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LabEx OSUG

Habitabilité dans des mondes changeants

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1 Context of the project

1.1 Open scientific, technological and methodological questions

Since 2020 the central theme guiding the actions and activities of the LabEx OSUG¹ is *Habitability in changing worlds*. We use here habitability as the ensemble of conditions to be fulfilled for any form of life. Habitability is linked to a location (= a habitat) exhibiting *a collection of resources and environmental conditions (abiotic and biotic) that determine the presence, survival, and reproduction of a population*.² We are using the concept of habitability to study a range of locations based on observations, to perform experiments to gain new process understanding, and to develop modeling tools to reinforce our predictive capacities. The studied objects range from celestial bodies (stars, planetary discs, exoplanets to planets) to terrestrial environments, where basic conditions for habitability up to complex requirements for human societies are examined. We address key challenges to realize breakthroughs responding to the following four major questions: 1. What makes and keeps planets habitable? 2. How can we integrate the multiple facets of habitability on Earth? 3. How is habitability maintained with limited resources? 4. How do natural hazards and associated risks contest habitability?

One of the main challenges is to identify habitable Earth-like planets and search for biomarkers in their atmospheres. Studies of the formation and evolution of planetary systems are key to understand the stellar and planetary parameters that enable habitability on Earth and potentially on other planets, as well as the stability of their atmospheres and climate. Such knowledge is crucial to understand how unique our own Earth is and to assess whether life could exist elsewhere in the universe. Habitability on Earth is intimately linked to the critical zone (CZ), the location of a wide variety of life forms and living organisms and the primary zone of human habitability.³ It also constitutes an important interface for major terrestrial compartments ranging from the deep Earth to the atmosphere. A comprehensive understanding of the CZ and linked compartments based on a tight coupling of observations, experiments, and models is required to examine future trajectories of the compartments influenced by global change and anthropogenic activities at a wide range of scales (e.g. from local to regional to global scales, from seconds to millions of years, and from genes to species to ecosystems). A better understanding of the interactions of the exploitation and use of natural resources, their quality and their limits considering environmental aspects, quality of life as well as social and economic aspects is required, since they are all important for long-term terrestrial habitability. The characterization and quantification of traditional and new natural resources (e.g. water, biodiversity, minerals, trace metals, renewable energy) is a major condition for their sustainable exploitation and for the development of mitigation and adaptation strategies concerning the sustainable exploitation of resources. To address how natural risks impact habitability or habitable zones, it is necessary to improve the knowledge of physical processes causing natural hazards and the cascade of hazards, to assess the vulnerability and capacity of the environment to withstand extreme events, to develop models for the adaptation of exposed areas and infrastructure and to improve their resilience. We focus on the impact and consequences of extreme events for urbanized and industrialized areas. The LabEx is anchored in the OSUG community, which regroups all local scientific actors in astrophysical, geoscientific, ecological and environmental research as well as social science teams working on topics in line with environmental science. This community has strongly evolved since the beginning of the LabEx in 2011 in terms of joint programs, coordination, planning and is now well-recognized as illustrated by the UGA international ranking in the domains covered by OSUG. The LabEx profits from major shared tools like 1. national and international research infrastructures (RIs), 2. shared analytical platforms and instrumentation, and 3. a dedicated center of expertise for the treatment and storage of research data and calculation (OSUG-DC). These tools will be further developed in the frame of the LabEx.

Long-term observations and RIs are indispensable tools in all scientific fields covered by the LabEx. 9 international and 4 national RIs⁴ in astronomy and astrophysics, material sciences and engineering, and Earth

¹ A glossary with a list of the participating units and research team and their acronyms as well as a list of used acronyms, abbreviations, and French terms can be found here: <https://nextcloud.osug.fr/index.php/s/RW6P3L2rC7mYyYq>

² Aarts et al., J. Anim. Ecol. 82, 1135-1145, doi.org/10.1111/1365-2656.12061, 2013.

³ e.g. Katling & Castling, Atmospheric evolution on inhabited and lifeless worlds, Cambridge University Press, ISBN 978-0-521-84412-3, 2017. Guillot & Hattori, Elements 9, 95–98, doi.org/10.2113/gselements.9.2.95, 2013.

⁴ International RIs: **ACTRIS** (The Aerosol, Cloud and Trace Gases Research Infrastructure); **ANAEE** (Analysis and Experimentation on Ecosystems); **CFHT** (Canada France Hawaii Telescope); **ELTER** (Integrated European Long-Term Ecosystem, critical zone and socio-ecological Research) including national RIs **OZCAR** (Observatoires de la Zone Critique, Applications et Recherche) and **RZA** (Réseau des Zones Ateliers - Infrastructure des Socio-écosystèmes); **EPOS** (European Plate Observing System); **ESO** (European Southern

System and environmental sciences and related national observation services (SNO) for long-term observations⁵ are crucial for the realization of the project. While OSUG members are involved in all of these activities, it should be noted that ACTRIS and EPOS with the status of a European Research Infrastructure Consortium (ERIC, a specific legal form that facilitates the establishment and operation of RIs) rely on the involvement at a very high level of OSUG members and that OSUG is mandated to represent the UGA, which co-carries the national French node of the ERIC ANAEE together with the CNRS. The LabEx will support the maintenance and the development of existing or innovative instrumentation and observation and monitoring activities in the frame of these services and projects with the goal to support the integration into international networks, wherever possible. The OSUG community will seize the unique opportunity of the co-location of ANAEE, RZA, ICOS and ELTER at the Jardin du Lautaret to tackle key research questions in a multidisciplinary manner⁶ at the crossroad between geosciences, ecology, and social sciences such as the relationship between snow cover dynamics, vegetation dynamics, and ecosystem functioning of and services from mountain grasslands relevant for certain aspects of the habitability of mountain areas. Strong synergies are also envisaged concerning sensor technology and the design of new sensor networks to better probe natural environments. Finally, the interoperability of RIs also translates into common data treatment, formatting, and quality-control, data assimilation, and a better integration of empirical data into modeling approaches.

Since physical, chemical, and optical analytical equipment will be instrumental to reach the goals of the LabEx, continued investments in state-of-the-art instruments for shared analytical platforms⁷ are envisaged. To maintain the existing expertise in the OSUG community concerning the analysis of chemical and physical properties of a wide range of natural matrices at high resolution, corresponding human resources with high-level expertise in the development and application of innovative analytical methods, instruments, and artificial intelligence approaches are also required. The OSUG community is a major contributor to the newly established national RI REGEF consisting of a network of analytical capacities and expertise in geochemistry. The LabEx supports the OSUG community to fully develop its role within REGEF according to its capacities.

The OSUG computer and data service (OSUG-DC)⁸ is considered as a major element to connect RIs, *in situ* measurements, as well as remote sensing observation via the harmonization of data assimilation, treatment, and visualization. In the frame of OSUG-DC, the LabEx supports the sustainability and accessibility of research data and meta data and fosters data sharing and openness policies impacting data harmonization, sharing practices, and cultures across the domains. The LabEx will be used to put in place relevant IT infrastructures and capacities concerning storage, data flow, computational needs, etc. as well as corresponding expertise and human resources. OSUG-DC helps the OSUG community access and efficiently use computing facilities, and aims to promote and support high-performance codes that provide a service to the community and are developed by OSUG members. It acts as a hub for coordinating high-performance computational needs in coordination with and in support of Grenoble Alpes Recherche Infrastructure de Calcul Intensif et de Données (GRICAD), the UGA Tier-2 HPC center. OSUG-DC is, furthermore, a major tool to reinforce the FAIR principles for data and codes generated within the OSUG community as well as open access to scientific results and information.

Alpine regions will continue to be a geographical focus of the LabEx. In the previous phases, research in the French Alps and other mountain regions has been developed to enhance our understanding and expertise of the geophysical, environmental, and social system of this specific geographical environment. The last three of the four major scientific questions will directly be addressed in the context of alpine research. Furthermore, alpine research continues to be a great opportunity for the OSUG community to enhance interdisciplinary research. Alpine regions are also a crucial element to combine different activities of the LabEx concerning for example research, observation, training, outreach, and mediation. They are a common focus area of three different LabEx projects (Innovations and territorial transitions in mountains ITTEM and UG@rchitecture)

Observatory); **ESRF** (European Synchrotron Radiation Facility) with the beamlines **FAME** (French Absorption spectroscopy beamline in Material and Environmental sciences) & **FAME-UHD** (Ultra-High Dilution); **ICOS** (Integrated Carbon Observation System) and **IRAM** (Institut de Radioastronomie Millimétrique). National RIs: **DATA-TERRA** (Integrated Earth System Observation) and **REGEF** (Réseau Géochimique et Expérimental Français). OSUG is also involved in the **CTA** (Cherenkov Telescope Array), which contributes to the LabEx ENIGMASS.

⁵ <https://www.osug.fr/missions/observation/>

⁶ Kulmala, Nature 353, 21-23, doi.org/10.1038/d41586-017-08967-y, 2018.

⁷ <https://www.osug.fr/l-institut/moyens-analytiques/>

⁸ <https://www.osug.fr/l-institut/services-communs/systeme-d-information/>

enhancing important interdisciplinary approaches in all of these activities and reinforcing collaboration between these LabEx in the frame of the so-called Mountain Research School (MRS) together with the Long-term socio-ecosystem research (LTSEr) platform Lautaret-Oisans linked to ELTER.

Training and education of students and early-career researchers (ECRs) contributes to the long-term objectives of the LabEx. It requires training on and with state-of-the-art and innovative equipment and instrumentation used in fields ranging from Earth and Environmental Sciences to Astrophysics and Planetary Sciences. Innovative methods are used to introduce students and ECRs to conducting long-term observations. Furthermore, innovative and high-level summer schools will be offered for ECRs. For example, the high-level school in the frame of the MRS contributes to the cross-disciplinary training of young scientist for a better understanding of on-going and future challenges for mountain socio-ecosystems.

