has, so far, proved to offer the most effective for the application of Big Data in the context of climate change.

Abstrakt

Změna klimatu je jednou z nejvýznamnějších globálních výzev, které je třeba zvládnout; současné řízení změny klimatu však nepřináší požadované výsledky. Tato práce tak zkoumá možnosti, které nástroje založené na Velkých datech nabízejí pro efektivnější řízení klimatické změny. Práce poskytuje přehled o současném stavu řízení klimatu a způsobu, jakým změna klimatu vstupuje také do oblasti bezpečnosti. Práce následně představuje koncept Velký dat a prostřednictvím dvou případových studií nabízí konkrétní příklady aplikací Velkých dat v kontextu klimatické změny. Je identifikováno několik kategorií aplikací Velkých klimatických dat i) monitorování chování, vnímání a sociálních postojů, ii) monitorování trhů a dodavatelských řetězců, iii) inteligentní budovy, energie a chytrá města a iv) monitorování uhlíkových emisí a monitorování přírodních podmínek a změn. Práce také zdůrazňuje hlavní kritiky a bariéry, kterým tyto aplikace čelí, mezi něž patří i) nedostatečný teoretický a metodologický rámec, ii) problémy s neprůhledností, odpovědností, a nedostatkem transparentnosti, iii) chybějící účinný systém řízení pro využití technologie, iv) složitost údajů o klimatu a klimatu, v) environmentální důsledky umělé inteligence. Diplomová práce dochází k závěru, že trend partnerství veřejného a soukromého sektoru, který je patrný i na obecné úrovni v globálním vládnutí, se zatím ukázal jako nejefektivnější pro aplikaci Velkých dat v kontextu klimatické změny.

Keywords

climate change, Big Data, governance, climate security, public-private partnerships, artificial intelligence

Klíčová slova

klimatická změna, Velká data, řízení, klimatická bezpečnost, partnerství veřejného a soukromého sektoru, umělá inteligence

Title

Big Data and governing climate change: opportunities and challenges

Název práce

Velká data a řízení klimatické změny: příležitosti a výzvy

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List of abbreviations

AI - artificial intelligence

CBDR - common but differentiated responsibilities

CDM - Clean Development Mechanism

CMIP - Coupled model intercomparison project

COP - Conference of the Parties

ECOSOC - UN Economic and Social Council

ETS - emissions trading scheme

EU – European Union

FAO - Food and Agriculture Organization of the United Nations

GHG – Greenhouse gas

Iot - Internet of Things

IPCC - Intergovernmental Panel on Climate Change

MRV - Monitoring, reporting, and verification system

NATO - North Atlantic Treaty Organisation

NDCs - Nationally Determined Contributions

OSCE - Organisation for Security and Co-operation in Europe

SDGs - sustainable development goals

STS - Science and Technology Studies

UN – United Nations

UNCED - UN Conference on Environment and Development

UNDP - United Nations Development Program

UNEP - United Nations Environment Programme

UNFCC – United Nations Framework Convention on Climate Change

UNOOSA - United Nations Office for Outer Space Affairs

US – United States of America

WEF - World Economic Forum

WMO - World Meteorological Organisation

Introduction

Climate change constitutes one of the most significant global challenges we are facing today. It has been defined as a "super-wicked" problem for its unprecedented spatial and temporal challenges, its obstacles to cognitive and social judgments, and its low "incentive" structure for those paradoxically best placed to address it in policy settings (Lazarus 2009). The challenges and risks it poses are not only environmental but also political, economic and societal. Therefore, the issue of climate change has been gradually gaining attention also in the international relations and international security community. Moreover, the rising number, complexity, and interconnectedness of issues on the international agenda contribute to the immense pressure on the global governance system that is at the same time undergoing shifts connected to the emergence of rising powers or the rising importance of non-state actors.

In this context, the actions of the international community with regard to the unprecedented challenges climate change poses are not achieving satisfactory results. Despite the issue of climate change evolving from initially a purely environmental matter to a matter of global political importance, the current climate commitments are not on track to meet the Paris Agreement goals.(*"Climate Commitments Not On Track to Meet Paris Agreement Goals" as NDC Synthesis Report is Published | UNFCCC* 2022) The current climate governance regime has undergone a long evolution and has reached some remarkable milestones; however, many governance, financial, institutional, and policy limits to efficient climate governance still persist. Climate change has thus been also increasingly framed as a security issue, and despite divergent discourses discussing the possible securitization of climate change, it is acknowledged that by entering the realm of security, the urgency to act and address the climate security challenge also rises. In this context, the proposal for a "Responsibility to Prepare and Prevent (R2P2) framework"(Werrell, Femia 2019) highlights the fact that while we are facing unprecedented risks, we also have an unprecedented foresight and a growing capacity to reduce uncertainty – that allows us to predict these risks and so also obliges us to use these tools and act.

Big data-based tools could take on this role and contribute to achieving more efficient climate governance. While still being a recently new phenomenon, Big Data have grown exponentially in volume and also in popularity and importance. The rapid advances in the field of Artificial intelligence and machine learning enable the processing of a huge amount of data, the technology is becoming cheaper and more available, and Big Data are gradually permeating all aspects of society. The integration and joint management of heterogeneous data and information that current technology enables can thus inform evidence-based policy making, enable effective climate change strategic planning, offer decision support algorithms or help integrate the socio-environmental factors in the climate change models. However, while Big Data offer enormous opportunities, they also pose diverse challenges, from privacy, transparency and opacity issues to the concerns regarding control of and access to data or to the environmental impacts of the technology itself.

Therefore, with the immense opportunities Big Data analytics offers, the question arises whether, after developing intelligent homes and cities, we could also develop smart governance and a smarter planet (Helbing et al. 2019) and manage to balance the risks and benefits of the technology. The research objective of this thesis is thus to provide a descriptive analysis of the possibilities and challenges of Big Data application with regard to climate governance.

Literature review

The subject of this thesis is very topical, and in consequence, there is a growing number of publications dealing with the topic of Big Data. On the other hand, it is still a relatively new field, and thus the research on this topic is still in its infancy. While climate change, global governance and Big Data all attract the attention of researchers, there are very few publications that would deal with the connection between these concepts and that would pay special attention to the application of Big Data tools for climate governance.

Many scholars investigate climate change, its effects, related risks and the way it is currently, or was in the past, governed (Behnassi, McGlade 2017; Jorgenson et al. 2019; Lazarus 2009; Bulkeley, Newell 2015; Heyvaert 2011). Others examine the global governance landscape on the general level (European Union Institute for Security Studies 2010) or the connection between climate, security and governance (Werrell, Femia 2019; Floyd 2015). The number of publications devoted to Big Data is continuously growing. Most scholars explore the concept of Big Data in general terms and provide an introduction to the topic (Mayer-Schönberger, Cukier

2014; Giardullo 2016; Ekbia et al. 2015; J. Mazzei, Noble 2020) while a few also examine the relationship between climate and Big Data (Espinoza, Aronczyk 2021; Sebestyén, Czvetkó, Abonyi 2021; Faghmous, Kumar 2014; Folk 2021; Ford et al. 2016; Zhang, Li 2020a; Ramrayka 2018). However, a comprehensive analysis connecting the concepts of climate change, governance and Big Data is currently missing.

Structure, Methodology and Research question

This thesis will thus try to offer a starting point for such analysis. It will introduce and work with the concepts of global governance and Big Data. Firstly, the thesis will introduce the challenges climate change poses and current responses to these challenges. The second chapter will then examine the concept of global governance and its current trends and then offer a historical overview of global climate governance, and also outline the relationship between climate change and security. The third and fourth chapters will then focus on the concept of Big Data, its definition, Big Data dilemmas and eventually its possible applicability in climate change governance.

The fifth – empirical - chapter will provide two case studies of concrete implementations of Big Data for governing climate change. These studies will be based on the information retrieved from the official websites of the initiatives organizing the project that applied Big Data for climate, their informative videos, news articles about these initiatives, final reports, or case studies published as part of some of the projects.

Lastly, an overview of the most significant challenges and barriers to the Big Data application for climate will be presented.

The research question of this thesis thus is: *What are the opportunities and challenges of Big Data application for governing climate change?* With sub-questions focusing on:

- *What are the concrete ways in which Big Data can contribute to more efficient governing of climate change?*
- *What are the main barriers that need to be overcome in this regard?*
- *Is the use of big data for climate governance a realistic possibility despite the identified barriers?*

1. Climate change

1.1 Climate change: the state of play

We currently live in the Anthropocene era, which is described as a period when humanity has become one of the most powerful, global and enduring forces of climate, geophysical, biological and chemical changes. While the greenhouse gas effect is a naturally occurring phenomenon, human activities can exacerbate this effect.(Bulkeley, Newell 2015, p. 25) Due to the anthropogenic emissions of carbon dioxide, "global climate may depart significantly from natural behaviour for many millennia to come."(Crutzen 2002, p. 23) Climate change indeed constitutes one of our time´s greatest and most pressing global challenges and is becoming a prominent topic in the field of International relations. It poses unprecedented risks to human societies, all organisms, and the planet. Its environmental, economic and social consequences are most likely going to be substantial, serious, and global. It has been defined as a "super-wicked" problem because of: i*) its unprecedented spatial and temporal challenges, ii) its obstacles to cognitive and social judgments, iii) and its low "incentive" structure for those paradoxically best placed to address it in policy settings.*(Lazarus 2009; Espinoza, Aronczyk 2021)

It is thus not only a scientific but also a political and societal challenge that needs to be addressed globally. Despite public concerns for environmental issues growing already since the 1970s and the 1980s, scholars observed a paradox where opinion polls and surveys suggested that "environmental matters attract high levels of concern among the public" however, "the public appeared to be relatively ignorant about the scientific basis and implications of these issues and unwilling to engage in behavioural change to address them." (Bulkeley, Newell 2015, p. 71) In the same vein, while the reports from the Intergovernmental Panel on Climate Change (IPCC) have been more and more alarming in their evaluation of the "change that increased levels of GHG (greenhouse gases) in the atmosphere may precipitate," (Bulkeley, Newell 2015, p. 1) the actions of the international community have been perceived and challenged as insufficient and not proactive enough to take up this wicked problem in a way that would prevent the bleakest predicted future scenarios.

Specifically, the IPCC has been consistently warning that global greenhouse gas emissions and temperatures have been risings for decades: "Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850."(IPCC 2014a, p. 2) Furthermore, it confirmed that: "human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history".(IPCC 2014a, p. 2) The interdependence of *climate, ecosystems and biodiversity, and human societies* is also recognized as well as the growing role of the *non-state and sub-national actors (cities, businesses, Indigenous Peoples, citizens including local communities and youth, transnational initiatives, and public-private entities)* have in addressing this global challenge.(IPCC 2022a, p. 2)

The global scientific community has also been becoming more and more confident in linking the specific observed impacts to human-induced climate change. These include:

- *more frequent and intense extreme climate and weather events* that have caused *widespread adverse pervasive impacts to ecosystems, people, settlements, and infrastructure*.
- With high confidence, the IPCC also assesses substantial damages, and increasingly irreversible losses, in terrestrial, freshwater, and coastal and open ocean marine ecosystems caused by climate change.
- Moreover, food and water security and physical health of people globally and the mental health of people in the assessed regions are also adversely affected by climate change.
- *Overall adverse economic impacts* are increasingly identified as attributable to climate change
- And climate change also contributes to *humanitarian crises where climate hazards interact with high vulnerability.*(IPCC 2022b, pp. 11–13)

Risks posed by climate change are thus significant, and the international security community has been analysing their possible impacts across a broad range of plausible emissions scenarios on *state fragility, instability, conflicts or readiness of military forces, critical infrastructure*, and the very existence of *low-lying island states and the world's growing coastal megacities*.(Werrell, Femia 2019, pp. 10–11)

Concerning the possible future scenarios, the IPCC warns about the “unavoidable increases in multiple climate hazards” and “multiple risks to ecosystems and humans” in the case of 1.5° Celsius overshooting above pre-industrial levels in the near term, while in the long term it is assessed that “many human and natural systems will face additional severe risks, compared to remaining below 1.5°C.”(IPCC 2022b, pp. 15–21) Similarly, or even more terrifyingly, Australian climate scientist Steven Sherwood, with a team of global colleagues, have recently published a paper that tried to narrow the uncertainty, and they estimated the increase in world temperatures over the next century to be between 2.6 and 4.1 degrees Celsius.(Schwartz 2020; Editorial Team 2020) While the threshold enshrined in the Paris agreement is 2 degrees, according to this research paper, there is “less than a 5 per cent chance of a temperature shift below two degrees,”(Schwartz 2020) which paints a very dire picture for the planet if GHG emissions are not significantly and rapidly reduced in the near future.

