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A new north-south divide for climate knowledge? A case study of climate projections in UNFCCC's National Communications

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A new north-south divide for climate knowledge? A case study of climate projections in UNFCCC’s National Communications

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ABSTRACT

A north-south divide in the production of climate knowledge exists. While the north is home to a variety of climate models, data infrastructures and climate experts, the south often lacks these attributes. We use a unique global dataset, the UNFCCC National Communications, to perform a global documentary analysis of scientific submissions from individual countries (n=189). Focusing on the production and use of climate projections, our research both supports, and importantly, challenges such a clear-cut north-south divide. For instance, the global north in general uses more complex climate modelling techniques, yet numerous countries in the global south have a higher scientific capacity than some northern ones. Beyond scientific capacities, the south emphasises mid-term timeframes (before 2060) more relevant for their adaptation decisions whereas the north prefers a long-term view and is generally more optimistic of global mitigation efforts. While the use of Global Climate Model (GCM) ensembles is widespread in the global north and south, the south's access to climate models is restricted to mobile climate projection tools. Although modelling tools such as PRECIS enable countries with little scientific capacity to produce useful climate risk assessments, these tools may hide a new divide between the global north and global south. Unable to customise inputs, such as country-specific observations or modelling information, the global south might become dependent upon the climate modelling tools circulated by the global north. Our research calls for a more nuanced and critical use of the north-south divide, and highlights that well-intended modelling and training efforts may unwittingly restrict, rather than foster, scientific capacities in the global south.

Keywords: Climate projections, climate scenarios, climate information, adaptation, North-South divide, role and use of climate science

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1. Introduction: the north-south divide

If countries are to adapt to the impacts of climate change it is critical that they have the scientific capacity needed to generate relevant knowledge as well as the ability to translate it into domestic policies and local decision-making (Ho-Lem et al., 2011). The thinking that science leads to policy action sits at the heart of the Intergovernmental Panel on Climate Change (IPCC) efforts to scrutinise climate knowledge to inform climate policies under the United Nations Framework Convention on Climate Change (UNFCCC). Yet a classic global north-south divide crystallised, in which a geographical imbalance over ‘who’ produces climate knowledge and ‘where’ it’s applied threatens to undo these efforts (Blicharska et al., 2017; Pasgaard and Strange, 2013).

Simply put, a “north-south divide has significant implications for how [climate] science is designed, produced, implemented, interpreted, and communicated” (Blicharska et al., 2017: 21)[1]. A major concern is that rich countries, historically the largest greenhouse gas emitters and less vulnerable to climate change, publish >80% of climate research articles. Research is also skewed towards mitigation favoured in the north, not adaptation advocated by the south (Pasgaard et al., 2015). Blicharska et al. (2017) argue that countries unable to produce locally-relevant climate knowledge and unable to integrate it into their national decision-making, then the national implementation of global climate agreements and a country’s ability to develop adaptive capacities can suffer. With a limited understanding of scientific research, and the interests and/or values at play in evidence-based arguments, it can be difficult for countries in the global south to challenge the fairness of global climate targets. In addition, the credibility, saliency and legitimacy of climate knowledge can suffer, as northern perspectives are perceived to bias proceedings and are insensitive to local contexts.

Quantitative studies have repeatedly revealed a north-south divide over the distribution of climate peer-reviewed publications (Karlsson et al., 2007; Pasgaard and Strange, 2013); the authorship of IPCC reports (Corbera et al., 2015; Ho-Lem et al., 2011); and the geography of IPCC expertise (Hulme and Mahony, 2010). For instance, 45% of non-Annex 1 countries have never contributed authors to the IPCC process (Ho-Lem et al., 2011). Such geographical imbalances between the countries that produce climate knowledge, and those who rely upon it, has far-reaching consequences. The wealth and educational level of a country (Ho-Lem et al., 2011; Karlsson et al., 2007) as well as the stability of institutional arrangements within it (Pasgaard et

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[1] We follow the north-south definition used by Blicharska et al. (2017), in which northern countries are either Organisation for Economic Co-operation and Development (OECD) members or high-income economies as classified by the World Bank. Conversely, other states are categorised as ‘southern’.

al., 2015; Pasgaard and Strange, 2013), are strongly correlated with scientific capacity[2]. Geographical imbalances between the countries that produce climate knowledge and those that are reliant upon it can have far-reaching consequences

Efforts to improve southern inclusiveness in science-policy organisations such as the IPCC (Yamineva, 2017) as well as endeavours to increase scientific capacity in the global south (Dike et al., 2018) have met various challenges. As Dike et al. (2018) explain, researchers in the global south may be: (i) less familiar with the publishing requirements of academic journals; (ii) unable to access global publications or databases; (iii) hindered by poor internet connections to submit new research; and (iv) less fluent in English. Such barriers can help explain why well-intended endeavours to foster inclusiveness have not managed to overcome imbalances in knowledge production (Yamineva, 2017).

If a fairer, more inclusive, international solution to climate change is to be achieved, it’s crucial that we understand not only how a north-south divide emerged in the first place but also why it persists today. A major challenge here is how to meaningfully compare countries with very different characteristics (e.g. size, wealth, education, stability). Measuring scientific outputs, such as peer-reviewed publications, has proved a reliable method (Karlsson et al., 2007; Pasgaard et al., 2015; Pasgaard and Strange, 2013). But such metrics assume that all countries have the same goals. A more appropriate measure of scientific capacity would involve comparing countries where the reporting requirements are the same. Any deviation from these reporting requirements – either going above and beyond or failing to meet set standards – would provide a clearer picture on the differences between countries. To that end, we use the UNFCCC National Communications dataset for the first time to assess the global north-south divide. Each country must submit a National Communication to report on their progress towards mitigation and adaptation commitments. As part of this process, UNFCCC provides countries with guidance and training on how to produce climate projections, which are to be submitted as part of the National Communications. Differences in national climate modelling efforts, therefore, will be revealing to substantiate claims of a potential north-south divide.

