Cloud Geographies: Computing, Data, Sovereignty

Louise Amoore

Introduction: A "beautiful sight"

In his Nobel lecture of 1927, the physicist Charles Thomson Rees Wilson described the cloud chamber experiments he had conducted from the late nineteenth century, and how they had transformed the capacities of modern physics into the twentieth century. From the observatory at the summit of Ben Nevis, Wilson had witnessed what he depicted as "the wonderful optical phenomena" of the formation of clouds (1927: 194). Inspired by what he had observed, Wilson spoke of cloud formations that "greatly excited my interest" so that "I wished to imitate them in the laboratory" (194). For Wilson, to reproduce in science the formation of clouds in nature was to advance understanding of the condensation physics of meteorology, and with it the taxonomy and classification of cloud forms.

Yet, when Wilson began to experiment with his cloud chamber apparatus, what he discovered was an unanticipated potential to see something not otherwise perceptible; phenomena that are beyond direct human observability. In contrast to the telescopes of the observatory, where the optic instruments had brought objects into human sight, Wilson's cloud chamber became a different kind of apparatus, one that brought something into perceptibility that precisely could not otherwise be seen. Though ionizing particles, such as alpha, beta and gamma radiation, could not be observed, the condensation trail in the cloud chamber showed the particle's path. Recalling his experiments with supersaturation levels, temperature, and the expansion of gas in his chambers, Wilson reflects in his lecture:

> I came across something which promised to be of more interest than the optical phenomena which I had intended to study […] We had a means of making visible and counting certain individual molecules or atoms which were in some exceptional condition. Could they be electrically charged atoms or ions? (Wilson, 1927: 196).

What Wilson's cloud chamber ultimately made possible for the twentieth century's study of particles, and the advent of quantum physics, was the ability to photograph and to perceive the movement of particles in an exceptional condition. As historian of science Peter Galison writes in his compelling account, "after the cloud chamber the subatomic world was suddenly rendered visualizable" (1997: 140). Charged or ionized particles could not be observed directly with optic devices, as with the instruments of microscopy or telescopy, but their traces and trajectories of motion appeared indirectly via the cloud tracks condensing on the nuclei. As Wilson reflects on his 1911 experiments: "I was delighted to see the cloud chamber filled with little wisps and threads of clouds" so that "the very beautiful sight of the clouds condensed along the tracks of the alpha particles was seen for the first time" (1927: 199). The cloud chamber apparatus, conceived for the human *observation* of processes of formation in nature, had become a technique for rendering *perceptible* movement beyond thresholds of human observation.

Almost exactly one century on from Wilson's 1911 cloud chamber images, the idea of *the cloud* is once more describing the advent of processes at scales that appear to transcend the observational paradigm, and exceed our capacities to see and to understand. Indeed, the 'cloud' in cloud computing is widely held to derive from the mapping of infrastructures of computer networks, where the visualization of a figurative cloud stands in for the complexity of the internet (Dodge and Kitchin, 2001; Dodge 2004). In the twenty first century, cloud computing promises to have effects on the geography of our world analogous to the effects of the cloud chamber on twentieth century science.

More precisely, the advent of cloud computing opens space for a renewed twinning of science and technologies of perception with geopolitical sovereignty. Such renewal signals an extension of historical technologies of imaging, mapping, and intelligence data collection into new modes of analysis and data linkage. In February 2015, for example, 17 US intelligence agencies – including the Department of Homeland Security (DHS), National Security Agency (NSA), Central Intelligence Agency (CIA), Department of the Navy, Department of the Army, National Geospatial Intelligence Agency, Defence Intelligence Agency, Office of the Director of National

Intelligence, Department of the Air Force, Federal Bureau of Investigation (FBI), Department of State, and Drug Enforcement Agency (DEA) – launched the 'ICITE' programme for the cloud-based storage, sharing and analysis of intelligence data. Here, once more, one can find the promise of a "beautiful sight" that Wilson celebrated, the making of pictures otherwise unavailable to the senses. [insert figure 1 here]. ICITE (pronounced "eye sight") is the Intelligence Community Information Technology Enterprise, a $600 million cloud computing contract with Amazon Web Services, providing a new intelligence and security data infrastructure. ICITE, it is promised, will "allow agencies to share data much more easily and avoid the kind of intelligence gaps that preceded the September 11, 2001, terrorist attacks" (Konkel 2014: 2). In this specific sense the data geographies of the cloud can be read as a response to the 9/11 Commission (2004: 269) findings of a failure to analyse across data "silos" held by different agencies.[1] As the US Director of National Intelligence James Clapper explained at the launch of the ICITE intelligence data programme, cloud computing allows government authorities to "discover, analyse and share critical information in an era of seemingly infinite data" (Konkel 2014: 2). The CIA's Chief Intelligence Officer, Douglas Wolfe, similarly expressed his hopes that the government security agencies would get "speed and scale out of the cloud, so that we can maximise automated security" (CIA 2014). The cloud promises to transform not only what kinds of data can be stored, where, and by whom, but most significantly what can be discovered and analysed of the world. The cloud's capacity to extend "big data" to a horizon of "infinite data" opens new spaces of what I have elsewhere called the politics of possibility, where security practices act upon future possible horizons, indifferent to their strict likelihood or probability (Amoore 2013). In short, the geography of the cloud is not merely supplying the spatial location of large volumes of data, but the means to map and to make perceptible the geography of our world in particular ways.

What is the geography of the 'cloud' in cloud computing? If it is the case that the architecture of the cloud is becoming ever more closely intertwined with geopolitics – from the sharing and actioning of intelligence data, to border controls, immigration decisions, and drone strikes (Jones and Johnson 2014; Adey, Whitehead and Williams 2011; Gregory 2014; Weber 2015; Shaw and Akhter 2014) – then what is the precise nature of these practices of data gathering, analysing and knowing? In this paper I will address the geographical character of cloud computing across two distinct paradigms. The first, which I will term *Cloud I*, or the *geography of cloud forms*, is concerned with the spatiality of data stored in data centres of cloud architectures. In the second mode, with *Cloud II* or the *geography of a cloud analytic*, I propose that cloud computing transforms what or who is rendered perceptible and calculable. Rather as the history of the cloud chamber is concerned with “the character of an instrument and the effects produced with it”, as Svetlana Alpers has put it (1998: 415), I am interested here in understanding the character of the instruments of cloud computing, and in their effects.

Cloud I: “Geography matters in the cloud”

Cloud geography I is concerned with the identification and spatial location of the data centres where the cloud is thought to materialize. Indeed, as computer science began to document the emergence of cloud computing, ‘geography’ came to have a specific meaning defined by where data and programs are spatially located. Thus, in a 2008 Association of Computing Machines (ACM) forum devoted to the advent of cloud computing, a transformation is described “in the geography of computation”, with “data and programs” being “liberated” as they are “swept up from desktop PCs and corporate servers and installed in the compute cloud” (Hayes 2008: 9). Such accounts of the cloud appeal to a geography of “scalable” computation which is thought to change radically with the expansion in the volume, velocity and variety of data (Boyd and Crawford 2012; Mayer-Schönberger and Cukier 2013; Kitchin 2014). There is need for some caution, however, in representing the geography of the cloud primarily in relation to the rise of twenty-first century “big data”. Indeed, the emergence of cloud computing has important origins in grid computing, distributed scientific data and, perhaps most significantly, in the notion of computing as a public utility. As the computer scientist John McCarthy addressed his MIT audience in 1961:

> Computing may someday be organized as a public utility, just as the telephone system is a public utility. The computer utility could become a new and important industry (1961: 2).