1.2 Responses to climate change

The future scenario predictions thus depend largely on the responses of the international community that can mainly fit into the categories of mitigation and adaptation. The mitigation efforts comprise the interventions with the aim to reduce the sources or enhance the sinks of GHG emissions, and the adaptation efforts constitute the “adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects”, and as such, they have the objective of moderating harm or exploiting beneficial opportunities.(Jorgenson et al. 2019, p. 7) These actions can take the form of technological, economic, institutional, regulatory, ecosystem-based, informational, and social measures but are also usually constrained by the results of past decisions or the current political landscape.(Jorgenson et al. 2019) What complicates taking up efficient action to react to climate change even further is the well-established fact that while the drivers of climate change are mainly international and global, the effects of it (as well as the effects of some mitigation or adaptation efforts) are experienced locally and so very differently by different communities around the world.

Correspondingly, the IPCC observes “progress in adaptation planning and implementation across all sectors and regions, generating multiple benefits”(IPCC 2022b, p. 22); however, this has been distributed unevenly. Moreover, an “immediate and near-term climate risk reduction” is perceived to be largely prioritized and, as such, is reducing the opportunity for transformational adaptation. (IPCC 2022b, p. 22) While options for future effective adaptation actions reducing risks to people and nature exist, the feasibility of their implementation "differs across sectors and regions,"(IPCC 2022b, p. 22) which weakens the overall picture. The IPCC also warns that effective solutions need to be "integrated, multi-sectoral, and addressing social inequities."(IPCC 2022b, p. 23) While the assessment is thus not wholly negative, significant progress can be made if what the IPCC terms "soft limits" to adaptation efforts are addressed. These limits constitute primarily *financial, governance, institutional and policy constraints* to efficient adaptation actions. This is why the next section of the thesis will investigate the global governance landscape and its handling of climate change and affiliated risks.

2. Global Governance

2.1 General trends in global governance

The term global governance evades an exact, generally agreed-upon definition, (Floyd 2015) but it is an increasingly important and used concept. It can indicate, for instance, "any form of creating or maintaining political order and providing common goods for a given political community on whatever level," (Bulkeley, Newell 2015, p. 11) however for the purposes of this thesis, which focuses on a common problem – climate change, the conceptualization of this term of will be based on the definition of the EU Institute for Security Studies stating that the global governance is *"the collective management of common problems at the international level.*" (European Union Institute for Security Studies 2010, p. 11)

It is not only the impacts and risks of climate change that are becoming increasingly intricate and more difficult to manage, but overall, the number of issues on the international agenda rises, and so do their complexity and interconnectedness. Moreover, the rapid globalization and the shift to a multipolar world further contribute to the complexity of global governance. The main effects of globalization observed by scholars in connection with global governance are: i) *the economic interdependence* taken up to another level mostly due to the rise of emerging powers; ii) *the interconnected nature of the challenges* on the international agenda; and iii) *the interwoven domestic and foreign challenges*, which means that the domestic politics significantly limits the room for negotiating international compromises and enabling efficient international cooperation to address these challenges. (European Union Institute for Security Studies 2010)

In concrete terms, the shift of power towards new emerging powers also signifies more suspicion of current institutional arrangements, as they are often perceived by countries like China, India, or Brazil to favour established powers and so the “legitimacy and credibility of the United States (US) and the European Union (EU) as political leaders is openly questioned.”(European Union Institute for Security Studies 2010, p. 25) However, the power on the global stage is not shifting only towards new emerging states but also towards non-state actors. While many global challenges cannot be effectively addressed by individual nation-states alone, even when acting together, they are not the only stakeholders in the game. Non-state actors can often possess better expertise, resources and legitimacy to address some of the most pressing challenges than national governments.(European Union Institute for Security Studies 2010, p. 40) Among others, the above-mentioned IPCC constitutes an excellent example of non-state actors providing essential sources of knowledge and expertise. With these abilities of non-state actors to “reframe issues and mobilise publics”, the trend of them contributing to the setting of the international agenda is expected to continue as well as the increasing importance of so-called hybrid, public-private partnerships (PPPs) in the global governance – especially in the field of sustainable development. (European Union Institute for Security Studies 2010, p. 41)

Overall, the pressure on the global governance framework is enormous, and the current performance does not seem to be satisfactory. To be able to address the current and future global challenges efficiently, it seems necessary to undertake far-reaching institutional reforms and innovations. Especially with climate change “trespassing the boundaries of environmental politics” and “becoming the subject of the global political, economic and security debate”, global cooperation cutting across these and other domains is needed. (European Union Institute for Security Studies 2010, p. 19) As suggested above, non-state actors can also play a significant role in this process as “old, and new policy domains would benefit from a greater engagement of non-state actors as partners in standard-setting, monitoring, and verification and as providers of scientific advice and field experience.” (European Union Institute for Security Studies 2010, p. 43) Before looking into possible future scenarios, however, an overview of the evolution and current state of global climate governance will be provided.

2.2 Global climate governance

2.2.1 Historical overview

Climate change became visible first as a scientific and environmental issue and therefore has been, for the most part, addressed by public officials as a "manageable, future-tense, environmental matter."(Werrell, Femia 2019, p. 12) The global framework for climate change governance, the relevant actors and institutions have been evolving since the 1980s. Already the first World Climate Conference, organized in 1979 by the World Meteorological Organisation (WMO), has identified "the burning of fossil fuels, deforestation, and changes in land use as the drivers of rising atmospheric carbon dioxide concentrations and, consequently, climatic changes" and has called for global cooperation.(Luomi 2020) The IPCC was then established in 1988 by the WMO and the United Nations Environment Programme (UNEP) to "provide policymakers with regular scientific assessments on the current state of knowledge about climate change."(*History — IPCC* 2022) The First Assessment Report by the IPCC was produced in 1990 and constituted the scientific basis for the negotiation of the United Nations Framework Convention on Climate Change (UNFCCC).(Zillman 2009) The UNFCCC was subsequently adopted in 1992 by 154 countries at the UN conference on Environment and Development (UNCED) in Rio and entered into force in 1994. While its declared ultimate objective was the "stabilisation of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (United Nations 1992, sec. 2) the adoption itself was according to some scholars (Gupta 2014) helped by the "absence of any legally binding targets to reduce GHG emissions and intentionally ambiguous wording."

The successful negotiation of the UNFCCC was the first major milestone in the history of climate diplomacy as it "provided a framework for global action on the issue."(Bulkeley, Newell 2015, p. 22) The goal of avoiding "dangerous anthropogenic interference with the climate system" (United Nations 1992) was evident; however, it was also acknowledged that not everyone had the same share in contributing to this problem. The UNFCC was thus working with the principle of "common but differentiated responsibilities" (CBDR). The countries included in Annex I of the Convention – 40 developed industrialized countries and economies in transition - were required to reduce their GHG emissions to 1990 levels by the year 2000 and also further agreed to "provide financial and other forms of support to developing countries for climate action,"(Luomi 2020) as these Annex II countries were "not yet in the position to assume their own obligations" (Bulkeley, Newell 2015, p. 22).

After the UNFCC entered into force, the main pressing question was how to truly and efficiently realize the commitments contained in it. (Bulkeley, Newell 2015, p. 22) It was recognized that binding commitments were indeed necessary to reduce GHG emissions, and negotiations regarding this issue began at the first meeting of the Conference of the Parties (COP) in 1995 in Berlin.(Bulkeley, Newell 2015, p. 20; Luomi 2020) Two years later, more than 150 countries signed the Kyoto Protocol, setting a time-bound limit on industrialized countries' GHG emissions – they were to be reduced by an average of 5.2 per cent below 1990 levels (during the period 2008 - 2012).(Bulkeley, Newell 2015, p. 21; Luomi 2020) However, for the Protocol to enter into force, it had to be ratified by 55 countries that account at least for 55 per cent of total Annex I countries' GHG emissions. This process took seven more years, and while the Kyoto protocol finally entered into force after Russian ratification,[1] the US under President G. W. Bush announced in 2001 that they were withdrawing from the Protocol since their "economic competitors in the developing world were not required to reduce their emissions." (Bulkeley, Newell 2015, p. 23; Luomi 2020) Despite the non-ratification by the US, the Protocol survived, and the Marrakesh accords from COP 7 in 2001 worked out the final rules and procedures for the Protocol.(The Conference of the Parties 2001) The Kyoto protocol, as a "mitigation-centric, 'top-down' instrument" (Luomi 2020) did introduce not only an "absolute cap on emissions to be divided among developed countries" (Luomi 2020) but also set up an emissions trading scheme (ETS) and created a Clean Development Mechanism (CDM). (Bulkeley, Newell 2015, p. 22) The developed countries were also obliged to provide "new and additional financial resources to meet the agreed full costs incurred by developing country parties in advancing the implementation of existing commitment."(Bulkeley, Newell 2015, p. 24) The main burden of responsibility thus was still on the developed (Annex I) countries, and "Kyoto lacked references to even voluntary commitments by non-Annex I parties,"(Luomi 2020) despite the fact that the GHG emissions in developing countries were growing twice as fast as in the developed by the early 2000s. (Baumert, Herzog, Pershing 2005)

[1] which tipped the share of the emissions of ratified Annex I countries over the 55 per cent limit

From the early 2000s, the negative effects of ongoing climate change began to be felt around the world. (Luomi 2020) The IPCC Third Assessment Report warned about “shrinkage of glaciers, thawing of permafrost, later freezing and earlier break-up of ice on rivers and lakes, … declines of some plant and animal populations, and earlier flowering of trees, emergence of insects, and egg-laying in birds.”(IPCC 2001) The international community had to advance its efforts towards cooperation on the climate change issue and the UNFCCC established the Adaptation Fund (AF) in 2001 to “finance concrete adaptation projects and programmes in developing country Parties to the Kyoto Protocol that are particularly vulnerable to the adverse effects of climate change.” (*Adaptation Fund | UNFCCC* 2022) In 2004 a Buenos Aires Programme of Work on Adaptation and Response Measures was agreed upon at COP 10. (Bulkeley, Newell 2015, p. 21) In the second half of the 2000s, the discussion circled around the question of whether also some developing countries should commit to some more binding GHG emissions reduction targets. The Bali Action Plan adopted at the COP 13 in 2007 used for the first time the language of developed and developing countries. (*Bali Road Map Intro | UNFCCC* 2022; Luomi 2020) The Plan called for a *long-term goal for emissions reductions*; nationally appropriate *measurable, reportable, verifiable mitigation commitments* (thus including developing countries taking up their appropriate share); *enhanced adaptation; action on technology development and transfer*; and *financial resources and investment* to support the afore-mentioned efforts. (The Conference of the Parties 2007; Bulkeley, Newell 2015, p. 24)

