Governing the Climate from Space: Measuring, Reporting and Verification as Ordering Practice

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‘I think a strong case can be made that the [Orbiting Carbon Observatory] should be reproduced as soon as possible. Here we are, on the verge of new international agreements, without thinking about how to monitor them. We are neglecting climate as an element of national security. We're not getting the information we need. Where are [climate] changes happening, and where are they going to happen?’

-Ralph Cicerone, President of the National Academy of Sciences
Speaking to Congress, 4 March 2009

Introduction

To measure, report and verify (MRV) flows of carbon has become an integral part of global climate governance. Since the Bali Action Plan was adopted in December 2007, the credibility of a future climate treaty has hinged on the development of an appropriate MRV system that guarantees effective greenhouse gas mitigation efforts in the post 2012 era (Ellis and Moarif 2009, Breidenich and Bodansky 2009, see also UNFCCC/CP/2007/6/Add.1). Although the MRV concept *per se* is a fairly recent innovation in climate politics, we will in this paper argue that it can be traced back to a whole series of techniques and practices that have been developed and refined throughout the UN negotiations on climate change. Ever since the signing of the United Nations Framework Convention on Climate Change (UNFCCC) in Rio de Janeiro in 1992, states have been asked to keep track of their national sources and sinks of greenhouse gases (GHG) and to regularly report their results according to a standardised set of guidelines developed by the Intergovernmental Panel on Climate Change (IPCC). Through the rise of carbon markets such as the EU ETS and the Clean Development Mechanism (CDM) of the Kyoto Protocol, this national GHG accounting has been complemented by new ways of measuring, reporting and verifying site-specific flows of carbon. In the new carbon economy we have in recent years seen the rise of a whole repertoire of procedures devised to turn one tonnes of reduced CO_2 (1tCO2) into a thinkable, credible and tradable commodity (Stripple and Lövbrand 2010).

Although closely associated with climate politics, many of these MRV practices have been developed in expert domains that typically appear too technical and specialised to be considered political. One such domain is the carbon cycle science community that for long has been involved in the invention and refinement of a wide array of methods and techniques for measuring the exchange of carbon between the atmosphere, oceans and land (see Lövbrand 2007, Dilling 2007). In this paper we draw upon Foucauldian governmentality studies to examine the political dimensions of these MRV practices. In particular focus is the constitutive role played by remote sensing technology and space-based accounting of carbon. In an age when satellite data allows us to observe Earth from the outside, new ways of seeing and acting upon environmental problems such as climate change have gained ground in science and policy circles. The comprehensive 'bookkeeping' of the Earth's sources and sinks of greenhouse gases offered by Earth Observation satellites, in combination with ground-based measurement stations and global circulation models, has not only allowed scientists to interpret the climate as a global interconnected system. In this paper we argue that space-based carbon monitoring and verification also orders carbon space and hereby enables new ways of thinking about and organising climate governance.

The paper is organised as follows. We begin by conceptualising MRV techniques as a political practice that orders and reconfigures the climate as political space. Although developed and performed without any direct intervention by the state, we approach the many methods and techniques for carbon measuring, reporting and verification as an important technical resource for governments that shapes the ways that the climate currently is conceptualised and governed. In the second section we exemplify our argument by outlining the techniques that have established 'the national carbon sink' and 'the global carbon economy' as two thinkable administrative domains in international climate politics. In the third section we ask what the introduction of space-based MRV techniques may do to this spatial organisation of climate governance. Although the carbon bookkeeping systems available through Earth Observation Satellites are fairly new and still under development, they hold the promise of systematic remote monitoring of carbon dioxide levels 'over any spot of the Earth's surface' (NASA 2008). Whether this calculative capacity will reinforce or challenge the spatial organisation of climate politics in the post 2012 era remains an open question. However, by drawing upon the expectations tied to NASA's Orbiting Carbon Observatory (OCO), we end by mapping out some possible answers.

Measuring, reporting and verification as ordering practice

In December 2007, the 13th Conference of the Parties to the UNFCCC agreed to initiate a process that would lead to the adoption of 1) 'measurable, reportable and verifiable' climate mitigation commitments by developed states, and 2) appropriate mitigation actions by developing states supported by 'technology, financing and capacity building, in a measurable, reportable and verifiable manner' (UNFCCC/CP/2007/6/Add.1). The exact wording of this Bali Action Plan was settled at the very last minute, and the MRV concept was thus born after great political turmoil. Ellis and Moarif (2009, p. 9-10) note that there are many possible aims and definitions of MRV in a post 2012 climate treaty. In essence the concept refers to a systematic and standardised measurement of national GHG emission trends and mitigation activities. Whereas *measuring* denotes the actual accounting techniques and methods that state and non-state actors may employ when estimating GHG emissions and removals, *reporting* specifies in which format, units and timing such estimates should be communicated. *Verification* in turn refers to an independent double-checking of these estimates. By confirming that signatory states' mitigation efforts actually correspond to their agreed commitments and have *real* atmospheric effects, MRV practices aim to build trust in global climate governance (Ellis and Moarif 2009, p. 10).

