REFLECTIONS ON SENSORS AND OBSERVATORIES IN THE CRITICAL ZONE

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INTRODUCTION

The environmental crisis significantly changes the daily practices of architects at the time of the Anthropocene, renewing attention to the planetary scale, or simply the earth (see for example the architects Design Earth[1] , and theoretically the architecture scholar Tyszczuk[2]). This Earth is either taken as a whole or as a composite of granular elements such as chemicals, soils, nutrients, water, winds, fungi, etc., recognizing that the habitability of our planet depends on these various entities and their entanglement (See Feral Atlas[3]). In any case, the field of architecture is gradually becoming interested in monitoring the environment, either by creating its own observatories (see for example Italian Limes, with the Alpine border monitoring[4]) or by relying on existing ones (see for example Territorial Agency with the ocean maps[5]). The project presented in this issue of Modi operandi is part of this trend. I myself became interested in environmental monitoring during my practice as an architect, and then during my PhD[6] , aiming to bring a new understanding of nature to better cope with climate change. In order to understand this trend related to observatories, I undertook empirical fieldwork using ethnographic methods, following scientists from a specific branch of earth sciences called the critical zone (CZ). During my fieldwork, I followed geoscientists in their laboratories but especially in their field. I will contribute to this essay with this field experience, having spent several months in critical zone observatories (CZOs), mainly in France and the West Indies, but also in laboratories, as close as possible to scientific practices, having followed the network of scientists and conducted several interviews during this work. I will also draw on my experience of creating an installation in a museum for the exhibition Critical Zones. 'Observatories for Earthly Politics'[7] , which aimed at reproducing an observatory with the landscape of instruments[8]. In this essay I will try to reduce the gap between these scientific practices and the architectural proposal of this issue.
In my research work, I bridge the critical zone and territorial landscape architecture with the design of alternative cartographies[9]. It is a matter to grasp the complexity of the composition of the critical zone, shifting the anthropocentric view (which divides the territory as a surface to be constructed), to a cosmopolitical view (a view from the inside that takes into account the depth of the ground and the cycles). The overall objective is to provide a more nuanced knowledge of what is called "nature" through visual tools and the production of meticulous cosmograms[10] linked to the scientific object Critical Zone[11]. This better understanding of the dimensions of this critical zone may bring a new understanding of landscapes and thus impact on architectural practice and its transformative agency in the New Climate Regime[12]. The project presented here by architect Menno Brouwer has taken a different turn, designing a different framework from the one found in the critical zone, I believe. Thus, in this essay, I will not comment on the architectural project itself but will extend the empirical knowledge on the notion of the critical zone, as the project passes quickly over it, which is quite understandable since it is not a research work on scientific practices but a frame of inspiration. However, I think it is important to provide some research on the critical zone and then to present an approach to what it could bring to the field of architecture.

CRITICAL ZONE AND CRITICAL ZONE OBSERVATORIES: CONCEPT AND FIELDWORKS

First of all, a few reframing comments on the critical zone, but especially on what are the critical zone observatories. The study of the CZ is a scientific program with a complex research infrastructure. In France, the CZOs have been structured into a national infrastructure called "OZCAR"[13], labelized and funded by various research institutions. The National US network is "CZO" and funded by the NSF National Program[14]. The international links are strong: scientists move from one observatory to another, exchange data, build research papers together, etc. The specificity of CZ science is the instrumentation of landscapes. Indeed, the critical zone observatories (CZOs) are at the forefront of geoscience in developing new sensors to cover the different dimensions and variables needed to understand the effects of the Anthropoceneat the territorial scale. The concept of the critical zone (CZ) refers to the Earth's habitable layer, "between the rocks and the sky". The CZ observatories are located in landscapes chosen as sentinels of environmental disturbances to study water, soil, air, living organisms and their interactions, in which processes are studied at all timescales (or "timescapes"). CZOs are highly instrumented places with sensors to monitor soil depletion, chemical water pollution, biodiversity loss, over the long term and how these processes are coupled and interfere in

