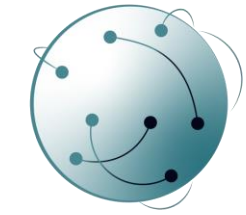

D8.5 Summary of Workshop "Open-Earth-Monitor" 2024

URL: **https://earthmonitor.org/about-the-project/**

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This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101059548.

Document Control Page

Project	Open-Earth-Monitor (OEMC)
Project, full title	A cyberinfrastructure to accelerate uptake of environmental information and help build user communities at European and global levels
Project number	101059548
Project start	June 1st 2022
Deliverable	D8.5 Summary of workshop ‘’Open-Earth-Monitor’’ 2024
Work Package	WP8 Communication, dissemination and collaboration
Document title	D8.5 Summary of workshop "Open-Earth-Monitor" 2024
Version	
Responsible author	Katya Perez Guzman, Ivelina Georgieva, Milutin Milenković, Steffen Fritz (IIASA)
Contributors	OGH
Date of delivery	30th November 2024
Due date of deliverable	30th November 2024
Type	DEC
Language	English
Rights	
Status	( ) In progress (X) For review ( ) Approved
Dissemination level	Public

Version history			
Version	**Implemented by**	**Date**	**Description**
V1	IIASA	30 November 2024	Includes summaries of sessions, and Annex with the abstracts.

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101059548.

Table of Contents

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List of Abbreviations

AI	Artificial Intelligence
APIs	Application Programming Interfaces
AutoML	Automated Machine Learning
CDSE	Copernicus Data Space Ecosystems
CEOS	Committee on Earth Observation Satellites
CNR-IRPI	Research Institute for Hydrogeological Protection
DEM	Digital Elevation Models
DGGS	Discrete Global Grid Systems
ECB	European Central Bank
ECI	Environmental Change Institute
EO	Earth Observation
EODC	Earth Observation Data Centre
ESA	European Space Agency
ETH Zurich	Swiss Federal Institute of Technology Zurich
EV-INBO	Integrative Management of Green Infrastructures Multifunctionality
FAIR	FAIR (Findable, Accessible, Interoperable, Reusable) data principles
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GFW	Global Forest Watch
GFZ	German Research Centre for Geosciences
GPP	Gross Primary Productivity
iDiv	German Centre for Integrative Biodiversity Research
IIASA	International Institute for Applied Systems Analysis
IPR	intellectual Property Rights
JRC	Joint Research Centre
KCEO	Knowledge Centre on Earth Observation
NFI	National Forest Inventory
OECD	The Organization for Economic Cooperation and Development
OEMC	Open-Earth-Monitor Cyberinfrastructure
OGH	OpenGeoHub Foundation
PNV	Potential natural vegetation
SAR	Synthetic Aperture Radar
SDG	Sustainable Development Goals
SEEA	System of Environmental-Economic Accounting
SITS	Satellite Image Time Series
SMAP	Soil Moisture Active Passive
SMOS	Soil Moisture and Ocean Salinity
SOC	Soil Organic Carbon

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UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
VITO	Flemish Institute for Technological Research
WRI	World Resources Institute
WSL	Swiss Federal Research Institute
WUR	Wageningen University and Research
WWF	World Wildlife Fund

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Executive Summary

The Open-Earth-Monitor Workshop is the second event organized under the umbrella of the Open-Earth-Monitor Cyberinfrastructure (OEMC) project and gathered in this year's event European and global experts to explore the application of Earth Observation (EO) in policy, business, research and society to tackle global environmental challenges. The Workshop emphasized knowledge sharing and networking within the EO community, connecting project partners, including data and environmental researchers, public and private sector developers, European Union (EU) decision- and policymakers, representatives from global institutions, the business sector and civil society.

Discussions covered a wide range of topics, including the use of remote sensing technologies and data integration to advance environmental monitoring efforts. The importance of climate and meteorological data for global and regional environmental assessments was emphasized, alongside the need for open science practices to improve data accessibility and collaboration across disciplines. Furthermore, the applications of EO in biodiversity preservation and ecosystem conservation were highlighted. Artificial intelligence, machine learning and deep learning architectures and tools were highlighted for their potential in environmental analysis and across the domain of EO. The presenters also showcased advancements in high-performance computing to support EO and also, multiple sessions delved into in-situ and citizen science data methods to complement EO datasets. In addition, the question about gender equity in the field of EO was brought up.

In conclusion, Open-Earth-Monitor Workshop 2024 underscored the potential of EO to drive policy impact by making environmental data actionable, bridging technical gaps, and aligning with policies such as the European Union's Green Deal and other sustainability goals. It highlighted ongoing efforts to integrate EO data with machine learning, support local and global policy needs, and promote an open science environment for sustainable future planning.

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1. Introduction

The Open-Earth Monitor Global Workshop 2024 is organized as part of the Open-Earth-Monitor Cyberinfrastructure (OEMC) project. It was held from 2nd –4th October 2024 and was co-organized by the International Institute for Applied Systems Analysis (IIASA) and the OpenGeoHub Foundation (OGH). The Workshop took place at the Laxenburg Conference Center, with parallel sessions at the IIASA premises in Laxenburg, Austria. This event focused on open-source Earth Observation applications for policy, business, research, and societal use and aimed to foster collaboration and innovation in the geospatial community.

Over the course of three days, the OEMC Global Workshop 2024 featured international keynote speakers, oral and poster presentations, and hands-on workshops. The participants had the opportunity to explore innovative solutions, forge meaningful collaborations, and advance the development of open-source geospatial research and applications within the fields of forest and biodiversity, soil, water and agriculture, and climate and health. The event aimed to foster practical partnerships that can drive progress in geospatial technologies for a wide range of fields, from policymaking to environmental research.

The OEMC Workshop included four different session formats:

- Keynotes: 30-minute talks held by special guests from institutions such as the European Space Agency (ESA), Max Planck Institute, EU Joint Research Centre (JRC), the Eidgenössische Technische Hochschule (ETH) Zürich and more, providing insights on cutting-edge geospatial developments. At the end of each session there was an appointed time for questions and discussions.
- Workshops: workshops were organized as practical sessions, focusing on open-source software and tools that support European policies and decision-making. Each workshop had a duration of 30-45 minutes depending upon the presenter and was led by one or more presenters.
- Oral talks: 20-minute presentations on the research and application of geospatial technologies in governance, industry, and public sectors, with a focus on the topics of forest & biodiversity, soil, water & agriculture, and climate & health. At the end of each session there was time appointed for discussions.
- Poster presentations: authors presented 5-minute summaries on the topics of their posters, related to OEMC's overarching themes listed above.

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2. Promotion and Dissemination Strategy of the OEMC Global Workshop (WP8)

The OEMC Global Workshop has been widely promoted through an array of channels and networks to foster engagement and visibility. This section provides a comprehensive overview of the Work Package 8 (WP8) promotional strategies and activities implemented to support the event. The promotion strategy for the OEMC Global Workshop focused on the following objectives: fostering collaboration within consortium members, its stakeholders and beyond; giving visibility to the OEMC use-cases by enhancing global participation; and highlighting essential themes related to Earth Observation and geospatial applications. The workshop aimed to connect European and global actors in open-source EO applications across policy, business, research, and society. The event brought together a broad array of participants—data and environmental researchers, public and private sector developers, EU policymakers, global institutional representatives, business professionals, and civil society members—to explore opportunities for advancing open-source geospatial research and applications.

The promotion strategy utilized multiple advertising channels to maximize reach. One of the channels used to promote was the OSGeo discussions forum, a widely recognized platform within the geospatial and EO professional community, which aimed to attract interest from a well-targeted audience. Furthermore, WP8 capitalized on the robust networks of all consortium partner institutions. Each member of the consortium promoted the event within their respective networks and some stakeholders were approached individually. Blog posts (1, 2) were published on the IIASA website and on the OpenGeoHub website, offering insights into the workshop's themes, timely released according to the IIASA and OGH's collaborative outreach plan.

Furthermore, in line with OEMC's promotional strategy we aimed to involve stakeholders associated with the OEMC use-cases by actively reaching out and engaging with them to ensure their participation in the event. Our efforts focused on maximizing their involvement in workshops, oral presentations, and discussions, fostering a dynamic and collaborative environment. All sessions during the global workshop were recorded and made publicly available and uploaded on the YouTube platform after the global workshop.

Under the main goals of the workshop were, as well, to address the barriers faced by women in the EO field in the EO field and gender representation through dedicated sessions and discussions, engaging participants. As part of the workshop's program, a special social event—a networking dinner held on October 3rd—allowed participants from various backgrounds to connect in a more informal setting. The dinner took place at IIASA's Schloss Restaurant. A summary of the statistics of the event follows below.

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2.1 Statistics of the OEMC Global Workshop

The OEMC Global Workshop brought together over 100 participants from around the world for this three-day event. In total, the workshop featured 63 sessions, including 35 oral presentations, 19 research posters, 8 keynote speakers, and 17 interactive workshops. Each session provided a valuable opportunity for participants to exchange ideas and gain new insights in the field of geospatial science. This rich field of presentations, discussions, and hands-on activities made the global workshop an impactful experience for all participants. The following graph illustrates the diverse international representation at the workshop, with participants from 15 different countries, the majority from Italy, Austria, and the Netherlands.

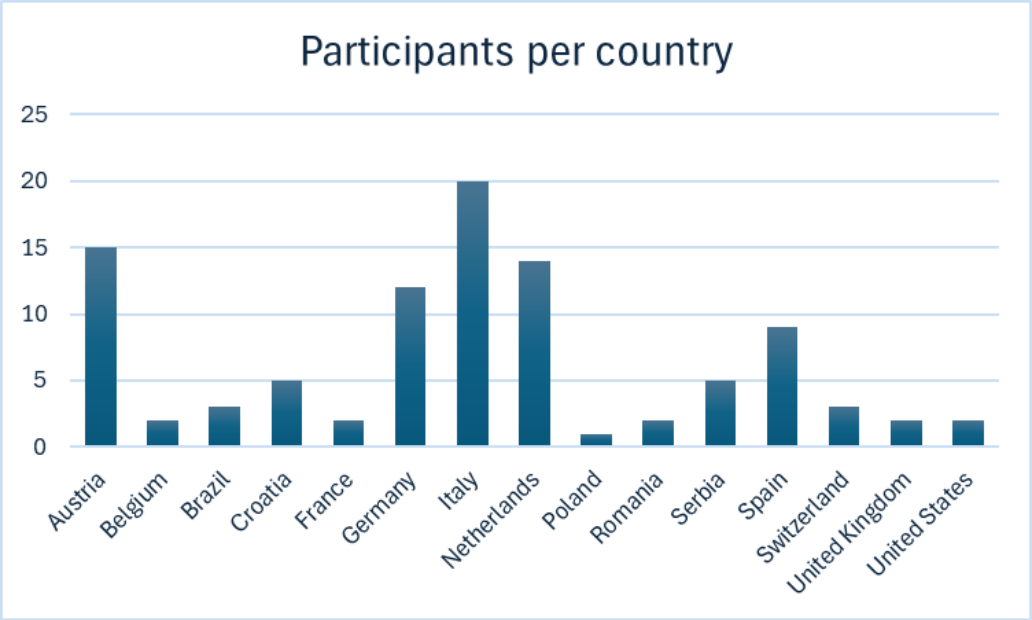

Figure 1: Participants per country in the OEMC Global Workshop 2024

A total of 98 participants registered for the OEMC Global Workshop 2024 using the pre-set registration form, with additional participants joining through on-site registration. The gender distribution among attendees included 71 participants identifying as male, 25 as female, and 1 as non-binary or gender non-conforming. The graph below illustrates the distribution of participants and their affiliated companies, institutions, agencies, or organizations, showcasing the number of attendees from each organization. Here included are the data for all participants who provided complete information during the registration process. In total, attendees represented 46 distinct companies, institutions, agencies, and organizations from across the globe, highlighting the workshop's broad international and interdisciplinary appeal.

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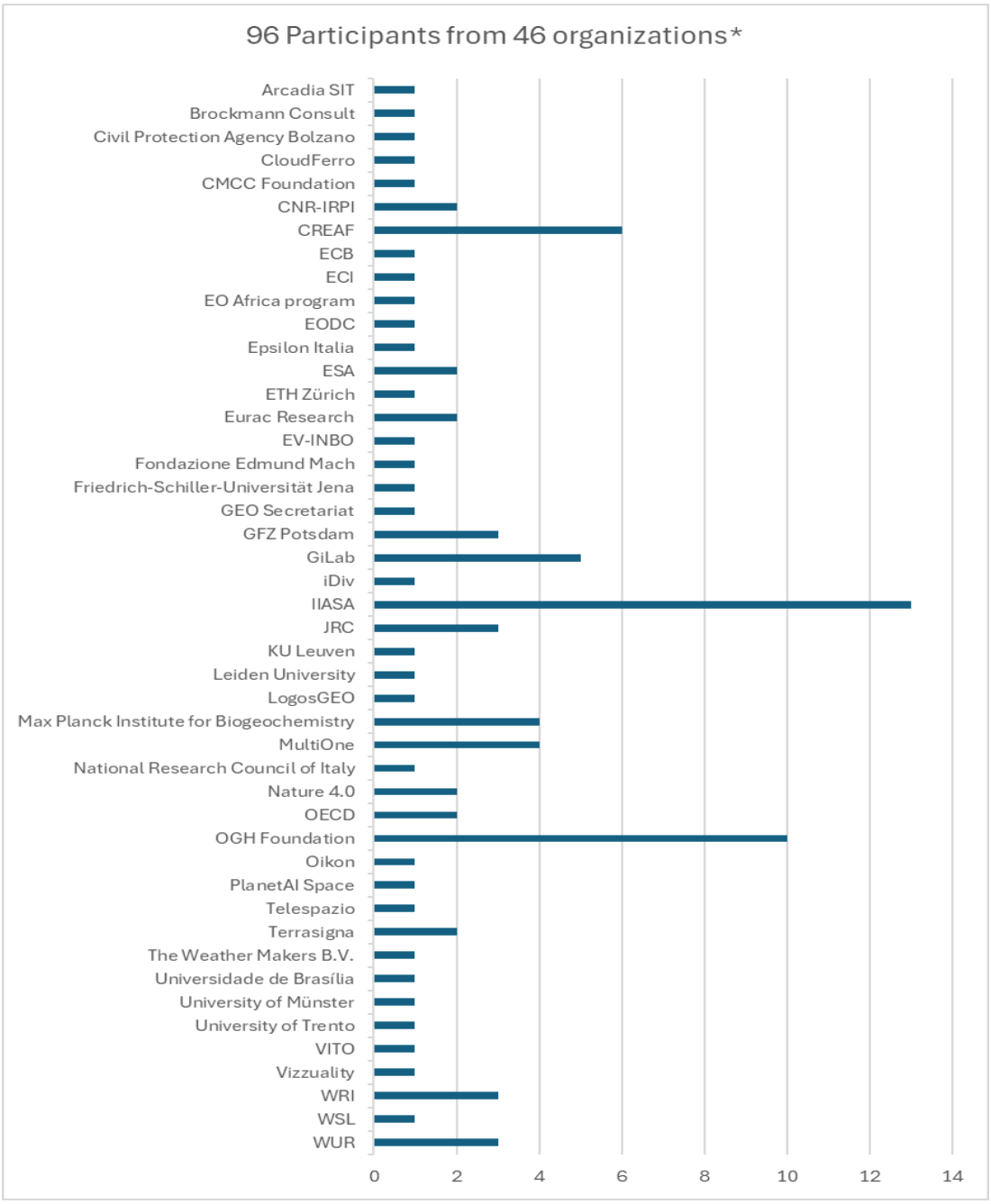

Figure 2: Number organizations and distribution of participants across these organizations in the OEMC Global Workshop 2024

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2.2 Participation of OEMC Stakeholders

One of the main goals of the global workshop was to engage and collaborate with all OEMC stakeholder groups: key stakeholders, use-case-related stakeholders, and general users. WP2 already defined those stakeholders in their deliverables D2.1, D2.3, and D2.9 (upcoming). A total of 21 OEMC stakeholders (two key stakeholders and 19 use-case-related stakeholders) attended the event. In addition, 11 participants affiliated with the same institution or working group as some of OEMC stakeholders also participated, providing a possibility to discuss and get feedback on the OEMC development from a larger group.

