III. Future images

As we will see throughout the chapters to come, scientists employ different strategies to make their science 'more open.' In the following, we will address one particular project of mediating simulation modeling knowledge to communities beyond the world of science: The development of the map-based online portal CIO. Very fortunately, I had the opportunity to become part of the CIO project team for the period of one year. This position did not only give me more privileged access to scientific practice, it also provided an opportunity to experiment with different methods of analyzing and characterizing geomedia platforms and their user communities.

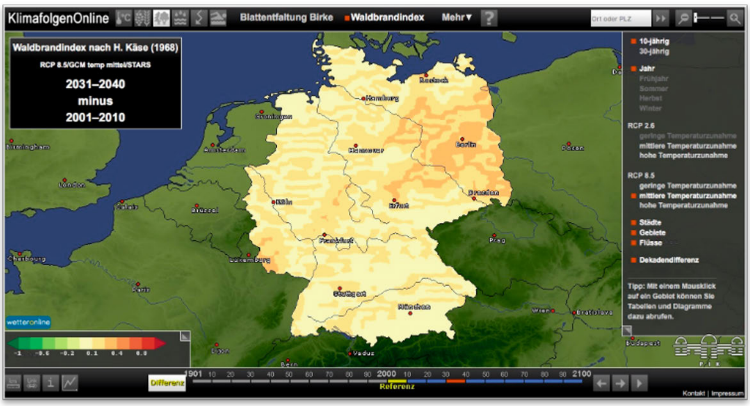

Figure 23: Snapshot of the CIO Graphical User Interface (GUI), as accessible through www.climateimpactsonline.com. Source: CIO Website

The experiment was guided by the question, "How do actors cope with the challenge of 'opening up' scientific knowledge, and how do they engage in parallel tactics of stabilization within this opening process?"

The CIO has been an experiment for PIK in multiple ways. It aims at translating numerical simulation outputs to a format that should be depictable on the web and understandable for nonscientists. The underlying scientific data of the platform builds on a number of research projects at PIK, calculating probable future impacts of climate change in Germany by means of computer simulations. The simulations were essentially driven by the regional climate model (RCM) developed at PIK (Orlowski 2007). Building on the highly detailed spatiotemporal temperature data generated by STARS, further impacts of these temperature changes were simulated by climate impact models such as SWIM (hydrology), IRMA (agriculture) and FORESEE (forestry). Traditionally, the way to make scientific knowledge public generated by these simulation processes is to write an academic publication. The insights from water-related simulations, for example, are gathered in the anthology *The Elbe River in Times of Global Change: An Integrative Assessment*[37] (Wechsung et al. 2014). The cover of the large-formatted book depicts a puzzle featuring a photographic image of the bed of the River Elbe in front of the skyline of the east German city. Within the analogy of the puzzle, the book aims at drawing together a complete image of the impacts of climate change expected in the Elbe area in Germany. The publication entails methodological explanations of the simulation experiments and interpretations of the results.

The transdisciplinary team of scientists also published their insights in a more accessible format – the *Elbe Atlas* (Wechsung et al. 2011). The atlas depicts a variety of maps showing multiple impacts of climate change on rivers, landscapes, industries and cities. While the

37 Original title in German: "Die Elbe im globalen Wandel: Eine integrative Betrachtung."

development of the atlas has been a cumbersome work for modelers and cartographers at the PIK, it did not change or interfere with the process of scientific knowledge production essentially. As a matter of fact, the acts of 'opening up' knowledge beyond the scientific community were undertaken after all simulation experiments had been carried out and conclusions had been made. The maps of the atlas illustrate the stabilized insights of the scientific work. From the perspective of the scientific process, the atlas comes after the publication, similar to a press release.

The CIO platform differs from these traditional models of science communication. It was originally developed to inform decision-makers, administrators and scientists about the local impacts of climate change in Germany. Subsequently, the portal was adapted to serve other user communities, such as pupils in German schools. Secondly, it tried to operationalize the concept of *climate services* (Krauss/von Storch 2012; Vaughan/Dessai 2014), enabling the reuse of climate data by commercial and noncommercial actors. Accordingly, the construction of the platform had been funded by the European Institute of Innovation & Technology and its climate-technology stream Climate-KIC. It was set up as a public-private partnership between PIK and the commercial weather-forecasting company WetterOnline. Thirdly, the platform was probed as an education tool to bring the topic of climate change into German schools. This alteration of the user community brought a number of fundamental issues to the surface regarding the aptitude of maps and diagrams to mediate a multifaceted phenomenon such as climate change.

Imagining users

As we have seen before, designing technologies and infrastructures always entails imaginations about prospective audiences and users. This is not only true for physical technologies and infrastructures but especially for those in the sphere of the digital, as Sally Wyatt highlights in her analysis of users and nonusers of the internet:

> To many people, cars reflect wealth, power, virility, and freedom. The Internet promises many of the same attributes on an even larger scale, with its possibility of global reach. The symbolic value of having Internet access is often presented as a sign of inclusion in a high-technology future. (2005: 70).

These promises might not be part of a homogenous master narrative (Star 1999) but be heterogeneous and sometimes contradictory. Nevertheless, drawing relationships between concrete technological devices and popular imaginaries around technology use can be helpful to understand how these devices work. A prominent imaginary for environmental geobrowsers, such as CIO has certainly been the 'digital earth,' most famously described by former US Vice President Al Gore as early as 1998. Gore highlights that:

> A new wave of technological innovation is allowing us to capture, store, process and display an unprecedented amount of information about our planet and a wide variety of environmental and cultural phenomena. (1998: 89)

Building on this availability of technology and information, he then imagined a new kind of interfacial device to connect people with such information.