Leading up to the COP 15 in 2009 in Copenhagen were the expectations that a new agreement would be adopted. (Luomi 2020) However, the process was complex, and the parties were struggling to find an agreement. When an agreement reached behind closed doors was presented to the plenary, a number of developing countries felt excluded and decided to block its formal adoption, and in light of the 2008 financial crisis, the search for compromise did not fully succeed. (Luomi 2020) The outcome was thus just a “taking note” of the Copenhagen Accords, and the agreement had “no legal force, no long-term global emissions goal, and no mechanism to ensure national pledges would add up to sufficiently ambitious global reductions in emissions.” (Luomi 2020) On the other hand, the Accord still presented some “important legacies”, and “with its 'bottom-up' approach to pledges, it also set the basis for the Paris Agreement.”(Luomi 2020)

At COP 16 in 2010, the Cancun Agreements were adopted. They elaborated on the Copenhagen Accord and restored “faith in the multilateral climate change process.” (Luomi 2020) Key elements here included “the target to hold the rise in global average temperature to below 2 degrees Celsius and voluntary unilateral climate action pledges by developed and developing countries towards 2020.”(Oberthür, Groen 2020, p. 804)

The negotiations for a new agreement by 2015 then started in 2011. In 2012, the countries agreed on a second commitment period for the Kyoto Protocol (2013–2020) through the Doha Amendment (Conference of the Parties 2012), and negotiations were intensifying with a significant breakthrough coming when the world´s two largest emitters, the US and China, announced a “joint commitment to reaching an ambitious 2015 agreement that reflects the principle of common but differentiated responsibilities and respective capabilities “in light of different national circumstances.”(Luomi 2020) The 2015 Agreement was then negotiated in Paris at COP 21.

The Paris Agreement constituted “the first multilateral climate change agreement that places legally binding obligations on emission reductions on all countries”(Luomi 2020) and provided “a renewed global framework for multilateral climate governance beyond 2020.” (Oberthür, Groen 2020, p. 804) It recognized that as national economies evolve, so too do their national responsibilities and capabilities regarding emission reduction or limitation targets. (United Nations / Framework Convention on Climate Change 2015) The agreement echoed the “bottom-up system” of nationally determined contributions that shall be communicated by each Party every five years,(United Nations / Framework Convention on Climate Change 2015, sec. 4) and as such, even developing countries are encouraged to move “towards economy-wide targets,” (United Nations / Framework Convention on Climate Change 2015, Art. 4) while the developed countries are to maintain the leadership role in finance. (United Nations / Framework Convention on Climate Change 2015, Art. 9) Both 1.5°C and 2°C thresholds are referred to in the Agreement, as well as reaching “global peaking of greenhouse gas emissions as soon as possible” and then achieving “a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century”. (United Nations / Framework Convention on Climate Change 2015, sec. 4) It was, however, also argued that “the universality of the Paris Agreement came with a cost to its effectiveness.” (Luomi 2020)

The Paris Agreement entered into force in 2016; however, the next year the US President Donald Trump announced the intent to withdraw from the Agreement and did so in November 2020. Unlike the second world´s top emitter, the first one – China – announced in 2020 that it "would aim for carbon neutrality before 2060", which was a major increase in ambition. After the presidential elections, the new US President Joe Biden stated that the US would re-join the Paris Agreement, which formally happened at the beginning of 2021.

The historical overview makes thus clear that from an issue raised at first mostly by scientists and environmentalists, the governance of climate change emerged as a global political issue that eventually received recognition by important international stakeholders. After its adoption in 1992, the UNFCC regime advanced a lot – it has "grown in weight, complexity, and participation." (Luomi 2020) Throughout the years, the collective global efforts dealt especially with the dilemma of how to differentiate the responsibilities of different countries with a different historical share in emitting the GHG and different current capacities to adapt and mitigate. At the same time, the question was how to create a regime that is efficient enough but also attractive enough for universal participation, and that manages to still keep the major global emitters on board while placing the biggest share of responsibility on them without leaving other countries at the table voiceless. (Luomi 2020) From putting the responsibility to reduce their GHG emissions only on developed countries at first, the negotiation finally led to even developing countries admitting that they need to "accommodate a more dynamic interpretation of the concept" (Luomi 2020) and reduce their GHG emissions according to their "different national circumstances."(United Nations / Framework Convention on Climate Change 2015)

During the climate governance negotiations, the governments often organized themselves into blocks and negotiating coalitions - like the OPEC grouping, Alliance of Small Island States AOSIS, or the G77 (comprising of less developed countries and China) – to advance their own goals and priorities and apart from deepening cooperation and stricter, finally also legally binding, obligations they also agreed on increased use of flexible market mechanisms to achieve emissions reductions.(Bulkeley, Newell 2015, pp. 18–20)

Despite the decades of developing the international regime, however, the current state of global climate governance is far from perfect or even satisfactory. Not only that goals that are set even higher would often be needed, but also, the current obligations do not seem to be fulfilled as expected. Civil society groups remain frustrated about the lack of progress – for instance, after the 2019 Chile-Madrid COP 25 that did not arrive to finalize the rules for carbon markets under the Paris Agreement even after "a year of unprecedented mobilization by the Fridays for Future movement." (Luomi 2020) It also remains unclear whether the global COVID 19 pandemic will help or hinder the process of agreeing on more ambitious climate goals and reaching them.

The overall picture would, however, be incomplete if some attention was not paid to non-state and subnational actors – including *businesses, cities, states, trade unions, and human rights and gender activists* – as they are becoming exponentially engaged in the process of governing climate change. (Luomi 2020) This fact is also acknowledged by the Marrakech Partnership for Global Climate Action, which formally recognizes the need for "collaboration between governments and the cities, regions, businesses and investors that must act on climate change." (*Marrakech Partnership for Global Climate Action | UNFCCC* 2022)

The intricate and complex process of governing climate change is thus, according to Bulkeley and Newell, further complicated by i) *the multiple scales of political decision-making involved;* ii) *the fragmented and blurred roles of state and non-state actors*; and iii) *the deeply socially and economically embedded nature of many of the processes that lead to emissions of GHG in everyday processes of production and consumption.* (2015)

Multinational corporations and consumers, as well as local and regional governments, play a role in the process. Moreover, the GHG emissions are also "shaped by processes and actors operating across national boundaries and only partially within the purview of the state itself," which means that the national government "have to engage in a form of negotiation and cooperation with non-state actors" and are becoming increasingly dependent on this cooperation to be able to realize their goals. (Bulkeley, Newell 2015, p. 3) Climate governance thus takes place not only in the international arena but also on the national and subnational level, in transnational networks, and in private sector projects. (Bulkeley, Newell 2015, p. 13) As for the private sector, „the industry accounts for more than one third of the energy consumed worldwide and uses more energy than any other end-user in industrialized and newly industrializing economies", hence "the business has been cast simultaneously as the problem and the source of solution to climate change." (Bulkeley, Newell 2015, p. 88) To effectively face the climate change challenge, "a constructive business engagement with the climate issue" is thus also needed. (Bulkeley, Newell 2015, p. 88) Yet the central role of international institutions and nation-states still stands as it is they who make the decisions about overall targets and means of delivering them. (Bulkeley, Newell 2015, p. 105)

Central to making these decisions then is the interaction going on between science and policy – especially in the work of the IPCC. While it is "an expert body made up of the world´s leading climate scientists," its work has not been purely above politics, (Bulkeley, Newell 2015, p. 26) which points to Michel Foucault´s observation that "*power and knowledge directly imply one another; that there is no power relation without the correlative constitution of a field of knowledge that does not presuppose and constitute at the same time power relations*." (Turkel 1990, p. 179) The presentation of scientific knowledge related to climate change does not happen above the political process but within it. It is thus necessary to recognize that despite the appealing idea of objective science, the nature of power and knowledge is interwoven and "in practice, the worlds of science and politics overlap." (Bulkeley, Newell 2015, p. 28) This complex relationship between science and politics will also be discussed in the subsequent chapters.

On the whole, climate governance is an immensely complex process happening on different levels, influenced by many stakeholders, and it also pertains to essentially all areas of political, economic and social life. With regard to the urgent nature of the climate change problem, new and more efficient ways to help this process are thus still needed, and it is the objective of this thesis to examine some of those in the next sections. However, first, a context will be provided for how the climate issue is being progressively framed as pressing global problem and how it is being connected to the concept of security, thus highlighting the urgency to act timely.

2.2.2 Governance and climate security

Climate change has been labelled as "a risk unprecedented in human history", "a challenge to human civilization and global governance that is unique to our time", (Werrell, Femia 2019, p. 5) or "a global environmental mega-crisis." (Warner, Boas 2017, p. 207) A growing body of literature analyses the threats to different levels of security caused by climate change. These threats could be both direct and indirect as climate change can be directly affecting security by "decreasing the readiness of security institutions" as it alters "their operational environment in significant ways" or indirectly "exacerbating stresses to the critical resources that underpin national and global security … including water, food, and energy systems." (Werrell, Femia 2019, p. 6) In the latter case, climate change is commonly referred to as "a threat multiplier" in the global security landscape. Specific examples of direct threats can include the island nations and sea-level rise, while more indirect threats are for instance "climate-driven stresses on natural resources" that can significantly diminish the nation's capacity to govern. (Werrell, Femia 2019, p. 6) This threatens both lives of people and also the whole international security governance system. Already the Fourth Assessment Report by the IPPC in 2007 stressed the link between climate change and security.[2] In 2009 then, the UN General Assembly adopted for the first time a "non-binding resolution on climate change as an international security problem." (Behnassi, McGlade 2017, p. 5) The following Fifth Assessment Report by the IPCC examines "both direct and indirect impacts [of climate change] on human systems, such as human health, food security and security of societal conditions" and warns, among other things, about a future that would amplify risks for "food and human security." (IPCC 2014b)

However, despite climate change entering the international security debate and being increasingly framed as a security issue, the UN and the IPCC constitute just one of the many stakeholders, and there is no generally agreed-upon definition of climate security while the debate goes on about whether possible securitization of climate change brings more advantages or risks. Rita Floyd observed the tendency of different security organisations to define climate security in different terms and thus to present competing ideas i) *on the source of the threat*, ii) *on who is to be defended*, iii) and on *who the most appropriate provider of security is.* (Floyd 2015, p. 123)

Floyd examines the discourses of the UN, the North Atlantic Treaty Organisation (NATO), the Organisation for Security and Co-operation in Europe (OSCE), the European Union (EU), and the US and identifies three competing frames or discourses of climate security. (Floyd 2015) First one is *climate security as a source of violent conflict*. In this case, attention is paid to the scarcity of renewable resources and also to the possible crisis linked to climate refugees. The second discourse highlights *climate change as a threat to national security* and is concerned

[2] namely food security in Africa and Latin America, water security in Australia and New Zealand, or energy security (IPCC 2007)

primarily with the threats to military bases and the danger of the military being unable to provide national security adequately. The last detected discourse, with the broadest definition of climate security, stresses *climate change as a threat to an individual*. According to this discourse, climate change can have "such serious negative consequences for human security that its destructiveness is comparable to that of war, and therefore should be treated equally seriously." (Floyd 2015, p. 125) Human security being defined as "*first, safety from such chronic threats as hunger, disease and repression; and second … protection from sudden and hurtful disruptions in the patterns of daily lives.*" (UNDP 1994, p. 23) What differs in these discourses are thus referent objects (nation-states, military readiness and human beings) and the interpretation of the threat (from war to nonviolent long-term environmental degradation triggered by climate change). (Floyd 2015)