As explained by Shapin (1998), a trust relationship is central to the very idea of empirical scientific knowledge. '(T)hose who have not seen these things know them by trusting those who have, or by trusting those who have trusted those who have' (Shapin 1998, p. 8). Since atmospheric GHG emissions (or the absence of them) are inherently difficult to see, standardised measurement, reporting and verification techniques and formats are devised to secure this trust relationship. By allowing geographically specific GHG data to stabilise and be comparable across time and space, a standardised MRV system holds the promise of a trustworthy post-2012 climate regime. Although observers have highlighted this central function of MRV, these techniques are often seen as secondary to climate politics (cf. Ellis and Moarif 2009, p. 34). In this paper, however, we seek to put MRV techniques in a different light. Paraphrasing Andrew Barry (2001, p. 10), we argue that any analysis of climate politics that does not consider the technical practices and devices that order and stabilise the climate as political space runs the risk of missing half the picture. Following findings from the diverse landscape of governmentality studies, we know that governing is more than a speculative activity. As argued by Miller and Rose (2008, p. 62), governing a sphere requires that it can be represented and depicted in a way that can enter the sphere of conscious political calculation. Hence, only when studying the many MRV practices that have given rise to particular ways of 'seeing' and 'knowing' the climate is it possible, we argue, to fully understand how the climate has been constructed as an administrative domain amendable to certain forms of political and economic rationality.

Political geographers have in recent years offered a wide range of examples of how material knowledge practices render the world visible and hereby open up new political spaces for government intervention. Following Michel Foucault's rethinking of government and writings on the rise of biopolitics in 18th century Europe (XXX), Murdoch and Ward (1997) have, for instance, examined the importance of statistics as a technology of government that makes visible domains of life that were once invisible. In a study of British agricultural reform during the 20th century, they show how the use of statistical representations and accounting procedures brought agriculture into being as a formal economic sector that, in all its diversity, could be conceptualised as a 'national farm' open for coordinated state intervention (Murdoch and Ward 1997). In a similar manner Braun (2000) has illustrated how the introduction of geological surveys in 19th Century Canada ordered and classified the Canadian landscape in ways that allowed the imagining of the nation as a single geological specimen. Through the circulation of maps, reports and specimens, Canada was reinvented as a 'mineral nation' and hereby drawn into global circuits of extractive capital (Braun 2000, p. 24-25). This linkage between the making of 'knowledge spaces' and 'economic spaces' is further illustrated in Agarwal's (2005) study of forest management in colonial India. When modern statistics, surveys and inventories were introduced in 19th century, Agarwal argues that forested lands were made up as a domain fit for modern government. The statistical representation of forests (e.g. volume, area, value, percentage of tree cover) allowed foresters to establish commensurability in their results and thus imagine Indian forest land as an economic resource managed by performance indicators such as yields and revenues (Agarwal 2005).

Rose-Redwood (2006) refers to geographical knowledge practices of this kind as 'geo-coding'. Through means of inscription (e.g. maps, statistics, surveys), geographical knowledge codes or orders abstract space and hereby constructs the very objects of government as something 'knowable'. Although Foucault's work on biopolitics drew attention to the means by which *the population* became visible as a problem of government through the development of statistical techniques, geographers have taught us how the same kind of mechanisms are used to understand and construct nature and territory as new domains of political and economic calculation. Just as the population is represented as an aggregated whole with certain regularities (e.g. rates of birth, death and illness) in the modern European state, Elden (2007) notes that the land it inhabits also is something that is understood in terms of its geometric, rational properties or 'qualities'. From this vantage point is territory more than land. According to Elden (2007, p. 578) it must be viewed as 'a political category; owned, distributed, mapped, calculated, bordered, and controlled.' Hence, what counts as territory does not precede its construction (Braun 2000, p. 28).

Whereas it may be tempting to ascribe this ordering of territory to a central government, Miller and Rose (2008) warn us to overestimate the unity of such calculative practices. Following Foucault's open definition of government (i.e. the conduct of conduct), they urge us to look beyond the state as the single point of origin or locus of power and instead start the analysis from the practices of governing themselves. By focusing on the heterogeneous assemblage of mechanisms, techniques and knowledges by which the natural and social world is represented, categorised and ordered, it is possible to map out the multiple centres of calculation and authority that shape the conduct of individuals in modern society (Miller and Rose 2008, p. 20). Although these knowledge practices may seem disparate and weakly linked they may, nevertheless, establish shared vocabularies, theories and explanations between agents across time and space. When doing so these technologies of government construct fields of visibility that shape and normalise the thought, aspirations and conduct of others. Hence, by paying attention to the actual mechanisms which make it possible to govern, governmentality studies help us to analyse how 'the technical itself has a politics' (Rose-Redwood 2006, p. 482).