> The Digital Earth would be composed of both the "user interface" – a browsable, 3D version of the planet available at various levels of resolution, a rapidly growing universe of networked geospatial information, and the mechanisms for integrating and displaying information from multiple sources. (ibid.: 91)

Interestingly, Gore provided a very detailed description of a prospective user and a concrete situation of interaction:

> Imagine, for example, a young child going to a Digital Earth exhibit at a local museum. After donning a head-mounted display, she sees Earth as it appears from space. Using a data glove, she zooms in, using higher and higher levels of resolution, to see continents, then regions, countries, cities, and finally individual houses, trees, and other natural and man-made objects. Having found an area of the planet she is interested in exploring, she takes the equivalent of a "magic carpet ride" through a 3-D visualization of the terrain. Of course, terrain is only one of the many kinds of data with which she can interact. Using the systems' voice recognition capabilities, she is able to request information on land cover, distribution of plant and animal species, real-time weather, roads, political boundaries, and population. (ibid.: 89)

As media scholar Pablo Abend has shown, the most direct interpretation of the Digital Earth concept has been the software Google Earth, which mainstreamed geobrowsing as a popular (i.e. widespread) practice (Abend 2013). More than ten years after the launch of Google Earth, it may be debated whether geobrowsing can be characterized as a genuine media practice or rather a short-term spectacle around the astonishing aesthetics of a new product. Nevertheless, Google Earth and similar devices have spearheaded aesthetics, functionalities and practice which have now been stabilized around all sorts of digital mapping tools, including route navigation devices. In addition to these popular practices, Digital Earth has been a pulse generator for more techno-scientific software, such as ArcGIS and Google Earth Engine, as well as for online data explorers built in the context of science communication (Hewitson et al. 2017; Neset et al. 2016).

CIO is an example of such a data explorer. Its brochure claims that the internet portal "enables you to investigate the impacts of climate change on Germany with just your computer" (PIK 2012). Such a characterization evokes great expectations: To provide a direct interface between people (users) and a complex body of knowledge (impacts of climate change in Germany). They come with an understanding of design aiming at a transparency of the interface (Bolter/Gromala 2003: 4): An interface is well-designed if it remains invisible to the user and establishes immediate (not mediated) access to the relevant information. However, there is a second aspect to transparency in the description. The platform aims at making climate information independent from the scientist, therefore, lifting limitations of information transfer in time and space. People will not be forced to visit the scientist and vice versa to learn about local climate change impacts. The information is always available and can be accessed everywhere though the web:

> The sole precondition for using the internet portal is an up-to-date internet browser. Anyone can use the portal. Administrative or technical hurdles have been dispensed with (registration or plugins for the browser are not required). The information is available to users free of charge. The stated aim is to win over the largest possible number of users – it is envisaged that all members of the general public who are interested can access it. (PIK 2012)

Semiotic elements

The first experiment in investigating CIO was to engage in a semiotic analysis of its visual components – maps, diagrams, dashboard elements and text. This analysis can draw from analytical approaches in visual studies (Mitchell 1987; Müller 2011; Panofsky 1972; Rose 2001), the description of scientific and technical imagery (Bredekamp et al. 2012) and iconological analysis of cartographic representations (Harley 1988).

The visual appearance of the Graphical User Interface (GUI) of CIO mashes up the aesthetics of weather maps, online geobrowsers (e.g. Google Maps) and scientific tools for visual analytics. A geographic map centered on the territory of Germany occupies most of the space available in the browser window. A number of navigation elements are structured around the map enabling the user to browse a variety of climate-related parameters for different time scales, geographic locations and alternative scenarios. On the top left, a number of buttons (or 'icons') represent different sectors of climate change impacts, namely, climate (thermometer), agriculture (cereals), forestry (trees), hydrology (wave and water drops), energy (lightning) and miscellaneous (person swimming in water). Users can then choose between different climate variables, such as mean temperature, wildfire risk or number of swimming days per year, by clicking on the different sectors. The information on these variables is represented on the map in false color, similar to a weather map. A slider at the bottom of the interface enables users to navigate a time axis. The timeline starts on the left with the year 1901 and ends on the right with the year 2100.

Users can choose between absolute or relative values when navigating the timeline. Absolute values, for example, could display the mean temperature in the decade between 2070 and 2080, while clicking on 'difference' would show the change of variables between two decades. More levels of complexity are introduced in a text box on the right, where users can change between different averaging intervals (thirty or ten years and seasons or annual), different scenarios of the future and orientation aids to be displayed or hidden in the map (cities, areas, rivers).

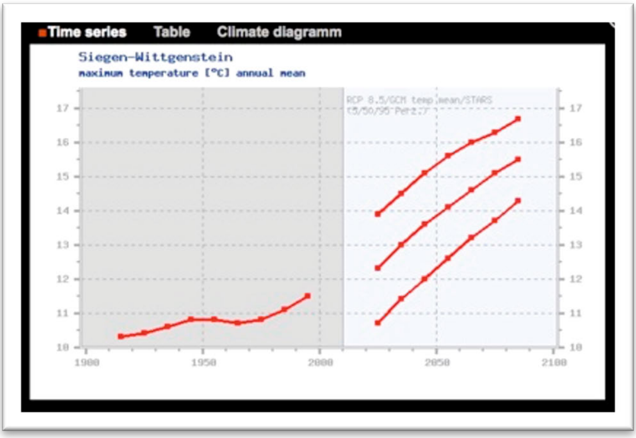

Figure 24: Maximum temperature (°C) annual mean in the region of Siegen-Wittgenstein with three different variations of future changes (model uncertainty). Source: climateimpactsonline.com

Users can also zoom in to inspect climate variables within a specific region on the map itself. A pop-up window opens by double clicking on a location and shows the local data in a histogram.

The fairly sophisticated navigation of the portal has been a frequent matter of debate within the project team. It exemplifies the challenges in translating scientific knowledge generated within computer simulations to make it accessible to a broader audience.

Unfolding the making of maps

In order to understand these challenges, we have to dig deeper and engage in an unfolding of the sociotechnical relationships within the construction of the mapping (Kitchin et al. 2013). Technically, CIO is a comprehensive Geographic Information System (GIS), hosted on the server and operated through the weather forecaster WetterOnline headquartered in Cologne. The primary challenge of CIO from a technical perspective was to translate modeling outputs of the STARS simulations into a format that could be depicted by the maps and GIS of WetterOnline. I interviewed several of the CIO project team members to learn more about this process.

