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The Space for Climate Observatory: powering space data, empowering vulnerable areas.

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Abstract

Despite the worldwide significance of Earth observation to better understand Earth's climate and the flourishing number of dedicated satellites resulting in readily available data, it remains difficult to fully leverage their potential for operational applications. Moreover, regardless of the emergence of such applications in many parts of the world, the lack of international coordination makes it difficult to have a clear overview of the existing solutions and to make available proven solutions to climate-related policy makers. In summary, while international coordination on EO data sharing and scientific use is well established, cooperation on operational applications, notably at a local level and including the private sector as a main actor, remains less mature. To make up for these shortcomings, the Space for Climate Observatory (SCO) was officially launched in 2019. Dozens of space agencies and international organizations have joined the SCO so far with the ambition to coordinate international efforts to support the emergence and the dissemination of operational tools for climate monitoring, mitigation and adaptation specifically addressing the needs of local decision-makers and of the wide public. These tools strive to provide capabilities for societal climate-related actions by making the best use of satellite data coupled with socio-economic and environmental data. There are currently more than 70 projects in the SCO portfolio located into 28 countries, covering various thematic areas including agriculture, water management, biodiversity etc. More than 250 institutions are directly involved in SCO projects, coming from industry, public entities and scientific institutes.

This paper aims to (i) anchor the SCO in the landscape of international organizations and alliances, as a major player in the field of initiatives using satellite data to contribute to the climate effort; (ii) to valorize how this initiative stands out with its approach based on local use cases, bridging research, innovation and societal value.

Keywords: Climate change, adaptation, satellite, international cooperation, operational use cases.

Acronyms/Abbreviations

Space for Climate Observatory (SCO),
United Nations Office for Outer Space Affairs (UNOOSA),
Intergovernmental Panel on Climate Change, (IPCC)
2015
United Nations Climate Change Conference (COP21)
World Meteorological Organization (WMO)
United Nations Sustainable Development Goals (UN SDGs)
United Nations Framework Convention on Climate Change (UNFCCC)
Global Climate Observing System (GCOS)
Earth-observation (EO)
United Kingdom Space Agency (UKSA)
Centre National d'Etudes Spatiales (CNES)
Greenhouse gases (GHG)
Copernicus Climate Change Service (C3S)
Data and Information Access Service (DIAS)
Group on Earth Observation (GEO)
Committee on Earth Observation Satellites (CEOS)
European Space Agency (ESA)
Space4climate initiative (S4C)
United Nations Environment Programme (UNEP)
United Nations Development Programme (UNDP)
The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)

1. Introduction

Climate change has a wide range of impacts on the environment, human societies, and economies. These impacts can be both direct and indirect, and they affect different regions and populations in various ways.

Scientists, especially under the aegis of UN institutions, have been documenting these climate changes, and feeding the collective awareness for over 3 decades. The Intergovernmental Panel on Climate Change (IPCC) is warning about the numerous impacts of anthropogenic climate change today and in the future. The latest assessment report on global warming, published on April 4th, 2022 [1] shows that no ecosystem is and will be spared and that the damages could be irreversible.
More recently, in its final instalment of the Sixth Assessment report providing a synthesis of the past eight years of climate change science, as well as economic and social analysis, IPCC states that policymakers should accelerate and prioritize adaptation to climate change this decade to avert rising risks for humans and nature—and many feasible and effective strategies already exist [2].

More recently, the World Meteorological Organization (WMO) warned on the high risk of occurrence of El Niño, which most often leads to a rise in global temperatures and increases the risk of extreme weather events in many regions [3].

As warned by the scientific community, the impacts of climate change, already being witnessed today, will increase in the future, even if greenhouse gas emissions slow down, making some very significant climate impacts inevitable [4]. Worldwide, one billion people living in coastal areas are threatened by rising sea levels or marine submersion [5], while more than 130 million people could fall into extreme poverty by the end of the decade. However, human populations are not the only ones affected. Nature is also declining at rates unprecedented in human history leading to a massive Sixth mass extinction. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) brings overwhelming evidence that around 1 million animal and plant species are now threatened with extinction, many within decades, more than ever before in human history [6].