In the following we employ this mode of analysis when examining how the climate has been represented and ordered as political space. We begin by drawing attention to the MRV techniques that have established 'the national carbon sink' and 'the global carbon economy' as two knowable and operable domains of climate governance.

Ordering carbon space - 'the national sink' and 'the global carbon economy'

To most observers it may seem natural to talk about climate change as a global phenomenon in need of global solutions. Since the late 1980s, we have come to accept the idea that the climate represents a global system that is affected by human GHG emissions. Whereas this understanding of the climate was taken on by the United Nations in the early 1990s and today is manifested by a long series of UN agreements such as the UNFCCC, the Kyoto Protocol and the Bali Action Plan, geographical governmentality studies remind us that there is nothing fixed or given about nature as a social category. Far from constituting a field of readily intelligible objects, Braun (2000, p. 15) claims that nature 'enters into history' partly through its cultural legibility. And indeed, a study of the brief political history of the climate suggests that it can be read in many different ways. In parallel to the political efforts to establish the climate as a global concern, we have during the past decades seen a range of alternative spatial representations of the climate as an arena for local (Bulkeley and Betsill 2003, Lindseth 2004), regional (McGee 2006) and trans-national (Bulkeley 2005) action. Whereas these attempts to rethink the climate as political space have raised questions about the rationality of interstate arrangements, we will in the following argue that they have gained authority only to the extent that they have been underpinned by credible MRV techniques that have stabilised this new spatial grammar as something knowable and operable. 'The national carbon sink' and 'the global carbon economy' represent two such examples.

The national carbon sink

In conventional political analysis the space of government is typically conceived of in terms of a relation between a national population and a national territory. The inside of the nation-state is the proper home of politics and the citizenry, and hereby the space where democratic government is possible. Outside the borders of the nation state is the domain of the international and the starting point for theories on regimes, common pool resources and interstate diplomacy. Whether conceived of in terms of anarchy or hegemony, the international is typically understood as a political space where democratic government is no longer possible (Lövbrand and Stripple 2006). Although this distinction between the inside and outside of the nation-state has been subject to extensive scholarly debate and critique (Walker 1993; 2010), it still works as the central epistemological principle through which world politics are understood and ordered. From this vantage point the spatial understanding of the climate as a complex global system appears both theoretically appealing and politically challenging.

For scholars of international relations, the imagining of the climate as global space emerges as an interesting vantage point from which the territorial organisation of world politics can be studied and unbundled. Practitioners of climate diplomacy have, however, been faced with the practical challenge of moulding global flows of carbon onto territorial ground. In order to govern the climate in an effective manner, a range of climate experts have since the adoption of the UNFCCC been engaged in a complex methodological process to adjust the climate to the territorial borders of the signatory states. According to Article 4.1 of the UNFCCC (UN 1992), all parties to the convention are required to develop national inventories of their sources and sinks of greenhouse gases and to report the results on a regular basis to the UNFCCC secretariat in Bonn. Although this national GHG accounting made little sense to climate science at the time, it was the direct result of the interstate negotiations in the early 1990s. In order to allocate responsibility for climate mitigation efforts among the negotiating states, it was necessary to first know how much carbon that is emitted and sequestered within respective state borders. Hence, the global cycling of carbon between the atmosphere, oceans and land, that for long had preoccupied climate scientists, had to be broken down into the conventional geopolitical grammar of the nation-state.

In order to make these GHG inventories comparable across national borders, the IPCC has since the early 1990s been engaged in a process to develop guidelines for national GHG reporting. As clarified in the introduction to the revised 1996 IPCC guidelines, common reporting instructions are needed in order to accommodate inventories that have been developed at different levels of detail and with different methods. As a consequence all states are asked to account for their emissions and removals according to a standardised set of definitions, units and time intervals (see IPCC 1996). While these standardised reporting procedures were designed to keep track of national emission trajectories and hereby facilitate the political negotiations leading up to the Kyoto meeting in 1997, they also held great promise for large emitters with substantial forest areas. Drawing upon results from atmospheric transportation models and biomass inventories in high to mid-latitude forests, a number of states in the Northern hemisphere such as the USA, Canada and Russia saw great potential in a net accounting and reporting system that would allow them to subtract the amount of carbon stored in biomass and soils from their annual GHG emissions. Although this net accounting system turned into a central part of the compromise deal in Kyoto, it became subject to intense negotiations in the years that followed the Kyoto meeting (for an overview, see Lövbrand 2009).

When the negotiating parties reconvened in the convention's Subsidiary Body of Scientific and Technological Advice (SBSTA) in June 1998, a number of questions of technical kind were raised. Which land use categories should be included in a net accounting system? How should a forest be defined? From which base year should land-based carbon removals be calculated? How should states best factor out carbon uptake resulting from natural processes rather than direct human-induced land use activities? While the answers to these questions may seem highly technical and thus outside the domain of the political, we should not underestimate their political effect. As we have argued elsewhere (Lövbrand and Stripple 2006, Lövbrand 2007), the very idea to monitor and report *net* emissions of GHG on a national basis did not only redirect the spatial and methodological focus of the carbon cycle science community. The development of standardised definitions and accounting methods for changes in terrestrial carbon stocks also made it possible to compare very different kinds of carbon measurements across time and space, and thus establish 'the national carbon sink' as a credible spatial organisation of climate governance.

