Satellite data for climatic purposes

Fostering data tractability to meet the needs of climate data user

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ABSTRACT

Satellites dedicated to climate purposes rely on increasingly complex sensor systems and data interpretation strategies to ensure the consistency of climate datasets and their adequacy with the changing needs of diverse communities. Producing homogeneous datasets from satellite data nonetheless encounters persistent difficulties from calibration and sensor evolution to limited mission lifespan. This paper mobilises resources from data epistemology and from the study of knowledge infrastructures to examine a tension running across these practices. Thus, satellite data are treated as raw and intrinsically objective objects in global and institutional contexts, where fixed quality standards allow epistemically distant communities to cooperate, yet are used as malleable objects in local contexts, where their reliable interpretation is acknowledged as a problem. The analysis draws on five months of ethnographic fieldwork conducted in Japan with researchers, engineers and agency staff working on Earth observation. The results are organised around four received ideas. Firstly, satellite data are not raw: the role they are asked to play varies historically and socially, and the ground reference against which they are validated proves to be a maintained artefact. Secondly, satellite data do not simply measure a phenomenon, the choice of variable and grain together settle what counts as phenomenon, which is why the same data can support opposing conclusions. Thirdly, the quality and continuity of a series are not purely technical, they depend, among others, on social, cultural and political elements. Finally, better data do not settle disagreement between communities since interpretative frameworks and the narratives that justify them outlive their evidential base, with distributive consequences for the population concerned. The paper concludes that both attitude to satellite data is legitimate, and adequate to distinct purpose, coordination in one case and interpretation in the other, difficulties arise when the first is exported into contexts calling for the second. Treating satellite data as tractable objects yields a more adequate account of how teams build datasets in other optics than the one of an "objective lens" on earth observation.

Keywords : Earth observation data; climate datasets; data tractability

INTRODUCTION

The growing commercialisation of satellite applications has led their number to increase spectacularly over the past decade from 1,400 active payloads in 2016 to more than 18,000 in 2026 [1,2]. The provision of internet and telecommunication services emerges as a primary driver for the exponential growth in the number of satellites. SpaceX alone accounts for nearly two-thirds of all current active payloads, operating a fleet of more than 10,000 Starlink satellites [2]; while the People's Republic of China is concurrently overseeing the deployment of three separate

megaconstellations, each composed of more than 10,000 satellites [3]. But satellites broaden other horizons than those of telecommunications and the provision of internet access. Building on their global perspective and the vast amounts of continuous data they allow to generate, satellites emerge as a key constituents of a variety of epistemic and service-oriented infrastructures, attracting a flourishing ecosystem of private actors.

On the service side, in addition to their usefulness for the establishment of global internet and telecommunication infrastructures, satellites also offer valuable navigation and traffic management tools [4], environmental and hazards monitoring solutions [5], as well as military defense and intelligence capacities [6]. On the epistemic side, satellite data have been credited with substantial progress in meteorology, climate and environmental sciences. As they enable to generate continuous streams of data encompassing the entire planet, satellites have been praised by scientists for allowing the manufacture of spatially and temporally more homogeneous datasets as well as for new phenomena and variables to be conceptualized and measured, particularly on large scales [7]. When combined with numerical models, this unbroken and comprehensive flow of near-real time data also constitutes a crucial resource for both research purposes, the provision of services and political decision making [8].

If satellites and the data they produce thrive on their adequacy to reach the epistemic and practical goals of a variety of user communities coming from the civilian, scientific, political and military spheres; this adequacy only appears loosely tied to the purposes that motivated the data to be generated in the first place. It is indeed commonplace for satellite data to be multi-purposed in the sense that data produced by a given satellite for a specific purpose turn out instrumental for attaining some other purpose. Sometimes, the repurposing of satellite data rests on significant differences in the way they are interpreted. For instance, the very same data produced in the spectral bands 31 and 32 of the MODIS (Moderate Resolution Imaging Spectroradiometer) instruments embarked on NASA's Terra and Acqua satellites serve, depending on the interpretational framework, to reconstruct a variety of environmental variables such as surface and cloud temperature, vegetational index, or volcanic ash monitoring [9, 10, 11]. Other times, the repurposing of satellite data involves little or no disparity in the interpretational frameworks. In those cases, the multi-purpose nature of satellite data comes from the closeness of the informational content required by the different user communities to fulfill their goals. For instance, GNSS-R data (Global Navigation Satellite System- Reflectometry, referring to the production of environmental information from the way navigation-purposed signals are reflected by the Earth's surface) play out as instrumental for satisfying a number of different research, policy-making and military purposes [e.g. 12].