While it is thus evident that no one definition of climate security is universally accepted, the question remains whether climate security as a framework for the governance of climate change can be indeed beneficial and whether it can advance the calls for urgent action. Especially since the efforts to tackle climate change are still failing and handling the issue as a security issue might possibly bring about a change and correct the "mismatch between the analysis of the severity of climate security threats and the political, diplomatic, policy and financial effort countries expend to avoid the attendant risks." (Behnassi, McGlade 2017, p. 16) Many scholars investigate this process, and for instance, Maria Julia Trombetta confirms that "attempts to consider environmental problems as security issues are transforming security practices," (Trombetta 2008, p. 585) the WBGU Report (2008) "makes it clear that climate policy is preventative security policy" and speaks about the need of developing an ambitious one over the next 10-15 years, and Dalby believes that climate change does indeed have consequences on humans and planet globally and that we might need to think about the security in relation to climate change in a new way. (Dalby 2013)

One argument for making climate change a security issue is that the challenges it poses are enormous and must be appropriately managed, which would be best done by "preventive and security-sensitive responses." (Behnassi, McGlade 2017, p. ix) It is also argued that climate change framed in security terms can "act as a stimulus to international cooperation and convergence in tackling common climate-change challenges." (Behnassi, McGlade 2017, p. 4)

Mabey et al. then believe that a “peaceful management of even moderate climatic changes will require investment in increased resilience in national and international security and governance systems.” (Behnassi, McGlade 2017, p. 16) Mohamed Behnassi also argues that “climate security allows for climate change to be characterised as a ‘threat’ facing all nations, organizations and individuals”, and therefore, according to the Japanese government, “climate change policy and governance can be granted a higher priority at a national level.” (2017, p. 19) The securitization of climate change can thus “generate expectations of positive change, due to the fact that security constitutes a matter of high politics par excellence, and given the possible positive advantages of managing the issue through a security framework.” (Behnassi, McGlade 2017, p. 18) The concept of climate security thus recognizes the need for urgent action and can play “a facilitative role with respect to negotiations concerning the future climate regime.” (Behnassi, McGlade 2017, p. 19) Brown et al. believes that “a ‘securitized’ climate debate might be able to marshal sufficiently compelling arguments to encourage the politicians to do something about reducing emissions and investing (carefully) in adaptation.” (2007)

On these claims also rests a newly forming “Responsibility to Prepare and Prevent (R2P2)” framework – “A Climate Security Governance Framework for the 21st Century.” (Werrell, Femia 2019) It was developed by the Center for Climate and Security and was first presented before the UN Security Council in 2017. (Sikorsky 2021) It is based on the premise that “if governments and intergovernmental institutions have (or can develop) the tools to anticipate climate risks to security, it follows that they have a responsibility to mitigate those risks.” (Werrell, Femia 2019, p. 20) The framework stresses the fact that “though the risks are unprecedented, our foresight is unprecedented as well,” however it also acknowledges that “while there is an unprecedented amount of climate change and climate security data available, and an unprecedented ability to anticipate climate change risks,” transferring and communicating this information in a way that will help mitigate those risks remains still a significant challenge. (Werrell, Femia 2019, p. 16)

Therefore, both in public discourse and the literature on the topic, climate change and security have been increasingly linked together in recent years, even though a full, global securitization of climate change, as outlined by the Copenhagen School, has not taken place yet. (Boháčová 2021) Still, climate change is now indeed considered to be a security topic, and framing climate change in terms of security highlights the need for urgent action. According to the R2P2 framework, we have an obligation to "harness scientific and technological tools to better predict, monitor, and prepare for a range of plausible future scenarios." (Werrell, Femia 2019, p. 5) Some of the biggest challenges of today, including demographic, economic or technological shifts, can both contribute to "an era of unprecedented risks" but also to the "unprecedented foresight" and management of those risks. However, the technological possibilities and capacities by themselves do not automatically lead to better preparedness and more efficient dealing with the problem of climate change. That is why the next chapter will introduce the concept of Big Data and investigate the possibilities and challenges of governing climate change more efficiently with Big Data tools.

3. Big Data

3.1 Introduction to Big Data

Big Data is still a relatively new concept that lacks one precise, all-encompassing, universally agreed-upon definition. That, however, does not prevent an increasingly growing popularity of the term that is closely associated with the exponential growth of the amount of data we produce and collect every year.

The data can now also be increasingly collected from new sources such as internet clicks or machine sensors, especially as "since 2008 the number of things connected to the internet has exceeded the number of people on earth." (Hansen, Porter 2017, p. 9) The amount of data we produce doubles every year and it was estimated in 2017 that in 10 years there will be 150 billion networked measuring sensors, which is twenty times more than people on Earth, and so the amount of data will double every 12 hours. (Helbing et al. 2019) Another estimate suggests that the Internet of Things will generate more than 400 zetabytes of data by 2018, which will be more than 50 times the amount of data centre traffic in 2014.(Cisco 2014)

The amount of data available today is thus ever-expanding, and at the same time, the artificial intelligence (AI) field is also advancing at an impressive rate, with the progress in machine learning contributing to the automation of data analysis. (Helbing et al. 2019) The data have not been growing only in size but also in complexity, and as new algorithms are developed to deal with diverse data from different sources, the field of data science firmly enters the mainstream of scientific debate. (Faghmous, Kumar 2014)

With Big Data and data analysis becoming the "buzzwords" of the present time, Mayer-Schönberger and Cukier identified three shifts caused by Big Data in the way we analyse information "that transform how we understand and organize society." (Mayer-Schönberger, Cukier 2014, p. 12) Firstly, we can analyse much more data; secondly, with more data, we can loosen up our desire for exactitude and gain more insight on the macro-level; and lastly, we now focus more on patterns and correlations instead of causality. Not only do the (Big) data now permeate almost all aspects of our everyday lives, but they also change how we analyse issues and problems that constitute the subject of various disciplines, including political science.

Mayer-Schönberger and Cukier also stress the fact that "technology has reached a point where vast amounts of information often can be captured and recorded cheaply." (Mayer-Schönberger, Cukier 2014, p. 101) We can thus frequently collect data passively, data is available at a lower cost than before, and data values do not diminish when used since they constitute "non-rivalrous good." (Mayer-Schönberger, Cukier 2014, p. 101)

Similarly, Helbing et al. highlight the interesting new possibilities afforded by Big Data "as more data become less costly and technology breaks barriers to acquisition and analysis, the opportunity to deliver actionable information for civic purposes grows." (Helbing et al. 2019)

3.2 The conceptualization of Big Data - The Vs of Big Data

While there is more or less a general consensus on the revolutionary potential of Big Data, an agreement on the definition of this concept is, as already mentioned, not so straightforward. Big Data do not just mean „a lot of data," it also means fast and automatic generation of a high volume of information and delegation of data collection to an automatic device. (Giardullo 2016) The scholarly discussion about what constitutes all the unique features of Big Data that distinguish them from conventional data has still not reached one clear conclusion; however, Ekbia et al. identified three main categories of definitions in the current literature. (2015)

One category of literature, which Ekbia et al. termed *"product-oriented,"* emphasizes the size, speed, and structure or composition of Big Data. The *"process-oriented"* category then focuses more on the "processes involved in the collection, curation, and use of data," stressing the novelty of processes through which Big Data is stored, managed, aggregated or analysed. Lastly, the "*cognition-oriented*" category of literature highlights "the way human beings, with their particular cognitive capacities, can relate to data" and scrutinizes the challenges posed by Big Data to human cognitive limitations. (Ekbia et al. 2015)

To elaborate on the concept of Big Data in more detail and to capture all the features that the above-mentioned strands of literature touch upon, we can refer to the "Vs of Big Data" that are usually used to describe Big Data in a comprehensive way in both academic and business environment. The concept of "Vs of Big Data" has also evolved over time, and while it started with just 3 Vs, nowadays, it can include up to 10 or 12 Vs. The original 3 Vs were coined by the Gartner group and stand for: ***volume, variety*** and ***velocity***. (Jagadish 2015, p. 49)

> The ***volume*** refers to the massive amount of data collected, which is likely to continue to rise. (J. Mazzei, Noble 2020, p. 3)
>
> The ***variety*** implies the diverse structure and forms of data we use and analyse, since nowadays the data does not take only a numerical form, but we also deal with raw, semi-structured, and unstructured data from many diverse sources (web pages, web log files, search indexes, social media forums, email, documents, sensor data, images, video footage, GPS signals, etc.)
>
> The ***velocity*** then captures "the rate at which the data arrives, is stored, and retrieved for processing." (J. Mazzei, Noble 2020, p. 4)

Gradually the concept of Big Data evolved and more "Vs" were added by scholars – at first with the addition of two other characteristics, the concept of 5V was introduced, but now the concept has expanded up to 12 characteristics in total.

> IBM pushed for adding a 4th V – ***veracity,*** (Jagadish 2015, p. 49) referring to the data quality and trustworthiness of the data. (J. Mazzei, Noble 2020, p. 4) This trustworthiness of the data is connected to "the provenance or reliability of the data source, its context, and how meaningful it is to the analysis based on it." (Firican 2017)
>
> Completing the 5 Vs characteristics of Big Data then is the ***value*** (Sebestyén, Czvetkó, Abonyi 2021, p. 4) that relates to "how data can be leveraged for benefit in the form of financial gain or some other outcome of organizational import, such as operational efficiency or knowledge creation." (J. Mazzei, Noble 2020, p. 4)

The additional characteristics of Big Data that caught the attention more recently include:

the ***Variability***, that is "the changing nature of Big Data," (J. Mazzei, Noble 2020, p. 4) or "the inconsistencies of the data flow." (Khan et al. 2018, p. 2)

the ***Visualisation**,* which points to the challenge of visualising Big Data (due to limitations of in-memory technology and poor scalability, functionality, and response time), the need to find different ways than traditional graphs to represent such data, (Firican 2017) and also to the requirement to make these data comprehensible in a manner that is easily understandable. (J. Mazzei, Noble 2020, p. 4)

the ***Validity**,* which is similar to but ultimately different from veracity (Khan et al. 2018, p. 2)[3], focuses on how accurate and correct the data is for its intended purpose. (Firican 2017)

the ***Viability**,* referring to the possibility of the data to be analysed in a manner to make it decision-relevant for the stakeholder (J. Mazzei, Noble 2020, p. 4) or the capability of Big Data "to be live and active forever, and able for developing, and to produce more data when needed." (Khan et al. 2018, p. 4)

the ***Volatility*** indicates the life duration of data - that is, for how long the data is valid and for how long it should be stored. (Khan et al. 2018, p. 3) Attention needs to be paid to the volatility mainly due to the velocity, variety and volume of Big Data (Firican 2017) since limitations to storage capacities still exist and we need to determine at what point is data no longer relevant and applicable to the current analysis, and at the same time while for some specific sources, the same data will always be there; for others, this is not will be the case. (Khan et al. 2018, p. 3) Ultimately, "understanding what data is out there and for how long can help us to define retention requirements and policies for Big Data." (Khan et al. 2018, p. 3)

the ***Vulnerability*** proposed by some stresses the new security concerns brought about by Big Data, mainly the possibility of a "Big Data breach" (Firican 2017) and in general, people's concerns about their personal data. (Sheetal 2017)

[3] Since a data set may not have any veracity problems but may not be also valid if not properly understandable.

the ***Viscosity*** is also suggested by some, and refers to the complexity of management of Big Data (Khan et al. 2018, p. 3) or "the resistance to flow in the volume of data" (Wang 2012) stemming from the fact that the data tend to come from different sources and the linking, matching and transformation of this data is intricate.