It is, thus, in the second half of the twentieth century, that the imagination of computing as a scalable public utility emerges. The apparent novelty of twenty-first century cloud computing is, more specifically, novel in relation to the personal computing of the 1980s. The advent of cloud computing displaces the personal with the mobile digital device, migrating computing from individual PCs and private corporate servers to vast data centres accessible over the internet (Zhang, Cheng and Boutaba 2010). From 2006, when Amazon Web Services launched its Elastic Compute Cloud (EC2), the architecture of cloud computing had begun to develop the three components now most recognisable in the cloud: *Infrastructure as a service*, in which hardware, servers, storage, cooling, and energy are supplied; *platform as a service*, in which the software stack is accessed via the cloud; and the *applications layer*, in which data analytics capacity is supplied via the cloud. Across the components of cloud architectures, the emphasis is on scalable computing, where the client pays for what they have used, combined with distributed computing, where multiple concurrent users can share and combine their data and their analyses.

Of course, geographers are familiar with this ostensibly scalar process of what Lamia Youssef (2008) calls the “export of computational work”, as we share the most recent draft of a paper with our collaborators via Dropbox, or upload text or an image to Facebook or Twitter, use Gmail, or as our department’s managed servers are relinquished in favour of cloud infrastructure. As the ACM conclude, the digital device communes with a “virtualized” architecture of “unseen computers, whereabouts unknown, possibly scattered across continents” (Hayes 2008: 9). However, as they heed Sam Kinsley’s (2014) timely call for attention to the materiality of virtual geographies, and for the need for precise accounts of where and how the virtual is actualized, geographers will encounter a vocabulary of virtualization in cloud computing which actually means something quite specific: a single computer hosting multiple simulated or virtual machines. In this respect, the whereabouts of “unseen computers” is not unknown at all, but rather the cloud is actualized in data centres, located in places with plentiful land, favourable tax rates, affordable energy, water for cooling, and proximity to the main trunks of the network. As Benjamin Bratton writes, the “cloud is not virtual; it is physical even if it is not always on the ground, even when it is deep underground” (2015: 29). Hence, within the terms of computer science at least, “geography” is said to “matter in the cloud” (Radiant 2015). When computer scientists ask “where is the cloud” what they denote as the “geographical questions” concern the data centres thought to “underlie the clouds”, their “physical location, resources, and jurisdiction” (Jaeger 2009: 4). When, for example, Google locate a new data centre in the tax-friendly state of Georgia, or the Swedish Internet Service Provider Bahnhof installs a data centre in the cool confines of a former nuclear bunker under Stockholm, or Sun Microsystems design a portable data centre inside a standard shipping container, the matter of geography is thought to reside in the spatial location of data storage.[2]

I propose that we think of this cloud geography as *Cloud I*, or a geography of cloud forms. Here, the geographic denotes something akin to the spatial dimensions of an arrangement, perhaps even what John Allen (2004) called the “whereabouts of power”. It is this imagination of the cloud as a dispersed yet spatially located array of data centres that is present in computer science, and that has extended into geographical, and even political and geopolitical debate. So, for example, following the disclosure of the extent of US authorities’ access to European citizens’ data via US data centres, the EU has sought to develop a ‘European cloud’ in which to imagine they might store safely European data under European jurisdiction (European Commission 2013). Similarly, following the US subpoena and mining of European financial transactions (de Goede 2012), the major Society for Worldwide Interbank Financial Telecommunications (SWIFT) has moved its cloud provision to an underground data centre in Switzerland (Flinders 2012), and the Canadian government has legislated for what it calls “data sovereignty”, where domestic public data traffic must not leave Canadian territory. Understood as a spatial arrangement, materialized in and through data centres, the abstract deterritorialized cloud is thus reterritorialized as an intelligible and governable entity.

The representation of the cloud as a territorial spatial formation is not without its geopolitical consequences, however. Following the exposure of the PRISM programme in 2013 (Greenwald 2014; Harding 2014), the UK Intelligence and Security Committee (ISC) of Parliament – the sole body responsible for public oversight of security and intelligence powers in the UK – called the Foreign Secretary Philip Hammond to testify to the committee. At the time of writing, Hammond is the final signatory of all warrants authorizing the interception and analysis of 'external' communications data, conventionally understood as where one 'end' of the communication is located externally to the UK. In his testimony this figure of final sovereign authority manifestly fails to understand the complex spatial form of data stored, transferred or analysed in the cloud:

> Q: "The distinction between internal and external to the UK is important because there are tighter restrictions on analysing internal data… But if the sender and recipient of an email are both in the UK, will it be treated as internal even if the data is routed overseas on its journey?"
>
> A: "So, I think… er…and I invite my colleagues to step in if I get this technically wrong… But I think…er…its an internal communication".
>
> *(At this point the civil servants flanking the Minister lean in "I don't think that can be right").*
>
> A: "Let me finish my train of thought… my understanding is, er, because of the technical nature of the internet… it is possible it could be routed to servers outside the UK… Please correct me if I misinterpreted that… I'm sorry, I have misled you in my use of terms… I'm trying to be helpful".
>
> Q: "Well you will be relieved to know that was the easy one. Now, the case of social media… if all of my restricted group of Facebook friends are in the UK… and I post something to Facebook, surely that should be internal?"
>
> A: *(following whispers from civil servants)* "erm… no actually if you put something on Facebook and the server is outside of the UK it will be treated as an external communication".
>
> Q: "What about cloud storage, where no other person is involved at all. It may be my decision to upload photographs to Dropbox. Would these communications be regarded as external because they are on US servers?"
>
> A: "Aaah… er. My colleagues will… oh… well…. Yes I am advised if the server is overseas they will be regarded as external" (Intelligence and Security Committee 2014, *my additions from video of testimony*).

The UK Foreign Secretary's testimony before the ISC exposes the difficulties and limit points of a territorialized juridical form in the face of cloud computing. In *Cloud I*, where the geography of cloud forms is everything, the cloud has become centred on *where* data is collected and stored. Indeed, the Anglo-American juridical tradition has founded its privacy protections precisely on the ‘consent’ required for lawful storage and collection. However, as Kate Crawford and Jason Schultz argue, the new predictive “approaches to policing and intelligence may be both qualitatively and quantitatively different from surveillance approaches”, and thus enable “discriminatory practices that circumvent current regulations” (2014: 99;105). Crawford and Schultz suggest that an alternative space for democratic oversight might lie in what they call “a right to procedural data due process”, where constraints and oversight mechanisms are placed upon the algorithmic processes of data analysis (2014: 110). Thus, even as the cloud overflows and exceeds the categories and practices of bureaucracy and law, what has come to be at stake politically has become a struggle to wrest the cloud back into a form over which one can have oversight, to expose its “bias” and demand neutrality, to make it comprehensible and accountable in democratic fora, and to render the cloud bureaucratically and juridically intelligible.