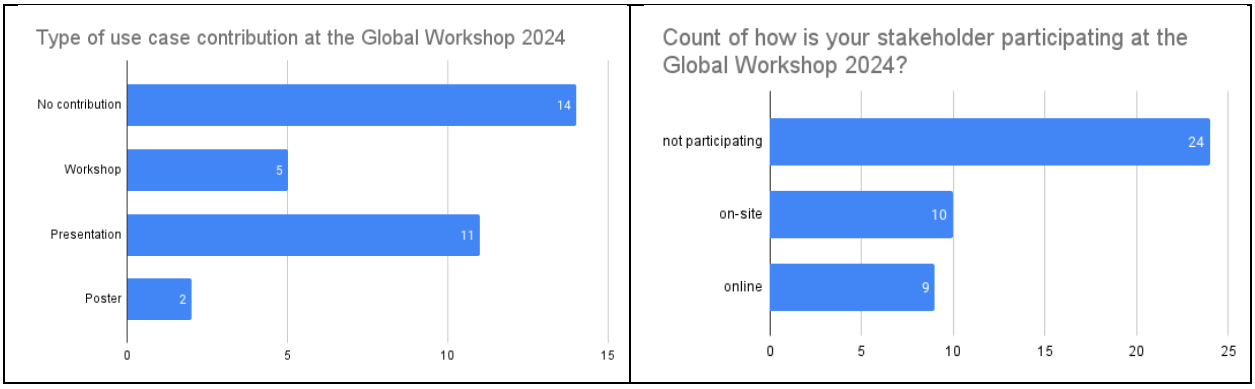

Figure 3: Contribution and distribution of use-case-related Stakeholders in the OEMC Global Workshop 2024

The OEMC stakeholder strategy foresees the involvement of the key stakeholders in keynote speeches at OEMC events and in collecting general recommendations and feedback through direct interaction and discussions between stakeholders and the OEMC executive board. At the OEMC Global Workshop 2024, eight keynote speeches were delivered. Among the speakers were: key stakeholders, two from the same organization as the key stakeholders, and one from the same organization where a use-case-related stakeholder works. The remaining three keynote speakers included: a young researcher who won the best poster award at the last global workshop and two experts from Austria, the host country for this year's workshop.

As reported by the use-case leaders, 19 OEMC use-case-related stakeholders (10 on-site and 9 online) were involved in 5 joint workshops with the use-case leaders, 11 presentations, and 2 posters at the OEMC Global Workshop 2024. It is noted that the number of stakeholders participating, and the number of stakeholder-related contributions do not match exactly because several stakeholders were involved in the same use-case and thus with single contribution per use-case, and several stakeholders attended the workshop without direct contribution, however participated in bilateral discussions with the use-case leaders. More details about these co-developments with stakeholders are given in the summaries below.

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Table 1: List of the use-cases and their stakeholders who participated at the OEMC Global Workshop 2024

Title	LP org	Stakeholders	Stakeholders' Names	Contribution type	Title of the contribution, if applicable	Stakeholder participation
Mosquito alert system for Italy (zanzara tigre)	OGH	Emilia-Romagna region (RER)	Paola Angelini, Dr Daniele Da Re	Workshop	Inferring spatiotemporal dynamics of mosquitoes in Italy using machine learning	on-site
Global monitoring system for livestock and grasslands / pastures	OGH	WRI	Lindsey Sloat	Presentation	Monitoring livestock and agricultural systems - A data harmonization-based approach	on-site
		LAPIG/UFG	Laerte Ferreira		Nathália Teles: A Multi Source Remote Sensing Approach for Large Scale Mapping of Other Wooded Lands	online
Large-area estimation of forest carbon emissions	GFZ	WRI	Sara Carter	No contribution		on-site
		OECD	Ivan Hascic, Mikael Maes, Rodrigo Piarro, Abenerzer Zeleke			on-site
EU-rapid forest disturbance monitoring tool	WU	JRC	Alessandro Cescatti, Guido Ceccerini, Loic Dutrieux, Pieter Beck	Presentation	Assessing forest disturbance dynamics and drivers using radar satellite data	on-site

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Tropical deforestation monitoring and characterisation tool	WU	INPE	Gilberto Camara	Presentation	Assessing forest disturbance dynamics and drivers using radar satellite data; Monitoring Deforestation-related land use change and Carbon Emissions for EUDR and climate policies	on-site
		WRI	Sarah Carter			on-site
Tool to estimate local temperatures changes following an increase in forest cover	MPG	JRC	Alessandro Cescatti	Presentation	Exploring the biophysical impacts of potential changes in tree cover in Africa	online
Planet health index	MPG	ECB	Andrej Ceglar	Presentation	Systemic human-biosphere-atmosphere monitoring and diagnostics	on-site
High resolution SWE in selected mountain regions	EURAC	Office for Hydrology and Dams South Tyrol	Rudi Nadelet (Hydrologist) and Luca Maraldo	Poster	Integrating different remote sensing products to produce high spatial and temporal snow estimates in the cloud	online
Drought Monitoring at high resolution throughout Italy	CNR	DPC	Silvia Puca ed Emanuela Campione	Presentation	Drought monitoring across scales with open soil moisture remote sensing data	online
EU Flood risk maps at high resolution	CNR	Descartes Underwriting	Kevin Dedieu	Presentation	Dynamic Flood Susceptibility Assessment: Harnessing	online

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					High-Resolution Data for Effective Risk Reduction	
			Alessandro Girelli			
Global drought monitoring at high resolution	CNR	JRC	Andrea Toreti and Davide Bavera	Presentation	Drought monitoring across scales with open soil moisture remote sensing data	online
Development of EU-biodiversity monitor	ETH	Restor	Stephen Thomas	Presentation	Global Trait-Based Vegetation Monitoring	not participating
Development of the World-reforestation monitor	ETH					on-site
Data cube for spatial modeling for Sinai	OGH	Weather Makers	Eduardo Torres	No contribution	-	on-site
Tools for Digitalisation of Agriculture in Africa	OGH	Ethiopian MoA	Yohannes Redda	Presentation	Gully Erosion Monitoring in Ethiopia	online
		GIZ	Tewodros Gebreegziabher		Study of Community Resilience in 72 selected study sites	online
Tools and data for improved biomass estimation	IIASA	GAMMA	Maurizio Santoro	Workshop	Citizen Science Mobile App and Data in Support of Forest Mapping: Laxenburg Park Campaign	not participating
		Embrapa	Silvia Barbosa Rodrigues; Daniel Luis Mascia Vieira			online

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2.3 Key Sessions and Themes

Forestry and Biodiversity Monitoring:

- Global Forest Watch (GFW) celebrated its impact over the last decade, emphasizing accessible forest data for diverse stakeholders. Various sessions addressed challenges in data accuracy and local monitoring to support conservation efforts.
- Projects like Geo Trees and ForestNavigator combined remote sensing with ground data to validate and support biodiversity conservation and carbon sequestration efforts.

Agricultural and Environmental Policy Compliance:

- Presentations on livestock and crop monitoring used multi-layered data to map land use, which informs land degradation and agricultural policies. The WorldCereal project illustrated advancements in global crop mapping through open-source platforms.

Land Use and Climate Change:

- Land cover change analysis highlighted the impacts of land conversion on biodiversity and carbon emissions. Innovative uses of SAR data and AI-enhanced data cubes demonstrated improved temporal accuracy in detecting land disturbances and assessing climate resilience.
- Projects such as ForestNavigator explored climate neutrality, focusing on forest carbon stocks, biodiversity, and bioeconomy goals to meet EU's net-zero targets.

Water and Flood Risk Management:

- Flood prediction and water resource modeling were demonstrated with high-resolution Digital Elevation Models and machine learning, supporting risk reduction and sustainable water management.

FAIR Data and Open Science:

- Sessions underscored the importance of FAIR (Findable, Accessible, Interoperable, Reusable) data principles, discussing user-producer perspectives and the need for improved awareness, resources, and metadata standards. EarthCODE and GeoKnowledge Hub initiatives emphasized open science practices for accessible environmental data.

Gender Equity in Earth Observation:

- A workshop on gender inclusivity identified barriers for women in EO and proposed solutions such as mentorship and inclusive hiring practices to foster a supportive environment.

The OEMC Global Workshop underscored the potential of EO to drive policy impact by making environmental data actionable, bridging technical gaps, and aligning with the European Union's Green Deal and climate goals. It highlighted ongoing efforts to integrate EO data with machine learning, support local and global policy needs, and promote an open science environment for sustainable future planning.

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3. Session Highlights

In the sections below are enlisted two-paragraph summaries of each session, for each day, capturing key discussions, insights, and innovative applications presented by experts at the OEMC Global Workshop. These summaries provide a glimpse into the diverse topics covered, from advancements in EO and Artificial Intelligence (AI) integration to policy-focused solutions for climate resilience, biodiversity conservation, and sustainable land use. Each session reflects the workshop's collaborative character and commitment to leveraging open data for a sustainable future. For more details, please refer to the YouTube list linked in Section 2. In case some presenters were not able to confirm their summaries, we include the link to the respective YouTube presentation next to their title.

3.1 Wednesday 2 October

"Welcome Plenary" by Steffen Fritz (IIASA)

--

Keynote: "The Rise (and Fall?) of the Global Subject" by John Schellnhuber (IIASA) (YouTube link)

The OEMC 2024 Global Workshop began with a warm welcome by Steffen Fritz from the organizing team, acknowledging the efforts behind the Workshop's setup at the Laxenburg Conference Center in Vienna. The event was structured to facilitate networking and knowledge sharing, emphasizing the importance of EO in shaping global policies. Attendees were provided with QR codes for easy access to essential Workshop information and guided navigating the venue, which included both the Laxenburg Center and the iconic IIASA castle.

Keynote: "10 years of Global Forest Watch – from data to impact"– Elizabeth Goldman (WRI) (YouTube link)

"Monitoring livestock and agricultural systems: An ensemble approach based on data harmonization" by Leandro Parente (OGH) (YouTube link)

—

"Assessing forest disturbance dynamics and drivers using radar satellite data" by Johannes Reiche (WUR)

Johannes Reiche discussed in the session "Assessing Forest Disturbance Dynamics and Drivers Using Radar Satellite Data" the use of radar technology, specifically Sentinel-1, to monitor forest disturbances such as logging and canopy gaps. The presenter explained how radar data, with its ability to penetrate forest canopies, offers advantages over, and complementarities with optical sensors, capturing structural changes in forests that indicate disturbances. This radar data is processed to produce high-resolution alerts that are distributed through platforms like Global

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Forest Watch, supporting near-real-time monitoring for environmental enforcement. The tool helps identify illegal logging activities by showing canopy gaps and changes, which are then shared with relevant organizations for action.
Challenges in using radar data for disturbance detection include high omission rates in specific scenarios, such as large fires, where radar may struggle to detect changes due to the minimal structural remnants. To address this, the research incorporates complementary datasets, such as optical data, to enhance detection accuracy.

"Quantifying the (mis)match between in-situ and satellite time series: the case of eddy covariance flux observations" by Daniel E. Pabon-Moreno (MPG)

—

"WorldCereal: a dynamic open-source system for global-scale, seasonal, and reproducible crop mapping" by Kristof Van Tricht (VITO)

The first session "Quantifying the (mis)match between in-situ and satellite time series: the case of eddy covariance flux observations" included an approach to quantifying heterogeneity in eddy covariance tower data for monitoring carbon fluxes between the biosphere and atmosphere. Daniel Pabon-Moreno explained how eddy covariance towers, used to measure energy and carbon fluxes, face limitations due to their small spatial "footprint" and the need for combining tower data with remote sensing (satellite) data for larger-scale analysis. The project developed a dynamic metric based on the Jensen-Shannon divergence, allowing comparisons between tower data footprints and satellite resolutions to assess data consistency across scales. This metric was applied globally across various tower sites, revealing that only half of the locations studied offered reliable data for modeling due to heterogeneity within their landscapes, impacting the accuracy of carbon flux upscaling.
The session also highlighted the practical tools created to streamline data analysis, such as cloud-based notebooks that enable users to conduct footprint comparisons using Copernicus Data Space Ecosystem. While the Open Earth Monitor Project is still evolving, future plans include integrating these tools to improve model training. The session concluded with discussions on challenges, including the fluctuating footprint of towers, and plans for broader data integration.
The second session on "WorldCereal: a dynamic open-source system for global-scale, seasonal, and reproducible crop mapping" was presented by Kristof Van Tricht at the OEMC 2024 global workshop, detailing the project's evolution from an initial feasibility study to its current operationalization phase. Launched by the European Space Agency (ESA), WorldCereal developed the first global crop-type maps, initially focused on a limited number of crops. Now, it aims to build an open-source, cloud-based system for comprehensive, seasonal crop mapping. By leveraging known field locations, crop identification algorithms are trained and applied from local to potentially global scales. The project also established an open reference data repository, accessible via a web interface and API, for harmonized crop data, enhancing the dataset's usability and extensibility. The latest phase incorporates self-supervised learning models to improve feature extraction, boosting generalizability across different regions. This adaptive

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system is accessible through platforms like the Copernicus Dataspace Ecosystem, supporting users in generating custom crop type maps that align with their specific needs and regional interests.

“MeteoEurope1km: a high-resolution daily gridded meteorological dataset for Europe for the 1961–2020 period” by Aleksandar Sekulić (BG AC)

The presentation "MeteoEurope1km: A High-Resolution Daily Gridded Meteorological Dataset for Europe for the 1961–2020 Period" by Aleksandar Sekulić discussed the development of a gridded meteorological dataset spanning Europe. Covering five key variables—maximum, minimum, and mean temperatures, total precipitation, and mean sea level pressure — the dataset provides daily data at a fine one-kilometer spatial resolution, designed for applications in climate studies, agriculture, and policymaking. Sekulić outlined the methodology, emphasizing spatio-temporal regression Kriging methodology to model environmental trends and residuals. Additionally, the data was cross validated to ensure accuracy, particularly for temperature variables and sea level pressure, although precipitation presented some complexity due to its variability. The dataset will be made available on platforms like Zenodo, and efforts are ongoing to update it closer to real-time. Sekulić also demonstrated ways to access and use the data, including features on the dailymeteo.com platform, where users can interact with the dataset through point queries and chatGPT bot. Real-time expansion of the data and global scaling are in the pipeline, aligning the dataset with broad scientific and operational needs across sectors. This project represents a significant contribution to meteorological and climate research, offering accessible, high-resolution data for the European region.

Mapping land use management in Europe using remote sensing, in situ data and statistical information,” by Linda See (IIASA)

—

“High-resolution spatial information on livestock density and grassland management in Europe” by Žiga Malek (IIASA)

Both sessions focused on the development and application of sophisticated land use and livestock management models in Europe, emphasizing the importance of accurate, high-resolution data. Linda See presented the LAMASUS Project, which integrates various datasets to map land use changes, particularly under the EU Green Deal's policy framework. Using data from Corine Land Cover and other remote sensing products from the Copernicus Land Monitoring Service, the project mapped forest, cropland, grassland and urban land use management across Europe, supporting policy needs. These maps are accessible through Geo-Wiki, a tool developed for visualizing land cover and land use data, which helps stakeholders to interact with high-resolution land cover data. The land use management maps are used by various economic land use models in the LAMASUS project to evaluate the impact of policies aimed at reaching net zero while ensuring sustainable production.

