Calculating 'Climate Migrants':
An Emerging Topology of Power

Abstract

On what basis can it be said that climate change contributes to human migration? What are we to make of new statistical models used to construct the relationship between these two epochal phenomena? This article proposes Collier's conception of topology to characterise the novel politics of gravity modelling, a technique increasingly used to calculate numeric estimates of 'climate migrants'. These models do not simply signify a revival or repetition of political sovereignty, nor an affirmation of biopower, but a novel recalibration of power arising in response to the climate crisis. This recalibration signals the early stages of a new topology of power organized around intuitive calculation. To make this claim, the paper draws on recent discussions in geography on the relationship between calculation, number, and the political to first situate the models within contemporary critical scholarship on climate change and migration. It then examines the models' statistical logics, in particular how intuition, inference and the incalculable shape three facets of this emerging topology: the correlation of Earth science data with population-level economic data; the calculation of mobile populations; and the unique spatiality at stake in gravity modelling.

Introduction

In 2020, *New York Times Magazine*, in conjunction with Pro Publica, published a series of articles on the topic of climate change and human migration (Lustgarten, 2020a; Lustgarten, 2020b; Lustgarten, 2020c). Together, the articles sketched a future in which climate change would render large regions of the world uninhabitable, forcing millions of people from their homes. In many ways, there is nothing unique about these observations. As with similar media accounts, they simply dramatize what many in the climate change community have—rightly or wrongly—long taken for granted: that climate change is a looming migration crisis. What sets these articles apart, however, is that their claims rest on the outputs of an econometric modelling technique called gravity modelling. Gravity modelling has also been used recently by the World Bank to calculate numeric estimates of what it calls 'internal climate migrants' (Clement et al., 2021; Rigaud et al., 2018). In 2018, the World Bank declared that by 2050 the world could expect to see up to 143 million such 'internal climate migrants' in South Asia, Latin America and Africa. Three years later, it included much of Eurasia in an expanded geography to revise this figure upwards to 216 million. These

numbers now circulate throughout the global media ecosystem as seemingly reliable, authoritative estimates (Al Jazeera, 2021 ; Chowdhury, 2022 ; Lindsay, 2021 ; Parker, 2018).

Gravity modelling allows researchers to infer from newly combined data sets statistical estimates of a figure—the climate migrant—that was once said to elude calculation (Baldwin, 2013). It is the political stakes in the move from the 'incalculable' to the 'calculable' that are the subject of the present article. We argue that recent and growing interest in quantifying so-called 'climate migrants' (Adams and Kay, 2019; Beyer et al., 2023; de Sherbinin and Bai, 2018; Hauer et al., 2024; Hoffmann et al., 2021; Kelman, 2019), evidenced by the *New York Times Magazine* and World Bank reports, is symptomatic of an emerging topology of power taking shape in relation to the climate crisis. Versions of this emerging topology, broadly concerned with reconceptualising power in relation to geos or Earth, have been referred to as geopower (Grosz et al., 2017; Luisetti, 2019), kinopower (Nail, 2015) geoontopower (Povinelli et al., 2017), and planetary computerization (Gabrys, 2016). Topology is best known as a branch of mathematics, but it has also been used in recent years to characterize the operation of power beyond geometric notions of space and spatiality (Allen, 2011; Allen, 2016; Aradau and Blanke, 2018; Martin and Secor, 2013). Our use of topology is inspired by Stephen Collier (2009), for whom topology captures the way power is never settled or reducible in form, but is, instead, always in the process of being reassembled in response to the dynamic, ever-shifting contexts in which it is exercised and maintained. In examining how gravity modelling quantifies so-called 'climate migrants', we observe how this new topology of power, which seeks to capture an emergent set of planetary conditions, is taking shape at the threshold of climate change.

The article proceeds as follows. We first situate our argument in relation to existing debates on climate change and migration. We then examine how a gravity model calculates 'climate migrants', emphasising in particular the role intuition and ingenuity play in such

calculative practices. We then focus on three features that can help us better grasp this emerging topology of power: correlation, calculation, and relational spatiality, before considering our argument in relation to related analyses of calculation within studies of migration (Scheel et al., 2019; Trauttmansdorff, 2022) and seruity (Amoore, 2013; Amoore, 2014; Amoore and de Goede, 2008; Aradau and Blanke, 2018; de Goede, 2008; de Goede and Randalls, 2009). We conclude by considering the implications of our argument about topology and calculation for wider debates concerning 'the political' and sovereignty in relation to climate change. However, here we need to stress that our purpose is not to disparage modelling, but to distil its inherently political quality. If, as Mann and Wainwright (2018; 2015) have argued, the political is adapting to climate change, we find in these uses of gravity modelling a technique central to the adaptation of the political, one that uses the logic of statistical inference to calculate the figure of the climate migrant/refugee - a novel form of political difference unique to climate change.