As more and more Vs are being added, some scholars endorse some characteristics as crucial in Big Data conceptualisation while others highlight different ones. However, in the literature, there seems to be a general consensus at least on the fundamental 5 Vs, which is why this thesis will work with the conceptualization of Big Data based on the 5 Vs. While it is true that the additional characteristics are also valid and help to clarify the concept of Big Data, they are even more contested than the original 5 Vs. Table 1 and Table 2 provide a summary of the characteristics of Big Data introduced in this sub-chapter.

Table 1: 5 Vs-concept of Big Data

Characteristics	Description
Volume	the massive amount of data collected
Variety	the diverse structure and forms of data
Velocity	the rate at which the data arrive, are stored, and retrieved for processing
Veracity	the data quality and trustworthiness
Value	the benefits and value Big Data can be converted into in a specific context

Table 2: Additional characteristics of Big Data endorsed by some scholars

Characteristics	Description
Variability	the changing nature of Big Data
Visualisation	the need for and the specifics of visualising Big Data
Validity	the accuracy and appropriateness of Big Data for intended purposes
Viability	the possibility of the data to be analysed in a manner to make it decision-relevant for the stakeholder; the capability of Big Data to be live and active forever, and able to produce more data when needed
Volatility	the life duration of data
Vulnerability	the security concerns brought about by Big Data, the possibility of a "Big Data breach"
Viscosity	the complexity of management of Big Data, the resistance to flow in the volume of data

3.3 Dilemmas and paradoxes of Big Data

Big Data defined by their volume, variety, velocity, veracity, and value; however also raise many questions and dilemmas. As any tool or technology, they have a dual character and can serve good or bad purposes – they can be "empowering, liberating, and transparent, yet also intrusive, constraining, and opaque." (Ekbia et al. 2015, p. 1540)

One of the legal and ethical dilemmas increasingly attracting the attention of scholars, but now also the general public, is the issue of *privacy* protection, which becomes progressively harder. (Ekbia et al. 2015; Mayer-Schönberger, Cukier 2014) Policymakers today must thus address the question of the scope of individual privacy and the role of intellectual property protection. (Ekbia et al. 2015, p. 1535) In the words of Hansen and Porter, the *identity paradox* of Big Data stems from the fact that they can create "new opportunities and possibilities for avoiding unpleasant risks," but at the same time, they enable the identification of processes and people in new ways and as such can threaten an individual or collective identity and privacy. (2017, p. 5)

Similarly, the opacity of Big Data raises the question of *transparency*, which is also one of the paradoxes of Big Data identified by Hansen and Porter. While Big Data could make the world more transparent and predictable, "the machine-driven production of data, and the tools and techniques to make sense of them, are created by highly specialized people working in relatively closed government or commercial organizations and with methods that are not open to traditional scientific scrutiny." (Hansen, Porter 2017, p. 5) Moreover, the scale at which Big Data operate goes beyond our ordinary understanding and "the basis of an algorithm´s predictions may often be far too intricate for most people to understand," so to trace the data analysis performed becomes quite difficult and we face the problem of dealing with "black boxes that offer us no accountability, traceability, or confidence." (Mayer-Schönberger, Cukier 2014, p. 179) This is highly problematic, especially in the context of penalties based on propensities when Big Data predictions can determine punishments for people even before they acted (Mayer-Schönberger, Cukier 2014, p. 150) without offering a clear and understandable explanation of how such a conclusion was reached. Helbing et al. thus warn that the Big Data technologies must be "compatible with our society's core values" and we should pay special attention to protecting the basic rights of citizens, and Zicari and Zwitter emphasize the need for Big Data Ethics. (Helbing et al. 2019)

Yet another paradox of Big Data is the paradox of *boundaries* as Big Data, similarly to climate change, trespass, especially the territorial, boundaries and demand greater openness for its most efficient extraction and use, (Hansen, Porter 2017, p. 7) however at the same time they create new boundaries along the lined of the ownership and control over Big Data and Big Data infrastructure. (Hansen, Porter 2017; Ekbia et al. 2015) Extensive resources, "only available to a select group of players," (Ekbia et al. 2015, p. 1539) are needed to collect and analyse Big Data, and these players can then "create new and stronger boundaries to deploy Big Data as a form of control or to create commercializable rights over some part of Big Data." (Hansen, Porter 2017, p. 8) The issue of boundaries is thus also connected to the *paradox of power* that points to the possibility of increased accountability, serving the less powerful, thanks to Big Data, however at the same time, the already mentioned ownership, control, and knowledge produced by Big Data also contribute to asymmetric relationships and power imbalances between those who collect, store, and mine large quantities of data, and those whom data collection targets. (Hansen, Porter 2017)

Lastly, Hansen and Porter also mention the *paradox of objects* that refers to "a growing preeminence of quite autonomous objects, which displace and sometimes work against human cognitive capacities." (Hansen, Porter 2017, p. 7) There is a seemingly autonomous machine-driven process ongoing, yet at the origin of this process is the work and action of humans that, however, is not necessarily evident, and so the powers at work tend to be invisible behind seemingly autonomous technology.

3.4 Theory and Big Data

These dilemmas and paradoxes also raise the question of theory and Big Data. On the one hand, some authors declared Big Data to constitute the "end of theory" in doing science since "data would speak for themselves when present in sufficiently large quantities."(Anderson 2008; Giardullo 2016; Mayer-Schönberger, Cukier 2014) On the other hand, many also warned about connected methodological risks (Giardullo 2016) and the danger of presenting Big Data as the "silver bullet of modern research, where findings can be interpreted using a "theory-free" mindset." (Faghmous, Kumar 2014, p. 161) Faghmous and Kumar believe that there is a need "for theory-guided data science methods that blend the power of big data analytics with the caution of scientific theory and first principles" to gain valuable insight from Big Data. (2014, p. 162)

At the same time, if in a search for an applicable theory to examine the possibilities and challenges of the application of Big Data from social sciences perspective, the insights from Science and Technology Studies (STS) can help address some of the issues that Big Data raise, like the above-mentioned paradoxes of objects or boundaries and power.

The STS scrutinize the ways in which science and knowledge are socially embedded and produced and highlight the problem of taking technologies as finished products without considering the way in which they were produced and the power constellations and forces that were at play. (Harvard Kennedy School 2011) By trying to "open the black box of technology", the STS focus on how science is shaped by social interests (Felt 2017) and help to address relationships between humans and objects, considering "the entanglement of humans with non-human objects in social practices and socio-technical networks." (Hansen, Porter 2017, p. 7) While acknowledging the influence of technology on social development, the STS thus also highlight the influence flowing in the opposite direction that should also be addressed so that the powers at work do not remain invisible behind seemingly autonomous technology.

Nevertheless, despite the dilemmas and theoretical struggles connected to Big Data, they are being collected, analysed and put into action, and so they do need to be given attention in research as they present and bring many opportunities and changes in society, politics and the economy and we need a more comprehensive understanding of the drivers, barriers, and challenges to Bid Data applications.

3.5 The potential of Big Data

With the continuing technological advances and the certainty that "the amount of data will continue to grow, as will the power to process it all," (Mayer-Schönberger, Cukier 2014, p. 190) the claims that Big Data can radically alter the way our society works and that our society is at the crossroads between opportunities and risks appear more frequently. (Helbing et al. 2019) Helbing et al. are convinced that "the way in which we organize the economy and society will change fundamentally" and that "Big Data, AI, cybernetics and behavioural economics are shaping our society." (2019) Jagadish believes that Big Data "now impacts nearly every aspect of our modern society, including business, government, health care, and research in almost every discipline: life sciences, engineering, natural sciences, art & humanities." (2015, p. 49) Mayer-Schönberger and Cukier expect Big Data to change the nature of business, markets, and society, (2014, p. 15) and reshape "the way we live, work, and think." (2014, p. 190)

Big Data are increasingly being discussed in various circles – the number of academic publications and initiatives related to this topic is consistently growing, (Ekbia et al. 2015, p. 1524) as is the notion that Big Data are becoming a significant corporate asset. (Mayer-Schönberger, Cukier 2014, p. 16) Big Data has also been dubbed "the new oil" (Ekbia et al. 2015; Espinoza, Aronczyk 2021) for the immense potential they yield for commerce, innovation or social progress. (Helbing et al. 2019) As Big Data are gaining visibility even in social sciences, some even claim that they also help to overcome the division between humanities and computer sciences. (Giardullo 2016)

The question remains whether the potential of Big Data can be demonstrated in evidence-based decision-making processes not only in business settings, where the promissory rhetoric around Big Data resonates strongly (Giardullo 2016, p. 537) but also in policy settings. There is indeed growing popularity of Big Data in the world of politics. States and international organisations now work with Big Data in diverse spheres, (Helbing et al. 2019) and for instance, the defence sector is also increasingly using Big Data to become more efficient and more effective. (Holford 2017) There is also a recognition that Big Data "will become integral to understanding and addressing many of our pressing global problems," including tackling climate change through possibly better understanding what the most efficient and effective ways to adapt to and mitigate this process are. (Mayer-Schönberger, Cukier 2014, p. 190) The next chapter will thus focus on how specifically Big Data can help in more effective climate change governance.

4 Big Data and governing climate change

4.1 Big Data and governance

While Big Data have received considerable attention in recent years, their significance in relation to governance and global governance has received much less. (Hansen, Porter 2017, p. 3) In one of the few research papers on this topic, Krause Hansen and Porter argue that the special relevance of Big Data for global governance is twofold. First, "*Big Data can create automated* *forms of governance*" and second, "*Big Data are associated with new boundary issues that are not primarily territorial, but rather about access to and control of data.*" (Hansen, Porter 2017)

The debate about automated forms of governance again recalls the paradox of enhancing human capacities while, due to the increasingly independent role of algorithms, reducing human control at the same time. Moreover, it invokes the issue of the hidden powers at play, of those who "create and mobilize Big Data" and also the "taken-for-granted automated infrastructures" (Hansen, Porter 2017, p. 5) to which the attention is drawn by the Science and Technology studies.

The critique or even fear of automated governance appears especially in relation to automated decision-making when algorithms can be the basis for granting loans, setting insurance premiums, detecting tax evasion, money laundering, drug trafficking, smuggling, or terrorist activities (de Laat 2017) by stressing the issues of lacking transparency and possible bias. Some fear the possibility of "an automated society with totalitarian features" (Helbing et al. 2019) and some stress the need to establish clear governance frameworks for algorithmic transparency and accountability (European Parliamentary Research Service 2019). It is therefore critical for public institutions and governing bodies to also deal with the issues of transparency and bias, since transparency and accountability should thus justify to citizens how governmental power has been exercised even if the governance is automated. (Yeung 2018)

At the same time, the notion of boundaries evolves in the data and information age. Global governance itself involves "a rich and dense set of connections that span borders" and Big Data are "complementary to the development of dense relations across borders." (Hansen, Porter 2017, p. 9) Nevertheless, while helping to transcend some borders and boundaries and linking "knowledge, humans, and objects in novel ways that differ starkly from traditional state-centric models of international relations," Big Data also contribute to the creation of new boundary issues connected to the control over data and could be "harnessed by existing powerful actors," either states or also big companies, "to reinforce their own power and the institutional arrangements which sustain it." (Hansen, Porter 2017, p. 10)

The topic of Big Data in global governance is thus still very new and relatively little explored and Hansen & Porter (2017) mostly focus on the paradoxes of Big Data and social sciences scholars nowadays primarily raise many issues connected to Big Data in (global) governance that need to be investigated further. (Helbing et al. 2019) Nonetheless, the global governance landscape is undoubtedly evolving (Bulkeley, Newell 2015, p. 105) and as "Big Data become even more entangled in the knowledge production and circuits that are central to global governance" (Hansen, Porter 2017, p. 17) it is appropriate to look at both the risks and the opportunities that Big Data offers in this and outline what it needed from the adaptation community to maximize this opportunity" needs to be addressed context, and for the purposes of this thesis especially in the context of climate change.