Clemens Rechstein told me that the output data of all the relevant simulations at the PIK had to be collected and put into a homogenous matrix stored on the central servers of the institute:

> We have a giant variable list. It has these subcategories. There's the variable name, a variable description, a unit of measurement, and a few other things. They're all in there. And it's expandable, too. It's basically a matrix, where all individual data are stored. (Interview with Clemens Rechstein, translated by the author)

The format was optimized to fit the affordances of the GIS of the company WetterOnline, which is normally used to depict weather maps for Germany.

> And then we agreed on a format with them, actually a relatively simple format, the maps with a certain resolution. (…) At any location, with a certain precipitation, tree growth and so on. (Interview with Clemens Rechstein, translated by the author)

Figure 25: Clemens R. pointing at ‘data’ of the CIO.
Source: Own photo

Such data curation has multiple facets. Data have to be aggregated and restructured to ensure performance and interaction in the GIS. While the original datasets mostly have a European scope, data in CIO needed to be ‘cut out’ to depict only the territory of Germany. In addition, some simulation models do not ‘respect’ political borders at all but run within other logical entities (e.g. cross-national river flows).

Figure 26: Internal (right) and published version of CIO.
Source: Own photo

Rechstein developed his own local visualization tool that runs on the PIK's servers to do the data cleaning work and enable communication within the relevant group of data contributors. Figure 26 shows this internal version (monitor on the right) and the public version provided by WetterOnline (laptop on the left). As one can imagine, these tasks are time-consuming and so are maintenance and updating works. As Clemens Rechstein tells me, these activities are typically not accounted for in scientific project funding. Accordingly, he had to find time for these tasks between his other projects.

After receiving the data from PIK via an application programming interface (API), WetterOnline then generates images out of the data:

> And they created these pictures out of it. Everything you see here is practically not calculated on the fly, but calculated in advance. Every picture. And there are thousands of these pictures. If you zoom in here now [zooms in], it's a new image. And that's what they did at WetterOnline. They calculated it all in advance. (Interview with Clemens Rechstein, translated by the author)

The choice of color schemes has been one of the major issues of debate within the project team. Researchers are often reluctant to break rules of coloration in popular representations of their work because they fear giving away scientific integrity. A similar debate is linked to interpolation. In fact, the final images do not depict the original data points but use a smoothening algorithm which makes them visually more appealing:

> Well, you don't see the pixels here. You would see them theoretically. You can't see them here, however, because WetterOnline smoothed everything. (Interview with Clemens Rechstein, translated by the author)

The interpolation creates the feel of the weather map and draws the aesthetics away from scientific visualization. The resolution of the data in particular cases has also been lowered for legal concerns, for example, in the depiction of agriculture:

> For agriculture, they [the relevant lead scientists] did not want to have the data maximally resolved, only to federal state levels. It's a matter of data protection that you can't zoom onto the level of individual farms. Agricultural yields are subject to data protection. (Interview with Clemens Rechstein, translated by the author)

After the rendering of the images, the latter can be integrated into WetterOnline's GIS, which finally enables the navigation and depiction in the browser:

> [...] and then you can navigate here. The whole navigation has been programmed by them [WetterOnline]. (Interview with Clemens Rechstein, translated by the author)

As we can see with all these small but manifold transformations, the information depicted in such platforms is all but 'raw scientific data.'

Paradoxically, a lot of translation work is necessary to make information appear as 'raw data' which can be navigated interactively in a web browser.

While the PIK researchers have always highlighted a hierarchy in the division of labor between them (scientific content) and their project partner WetterOnline (technical operator), this boundary work between science and technology or content and form did not always match the actual balance of forces in the project. Along the line, the WetterOnline GIS had been the stable (we may even say rigid) central element to which all other more fluid (human and nonhuman) elements had to position themselves. This includes elements such as the GUI's symbols, the scientists and the datasets. It is important to highlight here that this is not about traditional principal-agent problems (Jensen/Meckling 1976) between institutions (PIK, WetterOnline) but about a stickiness of (digital) infrastructure.

The public side of the interface

What happens if data mediated through such systems and interfaces go public? How do people make sense of visualized data in concrete settings of mediation and translation? We can draw on approaches from the fields of symbolic interactionism and praxeological media research to analyze situations of open science in action. Karin Knorr-Cetina argues in an article published in 2009 for a renovation of Goffmanian thinking to deal with situations including "synthetic components" (2009: 63), understood as elements mediated through electronic information technologies. In the traditional understanding of symbolic interactionism, a situation was "a physical setting or place with a physical coming together, a human encounter, typically taking place" (ibid.: 64). In the context of a situation, there was something "analytically prior and theoretically foundational about physical encounters in physical settings" (ibid.). However, in a networked society, many areas of everyday life have migrated to the "internet" or "virtual spaces" (ibid.:

65). For Knorr-Cetina, situational analysis needs to conceptualize "the presence of different electronic media and their contributions to both 'situations' and the coordination of interaction" (ibid.). Synthetic elements may change the temporalities of the situation, thus, restructuring the interaction order: "[S]ynthetic situation's assemblage and projection is a continuous project" (ibid.: 71) and "behavioral settings may extend in space and time" (ibid.: 64). Knorr-Cetina states that synthetic situations "carry a time index; their components tend to require frequent or continuous updating or else their iterated presentation as still 'live' and relevant" (ibid.: 72). Of course, spatial concepts never purely denied temporal processes, but they tend to treat them as externalities:

> [T]hey imply that time is something that passes in the spatial environment and is extraneous to the environment itself. Presumably, we also express durability through spatial concepts. The synthetic situation, however, is inherently in flux; it has none of the durability of a physical situation. (ibid.: 73)

Knorr-Cetina highlights three features of synthetic situations in her conceptualization: 1) "They are entirely informational, 2) ontologically fluid and 3) may project a party to the interaction" (ibid.: 70). Empirically, Knorr-Cetina's conceptualization of synthetic situations builds mainly on observations of working arrangements and their *scopic systems* in the field of high-frequency trading:

> When combined with a prefix, a scope (derived from the Greek *scopein*, "to see") is an instrument for seeing or observing, as in periscope. In such markets, a scopic system is an arrangement of hardware, software, and human feeds that together function like a scope: like a mechanism of observation and projection, here collecting, augmenting, and transmitting the reality of the markets, their internal environments and external context. Within this domain, the mechanism is reflexive: the system mirrors a world that participants confront like an external reality while also being part of it and contributing to it through their postings and transactions. (ibid.)