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The discussion also included an in-depth exploration of livestock management, presented by Žiga Malek, who mapped grazing patterns and ruminant livestock density across Europe. Recognizing the diversity of livestock practices, Žiga's team gathered subnational data on grazing from multiple sources, noting regional differences such as high-density, zero-grazing systems in Northern Italy versus extensive grazing in Ireland. The team developed machine-learning models for each bioclimatic zone in Europe to capture these variations, producing a grazing probability map. The findings highlight the ecological implications of various livestock management practices, with distinct environmental impacts based on region-specific practices. This work will help refine European land-use policies, supporting sustainable land management and enhancing the effectiveness of conservation measures across the continent.

"Assessing population exposure to air pollution: A multi-pollutant indicator framework for OECD countries and partners" by Mikaël Maes, Ivan Haščič (OECD)

The session "Assessing population exposure to air pollution: A multi-pollutant indicator framework for OECD countries and partners" by Mikaël Maes, Ivan Haščič highlighted the development of a multi-pollutant indicator framework to assess population exposure to air pollution across the OECD and partner countries. The initiative stems from the urgent need to address air pollution, a leading global environmental health risk, responsible for 4.5 million deaths in 2019 alone. The framework leverages Earth Observation (EO) data, ground-based measurements, and hybrid datasets to analyse exposure to key pollutants such as fine particulate matter (PM2.5), nitrogen dioxide (NO2), and ozone (O3). The team presented findings from various global datasets, including the Global Burden of Disease (GBD) dataset, Copernicus CAMS reanalysis data, and private data from Plume Labs, comparing their strengths and limitations. While significant declines in pollutant exposure were observed in OECD countries over two decades, the levels in partner countries, particularly in populous regions like India and China, remain alarmingly high, and exceed WHO Air Quality Guidelines in many countries.

A major challenge discussed was the inconsistency between global and national datasets, raising questions about data resolution, methodological differences, and the integration of ground-based data in global models. The findings underscore the importance of improving data interoperability and accessibility while maintaining methodological rigor. The analysis also revealed the impact of events such as the COVID-19 pandemic on air pollution levels and highlighted disparities in exposure within countries, especially between urban and rural areas. The team emphasized the need for enhanced collaboration, improved calibration of models with national data, and continued development of EO tools to inform policy actions effectively. These underlying data sources and indicators are pivotal for shaping air quality policies and evaluating their effectiveness in mitigating health risks associated with air pollution.

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“User and producer perspectives for FAIR environmental data” by Katja Berger (GFZ)

The session “User and producer perspectives for FAIR environmental data” presented by Katja Berger at the OEMC 2024 Global Workshop addressed the principles of FAIR (Findable, Accessible, Interoperable, Reusable) data, highlighting findings from a recent survey conducted as part of the OEMC project. Katja shared insights into data accessibility and usage trends among both users and producers, noting a significant gap in FAIR data awareness—especially among users. The survey revealed that while open, accessible data is highly valued, challenges persist around resources, technical expertise, and maintaining metadata standards. Producers expressed resource constraints as a key barrier, whereas users indicated a lack of awareness about FAIR principles. This feedback reinforces the need for enhanced communication and support to increase the adoption of FAIR practices in environmental data.
In discussing FAIR data applications, Katja emphasized the importance of accessible data for diverse sectors, including agriculture, biodiversity, and nature conservation. The project also examined user feedback regarding data requirements, revealing that while global data is typically produced, users often require data at more granular, local levels. This discrepancy underlines the need for platforms that bridge these levels effectively. The session concluded with a dialogue on the challenges of representing global data, the importance of indigenous data sovereignty, and the need for interoperability and robust licensing frameworks to support FAIR data principles in an equitable and globally inclusive way.

“Streamlining Earth Observation Data Sharing with the zen Python Library” by Rolf Simoes (OGH)

Rolf Simoes' presentation on "Streamlining Earth Observation Data Sharing with the zen Python Library" introduced the Zen library, a Python tool designed to facilitate the sharing of large Earth observation datasets via the Zenodo platform. This library simplifies interactions with Zenodo's API, automating the process of uploading, organizing, and updating metadata for complex datasets. Simoes highlighted the motivation behind developing this tool: traditional web interfaces can be cumbersome when managing large volumes of Earth observation data, often spanning gigabytes and involving hundreds of files. The Zen library provides an efficient, programmable interface that helps researchers maintain organization and reduce errors, making the data-sharing process smoother and more reliable.
During the workshop, Simoes demonstrated key functions within the Zen library, including the setup of new datasets, uploading files, and configuring metadata to ensure discoverability. He also discussed the importance of open science and data accessibility, emphasizing how Zenodo, powered by CERN’s Invenio RDM framework, is built to support FAIR principles (Findable, Accessible, Interoperable, and Reusable). Through Zen, users can directly manage their datasets, create digital object identifiers (DOIs), and ensure compliance with data-sharing standards, making it a valuable tool for researchers in the Earth observation community who require efficient and robust data management solutions.

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“Actual and potential habitat and vegetation type mapping to support conservation science” by Martin Jung (IIASA)

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“Land cover change and biodiversity pressures: A global analysis leveraging EO data” by Mikaël Maes, Ivan Haščič (OECD)

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“Dynamic Flood Susceptibility Assessment: Harnessing High-Resolution Data for Effective Risk Reduction” by Hamidreza Mosaffa (CNR) (YouTube link)

The session “Actual and potential habitat and vegetation type mapping to support conservation science” by Martin Jung centered first about the critical role of habitat and vegetation type mapping in supporting conservation science, particularly for biodiversity assessments, restoration planning, and evaluating extinction risks. It outlined two primary approaches to vegetation mapping: integrative methods that combine existing maps and datasets, and predictive methods that utilize Earth observation data to directly predict vegetation types. Martin Jung emphasizes the advantages of regional vegetation mapping over global mapping, as it captures local contexts and improves accuracy, especially for complex habitats. A case study from the Austrian-Hungarian border is presented, showcasing the use of advanced deep learning algorithms to map diverse and ephemeral habitats like soda ponds. Additionally, the session explored potential natural vegetation (PNV) mapping to assess land potential and inform restoration efforts. It discusses how PNV mapping can aid in understanding the impacts of climate change on vegetation distribution. The conclusion emphasizes the need to focus on thematic and temporal resolution in vegetation mapping and suggests integrating process-based modeling with data-driven approaches to advance the field.

The second session “Land cover change and biodiversity pressures: A global analysis leveraging EO data” focused on the integration of global land cover datasets to assess biodiversity pressures, particularly for the OECD’s needs. Mikaël Maes and Ivan Haščič from the OECD presented the challenges of using land cover data as proxies for biodiversity monitoring. Due to a lack of globally consistent biodiversity data, they utilized satellite-derived land cover datasets to track changes in natural vegetation and identify anthropogenic pressures on ecosystems. However, this approach faces obstacles, particularly in aligning with national statistics. They highlighted that global land cover datasets, such as the Climate Change Initiative Land Cover, World Cover, and Dynamic World, vary significantly in their classifications, temporal spans, and resolutions, resulting in divergent outcomes for biodiversity assessments.

Mikaël detailed the creation of biodiversity indicators based on land conversions and the challenges of harmonizing these with national data. The team focused on tracking land cover transitions between (semi-) natural areas and anthropogenic ones, observing patterns like tree cover loss, cropland expansion, and urbanization across OECD and partner countries. They noted significant discrepancies between national datasets and satellite-derived global data, which complicates their use in policy contexts. The session concluded with a call for improved

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data harmonization, investment in long-term data consistency, and enhanced indicators for distinguishing natural versus human-induced land changes, which could provide more reliable insights for global biodiversity and other environmental policies.

“Data Spaces: the EC solution for environmental, biodiversity and climate challenges. Different approaches on multisource data, semantics, FAIRness and sovereignty” by Joan Maso, Ivette Serral (CREAF)

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“Geo-AutoML with Scikit-map” by Leandro Leal Parente (OGH) (YouTube link)

The session on “Data Spaces: the EC for Environmental, Biodiversity, and Climate Change Challenges” focused on the role of data spaces in supporting the European Green Deal and addressing multi-source data integration issues. Challenges like semantic interoperability, metadata documentation, and multidimensional data cubes were explored. The session emphasized the importance of secure and trusted data exchange frameworks, which allow multi-source data—including remote sensing, Internet of Things, and citizen science contributions—to be integrated effectively. Presenters highlighted the Green Deal Data Space as a European Commission initiative designed to facilitate data sharing and transparency, aiding in environmental and biodiversity conservation efforts.

Participants discussed various technical and conceptual hurdles, including the need for common standards and robust APIs to ensure data accessibility and security. A significant focus was on semantic tagging to standardize data descriptions across sources, enhancing data reliability for environmental monitoring and policy development. Case studies demonstrated how AD4GD, FAIRiCUBE, USAGE and Open Earth Monitor, and other related projects under the EuroGEO Action Group on the Green Deal Data Space are operationalizing these standards. The session underscored the evolving need for adaptable data governance, as well as data sovereignty considerations, to balance open data access with privacy requirements in ecological and environmental data applications.

“The nrt Ecosystem: A Unified Approach to Forest Disturbance Monitoring” by Kenji Ose (JRC)

Forest disturbances, whether biotic, abiotic or anthropogenic, are increasing in Europe and impact many ecosystem services. They affect the forestry sector, tourism and the EU's ability to meet its climate targets. Early detection of these disturbances, including bark beetle infestations that ravage spruce forests, is essential to enable rapid intervention, such as sanitary cut, and limit damage. The nrt package, developed by the Joint Research Centre (JRC) of the European Commission, addresses this need by providing an open-source tool in Python for continuous forest monitoring.

The nrt package uses time series analysis of satellite images to identify anomalies that may indicate forest disturbance. It offers access to several monitoring algorithms, such as MoSum,

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CuSum, EWMA, IQR and CCDC, and is optimized for fast computation and scalability, allowing to process large datasets. The nrt package is complemented by nrt-data, which provides test and demonstration data, and nrt-validate, which allows validating classifications and creating reference data.

A working prototype using the nrt package has been deployed in Estonia, demonstrating its ability to monitor large-scale disturbances. Development of nrt continues with the exploration of new approaches, such as parameter optimization and anomaly labeling.

Community contributions are highly encouraged!

3.2 Thursday, 3 October

Keynote: "Open data, open science and open platforms: way forward with Earth Observation in the actual climate crisis" by Inge Jonckheere (ESA ESRIN)

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Keynote: "Towards a multi-frequency SAR datacube for global monitoring of dynamic land surface processes" by Wolfgang Wagner (TU Wien, EODC)

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Keynote: "Can Brazil achieve zero deforestation in Amazonia?" by Gilberto Camara (INPE)

Inge Jonckheere led the Keynote session on " Open data, open science and open platforms: way forward with Earth Observation in the actual climate crisis" at the OEMC 2024 workshop, highlighting ESA's Earth Code initiative, which is designed to support open science and FAIR (Findable, Accessible, Interoperable, Reusable) data principles. Inge discussed ESA's commitment to providing long-term, secure, and accessible storage for Earth observation data, fostering collaboration among researchers, policymakers, and society. The initiative includes a robust cloud-based infrastructure allowing for efficient data sharing, code reuse, and visualization, which is crucial for research transparency and policy impact. Inge emphasized that ESA's role is not just only as a data provider but also as an enabler of actionable insights as well as applications of Earth observation data for societal benefits.

The discussion also touched on the challenges of maintaining data quality, managing intellectual property rights (IPR), and ensuring interoperability between diverse datasets and platforms. A central focus was on ESA's collaboration with other agencies, such as the European Commission, to harmonize IPR policies and improve data accessibility across European-funded research. By integrating educational resources and encouraging user engagement, ESA aims to build a sustainable and inclusive community that supports open data practices. Participants discussed the importance of data visualization for policymakers and the need for open science practices to make research outputs widely available, ultimately aiding global environmental and climate efforts.

The second keynote session "Towards a Multi-Frequency SAR Data cube for Global Monitoring of Dynamic Land Surface Processes" discussed the development of a multi-frequency SAR (Synthetic Aperture Radar) data cube, aiming to improve the accuracy and temporal coverage of

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global land surface monitoring. Wolfgang Wagner presented how this data cube integrates multiple SAR datasets, such as Sentinel-1 (C-band) and the upcoming ROSE-L (L-band), to capture complex surface dynamics like soil moisture and vegetation structure changes. By combining different frequencies, the system enhances detection capabilities for various land features and processes, providing more detailed insights into flood monitoring, soil health, and biomass estimation.

The session emphasized the challenges of optimizing these datasets for time-series analysis, especially considering the need for consistent, reprocessed data to support accurate long-term monitoring. The integration of multiple SAR frequencies also aims to address limitations in spatial and temporal resolution, with plans for the data cube to support environmental and emergency response applications, such as flood mapping and soil moisture assessments, through automated, near-real-time processing. The project underscores the potential of a multi-frequency SAR approach to advance global land monitoring efforts and inform policy on issues such as climate resilience and sustainable land management.

The third Keynote session "Can Brazil Achieve Zero Deforestation in Amazonia?" at the OEMC 2024 global workshop examined Brazil's ambitious goal to halt deforestation in the Amazon by 2030. Gilberto Camara highlighted Brazil's reliance on satellite data and open-source technology for tracking deforestation, underscoring the country's comprehensive approach through plans like the Action Plan for Prevention and Control of Deforestation in the Legal Amazon. The discussion emphasized the challenges Brazil faces, including political resistance from Congress, pressures from agriculture and mining interests, and organized crime involvement in illegal deforestation. Notably, 85% of deforestation in Brazil is illegal, and enforcement requires a robust rule of law and accountability measures to succeed.

Gilberto also detailed the historical context, noting that effective anti-deforestation measures in the past had reduced deforestation by 80% but faced setbacks with policy reversals and weakened environmental protections under previous administrations. Currently, Brazil's efforts are focused on enforcing environmental laws, promoting responsible supply chains, and expanding monitoring tools to deter illegal activities. For zero deforestation to become a reality, the Brazilian government needs unwavering political support, increased regulatory enforcement, and international cooperation to address the root economic drivers and governance challenges in the Amazon.

Women in EO and Policy by Katya Perez Guzman (IIASA)

The session titled “Women in Earth Observation: Barriers and Strategies for Gender Inclusion” at the OEMC 2024 global workshop focused on the barriers women face in the field of Earth observation and strategies to improve gender representation. Katya shared a fictionalized story based on real experiences from women in Earth sciences to illustrate challenges such as societal stereotypes, lack of female role models, and self-confidence issues. The survey data presented showed that only 28% of the Earth observation workforce is female, with stereotypes and lack of

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confidence being key barriers. The session invited participants to reflect on their experiences and propose ways to better support women within the OEMC project and in their own institutions.
Interactive activities allowed attendees to brainstorm practical steps for promoting gender equity, such as mentorship programs, inclusive hackathons, and engaging outreach. The session concluded with a discussion on moving beyond merely fulfilling EU requirements to implementing impactful measures within the project. Suggestions from participants, such as facilitating hackathons that address gender-relevant topics and encouraging more inclusive hiring practices, will inform a gender-focused report for the European Union. The emphasis was on creating a genuinely supportive environment for women in STEM, tackling both visible and subtle gender biases.

“A Multi-Source Remote Sensing Approach for Large-Scale Mapping of Other Wooded Lands” by Nathália Teles (LAPIG) (YouTube link)

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“Multi-decadal trend analysis and forest disturbance assessment of European tree species: concerning signs of a subtle shift” by Carmelo Bonannella (OGH)

The session "Multi-decadal Trend Analysis and Forest Disturbance Assessment of European Tree Species: Concerning Signs of a Subtle Shift" by Carmelo Bonannella discussed trends in forest dynamics across Europe, focusing on species distribution changes due to climate and disturbance events. By applying a trend analysis to pixel-based data over multiple decades, the study revealed how tree species such as spruce and beech are adapting their ecological niches, potentially moving to higher elevations or latitudes. The analysis indicated that while most tree distributions remain stable, disturbances like drought, fire, and pest invasions have created notable "hot spots" where certain species exhibit declining trends, especially in areas impacted by severe climatic events.
Carmelo underscored the complexity of interpreting these trends, noting that fluctuations could reflect either short-term noise or genuine shifts in species niches due to environmental stressors. For example, some regions in Central Europe showed declines in spruce due to planting practices outside the species' native range, which makes these areas particularly vulnerable to disturbances. This large-scale assessment aims to guide future conservation and forest management strategies, suggesting that monitoring forest stability and identifying disturbance hot spots could help mitigate potential issues in biodiversity and forest health.