Hence, satellites manifest themselves as powerful infrastructural constituents, and the data they enable to produce and propagate emerge as helpful to meet the needs of a vast array of different user communities. In this article, building on the malleability and liability of satellite data to be repurposed and acquire some evidential value for achieving a broad array of different purposes, we propose to explore the tension between two kinds of attitudes adopted by different actors towards satellite data, depending on their context. The first attitude appears more commonly within infrastructural and institutional contexts, where the diverse objectives of different user communities coalesce. In such global contexts where communities with very distant epistemic practices and cultures come together and cooperate, and satellite data are typically considered as raw and intrinsically objective objects, whose epistemic value is guaranteed by fixed quality standards [13]. The second attitude is more endemic to contexts where the different user communities share a common background. In these local contexts where the project is producing adequate and reliable interpretation of data, satellite data are simultaneously (i) valued for the

access they enable to big spatial scales, (ii) acknowledged as objects whose reliable interpretation poses considerable problems. As a result, satellite data appear in such local contexts better conceived as malleable objects, whose content is partly determined by methodological choices to overcome their heterogeneity and to secure their epistemic power [14].

By focussing on climate-related use of satellite data and drawing on recent debates in data epistemology and infrastructures studies, as well as on fieldwork conducted alongside Japanese space actors and climate scientists, we develop an interdisciplinary framework to account for these two attitudes. This article aims to show that, if these two attitudes appear warranted within their own contexts, they ought not to be conflated. In other words, we argue that allowing for satellite data to be locally considered as malleable objects, whose interpretation is flexible and evolves together with other sources of data in an *adequate-for-purpose* manner, provides a stronger epistemic strategy than treating satellite data as fixed objects with rigid interpretation frameworks. We support that our empirical analysis shows that allowing for data malleability provides a more satisfactory framework than conceiving satellite data as raw objects in order to account for the multiple ways different user communities manipulate data and justify their methodological choices locally when they build homogeneous climate datasets from heterogeneous data. In addition, building on the notion of boundary object, we also provide an explanation for the legitimacy of appeals to strict quality standards and interpretational frameworks in global contexts. Strict quality standards and referring to satellite data as fixed objects emerges as an epistemic stronger strategy in global contexts as it enables different user communities to cooperate and interact with satellite data in meaningful ways given their own epistemic contexts.

In this article, we propose to elucidate this apparent contradiction between appeals to satellite data as interpretatively rigid/malleable objects depending on the context of use (global/local). In the first section, we contextualize our empirical materials by presenting our fieldwork methodology. In the second section, we present key insights from data epistemology and infrastructures studies. This blend of conceptual resources will encourage us to pay attention to how contextual elements shape data's interpretation. The concept of boundary object will emerge as particularly insightful to investigate on those contextual dependencies, highlighting that satellite datasets can function as evidence for local knowledge claims as well as vehicles for cooperation. In the third section, we will display our main empirical results by structuring our discussion around four preconceived ideas ([Les 4 idées préconçues]) before developing some of its implications and future prospects in the conclusion.

ETHNOGRAPHICAL MATERIALS AND METHODS

The ethnographic material presented here was collected by one of the authors of this article (Susie Pottier), an anthropologist, over five months of fieldwork in Japan funded by the Chaire Espace, ENS-PSL.