Hence, rather than challenging the territorial grammar of the nation-state, much of the techno-scientific infrastructure of the UN climate regime has worked to reinforce it. Or, as expressed by Stripple and Paterson (2007), the politics of climate change is not 'beyond the state' to the extent that is often assumed, but territorialisation is the process that is 'singing climate politics into existence'.

The global carbon economy

The 'global carbon economy' is another spatial construction that has become established as a thinkable administrative domain in international climate politics through specific techniques and rules that aim to measure, report and verify flows of carbon throughout our economies. Sometimes these flows are measured vis-à-vis a baseline (e.g. in the CDM of the Kyoto Protocol) and other times vis-à-vis an absolute level, a 'cap' (like in the EU ETS). With the entry into force of the Kyoto Protocol, the inception of the EU Emissions Trading Scheme (EU ETS) in 2005, and the more recent development of regional carbon markets in North America, Japan and Australia, global transactions in emission reductions have thus become more than mere social imagining. As estimated by the World Bank (Ambrosi and Capoor 2009, p. 1), as much as 4 811 million tons of carbon dioxide were traded by public and private actors in the year 2008 to a total value of 126 345 million USD.

The growth in carbon markets has implied the establishment of a range of new carbon currencies. The European Union Allowance (EUA), the Certified Emission Reduction (CER) and the Verified Emission Reduction (VER) are just some of the many labels currently used to conceptualise the transfer of one ton of avoided or sequestered carbon dioxide emissions from one part of the world to another. Central to the imagining of such carbon transactions is the idea that reductions of greenhouse gas emissions (translated into carbon dioxide equivalents) have the same atmospheric effect wherever they are carried out. Although the activities underpinning the avoided emissions may involve different people under very different circumstances, climate science tells us that a ton of carbon dioxide equivalents (1 tCO2eqv) is the same irregardless of its location on Earth. The geography of carbon mitigation practices does not matter. This imagining of an atmospheric mixing of carbon can be traced back to a long series of developments within meteorology and biogeochemistry during the past 100 years.[1]

When the Swedish chemist Svante Arrhenius presented his pioneering work on the human induced greenhouse effect in 1896, the global cycling of carbon had recently gained recognition within the scientific community. During the 20th century, the exchange of carbon between the main reservoirs (the atmosphere, oceans and the terrestrial biosphere) was studied in further detail and hereby offered empirical support to Arrhenius' controversial theory. When the UNFCCC was negotiated in the early 1990s, the scientific interest in *global* carbon flows was prevalent. However, as outlined in the previous section, the interstate negotiations on climate change implied that states began to monitor and report their sources and sinks of greenhouse gases on a national basis (Lövbrand and Stripple 2006). Whereas these calculative practices enabled the imagining of a national carbon space, they have also been central for the imagining of a global carbon economy. When the Kyoto Protocol was added to the UNFCCC in 1997, it included three flexibility mechanisms that were designed to help developed states to meet their quantified emission reduction targets in a cost-effective manner. The Clean Development Mechanism (CDM) is the most famous of these market-based mechanism and allows developed states to gain carbon credits for investments in emission reduction projects in the developing world (for an overview, see Lövbrand et al. 2009).

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[1] A vast array of literature substantiates this claim. Examples from the field of meteorology include Clayton (1927), Chapman (1930) and Haurwitz (1948). For a recent see review see Weart (2003).

The contemporary trade in these carbon credits, known as Certified Emission Reductions (CERs), has only been possible through the establishment of a set of multilateral verification, validation and certification practices developed through the UN climate negotiations and implemented and refined by the CDM Executive Board. These MRV techniques have allowed the emission reductions generated by locally specific CDM projects to be 'spatially fixed' (Bumpus and Liverman 2008, p. 134) and thus possible to approach as a tradable commodity. Hence, through the workings of the globalized carbon economy, specific ways of reducing emissions are today abstracted from their local context, objectified through a range of standardized measurements and verification practices, and made available for sale in the different carbon markets around the world.

Carbon markets	Compliance market	Voluntary market
Cap and trade	Kyoto Emissions Trading (IET), EU ETS, New Zealand ETS, Australian ETS, Regional Greenhouse Gas Initiative (RGGI), California Climate Registry (CCAR), Individual Carbon Allowance	Chicago Climate Exchange (CCX) Japanese Voluntary ETS
Baseline and credit	Clean Development Mechanism (CDM), Joint Implementation (JI)	Voluntary Carbon Offsetting

Table 1: Compliance and voluntary carbon markets

As indicated in Table 1, the CDM only represents one of many carbon markets that currently trade emission reductions. Although these markets differ in their construction (compliance vs. voluntary, cap and trade vs. baseline and credit), they all represent 'regimes of value' that have become thinkable and operable through a similar set of MRV practices. As we have argued elsewhere (Stripple and Lövbrand forthcoming), climate science and resource economics offer the underlying *system of thought* that make it possible to temporarily freeze people and places into an 'imaginary space' so that the calculative work of MRV can be performed. The extent to which these markets will coalesce after 2012 does, however, remain an open question. The linking of carbon markets in various locations is dependent on the recognition of the legitimacy of each other's carbon currencies. This recognition requires, in turn, that carbon market actors trust that carbon credits in other systems are generated in a measurable, reportable and verifiable manner.