To understand the extent to which the global north-south divide manifests itself for climate knowledge, in this paper we explore the characteristics of countries’ climate projections and their underlying modelling efforts in UNFCCC National Communications. Section 2 explains how we collected the data. Section 3

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[2] We understand scientific capacity as both the production as well as use of scientific knowledge, as defined by Ho-Lem et al. (2011).

explores what differences emerged over which countries complied with UNFCCC reporting requirements and what this means. Section 4 identifies similarities and differences in the modelling characteristics used by countries in the global north and south. Section 5 details how the climate futures[3] reported differ between the north and south. Section 6 and 7 offer a discussion about the emergence of a new, and mostly hidden, north-south divide.

2. Data and methods

In 2017, we conducted a documentary analysis of countries' most recent National Communication (n=189), submitted to the UNFCCC between 30.10.1999 and 31.12.2016. National Communications are a unique global dataset, which report on the progress of a UNFCCC member's mitigation and adaptation commitments. Reporting guidelines detail what each submission ought to include, such as a country's vulnerability to climate risks; greenhouse gas emissions; climate policies and actions; proposed training and public awareness initiatives: as well as other key performance criteria. These submissions are authored and officially signed-off by the countries in question.

Analysis of the UNFCCC National Communication dataset has been undertaken for a number of comparative studies, from the formulation and implementation of climate policies across different countries (Albrecht and Arts 2005) to tracking progress made on global adaptation by differentiating global leaders from the laggards (Lesnikowski et al., 2015). For the purpose of this research, we compare the scientific capacities of countries from the global north and south by closely examining the climate projections and their associated climate modelling characteristics. UNFCCC provides clear guidance (UNFCCC, 2008) and training sessions (UNFCCC, 2012, 2016) on what National Communications should include. Analysing deviations from these reporting requirements – by either going above and beyond or failing to meet expected standards – are indicators for different scientific capacities, potentially revealing a geography of knowledge.

To do this, we downloaded the most recent National Communication submissions from the UNFCCC website (n=189). Each submission was weighted equally, irrespective of when it was written (see Supplementary Materials). All the submissions were manually coded. This involved reading each document and recording answers to a range of questions concerning

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[3] In this article, we use the term 'climate futures' to spotlight ways of envisioning futures in order to discuss climate change today. As such, 'climate futures' emphasise multiple socio-economic and temporal frames used to describe climate change in the future. We introduce 'climate futures' to make clear we are not comparing plausible future states of the climate in a particular region ('future climates').

climate projections in an Excel database. These questions included (i) were Global Climate Models (GCMs) or Regional Climate Models (RCMs) used; (ii) what downscaling techniques were used (e.g. statistical/dynamical); (iii) how many emissions scenarios were used; and (iv) which time horizons were used (e.g. >2080s) (see Supplementary Materials for a full list).

We define a 'set of climate projections' as one product, potentially encompassing multiple climate models, outputs, and emission scenarios to describe multiple yet coherent climate futures. This includes, for instance, aggregating climate information from multiple climate models and/or climate model runs for one emission scenario. When a country reported more than one set of climate projections, we applied two criteria to narrow the selection down to one set. First, we prioritised the set of climate projections that focused on the entire country, rather than a single geographical region. Second, we selected the climate projection that contained higher concentrations of information (measured as the relative space used by text descriptions, graphs and tables).

3. Did all countries include climate projections in their National Communications?

Of the 196 UNFCCC member states, 189 countries submitted National Communications[4]. In 90% (n=170/189) of cases, the countries' submissions included climate projections as part of the states' vulnerability and adaptation assessment (see Figure 1). While the UNFCCC reporting guidelines do not prescribe how the climate projections should be done, a broad consensus emerged. The majority of countries (n=126/189, 67%) provided a single, national, set of climate projections. A minority of countries (n=43/189, 33%) chose to report multiple sets of climate projections. Of interest here is that countries in the south (n=36/132, 27%) were twice as likely to produce multiple climate projections compared to northern countries (n=8/57, 14%). Multiple climate projections often focused on several different spatial or administrative scales (e.g. regions, cities and airports), and could be used to inform local government policies and decision-making.

Our data does support a north-south divide in climate knowledge – but a divide that plays out differently to what might be expected from the literature (cf. Blicharska et al. 2017; Karlsson *et al.* 2007; Pasgaard & Strange 2013; Pasgaard *et al.* 2015). We found an almost complete reporting compliance of climate projections by the south (n=124/132, 94%), even though the

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[4] Iraq submitted a National Communication but it was not available for download. For the purposes of this study, Iraq was not considered in the 189 submitted National Communications.

vulnerability section reporting guidelines for non-Annex I countries of the UNFCCC are voluntary. By comparison, only 81% (n=46/57) of submissions in the north complied with this reporting requirement. For example, Australia, Canada, Italy, and Spain did not report any climate projections. Further research revealed that Australia (CSIRO and Bureau of Meteorology, 2007), Canada (Barrow et al., 2004) and Spain (Gutiérrez et al., 2012) had already produced national climate projections, but they seem not to be properly accounted for in the reporting to UNFCCC. In addition, Bahrain, Egypt, Qatar and the United Arabs of Emirates, which are classified as high-income countries by the World Bank and thus categorised as northern countries (cf. Blicharska et al., 2017), also failed to provide climate projections.