1.2 Socio-economic or cultural issues

The LabEx aims to provide relevant scientific expertise to analyze, understand, maintain, and, if necessary, reconstruct long-term habitability on Earth, placing it into broader perspective through comparison with other planets. Human habitability on Earth can only be ensured if urgent and threatening issues related to the anthropogenic impact on climate, biodiversity, and resources can be resolved. Knowledge based on long-term observations of the natural and astronomical systems contributes to the comprehension of the evolution of these natural systems leading to major breakthroughs required to accompany societal and economic transitions from local to global scales based on scientific evidence. Similarly, the generation of forecasts and scenarios (e.g. climate, biodiversity, ecosystem services) based on statistical and mathematical developments carried out at OSUG are instrumental to provide data and guidance for action, adaptation and mitigation of anthropogenic impacts (e.g. to meet the EU Biodiversity Strategy for 2030). The objective is to deliver useful and significant scientific results to reach the United Nations sustainable development goals SDG 6 (Water), 7 (Energy), 9 (Habitat), 11 (City), 13 (Climate action), and 17 (Partnership). A further objective of the LabEx is to undertake strong outreach and communication actions to transfer newly generated scientific knowledge to the general audience as well as local stakeholders in a science-territory approach. This requires maintaining important outreach activities, often in line with established or new local exhibition venues and institutions⁹ like the OSUG *Espace muséographique* on the UGA campus, the Jardin du Lautaret, or the new Grenoble science center *Cosmocité*. The interaction with local stakeholders will be enhanced and new transdisciplinary methods will be tested and, if successful, put in place. This interaction is driven by the conviction that scientific results should form the basis for public action needed to transform the society to maintain habitability.

Since the LabEx includes mountain regions as focus areas, knowledge transfer and interaction with local stakeholders in the French Alps will be a major objective. The temperature increase in mountain regions is larger than the global average, the impact of anthropogenic activities on the biodiversity is amplified in high altitude regions, and alpine areas are more vulnerable to natural risks. Therefore, the objective of the LabEx is to provide scientific expertise for these vulnerable regions and their local stakeholders. This also concerns countries in the intertropical zone, which are highly vulnerable to the impact of anthropogenic activities (exploitation and use of natural resources, sea level rise, exposition to natural risks, etc.) influencing the habitability of certain regions. Due to long-standing cooperation with these countries in line with the IRD strategy, the transfer of scientific expertise and knowledge to selected major local (non-)academic stakeholders in South America, Africa, and Asia remains a focus of the LabEx. These aspects will be covered in an adapted outreach strategy.

1.3 Summary of preliminary results already obtained

Since 2020, 39 new projects related to research and monitoring have been selected and financed. These projects fall in the so-called categories standard (budget <40 k€, 23 projects in 2020 to 2022), flagship (<80 k€, 10 projects 2021 & 2022) and strategic (<150 k€, 6 projects in 2022). All projects are contributing to the four major scientific questions and/or the structural objectives guiding the LabEx since 2020. Due to the force of the OSUG community, numerous results have been produced, which are documented in more than 375 peer-reviewed scientific publications acknowledging the LabEx during the period from 2020 to 2022.¹⁰ These publications obviously also contain results obtained due to investments during the previous phase into state-

⁹ <https://www.osug.fr/grand-public/lieux-a-visiter/>

¹⁰ <https://publi.osug.fr/waodss/modules/export.xql?format=html&tag=LABX56-man&tag=LABX56&max=-1>

of-the-art equipment, PhD projects, and long-term activities. In the period from 2020 to 2022, 16 articles were published in Science, in the Proceedings of the National Academy of Sciences or in journals of the Nature group dealing among others with the characterization of a planet in the b Centauri binary system,¹¹ abrupt changes of atmospheric CO₂ during glacial and interglacial periods,¹² the application of AI tools to analyze glacier mass change due to climate change,¹³ the observation of subglacial hydrology with seismic tools,¹⁴ or the global protection of biodiversity.¹⁵

The RIs related to the LabEx provide tools and services to scientists enabling them to conduct research and observation projects at a high level. Therefore, the LabEx ensured the maintenance and implementation of services provided by the identified RIs to allow an optimal and accessible use of these services and, thus, to reinforce scientific excellence in the OSUG perimeter. For example, the LabEx provided funding for the replacement of instrumentation for ACTRIS that went missing during the COVID pandemic, the development of new data services for EPOS, or the GRAVITY+ instrument upgrade at ESO. OSUG has been recognized by CNRS/INSU+INEE and IRD as a strategic partner for RIs and the involvement of OSUG member in the RIs and their leadership has contributed to the international visibility of UGA. In the frame of RZA, the ZA Alps driven by OSUG develops a specific scientific approach based on observations and experiments on selected sites to conduct long-term multidisciplinary research. In the last three years the LabEx supported a convergence between OZCAR and ZA Alps to build the LTSE platform Lautaret-Oisans in a whole-system approach. For example, the LabEx co-financed a tower to monitor greenhouse gas fluxes under half year snow cover, which is now associated to ICOS-Ecosystem. As a result, the platform is recognized as the most advanced French ELTER platform. Furthermore, OSUG is a major actor of ANAEE due to the implication in the Jardin du Lautaret open-air ecosystem platform providing versatile facilities to simulate environmental impact of land-use change, pollution, biological invasions, and extreme events and in the eDNA analytical platform devoted to DNA metabarcoding analyses of the environment.

In 2021, we decided to go further in structuring our involvement in RIs in order to provide strong, visible, and long-term support to the construction, implementation, and development of the associated services. This resulted in local road maps for each RI describing their contribution to OSUG and the LabEx, the available means, and the needs of the RIs. The roadmaps aim to set up a more in-depth strategic and resource-oriented thinking for each RI and to plan OSUG financial support for 5 years or more, in accordance with the (inter)national policy of the RIs. LabEx funding in response to the investment and development needs is reflected in a multi-annual expenditure plan with a support for each RI adjusted according to the degree of maturity. The first expenses in line with the plan were recently validated concerning for example the hiring of technical staff for the beamline FAME or IT staff for the upgrade of database services related to astronomical RIs and REGEF.

The OSUG computing and data service (OSUG-DC) operates the IT infrastructure of the federation in complementarity with those of the UGA site (GRICAD/DGDSI services) and delivers a software support for the provision of scientific data. Since OSUG is responsible for long-term observation data and for related services of several national observing services and some of the RIs, OSUG-DC plays a role in the coordination or as a partner in the management of observational data. The LabEx has had a large structuring effect on OSUG-DC because it has supported its development since 2011 by funding projects and contracts to expand existing and new services. The entire IT service at OSUG currently regroups 17 IT staff including 1 engineer funded by the LabEx and 3 externally-funded engineers.

In the field of Astronomy-Astrophysics, OSUG is involved in major instrumentation programs (ANO-2) and is responsible for three data services (ANO-5) that rely on its regional center of expertise OSUG-DC. The development of these services (SSHADE-F, JMMC/MOIO, SPHERE HC-DC) and the delivery of our contributions to ELT instrumentation (HARMONI, MORFEO) are a priority. The increasing attention paid to data requires

¹¹ Janson et al., A wide-orbit giant planet in the high-mass b Centauri binary system, NATURE 600, 10.1038/s41586-021-04124-8, 2021.

¹² Nehrbass-Ahles et al., Abrupt CO₂ release to the atmosphere under glacial and early interglacial climate conditions, SCIENCE 369, 10.1126/science.aay8178, 2020.

¹³ Bolibar et al., Nonlinear sensitivity of glacier mass balance to future climate change unveiled by deep learning, NATURE COMMUNICATIONS 13, 10.1038/s41467-022-28033-0, 2022.

¹⁴ Nanni et al., Observing the subglacial hydrology network and its dynamics with a dense seismic array, PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA 118, 10.1073/pnas.2023757118, 2021.

¹⁵ Smycka et al., Tempo and drivers of plant diversification in the European mountain system, NATURE COMMUNICATIONS 13, 10.1038/s41467-022-30394-5, 2022.

maintaining the high level of expertise acquired and a capacity for evolution on SSHADE-F, in particular in connection with the RI REGEF. This support corresponds today to 3 software development engineers and 1 IT network specialist. In the Solid Earth domain, OSUG hosts a team of 3 engineers for the national seismological data center RESIF-DC. Their mission is to distribute and archive all data from the French permanent and mobile seismological networks gathered in the RI RESIF or by RESIF partners. The RESIF data center is integrated in EPOS through the Federation of Seismological Data Centers in Europe and in the worldwide seismological data distribution network. In the field of Surfaces and Continental Interfaces, OZCAR gathers data from about 20 SNOs and other observatories, among which the SNOs OHM-CV, AMMA-CATCH, GLACIOCLIM, and Draix Bléone are led by OSUG. To make heterogeneous data/metadata more accessible, a common information system for in situ data is being built under the aegis of the Continental Surfaces data service THEIA|OZCAR.

The activities of the Training/International component are strongly linked to the international mobility of researchers and students to and from Grenoble. These activities could only be carried out to a very limited extent in 2020 and resulted in a strong demand after the project call at the end of 2020. Despite the unfavorable sanitary situation, the high-level summer schools European Research Course on Atmospheres (ERCA) and the MRS were maintained or newly installed. ERCA, continuously supported by the LabEx since 2011, offers training in atmospheric and climate sciences to address social challenges of global change and air quality, hydrology and oceanography, and environmental chemistry. The 30th session took place in Grenoble and at the *Observatoire de Haute Provence* in January 2023 with J. Steinberger's (University of Lausanne) opening seminar *Living well within Limits* in line with the major topic of the LabEx. In 2021, the LabEx created the MRS as an annual summer school together with the LabEx ITTEM. It offers training in interdisciplinary approaches involving Human and Social Sciences and Earth and Environmental Sciences within mountain territories. The school aims to develop research, development, and training activities around the trajectories of mountain territories facing environmental, social, and economic risks and reinforce methods for observing the coupled Earth/Ecosystem/Society system. It is organized in the form of an itinerary in the area of the LTSER platform Lautaret-Oisans and with the Jardin du Lautaret as a major hub to provide logistical support and accommodation. The participants observe, experiment, and exchange in situ with researchers and actors in the area and around their research theme in different formats. For example, a public performance of a play, dealing with the influence of environmental changes in the French Alps on various anthropogenic activities, will take place to create an opportunity for the participants to reflect on their own research and engage in a dialogue with local audience members.