The synthetic situation described in the following is certainly not as interactive as the one described by Knorr-Cetina. Nevertheless, her conceptualization of the synthetic situation may serve as a methodological device to engage in further analysis of the socio-technical mediations between (materialized) data and (becoming) users. The following ethnographic vignette describes a concrete operationalization of a data-interface 'in the wild.'

Every year, about seventy scientific institutions in Berlin and Potsdam open their doors and invite the so-called 'interested public' to the Long Night of the Sciences, including numerous presentations, experiments, meeting spaces and other formats of science communication. Between other projects, PIK presents the educational version of the web portal CIO at the event, which is advertised in the program of the Long Night with the following words:

> Climate impacts in Germany. What does global warming mean for the individual regions in Germany? Where does agriculture have to adapt, where can we go swimming more often in the future? KlimafolgenOnline provides answers. Demonstration, information stand: From 17.00 to 23.00, rotunda, ground floor. (Verein Lange Nacht der Wissenschaften e. V. 2017)

I receive a staff badge for the Long Night of the Sciences 2017 thanks to my status as a visiting scientist at PIK. While not having any fixed obligations at the event, I promised to help out wherever needed. Together with other visitors (mostly families, pensioners and scientists), I reach the Telegrafenberg at 6 pm, around the beginning of the Long Night. When I arrive on the mountain, the event is already in full swing; many visitors have made it to Potsdam and up the mountain. Events take place at PIK as well as all the other research institutions at the Albert Einstein Science Park (GFZ, AWI and AIP).

The main PIK building hosts a number of exhibits, mainly posters, experimental installations and computer screens. A scientist is assigned to every exhibit, explaining his/her work to visitors by making use of the artifacts available. The setting for CIO is the following: A large television display on a stand shows the GUI of the new CIO educational version (beta) in the full screen mode of a web browser. As a backup, a second tab enables one to open the stable classic version of the portal. A bar table is set up in front of the screen, featuring a mouse for GUI navigation purposes and a stack of well-designed brochures introducing the web portal. When I arrive, Sabina, the intern of the department, is standing in front of the screen at the bar table. Sabina is studying Global Change Management at the University of Eberswalde, where she is writing her master thesis on the deployment of CIOs in schools. After a while, she is replaced by the educational expert, Irina, who is leading the educational project, which aims at explaining climate impacts in Germany using the web portal. Numerous visitors come by and interact with the CIO setting – the scientists, the stand, the visual interface. Two older ladies, for example, approach the stand and ask Irina what this is all about. Irina explains that the screen visualizes the climate consequences in Germany. The two women are particularly interested in the risk of wildfires and the drought in Brandenburg, as they were reading about this in a newspaper. They ask Irina how this might develop in the future. Irina chooses the visualization of wildfire risk on the CIO map and explains the connection between a lack of precipitation, flat-rooted pines and the danger of desertification in parts of Brandenburg.

Figure 27: Interactive setting of CIO at the Long Night of the Sciences 2017. Source: Verein Lange Nacht der Wissenschaften e. V. (2017)

Half an hour later, Irina hands the stand over to Tim, who significantly developed the web portal and oversees the scientific soundness of the climate information shown. After a while, a visitor, about seventy years old, reaches our stand. He asks: "What is this about?" and lets Tim introduce the functionalities and information shown in the CIO portal. The man listens. After Tim's introduction, the visitor mentions having read about a connection between climate change and the Syrian war. According to the relevant article, climate change had been one of the triggers of the war. Tim mentions that there are different views on this relationship. In particular, he cites a PIK study which had shown that this connection was not as strong as the media sometimes reported. According to the PIK study, the famine causing social unrest in Syria before the civil war had been triggered by high food prices caused by the sanctions against Russia, not by the drought caused by the climate. The visitor thanks him for this explanation and continues on his way to the next stand. The next visitor seems to have a background in the natural sciences. He wants to know from Tim how the different variables shown in CIO are related.

I move over to take a look at the other exhibits in the context of my ethnographic endeavor. Later, I enter the room next to the cupola to meet some of my other informants. Frederik Willkomm is standing behind a counter selling local wine to visitors. Both he and his father were working at the vineyard based in the Brandenburg region. When I approach him, he is just chatting with a visitor: "Yes, there might indeed also be rare cases where climate change is doing good. For example, for wine growing in Germany. The production of this regional wine will be much easier with growing temperatures." I buy a glass of 'Solaris' (a German crossbreed grape grown here in Brandenburg) and go back to the CIO stand. When Tim is called to another event at short notice, I take over the mediation myself. When I am standing in front of the portal, a middle-aged father and his primary school-aged daughter join me. The father asks what this is all about. Since I had just looked at the Huglin index for wine-growing, I told him that the consequences of climate change on winegrowing in Germany could be seen here. The two of them listen to me and the father asks how the scale works. I explain that these are different types of wine that could be cultivated. The two do not understand at first what the navigation on the portal shows or what exactly can be seen. When I explain that you can switch between different climate scenarios with a button on the right, the father says, "Ah, now it's clear." The girl says that climate change could lead to a situation where there are no longer enough bees available to pollinate the plants. The father then asks whether there is any information about the danger of forest fires in the Osnabrück area. He owned a piece of forest there. We look at the consequences of the climate change for the forest fire danger and the forest formation for beech and birch, which grow in his forest. The father seems very interested in this information. After one hour, I hand the stand over to Tim, who arrives with his own family. I continue my visit to the other exhibits, leave the Telegrafenberg at around 11 pm and take the train back to Berlin.