In the south, the n=3 Small Island Developing States (SIDS) of Barbados, Dominican Republic and Papa New Guinea also failed to report any climate projections. This finding echoes that of Pasgaard et al. (2015) where SIDS are correlated with lower numbers of climate change publications. However, this omission may also be influenced by current GCMs and RCMs struggling to produce reliable, highly resolved outputs for small islands. Aware of other southern countries' knowledge and resource constraints, the UNFCCC ran several 'hands-on training workshops' before the submission of National Communications, introducing free-to-use and well-established community tools such as PRECIS and MAGICC/SCENGEN (UNFCCC, 2016).

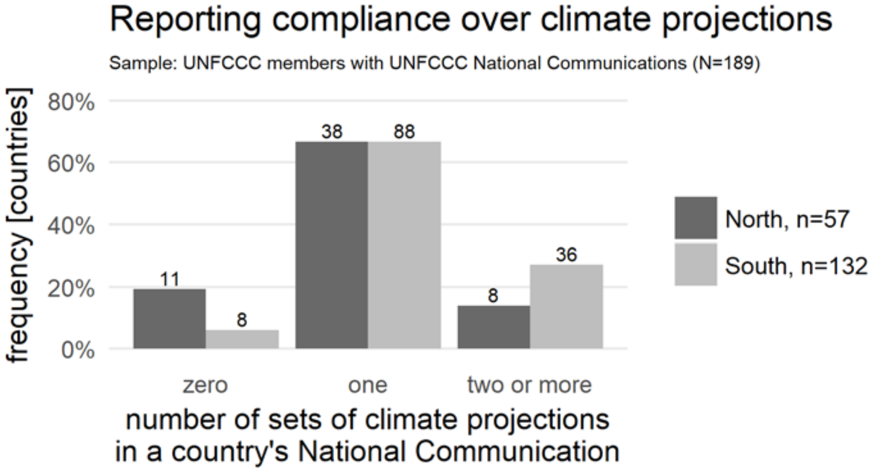

Figure 1 – The global distribution of climate projections reported by northern and southern countries in UNFCCC National Communications.

4. What climate model characteristics do National Communications submissions share?

Of the n=170 (out of 189) National Communications that provided climate projections, our research found two important north-south differences in modelling characteristics: (i) the complexity of the methods used, and (ii) the number and type of climate models run (e.g. Global Climate Models (GCMs) vs. Regional Climate Models (RCMs)). These modelling choices reflect the climate expertise, knowledge and scientific capacities available to each country, while also being influenced by wider social, political and economic factors.

4.1 Climate modelling complexity

As shown in Figure 2, we created a rank order from the least to the most complex climate projections approaches. For instance, while some approaches do not require specialist knowledge to produce climate projections, others allow a high level of customisation with different sets of observations, models or statistical methods. Modelling efforts were classified according to one of six groupings:

1. *Other.* No details provided about the methods or data sources used. Five countries in the north (11%) and six in the south (5%) fitted into this category.
2. *Lookup.* Existing datasets, such as the United Nations' Climate Change Country Profiles (McSweeney et al. 2010), are used to insert tables or figures into the National Communications. No data customisation is possible.
3. *Plug-and-play.* Software packages including MAGICC-SCENGEN (Wigley, 2008) and SimCLIM (Warrick et al., 2005) are used to calculate future climates using a simple energy-balance model with pattern-scaling. Some data customisation is possible.
4. *GCM only.* Raw data is downloaded from portals such as 'Climate Explorer' (Trouet and van Oldenborgh, 2013) and projections produced using one or multiple Global Climate Models (GCMs). However, the spatial resolution of GCMs (100km and more) cannot account for topographical features such as mountain ranges or islands.
5. *Statistical downscaling.* GCM outputs are downscaled using statistical techniques to achieve a higher spatial resolution. A high level of technical skill is required to perform downscaling competently (Wilby 2002).
6. *Dynamical downscaling.* A highly demanding technical approach for producing high-spatial resolution outputs (e.g. <25km) using RCMs. Freedom for customisation is high. However, RCMs have issues with nonlinear feedbacks and miss long-distance climate linkages (teleconnections).

Figure 2 reveals a north-south divide for the complexity of the climate modelling used. Whereas the majority of the northern climate modelling efforts (n=31/46, 67%) mapped onto the most complex category (i.e. dynamical downscaling), the majority of southern climate modelling efforts (n=78/124, 63%) focused on the computationally less demanding categories (e.g. lookup, plug-and-play, GCM only). The lack of scientific infrastructures, and data availability, may help explain the preference for less demanding climate modelling approaches. For instance, one of the advantages of plug-and-play methods, such as MAGICC-SCENGEN, is that they can be stored on USB devices and run offline, getting away from internet bandwidth problems. Furthermore, empirical studies have shown that simple energy balance models can perform surprisingly well compared to more complex climate models (e.g. GCMs) but require a fraction of the skill, resources, and time involved (Shackley et al., 1998).

That said, nearly a quarter (n=30/124, 24%) of southern countries made use of the most complex modelling approach: dynamical downscaling, using Regional Climate Models (RCMs). This could be because RCM runs, which are essential to performing high-resolution dynamical downscaling, are increasingly available in the south through modelling initiatives such as CORDEX (Giorgi et al., 2009) and free-to-use modelling software packages such as the UK Met Office's PRECIS model (Jones *et al.* 2004). Until recently, RCM usage had been largely restricted to the global north and developed via European projects such as ENSEMBLES (van der Linden and Mitchell, 2009).