The fieldwork was split into two. The first, from June to August 2025, was mobile across southern Japan with a change of location roughly every week, including Okayama, Tottori, Kitakyūshū and Ōita. The goal was to speak with a lot of different space actors to vary perspective and point of view. The second stay, from December 2025 to February 2026, was based in Sapporo for three months, to obtain repeated contact with the same people. The wider project concerns how sustainability is formulated in the Japanese space sector. Earth observation emerged during the first stay, when questions about validation, indicator choice and dataset continuity recurred across exchanges with researchers.

For the material used here, the corpus comprises exchanges with around twenty researchers and ten doctoral students and students working on Earth observation, attached to half a dozen Japanese universities, among them Okayama University and Hokkaido University. Their specialisms include dryland studies, tropical peatland carbon accounting, atmospheric physics, hydrology, forest ecology, geographic information systems and astrophysics. Most exchanges took place in English, some in Japanese, and technical discussion generally moved between the two. Several quotations are in non-native English and their syntax reflects this.

Three modes of engagement generated the material: observation with note-taking during stays of several days at universities, including guided laboratory visits; semi-structured interviews conducted from question guides and not recorded; and informal conversation, which proved the most productive register and the source of much of Section 4. Verbatim wording is preserved; abbreviated notes have been restored in syntax without alteration of content. Participants are identified by professional position rather than by name. The corpus is exploratory. It supports claims about the existence and shape of practice, but we do not generalize it.

THEORETICAL BACKGROUND

Insights from data epistemology: Leonelli's relational account and Bokulich & Parker's pragmatic-representational view

Data epistemology is animated by long-standing debates surrounding data's content and function within scientific inquiries. The principal concerns in these debates relate to the kind of access to the world, to phenomena or to other scientific entities that data warrant. In this section, by bridging some recent contribution to these debates in data epistemology with works originating from infrastructural studies, our aim is to provide a better understanding of the value of satellite data for the production of climate information. We will first present Leonelli's relational account and Bokulich & Parker's pragmatic-representational view. As both accounts argue that data provide a mediated access to the world's phenomena, they will enable us to better understand how the evidential value of satellite data can be secured despite the contextual dimension influencing their interpretation. We will then turn to infrastructural studies, incorporating the notion of boundary object to better characterize the way satellite datasets travel and function as evidence across epistemic contexts.

In the relational account of data proposed by Leonelli [15,16], data denote fungible material artifacts, whose interpretation is susceptible to change at every production and processing stage depending on the kinds of relationship that researchers establish with them in specific epistemic contexts. Data are here defined by their function (e.g. how they relate to knowledge claims in given epistemic contexts) rather than by their intrinsic content (e.g. how similar they are to a given feature of the target entity).

Leonelli identifies two kinds of indexical choices that bear an influence over data's evidential value. The first kind of choices relate to the production and manufacture of the material artifacts that will be functioning as data. Leonelli argues that those processing choices play a determinant role on the kind of surface regularities (patterns) that data will be taken to display by conditioning material characteristics of artifacts. The second kind of choices relates to the modelling of data. That is, to how identified patterns in data will be linked to knowledge claims

about phenomena. Leonelli argues that the methodology chosen for aggregating the data will have an influence on which patterns will be taken as being relevant given the purpose at hand. In this case, indexical epistemic motivations play an important role [16].

Let us now turn to our second epistemological resource, Bokulich & Parker's pragmatic-representational view of data that provides an alternative standpoint over data's contextual dependencies. Bokulich & Parker take data to be those objects that an agent collects and selects from the empirical world on the basis that she believes it be causally informative about aspects of the world she is interested in. As products of physical interactions with the world, data are understood as possessing some intrinsic representational content: they relevantly document empirical events where target aspects of the world are understood as having played a causal role [17].