places of living. Critical zone scientists thus make a pragmatic contribution to notions such as the Anthropocene[15] , the New Climate Regime or Gaia[16] , terms that are becoming more widespread among the environmental humanities. Therefore, in the observatories, geoscientists decompose landscapes, through their observations of soil, rivers, and atmosphere. Scientific instruments and practices monitor various natural features over the long term, in order to trace their unexpected trajectories. This knowledge can bring a new understanding of territories and the Earth, more attuned to the various cycles and their overlapping dynamics.
In contrast to the IMS which focuses on seismic, infrasound, radionuclide and hydro-acoustic monitoring observation and identified by Brouwer's project[17] , the critical zone observatories record many other parameters such as geochemistry, hydrology, pedology, etc., as scientists from different disciplines address complex environmental problems. This is the paradigm of the CZ, a network, a method and a concept: the uniqueness and strength of CZ observatories lies in the scattered nature of the instruments that cover the landscape. For what scientists are looking for is the movement of the Earth's entities. The meteorological station is therefore, for example, located at the top of the CZO, at the highest point, while the riverlab (a laboratory for studying the river) is located at the lowest point, at the mouth of the river, meters down below. Then soil samples, gutters under trees, baskets to collect leaves, etc. are scattered on the ground in the watershed so that scientists can follow the movements of chemical particles. Where do the calcium and phosphorus needed by the plants go, accumulate or leave, or where do pollutants, nitrates, etc. go? What scientists are trying to do is to understand the biogeochemical cycles through the earth's layers, both laterally and vertically. Therefore, there is not one single location to monitor the critical zone but several. The CZ is a network of instruments, just as CZOs are a network of observatories across many locations on Earth. The CZ is necessarily multi-site and networked.
In the CZ observatories, importance is given to outdoor laboratories, with sensors spread across the landscape, as scientists need to gather multiple (and non-centralized) viewpoints, as there are many variables to understand the landscape. Also, the logic of watersheds requires attention to the whole territory, not just one point: scientists measure the "entry point", the "exit point" and "everything in between". This reinforces the importance of landscapes as instrumented places. Sometimes scientists use low-tech, low-cost instruments, and sometimes an entire, expensive geochemical laboratory is brought in. The different ranges of instruments are also the specificity of the CZ.
The project presented by Brouwer does not emphasize this specificity, although it mentions it: "Critical Zone science is conducted through a wide variety of sensing devices and monitoring instruments. An investigation into the sensing devices used in Critical Zone science has been made through an inventory. This inventory includes devices such as acoustic emission sensors, gravimeters, atmospheric sensors and seismometers. The inventory reveals the large amount of sensing devices used in critical zone science, their specific conditions and required infrastructure." But then this fundamental parameter is dismissed by suggesting a new one: "The project facilitates these different sensing devices and combines them in one single project to understand the Critical Zone as one complex system. The project distributes the sensing devices used to research the Critical Zone in one single project". Therefore, there may have been confusion between the scales of the concept of the critical zone - as a holistic approach to studying all compartments of the earth – on one hand, and the critical zone observatory - as the physical location where the critical zone is studied, on the other hand. In the following, I will try to show that the scientific paradigm of dispersed objects is necessary for this science, but that it can also make us reconsider architecture and landscape.

ETHNOGRAPHIES CONTRIBUTIONS

While the architectural design suggested in Brouwer's project may be interesting for understanding a site in a different scientific setting, it may be inadequate for the study of the CZ where a multiple set of sensors in several observatories are deployed. Scientists in the CZ focus on areas with observatories scattered around the world, making the climate change story more complex. The CZ is the thin layer on the Earth's surface that extends vertically from bedrock to the canopy, where water modifies it, flows through it, alters it. Scientists are studying this critical zone threatened by the Anthropocene in observatories within natural landscapes, equipping forests, coasts, agricultural fields, etc. with instruments to monitor wind, chemistry, gravity, biodiversity, etc., which are all components of a landscape. Following these scientists at work in these observatories, I have heard many stories about the unexpected behavior of various entities, which change our understanding of nature. Each time, these stories start from the field, from the tour of an instrument. Indeed, like Brouwer's project, the starting point of the sensors is very relevant because they allow us to see, to understand, to capture phenomena occurring

in a landscape of which the inhabitants are not aware. However, the sensors are attached to people, scientists, who operate them, maintain them, repair them, install them, then read them, extract data and draw results from them, discuss them, come back to develop new sensors to be installed again in the field. So we have to take into account the whole world, not just the machines.
Perhaps we need a more contextualized approach, and to follow closely the technical equipment, the device, where it is made, by whom, for what purpose. This can be done using ethnographic methodologies, following scientists in action to understand what they are doing. This method is widely used in anthropology or in science and technology studies[18] and even in architecture[19]. By carrying out ethnographic observations, and by following science in the making, or even any other practice, one cannot design a project without taking into account those practices. Perhaps architecture should restructure its discipline not by building more "things" but by building communities, mainly by asking: how to work with scientists in collaborative ways?