“Big Data Analytics in Open Geo Hub Cloud using SITS” by Gilberto Camara (INPE), Rolf Simoes (OGH)

The session on "Big Data Analytics in Open GeoHub Cloud using SITS" focused on leveraging the R package "Satellite Image Time Series (SITS)" to analyze extensive Earth observation datasets effectively. This approach uses SITS to process and harmonize large volumes of time-series data, allowing researchers to identify patterns and trends in environmental variables over

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time. Gilberto and Rolf highlighted the integration of SITS with cloud-based resources, enabling scalable processing capabilities for diverse applications, such as monitoring of forests, land use and land cover mapping, and change detection. The package offers a technological solution to work with multiple satellite image collections and work with time-series across vast geographical areas.

One of the main advantages discussed was SITS's ability to handle multi-source data, ensuring consistency in spatial and temporal dimensions while accommodating data from various satellite missions. This harmonization is critical for working with time-series and producing reliable and consistent Land Use and Land Cover maps. The session also underscored the importance of open data and open source software like SITS in democratizing data access, and processing as users across different sectors can run SITS without needing extensive computational resources. The use of cloud storage in combination with SITS exemplifies a powerful tool for advancing global-scale environmental monitoring and decision-making.

"Global Forest Watch: the latest data and tools to better protect forests" by Myroslava Lesiv, Elise Mazur, Elizabeth Goldman (WRI)

The session "Global Forest Watch: the latest data and tools to better protect forests" covered advancements in global forest management mapping, including hands-on exercises for participants using the GeoWiki platform. Myroslava outlined efforts to refine forest management maps since 2017, aiming to improve the accuracy and resolution of global land use maps, which are essential for policymaking. The mapping process has faced challenges with data accuracy and the difficulty of crowd-sourced training data. To address these issues, they have incorporated expert validation and regional knowledge, employing advanced modeling techniques and satellite imagery from Sentinel-1 and Sentinel-2 for precise classifications. The updated maps include new categories like rubber and fruit tree plantations and are expected to be released in 2025.

Liz Goldman from Global Forest Watch (GFW) discussed the need to differentiate between natural forests and planted trees to aid stakeholders in monitoring deforestation. GFW's spatial database of planted trees has evolved since 2019, expanding coverage to 158 countries and incorporating carbon removal factors. Elise Mazur from Land & Carbon Lab presented work building off Myoslava and Liz's work to create a map of natural lands including a natural forest class by compiling multiple datasets identifying natural land covers and non-natural land uses. This map was built for the Science Based Targets Network target on no conversion of natural ecosystems and can be applied to other regulatory and voluntary targets. The session included a live demonstration on GeoWiki, allowing participants to explore forest management layers and natural forest data through high-resolution maps, assess historical data, and provide feedback. This interactive segment showcased GFW's tools for hands-on environmental data analysis, helping users navigate the complexities of forest cover and land use classifications.

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“Exploring the application of open Earth Observation datasets for SEEA carbon accounting and its comparison with the GHG country reports to UNFCCC” by Arnan Araza (WUR)

The session on “Exploring the application of open Earth Observation datasets for SEEA carbon accounting and its comparison with the GHG country reports to UNFCCC” by Arnan Araza explored how Earth Observation data can be utilized for carbon accounting following the SEEA (System of Environmental-Economic Accounting) framework, a UN international statistical standard. Arnan demonstrated how open EO datasets can allow compilation of accounts from multiple carbon pools such as above-ground carbon, below-ground carbon, deadwood, litter and soil organic carbon. He highlighted the utility of EO in providing high spatial and temporal resolution inputs, which aligns with the SEEA framework’s focus on tracking small land-use changes, such as annual transitions from forest to agriculture. The session also emphasized the importance of validating EO data with independent in-situ measurements and integrating both to enhance the precision of carbon accounting outputs.

Presented in the session is the preliminary comparison with GHG country reports submitted to UNFCCC i.e., contributions from the Land Use, Land-Use Change, and Forestry (LULUCF). Unlike the System of Environmental-Economic Accounting (SEEA), which integrates both stocks and flows, the UNFCCC country reports focus solely on fluxes. Another key difference includes possible discrepancy in forest area and managed forest definitions. Such differences may explain the preliminary discrepancy among the carbon accounts using two frameworks. The session concluded with key takeaways emphasizing that EO enables a SEEA-based framework to adopt flexible forest management definitions and other parameters, making it more comparable with UNFCCC. Additionally, EO was highlighted as a potential data source not only for SEEA but also for UNFCCC country reports, addressing gaps in annual reporting by countries.

“Large-scale EO processing with xcube on CDSE” by Pontus Lurcock (Brockmann **Consult)**

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“Time-series reconstruction of global scale historical Earth observation data by seasonally weighted average” by Davide Consoli (OGH)

The session titled "Large-scale EO processing with xcube on CDSE" explored the capabilities of xcube within the Copernicus Data Space Ecosystem (CDSE) to support large-scale Earth observation (EO) data processing. Pontus highlighted how xcube’s modular structure allows seamless integration with various APIs and data formats, enabling efficient processing of vast datasets stored in cloud environments. A key feature of xcube on CDSE is its flexibility to operate both in interactive server mode for dynamic data exploration and in batch mode for large-scale processing, catering to diverse EO data analysis needs. The system’s API endpoints and xcube viewer facilitate efficient data navigation, making it suitable for intensive environmental applications like land monitoring and climate assessments.

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Pontus also emphasized the technical infrastructure supporting xcube, such as Docker containers and cloud resources, which enable scalable processing workflows. This setup allows users to customize processing parameters, cache data locally, and interact with cloud-stored data without substantial lag. Furthermore, xcube's capability to generate virtual data representations enhances data accessibility across applications, demonstrating its potential for large-scale EO projects requiring high-resolution, near-real-time insights. This integration with CDSE represents a significant advancement for EO data users, streamlining access and processing of critical environmental data through flexible, scalable solutions.

The session on "Time Series Reconstruction of Global Scale Historical Earth Observation Data by Seasonally Weighted Average" presented a technique developed by OpenGeoHub to address missing data in satellite images, particularly in datasets like Landsat, which are affected by cloud cover, snow, and atmospheric interference. Davide explained how this method involves aggregating data on a monthly basis and applying a seasonally weighted average to reconstruct missing pixels, producing continuous time series suitable for environmental monitoring applications. By assigning weights based on seasonal relevance and temporal proximity, the approach minimizes errors from land cover changes. This reconstruction method is especially beneficial for time-series analysis in fields such as crop phenology and land degradation monitoring, where consistent, gap-free data is essential.

Davide further discussed that this reconstruction method supports applications like grassland mapping, soil carbon monitoring, and crop productivity analysis, contributing to more accurate environmental modeling. OpenGeoHub's approach leverages high-performance computing resources to handle the large data volumes required, achieving high spatial resolutions that address the limitations of coarser datasets used in many current monitoring tools. The session underscored the importance of filling data gaps effectively, as these gaps can lead to propagation errors in models, potentially misinforming environmental management decisions. The reconstructed data will be integrated into the Land Degradation Neutrality Tool under the Open Earth Monitor project, providing stakeholders, including farmers and policymakers, with high-resolution insights essential for sustainable land management.

"Systemic human-biosphere-atmosphere monitoring and diagnostics" by Gregory Duveiller (MPG)

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"Spatiotemporal prediction of SOCD for Europe (2000–2022) in 3D+T" by Xuemeng Tian (OGH)

The session on "Systemic Human-Biosphere-Atmosphere Monitoring and Diagnostics" explores the development of a Planetary Health Index to capture the interactions between human, biospheric, and atmospheric domains. The objective is to simplify the complexity of Earth system data into essential indices that act as diagnostic tools, much like medical indicators for human health. By summarizing large datasets from socioeconomic, biospheric, and atmospheric sectors, the initiative aims to identify "syndromes of change" that signal significant environmental shifts,

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potentially due to human activity, natural disturbances, or socioeconomic changes. Gregory presented this model as a pathway for tracking and understanding environmental health across countries, which could inform both regional and global policy.
The concept employs a data-driven approach to try to identify trends and causal relationships within the Earth system, recognizing the temporal and spatial dynamics that affect planetary health. By analyzing shifts in these indices over time, the project hopes to detect legacy effects, teleconnections, and concurrent fluctuations across domains, offering insights into how economic or environmental events in one area may impact another. While current results still do not show such effects, the effort will still establish an open framework that will be applicable to other datasets from the target stakeholder, the European Central Bank. The presentation also emphasized the importance of interpretability and consistency in these indices, ensuring they are scientifically robust yet accessible for policymakers. This effort is part of a broader aim to build a reliable, comprehensive monitoring framework that can assess global health status through simplified, actionable data.
The session on “Spatiotemporal prediction of SOCD for Europe (2000–2022) in 3D+T” by Xuemeng Tian discusses a framework to model and predict soil organic carbon (SOC) density, utilizing a seven-step modular process involving data preparation, model calibration, and validation. The approach relies on environmental covariates, including vegetation and soil spectral indices, derived from high-resolution satellite data. SOC density serves as a crucial indicator of soil health, supporting ecological functions. The process begins with the collection and harmonization of SOC measurement data and covariate layers, followed by covariate selection, model fine-tuning, prediction evaluation, and concludes with map production. The Lucas soil survey serves as a reference for ensuring data consistency, and the team applies transformations for comparability across other datasets.
Xuemeng highlights challenges, including the slow rate of SOC change over time, which makes detecting temporal variations with machine learning models difficult. Therefore, caution is advised when interpreting SOCD maps. The pipeline, implemented with tools like Scikit-Learn and Scikit-Map, is designed for flexibility, allowing individual steps to be executed by different team members and reassembled as a cohesive workflow. This structured framework highlights the importance of accurate SOC data for environmental monitoring and aligns with OpenGeoHub’s efforts to advance reproducible, large-scale environmental datasets for soil health assessment.

“Playing the water cycle game: data from space for flood risk mitigation and better-managing water resources” by Luca Brocca (CNR)

The session on " Playing the water cycle game: data from space for flood risk mitigation and better-managing water resources” by Luca Brocca focused on using predictive models and digital platforms to anticipate river discharge levels and manage water resources effectively. By simulating scenarios with soil moisture and precipitation data, the model can forecast peak discharge levels, indicating potential flooding. Luca demonstrated how exceeding set thresholds (yellow and red lines) could signal the need for preventive action by civil protection. This tool,

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initially tested in the Po River Basin in Italy, offers an interactive experience, enabling users to adjust parameters and observe potential impacts on water flow. The model's utility lies in its ability to give real-time insights, particularly for flood-prone areas, supporting informed decision-making. Another key aspect of the presentation was the role of digital twin platforms in water resource management, especially in addressing droughts and water scarcity issues. The tool allows stakeholders to simulate water usage scenarios across industrial, civil, and agricultural sectors, with a focus on balancing supply and demand. Emphasizing the agricultural sector's high-water demand, particularly during summer, the model integrates diverse inputs such as snowmelt and soil moisture data to predict water availability over a seasonal period. The project underscores the need for collaborative development with local agencies to enhance functionality and ensure that digital tools meet regional management needs, ultimately supporting efficient, sustainable water use and proactive flood risk reduction.

“Exploring the biophysical impacts of potential changes in tree cover in Africa” by Gregory Duveiller (MPG)

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“ForestNavigator: combining forest monitoring and modeling for assessing policy pathways towards EU climate neutrality” by Fulvio Di Fulvio (IIASA), Andrey Lessa Derci Augustynczik (IIASA), Petr Havlik (IIASA)

The session titled “Exploring the Biophysical Impacts of Potential Changes in Tree Cover in Africa” by Gregory Duveiller focused on the implications of tree cover alterations on local climate in Africa. The presentation examined how ongoing deforestation, primarily for commodity crops, and reforestation efforts are shifting the landscape and influencing biophysical processes. Gregory discussed initiatives such as ecosystem restoration, which can lead to localized cooling effects due to increased vegetation. The presentation also highlighted how these biophysical changes can impact factors like temperature, carbon flux, and even cloud cover, as forested areas tend to create larger cloud formations compared to grasslands. Furthermore, Gregory presented modeling techniques used to quantify the effects of land cover changes, such as comparing temperature differences between forested and non-forested areas to infer the cooling or warming effects of various vegetation types. The session emphasized that while forest cover generally contributes to cooling, the extent varies based on water availability and regional conditions. These findings underscore the complex interplay between tree cover and climate, as well as the potential benefits of reforestation and sustainable land management strategies to counterbalance deforestation in Africa. The research aims to provide insights for policymakers on how best to manage land use to achieve climate goals while supporting biodiversity and ecosystem resilience. The session "ForestNavigator: Combining Forest Monitoring and Modeling for Assessing Policy Pathways Towards EU Climate Neutrality" presented by Fulvio di Fulvio highlighted efforts to leverage both monitoring and modeling tools to support the EU’s climate neutrality goals. The project integrates remote sensing, national forest inventory (NFI) data, and socioeconomic drivers to create a comprehensive modeling framework that can project EU forest

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mitigation pathways, including impacts of climate change on forest growth, and the impacts of natural disturbances like drought, windstorms, beetles and wildfire. The ForestNavigator framework combines detailed forest data with climate and economic models, aiming to create pathways that maximize carbon sequestration and align forest management practices with EU climate policies. Fulvio noted that EU forests currently act as a significant carbon sink but face challenges from declining forest sink capacity and extreme climate events, which threaten their ability to contribute to net-zero emissions targets.
The ForestNavigator platform allows policymakers to explore pathways that incorporate biodiversity conservation, bioeconomy goals, and mitigation strategies. Through the use of process-based models, the platform can simulate different managements and climate scenarios, assessing their short and long-term impacts on forest carbon dynamics. This integrated approach, which also includes calibration with ground and remote sensing data, aims to address policy gaps by providing accurate timely data for forest-based climate mitigation efforts in the EU. The ongoing challenge lies in harmonizing data from varied sources to keep the projections reliable and relevant. The session emphasized the need for near real-time data to capture rapid environmental changes accurately, also by means of remote sensing observations, for reflecting observed rapid changes in the modeling of policy relevant pathways.