Drawing from Adele Clarke's (2003) situational mapping approaches, we may visualize the situational setting at the Long Night of the Sciences, as shown in Figure 28. The components of the synthetic situation include human elements (visitors, scientists, science communicators), physical elements (a screen, a table, a computer mouse, brochures, computer servers, cables, architecture) and symbolic elements (the images and text shown within CIO and represented within the accompanying brochure about CIO).[38] We can identify and characterize interactions between the constituting elements of the situation by means of a relational analysis. Every interaction establishes a relationship, which can then be visualized within the situational map. A scientist, for example, establishes a connection with a visitor. The scientist uses the mouse to interact with CIO. The scientist illustrates an argument by pointing to the maps depicted within the platform. There is also an additional category of elements, such as the internet connection, the GIS, the science park and the science communication event. These components and their relationships differ from the others regarding their temporal permanence. While relationships between the scientists, visitors and the GUI emerge within the temporal period observed, others were stable throughout the period of five hours. We could differentiate these two classes of relationships – emerging and stable – through the dichotomy between agents and (infra-)structure, but, as we see through this study, this distinction depends on our spatial and temporal scope of analysis, establishing different constellations of relationships. In our case, relationships that emerged before the temporal window of the Long Night of the Sciences observed became 'structural' and elements emergent within the observational period became 'agents.' There is no

38 The categorization into human, physical and symbolic elements is derived from Rammert (2007: 19).

substantial distinction between these elements, for example, regarding the dichotomy of enduring stuff and mobile people. Considering this relative status of all entities and relationships, I prefer the term 'element' to other categorizations, such as 'agents,' 'actors'[39] or 'actants.' The term 'element' highlights its fluid ontological status and is agnostic to its role as 'actor' in ever-changing actor-networks.

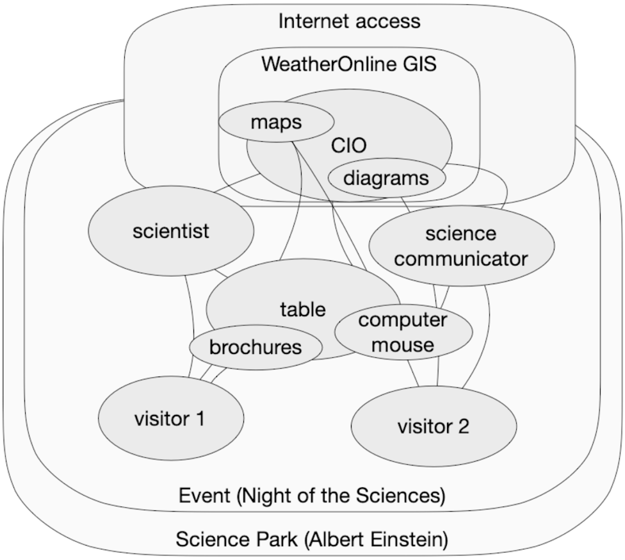

Figure 28: Interactional space at the Long Night of Sciences 2017.
Source: My own visualization

The same agnosticism can be applied to the visual representation of the situation, be it a photographic image (Fig. 27) or a situational map (Fig. 28). There is no claim of substantial truth in these visualizations. They have to be considered more as perspectives by us or others, mediated through different cultural techniques of inscription (e.g. mapping,

39 I will use the term 'actor' occasionally to refer to human participants of a situation or technological setting.

photography). It is useful to overlay different genres of inscriptions and engage in techniques of triangulation, as proposed in Chapter I. The result is a collage (Kalthoff 2010) which highlights different perspectives and readings of a situation without raising claims for substantial representation.

Script of a situation

While there have been varieties and iterations, interactions with CIO at the Long Night of the Sciences all ran according to a similar interaction order. Inspired by the program to 'run a kitchen' (compare Fig. 12), I developed a script formalizing the interactions regarding the Long Night of the Sciences:

(1) Navigating through the architecture of the PIK building and the suggested route of the exhibition, visitors approach the setting of scientist, stand and screen.

(2) An exchange of greetings takes place between the scientist and the visitor(s).

(3) The screen catches the attention of the visitors.

(4) Visitors are asking: "What is this about?" or "Can you tell us something about this?" Alternatively, the scientists propose, "May I tell you something about it?"

(5) The scientist chooses one topic addressed within CIO, such as forestry, water or agriculture. Making use of the map, he/she explains what impacts are observed or expected according to the research at PIK.

(6) The visitors take the scientist's story as a trigger for a broader discussion of issues, which are not directly related to the information shown on the map of CIO.

Analyzing this sequence and comparing ('overlaying') my observations ('visualizations of observations') with those made in other situations in the field, one issue is increasingly salient: Most alleged 'users' of the platform were reluctant to touch the input device (mouse) suggested, navigate with the dashboard (pointer, icons, menus, map, sliders) proposed or browse through the data and curated information on their own. The fact that no visitor approached the CIO setting (screen, table) when the human hosts were absent confirms this assessment. In this sense, the GUI on the screen without the scientist was like a telescope without a scientist. It may be fun for children and curious adults to gaze through the lenses of a telescope, but this uninformed interaction with a scientific instrument is not likely to increase the spectators' understanding of stars. By contrast, it may make the spectator interested in acquiring this information by seeking an interaction with a scientist or other informational mediator (e.g. climate information websites, Wikipedia, online press dossiers on climate change).

To put this differently, there is no established practice of 'using' a technological artifact like the CIO platform by browsing through datasets or, more realistically speaking, through maps and diagrams. By contrast, the CIO has been extraordinarily useful as a presentation tool for researchers explaining local climate change impacts to nonexpert audiences. In this traditional format of science communication, the researcher talks about the insights from his/her experiments and puts them up for debate. In a contemporary understanding of science communication, this goes beyond reducing the 'information deficit' of the audience but may include debates about perceptions and consequences at an eye level (Sturgis/Allum 2004). This discussion (see 6 above) can be considered as the essential part of the discussions, considering its temporal length, density and commitment among participants. The topics of discussion witnessed included: What impacts are expected at my home or living area? What changes in my social world, for example, family, children, field of work? As an expert, how would you rate the facts XY discussed in the media (e.g. climate as a trigger for social conflict in Syria, climate change as a threat to bee populations)? What is your personal opinion regarding the controversy about the robustness of climate science and model-based predictions? Arguably surprising for the climate scientists, concerns about the data depicted in the maps were not among the questions posed most frequently.