4.2 Big Data and Climate change

The main „boost of overconfidence" regarding data-driven decision-making is visible mostly in business or economic environments, (McAfee, Brynjolfsson 2012) while "in social science, there is no such strong discourse." (Giardullo 2016, p. 537) Yet, the technological developments are transforming research not only in the natural but also in social sciences - improved climate models and predictive tools are now available, (Werrell, Femia 2019) and the question of "how Big Data can inform adaptation research and decision-making" (Ford et al. 2016) needs to be addressed.

According to the National Academy of Sciences of the USA, a "careful application of Big Data could revolutionize our understanding of how to manage the risks of climate change", and it also provides "an enormous and untapped opportunity to diversify our understanding of adaptation and inform decision-making." (Ford et al. 2016)

Similarly, Sebestyén, Czvetkó and Abonyi contend that Big Data and advances in data science and information technology enable the "integration of various disciplines and research outcomes" and thus help to integrate "the socio-environmental factors in the climate change models." (Illingsworth 2016) This integration is necessary for efficient policy and decision-making and effective climate change strategic planning as global climate change governance requires "complex models and sources of information." (Illingsworth 2016) The advantage the Big Data analysis, in comparison with traditional "small data" analysis, offers in relation to climate change is the possibility to systemise, process, evaluate, and harmonise heterogeneous data and information sources. (Illingsworth 2016)

As the connection between climate and social sciences is being discussed more regularly, it is acknowledged that “an interdisciplinary approach is essential in terms of the identification of almost every climate-related problem and development of their solutions.” (Illingsworth 2016) Big Data analysis enables an “integration and targeted systematization of scientific knowledge” (Pauliuk 2020), and a synthesis of quantitative and qualitative analyses and thus allows for examining the “complex relationship between human and natural processes involving social, political, geographic, and cultural context.” (Illingsworth 2016) As such, Big Data can contribute to a “better understanding of the complex issue, monitoring changes, supporting decision-making, and bringing about in-time interventions.” (Illingsworth 2016)

Still, while there is a consensus regarding the potential of Big Data “to make our economy greener in a more fundamental way,” (Editorial Team 2020) the application of Big Data in this context, especially at the global level, seems to be still in its infancy. Faghmous and Kumar claim that this could be due to “the complex nature of climate data” and the fact that “Earth is a complex dynamical system like none we have studied before,” so while Big Data´s application success has been celebrated in other fields “big data–induced progress within climate science has been slower.” (2014, p. 155)

4.2.1 Big Climate Data Sources

Nevertheless, vast amounts of data relevant for analysing climate change and informed decision-making regarding its governance already exist, and their amount continues to rise.

Firstly, state-of-the-art technologies provide an increasing amount of ever-more-accurate ***Earth observation Big Data***. According to the United Nations Office for Outer Space Affairs (UNOOSA), as of 2017, there were approximately 4,300 Earth-orbiting satellites, out of which approximately 380 were being used for Earth observation. (Werrell, Femia 2019, p. 8) “Petabytes of Earth observation data have been collected and accumulated on a global scale at an unprecedented rate”, and still more and more satellites are planned to be launched for various Earth observation missions. (Zhang, Li 2020a, p. 2) Moreover, satellites can be used in combination with drones or Unmanned Aerial Vehicles (UAVs) to monitor and collect data about changes in food and water supplies on land, and they can also monitor even conflict areas like South Sudan and Syria. (Werrell, Femia 2019, p. 8)

Secondly, ***climate model simulations*** also provide "a wide array of future climate scenarios, as well as real-time monitoring of current climatic changes", (Werrell, Femia 2019, p. 14) and the amount of data from these simulations is progressively rising. (Zhang, Li 2020a, p. 1) Their resolution is also continually increasing even though "increasing the resolution of climate models by a factor of two means about ten times as much computing power will be needed." (Zhang, Li 2020a, p. 1) A framework known as Coupled model intercomparison project (CMIP) has been one of the essential elements of climate science at present and big simulation data from various CMIP experiments have been largely used in the various IPCC assessment reports. (Zhang, Li 2020a, p. 3) While projections regarding local-scale climatic changes and ecological interactions are still permeated with uncertainties, global climate projections offer quite a clear picture of the future of global climate and could thus help with better planning for this future. While some uncertainties remain, Werrell and Femia are convinced that "our predictive capabilities regarding climate change are quite good." (2019, p. 8)

Lastly, also the ***data generated by the Internet of Things (IoT)*** can offer helpful insights for instance into the way markets works or consumers behave as almost every sector of our manufacturing and food production industries is covered by the IoT. (Editorial Team 2020)

4.2.2 Big Climate Data Applications

As suggested, the possible Big Data applications in the context of climate change and its governance are multi-fold, and this section will attempt to categorize the applications that are proposed in the literature while at the same time acknowledging that these are interconnected, and there are no clear-cut distinctions between the different categories.

Monitoring Behaviour, Perceptions and Social Attitudes

Firstly, Big Data can be applied to *monitor behaviours, perceptions and social attitudes*. As Big Data analytics enables the use of automatically collected real-time data, it could help monitor people's movements and examine the *dynamics of human mobility* in a changing climate for instance, by using anonymized records of cellphone use. (Ford et al. 2016) It could also help with *early warnings* and so enhance the capacity to *timely respond to climate change* by

employing the data collected from social networks[4] in internet search engines and so detect epidemics or areas affected by hazard events. (Ford et al. 2016)
Big data can also be employed to monitor how climate adaptation efforts actually affect perceptions and behaviour of people and through social media sentiment analysis they can provide insights into the opportunities to shape social attitudes. (Ford et al. 2016; Sebestyén, Czvetkó, Abonyi 2021)

Monitoring Markets and Supply Chains

Secondly, Big Data analytics can provide comprehensive *monitoring of markets and supply chains.* This can be helpful since for the markets to operate effectively, as much information as possible about the products[5] that are traded on them is needed. (Editorial Team 2020) By bringing transparency to global supply chains, an *improvement in social and environmental sustainability in supply chains* can be achieved. (Ramrayka 2018; Dubey et al. 2019; Hazen et al. 2016) An example of this approach is the Trase platform that connects independent data sources "to reveal the trade flows for commodities such as beef, soy and palm oil," i.e. mainly the commodities that pose a major risk to forests, and as such shows how exports are linked to agricultural conditions and enables a better understanding of the risks and identifying of the opportunities for more sustainable production. (Ramrayka 2018)
Zhang and Li also mention not only optimization of supply chain management, which may result in "significant energy saving and related carbon emissions reduction", but also efficient roadway network management and natural resource management, which is also mentioned by Song et al., (2017) that both can have significant impacts on the environment. (Zhang, Li 2020b)

Smart buildings, Energy and Smart cities

Thirdly, Big Data analytics present possibilities for *improved efficiencies in energy management and the building of smart buildings and cities.* It can "augment the informational landscape of smart sustainable cities", (Bibri 2018) or by coupling building sensors to smarter control systems, it can "form the basis of smart buildings." (Zhang, Li 2020b, p. 279) Also, through improved energy use efficiency and widespread implementation of low fossil-carbon energy

[4] This could include geotagged tweets, monitoring or recently uploaded photos of affected areas, or monitoring search queries related to climate-related diseases.
[5] like their origin and how they were produced

systems, Big Data can help with exploring the possibilities of smart cities and sustainable communities. (Zhang, Li 2020b; Sebestyén, Czvetkó, Abonyi 2021)

Carbon monitoring and Monitoring of natural conditions and changes

Lastly, Big Data can contribute to *carbon monitoring and monitoring of natural conditions and changes linked to climate change* and so enable more efficient interventions or informed decision-making.

By combining data captured via satellite imagery and artificial intelligence, Big Data analytics enables monitoring of forests and land use, (Ramrayka 2018) tracking animal conservation outcomes, (Schwartz et al. 2019) or monitoring of seasonal changes in climate change. (Manogaran, Lopez 2018) Big Data analytics can also determine soil conditions and humidity "to estimate energy consumption or greenhouse gas (Sebestyén, Czvetkó, Abonyi 2021, p. 17) emissions that enable optimal processes and interventions to be predicted," (Sebestyén, Czvetkó, Abonyi 2021, p. 17) or it can be the basis of so-called precision agriculture – "a farming management that is performed at the right time, right place, and appropriate intensity." (Zhang, Li 2020b, p. 275)

Some concrete examples of monitoring natural conditions and applying Big Data include the efforts of Pulse Lab Jakarta[6] that through its Vulnerability Analysis Monitoring Platform for Impact of Regional Events (VAMPIRE) platform "analyses satellite imagery and creates maps that incorporate anomalies related to climate and rainfall to help track slow-onset climate changes." (Folk 2021; Pulse Lab Jakarta 2022) or Manitoba Bioeconomy Atlas project, which created a web-based spatial inventory of biomass sources, so that biomass producers can optimally locate biomass refineries, and biomass consumers can source biomass and calculate costs. (Folk 2021; ISSD 2022) Furthermore, the Orbital Insights platform used geospatial analytics to help to track tree loss; (Orbital Insight 2022) the Planet Labs startup collaborated with California state to develop a satellite capable of detecting the "point source" of climate pollutants, monitoring leaks and other anomalies at specific locations; (Planet Labs 2022; Ramrayka 2018) or the US climate change think tank Woods Hole Research Center used a

[6] a joint effort between the UN and the government of Indonesia

satellite-based tool to create a global carbon monitoring map to "transform how the world measures and tracks changes in forest carbon." (Woodwell Climate 2022; Ramrayka 2018)

Ultimately, Big Data are presented as means for facilitating collaboration, as "a source of key information for decision-makers" for "creating and adapting appropriate strategies, determining current, and upcoming issues, or identifying stages of recovery for taking actions in time", and they can provide evidence for policymaking and legislation. (Aragona, De Rosa 2019)

4.3 Public-private collaboration

The question remains of how to make all the suggested Big Climate Data Applications possible. A possible approach to address the already mentioned issues of access to and control over data combined with the access to the state-of-the-art technologies and the issue of who has the actual power and authority to make use of Big Data possible on a larger - even global - scale, is the public-private collaboration.

On one hand, many "Open data" initiatives, which are based on the idea that "the best way to extract the value of government data is to give the private sector and society in general access to try," exist. (Mayer-Schönberger, Cukier 2014, p. 116; Sebestyén, Czvetkó, Abonyi 2021) On the other hand, the popularity of "Data for good" initiatives, where "companies in the technology, finance, and retail sectors supply their proprietary datasets to development agencies, NGOs, and intergovernmental organizations to help solve an array of social problems" (Espinoza, Aronczyk 2021, p. 1) also rises.