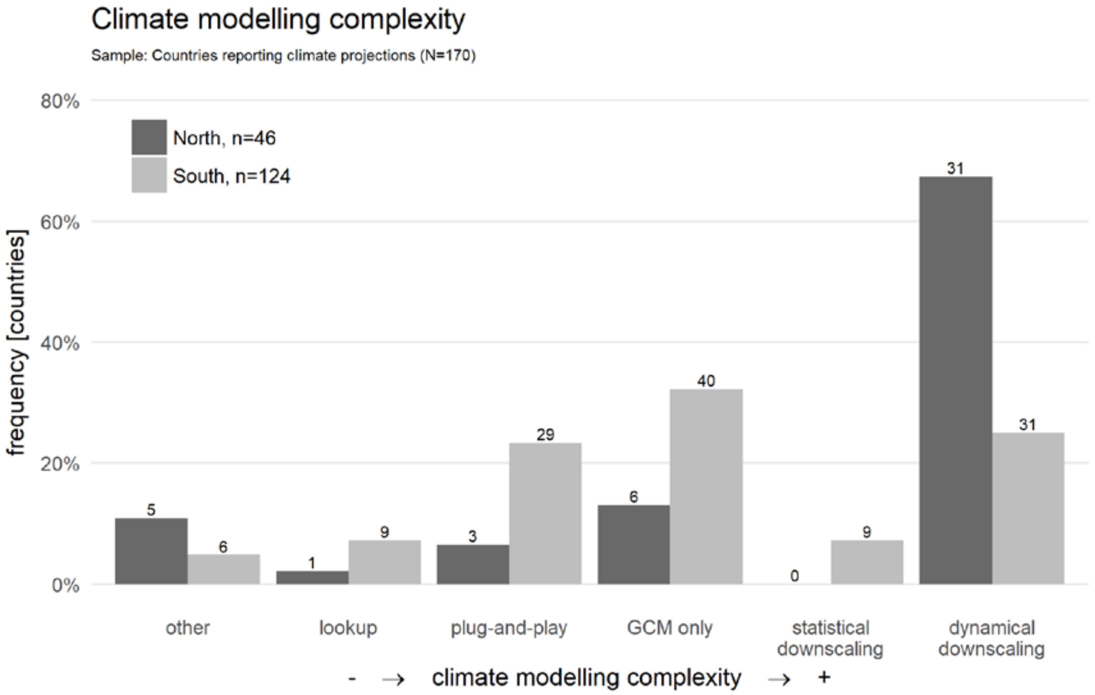

Figure 2 – Distribution of climate modelling complexity in the north and south, ranked from less complex (left) to more complex (right).

4.2 Number of climate models used

Figure 3a is a boxplot that shows how many Global Circulation Models (GCMs) were used in both the north and south to produce climate projections for their National Communications. Excluding the outliers, where Finland in the north ran 28 GCMs and Argentina in the south ran 42 GCMs, the data shows little difference in the distribution of GCMs used. The use of multiple GCMs is encouraging, given that multi-model ensembles inform about certain aspects of structural uncertainties in climate modelling practices (Knutti *et al.* 2010; Kreienkamp *et al.* 2012; Parker, 2010). The availability of multiple GCM runs from projects such as the Coupled Model Intercomparison Project (CMIP, e.g. Meehl et al., 2014) may have also played a key role in enabling this change.

Figure 3b shows that whilst the median number of RCMs used by both countries in the north and south is the same: 1, the distribution of RCMs is positively skewed in the north. The upper tail of northern countries is longer than the upper tail of the south, mainly due European countries making use of the EU-funded ENSEMBLES projections (van der Linden and Mitchell, 2009). Figure 3b gives thus light empirical support to the existence of a north-south divide regarding the use of multiple RCMs. However, a closer analysis reveals that this median equality might be misleading, as it is an effect of the north-south definition used by Blicharska et al. (2017). Northern countries using a single RCM include high-income states such as Brunei Darussalam, Chile, Trinidad and Tobago, Saudi Arabia and South Korea. This sampling issue partially masks the extent of the divide. Overall, of the countries that use a single RCM (n=36/62, 58%), the free climate modelling software package PRECIS (Jones et al., 2004) is the most common (n=17). This indicates that the recommended use of multi-model ensembles (Knutti et al., 2010) has not as yet been transferred to the use of multiple RCMs as well. This may change as the global availability of RCMs increases through initiatives such as CORDEX (Giorgi et al., 2009). However, as computational complexities, time involved, and resources needed all increase, it becomes harder for southern countries to match the modelling capacities of the north.

On the surface, these findings reveal little evidence of a north-south divide in producing climate knowledge. Northern and southern countries make similar use of GCM outputs. However, closer inspection reveals some subtle yet important differences when modelling complexity as well as financial and human resources involved increase. Southern countries were less likely to use an RCM, and if they did, these countries were restricted to free-to-use tools such as PRECIS.