“The GEO Trees Project” by Dmitry Shchepashchenko (IIASA)
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“Drought monitoring across scales with open soil moisture remote sensing data” by Jaime Gaona (CNR)

The session on "The GEO-Trees Project" presented a collaborative initiative aimed at bridging remote sensing experts and the ecological community to improve biomass and canopy height mapping through reliable ground data collection. The GEO-Trees project involves several institutions, including IIASA (Austria), CNRS (France), Smithsonian Institution (USA), University of Leeds (UK) and ESA, working together to validate biomass and canopy measurements using both ground and satellite data. Dmitry explained how the initiative prioritizes large forest plots (over one hectare) for accurate validation and seeks to standardize measurements across regions. New collaborations with ecological networks are underway, and there is a significant focus on making data open access, enabling broader usage and fostering a sustainable approach to continuous data collection, especially in regions like the tropics, where changes are rapid.
The session highlighted technological advancements such as the use of the Biomass R-package, which processes tree-level to plot-level data, calculating biomass with multiple methods and accounting for uncertainties. The GEO-Trees database, accessible through a web portal, hosts over 300 locations with detailed plot information, including biomass and canopy height. The initiative has recently expanded to include “super sites”, larger plots with extensive data, supported by funding from the Bezos Foundation to establish around 100 plots in tropical regions. This open-access framework aims to support current and future space missions by providing

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validated ground data, which is critical for both model calibration and the validation of remote sensing data in biomass and forest structure studies.
The session on “Drought Monitoring Across Scales with Open Soil Moisture Remote Sensing Data” explored the use of open-source soil moisture data derived from various satellite missions, such as SMOS and SMAP, to monitor drought conditions effectively across different geographic scales. The presentation highlighted the importance of soil moisture as a critical variable in the water cycle, influencing agricultural productivity, hydrology, and climate change impacts. Soil moisture data from both active and passive remote sensing sources was compared, showing how variations in spatial and temporal resolutions affect the precision of drought monitoring. Jaime discussed the European Drought Monitor and Flood Forecast as well, as examples where soil moisture data is integrated to provide timely information on drought and flood risks, supporting decision-making for disaster response and resource management.
Challenges in utilizing these data sets, especially for non-expert users, were a focus of the session. Jaime explained that combining soil moisture data from different models and remote sensing sources can sometimes introduce inconsistencies due to differing resolutions and data collection methodologies. He demonstrated how integrating various data sources, despite these challenges, can improve the robustness of drought assessments by leveraging the unique strengths of each dataset. For example, Sentinel-1 provides high-resolution soil moisture data that captures localized changes, making it suitable for finer-scale drought monitoring, while larger-scale models offer broader regional insights. The session underscored the potential for these open data sources to enhance environmental monitoring, especially when combined with new tools that make data more accessible and applicable to a wide range of users.

“Spatiotemporal Machine Learning: fitting models and generating predictions using time-series data” by Tomislav Hengl (OGH)

—

“Accessing global scale, historical and complete Landsat data” by Davide Consoli (OGH)

The workshop “Spatiotemporal Machine Learning: fitting models and generating predictions using time-series data”, led by Tomislav Hengl, delved into spatial-temporal machine learning's application in environmental data modeling, focusing on the unique challenges of integrating both time and space correlations. Tomislav introduced key concepts like the complexities of modeling highly dynamic environmental variables (e.g., soil moisture, temperature) and explores the differences between traditional geostatistics and machine learning for these data types. He emphasized the importance of sampling design for dynamic data, showcasing how models can capture seasonal and spatial variations effectively. Additionally, he presented examples from datasets such as the Copernicus Land Monitoring Service, illustrating how transformation techniques and Random Forest algorithms can improve predictions.
A significant discussion point was model validation, where Tomislav explained methods to avoid overfitting and highlights the necessity of rigorous testing, such as removing entire stations to yield realistic performance metrics. The session also touched on cumulative variables and

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advanced covariate analysis, discussing the role of long-term trends in environmental models. Tomislav concluded by underscoring the need for exhaustive datasets and incorporating biophysical theories into model design, noting that these steps help bridge gaps and ensure data completeness in spatial-temporal machine learning applications. The data used in the workshop is from: *Hackländer J, Parente L, Ho Y, Hengl T, Simoes R, Consoli D, Şahin M, Tian X, Jung M, Herold M, Duveiller G, Weynants M, Wheeler I. 2024. Land potential assessment and trend-analysis using 2000–2021 FAPAR monthly time-series at 250 m spatial resolution. PeerJ 12:e16972*

The second session “Accessing global scale, historical and complete Landsat data” by Davide Consoli, focused on making global, historical Landsat data accessible for large-scale environmental analysis. Davide highlighted the challenges with cloud cover and other artifacts that often render Landsat images less usable. To overcome this, the team preprocessed and reconstructed the data by filtering out clouds, temporally aggregating, and reconstructing missing data points. The dataset, spanning over 26 years with around six images per year, comprises a vast 100 TB of information at a 30-meter resolution, providing a comprehensive source for environmental and land use studies. Davide introduced a Colab notebook designed for hands-on access, allowing users to retrieve, manipulate, and even download this extensive dataset, although performance may vary depending on internet speed.

This data processing supports use-cases like land degradation monitoring, as the data includes various bands essential for analyzing environmental change over time. The reconstructed dataset is particularly beneficial for evaluating land productivity, soil carbon, and land cover, critical indicators for land degradation neutrality. By collaborating with organizations such as the UNCCD, the team aims to support land degradation assessment at a finer 30-meter resolution, which is a notable improvement over the existing 250–300-meter products, thus enabling more precise environmental modeling and policy support.

3.3 Friday, 4 October

Keynote: “Implementing Open EO Knowledge and the journey towards users’ engagement” by Paola De Salvo (GEO)

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Keynote: “Rethinking the grid: Towards less distorted imagery and AI” by Daniel Loos (MPG)

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Keynote: “EO for Policymaking in the EU” by Marc Dowell (EC JRC) (YouTube link)

The first Keynote session "Implementing Open EO Knowledge and the Journey Towards User Engagement" by Paola De Salvo emphasized the role of the Group on Earth Observations (GEO) in making Earth observation data widely accessible and actionable. GEO, a global partnership of 116 member states, is committed to open access to environmental data from satellite and in-situ observations. This commitment is demonstrated through the development of the GeoKnowledge

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Hub, an open platform that offers knowledge packages and tools designed to support policies addressing global challenges like climate change, food security, and biodiversity. The platform aims to empower users worldwide, particularly in underserved regions, by democratizing access to critical environmental data and tools.
In her talk, Paola discussed the collaborative and evolving nature of the GeoKnowledge Hub, which is built upon open-source infrastructure and supported by an engaged community. The platform's success hinges on both content development and active user engagement. GEO has conducted webinars and workshops to introduce the platform to a broad audience, with notable success in engaging new users and organizations. Furthermore, GEO is addressing barriers to adoption by integrating additional languages and forming partnerships with universities and governmental entities, ensuring that Earth observation data can be utilized effectively across diverse contexts.
The second Keynote session "Rethinking the Grid: Towards Less Distorted Imagery and AI" by Daniel Loos discussed the importance of reducing image distortions in Earth observation to improve both visual accuracy and AI performance. Traditional mapping systems project Earth's three-dimensional surface onto a two-dimensional plane, creating distortions, particularly near the poles. Such distortions not only misrepresent the relative sizes of geographical features but also affect AI and machine learning models trained on these images. Daniel explained that neural networks often struggle to generalize when trained on distorted data, leading to limitations in their application to real-world, transformed images.
To address these challenges, Daniel proposed utilizing discrete global grid systems (DGGS) based on hexagonal or polyhedral structures, which offer more accurate area representations. DGGS allows Earth's surface to be tessellated into equal-area tiles, minimizing data redundancy and improving computational efficiency for large datasets. Implementing these grids can also streamline data processing by reducing the volume of data loaded, which is critical in machine learning. Daniel highlighted the benefits of rotationally invariant hexagonal grids, which facilitate faster model training and improved generalization in AI applications.

"Deriving policy-relevant geodata from satellite images: lessons learned in the GEO.INFORMED project" by Stien Heremans (KU Leuven) (YouTube link)

—

"Global Trait-Based Vegetation Monitoring" by Felix Specker (ETH Zurich)

The second session "Global Trait-Based Vegetation Monitoring" by Felix Specker introduced a novel approach to monitoring vegetation globally through trait-based metrics, as part of the Open Earth Monitor project. This method aims to assess ecosystems' health by focusing on biophysical traits like leaf area index, chlorophyll concentration, and water content, which are directly linked to ecosystem functions such as transpiration and primary productivity. By using radiative transfer models and Sentinel-2 satellite data, Specker's team simulates the expected reflectance of these traits, generating training data for machine learning models to predict vegetation traits from

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satellite imagery. This hybrid modeling approach, combining mechanistic and machine learning techniques, enables the generation of global maps of vegetation traits.
Felix discussed how these trait maps could support biodiversity conservation efforts, with applications including functional diversity assessment and ecosystem restoration monitoring. A use-case on the Yucatán Peninsula demonstrated the ability to track reforestation progress by comparing current vegetation traits to baseline values from intact neighboring forests. The project's outputs are made available through the Restore platform, allowing restoration practitioners worldwide to measure and communicate their progress in restoring degraded lands to natural, biodiverse ecosystems.

“Citizen Science Mobile App and Data in Support of Forest Mapping: Laxenburg Park Campaign” by Milutin Milenković (IIASA)

—

“Inferring spatiotemporal dynamics of mosquitoes in Italy using machine learning” by Carmelo Bonannella (OGH), Daniele Da Re (U.Trento)

The OEMC use-case 32 was presented at the workshop “Citizen Science Mobile App and Data in Support of Forest Mapping: Laxenburg Park Campaign”, where the use-case leader, Milutin Milenković (IIASA), presented the mobile app tools developed within the use-case, and the Stakeholder, Silvia Barbosa Rodrigues (University of Brasília, Embrapa), participated online and presented the feedback they collected during the Stakeholder field testing of the Forest-Quest app functionalities, i.e., the augmented reality implementation of the Bitterlich method. During the discussion session, several additional functionalities were identified with the Stakeholder and the other workshop attendees for further app development.
The second session "Inferring Spatiotemporal Dynamics of Mosquitoes in Italy Using Machine Learning" by Carmelo Bonannella and Daniele da Re, presented a machine learning-based study on monitoring the spread and activity patterns of the tiger mosquito (Aedes albopictus) in Italy. Recognized as a public health concern due to its potential to transmit diseases, the tiger mosquito has a high adaptive capacity, requiring continuous surveillance. Carmelo and Daniele used environmental variables, such as temperature, humidity, and precipitation, in combination with data on mosquito populations from trap counts to train machine learning models that predict mosquito activity across different regions and times. This predictive capability aims to support local health authorities in optimizing mosquito control measures.
The study underscored the value of accurate, real-time data integration, highlighting the difficulties in capturing mosquito lifecycle variability due to changing environmental conditions. The project is part of the Open Earth Monitor Project’s broader objective of supporting actionable insights for public health interventions. Discussions in the workshop focused on enhancing model accuracy, potential scaling to other regions, and integrating citizen-reported data on mosquito sightings to improve predictive models.

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“Mapping Cocoa Farms Across Pantropical Regions Using High-Resolution Satellite Imagery and Deep Learning” by Robert Masolele (WUR) (YouTube link)

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“EarthCODE – A FAIR Open Science environment for the Earth sciences” by Garin Smith (Telespazio)

The second session "EarthCODE – A FAIR Open Science Environment for the Earth Sciences" by Garin Smith presented EarthCODE, an initiative designed to foster a FAIR (Findable, Accessible, Interoperable, Reusable) Open Science environment tailored for Earth sciences research. EarthCODE addresses the pressing need for open and accessible data in Earth sciences, aiming to streamline data sharing and collaboration among researchers globally. Garin explained how EarthCODE integrates with existing data repositories and platforms, promoting a unified ecosystem that supports standardized data formats and enhances data interoperability. Through these standards, EarthCODE enables scientists to access and share datasets efficiently, fostering innovation and accelerating the research process in fields like climate science, ecology, and geospatial analysis.
Garin presented how, in addition to providing technical infrastructure, EarthCODE also emphasizes community engagement and education to ensure researchers adopt FAIR principles effectively. The platform offers resources for scientists to make their datasets compliant with FAIR standards and supports computational tools that facilitate data analysis and model sharing. The presenter also discussed EarthCODE’s role in reducing research redundancy by making data from various Earth science projects available to a broader audience, ultimately contributing to a more transparent and collaborative scientific environment. By aligning with open science practices, EarthCODE aims to set a new standard for how data in the Earth sciences is managed and disseminated.

“High-Resolution Gross Primary Productivity: Modeling and Mapping Dynamics” by Serkan Isik (OGH)

—

“Using GRASS, SAGA, and Whiteboxtool to map global high-resolution land relief parameterization adopting Equi7 projection system” by Yu-Feng Ho (OGH)

The session “High-Resolution Gross Primary Productivity: Modeling and Mapping Dynamics" by Serkan Isik delved into the creation of a high-resolution (30-meter) global map for Gross Primary Productivity (GPP), which models the rate at which ecosystems convert sunlight into biomass. Using Landsat satellite data combined with land surface temperature from MODIS and photosynthetically active radiation (PAR) from CERES product, uncalibrated GPP and grassland GPP maps are generated on a bimonthly and annual basis, providing critical insights into land productivity and carbon sequestration potential. The GPP model is based on a light-use efficiency approach, linking incoming solar radiation with vegetation's efficiency in converting this energy to

biomass. This project emphasizes applications in climate change studies, agriculture, land degradation monitoring, and land productivity assessments, offering insights at a finer scale than previously available global products.

Serkan also highlighted the model's flexibility, allowing for adjustments in land cover and vegetation productivity to tailor outputs to specific regions or biomes. The GPP dataset's extensive temporal coverage, spanning over two decades, facilitates trend analysis, supporting long-term environmental monitoring and climate adaptation efforts. To validate the model, Isik's team used flux tower data from networks like FluxNet and AmeriFlux, ensuring accurate readings across diverse biomes. The Open Earth Monitor platform serves this data, providing open access and enabling researchers to visualize productivity changes globally, especially in grasslands where vegetation monitoring is crucial for sustainable land management. These products are linked to "*Global monitoring system for livestock and grasslands / pastures"* and "*Land Degradation Neutrality tool"* use-cases in the project.

The second session "Using GRASS, SAGA, and Whitebox Tool to Map Global High-Resolution Land Relief Parameterization Adopting Equi7 Projection System" by Yu-Feng Ho demonstrated the use of open-source GIS tools—GRASS, SAGA, and Whitebox Tool—in mapping high-resolution terrain parameters, such as slope, aspect, and topographic wetness, essential for earth system modeling and soil analysis. By adopting the Equi7 projection system, the project enables seamless mapping across continental scales, optimizing spatial accuracy for diverse Earth observation tasks. The methodology relies on digital elevation models (DEMs), leveraging various sophisticated software to assemble a comprehensive terrain dataset that facilitates accurate environmental and hydrological modeling at a 30-meter resolution.

According to Yu-Feng, this terrain parameterization enhances understanding of ecological processes by factoring in geomorphological characteristics critical for soil moisture, erosion studies, and climate-impact analysis. Yu-Feng's workshop included a practical session demonstrating how to access and process DEMs using SAGA, GRASS, and Whiteboxtool in QGIS integrated with the Equi7 system, showcasing the open-access nature of the data for researchers worldwide. The integrated approach developed by Open Earth Monitor address current limitations in terrain data availability, aiming to standardize and make accessible high-quality global terrain data for scientific and practical applications.

4. Main Discussion Points and Main Conclusions from the Global Workshop

Main Discussion Points:

Role of Earth Observation (EO) in Policy and Sustainability:

- EO data's role in monitoring compliance with environmental policies, particularly for the European Green Deal and EU Deforestation Regulation (EUDR).
- Use of EO in tracking deforestation, biodiversity pressures, and land-use changes for environmental conservation and policy enforcement.

Data Harmonization and Accessibility:

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- Addressing data integration challenges across multiple sources, especially for projects like Global Forest Watch and WorldCereal, which involve multi-layered datasets for forestry, crop, and livestock monitoring.
- Importance of FAIR data principles and overcoming barriers in data accessibility, metadata standards, and interoperability to support a wider user base.

Advancements in Remote Sensing and AI:

- Integration of SAR data, AI, and machine learning to improve monitoring capabilities for land disturbances, forest biomass, and habitat types.
- Exploring multi-frequency SAR datacubes and Automated Machine Learning (AutoML) for efficient spatial data analysis, aiming to enhance global monitoring efforts with real-time insights.

Climate and Biodiversity Conservation Efforts:

- Projects like ForestNavigator focus on integrating EO data with climate and socioeconomic models to project carbon stocks and ecosystem resilience in line with EU climate neutrality goals.
- Discussions on using trait-based vegetation monitoring and high-resolution data for effective biodiversity assessments and ecosystem restoration.

Water Resource and Flood Risk Management:

- Utilization of high-resolution Digital Elevation Models (DEMs) and machine learning for predictive models in flood and drought risk reduction, especially for real-time applications in flood-prone regions.
- Emphasis on digital twin platforms to support water resource management through scenario simulations.