Among the critical geographical accounts of cloud computing, the desire to wrest the cloud into an intelligible form similarly finds expression in methods of visualization. The geographer and artist Trevor Paglen seeks to “make the invisible visible”, reflecting that “the cloud is a metaphor that obfuscates and obscures” the material geographies of the “surveillance state” (Paglen 2014). Paglen’s work is concerned with bringing the geopolitics of cloud computing back into a human line of sight through visualization. His methods deploy optical devices of many kinds to bring back into human vision that which would otherwise exceed the limits of observation. His ghostly images of the NSA’s data centres are photographs taken at night with a long-focus lens from a helicopter; and his photographs of the secret installations of military and drone bases in the Nevada desert are taken with adapted telescopic instruments of astronomy (Paglen 2010).

The optical instruments deployed by Paglen belong to a paradigm of observation in which, as Peter Galison describes, one is offered “a direct view” of things otherwise “subvisible” (1997: 72). As Paglen accounts for his own work:

> My intention is to *expand the visual vocabulary* we use to see the US intelligence community. Although the organizing logic of our nation's surveillance apparatus is invisibility and secrecy, its operations occupy the physical world. Digital surveillance programs require concrete data centres; intelligence agencies are based in real buildings… if we *look in the right places* at the right times, we can begin to glimpse the vast intelligence infrastructure (2014, *my emphasis*).

So, for Paglen the challenge is to "expand the visual vocabulary" in order to see more clearly the geopolitical technologies of security, or rather to bring into vision the things which would otherwise be obfuscated by the cloud.

Yet, what are the "right places" and "right times" to look and to observe? Indeed, what would be the way of seeing appropriate to what art historian Jonathan Crary (2013) calls a "relocation of vision" taking place with computation, or appropriate to the digital mediation of cultural objects identified by Gillian Rose (2015)? If the cloud is to be observed in the secret glimmering buildings of the NSA's data centres in Paglen's images, then could his "real buildings" also be located in other places? Could they be observed, for example, in the rented North-London offices where a small team of physics graduates write algorithms for risk-based security (Amoore and de Goede 2008; Amoore 2011)? Must the material geography of cloud computing be found in the buildings or territories where it is thought to actualize? Could the "right place" to look also be in the lines of code of a clustering algorithm used in anomaly detection, or in the generative logics of evolving algorithms (Parisi 2013)?[3]

To be clear, the point is that the desire to "open the black box" of cloud computing and to expand the visual vocabulary of the cloud, to envision the cloud and its properties in geographic space, dwells within and alongside the paradigm of observation. In Stephen Graham's work on cities and warfare, for example, he writes of "systems of technological vision" in which "computer code tracks and identifies" (2011: 66). Such technologies of vision, it has been noted across political geography, operate increasingly along vertical dimensions, requiring new forms of critical observation and attentiveness (Graham 2016). The emphasis in political geography has been placed overwhelmingly on bringing the abstract world into vision. There are, however, crucial aspects of these technologies which cannot be brought into human vision where, for example, algorithms are communicating with other algorithms at speeds beyond human observational capacity (MacKenzie 2016).

And so, *Cloud I*, a cloud geography of *forms*, asks the question "where is it?"; "what type is it?"; "can we map it?"; "can we recognize it?" As it was with the early classification of cloud forms, when Luke Howard first proposed names for cirrus, cumulus, and stratus in 1803, a linear system of genera and species was proposed to "enable people to think coherently about clouds" (Scorer 1967). The system of classification of cloud forms was later described as "quite ridiculous for clouds" because they are not fixed forms but ever in-formation, and indeed analogue algorithms were devised to "diagram" the observational pathways of cloud formation (see figure 2). [insert figure 2 here]. In short, *Cloud I* sustains the idea that one can have a more beautiful sight, a means of seeing more clearly and rendering coherent and intelligible. The telescope and camera Paglen brings to the scene of data deployment belongs to a particular history of observation, one of "visualizing technologies without apparent limit", one might say with Donna Haraway (1988: 581). Yet, what might it mean for geography *not* to enable coherent thinking about the cloud? If geographers determine instead to "stay with the difficulty", as Haraway has put it, of partial and indeterminate lines of sight, then all apparently coherent technologies of observation become "active perceptual systems" with "partial ways of organizing worlds" (Haraway 1988: 583). In the second variant I discuss here – *Cloud geography II*, drawing on Peter Galison's distinction between mimetic and analytical scientific instruments (1997: 97) – cloud computing appears as a *Cloud analytic*. Here, the cloud is a bundle of experimental algorithmic techniques acting upon the threshold of perceptibility itself. As Galison reminds us, in the cloud chamber "we do not actually see things", though what we do see "has a close relation to them", what he calls an "almost seeing" of otherwise subvisible entities (1997: 67). Understood thus, to say the cloud somehow obfuscates a real world of geopolitics is to miss the point somewhat. The cloud is not an obfuscation, far from it.[4] Like the cloud chamber of the twentieth century, contemporary cloud computing is about rendering perceptible and actionable (almost seeing) that which would otherwise be beyond the threshold of human vision. Where some claim the cloud makes the geographies of power in our world unintelligible, I propose that it is an important element of what Karen Barad calls the very "condition of intelligibility" (2007: 176).

Cloud II: "Changing the Aperture of Observation"

The geography of cloud as analytic, what I will call *Cloud II*, displaces the question "where is the cloud?" with "how does it perceive and analyse the world?" In this mode, cloud geography engages a flourishing debate across the humanities and social sciences on algorithmic modes of reason (Parikka 2010; Parisi 2013; Erickson et al 2015; Hayles 2012; Lemov 2015). As historian of science, Lorraine Daston and her colleagues have traced meticulously in the emergence of algorithmic rationality, the profound uncertainties of the Cold War nurtured a desire for "the crystalline definiteness" of algorithms that could "cope with a world on the brink" (Erickson et al 2013: 30). The decision procedures and axiomatic methods of algorithm appeared to extend the faculties of human reason so that they "no longer discriminated among humans, animals, and machines" in the capacity to analyse, to decide and to act (Erickson et al. 2013: 9). What we see here is the entwining together of human and machine modes of reasoning such that what Henri Bergson calls the "organs of perception" of the world are composite beings (1912: 31).

Understood in terms of the intertwined faculties of human and machine, the contemporary spaces of cloud computing exceed the territorial geographies of the location of data centres, becoming instead a novel political space of calculative reasoning (Elden 2001; 2010). Returning to the site of the ICITE programme, what kinds of perceptions and calculations of the world, what kinds of geographies, become possible with the algorithmic instruments that gather in cloud space? When the seventeen US intelligence agencies upload or analyse data in ICITE they access software as a service, so that they are not merely "joining the dots of their data" but, in fact, combining their modes of analysis. Among the ICITE platforms is *Digital Reasoning* software, a set of machine-learning tools for analysing and deriving meaning from information:

> The volume, variety, and velocity of today's information provides unprecedented opportunities for analysts, yet also creates the daunting challenge of extracting meaningful value from this information. From its inception, *Digital Reasoning* designed its machine-learning based analytics platform, *Synthesys*, with the goal of extracting value from complex, often opaque data. *Synthesys* empowers the analyst with advanced situational awareness, enhancing cognitive clarity for decision-making (Digital Reasoning 2015).