In response to disasters of unprecedented magnitude, Climatology and Earth observation sciences have become major stakes for (i) understanding and modelling the mechanisms of climate evolution and (ii) providing data and robust forecast for adaptation and mitigation strategies.

Indeed, scientific instruments on board satellites allow us to acquire increasingly precise measurements of our environment, our land or marine ecosystems. Without these measurements, it would be almost impossible for scientists to model climate change, to warn us about extreme events (storms, hurricanes, tornadoes, etc.) and to study their consequences on a global scale (drought, floods, fires, coastal erosion, etc.). Hundreds of EO satellites have been used since the mid-1960s [7], and the growth is exponential since the emergence of Newspace companies.

In this context, the international space community's efforts must be sustained over time, as there are three main challenges to be met: (i) improving technologies so that measurements reach an accuracy that allows them to be used operationally, (ii) inter-calibration of the measurements obtained so that satellite data can be integrated into models without fear of errors related to the origin of the data, and (iii) international cooperation between agencies, scientists and those responsible for in situ measurements.

Acknowledging the strengthening of a global political will, urged by the climate crisis, adaptation policies, based on space data and technologies, are currently blooming worldwide.

Under this multilateral collaborative environment, a constellation of key international initiatives and intergovernmental coordination bodies are expanding worldwide to contribute to the international efforts using space technologies and applications to support climate adaptation, mitigation, monitoring and resilience, as mapped by the United Nations Office for Outer Space Affairs (UNOOSA) in 2022 [8].

Gathered in India in early 2015 under the aegis of the International Academy of Astronautics, then at the Paris Air Show at the invitation of CNES, space agencies from around the world adopted in September 2015 in Mexico City a common Declaration. It highlights the unique contribution of satellites to the measurement of essential climate variables (26 of the 54 essential climate variables can only be observed from space) [9] and the fight against natural disasters. This global mobilization, orchestrated by CNES, resulted at the time of COP21 in the confirmation of the Franco-German program Merlin, intended to measure methane emissions, and in the announcement of the start of the MicroCarb program measuring carbon dioxide emissions in preparation for the Copernicus program anthropogenic carbon dioxide monitoring mission [10]. The success of COP21 further amplified the efforts of the international space community through the elaboration of the New Delhi Declaration in 2016, emphasizing greenhouse gas emissions and the role of satellites for their measurement, thus promoting France's decisions internationally.

A new meeting of heads of space agencies, dedicated to climate change issues, took place in Marrakech on November 11, 2016 during COP22: it was the first meeting of heads of space agencies during a plenary meeting of the COP. *The Marrakech Declaration*, centered on the contribution of the space sector for the management of water resources (for example, we can cite the Franco-American SWOT mission [11]) was then finalized. Presented in December 2017 by CNES during the One Planet Summit, the *Space for Climate Observatory* is the result of this mobilization of space agencies since COP21.

This paper aims to enlighten how the SCO stands out in the international landscape by developing end users oriented operational products, making the most of spatial and in situ data. The SCO has become an original international alliance that aims to scale up local projects for vulnerable areas all over the world.

In this paper, we delve into the SCO initiative, exploring its triggering factors and the complexities of the stakeholder ecosystem. We then outline the objectives of the SCO. Drawing on the pioneering SCO in France, we provide illustrative examples of the initiative's impact. Key figures from the SCO project portfolio are presented, offering valuable insights into the tangible outcomes achieved thus far. Specifically, we emphasize the projects' success in promoting science to benefit society and their contributions to nourishing the development of climate services. Moreover, we examine how the SCO projects align with the Sustainable Development Goals (SDGs). By addressing societal challenges through collaborative scientific efforts, the SCO plays a vital role in advancing global sustainability targets. Lastly, we present future perspectives for the SCO initiative, acknowledging its potential for growth and impact.