'Climate Migration'

That climate change will amplify global migration is a standard assumption in contemporary climate change discourse (Boas et al., 2019). Space precludes a full rehearsal of the idiosyncratic nature of this assumption. Instead, we start with the simple observation that political disagreement about climate change and migration can be divided into two schools of thought. The first assumes that the migration effects of climate change must be governed, and that effective governance requires actionable forms of knowledge. 'Actionable knowledge' can describe just about any knowledge that clarifies how the impacts of climate change either directly or indirectly affect migration (Robert and François, 2018; van der Geest et al., 2023). We understand governance in this context as any attempt (or desire) to govern, control or regulate those whose mobilities and/or immobilities are said to be the direct or indirect result

of climate change. Examples of governance might include border measures, adaptation policy, urban and infrastructural design, labour policy, financial innovation, militarism and human rights law.

The second school is less concerned with elaborating a model of governance than with evaluating the logics and rationalities advanced by the first. Typically, this has meant theorising how actionable knowledge relates to, extends, deepens or reinforces existing forms of power, such as neoliberal political economy (Bettini, 2017; Felli, 2012; Methmann and Oels, 2015), race (Ahuja, 2021; Baldwin, 2022), colonialism (Baldwin, 2012; Farbotko, 2010; Sultana, 2022) and power/knowledge (Nash, 2019; Nicholson, 2014). While the argument we put forward might appear to fall within this latter school, Collier's notion of topology allows us to approach attempts to quantify 'climate-induced migration', such as gravity modelling, as symptomatic of an *emerging* topology of power whose contours are discernible but still not yet fully formed. Our proposition is not that gravity modelling merely reinforces or extends already existing forms of power, but that it forms part of an extensive recalibration of power in response to the climate crisis (Wainwright and Mann, 2015). We explain our reasoning for this later.

Numerous attempts have been made to quantify so-called 'climate migrants' or 'climate refugees'. Nicholls et. al. (2011) suggested, for example, that by the end of the century 187 million people could move due to sea-level rise, while more famously Myers (2002) proposed this number to be as high as 200 million by 2050. Christian Aid (2007) went even further, putting this figure at 300 million. Francois Gemenne (2011) sought to challenge early attempts to quantify so-called 'climate migrants' or 'climate refugees' for their instrumentalism, and on the basis that they served to raise alarm about the severity of climate change at the expense of methodological rigour (see also Brown, 2008a; Jakobeit and Methmann 2012). His point was not, however, to contest quantification, but to encourage a

more dispassionate, less instrumental approach to modelling. “Scenarios, multi-level analysis or agent-based modelling,” he argued, “…could provide numbers that would be policy-relevant and yet scientifically sound” (p.48). For Gemenne, “more accurate estimates and projections” should be understood as “an important step for developing adequate policies.” This call sits alongside similar claims for a neutral ‘climate-migration’ knowledge untainted by politics (McLeman, 2014). Quantitative modelling has since undergone something of a renaissance in the field (Adams and Kay, 2019; de Sherbinin and Bai, 2018; Hoffmann et al., 2021; Schewel et al., 2024), as a growing epistemic community apply ever-more advanced statistical techniques to larger, more refined datasets – seemingly moving beyond the critiques of early efforts to enmurerate climate migrants (Brown, 2008).

Gemenne’s desire to mathematise the climate-migration relationship contrasts starkly with those who understand the category of the climate migrant to be an empirical impossibility. Bettini (2019) captures this position most succinctly when he writes that “the figures of climate refugee/migrant cannot be justified by their empirical referents, which—emphatically put—do not exist” (p.337). The figure is indeterminate and becomes defined, paradoxically, by its lack of definition (Nicholson, 2014). In this way, the climate migrant stands as an example of the incalculable. Without a concrete definition, how can this figure be known? How can it be counted? Because of this seeming paradox, there can be no prior referent called ‘climate-induced migration’, no prior ‘figure of the climate migrant/refugee’, waiting to be apprehended with the right methodology. Instead, as with all performative categories, the presumed, underlying referent is only ever an effect of the knowledge practices—gravity modelling, in our case—that seek to discern what they already presume to know in advance. This is precisely why critics have devoted so much time to deconstructing knowledge claims about ‘climate-induced migration’. Such claims are based on an epistemic

disjuncture that structures the entire discourse. Scrutinising such knowledge claims has thus become an important area of ethical practice in relation to climate change.