Digital Reasoning's algorithms were developed for anomaly detection in the wholesale financial industry, written to enable the analysis of "terrabytes of emails per day to detect hints of insider trading" (Leopold 2015). The software performs the role of what Katherine Hayles (2015) calls a "cognizer", carrying out the cognitive steps to detect norms and anomalies in vast data sets and, as it does so, deciding what or who will come to materialize, to matter, from the background noise. As *Digital Reasoning*'s CEO, Tim Estes, explained to an assembled group of security analysts in Washington DC, the machine-learning tools "sift through sensor data, emails and social media chatter", bringing "structure to human language" and "changing the aperture of observation" (Leopold 2015).

What would it mean to change the aperture of observation? Let me agree, curiously and peculiarly, with this vendor of software to the Department of Homeland Security and the NSA and say, yes, the aperture of observation is changing, though not in such a way that the promised "complete picture" is delivered to the analyst. The MapReduce software framework that is used does change the aperture, for it makes possible the distributed analysis of big data across data forms, and across sovereign jurisdictions (Amoore and Piotukh 2015). Put simply, in *cloud geography II*, where we are interested in the analytic, it is not so much the "where" of the data that matters as the capacity to extract patterns in information, indifferent to the location or data type.

With the advent of cloud computing, the aperture of observation becomes an aperture of "almost seeing", in Peter Galison's terms, or a means of "correlating and synthesizing large volumes of disparate data" (Office of the Director of National Intelligence 2015) so that geopolitical action can take place on the basis of what is almost seen of the world. As one analyst puts the problem: “it allows us to say correlation is enough. We can stop looking for models, throw the data at the biggest computing clusters the world has ever seen and let algorithms find the patterns” (Anderson 2008). Here I want to propose three characteristics of correlative cloud reasoning, and to suggest its significance for the geopolitical present.

Condensing traces

The geographies of *Cloud II* involve *condensing traces*, practices not primarily concerned with seeing or bringing into vision, but rather engaging a subvisible world, inferring from the traces and trajectories that condense at indeterminate points. Returning to my analogy with the apparatus of the cloud chamber, by the mid twentieth century, when CTR Wilson’s cloud chamber was being used in sub-atomic physics, the “purpose” of the instrument was described as being “to study the motion of ionizing particles from records of the drops condensed on ions formed along the trajectories followed by these particles” (Wilson 1951). The motion of particles could not be observed directly, but their trajectory perceived obliquely, via the visible drops condensed on the ions – the cloud “tracks”. Figure 3 shows one of the best-known cloud chamber photographs, C.T.R. Wilson’s image of alpha-emitting thorium, the cloud originating from an alpha ray passing through the chamber, its “trajectory disturbed in two places” (Gentner et al. 1954: 11). [insert figure 3 here] The newly-available images of radioactivity made the object perceptible via the records of condensed drops on the ions, observing the motion obliquely. In the compelling images from the cloud chamber one can locate a capacity to perceive the movement of otherwise sub-visible entities. The *chamber* of the cloud chamber is akin to an apparatus, in Michel Foucault’s terms, in that it “inserts the phenomena in question” within a “series of probable events” (2004: 6). In this sense, an apparatus is experimental to the extent that it is concerned with probable tendencies and trajectories, condensing a larger volume down to the probable event.

More specifically, as Karen Barad writes on the nature of the scientific apparatus, “apparatuses are the material conditions of possibility and impossibility of mattering” and “they enact what matters and what is excluded from mattering” (2007: 148). For Barad, the scientific apparatus is engaged in drawing the boundaries and properties of entities, in the very articulation of the world. Like the cloud chamber apparatus of the twentieth century, contemporary cloud computing is a kind of chamber or apparatus: it condenses the volume of data down to that which is probable or possible, enacting what matters and what is excluded from mattering.

In condensing the data traces of what matters in geopolitics, cloud computing enacts the matter of the person of interest at the border, the possible future disruptive event in urban space, the chains of association of no-fly lists, blacklists, and kill lists – like beaded drops of condensed data making action possible. Though the movement of the thing cannot be observed directly, it is perceived obliquely through tracks and trajectories of mobility. Indeed, *Cloud Geography II* poses significant questions for political geographical accounts of what it might mean to “secure the volume” or the “volumetric” (Elden 2013; Crampton 2010), or to have a “politics of verticality” (Weizman 2004; Adey 2010; Graham 2016). The analytical techniques available in the cloud do not strictly act upon the earth from some novel spatial dimension ‘above’ or ‘below’ the ground, but rather enrol the very space of calculation itself. As Stuart Elden notes, the term “volumetric” requires a detailed engagement with “the dimensionality implied by ‘volume’ and the calculability implied by ‘metric’” (2013: 15). Cloud computing acts upon the vast volume of data traces through a series of algorithmic metrics. In contrast with a securing *of* the volume, the pursuit of security *through* the volume precisely reduces and condenses the volume by means of the correlations within the data. The so-called ‘cognitive computing’ applications in the ICITE cloud, for example, use pattern recognition and sentiment analysis to identify political protests, civil unrest, “atypical” gatherings or events. Cognitive computing renders perceptible to the analyst “what matters” geopolitically, using the volume of cloud-based digital data precisely to reduce and flatten the field of vision. The relation between volume and flatness thus becomes one in which the tracks of association and correlation enact the horizon of possibility for the analyst. The volume is radically condensed down to the target data elements, like beaded drops on ionizing particles through which future trajectories of motion can be inferred.

Discovering patterns

The geographies of *Cloud II* involve the *discovery of patterns*, which is a highly specific calculative metric deployed in a volume of data. The repository of data in the US intelligence community's cloud, for example, is described as a "data lake" in which the "same raw data" can be analysed with "statistical functions" such as conventional regression, and with "machine learning algorithms" of "data discovery" (Radiant 2015: 6). Here, the relation of the data lake to cloud computing is metaphorically understood as the formation of clouds from the water vapour rising from lakes into the atmosphere.[5] Whilst the application of statistical analysis to intelligence data involves the analyst beginning with a deductive query or hypothesis, and building rules to test that hypothesis in the data, the advent of cloud computing presents the analyst with a volume and variety of data too great for conventional human hypothesis or deduction. In the context of a security paradigm that seeks out the "unknown unknowns", the volume of so-called "bulk data" in the lake – much of it transactions and social media data – is analysed with cloud techniques that promise to yield previously unseen patterns via processes of "knowledge discovery".

In contrast to a deductive form of reasoning by hypothesis testing, knowledge discovery algorithms deploy abductive reasoning, so that what one will ask of the data is a product of the patterns and clusters derived from that data. As Luciana Parisi writes on the algorithmic logic of abduction, "algorithms do not simply govern the procedural logics of computers" but take "generative forms driven by open-ended rules" (2013: 2), or which "derive rules from contingencies" (2013: 1-2). Understood in these terms, the knowledge discovery algorithms deployed in the cloud are generative and experimental, they work to identify possible links, associations and inferences. Such abductive forms deploy a distinct kind of causal reasoning, different from deductive reason where "deductions support their conclusions in such a way that the conclusions must be true, given the premises", and closer to "fallible inferences" where "the possibility of error remains" (Josephson and Josephson 1996: 12). Put simply, in the cloud analytic of *Cloud II*, it is, at least in part, the rules generated by the algorithmic rules that decide which fallible inferences to surface on the screen of intelligence analyst, drone pilot, or border guard.