In terms of communication and outreach, we built and developed a “communication service” dealing with communicating the latest scientific results, handling web sites for projects or for national services of observation, and in helping to create and support transdisciplinary groups on specific scientific or methodological targets, over several units/teams within OSUG. Furthermore, in order to face the challenges of tomorrow's world in an enlightened manner (global changes, resource management, prevention and forecasting of natural risks, etc.), the understanding of the world around us and of current societal problems must be accessible to everyone, in an adapted format, in a transparent manner, and as close as possible to the state of the art. According to the adopted outreach strategy, digital communication was emphasized to promote the image and productions of the OSUG federation in the academic world as well as in society and to federate its members around common issues. The communication service has produced nearly 40 short videos on diverse scientific results in the last two years. This content has been promoted on the social networks Twitter, Facebook, LinkedIn, and YouTube generating over 600000 views. Since the launch of the OSUG series on YouTube in October 2020, the channel has recorded more than 40000 views and 346 hours of streaming. The communication service initiated also long-form podcasts that will strengthen the online presence, particularly on audio streaming platforms that are becoming more popular among the young audience. The digital presence was complemented by events in cooperation with cultural and institutional players and local authorities and in line with previous activities: participation in annual scientific culture events (*Fête de la Science*, *Jour de la Nuit*, *Journées du Patrimoine*, *Nuit des chercheurs*, etc.), organization of an in-house day for researchers, organization of an internal day for OSUG members as well as major OSUG seminars, support for regular or unique local events for the general public (*Rencontre Montagnes et Sciences*, *Grenoble European Green Capital 2022*, etc.), development/support of projects (creation or co-production of exhibitions, artistic residencies, educational

content, etc.), and the management of the OSUG *Espace muséographique* including nearly 200 guided tours for ~2500 visitors since the opening of the hall in July 2016. Due to these regular communication and outreach activities, OSUG has been able to develop strong links to local actors and stakeholders. For example, the OSUG community represented more than half of the members of the scientific council of *Grenoble European Green Capital 2022*. Moreover, OSUG members constitute 90 % of the scientific council of *Cosmocité*, which will be inaugurated at the end of 2023. The scientific council is mainly responsible for developing the scientific content of this new local venue for transfer of scientific knowledge to different audiences.

Since the OSUG community includes a total of ~1400 members, the LabEx has supported activities related to inter-lab communication. Furthermore, a co-construction method making use of the collective intelligence was employed to develop a project for the improvement of the working quality. This project aiming at enhancing inter-laboratory collaborations and creating new links by a better knowledge of professions and persons, was selected in 2022 and received funding of 40 k€ by the CNRS. After this success, the OSUG community will facilitate the use of this method to deal with topics or challenges that may emerge in the future, striving to continuously improve the work environment of all OSUG members.

1.4 Summary of funding already obtained or applied for and in progress

The ambitious scientific and strategic goals of the LabEx cannot be realized with the LabEx funding alone. The LabEx is embedded in a research environment created by the participating units and research teams, which bring additional recurrent funding from their supervising authorities and external project-based funding. Funding that can be directly attributed to the LabEx and its objectives are, for example, the annual endowment of the supervising authorities to the RIs and SNOs made available to the responsible local scientists on the order of 423 k€ from CNRS/INSU, 140 k€ from CNRS/INEE, and 159 k€ from IRD. Further observation and research activities are annually supported with 205 k€ out of the OSUG budget, to which the supervising authorities CNRS, UGA, IRD, INRAE, and Météo France contribute. All numbers correspond to the funding of the year 2023, which we assume will remain unchanged or will even increase during the next funding period. OSUG further supports the maintenance and expansion of various services with respect to e.g. OSUG-DC or other technical services. Not included in these numbers are the salaries for the permanent staff at OSUG or in the units and research teams financed by the supervising authorities (for example the number of permanent technical staff at OSUG has increased from 14 in 2016 to 22 today).

Due to the participation of research-strong institutes, additional funding has been obtained and we are confident that the OSUG community has the capacity to maintain this level of external funding within the framework of various national and international projects, which concern at least partial aspects of the LabEx. However, these do not currently concern the overarching topic of habitability. Therefore, we refrain from listing such projects, which continue until 2025 and later, in detail here. While certain aspects of the LabEx will certainly profit from the involvement of parts of the OSUG community in the local projects ACME, Origin of Life, GI2R, and Patrimialp Tools, financed by the IDEX UGA with budgets ranging from 350 to 600 k€, these projects cover large interdisciplinary topics. For example, Origin of Life fosters work by going beyond the OSUG community by supporting projects with chemists and biologists and bridging the research poles PAGE and CBS at UGA.

2. Scientific and technological quality of the project

2.1 Clarity and ambition of the scientific questions posed; relevance and innovative nature of the project from a scientific and methodological point of view in relation to the state of the art

The major scientific questions described above, which are well in line with the major fields of expertise of the participating institutes, will be addressed according to three major topics described in more detail below, to which the participating institutes and research teams will contribute in variable configurations. Based on the existing expertise, mountain regions will be a special focus without neglecting other vulnerable regions.

What are the origins of habitable planets and zones? The origin of habitable planets and zones will be addressed by combining our expertise in astronomy, astrophysics, atmospheric science, climatology, ecology, environmental science, geochemistry, geomorphology, geophysics, oceanography, and planetary science. The detection of more than 5000 extrasolar planets has revealed the diversity of planet formation and evolution, which condition the extent and stability of the habitable zone. Only a very limited number of these planets is potentially habitable making the identification of Earth-like planets one of the main challenges. We will study

the origin and formation of such habitable planets and the astrophysical and planetary parameters that contribute to maintain habitability. We will use protoplanetary discs and the Solar System as templates for the identification of reservoirs of volatiles and complex organics. We will use Earth as an example of a planet maintaining atmospheric and climate stability. We will address the question how unique our own Earth is and search for biomarkers in the atmospheres of other planets to assess whether life may exist elsewhere in the universe. Understanding the origins of life is a major theme combining observations from different RIs and the expertise of different OSUG units and research teams on this topic concerning for example interstellar dust, the structure of telluric planets, the climatic evolution of planets, the composition of the atmosphere of exoplanets, and the nature and presence of biomarkers.

Stellar and disc formation mechanisms produce a wide variety of planetary systems and bodies. The mechanisms at play in envelopes, discs, magnetospheres, winds, dust will be studied as they record chronological, dynamical, and chemical conditions at play during the formation and evolution from the interstellar medium to young stars and discs. Planets, satellites and small bodies will be studied to understand the driving processes and contributions to the past and present habitability of our own Solar System. Combining infrared to submillimeter observations from instruments at IRAM or ESO, for which the OSUG community is a major partner, with global simulations including advanced astrochemical models and radiative transfer, made possible by high-performance GPU computing, can deliver constraints for protoplanetary disc composition and structure during the initial stages of planetary formation. Support to develop the next generation of instruments at the VLT (SPHERE+) or ELT (HARMONI) enabling high-contrast, high-angular resolution and high-spectral resolution observations will be necessary in the search for biomarkers in the atmosphere of habitable exoplanets like Proxima b.

Radial velocity, transit, and direct imaging data will be studied to understand the architecture and orbital stability of extrasolar systems. The architecture of these systems will be compared to the specific architecture of the Solar System with four planets close to the Sun and four giant planets. This configuration played a key role during the formation of our planet stabilizing the terrestrial orbit and, thus, ensuring climate stability. Furthermore, beyond gravity, the presence of a magnetic field contributes to the preservation of a planetary atmosphere required for habitability. The dynamics of planetary cores are paramount to understand and predict the strength, morphology, and time variation of dynamo magnetic fields. We will exploit our expertise on the observation of mass, age, and composition of exoplanets with our expertise on the generation of planetary magnetic field and on terrestrial climate evolution. This will allow us to identify the ideal candidates for habitable exoplanets and to assess their ability to sustain a dense atmosphere. We will advance our understanding on natural (e.g. orbital forcing) and anthropogenic factors impacting terrestrial climate variability and stability at time scales ranging from 100 kyr cycles to recent centennial and millennial climatic variability based on an array of records at the poles and in the tropics. We will focus on cryospheric and marine processes, which have a strong impact on terrestrial habitability linked for example to the sea level and which likely constitute important components also for the climate stability of potentially habitable exoplanets.

The origin and resilience of different forms of life on Earth depend not only on the climatic and atmospheric stability, but are also impacted by tectonics and biogeochemical cycles, by catastrophic climate changes, and sporadic catastrophic events triggered for example by volcanism and asteroid collisions. We will contribute to the understanding of the origin of biodiversity by developing a unified view of the natural world. Combining our expertise in geology, geophysics, evolutionary biology, and climate and environmental sciences, we will test how far the emergence of biodiversity patterns have been driven by geological and climatic dynamics as well as feedback mechanisms between biodiversity and the physical and chemical environment. With a focus on mountain regions, we will use the recorded solid-Earth dynamics to understand the origin of biodiversity and the rate of diversification using novel phylogenomic tools and benefiting from geophysical observations depicting complex transient deformations of the lithosphere and erosion processes. We will use and reinforce methods, innovative tools and data already applied in the French Alps.