Despite this controversy, the desire to quantify the climate-migration relation persists. Because climate change is often said to be an inherently destabilising phenomenon, it stands to reason that knowing how climate change will affect social, political and economic phenomena like migration will provide us with some degree of ontological security. Quantification offer this reassurance. By revealing how many 'climate migrants' we might expect, where they are mostly likely to appear and what their movements are likely to be, gravity modelling seems to have resolved the paradox identified by critics like Bettini (2019) and Nicholson (2014) - in doing so rendering an uncertain future actionable through anticipatory governance (Anderson, 2010; de Goede and Randalls, 2009). Importantly, this anticipatory logic follows a broader tendency within contemporary liberal democracies to enrol calculation in the governing of risks associated with contemporary globalisation (Amoore, 2013; Aradau and Van Munster, 2011; Dean, 1998). Within this tendency, "scenario planning, risk profiling, algorithmic modelling, information integration, and data analysis become the authoritative knowledges of choice" (Amoore, 2013: 9). This further explains growing interest in the use of gravity modelling to quantify 'climate migrants'. The speculative knowledge produced by the World Bank and *New York Times Magazine* gravity models can be understood to authorize anticipatory forms of risk governance, which puts these models on a continuum with other methods of risk calculation employed to imagine uncertain, often catastrophic, futures and to serve as "call[s] to action" (de Goede and Randalls, 2009: 860). Despite this, here we wish to re-emphasise the novelty of climate change in relation to our argument and develop this distinct difference in the forthcoming analysis.

Gravity Modelling

In this section, we outline how gravity modelling works to *produce* the figure of the climate migrant. Our aim is neither to dismiss gravity modelling, nor evaluate the claims of the World Bank and *New York Times Magazine* models. Because neither of us are modellers, we lack the expertise to judge their methodological rigour or veracity. Our intention is simply to pinpoint why we judge gravity models in this context to be political, and situate their political logics within an emerging topology of power. Before examining the political ramifications of this claim, let us first consider what gravity modelling is and how it is used in the World Bank and *New York Times Magazine* reports.

Based on Newton's law of gravity (de Sherbinin and Bai, 2018), gravity modelling is so named because it gauges the 'gravitational pull' of one place over another based on their relative attractiveness. Its use in modelling migration is said to originate with Ravenstein's 1885 *The Laws of Migration* (Anderson, 2011). It works by assigning values to the various attributes of each place, such as income levels or housing affordability, to determine the relative appeal of each place under specified conditions. According to the World Bank report, gravity modelling "takes advantage of spatial regularities in the relationship between population agglomeration and spatial patterns of population change. These relationships can be described as a function of the characteristics known to correlate with spatial patterns of population change" (Rigaud et al., 2018: 63). This use of gravity modelling aims to account for the possible future interactions between people, locations and determinants by mapping elements that had previously correlated with population change and projecting these into the future. Importantly, the gravity models used by the World Bank and *New York Times Magazine* are not intended to produce either accurate predictions or forecasts, but "a plausible range of outcomes" (Rigaud et al., 2018: xix), scenarios that *could* happen. From a planning or development perspective scenarios are an important tool because they can assist planners

in preparing for, and adapting to, climate change (Schewel et al., 2024). However, for our purposes, the priority afforded to plausibility over accuracy is important for a different reason: it tells us that for the purpose of anticipating how climate change might affect migration, the accuracy of the quantitative estimates and the spatial distributions they generate are actually secondary to the technique itself. Whereas first-generation 'climate-migration' models were accused of fostering public alarm by producing large estimates of 'climate migrants' using unsophisticated models (Gemenne, 2011), the models under discussion represent a significant technical and methodological advance. Rather that provoking alarm they aim instead to foster a sense that future climatic uncertainty can actually be known and planned for within a range of plausible futures, a political logic sometimes referred to as premediation (Baldwin, 2016; Grusin, 2004). While the estimates they produce are certainly evocative, as well as potentially useful for planners, the political significance of this specific use of gravity modelling, we would suggest, is to be found not so much in its specific applications, although these are important, but in the technique itself.

How does the World Bank gravity model work? In the broadest sense, the model assembles three discrete data sets which are combined to quantify the number of 'internal climate migrants' in a designated jurisdiction over a given time frame. Importantly, the model does not directly *count* 'internal climate migrants' but *infers* them from the data (Clement et al., 2021; Rigaud et al., 2018; Schewel et al., 2024). The data sets used in the model are the Shared Socio-economic Pathways (SSPs) and Representative Concentration Pathways (RCPs), both of which are commonly used in mapping climate risk, and the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP), which holds data on climate impacts based on general circulation models. The SSPs are plausible future development trajectories for a given jurisdiction based on various demographic, economic, institutional, environmental, policy and technology parameters, used to gauge social, political and economic outcomes

over a defined period. The RCPs, by contrast, designate specific "greenhouse gas concentrations…corresponding to specific levels of radiative forcing" to gauge environmental outcomes under specified emissions scenarios. The model uses both RCP2.6 and RCP8.5 where the numeric values 2.6 and 8.5 represent the level of radiative forcing by 2100. The model also incorporates data on water availability and crop production from the ISIMIP, as well as sea-level data from another source.