Hence, the imagining of a global carbon economy is closely tied to the development of standardised MRV techniques that order global carbon space and make it susceptible to government intervention. The extent to which space-based carbon accounting systems can facilitate the development of such standardised techniques has been subject to scholarly debate for many years. In the following section we tap into this debate.

Measuring and verifying carbon from space

When analysing modern forms of rule, governmentality scholars typically ask us to look beyond grand political schemata or economic ambitions and instead draw attention to the seemingly humble and mundane mechanisms (e.g. techniques of notation, accounting, auditing) that make it possible to govern (Miller and Rose 2008, p. 32). Space-based carbon accounting systems are far from humble or mundane. In many ways they epitomise the Big Science projects of the Cold War era that Liftin (1999, p. 77-78) has called 'potent symbols of national prestige and crucial guarantors of national security.' By generating unprecedented quantities of geographical data, the satellite surveillance systems of the 1960s rendered states' territorial space transparent and were thus primarily used as a protection against military intervention. However, these military satellite systems also enabled new ways of seeing and studying the Earth. As argued by Schellnhuber (1997, p. C20), the race to the Moon in the 1960s opened up the technical capacity to look back on our blue planet in the middle of a dark, cold nowhere. This 'Earth reconnaissance' is so fundamental in the history of science that Schellnhuber talks about a second Copernican revolution.

A number of studies have examined the constitutive effects of this new planetary gaze (Lövbrand et al. 2009). Tracing the history of Earth observation satellites Jasanoff (2001) has, for instance, found a close linkage between the view of Earth from space and the sense of interdependence that gave rise to international environmental diplomacy in the 1970s. Although global environmental consciousness by no means is a direct response to the Apollo image of 'the full Earth', this image enabled the imagining of the planet as an appropriate spatial framing for sustainable environmental action (Jasanoff 2001, p. 332). Along the same lines, Höhler (2008) has argued that the view from space did not only allow the imagining of the Earth as a self-contained life-support system or 'spaceship'. The spaceship metaphor also made it possible to combine concerns about the planet with visions of global control in order to address the question of mankind's survival (Höhler 2008, p. 67). For Liftin (1999), however, Earth observation satellites do not harbour any given political logic. The early race to space, which gave birth to Earth remote sensing technologies, was driven by two superpowers in the name of national security and territorial sovereignty. Hence, satellite technology is in many ways linked to the spatial grammar of the nation-state. At the same time Litfin notes that the non-territorial nature of space activities also may challenge traditional notions of territorial exclusivity.

The approximately fifty Earth Observation satellites that were launched by the US National Aeronautics and Space Administration (NASA) as part of its Mission to Planet Earth programme in the 1990s, have led to a widespread information and data exchange among a global network of scientists and civic actors. According to Litfin (1999, p. 84) this new availability of satellite data has rendered the world transparent and may, in its global nature, undercut 'the characteristically modern conceptualization of the Earth as territorially demarcated.' Noting that there is no single or straightforward political logic of Earth observation satellites, we will in this section discuss the political effects of carbon accounting systems based on satellite technology. The extent to which the rise of space-based MRV techniques may challenge the spatial constructions of climate politics is yet to be seen. However, following the expectations tied to NASA's Orbiting Carbon Observatory (OCO), we discuss what sites and objects of politics that such geo-coding technology may (re)produce.

'Watching the Earth breath…..mapping CO2 from Space'

This year marks the 50th anniversary of Charles David Keeling's Mauna Loa carbon dioxide (CO2) record, the longest continuous measurement series of atmospheric CO2. Whereas ground-based measurements of this kind still represent the main method for tracking rising CO2 concentrations in the atmosphere, a great deal of money and scientific ingenuity has recently been invested in the possibility to monitor carbon from space. Although great hopes have been tied to satellite-based carbon accounting systems, Barry (2001, p. 17) reminds us that new technologies often circulate with difficulty. And indeed, on the morning of Feb 25 2009, the New York Times reported that 'nine years of work disappeared in five minutes yesterday when a NASA satellite crashed into the icy waters near Antarctica. Now climate scientists who worked on the ambitious effort to map the world's carbon dioxide are trying to figure out what comes next’.