2. Triggering the initiative

In 2017, the organizers of the One Planet Summit - Emmanuel Macron, President of France, António Guterres, Secretary-General of the United Nations, and Jim Kim, President of the World Bank - aimed to address the issue of climate change being given less priority in international agendas due to US withdrawal of the Paris Agreement. They believed that unless countries were willing to accept defeat and the immeasurable damage that would follow, the fight against climate change should not lose momentum. It was felt that achieving the objectives of the Paris Agreement (COP21) would require greater commitment, more tangible decisions, and joint involvement from all those in public life and business. The first One Planet Summit was held in Paris on December 12, 2017, exactly two years after the adoption of the Paris Climate Agreement. More than 4,000 participants from various sectors committed to taking further action based on 12 transformative climate commitments. **The SCO is part of these**

commitments. Officially launched at the Paris Air Show in June 2019, it brought together 26 space agencies and international organizations to sign a Declaration of Intent.

In the continuity, SCO members worked together under the coordination of UNOOSA, with the implication of all SCO members, to clearly define the nature of SCO and formalize its governance through the **Charter on the establishment of the Space for Climate Observatory**. The SCO Charter entered into force on 1st September 2022 and is currently counting 36 signatories – Appendix A.

The objectives of this best-effort-based and non-binding alliance is to foster cooperation to support the **development of Earth-observation (EO) based operational tools for climate adaptation, mitigation and monitoring**.

3. A complex ecosystem of Stakeholders

Generally speaking, the downstream space sector is a complex ecosystem with a wide range of actors and downstream applications. The ecosystem complexity requires collaboration between various stakeholders, including government agencies, private companies, and research institutions, to foster innovation. These actors don't share a long history of cooperation. Local decision makers often have no idea that space data and private companies can help them in tackling climate change issues, and space companies and agencies have hard time gathering end users needs to develop new services.

Scientists specialists of satellite remote sensing play a critical role in shaping our understanding of the impacts of climate change, as well as the measures needed to mitigate and adapt to its effects. The scientific consensus on climate change has been a key driver of international cooperation and policy action on climate change. **Data scientists** are more and more involved to design new algorithms and process the huge amount of data.

Politics plays a significant role in climate diplomacy. International cooperation on climate change is shaped by a complex web of political, economic, and social factors, including national interests, geopolitical dynamics, and public opinion. Political leaders and decision-makers are responsible for developing and implementing policies to address climate change, and their actions can have a significant impact on global efforts to tackle this issue.

The civil society, which includes non-governmental organizations, and local decision makers plays a crucial role in driving action on climate change, especially as first users or co-designer of technical softwares that include innovative core methodologies and data. Civil society actors act as a bridge between scientific research and policy-making, bringing scientific evidence and community perspectives to the attention of policymakers using the latest technology available.

Space agencies play a critical role in providing Earth observation data. Satellites operated by space agencies provide critical data on a range of climate-related variables (temperature, precipitation, sea level, atmospheric composition) as well as a continuous monitoring of the Earth surface (satellites images). Some of these data are fully available like those of the European Earth-observation program, known as Copernicus.

In addition, space agencies support innovation. They invest in new technologies (satellites, sensors) and approaches for valorising EO data to tackle societal issues such as climate change adaptation. E.g. CNES is supporting SCO projects up to a CapEx of 8M€ of global investment over 6 years (2020 - 2026).
Finally, space agencies play a role in climate diplomacy, by supporting international cooperation on climate-related research and policy. They often collaborate with other national and international organizations to develop and implement joint climate initiatives, and participate in international negotiations and forums related to climate change.

***New space* companies** focused on earth observation satellite data and climate services are growing rapidly both in Europe and globally. The new space industry is expected to continue to grow and innovate driven by advances in satellite technology and data analytics, as well as increasing demand for climate monitoring and mitigation solutions.

Acknowledging the necessity to gather the stakeholders mentioned hereinabove, the SCO aims to enhance cooperation between them to provide operational tools for vulnerable territories. Its helps to fill the "last mile" gap between data and end users.

In this sense, a SCO project is a user-driven software that federates a consortium of scientists, service providers (newspace companies) and/or public authorities (public entities, space agencies) and final users (Politics, civil society) able to generate new knowledge, innovative and effective core methodologies and practical tools for decision support.