However, although constrained by the causal factors involved in their production, the evidential value of data is not fixed. Depending on the interpretational context, the same data may emerge as informative in unforeseen ways by the initial data collectors. In so far as indexical conventions of interpretations influence data's representational content, Bokulich & Parker argue that data's evidential value is a matter of contextual assessment. They propose to assess the evidential value of data in terms of their adequacy for achieving the particular aims of their users. To be suited for the pursuit of a given epistemic purpose, data will not only be subjected to epistemic constraints (i.e. having to satisfy a certain minimum level of accuracy, precision and resolution); but will also be subjected to practical constraints that influence how methodological choices are decided. For instance portability, choice of format, metadata, or background assumptions carried by data's interpretation framework will influence data's evidential value [17].

Bokulich & Parker's pragmatic-representational view of data provides helpful insight for explaining plural interpretations of the same data. Because data's evidential value is tied to the purposes they are used to help fulfilling, it is also determined by a number of contextual factors (methodological choices, how resources-demanding are the data to be used, what background assumptions they imply, etc.). As a result, the same data can not only serve to reach a variety of purposes, but may also support different conclusions when used for the same purpose in different contexts. Moreover, Bokulich & Parker point to the iterative nature of the way data are interpreted. Sometimes, this iterative process may bear an influence on data's adequacy with the users' purposes. This historical component underlying the production of data interpretations is instrumental to understand a dataset's adequacy with given purposes [17].

Despite their disagreements, Leonelli and Bokulich & Parker offer some important insights to understand the evidential value of satellite data by pointing to numerous epistemic and contextual factors, often closely indexed on the data producers and users motivations and resources. In the following, we propose to turn to knowledge infrastructure studies to dig into the infrastructural dimension of satellite data and better understand how they relate to the production of climate information.

Insights from knowledge infrastructures studies: the notion of boundary object

Satellites are vehicles inside large technical systems. As such, the reliability and the accessibility of the data they produce is tied to the methodological standards and other constraints imposed by the infrastructures they are embedded in. In this section, we will first turn to Edwards work on knowledge infrastructures before presenting the concept of boundary object.

Edwards concieves knowledge as the product of socio-technical systems. In his account, facts and theory inevitably rest on a patchwork of different networks of people, institutions,

technical and artifactual objects organised around sets of conventions and methodological standards; that is, on an infrastructure. However, this infrastructural dimension has epistemic consequences. Infrastructures indeed appear torn between the production of heavily centralized homogeneous and global standards that allow for the production of knowledge; and the local and heterogeneous practices and needs of their users. In particular, frictions arise from the methodological standards that codify how data are collected, stored, accessed, processed, communicated etc. The epistemic influence of those infrastructural frictions is furthermore enhanced by their evolution through time; i.e.: how users have to adapt to the evolving methodological standards imposed by the infrastructure due to changes in the technological and political contexts. As a result, accessing and manipulating data often requires a significant amount of time, effort, skill and other resources like money or computational power from particular users [18].

If Edwards appears more focused on the way infrastructure enables for the production, manipulation and communication of artifacts, shaping their evidential value by constraining the way they are encoded in physical mediums; other scholars have been more inclined to discuss their social dimension. Infrastructure does not only delimit the way data come to be produced and manipulated. They also shape the way agents interact, communicate and learn through them. Star & Ruhleder have for instance proposed an ecological conception of infrastructures where they are defined by their relational properties. By this line, infrastructures are first and foremost junctions between ways of interacting with objects. As such, they draw their operationability from a form of ambiguity. On one side, they simplify and uniformize the different practices and interests of their users. On the other side, they allow for different relational modes [19].

To secure the reliability of the knowledge produced while enabling for a variety of different relational modes with the infrastructure, one has to understand the translation process that allows for cooperation to be preserved in such ambiguous contexts. Star & Griesemer have proposed two principal vehicles for those kinds of translation: standardised methods and boundary objects. In their words, “Boundary objects are objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use and become strongly structured in individual-site use” [20, p. 393].

But boundary objects are more than mere interpretatively flexible objects. They are also tools to investigate how infrastructure allows for agents to cooperate in the absence of consensus. Furthermore, understanding the way boundary objects are mobilized, manipulated, negotiated and activated, can help in identifying some epistemic constraints posed by the infrastructure, as well as how some interests and practices are left unconsidered. In other words, boundary objects open insightful doors for investigating how knowledge is influenced by its infrastructural dimension, potentially posing matters of justice [21].