In the context of science communication in the fields of the natural sciences and climate science in particular, the preferential artifacts facilitating such debates are diagrams and maps (Schneider/Nocke 2014). I could observe on various occasions that maps and diagrams are essential elements enabling climate impact researchers to communicate the findings of simulation experiments to nonexpert communities. As a matter of fact, diagrams and maps support the credibility of the scientist, as they establish a circulating reference between the researcher present and the scientific process, the data and the other scientists involved. Visualizations materially realize scientific data in a situation (also see Chapter VI). In the words of Bruno Latour, they mobilize allies in the situation, preventing the scientist from being confronted alone with an audience. The presence of visualizations in settings of science communication are essentially anchoring the discussion and building trust.

This absence of proper 'users' and routinized 'user practices' poses a methodological challenge for investigation. In fact, I experimented with multiple ways of identifying and characterizing 'user' practices in CIO. This includes interviews with alleged power users (experts, local decision-makers), observing 'use' by looking over people's shoulders and recording interactions with digital tools (Abend et al. 2012). However, it became obvious that these experimental settings would create new users instead of describing existent practice. In-depth ethnography was the only way forward here to grasp the fragile, constantly evolving media practices involving the CIO platform.

Educational work

In 2015, the German Federal Foundation for the Environment (DBU[40]) funded a project by PIK called PIKee, which aimed at experimenting with online-based environmental education. The idea was to build on the experiences with the CIO platform to bring the topic of local climate impacts into German classrooms. The existing platform should be adapted within this perspective to fit a particular user community: Teachers and pupils. The work should be implemented by a team of pedagogic experts, together with the PIK scientists in charge of the CIO platform. The project activities started with a series of (about 40) workshops conducted with teachers and pupils in different schools throughout Germany. On the one hand, the workshops were conducted as a participatory design process, aiming at a technical reworking of the existing portal to fit the needs of a new audience. On the other hand, the workshops served to train the teachers addressing climate change impacts in class. Based on the feedback from teachers, an adapted version of the web portal was developed and finally launched in 2017. I participated in some of the workshops and other activities of the participative design process as a collaborator in the CIO project team. I also conducted interviews with the project team members, participated in the elaboration of guiding materials and co-edited an academic publication discussing the development process (Blumenthal et al. 2016).

As mentioned previously, the CIO platform turned out to be less self-explanatory than originally envisioned. The teachers also complained about a confusing setting of GUI elements:

> Figure 1 on the left also provides a first impression of the shortcomings of the graphical user interface design of the original portal. The small info box on the left-hand side has proved too small to truly aid orientation. The color legend on the bottom left-hand side can be easily overlooked. Also, the

40 Deutsche Bundesstiftung Umwelt (DBU). www.dbu.de, retrieved on May 7, 2019.

> original portal offered two separate helping systems (one can be activated by the bottom left-hand side ('i') and the other by the top ('?')). This has been a constant cause for confusion as users found it hard to find the information they required. (ibid.: 4)

The teachers in the workshops also criticized the high amount of technical and scientific terminology: "[…] a reduction of the scientific language was identified as a pressing issue" (ibid.). The project team invested a lot of work in solving these problems by redesigning and shuffling around GUI elements, reducing the number of technical terms and translating scientific terminology into everyday language:

> […] That was so obvious: 'RCP 2.6,' 'RCP 8.5.' – no one can remember that or build a connection to it. That is why we translated it to 'strong climate protection' and 'weak climate protection.' That way, people can still make sense of it, even if they are not so familiar with the matter." (Interview with Irina Ballhaus)

The extent of the design changes possible, however, was limited by the structure of the underlying GIS. This can be illustrated with the discussion about a design element that did not make sense in the GUI, but couldn't be removed.

> Simon Hirsbrunner: I noticed that it is still there.
>
> Irina Ballhaus: Yeah, it's still there. In brackets. That's because of these presets […]. We don't decide on that, it's what the computer is pulling out of it. It's automatic.
>
> SH: So you can't take it away?
>
> IB: You can't take it away. That's the way it is. Yes. [laughing]
>
> (Interview with Irina Ballhaus)

The platform generally turned out to be an enabler and a delimiter of all activities within the educational project. On the one hand, the original platform provided the starting point to think about further activities addressing the issue of local climate change impacts.

Figure 29: Comparison of old (left) and new (right) GUI of CIO.
Source: Blumenthal et al. (2016)

The technological availability of and experience gathered with the CIO platform had ultimately convinced funding agencies to support the pedagogic project, building on top of what already exists. On the other hand, this technological path dependency (Mahoney 2000) also narrowed the scope of the design process, with all the activities imagined to be strongly predetermined by the affordances of the existing platform. As several authors have shown, engineers often import solutions from one infrastructure to the next (Hughes 1983; Star/Bowker 2006: 232f). These solutions have been carried from WetterOnline's GIS into CIO, and from there into the educational project.

Acknowledging some of these concerns, the project team did not only engage in design improvements but also in tactics to work around the GUI. On the one hand, this entailed suggestions of navigation workarounds within the platform logic.

> Some of these suggestions could not be realized due to budget constraints, but it was possible to offer some workaround options: users can make screenshots or open an additional browser window for the cross-examination of individual maps. (Blumenthal et al. 2016: 4)

On the other hand, a number of additional materials were developed to mitigate the shortcomings of the online platform. This included a YouTube video explaining the CIO platform, a written guideline to teach climate change in class and sixteen units of teaching material focusing on particular thematic issues.