The crashed satellite was known as the Orbiting Carbon Observatory (OCO) and was designed by NASA to make precise, time-dependent global measurements of atmospheric CO2 from space. The OCO was launched from the Vanderberg Air Force Base in California on a dedicated Taurus XL Rocket on February 24th, 2009. However, a problem with the Taurus rocket prevented the vehicle to reach orbit and OCO crashed into the ocean near Antarctica soon after lift off. Immediately after the crash, Pieter Tans, an atmospheric scientist at the National Oceanic and Atmospheric Administration's (NOAA) laboratory in Boulder, Colorado, claimed that ’(b)ang--it's gone. It was absolutely terrible’. Nature’s editorial ‘Down but not out’ (2009) called for an immediate replacement along with a more long-term strategic plan for assessing global carbon flows. This call reflects the hope, money and effort put into OCO’s capacity to better monitor the global carbon cycle. In one of the early scientific publications on the OCO mission, Crisp et al. (2004) write that the OCO will make the first global, space-based measurements of atmospheric CO2 with the precision, resolution, and coverage needed to characterise carbon sources and sinks on regional scales. As such it was designed to complement ground-based measurements that currently rest upon a network of about 100 monitoring sites around the world. The OCO was also expected to revolutionise existing Earth remote sensing technologies.

Neither the American Earth Observation satellites (e.g. AIRS, TES), nor the Japanese GOSAT, have OCO’s capacity to measure the total column of CO2 (from the ground and up) with a precision of almost one part per million (ppm) or its spatial resolution less than one mile fro instantaneous measurements (Freilich 2009, p. 5). The OCO would have observed most of the Earth’s surface at least once every sixteen days. It had a planned operational life of two years and can therefore be understood as an ‘essential test of the engineering designs and measurement concepts required to develop a robust capability for monitoring emissions from space’ (Pacala et al. 2009, p. 4). When NASA late in 2008, a few months before the launch, described the OCO mission they put it both in a scientific and policy context. The scientific description revolves around OCO’s ability to provide the first complete picture of the geographic distribution and seasonal variation of both human and natural sources and sinks of CO2. While the concentration of carbon in the atmosphere is fairly well known, NASA notes that climate scientists still do not know precisely where all the carbon comes from and where it goes. As underlined by Crisp and Johnsson (2005), the current monitoring network does not provide spatial resolution enough to grasp the carbon cycle. From this vantage point, the 'NASA's Orbiting Carbon Observatory satellite will work as a detective from space, measuring the distribution of carbon dioxide thousands of times daily as it orbits the planet, providing the data to create very precise carbon dioxide maps that will help us confirm the whereabouts, nature and efficiency of the sinks absorbing the 30 percent of carbon dioxide that disappears each year from the atmosphere (NASA 2008, p. 8).

While tapping into the many scientific writings on the OCO (e.g. Crisp and Johnsson 2005, Crisp et al. 2004, Livermore and Crisp 2007), NASA also placed its orbiting carbon observatory in a policy context. In 2008 Edwin Sheffner, deputy chief of Earth Science at NASA's Ames Research Center, California, argued that 'the Orbiting Carbon Observatory will provide information needed for evaluating policy options and monitoring the effectiveness of efforts to reduce carbon emissions and increase carbon sequestration locally, regionally and globally' (NASA 2008, p. 15). Already before the launch of the OCO, NASA translated its calculative capacity into the spatial grammar of the UN climate regime. By enabling comparisons of net GHG emissions among regions and countries, the OCO was expected to improve the national measurement, reporting and verification procedures in a post-2012 climate regime. NASA also foresaw how the observatory would help tropical states with large forest areas to 'identify how changes in land use affect the amount of carbon being sequestered (NASA 2008, p. 15). Beyond the UN context, NASA envisioned a role for OCO in the new carbon economy. As the rights to emit carbon dioxide will become scarcer and emission rights will become an increasingly valuable commodity, '(o)bservations of the location, amount and rate of carbon dioxide emission into the air, as well as the stock and flow of all forms of carbon on land and in the ocean, will be needed to manage such a world market fairly and efficiently' (NASA 2008, p. 14).

A few months after the crash, the American Research Council sent a letter to Major General Charles F. Bolden, Jr., administrator at NASA to influence the impendent decision on a possible replacement of OCO. Written by a special committee conducting a study on GHG measurements for treaty monitoring and verification, the letter largely reproduces the spatial imagination of NASA. Here the OCO is framed as an important instrument for international climate policy, particularly monitoring and verification, because 'such capabilities may be an important consideration in treaty discussions at the December 2009 Copenhagen meeting of the United Nations Framework Convention on Climate Change' (Pacala 2009, p. 1). The authors note that current inventories under the UNFCCC are self-reported and not required regularly for all countries. Further, no independent data exists against which to verify the statistics used to estimate CO2 emissions. Because of its short two year mission, OCO would not by itself been able to track emission trends, but it would have 'served as a pathfinder for successor satellites designed specifically to support treaty monitoring and verification' (Pacala 2009, p. 3). While the author's expectations of a future OCO-like instrument are consistent with the spatial organisation of climate politics, they note that its MRV potential extends beyond contemporary administrative arrangements. A remote sensing technology of this kind has the technical capability to monitor emissions from selected cities and power plants. Many metropolitan areas are large enough to be sampled by OCO and would thus have demonstrated the capability of monitoring urban and power plant emissions.