Open Science and Inclusivity in EO:

- Importance of open data access through platforms like GeoKnowledge Hub and EarthCODE to democratize environmental data and support sustainable development in underserved regions.
- Focus on gender inclusivity in EO, with discussions on barriers faced by women and actionable strategies like mentorship and gender-relevant initiatives.

Main Conclusions:

EO as a Critical Tool for Policymaking:

- EO data is indispensable for effective policy enforcement on climate, biodiversity, and environmental issues, with growing applications across agriculture, forestry, and urban planning.
- Enhanced data integration, particularly with multi-source and multi-frequency data, can provide a more holistic view of environmental changes.

Need for Improved Data Harmonization and FAIR Standards:

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- Harmonizing EO data across scales and platforms is crucial for actionable insights, with FAIR data principles identified as essential to ensure usability across sectors and regions.
- Continued user-producer engagement is needed to address knowledge gaps and resource limitations for adopting FAIR standards.

Advances in AI and Machine Learning:

- Automation and machine learning in EO data processing, particularly with AutoML and SAR datacubes, show promise for scalable and accessible EO applications in environmental and disaster management.
- These tools, combined with open-source solutions, can reduce dependency on expertise, making EO data more accessible for decision-makers.

Targeted Conservation and Climate Resilience:

- EO-based models like ForestNavigator and Geo Trees offer valuable insights for biodiversity conservation and carbon sequestration efforts, supporting climate goals.
- Monitoring forest and biodiversity pressures through high-resolution, localized data is essential for effective ecosystem restoration and conservation policies.

Open Science and Gender Inclusion as Core Values:

- Open data platforms, such as EarthCODE, are crucial for creating equitable access to EO data, while inclusivity strategies, especially for women in EO, are necessary to foster a supportive and diverse environment within the field.
- The Workshop reinforced a commitment to open science practices to ensure EO benefits reach diverse communities and contribute to broader sustainable development objectives.

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Annex

Abstracts

Monitoring livestock and agricultural systems: An ensemble approach based on data harmonization, by Leandro Parente (OGH)

Approximate five billion hectares (38%) of global land area is used for agricultural system, contributing significantly to the loss of biodiversity and having a substantial impact on water resources and greenhouse gas emissions of the World. Aiming to support multi-scale environmental policies and decision-making process, several land monitoring systems / products were launched in the last years, including WorldCereal, GLaNCE, Dynamic World, UMD GLAD GLCLUC, GLC_FCS30D and Global Pasture Watch. Even though all these systems / products have different advantages, limitation, constraints and resolutions (thematic, spatial and temporal), in general they have a high potential to be combined to support different land cover and land use applications at global, national and local scale. Here we present a framework able to integrate global monitoring systems / products in an automated, flexible and reproducible way, taking advantage of new technologies such as cloud-optimized formats and cloud services. We demonstrated it integrating different crop and pastures classes in seamless monitoring system for the tropics, allowing the users to define their own area of interest, harmonization rules and overlap criteria. The implementation is publicly available in scikit-map (https://github.com/openlandmap/scikit-map) and all input layers publicly accessible through SpatioTemporal Asset Catalog (STAC).

Quantifying the (mis)match between in-situ and satellite time series: the case of eddy covariance flux observations by Daniel E. Pabon-Moreno (MPG)

Eddy covariance (EC) systems are commonly used to measure the net exchanges of energy, water carbon dioxide (CO2) and other trace grasses between the ecosystems and the atmosphere. Such measuring systems have been established in different ecosystems and climate regimes across the globe, thereby providing invaluable ground information to understand ecosystem dynamics at global scale. Although the number of EC stations installed worldwide (e.g. FLUXNET sites) are constantly growing with time, their spatial distribution is limited in comparison to the vast complexity of land ecosystems. Furthermore, EC towers track the exchange of energy and matter from an area (often referred to as a footprint) that spans some few hundred meters around and upstream of the measurement site (the so-called fetch), and which can vary according to meteorological conditions. Remote sensing (RS) and in-situ flux datasets are commonly combined to upscale the exchanges of carbon and energy at a global scale (e.g. the FLUXCOM project), as well as for calibration and validation activities. The challenge to do this correctly lies in trying to link the footprints of the EC measurements to those of the satellite measurements, a

task that is often disregarded or oversimplified. In this study we designed a methodological approach within the Open-Earth-Monitor (OEMC) project to estimate dynamically the match (or mismatch) between some likely proxies of EC footprints (approximated as circles with radius from 50 to 200 meters) and the footprints of (coarse) spatial resolution RS time series. To quantify the degree of mismatch we collect Sentinel-2 images at 10 meters resolution for several EC sites over Europe. Then, we compute the kNDVI vegetation index for all the sites masking clouds and cloud shadows. We also define proxies for different pixel sizes of satellite data ranging from 500 meters to 1500 meters radius around the tower. To compare the EC footprints with the Satellite pixel resolution we compute the Jensen-Shannon index that quantifies the amount of information (in terms of kNDVI) shared between both scales at every available time step. As a result, we provide initial recommendations of when in the year the sites are more suitable to be matched with satellite data according to the surrounding phenology. We expect these will open the possibility to correct biases in future upscaling fluxes exercises and remote sensing products calibration.

Workshop: MeteoEurope1km: a high-resolution daily gridded meteorological dataset for Europe for the 1961–2020 period by Aleksandar Sekulić (BG AC)

Daily gridded meteorological datasets are an important source of information for analysis of historical weather and many other research areas since they have no gaps in the spatio-temporal domain they cover. Most of the daily gridded meteorological datasets represent reanalysis or estimations from different remote sensing sensors or are generated by downscaling procedures. A daily gridded meteorological dataset for Europe at 1 km spatial resolution, named MeteoEurope1km, is created, covering the 1961–2020 period and consists of five variables: maximum (TMAX), minimum (TMIN), and mean (TMEAN) temperature, sea-level pressure (SLP), and total precipitation (PRCP). Spatio-temporal regression kriging, an interpolation method that combines multiple linear regression for trend modeling and space-time kriging for the estimation of the residuals, is used for interpolation of daily temperature variables. Ordinary kriging is used for SLP and PRCP, except that for PRCP an additional step to predict PRCP occurrence is applied using Indicator kriging. Combination of GHCN-daily, ECA&D, and SYNOP observations from OGIMET service is used as an observational dataset, with previous removal of duplicated stations and outliers. Geometric temperature trend, digital elevation model and topographic wetness index are used as auxiliary variables for temperature datasets. Accuracy assessment (leave-one-station-out cross-validation) shows high accuracy of the fitted models. Coefficient of determination for all temperature parameters and SLP is greater than 96%, while for PRCP is greater than 76 %. Root mean square error is 1.3°C, 1.6°C, 1.8°C, 1.5 mbar, and 2.5 mm for TMEAN, TMAX, TMIN, SLP, and PRCP, respectively. MeteoEurope1km is available as cloud optimized GeoTIFFs, and are accessible through dailymeteo.com portal, ZENODO, and R meteo package. Future work will be oriented towards increasing the spatial extent to other continents besides Europe, interpolation of other daily meteorological variables, and improving models performances by applying spatial machine learning methods, such as Random Forest Spatial Interpolation.

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The workshop will be structured in two parts. The first part will be focused on the methodology applied, accuracy assessment, drawbacks and future plans. The second part of the workshop will focus on MeteoEurope1km data access and usage (COGs, ZENODO, QGIS, R meteo, Python, REST API, portal).

Assessing forest disturbance dynamics and drivers using radar satellite data by Mikaël Maes, Ivan Haščič (OECD)

Satellite radar remote sensing utilizes long-wavelength energy that can penetrate clouds and is sensitive to changes in the physical structure of vegetation. These characteristics, in combination with the high spatial and temporal detail of new and near-future radar satellites, provide major opportunities for monitoring forest disturbances and regrowth dynamics.We provide an overview of recent research activities on the use of radar remote sensing to monitor forest dynamics and present key results achieved in the Open-Earth-Monitor project. These include forest disturbance monitoring, monitoring of forest loss drivers and carbon, and assessments of selective logging intensity. We will highlight how the near-future availability of freely available multi-frequency radar data from Sentinel-1 (C-band), NISAR (L-band), and BIOMASS (P-band) will improve our ability to assess forest dynamics. We will also discuss our open-source initiatives aimed at facilitating the adoption of radar data and change detection approaches by both the scientific community and country stakeholders.

WorldCereal: a dynamic open-source system for global-scale, seasonal, and reproducible crop mapping by Kristof Van Tricht (VITO)

The WorldCereal project, funded by the European Space Agency (ESA), aims to provide a comprehensive understanding of global cropped areas, irrigation practices, and the distribution of major commodity crops. WorldCereal has developed a dynamic open-source system that generates a range of products, including temporary crop extent, seasonal maize and cereal maps, seasonal irrigation maps, seasonal active cropland maps, and confidence layers. These products are based on the analysis of Sentinel-1 and Sentinel-2 imagery at 10 m spatial resolution, complemented by Landsat 8 imagery and AgERA5 meteorological information, and are updated at seasonal intervals for each agricultural system. WorldCereal has demonstrated the feasibility of global crop mapping by producing the first global, seasonally updated crop and irrigation maps for the year 2021. WorldCereal has also released a fully open, harmonized database of in-situ reference data related to land cover, crop type, and irrigation, enabling a broad community to access and contribute to this growing resource. WorldCereal is now entering a new phase, in which the system is being implemented as a cloud-based processing service in the new Copernicus Data Space Ecosystem. The system will offer more flexibility and customization options to users, allowing them to generate tailored crop type products for their regions of interest. Moreover, the WorldCereal product suite will be extended with eight new crops, and the in-situ

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reference database will be updated and expanded. WorldCereal will also conduct a series of regional use cases and capacity building activities to demonstrate the system's capabilities and to boost user uptake by the broad agricultural monitoring community. WorldCereal provides a vital tool for policymakers, international organizations, and researchers to better understand local to global cropping patterns and to inform decision-making related to food security and sustainable agriculture.

Mapping land use management in Europe using remote sensing, in situ data and statistical information by Linda See (IIASA)

There is currently a lack of high-resolution pan-European information on land use management, especially in terms of how forests, cropland and grassland are intensively and extensively managed. This is partly due to the lack of ground-based information, which is needed to downscale these types of management practices (some of which are captured in different types of agricultural censuses and surveys and National Forest Inventories) as well as the inability of remote sensing to capture different kinds of land use. This type of information is needed for economic land use modelling and for assessing policy impacts, such as the latest reforms from the Common Agricultural Policy (CAP) and other European Union (EU) Green Deal targets. These types of analyses are undertaken using economic land use models such as GLOBIOM and CAPRI, which is one of the main aims of the Horizon Europe funded LAMASUS project (https://www.lamasus.eu/).
One of the main inputs to the development of a land use management map is Corine land cover, which is a remotely sensed product developed by the Copernicus Land Monitoring Service every six years. First, we produced an annual time series of Corine from 2000 to 2018 by using the high-resolution land cover times series produced by OpenGeoHub and the BFAST algorithm applied to MODIS data to determine the year of change between the six-year production cycle of CORINE. Any remaining changes that were unaccounted for had the year of change selected randomly. Transition rules were also applied to ensure that the land cover/land use transitions were reasonable. Land use management classes for forest, cropland, grassland and urban areas were then devised in collaboration with the modelers in the LAMASUS project as well as around 30 stakeholders who participated in the first LAMASUS stakeholder workshop. Using different input data sets from remote sensing, in-situ data (from LUCAS), modelled data from CAPRI, and statistical information from agricultural censuses, surveys and other sources, rules were developed to allocate the Corine land cover classes to more detailed land use management classes. Here we will present the results of this mapping along with a method for how the map has been fit to official area statistics so that this information can be used by the economic land use models in LAMASUS.

Assessing population exposure to air pollution: A multi-pollutant indicator framework for OECD countries and partners by Mikaël Maes, Ivan Haščič (OECD)

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101059548.

Air pollution, particularly fine particulate matter (PM2.5), ground-level ozone (O3), and nitrogen dioxide (NO2), poses a significant global health risk, contributing to early mortality. Measuring population exposure is crucial for understanding and mitigating these health impacts. This paper leverages recent advancements in air pollution data to review various global air pollution datasets based on a criteria set. The framework facilitates comparisons between various hybrid datasets (combining ground-based and satellite measurements) and offers a methodology for constructing air pollution exposure indicators for PM2.5, O3, and NO2. It uses the Global Burden of Disease data to update the indicator set on the national and subnational levels across the 1990-2020 period. Results reveal that most OECD countries fall short of the World Health Organization's (WHO) 2021 air quality guidelines for PM2.5, O3, and NO2. Countries such as Chile, Korea, Poland, and Türkiye exhibit PM2.5 concentrations (population weighted) exceeding safe levels by a factor of four. Similarly, several OECD countries such as Korea, Italy, and Slovenia experienced severe O3 exposure in 2020, while non-OECD countries such as India displayed even higher population weighted O3 concentrations, exceeding safe levels by more than double. A sensitivity analysis further indicates that despite similar trends observed across different air pollution datasets, considerable differences are found between global datasets and national statistics. This highlights the need to further examine the accuracy of the various data sources and help guide policy analysis at the national and subnational levels. Given the widespread failure to meet safe air quality standards, our findings emphasize the urgent need for global policy actions to reduce population exposure to air pollution and safeguard public health.

Workshop: Streamlining Earth Observation Data Sharing with the zen Python Library by Rolf Simoes (OGH)

This workshop introduces the zen library developed as part of the OEMC project. zen can simplify the upload and management of Earth Observation (EO) datasets on the Zenodo platform, making it easier for researchers and developers to adhere to Open Science principles and share their data openly.
Objectives:

- Familiarize participants with the Zenodo platform and its role in Open Science.
- Introduce the zen library and its functionalities for managing EO datasets.
- Guide participants through hands-on exercises on uploading EO datasets; customizing metadata; and automating data management workflows.

High-resolution spatial information on livestock density and grassland management in Europe by Žiga Malek (IIASA)

Improving the sustainability of the European livestock sector requires high resolution spatial data. Otherwise, potential negative impacts of livestock related to local ecosystem degradation, as well as positive ones such as preserving cultural landscapes through grazing cannot be analysed. Data on livestock numbers usually used in scientific analyses are collected and provided by the

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European statistical office but are provided on a rather coarse spatial resolution of statistical regions. In addition, data on the actual use of grasslands, whether grazed, mown and the intensity of their use is not collected systematically or not at all. We provide an approach for mapping grazing livestock (cattle, small ruminants) density and the use of grassland for Europe. We first collected livestock numbers on a local level for all EU countries, which we harmonized, and supplemented it with statistics on actual outdoor grazing of animals. We then mapped areas that are grazed by combining EU-wide in-situ data on grazing with a set of socio-economic, terrain, soil and climate characteristics using machine learning. We then allocated grazing livestock on two different earth observation derived land use and land cover products: Corine land cover and the high-resolution grassland layer. Our approach enables identifying areas that are grazed, and combined with livestock statistics, also how intensively these areas are used either for grazing or mowing. Such information can support tracking the state of European grassland ecosystems, landscape conservation, as well as other environmental dimensions related to the livestock sector, such as nitrogen deposition, with a high spatial detail. Finally, by using regularly updated systematically collected data, we can update the data in the future.