Figure 30: Screenshot from the CIO video tutorial on YouTube.
Source: PIK

The YouTube video was produced with a whiteboard video software (www.videoscribe.co) which lets producers drag and drop visual elements and arrange them within the timeline of an animation. The storyline entails a short introduction to climate change and a detailed walk-through of the functionalities of the CIO platform:

> To provide an overview of the most important functions and how to navigate the portal, a tutorial (YouTube) was created using an animated introduction video. This tutorial is intended to help all user groups to easier access the functions and contents of the portal. (ibid.: 2)

The guidance paper (Blumenthal et al. 2016) addressed general issues regarding climate change communication; this includes the communication of uncertainties, connecting climate change to everyday life and facilitating behavioral change.

> Where can information on climate change be found? Which climate changes can be observed already today? How certain are projections about climate change? How can personal references to climate change be established? How can options for action be shown? (ibid.: 8)

Furthermore, comprehensive teaching materials were developed, which were tested and improved on over the course of the project period:

> In order to support teachers in using the portal, a variety of 16 teaching units were developed. The six "research workshops" were designed for individual sectors and are available in three different levels of difficulty. These levels may apply to different school or competence levels among students. Teachers can choose the one appropriate for their students' abilities. The "research workshops" can either be used during regular lessons or within interdisciplinary project work. Other teaching units are subject-specific. They have been designed for geography, but also for natural science subjects, mathematics or English lessons." (ibid.: 10)

In order to link to the community of teachers, the teaching units were uploaded to lehrer-online.de, an online platform providing a high number of teaching materials to educators. In its self-description, Lehrer-Online is

> the leading editorially supported material and service portal for teachers from all school types and levels. It focuses on tried and tested teaching units and materials that you can use in class without major preparation. In

> addition, Lehrer-Online offers you many innovative tools and functionalities that make your everyday life as a teacher easier. [41]

In the perspective of the CIO team, all of these artifacts were 'additional,' 'introducing,' 'giving an overview,' 'helping,' 'providing background information,' 'explaining' or 'supporting teachers in using.' By contrast, the geoplatform CIO has always been understood to be the main interface providing access to all relevant scientific knowledge. In the following, I would like to propose a different reading of the activities carried out within the PIKee project. This repositioning was enabled through a relational analysis limited to observable media practices during the temporal window of my fieldwork. Similar to the situational map of the Long Night of Sciences, I mapped the relationships between different elements (human, physical, symbolic) interacting within the PIKee project (see Fig. 31). The elements identified included pupils, teachers, scientists, science communicators, maps, diagrams, background texts in CIO, video tutorials, guidelines, teaching units, websites, TV news and street demonstrations. They also include institutions and infrastructures, such as the internet, the Potsdam Institute and the German school system. Accordingly, I have drawn lines for every interaction observed, mutually updating the set of elements. For the sake of readability, the situational map only depicts a selection of all the elements of analysis.

41 https://www.lehrer-online.de/ueber-uns/ last retrieved on May 29, 2019. Text translated by the author.

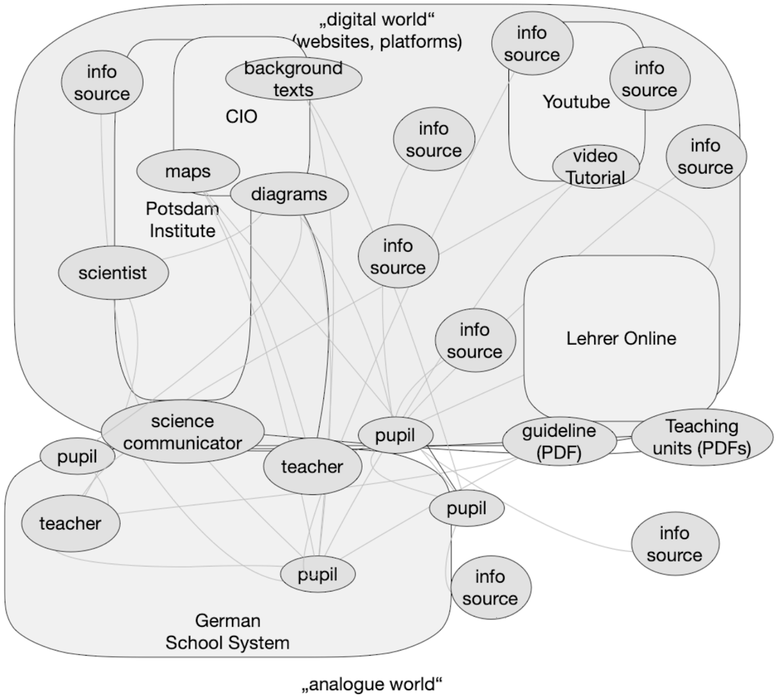

Figure 31: Interactional space of the educational project about CIO.
Source: My own visualization

The co-construction of technology and its users

We can characterize the design process of the educational PIKee project as a successful effort in building a sociotechnical infrastructure for the negotiation of climate change in schools. Susan Star and Geoffrey Bowker have shown that such *infrastructuring* entails a standardization of heterogeneous elements, including people, machines and symbolic artifacts:

> It is not just the bits and bytes that get hustled into standard form in order for the technical infrastructure to work. People's discursive and work

> practices get hustled into standard form as well. Working infrastructures standardize both people and machines. (2006: 235f)

While the CIO had always been presented as a working tool for 'users,' it actually took a lot of time and work to create a community with an especial practice and routine to 'use' the platform together with many other artifacts and techniques of knowledge acquisition. Nelly Oudshoorn and Trevor Pinch (2005) wrote in the introduction to their anthology *How Users Matter: The Co-construction of Users and Technology* that the design process of digital technologies always entails a co-construction and reconfiguration of users and technology.

The key aspect in co-creating 'users' was to focus less on information retrieval from the CIO platform and more on the daily media practices of teachers and pupils in the setting of the German school system. We can exemplify this with the routine of a teacher preparing and performing two hours of teaching addressing the topic of climate change.

> Teacher Nr. 2: You have to see it like this: It's Sunday afternoon. I'm sitting there and want to finish this quickly. [...] Well, we don't spend hours looking at it. That must be fast and self-explanatory. (Teacher testimony in a CIO workshop at a School in Berlin, translated by the author)

The preparation and teaching as a sequence of interactions may be formalized as the following sociotechnical script:

Day 1 (preparation):

- The teacher browses through Lehrer Online to explore possible topics to be addressed in class.
- The teacher decides to address climate change in the class and enters 'climate change' or 'environment' into Lehrer Online's search console.
- The teacher finds PIKee and CIO as a result of the query.