In an interesting white paper entitled 'The need for Atmospheric Carbon Dioxide Measurements from Space: Contributions from a Rapid Reflight of the Orbiting Carbon Observatory' (Boland et al. 2009), around 30 well-known scientists affirm this MRV potential of a future OCO-like mission. 'OCO's observations would have contributed directly to GHG source verification and quantification efforts by providing observational verification of CO2 emissions derived from fossil fuel inventories. As the US government considers mechanisms to address climate change through limiting greenhouse gas emissions, reliable, independent global measurements of atmospheric CO_2 will fulfil critical policy needs.' (Boland et al. 2009: 37). This group of mostly American scientists goes on to make the case for OCO with regards to land use and forestry issues:

> 'To date, the science community has struggled to arrive at a transparent and verifiable mechanism for quantifying GHG uptake due to land use change. By identifying and mapping natural sinks, OCO data would also have enabled more informed land-use decisions, accounting for their potential impact on atmospheric CO2. The National Carbon Accounting System (NCAS) of Australia (http://www.climate-change.gov.au/ncas/), based on remote sensed images of land use changes, has been proposed as a template for bridging the gap between carbon markets and scientific measurements (e.g., http://www.csiro.au/science/forestandcarbon.html). To tie such a policy tool to large-scale mitigation strategies we need to ascertain the relationship between

> the changes in land cover and subsequent changes in carbon flux. OCO measurements provided our best chance of making this link'. (Boland et al. 2009, XX)

The white paper ends with noting that the loss of the OCO delays delivery of critical data with policy relevance. To launch a rebuild of the OCO as soon as possible is necessary in order to provide the scientific basis for greenhouse gas policies currently under consideration.

Carbon accounting in the Amazon

One possible implication of an OCO like instrument would be to enable forest protection mechanisms, like Reducing Emissions from Deforestation and Forest Degradation (REDD), to function in a post 2012 climate treaty. Since tropical deforestation account for up to 20% of the carbon dioxide emitted by humanity each year, there are large expectations tied to the possibility of including a REDD like mechanism to allow developed countries to meet their obligations under the UNFCCC by paying tropical countries to preserve their forests. Part of the difficulty with REDD is that one must first determine how much carbon there is in a forest and then be able to monitor the changes year by year. Nature ran in October 2009 a long article on how a next climate treaty could tackle deforestation and where innovative sky-based monitoring of changes in the biomass was used (Tolleffson 2009). While this is not necessarily based in orbit, it is nevertheless the view from above that makes a difference.

Nature's article is about Greg Asner, a tropical ecologist with the Carnegie Institution for Science's global ecology department in Stanford, California. Asner's team uses a laser system to map trees and calculate the biomass of the forest. Satellites extend his view across the tropics, and he has developed automated software that can track annual changes in forest cover and calculate the biomass of the vegetation. The policy implication of this is clear: 'The fully integrated system is designed to measure the amount of carbon locked up in forests and to track changes over time — an exercise that may become a crucial foundation of the new climate treaty that global leaders are hoping to sign at the United Nations Climate Change Conference in Copenhagen this December' (Tollefsson 2009, p. 1048). Current methods for estimating biomass in forests use, basically, tape measures around trees in different plots. The biomass for every tree in a plot is calculated and those numbers are then used for modelling the biomass of the forest. Early results from Asner's research shows that remote sensing is as accurate as plot based measurements. With the remote sensing method, both the carbon inventory and the long-term carbon monitoring can now be cheaply and quickly performed. Asner has teamed up with Google.org and a forest-monitoring application will soon be freely available on the web. This will 'reduce start-up costs for tropical countries by providing them with processing power and easy access to freely available satellite data from agencies such as NASA and the Brazilian Space Agency' (Tollefsson 2009).

Discussion and conclusions

The theoretical departure for this paper is the literature on governmentality. Since first introduced by Michel Foucault in the 1970s (see Foucault's lectures from Collège de France in Burchell et al. 1991), the governmentality concept has been used and developed across numerous disciplines such as critical sociology, history, cultural studies and political geography (Rose et al., 2006; Rose-Redwood 2006). As indicated by the semantic linking of the words governing and mentality, Foucault's neologism draws attention to how we *think* about governing. Central to this analytical approach is the assumption that the ways in which we *represent* reality are intimately linked to the ways in which it is acted upon and governed. Although states and their political apparatuses remain important, they are not approached as the only locus of power. In focus are more often the dispersed practices, techniques, calculations, methods and instruments that render various aspects of reality amendable to government intervention (Rose-Redwood 2006). Studies of governmentality have drawn attention to mechanisms of knowledge production and the constitution of subjectivity originating from the contingent, every-day work of psychiatrists, social workers, accountants, economists, and spatial planners (Rose & Miller 2008, p.??). In sum, governmentality studies remind us that government does not only operate in relation to spaces defined and demarcated by geographical or territorial boundaries. Practices of government are just as much confined to zones formed through the circulation of technical practices and devices (Barry 2001: 3),