Let us now turn to our empirical work to better grasp how those insights from data epistemology and infrastructural studies play out in concrete settings.

RESULTS / DISCUSSION

4.1 Satellite data are raw

When we interviewed Japanese ecologists, biologists and climate scientists used to work with satellite data, they at first referred to satellite data by placing them at the bottom of a hierarchy, as

far more accurate than surface observation. Along this line, satellite data can be reliably interpreted only in reference to some more accurate data, usually collected on the ground. A sentence from one climatologist sums up this position: “Ground observation data provide true value. Satellite you can't trust, you have to validate”. And indeed, satellite data emerge as epistemically complex objects. Satellite instrumental systems measure light properties on large geographical scales. They are the product of complex instrumental systems on which experimenters cannot intervene to recalibrate as they are put in orbit. Also, it is common that very different entities share very similar signatures when measured from space (e.g. sea surface and clouds can produce very similar data as they both are water, sometimes at very close temperature).

In other words, satellite data appear disconnected to key local contextual factors that cannot be neglected when investigating a given phenomena. Ground measurements, on their side, measure a variety of different measurands on small geographical scales. Also, they can more easily be calibrated and thus appear more accurate, enabling to produce relevant interpretations of satellite data given the local contexts.

However, after this first reflex, the ground truthing approach is typically tempered along the discussions. Our interviewed researchers were indeed happy to complain that field collection yields records of poor quality, while at the same time presenting these data as indispensable and more accurate than what satellites can supply. An ecologist confirms this apparent contradiction by raising the very pragmatic and long-standing challenge of funding: “In theory, if we had enough money for research, then field data would be of excellent quality, since we would have the means to keep staff and instruments on site. But even poor-quality field data often tell us more than satellite data, even if the latter are a good complement. Paradoxically, it is because we have no money that we use these data”. Satellite data hence are appealing to researchers as they are relatively cheap to use compared to other kinds of data. This dimension appears closely connected to the infrastructural dimension of satellites, which enables for the automatic collection of continuous flows of data. However this infrastructural dimension also comes at an epistemic cost, some aspects of the production of data is inevitably opaque to the data user. As a climatologist framed it: “Satellite data are automatic and we depend on others to collect those data. It’s helpful, but which one is better ? Seeing is believing”. Connected to the cost of data, is the capacity to produce data in and of itself. Satellites allow to produce data concerning remote areas that would be very costly or difficult to reach. In this sense, the way we think about the usefulness of data acquisition is partly anthropocentric, but it is not the only factor influencing validation criteria.

Moreover, accuracy is understood in a variety of ways by our interlocutors, sometimes even changing meaning between successive statements of a single interlocutor. For instance, an experiment reported by an atmospheric physicist contradicts another discussion with an engineer from Mitsubishi Electric, who insisted that instruments and satellites must be built from “materials designed for space”. The physicist’s team had an onboard camera built by a small local company, setting aside the space qualification of materials imposed by the usual prime contractors: “They use materials that are said to be for space, so it is immediately much more expensive”. The device remained in orbit for two and half years without failure. Two accounts of what makes an instrument trustworthy thus coexist. One anchored in a qualification standard, the other in an operating one. The physicist’s team treated the duration of the successful mission as a relevant test.

Often, accuracy is conceived as a matter of trueness, of how well the instrument producing the data have been calibrated. By this line, satellite data appears less accurate than surface observation in light of the numerous epistemic issues that their calibration encounters. Other times, accuracy appears more closely connected to the process of data evaluation, that is, on the adequacy of the methodology used to produce and interpret the data. When adopting the validation paradigm,

users are more inclined to stress the limits of ground truthing and the adequacy of satellite data with their needs. Because satellite data and surface observation concern distinct scales, satellite data may emerge as more adequate given the purpose at hand. Ground truthing, by conceiving surface observations as epistemically stronger (because more accurate in the sense of better calibrated) inhibits the global scales observed by satellites to function as a valuable scale. In other words, the prioritization of small geographical scales, if warranted in some instances, may obstructs the production of relevant knowledge in other instances.