4. SCO Objectives

The objectives of SCO is to foster cooperation to support the **development of EO-based operational tools for climate adaptation, mitigation and monitoring**. These tools or projects must satisfy a minimum set of criteria:

1. They should address the specific needs of end users in a particular geographic area.
2. They need to propose practical and operational software solutions.
3. They should effectively utilize available data from satellites, environmental sources, climate studies, on-site measurements, and socio-economic factors, ensuring the data resolution is suitable for the problem at hand.
4. They must build upon existing operational and research infrastructures, services, and local data availability.
5. They should have the potential to expand and be applicable to multiple geographic areas.

Furthermore, SCO Projects are encouraged to fulfil optional criteria, including:

1. Bringing together scientists, companies, and public authorities to generate new knowledge, innovative methodologies, and practical decision-support tools.
2. Incorporating state-of-the-art methodologies, including the latest advancements in artificial intelligence and related computing infrastructures.
3. Promoting the use of open-source tools and moving towards an open final tool.
4. Proposing funding schemes that involve communities in the initial project phase and outlining the scope of involvement of the private sector for future developments.
5. Including an analysis of the associated business model.
6. Considering international cooperation with Least Developed Countries, and utilizing development aid to benefit these countries.

The goal is to target specific issues at the **local level**, and to **involve the end-users** – be it decision makers or citizens – in the design process to make sure that **the final tool suits their needs**.

Finally, the SCO serves as a diplomatic tool, facilitating global exchange and collaboration among space agencies. Apart from sharing and promoting locally developed solutions, the SCO is an integral part of various international initiatives, such as those led by the United Nations, the Group on Earth Observation (GEO), the Committee on Earth Observation Satellites (CEOS), the European Space Agency (ESA), the Space4climate initiative (S4C), and the World Meteorological Organization (WMO).

5. The pioneering SCO in France

The pioneering SCO in France has been federating since the end of 2019 all public expertise and research involved in public policies related to climate change within an inter-agency committee (22 national public organizations or agencies), as well as the relevant supervisory ministries, Ministry of Higher Education, Research and Innovation, Ministry of Ecological Transition. 11 of these agencies have already joined the International Charter and more to come. CNES is the Focal Point for France.

An annual call for projects has been set up since 2020 and progressively opened to SCO European partners. Proposals are reviewed by a pool of qualified reviewers who decide on the adequacy of the criteria of SCO projects. It is a robust process granting the SCO label, which is an international recognition, to integrate the portfolio and benefit from the proposed activities.

5.1 Key figures of the portfolio

Today, the SCO in France federates a portfolio [12] of more than 60 projects, which brings together a great diversity of stakeholders, thematic, methodologies and data.

The criteria for SCO projects are sufficiently broad to have created a real dynamic among **all actors in society**. The SCO portfolio in France now includes 260 public institutes and 40 private companies (see Fig.1).

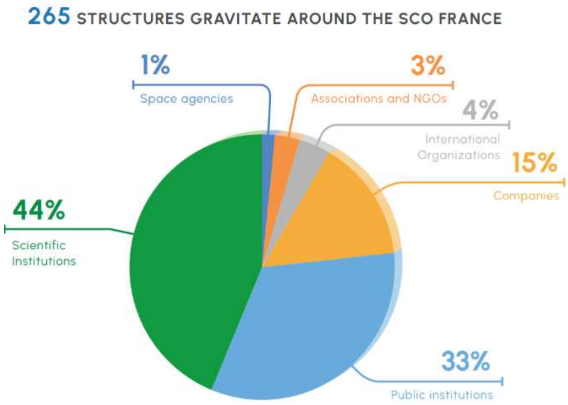

Fig 1. Typology of SCO project's stakeholders.

Working on the impacts of climate change requires addressing a very large **number of issues** over various locations (Fig. 4). The ones that have emerged in the portfolio relate to as urban adaptation, water management, biodiversity, resilience to natural disasters, land use or agriculture (see Fig 2.)