The rise of correlative abductive reasoning has serious implications for geographical enquiry, not least because error, failure or fallibility are no longer adequate spaces for critique – they have become essential to the capacity to recognise abnormalities and generate norms. When the ambitions for cloud-based analysis are for automated geopolitical decisions, it is precisely via the generative algorithms running in cloud software that these are pursued. As one of the designers of t-digest pattern detection software explains: “as small fluctuations occur in the event stream, our model can adjust its view of normal accordingly” (Dunning and Friedman 2014: 23). As the events of geopolitics become understood as an “event stream”, the apparatus of the cloud deploys algorithms such as t-digest to generate its malleable view of what is normal in the world from the ingestion of the data stream itself.

Returning to my analogy with the cloud chamber as apparatus, the twentieth century physicists were also engaged in abductive forms of reasoning that exceeded the deductive testing of hypothesis. The cloud chamber made it possible to detect previously unseen and unknown particles, via the patterns of unusual or abnormal cloud tracks. “The central problem of the interpretation” of cloud chamber “exploratory photographs”, as described in the physicists’ guide to cloud chamber technique, was the “recognition of the particles involved in a particular event” (Wilson 1951: 122). In order to interpret the detected patterns of scattering, cascades and showers, the physicists inferred from the “characteristic features of particle behaviour” (1951: 122). They could not begin with a hypothesis and test it in the chamber, for the uncertainties and contingencies of particle behaviour had become the very focus of their enquiry. The cloud chamber played a crucial role in the identification of hitherto unknown sub-atomic particles, rendered detectable through the generation of surprising new cloud tracks and trajectories. In the text accompanying the famous Rochester atlas of cloud images, Nobel physicist Patrick Blackett writes:

> The last two decades have seen an increasing use of two experimental methods, the cloud chamber and the photographic emulsion, by which the tracks of sub-atomic particles can be studied. All but one of the now known unstable elementary particles have been discovered by these techniques. […] This involves the ability to recognise quickly many different sub-atomic events. Only when all known events can be recognised will the hitherto unknown be detected (Blackett, in Rochester and Wilson, 1952: vii).

The atlases of ‘typical’ cloud chamber images definitively did not offer the scientist a taxonomy or classificatory system for identifying particles, forming the ‘rules’ for unknown future particles. Rather, the images provide a kind of ‘training set’ of data, allowing the scientist to become sensitive to the patterns and clusters of cloud tracks, so that they may perceive the disturbances and fluctuations of a new event. The discoveries of new particle behaviours – the first glimpse of the muon or the positron in the cloud chamber, for example – were not strictly observations of an object, but more precisely perceptions of something in close relation to it: the patterns involved in an event. As Peter Galison reminds us, the cloud chamber images “travelled” and were “widely exchanged, stored and re-analyzed by groups far distant from the original photographic site” (1997: 130). In this sense, *the cloud chamber is the site*, just as *the cloud is the site* in cloud computing, through which the event is recognized via its patterns, and where the analyst is trained in the perception of patterns in data.[6] To identify the geographies of the cloud site one must extend attention beyond the data centre and into the spatialities of perception itself.

Archiving the future

The geographies of *Cloud II* involve an archiving of the future, in which particular future connections are condensed from the volume of the data stream, rendered visualizable and calculable (de Goede and Randalls, 2009; Anderson 2010; Greenhough, Lorimer and Yusoff 2015). When Amazon Web Services (AWS) supply cloud computing to corporations and governments, the applications layer is configured as an “app store” so that users can select the analytics tools they want, paying for what they use. The app store was an important element of AWS’s tender for the ICITE programme, with the US Director of National Intelligence, James Clapper, announcing that “we have made great strides, the applications are in the apps mall, and the data is in the cloud” (Office of the Director of National Intelligence 2015: ii). In fact, of course, the significance is that both the apps and the data dwell together in cloud space, opening the possibility for seemingly infinite calculability, or what Katherine Hayles calls “infinitely tractable” data (2012: 230). The interface with the analyst visualizes precisely a sense of a reach into possible futures,[7] where the analyst becomes a desiring and wanting consumer, with the "apps mall and stores available from the desktop" and selling to users "thousands of mission applications" resembling "what Apple provides through itunes" (Office of the Director of National Intelligence 2012).

Let us reflect for a moment on what the NSA or CIA analyst browsing the apps mall might find to assist them in their missions. Among the thousands of applications, *Recorded Future* offer natural language processing and sentiment analysis software to "scrape the web" for signals of possible future threat:

> We constantly scan public web sources. From these open sources, we identify text references to entities and events. Then we detect time periods: when the events are predicted to occur. You can explore the past, present and predicted future of almost anything in a matter of seconds. Our analysis tools facilitate deep investigation to better understand complex relationships, resulting in actionable insights (Recorded Future 2015).

The significance of cloud space for *Recorded Future*'s analysis methods is that the conventional sovereign space of classified intelligence data is expanded to "use the volume" of so-called open source social media and internet data. *Recorded Future*'s applications run their algorithms across the boundary of public and private cloud computing, so that the analyst can explore the correlations between, for example, classified structured data in the Department of Homeland Security's files and the language and sentiment analysis of so-called 'open source' Twitter feeds and Facebook posts. In this way, the technology enables action in the present, on the basis of possible correlations between past data archives (such as national security lists) and archives of the predictive future.

In this cloud geography, the analytic is everything. Archived data in *Recorded Future* becomes unmoored and derivative of its context, even the so-called dirty or noisy data no-longer muddying the calculation, but rendered useful. As the security analysts draw together social media "junk" data with other structured elements, tagging metadata and sharing with other agencies, diverse data elements are rendered commensurate and made actionable geopolitically. As Orit Halpern suggests in her account of how data visualization and algorithmic rationality become governmental and social virtues, computation changes the nature of the archive (2014: 16). The nineteenth century form of “static” archiving and repository is supplemented in the twentieth century by what Halpern calls “an active site for the execution of operations” (2014: 40). Similarly, in the nineteenth century cloud chamber’s attempt to reproduce nature, the cloud tracks had been considered spurious dirt effects, not for scientific archiving. Yet, it was the tracks that became the thing of interest, the atlas of cloud chamber images knowing only the event of the track itself. Contemporary cloud computing is an active site for the execution of operations, as understood by Halpern, where the archive is generative of particular imagined futures.

The archivization of specific data elements with applications such as *Recorded Future*, then, produces particular futures, “the archivization produces as much as it records the event”, as Derrida writes (1995: 17). Rather as the photographic recording of the cloud tracks within the cloud chamber archived the possibility of future sub-atomic particles, so the digital recording of social media data in cloud computing archives the possibility for future geopolitical actions. Understood in this way, one could critically challenge the spatial power of the data centre as “archive”, as I have suggested we see in Trevor Paglen’s images, whilst leaving entirely intact Halpern’s “active site of operations”, a site capable of acting indifferent to the “where” and the “what” of data. Yet, there are creative-resistant practices within Cloud II which do offer an alternative sensing of the archive as active and generative site. In his installation ‘Five Eyes’ – commissioned by the Victoria and Albert Museum for their archive-focused exhibition ‘All of this Belongs To You’ – artist James Bridle invites the viewer to consider anew the relations between archive and futures. Bridle passed the V & A’s 1.4 million digital object records through an intelligence analysis system. The analytics “extract names, things and places, and creates searchable connections between seemingly disparate objects”, the resulting connections “difficult to grasp, often inscrutable to the human eye, reflecting the mechanical calculus that was used to generate them”.[8] Displayed in a series of five glass cabinets within the V & A’s tapestry galleries, the objects surfaced for our attention by the analytics are placed atop a “stack” of analogue museum files. The object displayed is thus generated in and through the archive itself, through the intimate connections learned by the algorithms. In Bridle's rendering of the archive one can sense the "upheaval in archival technology" noted by Jacques Derrida, the infrastructure making a claim on the future, on the very infrastructure of the "archivable event" (Derrida 1995: 18). [Insert figure 4 here].