What characterizes the Anthropocene? We will focus the characterization of the Anthropocene on the critical zone (CZ), which ranges from the base of the alteration layer to the atmosphere. It hosts a variety of life forms and living organism and it is an important interface for major terrestrial compartments, crucial for terrestrial habitability. The CZ supports human welfare since it encompasses the majority of natural resources exploited

for anthropogenic activities. At a global scale more than half of the generated economic income is highly or moderately dependent on ecosystem services: water, sun, soils, wind, plants, animals, etc.¹⁶ A majority of these services are intimately linked to the CZ. At the same time, the CZ is often degraded by anthropogenic activities and is also affected by many natural risks and extreme events. Our combined expertise in atmospheric and environmental sciences, biogeochemistry, ecology, ecotoxicology, geology, geophysics, meteorology, mineralogy, spectroscopy as well as in certain social sciences like anthropology, economics, sociology, geo-history and human geography is required to contribute to a more comprehensive understanding of the CZ and linked compartments. Based on a tight coupling of observations, experiments, and models, we will examine how these compartments have been influenced by global change and anthropogenic activities and how related ecosystem functioning and services have been affected. We will focus on mountainous regions (but not only), where the increasing urbanization and atmospheric pollution from the valleys interplay with a shrinking cryosphere, land use changes, and touristic or industrial activities. For example, the most recent estimates expect the disappearance of almost half of the glaciers worldwide and a rather complete melting of the glaciers in the Pyrenees and in the Alps in the most pessimistic scenarios¹⁷ making mountain regions especially vulnerable. At the same time, glacier retreat also offers novel opportunities for life and could offer new refugia for biodiversity. How biodiversity is building up along glacier retreat chronosequences and how it can be predicted across the entire European Alps will be a particular focus for the OSUG community.

The CZ is characterized by multifaceted compartments, which are linked by multiple interactions and feedback mechanisms. We aim to improve our knowledge of processes within each single compartment as well as of the multiscale interactions within complex environments. More specifically, this concerns a better understanding of physical and biogeochemical processes and cycles in surface (water/snow/ice, ocean, soils, atmosphere) and deep earth environments and at their interfaces, the study of the behavior and transfer of pollutants, and the study of global change drivers and how they will affect feedbacks between above- and below-ground biodiversity and linked ecosystem functions. Based on our expertise, we focus on the dynamics in the deep Earth in active settings such as volcanic and hydrothermal systems and the interactions between the cryosphere and other compartments of the CZ by the integration of several RIs. We will develop and apply new geochemical tracers and proxies including isotopes together with ecological (environmental genomics, biomarkers) and climate proxies. Innovative tools require combining novel inhouse and synchrotron-based characterization techniques with simulations. The impact of human activities on the CZ will be explored by using a variety of natural archives (e.g. peat, sediments, ice cores). Analyzing tipping points of ecosystems and the quality of the CZ requires to quantify the mass transfer, the transformation, and the (bio)accumulation of pollutants and emerging contaminants and their interactions with biotic and abiotic matrices in different compartments.

Concerning resources, we will apply our multidisciplinary expertise and knowledge in particular in mountain and inter-tropical regions to characterize and quantify traditional and new natural resources (e.g. water, minerals, trace metals, biodiversity, potential for renewable energy) and evaluate ecosystem services and more particularly the nature contribution to people's welfare. Relying on our expertise, we will focus on changes in the socio-eco-hydrological system intended to study the water transfer from the atmosphere to aquifers and vice versa and their associated time and space scales and analyze their response to land use changes and how these parameters have changed due to anthropogenic pressure. Analyzing the properties of different natural resources (e.g. concentrated vs. diffuse, regular vs. irregular, multiple physical, chemical, and environmental states) will help to determine how they are influenced by the use of resources and to elaborate related policies. Understanding the interaction between exploitation and use of resources, their quality, the limitations for the environment as well as social and economic aspects are important for long-term terrestrial habitability. A further focus will be to understand the status and dynamics of biodiversity and ecosystems considering current forcing factors including usage (e.g. tourism, exploitation), climate change, and pollution. This will feed into innovative modelling tools to provide alternative scenarios to better guide management.

The OSUG community possesses a long-standing and multidisciplinary expertise on natural risk assessments concerning earthquakes, geodynamics, tectonics, geo-resources, surface processes, landslides, ice and debris

¹⁶ https://www3.weforum.org/docs/WEF_New_Nature_Economy_Report_2020.pdf

¹⁷ Rounce et al., Global glacier change in the 21st century: Every increase in temperature matters, *Science* 379, 78-83, doi: 10.1126/science.abo1324, 2023.

flows, flooding, and snow avalanches mainly impacting habitability in mountainous regions. The close ties between OSUG scientists and decision makers grouped in the Alpine Center for Natural Hazards and Risks Prevention (PARN) as well direct links with the ministry in charge of risk prevention for three decades has strongly fostered the development of interdisciplinary research towards a better understanding of interrelations between natural, technological, and human systems. In this context, we aim to improve the knowledge of physical processes of natural hazards and the cascade of hazards and to assess the vulnerability and capacity of the environment to withstand extreme events. Data-driven methods (e.g. deep learning, ensemble-based data assimilation systems), original laboratory and in situ experiments, as well as a broad spectrum of modeling (discrete and continuous mechanical models, Bayesian spatio-temporal models, mechano-probabilistic models and meta-models, decisional models, qualitative systemic models), paying particular attention to the development of multi-scale approaches, will help to improve our understanding of physical processes impacting natural hazards considering climate and land use change and urbanization. It also enables a better estimation of uncertainties related to hazards. As far as risks are concerned, physical, systemic, and human vulnerability and their evolution for different territories can be assessed through both systematic surveys (i.e. historical archives and paleo-records) and remote sensing techniques.

What are the projections for the 21st century? Models are inevitable tools for predictions concerning the 21st century. The objective is to develop digital twins for major elements of the geo-biosphere crucial for habitability and able to quantify geological processes. We will focus on digital twins for the elements that are in the focus of the LabEx, i.e. the CZ, natural resources, and risks with a special focus on mountain regions. Developing such digital twins requires not only expertise in the concerned disciplines in natural sciences, but also expertise in the development and use of advanced models, innovative IT tools based on artificial intelligence methods, and advanced methods for the treatment, assimilation, and visualization of scientific data. The OSUG community will extend existing capacities and will develop new expertise mostly in collaboration with the communities involved in MIAI or the LabEx Persyval.

Concerning the CZ, future trajectories of the compartments influenced by global change and anthropogenic activities will be examined to predict future changes in socio-eco-hydrological systems for a better management and conservation of nature. Since climate is a major driving force for these trajectories, we will closely collaborate with partners in the National Earth System Climate Modeling Infrastructure CLIMERI especially concerning regional climate models to apply the best scenarios and, in return, exploit our expertise to provide better parameterizations for the feedback between the CZ and climate. We will apply our multidisciplinary knowledge in particular in mountainous regions to characterize and quantify traditional and new natural resources, which are intimately linked to the CZ and their sustainable exploitation. For example, while the impact of changes in precipitation regimes and land use on terrestrial hydrological regimes has been studied, the attribution is still a major challenge for predicting future changes in the socio-eco-hydrological system. We will identify potential tipping points concerning abrupt or radical changes that may occur as a result of the impact of ongoing climate change and changes in surface conditions¹⁸ and further related human activities using coupled models. For the evaluation of ecosystem services in a context of global changes, we will develop interdisciplinary long-term social-ecological research networks in partnership with local populations, territorial managers, and policy-makers with a special focus on mountain territories.

The long-term objective is the integration of economic and behavioral modules into the digital twins with feedbacks to the bio-geosphere to assess the vulnerability of natural resources in terms of quality and quantity associated with the increasing demands as well as their consequences on habitability conditions. With the help of such complex models, we will work on mitigation and adaptation strategies in case of shortages of natural resources including eco-engineering methods. We will for example contribute to strategies for the optimized management of subsurface systems solving water-energy issues at local, regional, and global scales. We will further participate in an active environmental and societal strategy for sustainably harnessing mineral resources using not only cutting-edge exploration techniques, but also accounting for the potential social conflicts and environmental constraints on production. The ‘green’ paradoxes (e.g. global gains vs. local impacts) will be analyzed and the emergence of new actors induced by the appetite for new resources and the rising interactions between these processes and the environment at different scales will be studied. We will further examine how

¹⁸ Lenton et al., PNAS 105, 1786–1793, doi.org/10.1073/pnas.0705414105, 2008.

renewable energies and their associated engineering solutions will impact and interact with other related resources (i.e. land, water, biodiversity). Robust digital twins also integrating the socio-economic sphere (or parts thereof) will allow the determination of sustainable trajectories for maintaining habitable zones and areas. Concerning natural risks, innovative models inspired by models developed for avalanche hazard forecasting will be developed in full synergy with observations and experiments addressing operational forecasting and short- and long-term predictions in other domains (e.g. snowmelt floods, rain-on-snow events, rate of seismicity). We aim at developing innovative risk assessment methods combining probabilistic hazard models and vulnerability relationships to evaluate different risk metrics for the design of optimal mitigation strategies and decision-making, with agent-based modeling for example. We will study the impact of global change and the urbanization on the evolution of risks through stochastic and high-resolution numerical modeling, generating an added-value for the evaluation of decision-making and prevention strategies to reduce risks and improve resilience. We will further explore nature-based solutions to reduce natural risks. Finally, by assessing the vulnerability and capacity of the environment to withstand extreme events, we intend to forecast the impact of extreme events and related consequences for urbanized and industrialized areas. Digital twins will be exploited as tools for decision-makers for the adaptation of exposed areas and infrastructures and the improvement of their resilience.

2.2 Precise and detailed definition of the nature of the expected results

We expect major scientific breakthroughs in the funding period in line with the above described major topics. Concerning the origins of habitable planets, we will provide statistically robust observations of the planetary architecture of thousands of nearby stars to determine the frequency and stability of rocky planets in the habitable zone. We intend to understand the fraction of elements, primordial water and organic matter inherited from the interstellar medium using radio to millimeter observations and astrochemical modeling. We will develop accurate models of planetary formation and evolution using constraints from infrared and millimeter observations, the characterization of the atmosphere of a diverse sample of nearby exoplanets, the search for biomarkers using space- and ground-based major facilities (JWST, PLATO, GAIA, ELT, VLT, VLT), space missions in our own Solar System, and geophysical laboratory measurements. Concerning the origin of habitable zones on Earth, we will develop an integrated vision of biotic and abiotic processes impacting the past atmosphere and the climate on Earth.