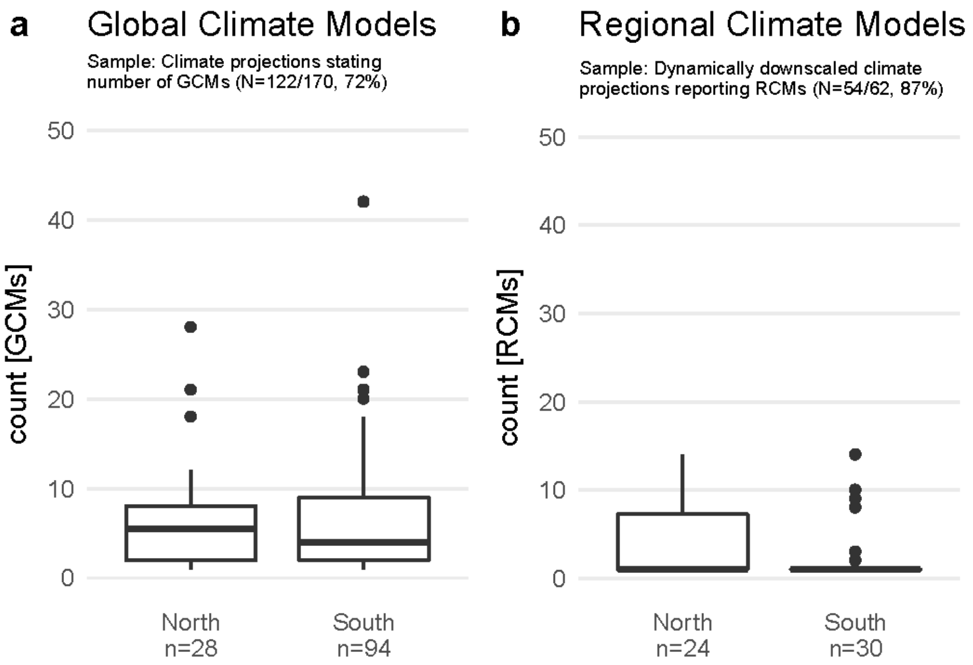

Figure 3a and 3b – Distribution of the number of Global Circulation Models (GCMs, left panel a) and Regional Climate Models (RCMs, right panel b) used in climate projections across countries in the north and south. While Fig. 3a shows that multi-model GCM ensembles are common for the majority of climate projections in both the north and south, most northern and southern climate projections with dynamical downscaling have used only a single RCM (Fig. 3b). However, the upper tail is longer for northern climate projections than for southern (positive skew). This indicates that a faint north-south divide in the use of multiple RCMs exists. Closer analysis reveals that sampling issues with who is classified as 'northern' and 'southern' mask the extent of this divide. Bold line denotes the median number of climate models used; box the 25th and 75th percentile; whiskers the 5th and 95th percentile; and points are outliers.

5. What type of climate futures do countries report?

For climate modelling, a key indicator of scientific capacity is not only the ability to use multiple, complex, and technically demanding models (e.g. dynamical downscaling) but also to incorporate different socio-economic conditions and timeframes to understand how different climate futures can develop. Too many time periods and/or emission scenarios can result in an inability to work through different variations, creating a decision-making paralysis. Too few, by contrast, locks the decision-maker into a deterministic view that discounts the importance of uncertainty (Hulme and Dessai, 2008; Parker, 2010). In addition, the common use of ensembles of GCMs is important in accounting for the structural uncertainty of climate models (Knutti et al., 2010; Parker, 2010). To that end, this section highlights: (i) how many time horizons were considered (e.g. up to

2050s or 2090s), in both the north and south; and (ii) how many emission scenarios were used (e.g. single vs. multiple).

First, the vast majority of both northern and southern countries used multiple time-horizons (n=129/170, 76%) up to the end of the century (Suppl. Fig. 2). IPCC guidance notes that '[t]he length of time period considered in the assessment studies can significantly affect results' (Knutti et al., 2010: 11). In response, the UNFCCC recommended that countries 'consider time frames ranging from 2030 to 2100' in order to incorporate uncertainty from socio-economic factors over the longer-term (e.g. after the 2060s) (UNFCCC, 2008: 12; see also Hawkins and Sutton, 2009).

Interestingly, a north-south asymmetry emerges only when comparing the single timeframe reported. Not only were northern countries (n=13/46, 28%) nearly double as likely to use a single time horizon compared to the south (n=19/124, 15%) (Fig. 4). The north (n=12/13, 92%) was also four times more interested in information at the end of the 21st century, selecting time horizons ending in the year 2090 or later. Only 21% (n=4/19) in the south did so. Conversely, southern countries (n=8/19, 42%) were five times more likely to choose a mid-term timeframe ending before 2060 than the single northern country (n=1/13, 8%), the Bahamas. Reasons for this north-south discrepancy may include the south's need to foreground the urgency of climate risks to leverage funding (e.g. through the Green Climate Fund); the need to convince national politicians and policy-makers of the urgency of climate change now and in the future; and the need to prioritise adaptation planning over mitigation efforts. One risk here is that if the projected future climate radically changes after 2050s then the long-term robustness of adaptation policies may be tested.