The model generates four distinct scenarios for each of the three regions in the study—Sub-Saharan Africa, South Asia and Latin America (Rigaud et al., 2018). A subsequent study expanded this geography to include East Asia and the Pacific, North Africa, Eastern Europe and Central Asia (Clement et al., 2021). The first is a benchmark reference scenario, which does not consider the impacts of climate change. Each of the remaining three scenarios is derived by combining a projected RCP with a projected SSP along with pertinent data from the ISIMIP and then coded affectively to give users a 'sense' of what the scenario implies. The first of these is the 'pessimistic scenario'. It combines RCP8.5—a high-emission, 'business as usual' outcome with significant fossil fuel dependency—and SSP4—a possible world of deepening inequalities. The second, the 'more inclusive scenario', combines RCP8.5 with SSP2—a 'middle-of-the-road' outcome with less inequality and more development. The last is the 'climate-friendly' scenario, which combines RCP2.6–substantially curbed global emissions–with SSP4. In each of these scenarios the gravity model creates a population estimate for a 14km^2 grid square, and with the ISIMIP data, assesses how many people might live in an area based on past correlations mapped forward to each scenario. The ISIMIP data is then applied to form an assumption as to the relative attractiveness of different locations at a given time and in a given scenario by weighing up the modelled push and pull factors of different locations. To calculate the number of 'internal climate migrants', the modellers compare population changes in the baseline scenario with

those in each climate change scenario for each 14km^2 grid. Any net population gains for each grid are then attributed to climate change. These gains are aggregated across the entire study area to arrive at the headline figures of 143 million (Rigaud et al., 2018) and 216 million (Clement et al., 2021) 'internal climate migrants' by 2050. Both headlines rely on the the 'pessimistic' scenario; the aggregated numbers for the other two climate change scenarios are not as large. Population movements occuring within each grid are not included in these calculations.

The gravity model used by *New York Times Magazine* operates in a similar manner, although it assesses the relative attractiveness of given grid squares in five different scenarios—four of which are based on combinations of SSP3 and SSP5 and RCP4.5 and RCP8.5, and one on SSP1 and RCP2.6 in which climatic impacts are rapidly curbed and inequalities lessened across Central and North America. It also maps transboundary migration, whereas the World Bank does not. It incorporates similar data from ISIMIP but includes additional data on political stability and violence from the World Bank's Worldwide Governance Indicators. This methodology suggests that 680,000 and 1 million climate migrants might pass over the US-Mexico border by 2050 (Lustgarten, 2020a).

Having set out the mechanics of gravity modelling, we now borrow from Louise Amoore (2013), to claim gravity modelling as political precisely because of two logics – intuition and inference – that together render the otherwise incalculable figure of the climate migrant calculable.

The Logic of Inference

Each estimate is evocative in its own way. It is not, however, simply their affective resonance nor narrative value that makes them political but that they are *inferred* from the data. These numbers do not correspond to an existing set of conditions in the world. Nor, as

Bettini might argue (2019), do they reflect some underlying empirical referent. They are, rather, inferences whose origins lie in the self-conscious decision to combine discrete data sets and to relate these data sets to one another through a defined set of rules and mathematical procedures. Prior to these technical procedures, there is no 'climate migrant' or 'internal climate migrant' in the world, waiting to be counted. Numeric estimates of 'climate migrants' only acquire their truth-like quality through the deliberate logic of statistical inference, giving the appearance of resolving the irresolvable and transcending an epistemological impasse. This is crucial for understanding how gravity modelling is symptomatic of a wider topology of power currently unfolding in relation to the contemporary climate crisis. Rather than merely describing the world as it is, these models are used to infer from these data an array of future possibilities that are used to formulate ideas about what the world might become. Most crucially, these inferences form actionable knowledge that can be enfolded into a wider political calculus, one used to authorise political interventions at virtually all scales of political activity. This ranges from the distribution (or consolidation) of power and resources through multilateral institutions to planning decisions about where to locate a well, or how to 'future proof' real estate markets in cities expected to become destinations for so-called 'climate migrants' (Marandi and Main, 2021). The production of these numbers offers a contemporary example of what Michel Foucault (1977; 1978) was describing when he said that power is not something one possess but is instead exercised through the formation of knowledge and is thus best conceived as productive and generative. From this perspective, gravity modelling, in the examples we consider here, should be understood as a set of mathematical techniques that are productive of the world, aligning with established understandings of models as constructing reality rather than simply representing it (Barnes and Hannah, 2001; MacKenzie, 2008; Prince, 2020; Thompson, 2022). By giving rise to new governmental interventions on the basis of speculative

knowledge, these techniques have the capacity to reconfigure existing social relations in the here and now.

The Logic of Intuition and Ingenuity

Amoore (2014) argues that mathematics "is an arrangement of intuitive propositions that make things happen in the world, that is written into the rules of what is to be secured" (p.429). We find this insight to be especially fruitful for conceptualising how the use of gravity modelling to quantify 'climate migrants' becomes political. Amoore's scrutiny zeros in on Alan Turing's emphasis on intuition and ingenuity as the decisive ingredients of calculation. For Turing, no prior means, or formulae, exist for solving novel problems using mathematics. Instead, "with intuition one feels one's way toward a solution" (Amoore, 2014: 427). That is, one must first rely on one's intuition to work out whether a problem is solvable and, only then, can one go about solving it. But one cannot rely solely on intuition to find one's way to a solution. For Turing, one must also develop the precise techniques to be followed for a solution to be reached. It is never enough to know intuitively the answer to a problem. The procedure used to find the solution is equally important. Indeed, as every mathematics pupil knows, one must always show one's working. Turing would describe this procedural working-out as ingenuity. The data one uses, the rules applied in assembling and correlating the data, and how these are interpreted together make the solution regularizable and repeatable. These also become the bases upon which a model can be improved or expanded, as was the case with the *New York Times Magazine* model, which was an "extended version" of the World Bank model (Lustgarten, 2020). Ingenuity along with intuition are the twin ingredients that together determine whether something can be arranged as calculation.