For a better characterization of the CZ in the Anthropocene requires a hybridization of knowledge from geosciences, ecology, and human and social sciences. We will quantify the frequency of catastrophic hydro-climatic events and work towards a detailed assessment of the loss of glacier mass and the consequences on mountain risks and water resources in relation to economic activities. As a result, we will contribute to a better comprehension of the behavior of complex fluid flows in highly varied regimes and multi-scale modelling to improve predictive tools for gravitational natural hazards in mountain regions including emerging risks such as glacial hazards. This will help to update past and future trajectories of hazards and risks in relation to climatic and environmental changes over longer time scales. We will seize the opportunity offered by the Jardin du Lautaret creating favorable conditions for an integrated approach to the functioning and dynamics of continental systems based on better observation and modelling of the couplings between bio-geophysical and socio-economic compartments. This will result in a better understanding of the vulnerability and adaptability of mountain socio-ecosystems, in particular mountain pastures, to global changes, in advances in the coupling between geomorphological processes and ecological dynamics in the high mountains and its links with gravity hazards and sedimentary inputs. We aim further for a quantification of fluxes of nutrients, pollutants, and organic matter in the headwaters of the Col du Lautaret catchment and the role of the seasonal snow cover for these fluxes. Finally, we will contribute to the characterization of crisis mobility with dark fiber technics.

The projections for the 21st century require the development of instrumentation and digital methods/tools to strengthen our observations of natural systems and better understand and anticipate trajectories and evolution. We will augment the capacity of our models to cover a large range of spatial and temporal scales. We intend to integrate heterogeneous physical and social data (video, social networks, satellite images, on-site measures) into dynamic models to forecast at almost real-time social and physical impacts of disasters. Moreover, we will develop predictive tools for air quality combining health indicators, social practices and for public decision makers and. We expect to develop robust digital twins of the geo-biosphere of the CZ with a

special focus on mountain territories and integrate the socio-economic spheres into the digital twins for specific regions of interest (mountain region, intertropical zone).

Concerning the major shared tools, the following technical, methodological, and structural objectives will be pursued. For the analytical platforms, we intend a better coordination of the laboratory analytical means to optimize human and financial resources. This includes a concerted policy for the development and support of existing and innovative skills contributing to secure and reinforce the scientific and technical expertise present at the diverse platforms. We will also develop a concerted policy of acquisition and upgrading of our analytical parks to reduce the carbon footprint of the acquisition of scientific equipment. Finally, we intend to work towards the opening of our analytical platforms to external (non-academic) users.

We expect a full exploitation of existing observation infrastructures (RI, SNO, ZA, etc.) and devices including a further development of associated services contributing to the integration in national and international structures. This will ensure major projects and prepare the scientific exploitation of the RIs and the production of scientific results. For the RIs in astronomy, we want to remain an actor for instrumental development, notably by contributing innovative concepts to ESO and ESA programs based on our scientific and technical know-how as well as by a strong engagement in and the exploitation of major space missions; potentially in line with activities at CSUG. For the RIs in Earth and Environmental Sciences we work towards a much better interoperability and a more efficient use of remote sensing observations to fully exploit observations obtained with ground-based RIs. We also intend to exploit smart sensors and develop methods to use intelligent and remotely-controlled sensors including Distributed Acoustic Sensing (DAS) to increase spatial coverage and to reduce the carbon footprint of monitoring activities. The support of the RIs should lead to a co-construction of long-term observatories on climate-human-nature relations, in particular in the framework of ELTER and ICOS. A further major goal is to establish OSUG as a center of expertise and data by gaining visibility on the data acquired in the observatories managed by OSUG. OSUG-DC links between various data platforms and metadata, generalizing their availability, and providing a mutualized pool of expertise related to the data processing and dissemination. In order to achieve this goal, OSUG-DC will put in place relevant IT infrastructures as well as human resources. More specifically, OSUG-DC will help to implement advanced methods related to deep learning and artificial intelligence for the analysis of large data sets generated by observations and model output, use and assimilate satellite data, and exploit new data sources such as video, meta-analysis, and social media. Additionally, OSUG-DC will consolidate numerical simulation capabilities with the aim to open access to high-performance codes developed for the next generation of European Exascale super-computers by OSUG researchers, contributing to the recognition of certain strategic codes and their outputs as genuine tools serving a broad (inter)national community in line with INSU policy. All data will follow the FAIR principles, and "orphan" data will be curated. OSUG-DC will also establish/reinforce the link with MIAI and GRICAD, and provide a service to support open access of scientific publications. In order to fulfil these goals, we plan to create a scientific steering committee, integrate new services such as the integration of new Theia Ozcar data, the construction of ISDeform service, build a biodiversity repository for data collected locally, support open access to major high-performance codes providing a service to a broad community. OSUG-DC is presently in the process of structuring its activities in order to consider all these evolutions.

The focus on alpine regions will help to affirm the position of OSUG as a leader in mountain research. This concerns the reinforcement of the existing know-how and expertise in the different disciplines in natural sciences applied to alpine regions. Particular actions in line with activities at OSUG-DC will be undertaken to develop tools to make data specific to mountains (for example climatic, hydrological, ecological data) connected and interoperable. However, mountain research requires also strong interdisciplinary approaches to respond to the specific needs of local stakeholders. In line with the LTSEr platform Lautaret-Oisans we will reinforce transdisciplinary methods applied to a defined territory to be able to export the knowledge acquired both methodologically and in terms of results. This will be a major objective of the MRS, which will from 2025 on be supported by the three LabEx OSUG, ITTEM, and UG@rchitecture. In the frame of the MRS we will realize the following actions (i) coupled theses for subjects, which are studied in parallel with a natural and a social science approach; (ii) an annual summer school offering training in interdisciplinary approaches; (iii) highly-visible outreach and training actions for mountain stakeholders to create or reinforce privileged links with local actors

like state and other public services, communities, habitants, natural parks, mountain professionals in agriculture, tourism, etc.).

Methods of co-construction based on collective intelligence seem to be the right tool to communicate within the OSUG community. The setting up of specific sessions concerning emerging topics will allow us to consider the needs of each person and to set up actions of collective interest. OSUG aims to develop within its federation a pool of facilitators trained in collective intelligence in order to provide members with animators, who can be mobilized internally to accompany them in the co-construction of their projects (innovative research projects, pedagogical innovation, collaborative workshops, new work methodologies, etc.).

2.3 Importance of the contribution to scientific and technological issues

The topics that are treated in the frame of the LabEx are well in line with current national scientific program issued by the four different domains covered by CNRS/INSU as well as with the scientific plan of CNRS/INEE currently under development. Moreover, topics like characterization of exoplanets, stability of terrestrial climate, the anthropogenic impacts upon Earth biodiversity, sustainable exploitation of resources, or understanding of natural risks are also part of the scientific challenges as defined in the transversal scientific prospective of CNRS/INSU presented early 2020. As a result, habitability was identified as a guiding topic for the national strategy of CNRS/INSU as presented during the annual assembly of all directors of the units adhering to CNRS/INSU, which took place in September 2022 in Grenoble. The topics that will be treated in the LabEx are also in line with the national strategies of the other OSUG supervising authorities IRD, INRAE, and Météo France as well as national organizations like CNES. At an international scale, topics like understanding how habitable planets form, forecasting earthquakes, mitigating the impact of anthropogenic activities on polar regions and on the intertropical zone, maintaining biodiversity, and interdisciplinary research in alpine regions are also part of the great scientific challenges defined by relevant European funding agencies and international scientific organizations like ASTRONET, Voyage 2050, the International Science Council, or the World Climate Research Programme. We will make sure that the intended development of the national and international RIs will be fully in line with the national strategy for RIs¹⁹ issued in 2021 by the French Ministry of Research as well as the roadmap of the European Strategy Forum on Research Infrastructures (ESFRI).

2.4 Scientific positioning of the consortium

OSUG is a public scientific institution dedicated to observation, research, training, and public outreach. It is engaged in all aspects of the Universe, the Earth and environmental systems. It includes about 1400 staff members in 9 research units, 5 associated research teams and 2 joint service units. The expertise of the OSUG community in observing, understanding, modeling and predicting the evolution of natural systems is highly recognized at an international level. The scientific excellence and reputation of the OSUG community is reflected, among others, in the high number of European projects (ERC, H2020, HorizonEurope, European RI), scientific awards for its members,²⁰ and its participation in a large number of highly funded national projects (so-called Equipex+ and PEPR, see ch. 4.4). Due to the integrating effect of the previous phases of the LabEx, OSUG now regroups all scientific forces in Astrophysics, Earth Sciences, Environmental Sciences, and Ecology in the Grenoble-Chambéry area at the Universities Grenoble Alpes and Savoie Mont Blanc. OSUG has close links to the four national research organizations CNRS, IRD, INRAE, and Météo France, which act as supervising authorities of OSUG. All six entities contribute with scientific, technical, and administrative staff covering a wide range of scientific disciplines needed to tackle the project. The strength of the LabEx is the integration of communities often acting disconnected (e.g. geosciences vs environmental sciences, natural vs social sciences).

2.5 Methodological positioning of the consortium

The LabEx builds on the strong involvement of the OSUG community in RIs, on the development of advanced instrumentation based on decades-long research and developments programs, on the innovative use of our analytical and remote sensing tools and mutualized technical platforms, as well as on our data processing and modeling capacities. The expertise of the OSUG community concerning these tools and methods is outstanding. The participating units are major components of its supervising authorities strongly involved in the

¹⁹ Stratégie nationale des infrastructures de recherche, <https://www.enseignementsup-recherche.gouv.fr/fr/strategie-nationale-des-infrastructures-de-recherche-50288>

²⁰ <https://www.osug.fr/actualites/distinctions/palmares-annuel.html>

implementation of their national scientific strategies. Besides its strong involvement in national or international RIs, OSUG is leading or contributing to around 30 SNOs hosting the related scientific and technical personnel, which consolidates OSUG's unique (inter)national position concerning its involvement in RI in different domains. As a result, the OSUG community is strongly involved in numerous national and international projects. While in the first phases of the LabEx the expertise in the different scientific fields was expanded and strengthened, these phases were also the opportunity to develop new interdisciplinary methods and approaches required to tackle scientific questions relevant for local stakeholders. In addition, the LabEx has reinforced links between research, observation, and training and strengthened existing or new international partnerships of the OSUG community. Strong communication actions helped to create a tightly linked community undertaking attractive outreach activities and providing policy-relevant information and advice.