Conclusions: Cloud Geographies

When a group of physicists showed me their cloud chamber experiments, I had expected the thing of interest around which we would gather would be the cloud tracks – the wispy trajectories of particles that had so captivated Wilson. But, instead we gathered around the apparatus itself, the physicists animated by much discussion on the optimal point of cooling, and whether thorium is a useful radioactive metal for the experiment. One of the group had worked at CERN with the Large Hadron Collider, commenting that "there is no reason why we couldn't have discovered the Higgs Boson using a cloud chamber, but it would take an inordinately long time".[9] So, for the scientists there is something already there to be discovered – manifest in the alpha tracks and cosmics in the chamber – but it is rendered perceptible by a specific experimental apparatus. The experimental apparatuses of cloud chamber and cloud computing, then, are not experimental in the sense of not yet validated, but specifically "experimental" in their capacity to bring something into existence. As Isabelle Stengers describes the "paradoxical mode of existence" of sub-atomic particles, they are simultaneously "constructed by physics", and yet "exceed the time frame of human knowledge", so "the neutrino exists simultaneously and inseparably 'in itself' and 'for us', a participant in countless events" (2003: 22). The physicists I worked with concurred that the cloud chamber is of the paradigm of experimentation – it brings something into being for us, whose existence would otherwise exceed our capacities, something definitively different to the microscopes and telescopes of the paradigm of observation. I wish to conclude by commenting on why this matters for our contemporary moment, when the specific apparatus of cloud computing brings something into being, discovering associations and relations otherwise unknowable.

For me, it is imperative that we try to formulate critical geographical accounts that do not re-play the observational paradigm of *Cloud I*, and the classificatory forms related to that paradigm. In Cloud I vision is the sovereign sense, afforded both the apparent objectivity and "inherent credibility" of the "most reliable of senses", and the the means of securing the state's claim to sovereign violence (Jay 2002: 268; Bal 2003: 13; Mitchell 2005). Yet, Cloud analytics visualize and render perceptible that which could never be observed directly, could not be brought into view as with an optical device. The algorithms for high-frequency trading, or for 'real time' credit scoring, or traffic flow in smart cities, or for 'open source' intelligence, write data trajectories into being, and in the main this is written by physicists, the experimental techniques of predictive analytics operating at speeds and scales exceeding those of human knowledge, in Stengers' terms. I want to propose that this has profound political consequences. The overwhelming response to the post-Snowden exposure of bulk data analysis has been technical and juridical enshrining of the principle that "no human eyes see it" (National Research Council of the National Academies 2015; Intelligence and Security Committee of Parliament 2015). We should, apparently, be reassured that knowledge discovery is conducted by automatic process, unsupervised or semi-supervised machine learning that is not observed by human eyes. For, apparently, no privacy could be infringed, no racialized categories inscribed, no errors of judgement made. As I have described, the claim to the absence of human eyes misses the point dramatically – it is precisely in the sub-visible experimentation that a person or thing of interest is brought to the surface of perception for action. The apparatus decides what or who matters. And so, we need to seek better geographical understandings of the more than human forms of perception acting beneath thresholds of observability.

Taking one further step (if we are to think, somehow, of how progress might be made in human geography), this cloud geography I have described – the world of ICITE, digital reasoning, and recorded futures – witnesses the proliferation of a correlative algorithmic reason, with material effects and consequences. In the final months of 2015, for example, via a case filed by four Muslim US citizens against the FBI, it has finally become public domain that "no fly" lists do not merely draw upon an archive of stored past known infractions, but are produced algorithmically, detecting patterns and clusters of possible associations (Tanvir vs. Lynch 2015). Here the person of interest emerges from the correlative links of financial transactions, travel patterns, social media postings, and associates. The data archive is, as Orit Halpern proposes, an active site of operations – little pieces of past correlations enter a training data set; the writer of the algorithm experiments with thresholds; more people and things enter a validation data set; and with this recursive and correlative reasoning sovereign decisions are made: to stop, to detain, to freeze a bank account, to target, to approve, or to deny an asylum claim.

For Isabelle Stengers, experimental scientific practices work through "the power to confer on things the power of conferring on the experimenter the power to speak in their name" (2003: 31). But, once the practice travels beyond "the specific site, a laboratory where they achieved their existence", they "unbind existence, invention and proof, change meaning" and become "vectors of scientific opinion – scientific factishes" (p.31). As algorithms written for casino or credit card fraud travel to border control, to security threat analysis, I propose that cloud computing similarly confers on algorithms the power to confer on the analyst the power to speak in their name: Here are the people and things with a link to terrorism; here are the possible fraudulent asylum claims; here are the optimal targets for the next drone strike; here are the civil uprisings which will threaten the state next week. The claims that are spoken in cloud computing programmes such as ICITE, confront our fallible, intractable, fraught political world with a curious kind of infallibility. In the cloud the promise is that everything can be rendered tractable, all political difficulty and uncertainty nonetheless actionable. The ICITE app store marketplace available on the screens of analysts renders geopolitics infinitely reworkable – the "geopolitical events" in the correlative calculus, a kind of geopolitical cloud chamber. As Timothy Cavendish, a protagonist in David Mitchell's novel *Cloud Atlas*, muses "what I wouldn't give now for a map of the ever constant ineffable? To possess, as it were, an atlas of clouds" (2004: 389). Programmes such as ICITE make just such a dangerous promise to sovereign authorities – a kind of atlas of clouds for the ineffable, a condensed trace of the trajectories of our lives one with another.

Acknowledgements

An earlier version of this article was presented as the annual Progress in Human Geography lecture at the RGS/IBG in 2015. I am grateful beyond words to the audience, whose questions and insights have influenced the final written version. My

profound thanks to Noel Castree and the journal's editorial team for granting me the honour of giving the lecture. The paper has also benefitted greatly from the comments of Marieke de Goede, Paul Langley, Ben Anderson, Tim Burt, and John Amoore, two anonymous reviewers for the journal; the Masters in Forensic Architecture group at Goldsmiths College; and the audience at a keynote lecture I delivered at the Copenhagen Business School's 'Thinking Infrastructures' event – my thanks to Martin Kornberger, Ann Christina Lange and colleagues. I am profoundly grateful to Durham physicists Paula Chadwick and Peter Swift for suffering a geographer's curiosity with such generosity.
This work was supported by the RCUK Global Uncertainties Fellowship Securing Against Future Events: Pre-emption, Protocols and Publics [Grant number ES/ K000276/1].