User and producer perspectives for FAIR environmental data by Katja Berger (GFZ)

Findable, Accessible, Interoperable, and Reusable (FAIR) data principles are composed of a set of guidelines focused on efficient discovery and data utilization, which are crucial for sharing scientific data effectively. Hence, adapting to the FAIR principles benefits diverse environmental applications and supports a diversity of policies. This study presents the findings of an extended user survey conducted within the Open Earth Monitor Cyberinfrastructure (OEMC) project, exploring user perspectives on FAIR environmental data. For this purpose, an existing survey targeted at both users and producers of geospatial data was extended to enhance the representability and have the widest feedback for understanding users' and producers' needs, expectations, experiences, and understanding of FAIR principles.
The survey included three blocks. The first block addressed the background and general information of the survey respondents. The second block inquired about the characteristics of the geospatial data that has been primarily used or produced. The third block investigated how user and producer group participants are familiar with the FAIR principles and which of those seemed most relevant to them. In addition, we fostered a target-specific participant selection strategy to cover the main institutions and relevant user groups.
The survey revealed a discrepancy in the preferred observational scales between data producers and users. While producers primarily focus on generating data at global scales, users frequently require data at local and regional levels. This finding underscores the need for improved communication and collaboration between data providers and users to ensure data production aligns with user needs. Furthermore, the survey identified findability and openness as the top priorities for FAIR environmental data, alongside clear licensing, comprehensive metadata availability, and detailed documentation.

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These findings emphasize the crucial role of robust data management practices and user-centric approaches in promoting the effective utilization of environmental data. Further key findings from user responses will be presented, highlighting user perceptions of FAIRness in environmental data, current gaps in FAIR implementation, and identified challenges. Based on these insights, we will discuss the implications of the survey results and propose recommendations for advancing the FAIRness of environmental data in the future. This research contributes to ongoing efforts within the OEMC project and beyond, informing strategies for improving the discoverability, usability, and overall value of environmental data for various stakeholders.

Actual and potential habitat and vegetation type mapping to support conservation science by Martin Jung (IIASA)

Earth observation data provides an invaluable resource to assess the state and condition of the environment. However, many domain–specific applications, such as the mapping of species-specific habitats and vegetation for conservation, often require specific spatial and thematic resolutions, rather than off–the–shelf products. And although remotely sensed data is critical to assess actual coverage, particularly for the assessment of restoration opportunities, knowledge on the potential distribution of habitats and vegetation is usually required. Here I will provide an overview of ongoing efforts to estimate current and potential vegetation types across global, European and local extents. I will focus both on approaches to integrate existing data sets for global and European habitat estimates, but also demonstrate the potential of earth observation data and deep learning to identify vegetation types at high resolution. Finally, I will highlight opportunities to bring the Earth observation and ecology community closer together particularly in the light of data gaps, harmonization and standards.

Land cover change and biodiversity pressures: A global analysis leveraging EO data by Mikaël Maes, Ivan Haščič (OECD)

Biodiversity loss is a critical environmental concern, with habitat destruction and degradation identified as key drivers. Recent advancements in computational methods and the ever-growing availability of Earth Observation (EO) data enable detailed analyses of land cover changes at unprecedented spatial and temporal scales. This paper develops a set of indicators of land cover and land cover conversions to assess potential pressures on terrestrial biodiversity and ecosystems. Key land cover conversions include deforestation/reforestation, cropland expansion/contraction, and urban/infrastructure development. We leverage two high-resolution datasets (i.e. the Copernicus Climate Change Initiative Land Cover [CCI-LC] and the Global Human Settlement Layer [GHSL] built-up area) to develop national and subnational indicators for all countries globally, spanning 2000-2020 for CCI-LC and 1975-2030 for GHSL. The analysis reveals a continued decline in natural and semi-natural vegetation cover in many OECD countries and partner countries since the 2000 baseline. For example, Brazil experienced a substantial loss

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of tree cover (200,000 km²) between 2000 and 2020, equivalent to an area exceeding Switzerland's landmass by a factor of six. Meanwhile, most OECD countries exhibited a net gain in tree cover during the same period. Urban development is another key reason for the observed decline in natural and semi-natural vegetated land where countries such as China and India displayed a significantly higher increase in artificial surfaces compared to OECD countries over the past two decades. Results currently only account for the ecosystem extent and do not account for the ecosystem condition. For instance, some grassland land cover may have been significantly modified by long-term grazing and is in fact intensively managed grassland (wild prairies vs grassland pastures). Therefore, these results should be considered alongside complementary data sources to provide a more comprehensive picture of biodiversity pressures and highlight that current global land monitoring EO products do not adequately meet the needs of policy analysts who require data at the interface of land cover and land use.

Dynamic Flood Susceptibility Assessment: Harnessing High-Resolution Data for Effective Risk Reduction by Hamidreza Mosaffa (CNR)

Accurate and timely flood risk assessment is paramount for effective disaster mitigation and preparedness. Traditional flood susceptibility maps (FSMs) often fall short by providing static representations, failing to capture the dynamic nature of flood risk in a changing climate. This study presents a novel dynamic FSM framework that integrates high-resolution climate data and temporal analysis to address these limitations. Developed within the context of the Open-Earth-Monitor Cyberinfrastructure (OEMC) project, our methodology offers a significant advancement in flood risk modeling.
To generate dynamic, high-resolution (1 km) FSMs for the Mediterranean region, we utilized the Random Forest algorithm. These maps uniquely adapt to varying seasonal conditions, precipitation intensities, and post-drought scenarios. Our model's adaptability stems from its training on a comprehensive dataset that combines flood and non-flood locations from the Copernicus Emergency Management Service (EMS) and the Global Flood Database v1. Additionally, we incorporated crucial factors influencing flood events, including elevation, slope, land cover, drainage density, soil moisture, and precipitation. Model evaluation employed cross-validation techniques utilizing both training and testing datasets. This comprehensive assessment confirmed the superior performance of the Random Forest model, solidifying its effectiveness as a robust tool for flood susceptibility mapping.

Workshop: Data Spaces: the EC solution for environmental, biodiversity and climate challenges. Different approaches on multisource data, semantics, FAIRness and sovereignty by Joan Maso, Ivette Serral (CREAF)

Integrity of natural ecosystems is one of the main concerns of current European and Global Green Policies, e.g., the European Green Deal. Public administration managers need reliable and long-term information for better monitoring of the ecosystems and climate evolution and inform decision

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makers. Data Spaces are intended to become the EC comprehensive solution to integrate data from different sources with the aim to generate and provide a more ready to use knowledge on climate change, circular economy, pollution, biodiversity, and deforestation. This workshop aims to discuss pros and cons of some technological solutions in terms of Data Spaces, OGC standards, semantic descriptions, datacubes, FAIR principles and sovereignty of data. It also intends to share lessons learned from main EC projects dealing with the topic: AD4GD, GREAT, B-cubed, Fairicube, etc.

Workshop: The nrt Ecosystem: A Unified Approach to Forest Disturbance Monitoring by Kenji Ose (JRC)

nrt is a Python package designed to streamline environmental monitoring efforts by offering a unified Application Programming Interface (API) for a diverse array of forest disturbance monitoring algorithms. This unified API simplifies the process for users, enabling easy comparison and integration of different algorithms that are optimized for rapid computation and scalable deployment.
Beyond its core functionality, the nrt ecosystem encompasses additional tools that enhance its utility and versatility. These include diagnostics, time-series simulation, generation of reference data, and computation of accuracy metrics. Collectively, these features make nrt a valuable resource for environmental monitoring and analysis, catering to a wide range of research and operational needs.
During the workshop, participants will engage in hands-on demonstrations covering the various aspects of the nrt ecosystem. This practical experience aims to equip attendees with the knowledge and skills necessary to effectively utilize this tool in their projects, enhancing their capability to leverage any of its components for their projects.

Landscape-scale And Spatially Explicit Representation of tropical vegetation dynamics and ecosystem carbon stocks (LASER) by Florian Hofhansl (IIASA)

Tropical vegetation dynamics and ecosystem carbon (C) stocks typically vary with local topography and forest disturbance history. Yet, neither remote sensing nor vegetation modeling captures the underlying mechanistic processes determining ecosystem functioning and therefore the resulting estimates often do not match field observations of vegetation C stocks, especially so in hyperdiverse tropical forest ecosystems. This mismatch is further aggravated by the fact that multiple interacting factors, such as climatic drivers (i.e., temperature, precipitation, climate seasonality), edaphic factors (i.e., soil fertility, topographic diversity) and diversity-related parameters (i.e., species composition and associated plant functional traits) in concert determine ecosystem functioning and therefore affect tropical forest C sink-strength. Here, we propose a novel framework designed for integrating in-situ observations of local plant species diversity with remotely sensed estimates of plant functional traits, with the goal to deduce parameters for a recently developed trait- and size-structured demographic vegetation model. Plant-FATE (Plant

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Functional Acclimation and Trait Evolution) captures the acclimation of plastic traits within individual plants in response to the local environment and simulates shifts in species composition through demographic changes between coexisting species, in association with differences in their life-history strategies. Our framework allows to project the functional response of tropical forest ecosystems under present and future climate change scenarios and thus should have crucial implications for assisted restoration and management of tropical plant species threatened by extinction.

Exploring additional in-situ measurements for the integration of eddy covariance system observations with remote sensing time series by Simone Sabbatini (DIBAF)

Among the many services in-situ datasets can provide to society, one of the more pressing interests currently active in the Earth Observation (EO) sector is the integration of in-situ and satellite datasets. The remote sensing community is actively using ICOS (Integrated Carbon Observation System) outputs for calibration and validation activities of satellite products. However, there are additional measurements currently excluded from the ICOS portfolio that could be beneficial for calibration and validation opportunities: for example, fraction of absorbed photosynthetic active radiation (fAPAR) and land surface temperature (LST) from thermal cameras.
An experimental setup was implemented on a subset of ICOS stations for estimating leaf area index (LAI), strictly related to fAPAR, from above- and below-canopy measurements of photosynthetic active radiation (PAR). The first longer-than-1-year datasets being available, we present some relevant preliminary results and the future direction of this activity. NASA recently published some best practices on LST measurements for validation of satellite products. At this scope, a single thermal camera of high accuracy is deployed on a network of measuring stations. We intend to check how this setup relates to different configurations, such as different camera models, or the deployment of 3-4 lower-standard sensors looking at different angles, thus increasing the spatial resolution. Additional points under scrutiny are: what is the heterogeneity of these variables in the eddy covariance footprint, and how can these measurements add value to the net ecosystem exchange (NEE) and its derived products? And how can the integration between satellite imagery and ground observations benefit from them?

A European Air Quality Monitor by Johannes Heisig (OEMC)

Air pollution is a health risk to millions of citizens in Europe. Critical concentrations of nitrogen-dioxide (NO2), ozone (O3), and particulate matter (PM10 and PM2.5) occur predominantly in densely populated areas affected by high volumes of traffic or industry. Although several thousand air quality stations scattered over Europe record hourly measurements, the EEA publishes continuous maps on an annual basis with considerable time lag. However, there is a public benefit in accessing such maps more timely. With the OEMC Air Quality Monitor we design tools which streamline the mapping workflow building on top of the EEA methodology. The process includes

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gathering and pre-processing data (both measurement and covariates) and making spatial predictions for the four mentioned air pollutants. We leverage public station measurements, gridded climate and atmospheric transport model outputs, and land cover and traffic information as well as open source software. This combination facilitates a transparent way to map air quality in Europe at one kilometer spatial resolution for daily, monthly, and annual intervals.

Satellite-based maximum entropy modelling for identifying potential soil microplastics hotspots by Bruno Ćaleta

The pervasive presence of microplastics in terrestrial ecosystems has emerged as a pressing environmental concern. Recent studies have identified soil as a major sink for microplastics contamination, potentially surpassing oceanic levels by factors ranging from 4 to 23-fold. The small size of microplastics and the complexity of soil matrices as sink substrates pose challenges for quantifying soil pollution. As a result, current analytical methods are limited in efficiency, making large-scale environmental assessments unfeasible. The vertical incorporation of microplastics into soil, along with the challenges of recognizing microscopic objects in satellite images, restricts the practicality of using remote sensing for direct large-scale environmental assessments. Hence, a more comprehensive approach is necessary to tackle these challenges. One potential solution involves utilizing satellite imagery combined with a maximum entropy model. By integrating locations where microplastic presence has been confirmed and extracted from soil samples, the maximum entropy model can establish a connection between satellite-derived environmental predictors and the presence of microplastics in soil. The aim of this research was to assess the practicality and viability of employing this approach in a real-world setting. To test our approach, we designed a case study covering wider administrative area of the City of Osijek, Croatia. For training data, we utilized 31 sampled locations where soil microplastics have been confirmed through previous research, along with environmental variables primarily derived through signal enhancement of Sentinel-based imagery. After literature review, a preliminary list of 31 environmental predictor variables was generated, covering various facets of microplastics input to the soil and their dispersion in the environment. These were tested for variance inflation factor (VIF) and spatial autocorrelation to identify statistically significant variables for model calibration. To relate environmental variables to microplastics presence, we leveraged maximum entropy model. The best-performing model underwent additional testing using various permutation tests to evaluate its robustness. We identified 4491 different sets of three environmental variables eligible for further examination. We employed each combination to train maximum entropy models using 5-fold cross-validation to identify the most robust model. Additional testing included jackknife cross-validation to identify and remove outlier samples. The best performing model, with an AUC under the ROC of 0.863, was the one trained using combination of environmental predictors including land cover (CLC+ Backbone raster product), soil moisture derived from Sentinel-1 imagery, and catchment areas determined through hydrological analysis of the digital elevation model. The output prediction map clearly delineates areas that highly likely represent pollution hotspots. This research demonstrates the feasibility of

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utilizing satellite imagery, in conjunction with topological analysis and maximum entropy models, to conduct large-scale environmental assessment and accurately pinpoint hotspots of soil microplastics contamination. This approach could significantly aid future stakeholders since the EU has taken proactive steps as of 2018 to tackle soil microplastics pollution, by implementing regulations, action plans, and initiatives to prevent plastic pellet loss. Furthermore, the European Commission has incorporated impact assessments into its decision-making process regarding microplastics. Advanced environmental monitoring techniques offer potential in tracking progress and quantifying effectiveness of forthcoming measures. Based in Croatia, Oikon Ltd. – Institute of Applied Ecology is recognized as a leading consulting company and research institute in the field of applied ecology across the region. Our expertise spans a wide array of environmental services, including nature conservation, industrial ecology, renewable energy, and more. With our interdisciplinary approach to ecology, we wanted to propose a practical solution for large-scale microplastics pollution monitoring, leveraging remote sensing and modelling techniques. Microplastics have been quietly infiltrating our soil, posing a significant threat to terrestrial ecosystems. Recent research suggests that soil might even outpace oceans as the primary sink for these pollutants. By integrating sample data and environmental predictors derived from satellite imagery with ecological modelling, we were able to confidently pinpoint hotspots of microplastics pollution in our case study area.