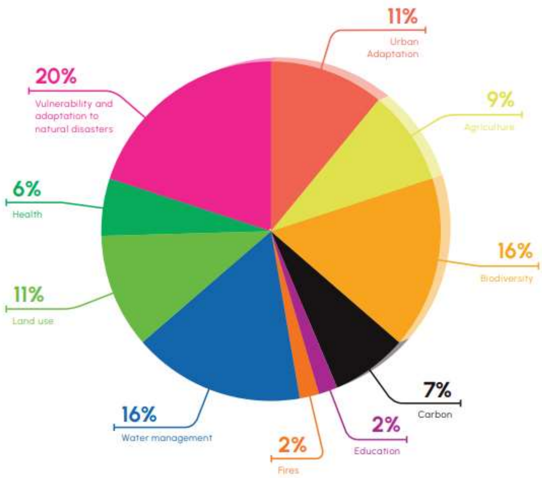

Fig 2. Topics covered by the SCO portfolio.

SCO projects use several **types of satellite data**, depending on the issue raised. A majority of them computes Copernicus Sentinel 2 and Sentinel 1 data, and within the framework of the SCO in France, high-resolution optical images from the Pleiades satellite are widely used, more specifically over urban areas, for land use detection but also to process Digital Surface Models.

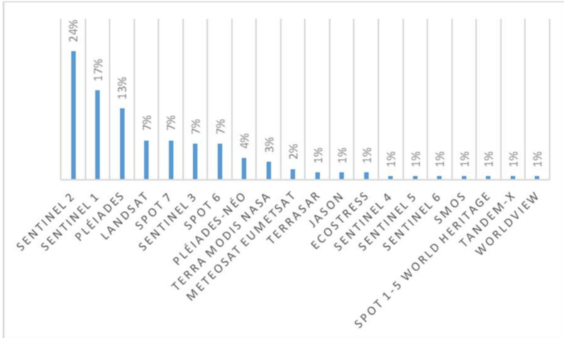

Fig 3. Diagram of Satellites data processed in SCO projects

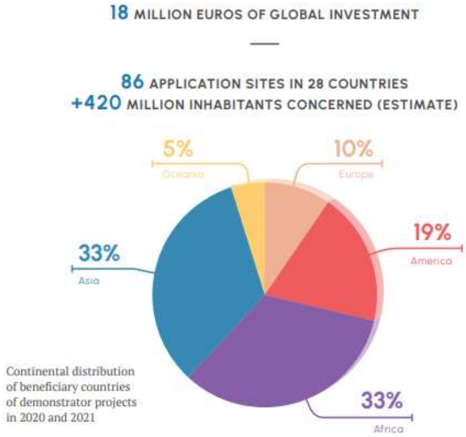

Fig 4. Location SCO projects.

The analysis of the SCO portfolio in France reveals two types of projects and consortium.

5.2 Promoting Science toward society

These consortia are led by scientists who valorize a methodology already published, make available the tools developed in a completely open manner and ensure a link with local communities. We are typically in the case of projects located in the least developed countries. Here are 4 examples of them:

VIMESCO-Rice [13] (https://www.vietsco.org) is a tool to monitor rice cultivation in the Mekong Delta and assess the impact of climate change on these crops using Sentinel-1 imaging and in situ data.

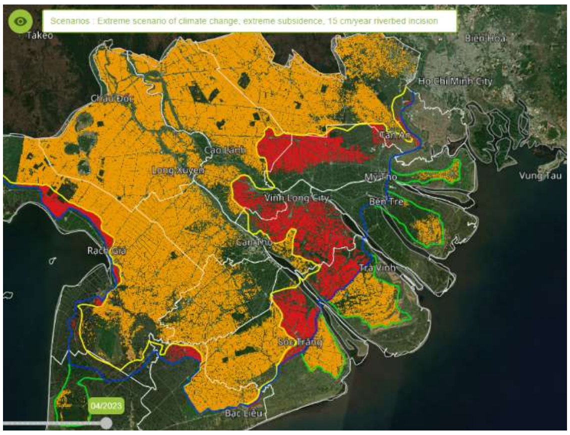

Fig 5. Screenshot of VIMESCO-Rice

OpHySE [14] (https://sagui.hydro-matters.fr/sagui/) is a real-time monitoring platform to assess river conditions and enhance navigability, starting with a demonstration in the French Guyana.