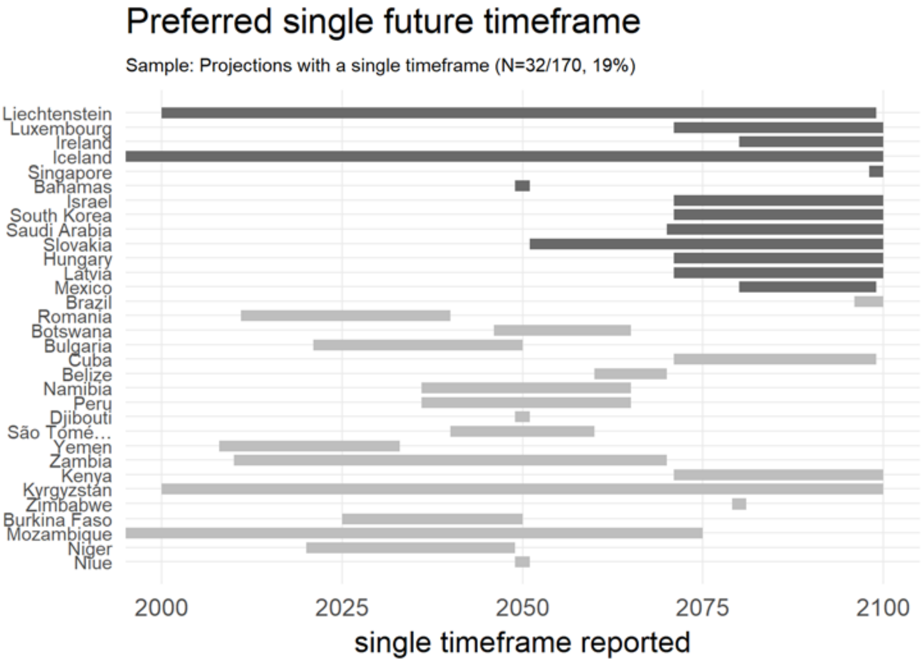

Figure 4 – Countries' preferred single timeframe. Northern states are depicted in dark grey, southern countries in light grey. The countries on the y-axis are ordered by GDP per capita, with the richest countries at the top. The states of Liechtenstein, Iceland, Kyrgyzstan and Mozambique have opted to report climatic changes using continuous, 'transient' timeframes without breaks.

Second, we found little difference between northern (n=46/46, 100%) and southern (n=114/124, 92%) countries over the reporting compliance and number of emission scenarios used (Suppl. Fig. 2). Whilst UNFCCC guidance (UNFCCC, 2008: 12) acknowledges that 'developing baseline scenarios can be complex and time-consuming', it is recommended that at least two emission scenarios be selected – one high and one low temperature response – to capture the envelope of socio-economic uncertainty (Kreienkamp et al., 2012). Our research indicates that the majority of countries both in the north (n=27/46, 59%) and south (n=70/124, 56%) heeded this advice by selecting two or three emission scenarios. In total, only a small number of countries (n=8/170, 5%) reported the use of four emission scenarios. Iran is an outlier, reporting all 18 available emission scenarios of MAGICC-SCENGEN.

Approximately a third of countries from both the north (n=17/46, 37%) and south (n=35/124, 28%) only reported a single emission scenario. Interestingly, a comparison of the single emission scenario's mitigation pathway reveals a preference for the worst-case among southern countries, while the north opted more often for a middle-of-the-road emissions scenario (see Figure 5). Only Saudi Arabia and the Bahamas, both northern countries using Blicharska et al. (2017) definition, used a very high[5] emission scenario (n=2/17, 12%). In the south, this ratio doubled to 26% (n=9/35). By contrast, 82% of northern countries (n=14/17) reported the use of a high emission scenario. These northern countries assumed a future where global population peaks mid-century and there is fast introduction of new and efficient technologies. The reported climate projections therefore reveal an important distinction between the north – whose National Communications presume a more optimistic outlook regarding mitigation efforts – and the south – whose National Communications opt for a worst-case scenario.

In terms of depicting multiple climate futures, no significant difference between the north and south emerges. Both make use of multiple emission scenarios and various timeframes, often until the end of the 21st century. Northern countries who reported only a single time period focused on longer-term climate

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[5] Very high emission scenarios: A2, IS92e, RCP8.5 and AF1I (n=9), high emission scenarios: A1B, IS92a, B2 (n=28), medium emission scenarios: RCP4.5, 2xCO2 (n=3), and low emission scenario RCP2.6 (n=0). Based on Burkett et al. (2014: 179).

change, whereas the south prioritised near-term time horizons (e.g. 2050s). If a single emission scenario was chosen, the north opted more frequently for a middle-of-the-road emission scenario, with a higher share of southern countries selecting a worst-case scenario.

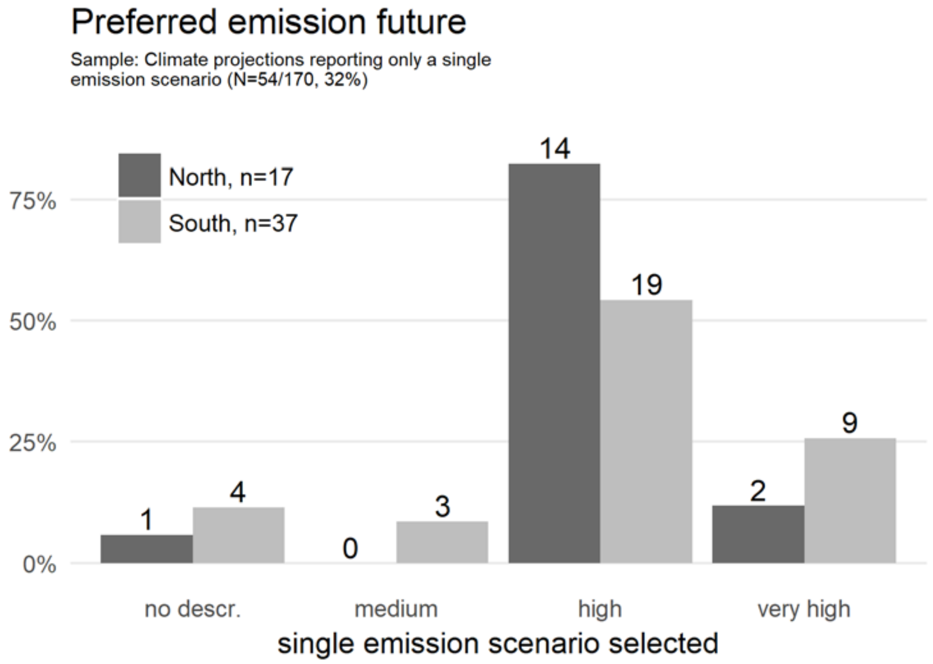

Figure 5 – countries' preferred single emission scenario.