3 Impact

3.1 Scientific impact on the scientific and technological fields involved

The LabEx will reinforce the role of OSUG as a major scientific hub for habitability and the related disciplines at an international level. The outstanding position and reputation of the OSUG community in the involved disciplines ranging from Astronomy, Geosciences, Environmental sciences, Ecology to Remote sensing is well documented by international university rankings. The support through the LabEx will help to maintain or even reinforce the role of the OSUG community in these disciplines. Moreover, the current transition of the society to limit the impact of climate change, to develop a more sustainable exploitation of natural resources, and to reduce the vulnerability to natural risks, which are all in line with the topic habitability, often requires new methods beyond traditional disciplinary fields. The LabEx will reinforce the role of the OSUG community as a major actor to provide scientific evidence to accompany such transitions. Interdisciplinary approaches and methods together with strong communication and mediation actions, which will be enhanced in the new phase, constitute the basis for this reinforced role and reputation of the OSUG community concerning the central topic of habitability. Due to this augmented visibility and based on the access to shared tools like analytical platforms, implication in long-term observations, and OSUG-DC, a strong participation of the OSUG community in (inter)national projects, networks and RIs can be expected. Recognizing the dynamic research and attractiveness, we aspire that the supervising authorities continue to hire permanent scientific and technical staff for the participating units and teams.

With respect to the analytical platforms, the LabEx will reinforce the available means combining advanced scientific expertise with state-of-the-art instrumentation, know-how in the interpretation of specific physical and chemical data (hyperspectral and radar data, isotopy), and advanced chemical and optical databases. The LabEx supports the OSUG community to remain innovative in terms of analytical solutions in all environmental matrices like ice, snow, water, air, soil, sediments, biota, extraterrestrial material, e.g. in the fields of pollutants, geo- and thermochronology, isotopic or organic tracers. This knowledge will allow us not only to strengthen our position in national or international structures, but also to participate in future large space missions.

Related to RIs, the LabEx will help to maintain and reinforce the role of the OSUG community in the national strategy and maintain its attractiveness for new permanent personnel dedicated to long-term observations assuring the important role of OSUG in the national and international community. OSUG strives to become a recognized training center for new scientific and technical actors for long-term observations of all components of the Earth system. Further objectives are to position OSUG as a leader on the interoperability due to the operation of RIs from different domains at the same site and to the expertise in the interoperability of data and become a leader on long-term observations on climate-human-nature relations. We also rely on the LTSER platform Lautaret-Oisans bringing together the essential elements of different disciplines in a single place that is both vast and well-defined. It offers the conditions for deploying knowledge development projects in connection with major infrastructures and national and international programs and makes it possible to involve stakeholders in the creation of knowledge as well as in its transmission.

Concerning data and models, we will work towards a recognition of OSUG-DC as a major hub at an international level for the treatment and fusion of data from the observation of natural systems combining corresponding hardware, software, and expertise. It will maintain its position in scientific calculation and use of models of natural systems. OSUG-DC will become a leader in the assimilation, treatment, and exploitation of multisource data including data from analytical or other platforms. Supported by the services offered by OSUG-DC, the

OSUG community aims to become a leader in the development and use of digital twins of natural systems with reinforced expertise in the CZ, in mountain regions, and related resources and natural risks.

In a joint effort with the LabEx ITTEM and UG@rchitecture, the Jardin du Lautaret, the LTSEr platform Lautaret-Oisans and ELTER, we envision to transform the MRS into a center of excellence for innovative training and experimental research on future scenarios for alpine regions facing global change. It builds on previous collaborations and research results (e.g. the evolution of mountain eco-systems or the sharing of space for different uses of nature). The MRS will foster in situ training and research on simulations of coupled social-ecological regional systems, bringing together big-data, modelling and digital twins for the CZ and qualitative and quantitative data on societal dynamics of the concerned mountain communities. The goal is to develop the MRS into a recognized hub for transdisciplinary approaches dedicated to the co-designing of transformative pathways together with concerned mountain stakeholders.

3.2 Importance of the contribution to the response to major societal issues

Due to their scientific expertise, OSUG members have strongly contributed to international reports in connection with intergovernmental platforms (IPCC, IPBES) or organization such as Global Mountain Biodiversity Assessment (GMBA; a platform for international and cross-disciplinary collaboration on the assessment, conservation, and sustainable management of mountain biodiversity), the Network for European Mountain Research (NEMOR; a network of institutions -public or private- undertaking research in mountain areas, which intends to promote research in these areas for their sustainable development) or Euromontana (a multi-sectoral association for cooperation and development of mountain areas). This involvement will be amplified by the development of Living Labs, for example in connection with the PEPR Solu-Biod. The erosion of biodiversity has been well documented for several years and is one of the major phenomena observed in the last decades concerning the CZ. The highly complementary OSUG community is one of the actors that can significantly contribute to the observation and understanding of this phenomenon. The implementation of the data collected in national and international databases is one of the actions relying in particular on OSUG-DC. Structures supported by OSUG members like the Regional Group of Experts on Climate Alpes-Auvergne and the *Observatoire de la Biodiversité Grenoble Alpes* contribute to a strong local involvement in interactions with stakeholders and local authorities, including in advising and co-construction of research projects, in order to respond to major societal issues.

3.3 Actions proposed for the dissemination of scientific and methodological results to the academic world

Since 2019, the scientific results issued by actions supported by the LabEx have been published in 110 to 160 publications per year acknowledging the LabEx.¹⁰ The objective is to maintain this number of scientific publications as well as the distribution of scientific results through conference contributions. Costs related to such activities will remain eligible in the frame of actions supported by the LabEx. Due to its reputation and importance, the OSUG community has strongly been involved in the development and writing of scientific programs of the supervising authorities like CNRS/INSU and INEE. Several OSUG members are leading major national projects and networks facilitating the distribution of scientific and methodological advances to the national community. The LabEx will continue to support such leadership roles in national projects or in national and international RIs. The exchange with different scientific audiences is supported in the Training & International component of the LabEx, which finances the (co-)organization of international seminars and workshops by members of the OSUG community as well as hosting invited scientists. Finally, summer and winter schools (co-)organized by the OSUG community like ERCA,²¹ the MRS,²² or the Snow Science winter school²³ are also occasions to transfer most recent results and innovative tools and methods to academic audiences.

3.4 Actions proposed for the dissemination of scientific and methodological results to society

Since our work has a strong echo in society, we are committed to transferring our knowledge and expertise to inform the public (and fight against “fake news”), to inspire young people, to train agents and decision-makers of communities, and to support public policies. We have a long tradition of undertaking several programs and types of actions that allow us to inform and work with actors from our territory. Within the framework of the

²¹ <https://erca.sciencesconf.org/>

²² <https://www.osug.fr/le-labex/actions-soutenues/mountain-research-school/>

²³ <https://www.slf.ch/en/about-the-slf/events-and-courses/snow-science-winter-school.html>

LabEx, we aim to strengthen our already wide range of actions in order to achieve a constant dissemination and transfer of our expertise and work to the society. Here we list a few of these actions, which are specifically important and will be continued or reinforced during the LabEx.

We regularly welcome in our premises (laboratories, museography space, geological collections, planetarium, Herbarium and Jardin du Lautaret living collection) external visitors: scholar groups, working groups, journalists, etc. and also political decision-makers to give them an overview of our research and observation work and make them aware of the topics at stake concerning the environment, resources and natural risks. We have an official program for the training of high school teachers with the Rectorat Grenoble, the local representation of the French Ministry of National Education, and we intervene throughout the year in various events concerning actions toward the general public (*actions grand public*). Several members of the OSUG community are actively working to make *Cosmocité*, equipped with a planetarium, a success and an important showcase of the scientific results of the LabEx. Finally, on a regular and recurrent basis, we will take part in various scientific programs in connection with existing local centers for the transfer of knowledge to non-academic audiences like the CASEMATE in Grenoble or the Eureka gallery in Chambéry, in large-scale events like the Mountain-Science Movie Festival (*Rencontre Montagne et Science*), or in national events such as the science festival (*Fête de la science*) or the patrimony days (*Journées du patrimoine*) or other broadcasted events aiming at a wide public audience like scientific documentaries. The participatory *Observatoire de la Biodiversité Grenoble Alpes* will be developed to enable training and awareness-raising activities addressing the general public, local authorities, schools, and private companies. In order to raise the awareness of citizens to our scientific disciplines and environmental issues, we are developing more and more projects for social and cultural outreach. Each year we propose artists' residencies and communication supports for the cultural world (theater, exhibitions, videos, ...).

The Jardin du Lautaret with the LTSER platform Lautaret-Oisans is a major tool for the OSUG community to facilitate the transmission of acquired knowledge both in terms of methodology and results thanks to a network of actors (elected officials, natural protected areas, socio-economic actors of the mountain). At the crossroads of environmental and societal issues, the role of the Jardin du Lautaret as a scientific mediator will be reinforced. The LabEx aims to consolidate actions undertaken for the training of professionals (mountain guides, tourism actors, agricultural professions, etc.) as well as for the general public (scientific visits and development of scientific tourism). In cooperation with *Cosmocité*, conference cycles will not only be organized in the Grenoble area, but also at the Jardin du Lautaret to disseminate knowledge as close as possible to the inhabitants and visitors of the Alpine spaces. These actions will benefit from the cooperation with various local partners and the partnership with Grenoble Alpes Métropole.

The understanding and management of natural risks for our territories benefit from the work of the intermediation association PARN. It is led by OSUG scientists and directly serves the communities and professionals of the Alpine territories. In addition, important challenges are linked to climate change and its numerous consequences on our territory and its impacts on water resources, biodiversity, agriculture and agro-pastoralism, mountain tourism, etc. To better respond to the needs of local stakeholders, we carry at OSUG the intermediation platform Regional Group of Experts on Climate Alpes-Auvergne inserted in a national network. Finally, many OSUG researchers from the disciplines of physical and biological sciences participate in scientific councils of National Parks and Preserves close to Grenoble or environmental and risk assessment agencies.