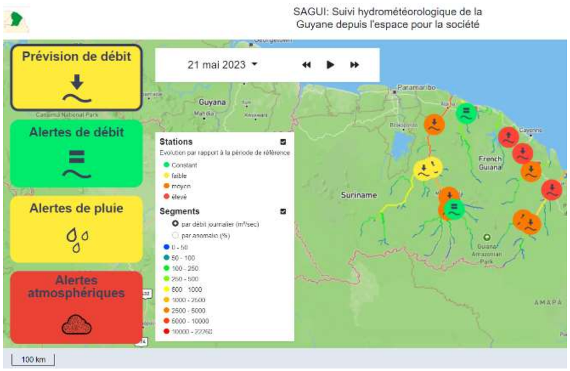

Fig 6. Screenshot of OpHySE

StockWater [15] (https://stock-water.pages.dev) seeks to establish a satellite-based monitoring system for tracking dam levels, enabling efficient water resource management by public authorities. Initially implemented in France, the project aims to replicate its methodology across Europe and India, with potential expansion to other regions of interest before scaling globally.

Fig 7. Screenshot of StockWater

BanD-SOS [16] (https://bandsos.github.io) is a pre-operational prediction system (within 36 to 48 hours) for cyclone-induced flooding and associated societal risks in the Bengal Delta. The system aims to provide real-time information for evacuation and protection efforts during cyclonic events while aiding the development of public policies for long-term resilience.

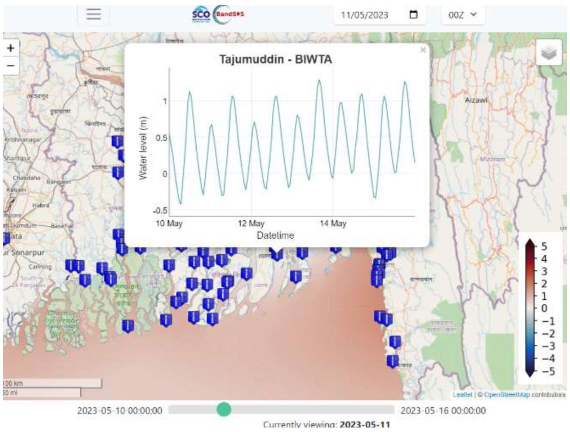

Fig 8. Screenshot of BAND-SOS

5.3 Nourishing the development of climate services

In these consortia, projects are carried out by private companies. For the SCO, it is a matter of energizing the private ecosystem for the development of climate services. These companies offer innovative services and, above all, ensure the sustainability of the service by creating a viable economic model over the long term. Here are some examples:

Tahatai [17], targeting decision-makers in the “îles du Vent” of French Polynesia, has developed a Datahub to automate the collection and calculation of useful indicators for the governance of the coastal zone, based on spatial and in situ data. The resulting reliable information allows for a better understanding of the evolution caused by climate change, as well as protecting biodiversity and identifying vulnerable areas on the coastline to anticipate potential risks.

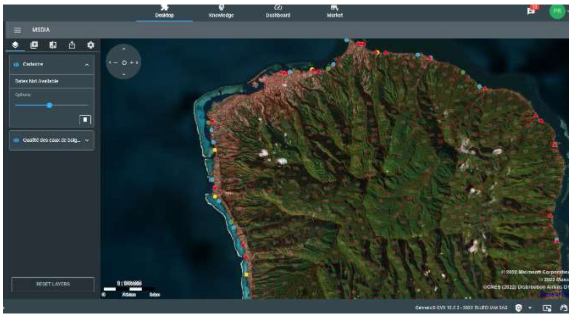

Fig 9. Screenshot of TAHATAI

The advancement of spatial data collection and our understanding of climate systems now allows for the estimation of precipitation quantity worldwide at a very fine scale using COSPARIN data [18]. **Gade Lapli** [19] leverages this new data to quantify risks related to extreme precipitation in locations highly vulnerable to climate change and often lacking forecasting capabilities, such as Haiti. The tool offers both an index to monitor precipitation changes caused by climate change, particularly during the cyclone season, and a real-time assistance service to track and better anticipate hydrometeorological risks.