6. Discussion: Does a north-south divide for climate projections exist?

Close examination of 189 countries' most recent UNFCCC National Communication submissions from 1999 to 2016, reveals a more complex picture than the current north-south divide debate paints. Our research provides three key findings. First, *an inverse north-south divide may exist*. Reporting compliance of climate projections varies geographically. 94% of southern countries provided climate projections whereas ft% of northern countries failed to do so. Second, *a north-south divide may not exist*. Both the north and south are able to produce climate projections and observe basic climate modelling norms (e.g. Global Climate Models (GCMs), ensembles, multiple emission scenarios and timeframes). Lastly, *a north-south divide does exist*. Southern countries used less complex modelling techniques and fewer Regional Climate Models (RCMs), while northern countries preferred long-term timeframes and a more optimistic mitigation scenario when selecting a single timeframe or emission scenario.

Our analysis provides (cautious) optimism that scientific capacities in the south may be improving, or that the gap between the north and south is less clear-cut. We found shared climate modelling practices in both the north and south, as well as a strong commitment in the south to identify and assess climate risks. Factors that have influenced the capacity of southern countries to perform the scientifically more demanding parts of the National Communications include: technology transfer in the form of free-to-use climate modelling software such as PRECIS; free training sessions provided by UNFCCC to give expert guidance on how to prepare climate projections for the National Communications (UNFCCC, 2012, 2016); financial support to help fund the National Communication process; and future funding released on completion of vulnerability assessments (e.g. GCF, 2017). Such initiatives align closely with recommendations made by Blicharska et al. (2017), Pasgaard et al. (2015), Pasgaard and Strange (2013), and Karlsson et al. (2007) on how to improve scientific capacity in the south.

Yet our research criticises how the north-south divide is defined – where the ‘north’ is depicted as having high scientific capacity, on the one hand, and the ‘south’ has low scientific capacity, on the other. In both cases a more complex picture emerges from the data. Northern high-income countries including Bahrain, Egypt, Qatar, and the United Arabs of Emirates did not produce climate projections, for instance. This suggests there are some ‘north’ countries with a level of scientific capacity that is equivalent to, or lower, than that attributed to countries in the ‘south’. In turn, there are countries from the ‘south’ such as Brazil (Nobre *et al.* 2013) and India (Dash *et al.* 2017) which are producing their own climate models. Such technical feats not only differentiate these countries from others in the ‘south’ but also elevate them above the scientific capacity of some ‘north’ countries as well. With the varying levels of resources, and commitments to meet reporting requirements, in both the north and south, it is clear that this binary is problematic.

Importantly, our research highlights concerns about modelling initiatives intended to improve scientific capacity in the south having the opposite effect. If countries are to prepare for climate change it is critical that they have the scientific capacity needed to generate relevant knowledge as well as the ability to translate it into domestic policies (Ho-Lem et al., 2011). However, the use of free-to-use modelling packages, combined with short training sessions that promote the use of such modelling tools (UNFCCC, 2016), can complicate the development of both qualities. For instance, data collection (e.g. measurement), synthesis (e.g. integration of different knowledge types), and validation (e.g. peer-review), all central to scientific knowledge production, are all missing ingredients in free-to-use modelling packages such as PRECIS. Indeed, such software restricts customisation, limiting the role of the scientist to pick the resolution, emission scenarios, and time horizon preferences. This contrasts with the climate projections efforts in the north in which modelling choices are far more elaborate, taking into account the national decision-making culture (Skelton et al., 2017). In other words, without such expertise climate tools act as black-boxes where epistemic interpretation, validation and customisation is impossible. This limits the level of technical understanding developed (Mahony and Hulme, 2012).

As a result, an institutional-political preference to produce climate projections for the National Communications, which fulfil reporting requirements (UNFCCC, 2008), may drive a new divide. Whilst modelling initiatives such as PRECIS are crucial to assessing climate risks for regions where little data, or scientific infrastructures, exist in the short-term (Jones et al., 2004; Mahony and Hulme, 2012), their *use* does not address longer-term concerns about geographical imbalances over who becomes an IPCC author (Corbera et al., 2015; Ho-Lem et al., 2011) or who publishes in high-impact journals (Karlsson et al., 2007; Pasgaard et al., 2015). Using the example of early-career climate scientists in Africa, Dike et al. (2018) emphasise the need to improve and support internal structures for producing climate science *within* individual countries. Otherwise a relationship of *dependency* between the south on the north will persist. PRECIS, for instance, provides regional modelling services for free. But in doing so, PRECIS obtains user data that can be used not only to improve the performance of other UK Met Office climate models (Jones et al., 2004; Mahony and Hulme, 2012) but also to understand where, and what, bespoke modelling services can be either sold or funded through further development aid. Such interests resonate with the research of Lahsen (2007) on the Brazilian climate science-policy interface. She found policymakers were often suspicious of international climate knowledge efforts, due to concerns that the interests and agendas of the global north were advanced, not the global south. Our research calls for a more critical stance towards exploring the north-south divide to understand the extent to which efforts to improve scientific capacity, and address geographical imbalances, may be masking or worsening the situation.