References

9/11 Commission (2004) ***The 9/11 Commission Report: Final Report of the National Commission on the Terrorist Attacks upon the United States*.** New York: WW Norton & Company.

Adey, P. (2010) ***Aerial Life: Spaces, Mobilities, Affects***, Oxford: Wiley-Blackwell.

Adey, P., M. Whitehead, and A. Williams (eds) (2013) ***From Above: War, Violence, and Verticality***, London: Hurst.

Allen, J. (2004) 'The Whereabouts of Power: Politics, Government and Space', ***Geografiska Annaler: Series B**,* 86:1, pp. 19–32.

Alpers, S. (1998) 'The Studio, the Laboratory and the Vexations of Art', in C. Jones and P. Galison (eds) ***Picturing Science, Producing Art***, New Haven: Yale University Press.

Amoore, L. (2011) 'Data Derivatives: On the Emergence of a Security Risk Calculus for Our Times', ***Theory, Culture and Society*** 28:6, pp.24-43.

Amoore, L. (2013) ***The Politics of Possibility: Risk and Security Beyond Probability***, Durham NC: Duke University Press.

Amoore, L. and M. de Goede (2008) 'Transactions After 9/11: The Banal Face of the Preemptive Strike', ***Transactions of the Institute of British Geographers*** 33:2, pp.173-185.

Amoore, L. and V. Piotukh (2015) 'Life Beyond Big Data: Governing with Little Analytics', ***Economy & Society*** 44:3, pp.341-366.

Anderson, B. (2010) 'Preemption, Precaution, Preparedness: Anticipatory Action and Future Geographies', ***Progress in Human Geography*** 34:6, pp.777-798.

Anderson, C. (2008) 'The End of Theory: The Data Deluge Makes Scientific Method Obsolete', ***Wired***, 23rd June.

Ash, J. (2015) ***The Interface Envelope: Gaming, Technology, Power***, London: Bloomsbury.

Bal, M. (2005) 'The Commitment to Look', ***Journal of Visual Culture*** 4:2, pp.145-162.

Barad, K. (2007) ***Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning***, Durham, NC: Duke University Press.

Bergson, H. (1912). ***Matter and Memory***. Mineola, NY: Dover Philosophical Classics.

Boyd, D. and K. Crawford (2012) 'Critical Questions for Big Data', ***Information, Communication and Society*** 15:5, pp.662-679.

Bratton, B. (2015) ***The Stack: On Software and Sovereignty***, Camb. Mass: MIT Press.

CIA (2014) Interview with Chief Intelligence Officer Douglas Wolfe, available at: https://www.cia.gov/news-information/featured-story-archive/2014-featured-story-archive/cia-creates-a-cloud.html last accessed November 24th 2015.

Cowen, D. (2014) ***The Deadly Life of Logistics***, Minneapolis: University of Minnesota Press.

Crampton, J. (2010) 'Cartographic Calculations of Territory', ***Progress in Human Geography,*** 35:1, pp.92-103.

Crary, J. (2013) ***24/7: Late Capitalism and the End of Sleep***, London: Verso.

Crawford, K. and J. Schultz (2014) 'Big Data and Data Protection: Toward a Framework to Redress Predictive privacy Harms', ***Boston College Law Review***, 55:1, pp.93-128.

Derrida, J. (1995) ***Archive Fever: A Freudian Impression***, Chicago: Chicago University Press.

Digital Reasoning (2015) ***Synthesis Mission Analytics***, Franklin TS: Digital Reasoning.

de Goede, M. (2012) ***Speculative Security: The Politics of Pursuing Terrorist Monies***, Minneapolis: University of Minnesota Press.

de Goede, M. and S. Randalls (2009) 'Precaution, Preemption: Arts and Technologies of the Actionable Future', ***Environment and Planning D: Society and Space***, 27: 5, pp.859-878.

Dodge, M. (2004) 'Seeing Inside the Cloud: Some Ways to Map the Internet', ***Media Art Net Lectures***, Karlsruhe, 24th January.

Dodge, M. and R. Kitchin (2001) ***Mapping Cyberspace,*** London: Routledge.

Dunning, T. and E. Friedman (2014) ***Practical Machine Learning: A New Look at Anomaly Detection***, Sebastopol CA: O'Reilly.

Elden, S. (2001) ***Mapping the Present: Heidegger, Foucault and the Project of a Spatial History***, London: Continuum.

Elden, S. (2010) 'Land, Terrain, Territory', ***Progress in Human Geography***, 34(6), pp.799-817.

Elden, S. (2013) 'Secure the Volume: Vertical Geopolitics and the Depths of Power', ***Political Geography*** 34:1, pp.35-51.

Erickson, P., J. Klein, L. Daston, R. Lemov, T. Sturm, M. Gordin (2015) ***How Reason Almost Lost its Mind: The Strange Career of Cold War Rationality***, Chicago: Chicago University press.

European Commission (2013) 'What does the Commission mean by secure cloud computing services in Europe?', ***Memo 13/898***, Brussels: European Commission.

Flinders, Karl (2012) 'Swift builds underground datacentre to keep bank transactions in Europe', ***Computer Weekly***, 30th April.

Friedberg, A. (2006) ***The Virtual Window: From Alberti to Microsoft***, MIT Press.

Galison, P. (1997) ***Image and Logic: A Material Culture of Microphysics***. Chicago: Chicago University Press.

Galloway, A. (2012) ***The Interface Effect***, Cambridge: Polity.

Gentner, W., H. Maier-Leibnitz, W. Bothe (1954) ***An Atlas of Typical Expansion Chamber Photographs***, London: Pergamon Press.

Graham, S. (2011) ***Cities Under Siege***, London: Verso.

Graham, S. (2016, in press) ***Vertical: The City from Above and Below***, London: Verso.

Greenhough, B., J. Lorimer, and K. Yusoff (2015) 'Future Fossils', Society & Space, available at: http://societyandspace.com/2015/08/28/future-fossils-greenhough-lorimer-yusoff/ Last accessed January 2016.

Gregory, D. (2014) 'Drone Geographies', ***Radical Philosophy*** 183

Haraway, D. (1988) 'Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective', ***Feminist Studies*** 14:3, pp.575-599.

Halpern, O. (2014) ***Beautiful Data: A History of Vision and Reason Since 1945***, Durham NC: Duke University Press.

Harris, E. (2015) 'Navigating Pop-Up Geographies: Urban Space-Times of Flexibility and Immersion', ***Geography Compass*** 9:11, pp.592-603.

Hayes, B. (2008) 'Cloud Computing', ***Communications of the ACM*** 51:7, pp.9-11.

Hayles, N. K. (2012)

Intelligence and Security Committee of Parliament (2014) 'Transcript of evidence given by the Rt. Hon. Philip Hammond MP', available at: http://isc.independent.gov.uk/public-evidence Last accessed November 2015.

Jaeger, P. (2009) 'Where is the Cloud? Geography, Economics, Environment and Jurisdiction', ***First Monday*** 14:5.

Jay, M. (2002) 'Cultural Relativism and the Visual Turn', ***Journal of Visual Culture*** 1:3, pp.267-278.

Jones, R. and C. Johnson (2011) 'Interventions on rethinking 'the border' in border studies', ***Political Geography*** 30:2, pp.61-69.