A SHORT TRAVEL IN A CRITICAL ZONE OBSERVATORY

Let's try to embody an observatory physically. What is it made of? If we were to describe an observatory, we would have to spend time at each sensor, moving through the landscape, a forest for example. Then we can finally be attuned to the "tidings of the earth"[20] . The instruments are anchor points: they allow us to see or hear the invisible elements hidden in landscapes: the depths, the ages of water, the symphony of chemicals in a river, etc. From and through the Earth, they give us the opportunity to listen to its whispers. From and through the Earth, they make us discover the many entities, parts, variations, heterogeneity, that make up the critical zone. We are inside of it, part of the critical zone in some way, we move through its hidden parts.
Let's better understand the science and technique of the critical zone, by going to an observatory, a forest in the Vosges, in eastern France, threatened by acid rain and drought (lack of water, parasites, decrease in forest cover). From station to station, the earth takes shape. Below is a description of the CZO map. A video of this map can be seen here (title CZO map – SOC).

Geoseismic station

The geophones are an instrument that sounds the ground at depth by sending vibrations through it and records the sensitivity of the soil to these variations in order to reconstruct rocks porosity down to -150 meters. Geophysics use lines, transects at several locations, here 7 lines of about 100 meters each. Vibrations are triggered on the ground and their propagation is followed. This instrument reconstitutes one dimension of the earth, making us feel the soil depth.

Weather station

Several devices record the variations of the lower atmosphere and the direction of all elements carried by the winds. The sulphur emissions from Asian industries that cause acid rain can cross the Vosges forest in less than 20 days.

Tree Station

Trees are sentinels of the environment. Large areas of the forest are monitored to understand whether or not there is resilience after storms, acid rain, pests and the impact of the forest industry. Large rectangular gutters are placed under the trees and collect rainwater to analyze its pollutants, including sulphur, which acidifies the soil and is responsible for the death of trees.

Gravimetric station

This machine records the signal from the water table at depth. But it is so sensitive that it also records other signals such as the force of gravity of the tides breaking on the sea coast hundreds of kilometers away, like echoes propagating to the continental forest. We go even deeper into what is going on in the soil

Piezometers and coring

The core samples extract soil from deep underground, at different places across the watershed, exposing previously unsuspected pockets of water at a depth of almost 120 meters. The water triggers chemical reactions in the rocks, possibly even allowing the presence of organisms. The boundaries of the CZ extend intensively into the depths.

Riverlab station

The Riverlab is a tiny laboratory set up directly in the field. Inside, the machine records the chemical variations of the river by letting the river water pass through its circuits in real time. More than 10 chemical components are measured every 20 minutes. Scientists show that they behave differently depending on the day and night, the season or the flood. It is a kind of microscope for geochemistry that decomposes the river into as many particles as there

are inside a drop of water. In this view, there is not only a river of water but there is a river of sulphur, a river of phosphorus, a river of calcium, a river of magnesium. It changes the way we understand the elements of a landscape.

These instruments, these sensors, offer different, unprecedented views of environmental phenomena and therefore enable us to rediscover the landscape, which is no longer a passive setting, but is crisscrossed by a multitude of phenomena, with lots of entities, which are invisible to the naked eye, and which can only be apprehended thanks to scientific sensors. Space is no longer seen from the sky, from above, but there is another relationship to space, from the ground, even from the micro. And it is the whole of the sensors that ultimately makes it possible to build this new understanding of the Earth.