According to Espinoza and Aronczyk the origins of data philanthropy can be traced to the 2009 World Economic Forum (WEF) annual meeting in Davos, where "executives, government officials, and development experts introduced the idea of Big Data as an untapped resource for human well-being." (Espinoza, Aronczyk 2021, p. 7) The rhetoric surrounding this idea suggested a true "win-win-win" state for all stakeholders - private firms, policymakers, and end-users (WEF 2011, p. 9) The UN also came to a conclusion that Big Data analytics is an opportunity to support the achievement of its sustainable development goals (SDGs) and in 2013 an Independent Expert Advisory Group on a Data Revolution for Sustainable Development was established by the UN. (Espinoza, Aronczyk 2021) Moreover, already in 2009 the United

Nations Global Pulse initiative that serves as the UN Secretary General´s Innovation Lab was launched. (Espinoza, Aronczyk 2021; UN Global Pulse 2022) It "brings together governments, UN entities, and partners from academia and the private sector to design, co-create, and scale innovations" (UN Global Pulse 2022) and for the last decade it "has sought out private sector data partnerships with companies such as social media businesses and mobile telecommunications." (Espinoza, Aronczyk 2021, p. 8) Furthermore, the UN Economic and Social Council (ECOSOC) Forum proclaimed in 2018 that "Big Data is a valuable business asset that the private sector can donate to governments for more informed public policy-making," and in 2019 the High-Level Panel on Digital Cooperation, established by the UN, also focused on the issue of private-sector data sharing. (Espinoza, Aronczyk 2021, p. 12)

5 Case studies

As demonstrated in the previous chapter, the idea of public-private collaboration in the context of Big Data and climate change is gaining more and more prominence as it could offer a solution to the dilemmas of data access, control and the power and authority to create policies. The following two case studies will thus focus on two instances of initiatives trying to build on the idea of public-private (non-governmental) collaboration and so will provide concrete examples of the application of Big Data for more efficient climate change governance.

Many challenges with similar intentions, which also served as an inspiration for the initiatives that this section examines, have been organized. French mobile network operator Orange has hosted two Data for Development (D4D) challenges; Spanish bank BBVA invited international developers to create apps powered by its anonymized, geo-located card transaction data; Telecom Italia also hosted a Big Data Challenge; the Infocomm Development Authority of Singapore (IDA) launched a Data Discovery Challenge; or the Bloomberg L.P. has hosted an annual Data for Good Exchange since 2014. (Espinoza, Aronczyk 2021; D4CA 2017; Bloomberg LP 2019)

However, the initiatives for this case study were chosen because of their unprecedented scope compared to the initiative mentioned above – in terms of the geographic coverage, the participation of a wide array of companies, the involvement of governments from all around the world, or the diversity of topics covered and data sources used. At the same time, the accessibility and availability of documents and detailed information about the challenges and projects, which is better compared to other similar initiatives, allow proper analysis. The sources used for the case study involved official websites of the initiatives or of their organizers and partners, informative videos published by them, news articles about the initiatives, final reports, or case studies published as part of some of the projects.

5.1 Data for Climate Action

Data for Climate Action (D4CA) were challenges hosted by the UN Global Pulse. First one was launched in 2014, and the second one was held in 2017. In these global competitions, companies from the technology, retail, finance, and telecommunications sectors provided "an unprecedented access to national, regional, and global datasets," which were anonymized to protect privacy, as well as "robust analytical tools" to the selected individuals and teams of data scientists and researchers.(D4CA 2017; Espinoza, Aronczyk 2021) The teams then came up with "pragmatic solutions to address climate change" (Espinoza, Aronczyk 2021, p. 1) and helped to "highlight the importance of a data revolution for accelerating climate action, and to foster cooperation around big data innovation to develop new climate solutions." (Tatevossian 2015a)

5.1.1 2014 Challenge

The 2014 challenge aimed to "unearth fresh evidence of the economic dimensions of climate change around the world using data and analytics." (UN Global Pulse 2014) The proclaimed aim of the challenge was to stress "the potential of the data revolution in understanding the choices we are making toward climate change" as well as to emphasize "the importance of accelerating climate action through cooperation involving academia, businesses and the public sector." (Tatevossian 2015b) Tracy Raczek, Senior Policy Advisor on Climate in the Executive Office of the Secretary-General, also affirmed that "Big data helps us more deeply understand how climate change can affect our economies, land, health and issues of inequality—with the ultimate aim of delivering solutions, it can empower individuals, communities and policy-makers to make more informed decisions." (UN Global Pulse 2014)

Participants of the competition came from 40 different countries and tackled over 20 different topics - from forestry, biodiversity and transportation to renewable energy and green data centres. (UN Global Pulse 2014) A high-level Advisory Board and Technical Committee of global experts in climate science, sustainable development and big data selected two winning projects, which were also invited to the 2014 UN Climate Summit, to share their research with

Heads of State, global business leaders and civil society leaders, and seven more projects were picked as “projects to watch”. (UN Global Pulse 2014)

The first winning project - “Global Forest Watch” (GFW) (*Forest Monitoring Designed for Action* 2017) - offered a monitoring system that provides real-time information on forests by combining satellite imaging, open data and crowdsourcing for open access to empower governments, companies, NGOs and the public to manage forests. (UN Global Pulse 2014) The second winning project presented a tool for farmers in Colombia (*Aclímate Colombia* 2017) that promotes climate-smart agriculture. It uses harvest monitoring data with climate data and seasonal forecasts to generate farming recommendations for rice growers to support their decision-making. (UN Global Pulse 2014) The “Projects to watch” focused on urban services monitoring, showing CO2 emissions from transport, quantifying impacts of climate change, or on energy monitoring systems.

5.1.2 2017 Challenge

The 2017 challenge was then organized around three major themes: *Climate Mitigation* (with sub-themes of Energy and Transportation), *Climate Adaptation* (with sub-themes of Agriculture & Food Security and Community Resilience), and *Climate & Other Sustainable Development Goals* (with sub-themes of No Poverty, Good Health & Wellbeing, and Reduced Inequalities).

Around nine leading companies provided the data and some participants of the Challenge also received cloud-computing support from Microsoft, and/or data-visualization support from Tableau.

The ambition of the Challenge was to facilitate pilot projects and operational solutions that would add to a “growing body of examples of the shared value of big data and public-private cooperation for climate action and sustainable development.” (D4CA 2017)

The presented idea behind the Challenge was that Big Data could describe how the climate is changing, but importantly, in addition to constructing a more complete picture, they can also show what solutions would be most effective in reducing greenhouse gas emissions and building community resilience. (D4CA 2017)

The Grand Prize Winner team focused on *electro-mobility in Mexico City* and evaluated different potential locations for electric vehicle charging stations, along with three different policies and their impact in terms of avoided emissions. (D4CA 2017) The Thematic Award Winners dealt with *Predicting and Alleviating Road Flooding for Climate Mitigation* in Senegal, *Ecosystem Monitoring for Management Application* in South Africa, and the *Impact of Air Pollution on Consumer Spending* in Spain.

Lastly, the winning projects in data visualization offered a *Framework for the Optimization of Winter Wheat Seeding Date* and a *Dynamic Spatial-Temporal Model of Urban Carbon Emissions* that provides near real-time understanding of hyperlocal patterns of carbon emissions across the city and can thus offer guidance to policymakers regarding the most efficient ways for reducing emissions through improvements to building and transit efficiency.

The data sources used included: traffic data from Waze, Google Places´ popular times, data on flooding, mobility data sourced from telecommunications data, satellite imagery, weather data, social media data, credit card transaction data, census data, or air pollution data.

5.2 Data 4 Better Climate Actions

Data 4 Better Climate Actions is a campaign launched by a group of global climate initiatives in 2021 that is „calling attention to the value of climate transparency to not only fulfil reporting requirements but to also drive good policy at the national level by advancing sustainable development priorities." (UNDP 2021) Its aim is to raise awareness about the "value of transparency in pursuing meaningful climate action." (UNDP 2021) The initiatives behind the campaign believe that transparency is essential for fulfilling the commitments of the Paris Agreement, and the driving idea behind the campaign is that "by having sound data and information systems in place, countries across the world will be able to better design, implement and track their Nationally Determined Contributions (NDCs) or long-term strategies." (Data 4 Better Climate Action 2021)

There are 14 global entities behind the initiative, and its partners include, for instance, the United Nations Development Program (UNDP), the United Nations Environment Program (UNEP), or the Food and Agriculture Organization of the United Nations (FAO).

As part of the campaign, governments around the world are encouraged to examine the climate risks they are facing and the gaps between the progress made in mitigating or adapting to these risks and the goals that still need to be reached in this regard. Therefore, the governments are invited to set up, and provide support to, national transparency frameworks – often with the help of the initiatives that are taking part in the campaign.

Until now, the campaign presented several climate transparency “success stories” on its website. The Initiative for Climate Action Transparency (ICAT) partnered with the governments in Mozambique, Sri Lanka, and the Dominican Republic to help develop stronger and improved or design a first-ever *Monitoring, reporting, and verification* (MRV) system.(*Strengthening Climate Transparency in Sri Lanka's Transport Sector* 2021; *Mandating a National Transparency System in the Dominican Republic* 2021; *Enhancing climate action in Mozambique* 2021) Road maps were developed to overcome the barriers and limitations of the current system or to establish a new centralized MRV. These systems can then help in assessing the impact of selected national policies and actions and in updating a tracking the implementation of the country´s NDCs.

In Mozambique, the project further highlighted the positive impacts climate policies can make on national development issues while simultaneously building institutional capacity. In Sri Lanka, the system enabled the government to collect the required data originating from several different ministries and agencies and to choose the most effective climate action. Similarly, in the Dominican Republic, the project helped to integrate governmental initiatives and to coordinate and collect data from different institutions.

In Bolivia and India, (*Revision of Bolivia's National Energy Balance and Greenhouse Gas Inventory* 2021; *An Integrated National Forest Monitoring System for Sustainable Forest Management and Conservation in Bangladesh* 2021) the projects focused on energy – energy balance, greenhouse gas inventory and possibilities for improving building energy efficiency. Through energy benchmarking, which required “collection of information on building energy consumption, floor area, building occupancy, operating hours, and connected electrical load”, (*An Integrated National Forest Monitoring System for Sustainable Forest Management and Conservation in Bangladesh* 2021) the project in India collected time-series energy consumption data and thus facilitated energy accounting, assessing opportunities for improvement, and quantifying or verifying energy savings.

The projects carried out in Bangladesh, Chile, Papua New Guinea, Ghana, the Democratic Republic of Congo, and Costa Rica (*An Integrated National Forest Monitoring System for*

Sustainable Forest Management and Conservation in Bangladesh 2021; *The National Forest Monitoring System as part of the National Strategy on Climate Change and Vegetation Resources in Chile* 2021; *National forest monitoring system provides better data, and enhances capacity in Papua New Guinea* 2021; *Establishing a multi-purpose national forest monitoring system to improve land use monitoring capacities in Ghana* 2021; *The Democratic Republic of the Congo establishes a national forest monitoring system to promote sustainable forest management* 2021; *Costa Rica's progress in developing a national land use, land cover and ecosystems monitoring system* 2021) tackled the issue of national forest monitoring systems and national land use, land cover and ecosystems monitoring system. These can bolster forest management and conservation activities and make forest and land use monitoring efforts more efficient and effective by combining components that are currently the responsibility of different institutions. Similarly, the project *Building global capacity to increase transparency in the forest sector* has produced six case studies from different countries on forests and transparency. (*Forest data transparency for climate action* 2021)

In the Philippines, Climate Change Expenditure Tagging (CCET) was employed to prioritize and assign codes to climate change programmes, activities and projects to achieve a climate-responsive budget and more effective climate investment programming. (*Achieving a Climate-Responsive Budget in the Philippines through Climate Change Expenditure Tagging* 2021)

Lastly, the projects implemented with the help of the LEDS GP's transport experts in Colombia, Mexico and Costa Rica focused on sustainable mobility and contributed to informed decision-making on low-carbon technology, sustainable modes of mobility, or pilot projects. (LEDS Global Partnership 2020)

5.1 Comparison

While both initiatives share some similarities, several differences and some evolution in what they put the spotlight on can also be observed.