- The teacher explores CIO, watches the YouTube tutorial, reads the guidelines and makes him/herself familiar with the worksheets.
- The teacher adapts the worksheets to his/her teaching subjects and course structure.

Day 2 (teaching):

- The teacher introduces the topic of climate change in class.
- The teacher gives pupils time to explore the material available, including CIO, the YouTube video and the worksheets.
- Pupils try to solve the problems given in the worksheets.
- The teacher and pupils engage in an open debate about the future with climate change.

The realization of this routine took four hours, including the teacher preparation and actual teaching experience. Acknowledging this time window (four hours), we can make an assessment of the time actually spent interacting with people and different kinds of artifacts. The actual 'screen time' on CIO appeared to be rather short. The time was equally distributed between browsing the platform, reading through background material, watching the YouTube video, filling out the thematic worksheets and debating aspects of climate change broadly.

An Anchoring device

Does this mean that the CIO platform could have been exchanged with another easy-to-produce video or a simple webpage collecting information resources on climate change? This is certainly not the case. The features of the platform were key to enabling the ultimate goal of the educational project PIKee – the facilitation of knowledge acquisition and debates about climate change impacts. I would argue that this role of the platform could be characterized as an *anchoring device.* This role bears some similarities with the description of Henderson's conscription device, which has been discussed previously. Building on Lucy

Suchman's (1988) description of the whiteboard's role in organizing work processes and Susan Star and James Griesemer's boundary objects (1989), Henderson refers to engineering sketches as 'conscription devices'[42] as they

> enlist the participation of those who would employ them in either the design or production process, since users must engage in the generation, editing, and correction of drawings during their construction if the design is to serve its intended function. (Henderson 1991: 452)

In a similar way as the sketches enable discussions of engineering processes in addition to WGs, the CIO facilitated debates about climate change among heterogeneous actors. The CIO enlists the participation of these actors for a debate of climate change impacts in an educational setting. In contrast to the conscription device, however, the CIO platform was an element that ran in the background of the interactions between participants of the education activities. Rather than enlisting people, it anchored and channeled the activities around climate change impacts. I could witness in the workshops and other activities within the project that debates often got lost in the complexity and versatility of the issues at stake. While such excursions into the unknown were fruitful to open debate, they threatened the frame of the educational setting and attributed roles of the participants. The teachers were all committed to address climate change in their curriculum, but they were haunted by the controversies around climate change and the fear of losing control in their classroom. The CIO platform was a way to anchor the discussions around 'the current state of science,' represented by a discrete container of maps, diagrams and accompanying text. Accordingly, it was unproblematic if debates drifted away from the scientific facts as they could always be navigated back to the platform. Consequently, it was possible to engage in open debates regarding the pupils'

42 Taken from an understanding of 'military conscription.'

everyday life perceptions and experiences of climate change. In other words, participants could transcend the boundaries of established practice in the class room without perceived border transgression.

A packaged body of knowledge

The role of the CIO as an anchoring device in the educational activities of PIKee was enabled through a number of characteristics that build trust among actors. What became clear during my analysis is that these features appear paradoxical once unraveled. However, this paradoxical nature is exactly their source of strength. The fluid symbolic outputs of such media technologies can mean different things to different people. This interpretative flexibility enables them to mobilize actors with very different attitudes towards climate, science and technology.

First of all, the homogenous aesthetics in the platform mediates a stability of the scientific facts contained. As we have seen previously, the harmonization of the underlying heterogeneous datasets for the depiction in the GIS has been cumbersome work, which is black boxed by the singularity of the CIO interface. Susan Star says that the CIO enables the construction of "a single voice that does not problematize diversity," which "speaks unconsciously from the presumed center of things" (Star 1999: 384). The construction of such a single voice would not be possible through the assembly of diagrams, maps and texts from exterior resources. It is exactly the singularity of the aesthetical feel and navigational logic that confines harmony. This single voice is not disturbed even by the fact that the underlying data has been repeatedly updated to reflect new scientific insights and improvements to former simulation outputs.

Secondly, the interactivity of the interface creates a potentiality for checking all the data by hand. A suspicious person might zoom through the maps, slide through the timeline and point at different scenarios without identifying any irregularities. The data seems complete, and there are no apparent blind spots on the maps. The proximity of the navigational logic and aesthetics of the interface to those of simulation modeling practice creates a perceived circulating reference between the facts depicted and the underlying scientific processes. In other words, data in CIO 'talks on its own.' We will see later (Chapter V) that this talking ability of 'raw data' is a fallacious imaginary. At this stage, it is only important to highlight that it must be characterized as a potentiality and a promise. While no one will actually check all the data in the platform, it suffices that the possibility is given by technological design. It was crucial in the activities observed within the PIKee project that the data could potentially be 'realized' within seconds in the concrete situation, namely, as a visible and understandable choropleth[43] map. To use a (potentially problematic) analogy: A person visibly carrying a gun necessarily transforms the relationships in a situation. This is independent of the weapon eventually being fired or not.

Thirdly, the fact that the entire body of knowledge in the CIO container comes from one institution established a well-defined actor of trust for the knowledge packaged. Here, we may understand trust as a tactic for the reduction of social complexity, as argued by Niklas Luhmann (2014). The individual scientific facts in the container are black boxes, which cannot be realistically situated or checked by outsiders of the simulation processes. The single producers of the scientific facts cannot be identified easily, which leaves the institution of the PIK, and climate science more generally, as the only actors to be trusted and challenged.

43 Wikipedia entry: "A choropleth map (from Greek χῶρος 'area/region' and πλῆθος 'multitude') is a thematic map in which areas are shaded or patterned in proportion to the measurement of the statistical variable being displayed on the map, such as population density or per-capita income." Retrieved on April 23, 2019, via https://en.wikipedia.org/wiki/Choropleth_map.