How does this relate to our discussion about gravity modelling? Intuition is precisely the sense or gut feeling one has that climate change is a mounting migration crisis. Although numerous critics have called this sense into question (Baldwin and Bettini, 2017; Hulme, 2011; Nicholson, 2014), for many the logic that climate change will catalyse new patterns of migration is so irrefutable that it now circulates as common sense. Intuition fuels this common sense along with the demand for solutions. We can understand intuition as the driving force behind Gemenne's desire for more sophisticated quantitative methodologies and the subsequent waves of methodological innovation. Intuition, however, is not neutral (Handby, 2022). Not simply the carrier of subjectivity, intuition (but also sense) is itself a site of political intervention, inasmuch as it is fabricated and sustained through historically specific operative logics (Massumi, 2014). But intuition is never sufficient. Calculation also requires a specific set of techniques, an arrangement of rules and procedures that can be followed but also refined and improved upon over time. The use of gravity modelling by the World Bank is exactly this, a specific form of ingenuity applied to a novel problematisation.

Towards a topological understanding of 'climate migrants'

To grapple with this novel configuration, we return to Stephen Collier's reading of Michel Foucault's Collège de France lectures from 1975 to 1979 (Collier, 2009; Foucault, 2003; Foucault, 2007; Foucault, 2008). There Collier observes a shift in Foucault's method whereby power is understood not as a coherent system, but as the means by which "existing techniques and technologies of power are re-deployed and recombined in diverse assemblies of biopolitical government" (Collier, 2009, p. 79). For Collier, this kind of "topological analysis focuses on the broad configurational principles through which new formations of government are assembled, without implying that they arise from some inner necessity or coherence". Collier's topological analysis allows us to approach anticipatory knowledge

about climate change and migration as a contingent formation of power, one assembled in response to a unique planetary crisis, as opposed to one emanating from or reflecting an already constituted form of power, such as sovereignty, the state, neoliberalism or ideology. In following this approach, by no means are we suggesting that this emerging topology of power is fully articulated, or totalising and epochal in nature, nor that it replaces these other modalities of power. It is most definitely unique, but it should be understood to work in conjunction with, not instead of, these other modalities. In fact, this is a key aspect of Collier's concept of topology of power, or what Foucault called a 'system of correlation'. Topologies of power can be understood to operate through the *correlation* of prior political technologies, logics, techniques, imaginaries and so forth, while at the same time remaining entirely novel. From this perspective, our contention is that there is no inner political logic to the discourse on climate change and migration that simultaneously informs and results from the World Bank and *New York Times Magazine* models; no prior yet concealed operation of power that analysts must work hard to uncover. Instead, this is an evolving planetary topology of power, not yet fully formed but borrowing from a range of prior technologies of power without being reducible to any one in particular. That is, it involves the correlation, or assembly, of its constitutive elements without being concerned solely with, for example, ensuring the continuity of capital accumulation, as Felli (2012) has argued, or with sovereignty and border fortification - a pervasive, and, as we argue, over-egged assumption in much writing on climate change and migration (Miller, 2017; Miller et al., 2021; White, 2011). While it is undoubtedly true that states are militarizing their borders in response to climate change (although, to be sure, they seem to be doing so *without* explicit reference to climate change), our view differs fundamentally from those who emphasize this aspect of state practice when diagnosing state responses to the migratory effects of climate change (Boyce et al., 2020; McLeman, 2019; Miller et al., 2021; White, 2011). Too much analytical

attention on borders and sovereignty, we would suggest, risks not only the fallacy of the territorial trap i.e., reducing the political logic of sovereignty to the border (Agnew, 1994; Agnew, 2009) but also risks overlooking recent transformations in the spatial logics of sovereignty (Mountz, 2013) as well as recent discussions about topology and space (Allen, 2016; Belcher et al., 2008; Collier, 2009; Martin and Secor, 2013). Even more importantly, though, an analytical preoccupation with borders stands to overlook how novel techniques like gravity modelling are contributing to the reconfigurations of political power in the face of climatic transformation.

In the remainder of this section, we grapple with these complexities by tracing the elements of this planetary power. In particular, we focus on three aspects of its emerging topology: the correlation of Earth science data with population-level economic data; the calculation of mobile populations; and the unique spatiality at stake in gravity modelling.