SENSORS AND PUBLIC EXPERIENCE

CZ science captures alarming and fundamental environmental issues at multiple sites, and through long-term monitoring of ecosystems. CZ sensors are therefore designed to look down into the invisible underground, redirecting our gaze to the ground, the earth, the mud. Why do we do this? Because there are many phenomena happening in the "subterranean" that we do not yet understand, such as macrobiotic life, waterways, rock weathering fronts, etc. The Earth, as Brouwer's project rightly mentions, is indeed a moving entity and we must become sensitive to it. The interest of the project of this issue lies perhaps in the fact that it asks what a better link between the instrument and the citizen could be. Indeed, the environmental crisis, or the disconnect between what scientists tell us and our lack of reaction to it, is perhaps due to the fact that there is no interrelationship between the feeling of the sensor and the experience of the sensor by citizens. A strong hypothesis that could explain the difficult dialogue between the social and natural scientific worlds is the lack of interface between the sensors and the citizens' experience of these sensors. As many authors advocate [21], a representation of the earth through sensors is needed to renew our relationships to the earth. To understand the environmental crisis (characterized by soil erosion, resource depletion, or the loss of biodiversity), we may need to consider the crisis of representation of the earth. With the idea that producing new narratives, new descriptions with alternative tools would allow us to re-equip ourselves in an unstable, uncertain world. It is true that architecture has neglected the sensor, leaving it to techniques. This could be an important task for architecture. How can we design a territory in such a way that the public experiences what the sensors detect? But also in a way that is respectful and aware of scientific practice?
In this sense, the workshops on materiality are interesting (section Analysis, Modi Operandi[22]), because they rematerialize a sometimes abstract thought. We see here that architecture does not deal with some hyperobject but is always confronted with objects, materials, something to touch and experience. This notion of experience is a legacy of pragmatist philosophers - Whitehead, Debaise[23], Latour, or Haraway[24] - and a key notion. The project further discusses the place of the human body and the experience we can have of the earth, a topic that is not addressed in the CZ sciences and that could make an important contribution to reducing the gap between scientists and citizens. To go further, we could also ask: how do we integrate non-human living bodies? As architects, we have a responsibility. How do we build politics? How do we reclaim the earth, build communities, share and debate ideas on a cosmopolitical level[25], not just human to human. Or should we see landscapes as bodies too - bodies without organs but with agency.

CONCLUSION: WHAT IS THE PLANETARY SCALE?

Two conclusive comments can be drawn from this perspective of the project with extracts from research on landscape in critical zones.
The first point is that thinking on the scale of the earth requires localized places and many dimensions. Contrary to the theories of 'hyperobjects' by Morton presented in the section Theory, Earth Magnitude[26], - and the project also empirically attests to this - we can only know and experience something, especially the earth, in one place. This does not mean that we cannot access knowledge from many places. On the contrary, it is through the network of observatories in the critical zone, in their variety and multiplicity, that an understanding of the 'earth' emerges, that is, what it feels like to be an earthling. The planetary scale is not a hyperobject that we cannot access but rather a network of pluriverses accessible through the sensors of the critical zone. For Latour, the meaning of the terrestrial is not to think as a whole, beyond the human perspective, but rather to look from the ground, from within, being embedded in multiple relationships with living beings with their own trajectories. It is through

fieldwork that one can experience this, looking closely at tiny particles through the sensors. The CZ sensors are not interested in the big things, but rather in the micro that leads to the macro, i.e. the biogeochemical cycles. In these cycles, scientists see human activity as traces, signatures - and especially disruptors - of the cycles.
The second point is that our experience of working with scientists makes us realize that it is not simply a matter of 'transporting/transposing' knowledge of the earth into architectural studies, but also of empirically constructing how we architects understand earth entities. And thus, to undertake a truly transdisciplinary work: to imagine new ways of learning from and with, to multiply the capacities to learn from and with and in the critical zone, in open weavings with scientists and inhabitants.

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NOTES

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3 Feral Atlas (2021), Curated and Edited by Anna L. Tsing, Jennifer Deger, Alder Keleman Saxena and Feifei Zhou. Stanford University Press. Website: https://feralatlas.supdigital.org/index

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5 https://www.territorialagency.com/oceans

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7 See the catalog of the exhibition with several essays on the critical zone by earth scientists and scholars in the humanities. ZKM catalogue Critical Zones. The Science and Politics of Landing on Earth. Publisher: MIT Press. Editors: Bruno Latour & Peter Weibel. 2020

8 "Critical Zone Observatory Space", installation by SOC at ZKM Center for Art and Media, Karlsruhe, in Critical Zones. Observatories for Earthly Politics, curated by Peter Wiebel and Bruno Latour. May 2020 - January 2022. http://s-o-c.fr/index.php/zkm_czos/. A description of the installation is published here: Arènes A. (2022) The Critical Zone observatory space, in Infrastructural Love: Caring for Our Architectural Support Systems, edited by A.Carbonell, H.Frichot, H.Frykolm, and S.Karami. Birkhäuser.

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