Lastly, our research highlights, and is subject to, some limitations with the UNFCCC National Communications dataset. Amongst the northern countries that failed to submit any climate projections in their National Communications, further research revealed that Australia (CSIRO and Bureau of Meteorology, 2007), Canada (Barrow et al., 2004) and Spain (Gutiérrez et al., 2012), have in fact all produced national climate projections. Why these climate projections were not included in the submissions is not clear. Yet such observations are helpful in revealing the challenges of working with global datasets where reporting requirements are either inconsistently met or simply ignored. Further, the voluntary nature of reporting National Communications for non-Annex 1 countries results in climate projections produced at irregular intervals (see Suppl. Fig. 1). While the majority (n=120/189, 63%) of Communications have been submitted between 2013 and 2016, the overall timespan of 16 years complicates comparison, as more recent submissions have more climate models available. Future research should critically examine what interrelated factors maintain, shift and potentially worsen the north-south divide in climate projections. Based on our research, four factors play an important role: (i) ‘goodwill’ efforts by global north climate scientists (predominantly Anglophone); (ii) capacity-building commitments from global north countries within UNFCCC; (iii) UNFCCC assistance provided to global south countries when preparing National Communications; and (iv) the financial aid attached to vulnerability assessments.

7. Conclusion

Our research cautions researchers against the uncritical use of the ‘north-south divide’. We argue that geographical imbalances in the production of climate knowledge do exist, but that the scientific capacities of individual countries do not always map neatly onto this dichotomy. Moreover, we suggest that whilst countries from the ‘south’ are becoming more proficient at *using* climate knowledge, especially free-to-use modelling software such as PRECIS, they have not as yet developed the capacity to *produce* climate information themselves. These countries, as a result, remain *dependent* on the northern knowledge, expertise and tools to assess climate risks. Urgent, critical, research is needed to examine the extent to which free-to-use modelling packages from the ‘north’ improve (or undermine) the scientific capacity of the ‘south’.

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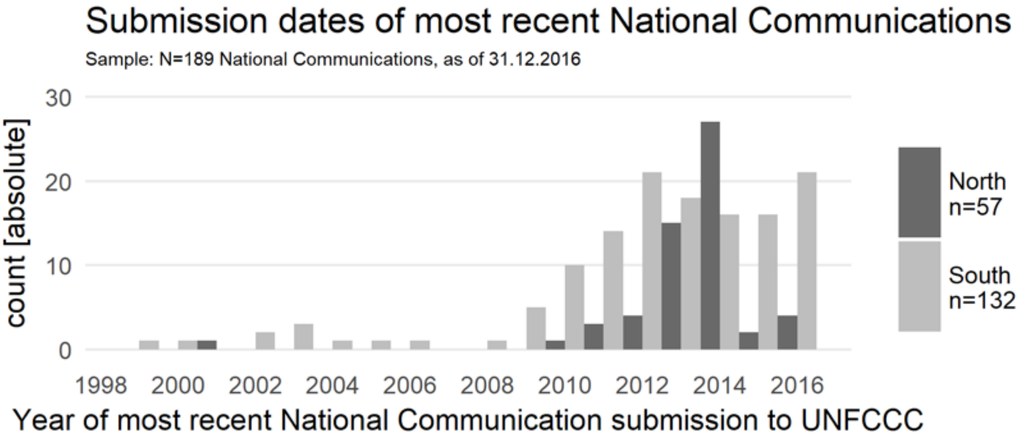
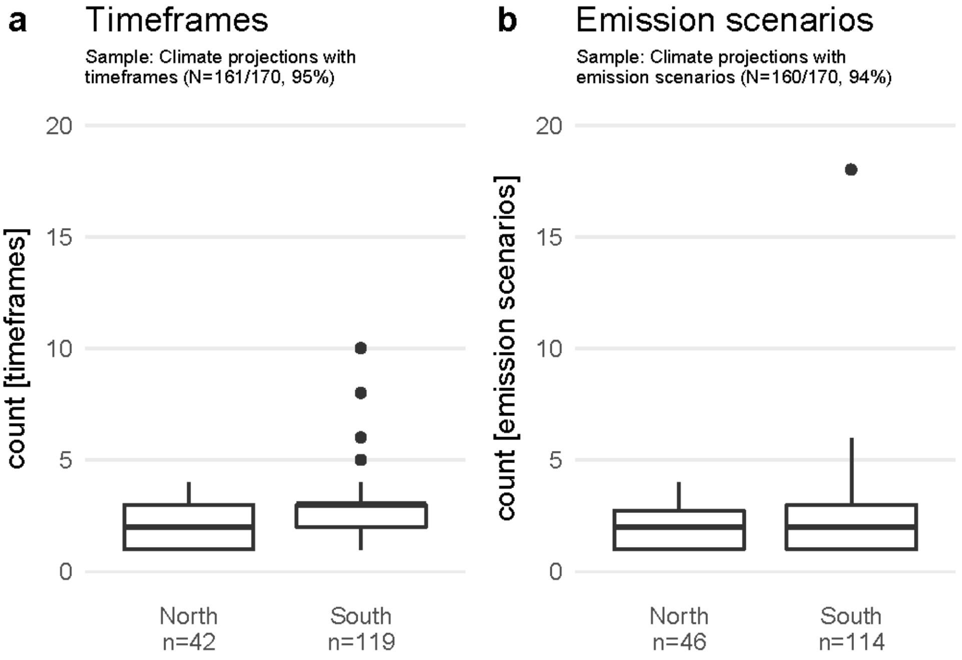
9. Supplementary Figures



Supplementary Figure 1 – Distribution of the submission year of UNFCCC members' most recent National Communication (as of 31.12.2016). Note the skewed distribution.



Supplementary Figure 2 – Distribution of the number of timeframes (left panel, a) and emission scenarios (right panel, b) used in climate projections across countries in the north and south. Both a and b give no indication of a north-south divide. Bold line denotes the median number of climate models used; box the 25th and 75th percentile; whiskers the 5th and 95th percentile; and points are outliers.