Josephson, J. and S. Josephson (1996) ***Abductive Inference: Computation, Philosophy, Technology***, Cambridge: Cambridge University Press.

Kinsley, Sam (2014) 'The Matter of Virtual Geographies', ***Progress in Human Geography*** 38:3, pp.364-384.

Kitchin, R. (2014) ***The Data Revolution: Big Data, Open Data, Data Infrastructures and Their Consequences,*** London: Sage.

Konkel, F. (2014) ‘The CIA’s deal with Amazon’, ***The Atlantic***, July 17th.

Langley, P. (2015) ***Liquidity Lost: The Governance of the Global Financial Crisis***, Oxford: Oxford University Press.

Lemov, R. (2015) ***Database of Dreams: The Lost Quest to Catalog Humanity***, Yale University Press.

Leopold, G. (2015) ‘CIA Embraces Cloudera Data Hub’, ***EnterpriseTech***, February 26th.

MacKenzie, D. (2016, in press) ‘How Algorithms Interact: Goffman’s Interaction Order in Automated Trading’, ***Theory, Culture and Society***

Mayer-Schönberger, V. and K. Cukier (2013) ***Big Data: A Revolution That Will Change How We Live, Work and Think***. New York: Houghton Mifflin Harcourt.

McCarthy, J. (1961) ‘Architects of the Information Society: Thirty-Five Years of the Laboratory for Computer Science at MIT’, lecture delivered to the MIT Centennial, July 1961.

McCormack, D. (2010) ‘Remotely Sensing Affective Afterlives: The Spectral Geographies of Material Remains’, ***Annals of the Association of American Geographers*** 100(3), pp.640-654.

Mitchell, D. (2004) ***Cloud Atlas***, London: Hodder and Stoughton.

Mitchell, W.J.T (2005) ‘There are no Visual Media’, ***Journal of Visual Culture*** 4:2, pp.257-266.

National Research Council of the National Academies (2015) ***Bulk Collection of Signals Intelligence: Technical Options,*** Washington DC: National Academies Press.

Office of the Director of National Intelligence (2015) ***Intelligence Community Information Technology Enterprise Strategy 2016-2020***. Washington DC: ODNI.

Office of the Director of National Intelligence (2012) ***ICITE Fact Sheet***, Washington DC: ODNI.

Paglen, T. (2010) ***Invisible: Covert Operations and Classified Landscapes***, Aperture.

Paglen, T. (2014) 'Trevor Paglen Offers a Glimpse of America's Vast Surveillance Infrastructure', available at: http://www.americansuburbx.com/artists/trevor-paglen last accessed January 2016.

Parikka, J. (2010) ***Insect Media: An Archaeology of Animals and Technology***, Minneapolis: University of Minnesota Press.

Parisi, L. (2013) ***Contagious Architecture: Computation, Aesthetics, and Space***, MIT Press.

Peters, J. D. (2015) ***The Marvelous Clouds: Toward a Philosophy of Elemental Media***, Chicago: Chicago University Press.

Radiant (2015) ***The Definitive Guide to the Data Lake***, Boulder Co.: Radiant Advisors.

Recorded Future (2015) 'Web Intelligence', available at: https://www.recordedfuture.com/web-intelligence/ last accessed January 2016.

Rochester, G.D. and J.G Wilson (1952) ***Cloud Chamber Photographs of the Cosmic Radiation***, London: Pergamon Press.

Rose, G. (2015) 'Rethinking the Geographies of Cultural "Objects" Through Digital Technologies: Interface, Network and Friction', ***Progress in Human Geography***

Shaw. I, and M. Akhter (2014) 'The Dronification of State Violence', ***Critical Asian Studies*** 46: 2, pp.211-234.

Stengers, I. (2003) ***Cosmopolitics***, Minneapolis: University of Minnesota Press.

Weber, J. (2015) 'Keep Adding: On Kill Lists, Drone Warfare, and the Politics of Databases', ***Environment and Planning D: Society and Space***,

Weizman, E. (2004) 'The Politics of Verticality: The West Bank as an Architectural Construction', in K. Biesenbach (ed.), ***Territories: Islands, Camps, and other States of Utopia***, Köln: Walther König.

Wilson, C.T.R. (1927) 'Nobel Lecture: On the Cloud Method of Making Visible Ions and the Tracks of Ionizing Particles', ***Nobel Lectures in Physics 1922-1941***, Amsterdam: Elsevier.

Wilson, J.G. (1951) ***The Principles of Cloud Chamber Technique***, Cambridge: Cambridge University Press.

Youssef, L. (2008) ‘Toward a Unified Ontology of Cloud Computing’, IEEE November 2008.

Zhang, Q, L. Cheng, and R. Boutaba (2010) ‘Cloud Computing: State-of-the-Art and Challenges’, ***Journal of Internet Services and Applications***, 1:pp.7-18.

NOTES

[1] The data of the 17 ICITE agencies includes data from sensors, satellites, UAV images, open-source social media, internet image files, text, video, and voice over internet files. For further discussion how these different forms of structured and unstructured data are ingested and analysed see Amoore and Piotukh (2015).

[2] Though Sun Microsystems brought to market the first mobile and modular data centres inside shipping containers, Google later patented designs for floating data centres of shipping container servers stacked within cargo ships. Appealing to the capacity of the floating data centre to respond to emergencies such as the Fukushima earthquake, and to store and analyse data in international waters, the Google cloud enters the geography of logistics and “pop-up” spaces (Cowen 2014;Harris 2015).

[3] As Luciana Parisi rather beautifully describes how the spatial outline of an object is overflowed by digital computational models: “What is at stake with these generative algorithms is that the notion of discreteness has changed, and now includes a model of interactive agents that evolve in and through time” (2013: 46). Understood in these terms, there could never be a definitive building or object in which to locate cloud computation, for the forms of these places would be (computationally) malleable and evolving.

[4] In his book The Marvellous Clouds, John Durham Peters proposes that digital media extend historical distributed infrastructures of the environment as media, so that “media are perhaps more interesting when they reveal what defies materialization” (2015: 11). Similarly, for Derek McCormack, techniques of remote sensing are better understood as “sensing spectrality” rather than “a project of techno-scientific mastery” (2010: 650)

[5] The data lake is imagined as distinct from the defined files and categories where governments and organisations historically stored their data, for in the lake all manner of different forms of structured and unstructured data can swim together. The lake is represented as giving itself up to be analysed in the cloud – transferring from a liquid to a gas and changing at the level of the particle. I owe my points on the lake and the cloud to colleagues whose work brings them to close proximity with the changing state of gas (Peter Forman), the physical formation of clouds (Tim Burt), and the spatial imagination of a perfectly liquid market (Langley 2015).

[6] In the past, the use of data mining techniques for security and intelligence was limited, in part, by the lack of available training datasets. The storage of data in the cloud provides a readily available supply of training data through which humans and algorithms can advance their capacities to perceive new emergent events.

[7] In his book ‘The Interface Envelope’, James Ash (2015) describes how digital interfaces structure the spatial and temporal perceptions of the viewers or players who “inhabit” the envelope. On the interface, see also Friedberg (2009); Galloway (2012).

[8] James Bridle’s interactive installation is available here: vam.ac.uk/hyper-stacks Last accessed June 2016.

[9] Observations conducted in the Department of Physics, Durham University, August 2015.