*1. **Correlating 'climatic' and 'mobility' governance***

Collier emphasises how by 1978 Foucault sought to foreground 'systems of correlation' in his diagnoses of power. While Collier renames these systems 'topologies of power', the central proposition is the same: in order to adapt to novel circumstances, prior forms of power would need to be repurposed and recombined, or *correlated*, in response to whatever novel conditions had arisen from an existing social or political formation. At the heart of these gravity models lies the correlation of two distinctive forms of data—those concerning environmental change at both the planetary and local scales, and those that capture trends in population, income, urbanisation and other economic factors. Each on its own is associated with distinct forms of government. The former is central to the way the climate has been made governable (Bulkeley, 2015; Edwards, 2010), while the latter is broadly associated with economy, social-welfare and the will to improve (Li, 2007).

When these data and their associated governing modalities are drawn together through gravity modelling, a different governmental rationality starts to take shape around a novel target: climatic mobility. In relation to the World Bank gravity models, we can start to imagine how governing this object comes to be understood as fostering the right disposition of people in relation to food production, housing, and transportation, for example, where the exigencies of sovereignty are reconfigured around optimising population mobility in relation to climatic forecasting. While it is certainly true that population mobility has always figured centrally in the political rationality of the modern state, the World Bank gravity model raises entirely new questions about the role that government, international institutions and the private sector play in managing such mobility. Similarly, while biopolitical regimes governing population health have been shown to consolidate sovereign authority (Braun, 2007), we find in the World Bank gravity model a repurposing (but not direct replication) of biopolitics, where the calculation of population health e.g., sanitation and health care, is re-optimised by factoring in climatic mobility, which is itself the result of calculating population wellbeing through data on climate change impacts and economy. The *New York Times Magazine* gravity model presents a slightly different political rationality, one more concerned with geopolitical stability and transboundary population flows, but still one focussed on optimising climatic mobility. Whilst this might involve state-led interventions, it is not reducible to the adapatation of state sovereignty concerned merely with protecting a designated population. It appears, instead, to be a planetary form of power aimed at optimizing human mobility under changing planetary conditions.

2. Calculation

Gravity modelling, as with all attempts to model the relationship between climate change and migration, establishes calculation as a key feature of this new topology. This is an obvious

point, and one emphasised earlier, where gravity modelling was said to be political precisely because it renders the incalculable calculable. Calculation offers reassurance that even though climate change implies the possibility of a chaotic future human mobility, there is nothing about this future that should be especially surprising. Since modelling offers the possibility that everything is calculable, no future exists that is not itself securable - at least in principle. But the point we wish to emphasise here is different: gravity modelling allows us to see how with the advent of climate change, the substance of governmental calculation is shifting. The relationship between calculation, politics and number has a long history (Crampton and Elden, 2006; Elden, 2005; Elden, 2007). Calculation was central to the formation of state territory, whether through, for example, the mapping of resources, population census data, health statistics and taxation. What gravity modelling reveals, however, is a novel form of calculation in which populations are reconceived as potentially mobile and thus potentially out of place as a direct consequence of shifting climatic conditions. With gravity modelling, we catch a glimpse of the way in which biopolitical calculation is no longer just about population health but is now increasingly concerned with optimising population health in relation to conditions of the Earth system. This is not merely the recalibration of biopower towards what Federico Luisetti (2019) and others have called *geo*-power (Luke, 1995; Yusoff et al., 2012), a formation of power that "inserts the life of *homo œconomicus* into the land, sea, and air, combining human populations' regulation with systems ecologies and Earth sciences" (Luisetti, 2019: 351). The logic of calculation we find in gravity modelling also allows us also to consider how biopolitics is moving closer to what Thomas Nail (2015) has called kinopower, a form of power that views social formations as "regimes of motion" (p.24; see also Cresswell, 2010; Merriman, 2012). We believe that the topology of power discernible in these gravity models should be approached as some combination of geo-power

and kino-power; a modality of power concerned with governing population flows in relation to the habitability of the Earth system.

3. Spatiality

And finally, gravity modelling provides a means of conceptualising how this unique topology of power produces, relies on and takes shape in relation to a unique spatiality – one not strictly geometrical or territorial. These models generate a specific kind of relational space, one in which one place is only understood to be of greater value in relation other places. Places acquire their gravitational allure not because of any inherent attribute but because they are deemed better than the alternative. What arises here then is a governmental logic forged on gradients of habitability, between places deemed habitable and those deemed less habitable. The key question thus becomes what precise form governing will take in relation to this unique anticipatory spatiality. It will surely entail optimising population flows in relation to expected alterations of the Earth system, but questions remain as to its character and purpose. What specific interventions will be deployed to optimise population flows? We have already alluded to what some of these might be: resettlement; insurance; and infrastructural development. But the question also arises to the primary aim of such techniques? Will such techniques be deployed to control flows of labour? Will they be used to facilitate capital accumulation or the preservation of elite enclaves? Or will they be used to consolidate state sovereignty? There are no straightforward answers to these questions. We raise them in support of our case that gravity modelling is a specific calculative technique from which to delineate the outer contours of a novel form of power that is very clearly taking shape in relation to climate change, but which is still yet to be fully articulated.