Rather than a dichotomy between two kinds of data, data (satellite and surface) seem to form a system. If the finished satellite product is corrected by being connected to reference data from the surface, that reference also appears to be subjected to a number of contextual factors and standards. In other words, the homogeneity of a dataset, climate dataset among them, cannot be defined as fidelity to a fixed anchor, since that anchor is itself an artifact subject to many contextual influences. In the practices we observed, data are constituted as relations between objects that evolve together, rather than as a fixed point on which everything must be based.

4.2 Satellite data measure the phenomenon

Many Japanese researchers raised, sometimes at length, the difficulty of establishing a definition for data that are meant to be seen as universal. The director of an ecology research centre mentioned this aspect when explaining the various definitions of vegetation indices that structure many research fields, desertification among them: “Since the 90s, since satellite data help us in producing climate data, we have an aridity index based on potential evaporation, energy, rainfall and so on. Agree or disagree with this index, when we meet with some kind of definition, they say it's a desert but based on what?”. The director continued: “Everyone is thinking around a definition, we need a common definition. It's difficult, European talk that way, Asian talk that way”.

Our interlocutor had recalled on the top of his head that international documents often disagree on the extent of the global desertification process: “a report from the turn of the 2000s puts the affected surface at ten to twenty per cent, a later report of the United Nations Convention to Combat Desertification speaks of a 2100 scenario of sixty per cent expansion, and a UN report retains forty-two per cent”. Our own tendency would be to ask which one is true, which one tells the truth, and which are false. Yet no such binary opposition appears in the discourse or the work of our interlocutors. What appears instead is a choice that adjusts the framing of the data to the audience receiving them.

In other words, different methodological and contextual factors come into play when assessing the adequacy of a definition with the needs of a data user. As with the reference standards discussed above, the choice of using or not a certain indicator to construct an index or to investigate on a given phenomena is determined by how satellite data is taken to relate with the phenomena and with other kinds of data (are they at the right scale, with the right resolution or accuracy to produce reliable information), and how those relationships are perceived by human beings (is the produced information adequate with the user needs?). Our director of the ecology centre illustrates “For defining degradation, satellite people often use the concept of biomasses, when they have enough data. Ground people use indicators like keys species, dominant species, vegetation, that’s what indicates degradation”. Many ecologists lament on the continuous lack of connection with human activities. “Everyone knows it, but humans are never truly shown or it's never really said ‘it’s human made’”. says one forest ecologist.

Amongst the factors that will influence our understanding of a phenomenon, the choices of the variable used is central. Given the paradigmatic variables used to describe a given phenomenon,

its understanding may be very different. Also, sensor characteristics may impose thresholds that may shape the research questions. Data accessibility may also come into play as a researcher specialized in drylands describes his use of satellite data: “I often use free images, SPOT is too expensive. I use Sentinel-2, from ESA. The images are refreshed every few days, but that is enough. It is convenient for very broad views, which is what I need most, but sometimes I need images of 10 m by 10 m because people want to see their village”. In this case the resolution requirement is constrained first by price, but also by sets of choices that don’t derive from a scientific need alone. Fieldwork and contact with local populations matter as much as the research itself, since good relations are what make the research possible, and buying higher-resolution imagery for that purpose is not a scientific decision. The same researcher continues: “In the region where I work, a cloud mass can sometimes be 5 km across, I need the locals on the ground to take measurements and photographs on their phones. They also have a great deal of traditional local knowledge that is indispensable to us”. Adequacy with the local epistemic context is also instrumental. Often, Adequacy of the data to investigate a phenomenon is more closely constrained by the user needs than by the data’s resolution as such. As our ecologist frames it: “Satellites we have now, ten km, but cloud size is smaller than that. […] For a large scale, 100 km I think it's enough to capture some environmental data change”. The sensor footprint may be larger than the phenomenon, but this does not forbid satellite data to adequately function as good evidence. What matters most is the object under study.