3.5 Commitment to open science and data

We are fully engaged in open science and are working towards the open access of scientific data. Within European RIs the FAIRisation (Findability, Accessibility, Interoperability and Reuse) of data will likely be fully realized until 2030. In line with these rules and with national and international legislation, we will implement tools to realize the objectives described in the *Schéma directeur de la science ouverte* UGA²⁴ concerning the open access to publications, data, codes and software. Coordinated by OSUG-DC we will develop and reinforce new or existing services to offer an adapted support throughout the full life cycle of data and codes. These services will be in line with the services currently under development for RIs like in the Geo-INQUIRE project,²⁵

²⁴ <https://scienceouverte.univ-grenoble-alpes.fr/science-ouverte-grenoble-alpes/les-engagements-de-luga/>

²⁵ <https://cordis.europa.eu/project/id/101058518>

in which the OSUG community is involved. The overall objective is to distribute and render accessible all scientific data generated within the LabEx until 2030 according to the FAIR principles. This will also be implemented in teaching activities with the support of the *Observatoire Junior* initiative, which aims at increasing students' awareness and practice of the FAIR principles through their direct involvement in monitoring activities. Concerning scientific publications, innovative tools to automatically generate lists of publications have been developed for the LabEx.²⁶ A working group of publication referents in the OSUG units is working towards a full registration of all scientific publication of the OSUG community in the archive HAL Open science.²⁷ While a large fraction of publications linked to the LabEx exists already in open access, in 2025 open access will be obligatory for all publications supported by the LabEx. From 2027 on, it will be required that access to data and codes related to a publication generated in the frame of the LabEx is fully ensured. According services, training actions, tools, and support will be reinforced or developed in the frame of the LabEx. We envision that in 2030 all publications of the OSUG community will be open access with all relevant data and codes easily accessible. All actions will consider local, national, and international structures and services like GRICAD, Maison de la modélisation et de la simulation, or Recherche.Data.Gouv to provide coordinated services and support via OSUG-DC corresponding to the specific needs of the OSUG community.

3.6 Actions proposed for the reinforcement of the UGA's international collaborations

The international visibility and attractiveness in one of the major strengths of the OSUG community expressed by countless collaboration actions with academic partners on all six continents. The LabEx aims to maintain and reinforce this strength by supporting research networks and by supporting international collaboration at individual levels. Like in the current phase funding will be made available via the international component to support workshops and seminars organized by the OSUG community related to topics of the LabEx.

Observations of the Earth system and the Universe are mostly maintained by international RIs. The OSUG community is well participating in these RIs, with some OSUG members playing leadership roles at international levels. The LabEx will help to reinforce the participation in the development and scientific exploitation of such RIs and specifically support OSUG members seeking to assume scientific and technical responsibilities in such networks at all levels.

Costs for visiting scientists are eligible in the frame of research projects. Exchange of Postdocs and PhD students will be supported by financing: i) their participation in high-level schools related to their thesis topic and ii) the accommodation of PhD students at participating units to acquire innovative methods and technologies. The LabEx will further (co)fund events like workshops, seminars, or high-level schools organized by OSUG members. Finally, one major action is the annual high-level course ERCA, for which support for international speakers and participants (especially students from inter-tropical countries) will be granted. Strong partnerships with numerous partners in inter-tropical and Mediterranean countries have been developed by the OSUG community and have successfully been supported since the beginning of the LabEx. The bidirectional exchange of scientists and students with these partners in the frame of training actions or field schools will remain a priority to support and develop long-term collaboration in line with actions supported by the CNRS, IRD, or UGA like so-called Laboratoire International Associé and Laboratoire Mixte International.

3.7 Development of experimental platforms for research or training

The development of analytical platforms is one of the major objectives of the LabEx described above. A variety of further experimental scientific platforms exist within the OSUG community, which are often unique and a prerequisite for the executed projects (e.g. the largest rotating platform in the world dedicated to fluid mechanics, cold rooms for the analysis of ice cores and other frozen samples or for experiments at below zero temperatures). The use, upgrade, and application of any platform will be supported similar to any other tool used during actions financed by the LabEx.

Experimental platforms are also important for teaching. Our *Campus de l'Environnement* approach will keep supporting the use of field instrumentation or platforms within or out of our campus since such measurements are the core of our scientific activities. We will encourage teaching activities that use RIs or corresponding data to create added-value to students training and to promote the use of those data by the next generation of

²⁶ <https://publi.osug.fr/waodss/modules/export.xql?format=html&tag=LABX56-man&tag=LABX56&max=-1>

²⁷ <https://hal.science/>

scientists and professionals., for example in a synergistic approach between teaching and observation in the *Observatoire Junior* initiative. In a Participative Science approach, regular courses will engage groups of students in producing/maintaining observation data on eco-socio-systems and commit them to a FAIR database handled by OSUG-DC. This applies in particular to the *Observatoire des Lacs Alpains* and the Jardin du Lautaret, whose use for field courses we will support. In addition, the already described *l'Observatoire de la Biodiversité Grenoble Alpes* is a platform that supports disciplinary and inter-disciplinary university training for the realization of tutored projects and training courses in various disciplines as well as participatory citizen actions.

3.8 Actions proposed for the valorisation (start-ups, transfer to industry) of research results

The OSUG community has established strong links to a number of private socio-economic actors in the region, whether through technology transfer (start-ups FLI, ALPAO, RSS that are outcomes of our research in innovative concepts for instrumentation, LabCom, ...), through exchanges and partnerships with companies (e.g. Air Liquid Advanced Technology, Pyxalis), or through funding offered by foundations, including the Foundations UGA and USMB. In the frame of the LabEx, we aim to identify links with industry, to work on the calculation of cost for the internal and external use, and develop economic models considering external use of these platforms as part of the development of analytical and other technological platforms available in the OSUG community.

3.9 Commitment to raising additional funds

To assure the participation of the unit CARTEL, their supervising authorities INRAE and USMB are committed to contribute additional funding in line with the number of scientist and professors participating in the project according to the details described in the supporting letters in the annex. This also applies to the unit Edytem and its supervising authority USMB.

The OSUG community has a long tradition to raise external funding and is committed to do so during the next funding period. This concerns funding for disciplinary and interdisciplinary projects linked to the attractive topics by national or international funding or space agencies, local or national foundations, in the frame of large national and international projects, or provided by the supervising authorities. As in the past, the OSUG community will seek national and international funding provided for or by RIs and related monitoring activities as well as for the development of OSUG-DC or analytical platforms. Finally, the OSUG community has been very successful in obtaining co-financing for PhD theses by national and international research organizations or foreign universities. Up to now, more than 75% (26 of a total of 34) of PhD projects funded by the LabEx received external co-funding. We are committed to maintain this external funding.

4 Implementation

4.1 Organization of activities in line with objectives

The activities supported by the LabEx will be grouped into the four components: research & observation, training & international collaboration, outreach & communication, and coordination & strategy with specific budgets allocated to each of the components. 70% of the available budget will be invested in research & observation projects to realize the aspired scientific advances and objectives. Fractions of 11%, 10%, or 9% of the budget will be dedicated to training & international collaboration, communication & outreach, or coordination & strategy. These are the initial ratios, which will be applied at the beginning of the funding period and which can be adjusted according to new requirements. The LabEx bureau will be responsible for the concrete planning of the expenses for each action, which will in all cases be validated by the Comité des DUs.

In the research & observation component a mixture of recurrent funding and project calls will be applied to identify the most promising projects and actions. The contribution to and development of the RIs, the analytical platforms (regrouped in REGEF), and OSUG-DC and related services require reliable funding, which are not adapted to annual project calls. Therefore, a new tool has been developed to accompany the RIs with recurrent funding for long-term actions and upgrading of existing or new services. The needs for each RI are documented in local roadmaps and are transformed in a multi-annual expenditure planning. This planning was for the first time elaborated in 2022 and was implemented in 2023. The needs are prioritized by the LabEx bureau and the final support is validated by the Comité des DUs. The roadmaps and the multi-annual expenditure planning remain dynamic documents, which will regularly be updated according to new developments and requirements without fixed deadlines. Such a mechanism can only be realized in the frame of the LabEx, which provides a

long-term planning capacity combined with a high level of reactivity to respond quickly to unexpected needs. An annual budget of 160 k€ is required for this expenditure planning.

To tackle the scientific challenges in an optimal way, different types of scientific projects (so-called standard, flagship, and strategic) will be financed if they fulfill a certain set of criteria. These were developed during a series of workshops in 2021 involving ~40 voluntary members of the OSUG community, the directors of the units and research teams, and the OSUG directorate. While all selected scientific projects need to be of excellent scientific quality and must deliver an important contribution to the advancement of the scientific axes and topics, flagship and strategic projects further contribute to the national and international visibility of OSUG. Further prerequisites for strategic projects are a long-term impact for the OSUG community and the reinforcement of a scientific or technological expertise, for which the OSUG community is (inter)nationally recognized. The increase in selection criteria is justified by the allocated budgets: 8 - 40 k€ for standard, 40 - 80 k€ for flagship, and 80 - 150 k€ for strategic projects. All projects allow expenses on running costs, equipment, and Master scholarships. While flagship and strategic projects are open to salaries for technical personnel and PhD students (currently ~120 k€), only the strategic projects allow the payment of postdoctoral fellows. Note that due to the budgets, flagship projects can only co-fund PhD projects. We estimate that during the 8-year period 4 to 6 Postdoc projects and ~15 PhD projects are required to advance the scientific topics including coupled theses with the identified partners: the MIAI and the LabEx ITTEM and UG@rchitecture. Like in the past, we expect a high fraction of co-funding for the PhD projects. This mode of operation minimizes the number of project calls by avoiding specific project calls e.g. for PhD theses or for large-scale equipment.