A *new* topology of power

To what extent is this topology new? Anxieties about 'climate migration' are often said to result in the hardening of political sovereignty (Miller et al., 2021), neoliberalism (Felli, 2012; Felli and Castree, 2012), or the expansion of biopower (Bettini, 2014; Bettini, 2017; Methmann and Oels, 2015). It is understandable why commentators have sought to explain 'climate change and migration' discourse with reference to such familiar vocabularies of power. Such familiar forms, however, are themselves unique responses to specific problematisations and – despite apparent similarities to any one of these forms a new vocabulary is needed to grasp the novelty at stake in efforts to quantify 'climate change and migration'. This is because calculating climate migrants is not a straightforward exercise of counting but is uniquely bound up with planetary conditions such that practice of calculating and thus quantifying 'climate migrants' is not just about governing migration in the context of climate change but bringing into being a fundamentally novel form of political difference both unique to and symptomatic of the planetary quality of the crisis itself (Baldwin, 2022; Bettini, 2019). Not only is it concerned with planetary conditions, first and foremost it emanates from, and thus reauthorises, a *planetary* consciousness long synonymous with European notions of a universal humanity (Pratt, 2007; Simpson, 2020). It also echos Foucault's suggestive notion that the sovereign is not one who, strictly speaking, exercises power over a territory, but over the "perpetual intrication of geographical, climatic and physical milieu with the human species [...] if he wants to change the human species" (Foucault, 2007: 23). In this section, we develop this argument by considering seemingly similar analyses of related governmental logics within migration and security studies.

One might be tempted to interpret this topology as merely an extension of similar practices of calculation now common in migration and bordering in general. Indeed, important parallels exist between such practices and those we identify here. It is certainly true that gravity modelling has been used to model international migration (Beine et al., 2016). It

is also the case that calculative technologies are widely used to monitor and govern more general patterns of migration (Aradau, 2022; Scheel et al., 2019; Trauttmansdorff, 2022; Valdivia et al., 2022). Both are underpinned by a desire to optimise migration as a system of value, to render migration calculable and thus an object of governmental concern, or even the way their respective sociotechnical infrastructures foster novel collective imaginaries (Trauttmansdorff and Felt, 2023). However, it is precisely the climatic, planetary aspect of calculation that sets this topology apart, one concerned with optimising the distribution of human populations in relation to planetary conditions, rather than with bordering, territory and national security - even while the latter may well fall within its remit.

One might also be tempted to draw paralells with contemrpoary security calculations (Aradau and Blanke, 2017). This is an important exercise, and one that we do without conflating the two cases for analyses. Louise Amoore's account of mathematics, discussed earlier in this article, is set within a wider discussion on the use of algorithmic, risk-based calculation in the war on terror (Amoore and de Goede, 2008; Aradau and Van Munster, 2007). It offers an important parallel to our discussion. The specific focus of Amoore's concern is the use of algorithmic computation in the calculation of another incalculable: the figure of the terrorist. One of her key insights is that 'risk-based' security decisions are political because they "involve combinatorial possibilities that have effects in the world" (p.423). Security decisions, such as whether to retain someone at an airport or border because they are thought to pose some kind of security threat, involve assessing the risk they pose to wider publics. Inferential algorithmic computation is the technique security agencies often use to make these assessments, and it is political because regardless of whether such assessments are accurate, they have material consequences for those subject to them. Rightly or wrongly, they cause people to be removed from aircraft, detained and deported. Moreover, what makes such algorithmic calculation powerful is that it allows security agencies to judge

someone's risk potential *in advance*. To gauge whether someone poses a security risk, one would simply need to assemble the right data, establish a set of rules about how the data is correlated, and interpret this data according to a set procedure. Doing so then allows the user to assess the extent to which someone is said to pose a threat and whether and how to intervene. Our examples of gravity modelling do something similar. Although neither is concerned with evaluating the potential security threats posed by individuals, both correlate otherwise separate datasets to calculate in advance how large numbers of people might respond to certain risk conditions. This, in turn, allows planners to anticipate where potential future conflicts or humanitarian crises might arise, and to consider whether and how to mitigate or cater to those possibilities.