The D4CA challenges mainly praised the "data philanthropy," expanded the "data for good" narrative and, in general, highlighted the immense potential of Big Data with respect to climate change. The challenges also aimed more at the business leaders, presenting climate change as a “low-risk” opportunity for them and calling for the “unique expertise of the private sector.” (Espinoza, Aronczyk 2021, p. 8)

The Data 4 Better Climate Actions initiative, on the other hand, did not take a form of a competition, as D4CA did, but of a campaign trying to raise awareness around and praise the importance of “climate transparency.” Its main focus is not on showcasing the possibilities for businesses to “do good” with their data in the context of climate change, but it focuses more on supporting the “good policy” by helping to establish monitoring systems and transparency frameworks for national and local governments around the world. As such, it often focuses not so much on the use of newly available data but rather on more efficient and effective gathering, coordination, and application of available data that public authorities often already have at hand. The added value of the projects under this initiative also stems from increased knowledge sharing and the participation of various stakeholders - public bodies, economic actors, or non-governmental organisations - from given sectors that become involved through different workshops and consultations.

What both initiatives have in common is their global ambition and participation of entities, businesses and governments from around the world. They showcase the applicability of Big Data in monitoring, evaluating impacts and also in developing new solutions. Projects from both initiatives come back to the same topics and cover the issues of forest and land monitoring, transport and electro-mobility, or energy monitoring. They also highlight pilot projects with the hope of advancing these from the local scale to the global one in the future.

6 Challenges, Barriers and Critiques

While there are thus undeniable opportunities and concrete, successful real-life applications of Big Data tools in the context of governing climate change, there are also challenges these applications have to face. These challenges, barriers and critiques should not imply that Big Data tools are not suitable for the purposes of governing climate change; however, they need to be acknowledged, understood, and, if possible, addressed.

This chapter thus offers an overview of the main categories of challenges, barriers and critiques Big Data face generally and also specifically with regard to climate change.

Big Data as a „silver bullet“ and the lack of theoretical guidance

The first category of challenges is not related only specifically to the relationship between Big Data and climate change but to the general Big Data rhetoric. The celebratory discourse around Big Data is primarily associated with the business and economic environment; however, the „notion that any problem data“ (Faghmous, Kumar 2014, p. 160) has become prevalent also in other domains and many scholars warn that “Big Data help us do what we already do better, and it allows us to do new things altogether; however it is no magic wand.” (Mayer-Schönberger, Cukier 2014, p. 193) In relation to the „end of theory“ Big Data narrative, it is also emphasized that without proper theoretical guidance, the Big Data analytics may offer spurious insights (Ford et al. 2016) and the issue of the quality of the data, their source, and sampling biases should not be neglected. The lack of theory-guided methodologies for Big Data analysis can thus result in a misuse or poor quality interpretation of the outputs of such analysis, and despite the immense opportunities Big Data offer in terms of understanding the climate and related policies, proper methods and theories must also be employed to produce meaningful results relevant for stakeholders involved.

The issue of opacity, accountability and the black box

As addressed in chapter 3, Big Data are intertwined with many dilemmas and critiques common to most current, cutting-edge technologies. Due to the complexity of the technology, the issue of opacity, transparency and accountability arises. This becomes even more important when Big Data tools are used on a large scale by public authorities and especially for automated governance. While Big Data may be generated autonomously, they do not operate independently of power;(Hansen, Porter 2017) therefore, careful consideration of the social embeddedness of technology and of the forces behind the creation of the technology, which can be further strengthened through the use of that technology, is needed. Moreover, the already mentioned issues of privacy protection and data access and ownership also need to be addressed. Many authors warn that there is considerable tension between different rights, like the right to privacy and the actions we “can” and “should” take to resolve global public problems. (Espinoza, Aronczyk 2021) It is thus oftentimes highlighted that in the first place all the human rights we consider “most fundamental to our humanity” (Espinoza, Aronczyk 2021, p. 12) need to be protected, and this belief also translates itself into policy documents and guidelines of international organisations. While the UN has issued "recommendations and guidelines for the use of Big Data related to SDGs" with the purpose of "ensuring privacy and increasing access to data worldwide," (Folk 2021) the EU, through its key funding programme for research and innovation Horizon Europe, aims to support excellent technologies, including for instance "Methods for exploiting data and knowledge for extremely precise outcomes (analysis, prediction, decision support), reducing complexity and presenting insights in an understandable way," (*Funding & tenders* 2021) however, it stated that the technologies have to be, above all, human-centred, ethical, and trusted. (EC 2021)

Governance system efficiently employing the technology

Yet another issue to be pointed out is that however powerful the current (and future) Big Data tools may be, they are only tools and do not resolve the climate change challenges alone. Werrell and Femia stress that well-resourced institutions and informed policymakers and needed to truly take advantage of the opportunities offered by Big Data tools, and a functioning governance system integrating the use of these technologies need to be developed. (Werrell, Femia 2019) The issue is not only extracting the right information with the help of Big Data tools but also getting it "to those responsible for addressing climate security risks." (Werrell, Femia 2019, p. 14)

This also again highlights the paradox of some entities having big data sets that remain unused or used for profit; others having the data however not having the technology and/or methods to gain useful insights from those; or those having the technology and know-how however not having access to the amount of data needed. While the "good data" and "open data" initiatives try to address this issue, some authors also warn that these types of initiatives can sometimes be better seen "as a strategy to legitimate extractive, profit-oriented data practices by companies than a means to achieve global goals for environmental sustainability." (Espinoza, Aronczyk 2021, p. 1)

The complexity of climate and climate data

The complexity of climate and climate data constitutes another category of Big Data application challenge connected specifically to the field of climate change. Compared to other fields, mining climate data is made progressively more difficult by the very complex character of the climate, the planetary system and the climate data. Since the Earth is a "complex, dynamic system in perpetual motion to balance energy and sustain its habitable environment," to understand the climate processes and changes, monitoring of the constant motion is needed and the challenge of managing a "continuously changing observing system" rises. (Faghmous, Kumar 2014, p. 157)

In addition to the *constantly changing observation systems,* Faghhmous and Kumar (2014) also identified other challenges the climate data pose to researchers: the *long-term data* needed for a full understanding of large-scale changes in the land, atmosphere, oceans, and cryosphere are *often lacking*; the data are largely *heterogeneous,* as many interacting variables influence the climate and are monitored using various technologies, some variable might not be observed at all while some data sources might, in the end, be redundant; data scientists usually do not directly take part in the data collection process and thus often have a *limited understanding of data´s variability and intricacies and of how data was collected and with what purpose.*

The technological limits and Green AI

Despite tremendous technological advances, some technological challenges still remain. The technologies for collecting, storing and analysing large amounts of data do exist; however, due to the fact that these technologies and infrastructures are complex and expensive, access to them is restricted not only for individuals but also in general for less developed countries, (Folk 2021) where also access to the Internet is limited as only about 35 per cent of the population in these countries has access to it. (World Bank 2020)

Moreover, the environmental costs of AI research have also gained the attention of scholars recently. (Spelda, Stritecky 2020; Schwartz et al. 2019) The field of AI seems to be oriented mainly towards the goal of improving accuracy; however, the computations required for deep learning research have a significant, non-trivial carbon footprint. (Spelda, Stritecky 2020; Schwartz et al. 2019) It is argued that the trend of "increasingly large and computationally-intensive deep learning models" is "both environmentally unfriendly … and expensive" and that the economic, social, and environmental costs of aiming mainly for improved model accuracy in AI should not be ignored. (Schwartz et al. 2019) With the goal of making AI more environmentally friendly and inclusive, scholars advocate for making computational efficiency another evaluation criterion and thereby advancing so-called "Green AI" research, which would also include reporting the computational price tag and, as such, providing transparency in research. (Schwartz et al. 2019) While it is acknowledged that also “Red AI”[7] has contributions to make, it is important to highlight the point of environmental costs related to red AI research, especially in the context of examining the possible AI contribution to fighting the challenges of climate change.

Conclusion

As the “Responsibility to Prepare and Prevent (R2P2) framework” states, the challenges the global governance system currently faces are unprecedented; however, so are, in theory, the abilities to face them, and we have the responsibility to fully make use of those. The current governance of climate change is not bearing the desired results, and climate change is also progressively becoming the subject of the international security debate, where the urgent need to act is stressed. Therefore, the discourse of technology as a saviour is gaining momentum. Although the changes and opportunities that new technology brings to all areas of social, political and economic life are significant, due to the relatively short time since the moment these technologies emerged, there remain many questions to be answered regarding the specific application possibilities, opportunities, but also challenges and barriers.

While increasingly popular, the concept of Big Data is not always clearly defined a properly understood. However, the 5V conceptualisation (volume, variety, velocity, veracity and value), on which there is currently the most general agreement, also defines well the climate and other data that are generated in ever-increasing numbers and that could offer some useful insight regarding the climate change. The progress in the field of Artificial intelligence and machine learning also enables the processing of this data that do not only come in large volumes but are also largely heterogeneous and continuously generated. The technological challenge, however, is not the only one Big Data applications face.

This thesis asked *What the opportunities and challenges of Big Data application for governing climate change are.* When examining *the concrete ways in which Big Data can contribute to more efficient governing of climate change*, first literature was consulted, and then two case studies were provided. Several categories of potential applications were identified, and many of

[7] AI research that seeks to obtain state-of-the-art results in accuracy (or related measures) through the use of massive computational power (Schwartz et al. 2019)

them were also already practically used within the framework of the initiatives described in the case studies.

Monitoring behaviour, perceptions and social attitudes was applied in the project that focused on the Impact of Air Pollution on Consumer Spending. *Smart buildings, energy and smart cities* was employed, for instance, the project on electro-mobility in Mexico City or the projects focused on improving building energy efficiency in Bolivia and India. *Carbon monitoring and monitoring of natural conditions and changes* was then demonstrated in the development of several forest monitoring systems in different countries of the “Global forest watch” project.

While many potential and already well-tried Big Data applications were thus identified, many *barriers that need to be overcome* were also detected. Some relate to Big Data in governance in general, some are more specific for the issue of climate change. The “Big Data as a silver bullet” narrative needs to be substitutes with proper methodological and theoretical guidance. The issues of transparency and accountability of new technologies used for making policy decisions also need to be addressed. The specifics of climate data in also need to be understood and the very technology that should help fight the adverse effects of climate change should not be largely contributing to that very problem.

Lastly, the *use of big data for climate governance as realistic possibility despite the identified barriers* depends largely on overcoming the barrier of not having an efficient governance system to employ the technology. What is clear from the case studies, as well as from the general trends in global governance, is that public-private partnerships are gaining importance and could offer an efficient way to make use of current technologies for addressing climate security risks. While the demonstrated instances of public-private partnerships do not resolve all the questions that Big Data applications for climate governance raise, they do provide examples of some success stories and possible paths to follow in the future that might offer the most efficient way to capitalize on the opportunities Big Data offer for climate governance.

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