The history of the international climate regime lends support to Barry's claim about the constitutional role of technical practices and devices. This paper articulates MRV practices as technologies that enable the climate to be constructed as an administrative domain amenable to certain forms of political and economic rationality. The 'national carbon sink' and the 'global carbon economy' exemplify this configuration of climate as *political* space. Without techniques for monitoring, reporting and verifying flows of carbon within national borders, or at the local site of a CDM project or an EU industry installation, the imagining of the national carbon sink or the global carbon economy would not have been possible. Hence, contemporary climate governance rests upon the technical capability to give carbon flows, produced by different people in different geographical sites, a certain degree of uniformity and comparability. From this vantage point the technological is not something that exists outside politics. Rather, the contestation of technological designs and practices may very well open up new sites and objects of politics (Barry 2001, p. 9).

The main aim of this paper has been to explore the ways of seeing and ordering the climate as political space enabled by the recent advances in space-based carbon monitoring and verification. What does space-based MRV techniques do to the spatial organisation of climate politics? Do remote sensing systems for atmospheric carbon such as NASA's Orbiting Carbon Observatory open up new sites and objects of politics? As outlined above, the view of Earth from space tends to reinforce conceptions of globality and holism. OCO's capacity to map carbon stocks and flows, real time exchanges between different reservoirs, does certainly enhance the biological, or even organic, imagery of the Earth as a single living organism. As NASA puts it on their home page: "Watching the Earth breath….mapping CO_2 from space". As outlined above, much of the expectations tied to OCO reinforce the spatial grammar of the UN climate regime. By offering new tools for national measurement, reporting and verification, this remote sensing technology invokes images of global carbon control. At the same time the MRV capacity of this satellite technology may very well produce a more fragmented geopolitical space. By measuring sources and sinks of carbon 'vertically', i.e. from the ground and up, OCO-like satellites hold the promise of a spatial geography of carbon where we almost instantly (every 16 days) know the CO2 levels 'over any spot of the Earths surface'. Similar to more traditional forms of air pollution (e.g. sulphur, nitrogen oxide, persistant organic pollutants, ground level ozone, heavy metals etc), the exact carbon content of the airspace will now be much clearer. The almost instantaneous net accounting of carbon implies that events such as forest fire or traffic congestion will leave an immediate footprint in the record.

We do not know yet what the more precise geopolitical imagination of the flows of carbon will imply, but to allude to Rose-Redwoods' concept of the 'geo-coded' we might think in terms of a carbon-coded world. It is conceivable that political spaces (states, urban regions, remote localites, cities, communities etc.) can be held accountable in new ways. An OCO like instrument would offer reliable and independent data for the verification of the self-reported national communications of greenhouse gases. However, OCO would also enable independent information of the carbon flows from spaces that are not urged to (or cannot or do not want to) report on their carbon emissions. Early results from the NASA funded 'Vulcan project' at Purdue University is interesting in this respect (Guerney et al. 2009). They write that the 'Vulcan project has achieved the quantification of the 2002 U.S. fossil fuel CO_2 emissions at the scale of individual factories, powerplants, roadways and neighbourhoods on an hourly basis. We have built the entire inventory on a common 10 km x 10 km grid to facilitate atmospheric modeling. In addition to improvement in space and time resolution, Vulcan is quantified at the level of fuel type, economic sub-sector, and county/state identification.[2]

It is also likely that better measurements will enable flows of carbon to be turned into commodities to be sold on the carbon market. The precise carbon-codification of particular spaces will probably enable forest protection mechanisms, like REDD, to take off. To measure, report and verify changes year by year over a certain area is what makes the commodification of forest-carbon possible. In a wider sense, one might ask what an OCO-like carbon codification of the world would do to our understanding of the political dimensions of emissions. For example, would the old insistence that all emissions are not equal, that it is crucial to differentiate between for example 'survival' and 'luxury' emission, get renewed attention? Or is it more likely that a carbon codification of the world that follows a spatial grammar of aggregation will make different categories of emissions invisible. Its seems likely that an OCO like instrument would contribute to the homogenization (or singularization?) of particular carbon-spaces, but that the technology also makes it possible to disaggregate the numbers along the lines of the Vulcan project.

Technologies such as MRV help to stabilise and arrange the climate as political space. Space-based technologies are one of the many MRV practices that order the climate and makes it amenable for political interventions. To understand the current shape of climate politics and possible climate policy futures, we must pay more attention to how practices like MRV have enabled the climate as an administrative domain and how they shape the realm of the possible. In current understandings of climate policy, technologies have a politics, that is far to often neglected and must be brought to fore in political analysis.

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[2] (http://www.purdue.edu/eas/carbon/vulcan/index.php)

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