Amoore emphasises that in the realm of risk decision-making, the accuracy of algorithmic calculation is entirely secondary to the composition of the calculative technique. What matters most is the precision with which the calculation is reached. As she puts it, it "does not matter whether something can be predicted, only that it can be arranged as calculation" (2014, p. 426). Within the context of the war on terror, political authorities were forced to confront the inherent unknowability of the future. Security threats lurked everywhere. But for security agencies to acknowledge the unknowability of the future would have been to admit a certain degree of insecurity and thus an inability to be prepared for all eventualities. Algorithmic calculation would solve this problem and allow political authorities to promise a measure of security in an otherwise inherently insecure world. "The assumption here is that, in effect, there can be no incalculable that cannot be acted upon. Thus, there can be no insecurity—everything is securable" (ibid, p. 435). "Calculability," for Amoore (2014), "[would] never [be] in question" (p.425). We argue that similar reasoning applies to the use of gravity modelling in calculating the figure of the climate migrant. While it is certainly true that the algorithmic techniques at the heart of Amoore's analysis differ

greatly from the gravity models that concern us, both are mathematical techniques that annul future uncertainty by rendering the incalculable calculable. The gravity models put forward by the World Bank and *New York Times Magazine*, as with other modelling techniques, allow their users to insist that future 'climate migration' can be imagined and planned for, even while acknowledging that these techniques are not intended to provide accurate predictions. While the first wave of quantitative estimates Gemenne railed against (2011) might have been clunky and methodologically unsound, the World Bank and *New York Times Magazine* models represent a new level of calculative precision. The quantitative estimates and spatial distributions they arrive at may not be accurate, but the procedures they deploy are a significant advance on what came before. They render the unknown future actionable and contribute to a sense in which the migration effects of climate change are securable and thus not necessarily a problem. This also happens to be one of the key messages in the first of the two World Banks reports: "Internal climate migration may be a reality *but it doesn't have to be a crisis*. Action taken across three major areas could help reduce the number of people being forced to move in distress" (Rigaud *et al.*, 2018, p.xxv, our emphasis). Amoore's emphasis on precision and technique is therefore of vital importance. Calculative techniques, such as algorithms and gravity modelling, are not merely responses to what happens in the world but are themselves *world-making* ("an arrangement of intuitive propositions that make things happen"). This is what makes them political and why scrutinizing them, and modelling more generally, is of such great ethical importance in the context of climate change.

Calculation, sovereignty and the political

Finally, let us now consider the implications of our argument for 'the political' and the related concept of sovereignty. This brings us into dialogue with Mann and Wainwright's (2018) important theory concerning the adaptation of the political alluded to earlier. For these writers, the "fundamental adaptation that climate change demands of humanity is political,"

which they define "not [as] the arena in which dominant groups impose their interests and subaltern groups resist; [but] rather the ground upon which the relation between dominant and dominated is worked out" (p. 80). By this account, the political is not reducible to the familiar story of the border where powerful states impose their authority on migrants and refugees. It refers instead to the means by which political difference itself is formulated. One implication of this reading of the political is that we cannot merely assume the existence of climate migrants/refugees to which states are merely responding by ratcheting up border fortification. Rather, we must look to the very forms of knowledge by which this category of political difference is fabricated to gain some understanding of how forms of political domination are adapting to climate change. The World Bank and *New York Times Magazine* gravity models discussed above offer a powerful starting point for tracing these complicated processes.

But Mann and Wainwright go further. They argue that the adaptation of the political will also likely entail "a more or less radical shift in the existing form of sovereignty that will enable the world's most powerful states to engage in planetary management" (p.80). What form would this radical shift in sovereignty take? Their answer is that it will likely entail some version of a liberal capitalist '*planetary* sovereignty' (our emphasis). While one could certainly challenge this claim (and indeed, much of their argument is concerned with elaborating other forms sovereignty might take in relation to climate change), we would simply point out the parallel between the topology of power traced above and Mann and Wainwright's claim that political sovereignty is being repurposed in response to the unique challenges of the climate crisis. The advantage of Collier's topological reading of power, however, is that it allows us to consider how sovereignty is reconfigured as *planetary* sovereignty. Whereas the former is defined territorially, the turn to planetary sovereignty suggests a different kind of geographical imagination. Here, again, the gravity models

considered above are instructive. If, following Carl Schmidt, the sovereign decision is conventionally understood as the act of distinguishing between friend and enemy, by examining these models we can discern a very different conceptualisation of the political. Not one based on the explicit declarations of the sovereign, but one founded on intuition and bound up in the technical details of very precise calculative practices that infer political difference from uniquely combined data sets. Whereas Schmidt's sovereign decision is nationalist and territorial, the form of political difference produced by the gravity models is planetary in scope and based on drawing a very different kind of distinction. Not one based on inside-outside or friend-enemy, but between, for example, the sedentary and the potentially non-sedentary, normal mobility and potentially deviant mobility, those at risk of mobility and those not, or those considered human and those deemed less than human (Baldwin, 2022).

The logic of statistical inference is what reifies this unique form of political difference specific to climate change—the figure of the climate migrant. However, that it does so speculatively signals to us that the political appears to be adapting to climate change through the logic of anticipation (de Goede and Randalls, 2009) in ways more nuanced than simply states doubling down on border violence. It mathematizes the anticipation of political difference and thus authorises modes of governing that seek to act on those *before* they become a problem. Our claim is that by examining the logic of statistical inference—specifically in the form of gravity modelling used by the World Bank, the *New York Times Magazine* and Pro Publica—we stand to learn something unique about how political power is adapting to climate change and to what effect (Baldwin, 2022; Eriksen et al., 2015; Mann and Wainwright, 2018).

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