Fig 9. Screenshot of GADE LAPLI

Space4Irrig [20] provides, through a web platform, high-resolution soil moisture maps (at the plot scale), maps of irrigated crops, and actual water requirements of crops in the Occitanie and PACA regions, France. Soil moisture maps are provided on 15 to 20 dates per month. Maps of irrigated areas and water requirements are provided on a monthly basis between 2017 and 2022.

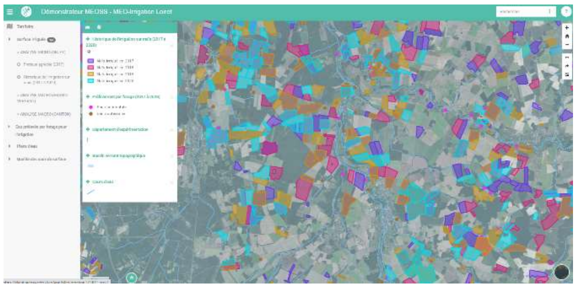

Fig 10. Screenshot of Space4Irrig

LITTOSCOPE [21] has developed an operational solution for the study and visualization, in the form of spatial indicators, of permanent (due to global sea level rise) and temporary risks of marine submersion during extreme events involving exceptional waves.

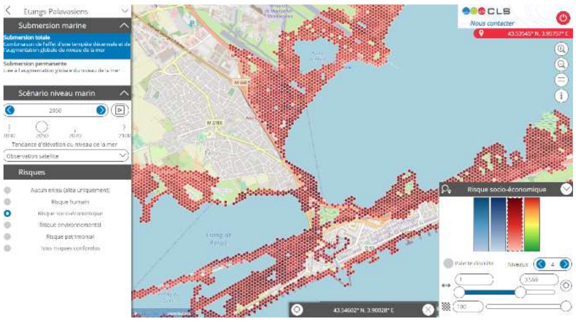

Fig 11. Screenshot of Littoscope

FLAUDE [22] proposes an operational and automated tool for analyzing the consequences of strong and sudden climatic events (such as heavy rainfall followed by floods) using satellite and in situ data. This includes monitoring blockages and vineyards in the Aude department.

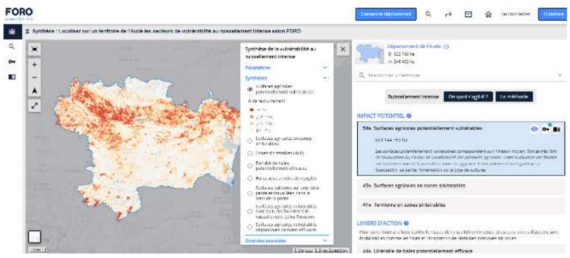

Fig 12. Screenshot of FLAUDE

6. Solutions to Sustainable Development Goals

Through its various projects, implementations, and partnerships, the SCO actively and directly contributes to several of the 17 UN Sustainable Development Goals (SDGs). Additionally, it places significant emphasis on vulnerable territories by developing on-site demonstrations and conducting training sessions to ensure that local teams can effectively utilize the tools.

6.1. UN SDG 13: Take urgent action to combat climate change and its impacts

All SCO projects address UN SDG 13 [23], thereby enabling the implementation of tools and strategies for public policies in this domain. On average, each of the 50 SCO projects in France involves one to two public institutions, aiming to enhance resilience against flooding, mitigate urban heat islands, support the transformation of rural areas, and improve forest fire management.