A Geographic Information System (GIS) engineer who runs a small remote-sensing company shows the reverse operation (from the object to the question), agrees on this point. His firm has developed an application for the monitoring of rice harvesting that converts satellite observations into two pieces of information: the protein content of the grain and the optimal harvest date. The geographic information system superimposes layers of distinct origin onto a single cartographic support. Orbital data enter an interpretive framework built around a concrete agronomic decision, rather than around a climate variable. However, he expressed concerns over the limits of his data: “People use it, but I’m not sure how they used it. When you speak to non-scientists you are already in some kind of interpretation, so you speak with probabilities”. The user’s need is not only changing; it also remains partly opaque to the person who produces and analyses the data, and managing those blind spots in the information produced is far from an easy task.

4.3 The quality and continuity of a series are technical matters

The physicist who mentioned the drought episode also describes an operation conducted by a spatial agency before a high-resolution observation satellite was placed in orbit. The cost of high-resolution imagery restricted its use to a small number of expert actors. The agency published free simulated data on a national platform, at a resolution equivalent to that of the future sensor, together with an analysis environment and complementary datasets. The aim was to allow companies to develop their algorithms and processing chains before launch. Today, many firms use this free-sample arrangement as the basis for selling a complete satellite imagery service.

The operation inverts the sequence that runs from sensor to data and from data to interpretation. The published data are the product of a simulation; their function is to bring into existence the interpretive frameworks that will make the real data usable at the moment they are produced. The framework precedes the instrument, and it is built as much to capture a market as to answer a question. Conversely, global datasets such as precipitation products, made freely available by agencies including JAXA, support monitoring systems in agriculture, in fire management and

in fisheries. The sensor does not change, depending on the community and its needs, the interpretive framework does.

Breaks in homogeneity, and the gaps in a database are not due to from methodological determinants that are restricted to scientific methodological choices. Our atmospheric physicist describes a shift in what administrative bodies count as science: “Projects called ‘meteorological’ are no longer considered scientific, so they now depend on the Japanese meteorological agency. We can no longer submit scientific proposals. So, really different from 15 or 20 years ago, ridiculously hard to send something into space”. The constraints here are not only physical but show that the continuity of the produced data series depends on decisions taken by people on the ground, depending on their economic and cultural contexts.

The director of a university satellite research centre describes the funding regime within which these choices are made. State grants to national universities have been declining since their change of legal status in the early 2000s, and the criteria for their allocation now include international standing and the volume of English-language publications. “Datasets are far from neutral, if only through our choices about what we count as having scientific value. When I began my doctorate, a very long time ago [laughs], it was fundamental research. Today it is applied research. Applied, applied. Everything has to be framed that way in order to obtain funding”. An astrophysicist at Hokkaido University supports this account, noting that the vocabulary of values in national policy discourse and documents varies over time, and that the number of occurrences of terms belonging to fundamental science declines gradually, replaced by a strategic argumentation increasingly oriented towards militarisation and the commercial applications of applied science.

Norms applying to the sensors follow the same logic. As we saw above, an atmospheric physics team set aside the space qualification of materials and had an onboard camera built by a small local company, which operated for two and a half years without failure. What appears in a mission document as a technical requirement is here a cost decision, taken under a funding constraint and validated after the fact by an operating record.

These determinants leave a material trace in the datasets themselves, in the form of the version number. Every major climate series is versioned: processing baselines, collections, releases. Each release is a distinct object, produced under the standards, funding and purposes of its moment; a conclusion established on version N may not survive version N+1. This is where the notion of boundary object becomes precise. A given release is plastic enough to serve the local needs of several communities while retaining a common identity across sites, which is what allows cooperation without consensus within infrastructural contexts.