While all project calls are made known to all OSUG members, the final submission of strategic projects is only possible through the directors or the team leaders. This leads to a coordination and convergence of the strategic projects before submission, a stronger involvement of the directors and team leaders in the construction of the projects, and a significant reduction of the number of submitted projects. Moreover, the call for strategic projects will only be launched every second year with an estimated budget of 440 k€ (or an annual budget of 220 k€). For the flagship and standard projects annual project calls open to the entire OSUG community will be launched, for which total budgets of 220 k€ and 150 k€ are planned. Since the conditions for standard projects are very similar to the conditions for exploratory and emerging projects in the annual UGA project call Research Initiatives in Grenoble Alpes (IRGA), the goal is to coordinate the submission and evaluation of this type of projects with the research pole PAGE. While the first criterion for the selection of a standard project, the scientific quality, can be realized by the research pole, the evaluation of the relevance for the LabEx will be carried out by the bureau, which will propose selected projects for funding to the Comité des DUs. The evaluation of the flagship and strategic projects will be organized by the LabEx bureau with the help of internal and external expertise based as far as possible on existing OSUG instances. We will work to align calls for flagship or strategic projects with UGA calls for the funding of large equipment.

To support the intended training & international collaboration actions, annual project calls open to the entire OSUG community will be launched. Innovative training actions in line with the described platforms or exploiting observation tools and methods will be supported. To enhance international collaboration projects will be financed that cover running costs for the international exchange of students and researchers, for the organization of workshops and conferences, or that contribute to high-level teaching actions for international audiences. 25% of the budget for the international exchange is reserved for the exchange with partners from inter-tropical countries. The evaluation of the projects will be done by the existing OSUG Commission Formation. The recurrent co-funding of the summer schools ERCA and MRS are also part of this component. An annual budget of 115 k€ will be allocated to this component, split up into 40 k€ for training actions, 40 k€ for international collaboration, and 35 k€ for the high-level schools.

The envisaged outreach & communications action will be financed with an allocated annual budget of 105 k€. This budget includes the salaries for support staff with strong expertise in meditation, outreach, and communication actions as available in the corresponding OSUG service. 15 k€ in running costs are allocated to support innovative outreach and communication actions, which can be proposed by any member of the OSUG community and will be evaluated by the existing OSUG Commission communication. Finally, a budget of 100 k€ will be allocated to coordination & strategic activities. This includes the salary for support staff acting as project officer responsible for all administrative and organizational processes, potentially shared with other projects.

We envisage further the recruitment of support staff for the implementation of emission reductions (see ch. 4.5) or other future strategic activities and unexpected and emergency costs or risky, but innovative actions.

4.2 Feasibility and risk management

Albeit the high ambitions and challenging objectives, we presume that the feasibility of the LabEx is very high since it will be executed by a strong community, whose performance and scientific expertise is widely recognized. Since 2011, the LabEx has created a strong, collaborative community with extensive experience in cooperation and interdisciplinary approaches. While the objectives concerning the RIs, the analytical platforms, and OSUG-DC have been pursued since the beginning of the LabEx, the scientific axes as defined according to the topic habitability have already been elaborated since 2020. Moreover, the community can rely on international, national, and local structures and cooperation ranging for example from international RIs to other local LabEx. Last, but not least, OSUG can count on the relentless support of its supervising authorities.

The following points were identified as risks to the implementation of the objectives. The implementation requires the hiring of highly qualified scientists, experts, postdocs, and students, who act in a highly competitive national or international environment. Since salaries under French civil service rules are often not competitive, we need to offer other benefits to attract the best candidates. This includes a creative and stimulating work environment, which for example is created for IT specialists by the dynamics of OSUG-DC. Here, we will work on training forms to educate our own IT junior staff within OSUG. In addition, we are working relentlessly to create an inclusive work environment to foster the implication of under-represented groups at all levels. Finally, the multitude of non-coordinated project calls can lead to community fatigue and an unnecessary waste of resources. Therefore, we will, whenever possible, work towards a further reduction and homogenization of the project calls by the LabEx aiming at a better coordination with other (local) funding sources to efficiently support the dynamics of the OSUG community.

4.3 Justification of the budget and its annual projection

The implementation of the LabEx requires funding for the salaries of PhD students, post-doctoral fellows, research support staff, visitors, and Master scholarships, running costs for consumables, travel expenses, or services, and investments for scientific equipment. Since the exact distribution of the funding between salaries, running costs, and investments are not possible at this stage, since it depends on the selected research projects and the demands in the frame of the multi-annual expenditure planning for the RIs, the described scientific program provide indications for an estimate of the expenditure blocks.

In order to achieve the planned scientific breakthroughs, to secure and develop existing and new scientific and technical expertise, to create new services related to the RIs, the analytical platforms and OSUG-DC, and to pursue interdisciplinary approaches, expenses for additional high-level scientific and technical personnel are essential. We estimate that overall 44 % (or ~475 k€) of the available annual budget will be invested in human resources (excluding Master scholarships). We estimate that this corresponds to the salary for ~940 person-months (or 10 full time annual contracts) for the 8-year period including the Postdoc and PhD projects (ch. 4.1). We further estimate that 22 % (or ~2 M€ during 8 years) will be invested in scientific equipment. Finally, approximately one third of the budget will be spent on running costs needed to exploit for example already available scientific equipment, efficiently use and exploit use observational data, develop and maintain international collaboration, and perform strong training, outreach and communication actions. Concerning the annual projection, we expect a relatively homogenize expenditure of the allocated budget throughout the running time of the LabEx. Details for the annual expenses in the different components are given in ch. 4.1.

4.4 Consideration of possible funding from national strategies of the AIP4

Due to the strong implication of OSUG members in the RIs, the OSUG community obtained additional funding in the frame of 6 EQUIPEX+ projects. 4 projects support the development and acquisition of instrumentation for RIs: 1. F-CELT provides multi-year support to instrumental projects in line with ESO instrumentation of ~10 k€ per year; 2. OBS4CLIM finances ~450 k€ over 4 years to equip the stations led by OSUG members, Chacaltaya and Amsterdam Island, according to ACTRIS standards; 3. TERRA FORMA supports the deployment of all 10 technological developments including new environmental sensor technologies and sensor networks at the Jardin du Lautaret as one of the three demonstration sites and the development of spectro-imagers and their applications in hydrology and ecology by OSUG members corresponding to an investment of 50 to 100 k€; 4.

MAGNIFIX financed the renovation of the two lines FAME and FAME-UHD with a new spectral imaging station for ptychography with ~3.6 M€. 2 further projects will contribute to enhance our capacities concerning the treatment of observational data: 1. GAIA-DATA provides 500 k€ in equipment (computing, storage, and network) for the Grenoble node as one of the 8 'backbone' nodes for digital data and service infrastructure, which will be hosted at GRICAD and scientifically managed by OSUG; 2. MARMOR finances the recruitment of IT specialists for the development of services linked to Résif/EPOS with 127 k€.

The OSUG community is also strongly involved in 8 PEPR projects (Fair Carbon, OneWater, TRACCS, Irima, Solubiod, SOSUSol, Origins, DIADEM). The project DIADEM will provide 774 k€ for the design of reactor cells and detectors for the lines FAME and FAME-UHD as well as 100 k€ for online data analysis. In the frame of the Fair Carbon project, the OSUG community is involved in various actions related to the dynamics of carbon from land to coastal areas during the Anthropocene, which will be supported with ~460 k€ mainly using the analytical platforms and the related RIs. The other projects have only started recently and the exact organization of the projects and the implementation of the various actions is in most cases not yet finalized. It can be assumed that due to the outstanding scientific expertise of the OSUG community and the participation of a large number of OSUG members in the coordination of the projects, important elements will likely be implemented in Grenoble: e.g. IPAG is strongly involved in the work pages *Photonics* and *Compact spectrograph* of the project Origins. Nevertheless, it is currently impossible to identify further precise financial contribution due to these projects.

4.5 Commitment to the evaluation of the carbon trajectory during the project

The OSUG community is not only engaged in the evaluation of greenhouse gas (GHG) emissions. The *reduction* of the emissions caused by our professional activities is a major concern for OSUG and is frequently discussed within the units and teams, which led to a number of engagements and charters in the different units. An OSUG working group composed of representatives from all participating institutes helps to share ideas on this topic, to harmonize practices and tools, and to make proposals for the reduction of emissions. According to French law, the LabEx will engage to reduce the GHG emissions by 50% in 2030 compared to the emissions in 2015 by developing a concerted policy to harmonize practices considering the specificities of the various disciplines in line with the strategy of the supervising authorities.

To achieve this goal, we will engage in actions to accompany the actors at different levels ranging from raising awareness of the actors and decision makers, quantifying GHG emissions, identifying measures for the reduction of emissions, etc. OSUG will start such actions as soon as possible. Nevertheless, the need of an additional project officer to reinforce and accelerate the implementation of this strategic activity was identified. This recruitment is part of the coordination & strategy component of the LabEx. We intend to reach the following milestones to realize the proposed reductions. In terms of emissions generated by activities directly funded by the LabEx, we have taken the first steps. To raise awareness, the participation in the atelier *Ma Terre en 180 min*²⁸ is mandatory since 2022 for the project leads of Research & Observation projects. This requirement will be extended this year to all benefiting from LabEx funding. From the beginning of the new LabEx phase, all proposals or demands for support will require an estimate of the GHG emissions linked to the project activities. This budget will be established with a tool developed by the initiative Labo1.5 adapted to scientific activities. Based on the experience gained with the emission budgets from 2025 on, GHG emissions will be considered as soon as possible as an additional criterion in the selection of projects, but not later than 2027. Budgets of GHG emissions caused by project activities will be established from 2025 on to verify that the LabEx effectively contributes to the reduction targets. If needed, training actions and the development or reinforcement of tools used to establish emission budgets will be supported.

The LabEx will support the entire OSUG community to reach the reduction targets. This concerns further training offers such as the large-scale use of *Ma Terre en 180 min*²⁸ and its further development and professionalization. Moreover, new guidelines for purchasing, for travel, for the consumption of heating and energy, etc. (e.g. upgrade of existing equipment and instruments instead of replacement; lending and mutualization of instruments and equipment; joint acquisition of consumables; enhanced equipment for virtual reality and avatars to avoid travel; smart sensors; ...) will be supported. The activities will be in line with guidelines by the UGA Vice-Presidency Social and Environmental Responsibility or by the other supervising authorities.

²⁸ <https://materre.osug.fr/>