6.2. UN SDG 15: Preserve and restore terrestrial ecosystems

Forests, alongside Mangroves [24] and TropiSCO [25] projects, play a crucial role in the second objective of SDG 15. www.tropisco.org, a flagship SCO project, introduces the world's first platform capable of visualizing tropical deforestation in near-real time. Its indicators also contribute to other targets of SDG 15, including the fight against poaching.

6.4. UN SDG 6: Ensure access to water and sanitation for all and ensure sustainable management of water resources

Earth observation data plays a vital role in assessing and monitoring the condition of watersheds. For instance, the OpHySE [26] project examines seven rivers in French Guiana in partnership with the International Office for Water. Furthermore, the AmSudSat project [27], involving the Brazilian National Water Agency, focuses on the integrated management of water resources, particularly transboundary resources. It aims to develop a system for monitoring and forecasting the flows of major South American watersheds, aligning with the fifth target of SDG 6.

6.4. UN SDG 17: Revitalize the global partnership for sustainable development

Each SCO project operates through a consortium of actors with complementary skills, often combining public and private entities, scientists, and occasionally international organizations and associations. This multi-sectoral collaboration facilitates the development of decision-making tools that directly address local challenges.

7. Perspectives

The success of the SCO sets a strong foundation for its future as an international alliance. Building upon this success, the SCO has a unique opportunity to make greater impacts.

In the near future, the SCO will make emerge more projects worldwide from its signatories and will explore opportunities to expand its membership to include more countries and institutions worldwide. This would foster greater global collaboration and knowledge sharing, enabling a broader range of expertise and resources to be mobilized.

The SCO will also focus on strengthening its capabilities in sharing the operational tools of the portfolio. By fostering partnerships with other members, the SCO can ensure access to a wide range of climate data sources and services, facilitating comprehensive analysis and informed decision-making.

By capitalizing on its accomplishments, the SCO will take on new challenges and pursue ambitious goals, solidifying its position as a leading force in providing tools to tackle the impacts of climate change.

Acknowledgements

We would like to express our sincere gratitude to all individuals and organizations involved in the SCO initiative for their invaluable contribution to the success of this endeavor. We extend our appreciation to their unwavering commitment, particularly during the challenging period of the Covid pandemic, which has demonstrated their resilience and dedication.

We would also like to acknowledge the remarkable mobilization of the French ecosystem since 2020. The exceptional work carried out by businesses and laboratories in shaping and implementing these projects has been instrumental in driving the SCO initiative forward. Their tireless efforts, expertise, and

collaboration have played a crucial role in achieving the objectives of the SCO.

Appendix A List of SCO Signatories

Politique scientifique fédérale belge (Belgium)
China National Space Administration (China)
Space Science and Geospatial Institute (Ethiopia)
European Space Agency
Agence Française du Développement (France)
Centre de coopération internationale en recherche agronomique pour le développement (France)
Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'aménagement (France)
Centre national de la recherche scientifique (France)
Centre National d'Etudes Spatiales (France)
Centre Scientifique et Technique du Bâtiment (France)
Institut de recherche pour le développement (France)
Institut national de l'information géographique et forestière (France)
Institut national de recherche pour l'agriculture, l'alimentation et l'environnement (France)
Office français de la biodiversité (France)
Office national des forêts (France)
Service hydrographique et océanographique de la Marine (France)
Agence Gabonaise d'Etudes et d'Observations Spatiales (Gabon)
Indian Space Research Organization (India)
International Society for Photogrammetry and Remote Sensing
United Nations Development Programme
United Nations Environment Programme
United Nations Office for Outer Space Affairs
Italian Space Agency (Italy)
Malta Council for Science and Technology (Malta)
Mexican space agency (Mexico)
Philippine Space Agency (Philippine)
Agência Espacial Portuguesa (Portugal)
Office for Space Technology and Industry (Singapore)
Slovak Space Office - Industry Branch (Slovakia)
Swedish National Space Agency (Sweden)
Geo-Informatics and Space Technology Development Agency (Thailand)
United Arab Emirates Space Agency (UAESA)
United Kingdom Space Agency (UKSA)
National Oceanic and Atmospheric Administration (NOAA)

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