4.4 Better data settle the disagreements

“Definition is always difficult” an ecologist told us. He continued: “You cannot define drought today. […] Each country have their own ‘below average’, climate variability is always extreme now, max and min are always more and more”. The threshold that triggers the qualification of drought is defined against a national average, and that average shifts under the effect of the phenomenon it is used to measure. A further interview was conducted with this ecologist together with a hydrologist and an atmospheric scientist. Discussing terrestrial water storage derived from gravimetric missions, and the confrontation of those results with the physics of ocean fluxes, the three researchers spoke at length about divergences between teams, and about the fact that these divergences do not arise from the physical data but from the interpretation and from the causal narratives accompanying it. Such divergences can appear between Japanese laboratories, but in

their account they appear above all between countries: “You in Europe have a cautious view, as long as it is not proven it does not exist. We in Japan have fewer rigid separations, because we mostly think in terms of relations. In China and Korea too, it is easier to discuss these subjects with Koreans than with Europeans”. This typology is an actor’s category rather than as a finding of its own. Its interest lies in the use our interlocutors make of it. Practitioners working on the same gravimetric products mobilise a geography of styles of reasoning in order to account for a disagreement they locate outside the data. What the passage establishes, and what our argument requires, is the location itself. Better instruments and longer series do not dissolve the disagreement, because the disagreement is not held in the measurements.

The distributive stakes of this persistence are visible on the Japanese side as well, in a different register. The director of the ecology centre observes that the definition of degradation is tied to efficiency and depends on the interlocutor; within government, he notes, it is tied to capital, “which means, North and South have issue”. The counterpoint appears in his own practice, the resolution required so that inhabitants can recognise their village, the measurements and photographs taken by local people on their phones, the traditional local knowledge described as indispensable. Which knowledge counts as data, and which indicator becomes institutionalised, are not neutral questions for the populations concerned.

Taken as a whole, these observations highlight the gap that our fieldwork brings to light. The practices we observed are flexible in every respect. Reference standards are maintained rather than prescribed; indicators are revised; criteria are defined based on the question being asked; and frameworks are developed even before the instrument exists. The official discourse accompanying this data, on the other hand, remains rigid, as we have seen with the vocabulary of national policy documents, whose terms remain constant even as their function evolves. This discourse is directed at evaluators, donors, and international organizations, which require stability to ensure coordination. Returning to the two attitudes outlined in the introduction, the difficulty does not lie in the fact that one of them is wrong, but in the fact that each serves a distinct purpose.

CONCLUSION

This paper highlights a tension familiar to every Earth-observation scientist and communities working on monitoring our planet. At the same time, instruments and practices must be revised continuously to meet evolving user requirements, while the datasets must remain homogenous and coherent over decades if they are to be usable (and used) for climate and other observations. Our research shows that this tension is not resolved by better instruments or longer series, because it is not located in the measurements. We discussed four received ideas based on our Japanese fieldwork. Firstly, satellite data are not raw, they are historically and socially variable in the role it is asked to play. Secondly, satellite data do not simply measure a phenomenon, the choice of variable and grain together settle what counts as the phenomenon. Thus and thirdly, the quality and continuity of a series are not purely technical, they depend, among others, on funding regimes, national administrations or business models. A framework can be distributed before the instrument is sent to space or a series can break because a research domain has been reclassified. Finally, better data do not settle disagreement, since interpretative frameworks and the narratives that justify them outlive their evidential base.

These findings support the position advanced in our introduction. Treating satellite datasets as tractable material artefacts, whose interpretation frameworks evolve together with other sources of data, does provide a better account of how scientists and engineers actually manipulate data and justify methodological choices. Fixed standard and rigid frameworks are what allow a dataset to travel globally, between communities that share no common background. Where distant

communities must cooperate, data have to travel, and fixed standards are what allow them to travel. Where the task is to interpret, malleability is what makes interpretation possible, especially locally. The concept of a “boundary object” explains how a dataset can fulfill both of these functions at the same time. Our research adds a limit to that analysis : each release of data is a distinct artefact and a conclusion drawn from a given version may not be true for the next one. Boundary objects have a lifespan, the length of which is determined by the reprocessing cycle. A cycle that depends on the infrastructure in which the satellites are integrated rather than on the phenomenon being observed.

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