Ground measurements and in-situ observations from the OEMC project for the support of environmental policies and the benefit of society by Simone Sabbatini (DIBAF)

The collection of representative observational datasets in environmental sciences is crucial for advancing the understanding of the phenomena under consideration. The integration between in-situ datasets with remote sensing and machine learning techniques makes possible reliable predictions and analyses with enhanced precision and resolution. The OEMC project aims at supporting informed decision making on environmental policies for the benefit of the whole society, by combining in-situ measurements and remote sensing datasets. Here we investigate the impacts of some of the OEMC in-situ datasets on society and policymakers: how are the in-situ datasets supporting the use-cases of the project? What is their combined potential in terms of technological advancement and knowledge boost? The following categories of OEMC in-situ data, their benefits, and relation to sustainable development goals (SDGs) are scrutinised. GHG fluxes: GHG fluxes ground observations, combined with satellite data, can be proficiently used for calibration and validation of models, with benefits in terms of better predictions, development of early warning systems, better understanding of climate change impacts, ecosystem services, etc. Current and potential stakeholders are the Intergovernmental Panel on Climate Change (IPCC) and international projects such as the Global Carbon Project (GCP) and FluxCom initiative. UNFCCC is also using GHG flux data. Related SDGs include 11, 12, 13 and 15. Forest biomass: in-situ observations of forest biomass are fundamental in refining the assessment of global forest carbon stocks and their change under natural and anthropogenic drivers. These data serve the needs of a wide range of stakeholders, from both the scientific and

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the policy making sectors, interested in quantifying the actual carbon sequestration capacity of forests and refining estimates of forest inventories. Policies such as the European Forest strategy and monitoring of SDG 15 will benefit from such datasets.
Marine and terrestrial biodiversity: these datasets support projects and activities of biodiversity conservation, a fundamental branch of Earth science and a crucial aspect for the survival of humanity. Potential stakeholders include the European Environmental Agency (EEA) and the Joint Research Centre of the European Commission (JRC), and policies such as the European Biodiversity strategy and SDGs 14 and 15.
Ocean and coastal datasets: the importance of ocean and coastal organisms for the balance of the biosphere becomes more and more evident, but scientific knowledge is still limited in comparison with the terrestrial counterpart. Increasing the monitoring of these ecosystems is crucial, in particular for human communities living in coastal areas. EEA and JRC are included in the stakeholders interested. Related SDG: 14
LCLU: in-situ land use and land cover information derived from processing land surveys data and satellite imagery support land degradation alert systems and EO mapping. Potentially supported SDGs are 11, 12, 13, 14 and 15.
Automated ground observations: automated measurements of biological processes support the validation of EO products and provide input for ecological modelling. Data consistency is enhanced by the availability of a continuous dataflow from field sites where sampling is logistically or financially constrained. Possible applications include early warning systems in agricultural, forestry, and urban greening sectors, improved agronomic and silvicultural practices, monitoring ecosystems productivity and biodiversity levels. Potential stakeholders are the EEA, the JRC, entities involved in mandatory and voluntary carbon markets (UNFCCC, UNDP, private companies), national governments and local administrations. Related SDGs are 11, 12, 13 and 15.
Citizen science: citizen science in-situ data for training and validation of EO mapping models can play a fundamental part in supporting environmental policies, covering a wide range of topics, from deforestation to aboveground biomass assessment, from crop type to land use and land cover distributions. The European Green Deal is expected to greatly benefit from this type of in-situ datasets, and SDGs 13, 14 and 15 will potentially be supported.
In-situ and gridded integration: although the combination of in-situ and gridded datasets is common, their spatial resolution often differs. A case study focusing on eddy covariance data tries to shed light on the overlapping degree of ground and satellite footprints, with benefits for society in terms of technological advancements and a deeper understanding of how ecosystems react to climate change, with potential benefits for SDGs 13 and 15.

Assimilating Leaf Area Index and Soil Moisture from Optical and SAR Data into the WOFOST Model to Improve Maize (Zea mays L.) Yield Estimation by Gebeyehu Abebe (Debre Berhan University)

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101059548.

Crop Simulation Models (CSM) are commonly used to estimate crop yield at a local scale. Meanwhile, Remote Sensing (RS) data provides valuable information on crop parameters like soil moisture and leaf area index (LAI) across different spatial scales. Data Assimilation (DA) is a powerful technique that combines CSM and RS data from satellite imagery to enhance simulated crop state variables and model outputs, such as total biomass and yield. In this study, we aimed to implement a joint assimilation strategy for LAI and soil moisture data in the WOFOST model. The goal was to simulate rainfed grain maize yield at the field scale and evaluate its performance at both the field and administrative zone levels. The Ensemble Kalman Filter (EnKF) algorithm was applied to achieve this integration. The LAI and soil moisture data were sourced from Sentinel 3 and Soil Moisture Active Passive (SMAP) L3 Radiometer Global Daily 9 km Soil Moisture, respectively. The study tested various assimilation scenarios, including deterministic modeling, independent assimilation of LAI from Sentinel 3, independent assimilation of soil moisture from SMAP, and joint assimilation of both LAI and soil moisture data. Ongoing validation involves comparing the simulated grain maize yield with field observations and independent grain maize statistics data in the major maize-growing administrative zones of western and southwestern Ethiopia. The expected outcomes include improved accuracy in grain maize yield predictions at the field scale and enhanced crop monitoring and forecasting at local and national levels.

EO Exploitation Platform Common Architecture by Chandra Taposeea-Fisher (ESA), Garin Smith

The ‘Exploitation Platform’ concept derives from the need to access and process an ever-growing volume of data. Many web-based platforms have emerged - offering access to a wealth of satellite Earth Observation (EO) data. Increasingly, these are collocated with cloud computing resources and applications for exploiting the data. Rather than downloading the data, the exploitation platform offers a cloud environment with access to EO data and associated compute and tools that facilitate the analysis and processing of large data volumes. The Exploitation Platform benefits users, data providers and infrastructure providers. Users benefit from the scalability & performance of the cloud infrastructure, the added-value services offered by the platform – and avoid the need to maintain their own hardware. Data hosted in the cloud infrastructure reaches a wider audience and Infrastructure Providers gain an increased cloud user base. Users are beginning to appreciate the advantages of exploitation platforms. However, the market now offers a plethora of platforms with various added value services and data access capabilities. This ever-increasing offer is rather intimidating and confusing for most users. In order to fully exploit the potential of these complementary platform resources we anticipate the need to encourage interoperation amongst the platforms, such that users of one platform may consume the services of another directly platform-to-platform. EOEPCA (EO Exploitation Platform Common Architecture) is a European Space Agency (ESA) funded project with the goal to define and agree a re-usable exploitation platform architecture using standard interfaces to encourage interoperation and federation between operational exploitation platforms - facilitating easier access and more efficient exploitation of the rapidly growing body of EO and other data.

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Interoperability through open standards is a key guiding force for the Common Architecture: platform developers are more likely to invest their efforts in standard implementations that have wide usage; off-the-shelf clients and software are more likely to be found for standards-based solutions. The EOEPCA system architecture is designed to meet a set of defined use cases for various levels of user, from expert application developers to consumers. The architecture is defined as a set of Building Blocks (BBs), exposing well-defined open-standard interfaces. These include Identity and Access Management, Resource Discovery, Data Access, Processing Workflows, Data Cube Access, Machine Learning Operations, and more. Each of these BBs are containerized for Kubernetes deployment, which provides an infrastructure-agnostic deployment target. The exploitation platform is conceived as a 'virtual work environment' where users can access data, develop algorithms, conduct analysis and share their value-adding outcomes. The EOEPCA architecture facilitates this through a Workspace BB that provides a user-centric platform experience in which the standard discovery, visualisation and access interfaces are re-used for user-owned resources maintained within the platform - including data, applications, added-value products (from processing), etc. This is supported by an Application Hub building-block that provides interactive web-tooling for analysis, algorithm development, data exploitation and provides a web dashboard capability through which added-value outcomes can be showcased.

Satellite-based methane discovering and monitoring: Revolutionizing air pollution control
by Santiago Vargas Domínguez (National University of Colombia), María Fernanda

Air pollution has emerged as a critical global concern, exerting adverse impacts on natural ecosystems and exacerbating the pace of climate change. Despite the existence of mitigation strategies, the accurate quantification of methane emissions remains a formidable challenge, impeding progress towards meeting emission reduction targets set for 2030. This study is dedicated to addressing the urgent global issue of air pollution, with a particular focus on methane emissions, known for their significant contribution to climate change and associated environmental and health hazards. Conventional monitoring techniques have proven inadequate, leaving millions of abandoned oil wells unchecked in their methane emissions, thus demanding a comprehensive solution. In response, we present a novel technological advancement based on satellite data, to facilitate the precise measurement, detection, and ongoing monitoring of methane leaks. By harnessing breakthroughs in deep tech disciplines such as Earth observation integrated with machine learning, astrophysical methodologies, theoretical chemistry, and computational fluid dynamics, this technology enables the identification of methane leaks across diverse geographical locations worldwide.
Furthermore, this study underscores the critical importance of fostering collaboration and information exchange among stakeholders to optimize the effectiveness of emission reduction endeavors. Through its innovative approach and interdisciplinary collaboration, this work aspires to deliver a significant contribution towards mitigating climate change impacts and safeguarding natural resources for the benefit of future generations.

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The interoperable alternative map browser for the datasets produced in OEMC by Joan Masó (CREAF), Imma Serra (CREAF)

One of the major challenges in data management is (and in the project OEMC) is demonstrating the correct implementation of the FAIR (Findable, Accessible, Interoperable and Reproducible) principles. To make data accessible, it is required that “data is retrievable by their identifier using a standardised communications protocol that should be open, free, and universally implementable”.
OEMC has produced a list of datasets that are exposed to the public with elegant Open-Earth-Monitor App. Our talk will focus on demonstrating the interoperability of the approach taken, showing an alternative web map browser that gives access to the same OEMC datasets. This web map browser was deployed using the original MiraMon Map Browser technology without any customization and using only Open Geospatial Consortium (OGC) standards web services calls, demonstrating the technical interoperability of the OEMC services. The presented visualization portal goes beyond simple visualization by combining the OGC WMS standard with modern web browser capabilities. During the talk, we will demonstrate how to access OEMC datasets through MiraMon browser functionalities, such as query by location, multiple projections support, reading storymaps, and data multidimensional support among others. An important feature of the visualization portal is that it allows the final users to provide common feedback about the data (such as star rating and comments) that are shared with other users as well as to produce and share their own storymaps and this way share the knowledge gained by analysing the data.

Integrating different remote sensing products to produce high spatial and temporal snow estimates in the cloud by Valentina Premier (EURAC)

Hydrological planners need accurate and up-to-date information on snow dynamics. The OEMC project aims to improve the measurement of the Snow Water Equivalent as an estimation of the available water stored in snow covered areas in the Alps to support planning activities such as hydropower, agriculture and drinking water. To reach this objective high spatial and temporal information is required. Several remote sensing sensors exist with different spatial and temporal resolutions and hence different potentiality. To produce optimal results, integration of different data sources is necessary. This requires large computational resources as well as huge data amounts. In this context, standardized cloud processing APIs such as OpenEO serve as powerful processing tools that can promote openness and reproducibility. In this talk we will present how we exploited cloud native EO to improve the development of snow products, such as snow cover fraction and snow water equivalent maps.

The evolution of the OSS4gEO, a FOSS4G resources platform initiative by Codrina Maria Ilie (TERRASIGNA)

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101059548.

At the OEMC Global Workshop in 2023, we presented a community led initiative part of the wider Open Innovation framework at European Space Agency that worked to implement an open, interactive, user intuitive platform for a constantly updated, comprehensive and detailed overview of the dynamic environment of the open source digital infrastructure for geospatial data storage, processing and visualisation systems. Today, we have over 450 documented geospatial FOSS projects, interconnected into the FOSS4G ecosystem.
At the OEMC Global Workshop of 2024, the team presents the work done within the next steps, identifying quality metrics for open-source software and assess the connection with the health of the associated project and thus paving the way to understand the benefits as well as the pitfalls of certification in geospatial open-source software.

OPTIMIZING UAV DATA PROCESSING FOR PATTERN CLASSIFICATION WITH CNN ON LOW TO MODERATE-QUALITY IMAGERY by Linara Arslanova (Friedrich-Schiller-University Jena)

Over the last decade, UAV systems have enabled high-resolution data collection for various applications at relatively low costs and with great flexibility in acquisition time and parameters [5]. This data can serve as a valuable reference for large-scale space-borne applications. However, the flexibility in image acquisition presents challenges related to varying data types
and quality, which are affected by environmental conditions, sensor specifications, and radiometric calibration. Capturing comparable reflectance values with UAV systems is particularly challenging, and many early studies relied on minimal preprocessing or raw digital number (DN) values [4]. Given that some datasets' spectral information (reflectance/DN) may not be directly comparable, a classifier that emphasizes generalized texture information is needed rather than relying solely on spectral data. Among common machine learning (ML) techniques, the convolutional neural network (CNN) of deep learning (DL) has proven to be a successful tool in classifying images of land use from remote sensing data [1, 2]. CNN allows high-order representation based on generalized texture information already used in crop classification [7, 3, 6]. Our research explores the potential of using low-to-moderate-quality UAV data for agricultural pattern classification, focusing on how color-balancing techniques can enhance data consistency when images are captured under variable lighting conditions. We evaluated the performance of CNNs in classifying agricultural patterns using moderate- to low-quality, high-resolution (0.07-meter) optical multispectral data collected from three agricultural test sites in Germany. We used models trained exclusively on samples converted to reflectance values and applied them to images impacted by different sunlight conditions, including digital number (DN) and reflectance data. The models were trained to classify small-scale agricultural patterns, such as damaged and undamaged canopy, weed-infested and bare soil areas, across four crop types: winter wheat, rapeseed, corn, and spring barley. This study, funded by the German Federal Ministry for Economic Affairs and Energy (FKZ: 50EE1901), is carried out in collaboration with CLAAS E-Systems GmbH to develop an application for crop monitoring based on Sentinel-1 data.

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Open data, open science and open platforms: way forward with Earth Observation in the actual climate crisis by Inge Jonckheere (ESA ESRIN)

In the face of the escalating global climate crisis we are facing, the integration of open data, open science, and open platforms has emerged as a transformative approach in Earth Observation (EO) and its applications. This abstract explores the pivotal role of these interconnected principles in addressing these climate challenges in the European Space Agency (ESA). Open data initiatives have democratized access to valuable EO datasets, fostering collaboration and innovation across a wide range of stakeholders from policy makers, policy owners to scientists, and end users as farmers. By facilitating transparency and accessibility, these initiatives enable a deeper understanding of Earth's systems, crucial for informed decision-making amidst climate uncertainty.
Coupled with open data, open science practices advocate for transparency, reproducibility, and the sharing of methodologies, results, and findings. This collaborative view not only accelerates scientific discovery but also cultivates a culture of accountability essential in confronting the multifaceted complexities of climate change and the climate finance behind it. Furthermore, the integration of open platforms also in ESA provides a dynamic infrastructure for EO research and application development. These platforms not only streamline data management and analysis but also empower communities to co-create solutions tailored to their unique challenges, fostering resilience in the face of environmental threats, which ESA is supporting through many of its projects and programmes.
As the climate crisis intensifies, the synergy between open data, open science, and open platforms offers a promising pathway forward in EO endeavours. By fostering inclusivity, innovation, and collective action, this integrated approach holds the potential to catalyse transformative change, safeguarding our planet for future generations making good use of all ESA's EO missions and options.

Towards a multi-frequency SAR datacube for global monitoring of dynamic land surface processes by Wolfgang Wagner (TU Wien, EODC)

Due to their ability to observe the land surface irrespective of weather and lightning conditions, radar satellite constellations are indispensable for monitoring of highly dynamic land surface processes. While in the past only scatterometer missions allowed consistent monitoring at global scale, albeit at very coarse spatial scales, this has changed fundamentally with the Copernicus Sentinel-1 mission that stands out as one of the most successful Synthetic Aperture Radar (SAR) missions. With its novel combination of high spatial and temporal resolution, long-term mission planning, and open data policy it has served as a role model for the conceptualization of future radar missions. With the upcoming launches of the Japanese Advanced Land Observing Satellite-4 (ALOS-4) satellite, the NASA-ISRO SAR Mission (NISAR), ESA's Biomass mission, and the Copernicus Radar Observing System for Europe in L-band (ROSE-L) satellites, there is now the opportunity to monitor dynamic processes at high spatial resolution (10-20m) with short revisit

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times (1-3 days) at multiple frequencies (C-, L-, and P-band). In this presentation I will discuss a collaborative effort of the Vienna University of Technology (TU Wien) and the EODC Earth Observation Data Centre to build a global multi-frequency SAR datacube suited for applying hybrid algorithms combining physical models and machine learning. Furthermore, I will show examples of how we use this tailored datacube for the monitoring of soil moisture, floods, vegetation, and soil structural characteristics.

A Multi-Source Remote Sensing Approach for Large-Scale Mapping of Other Wooded Lands by Nathália Teles (LAPIG)

The primary objective of this study was to develop and evaluate different remote sensing techniques for mapping Other Wooded Lands (OWL), while also assessing the accuracy and uncertainties associated with classifying OWL class compared to forest and grasslands. Additionally, we aimed to design a scalable process for large-scale OWL mapping. As defined by the Food and Agriculture Organization (FAO), OWLs are areas with 5-10% tree canopy cover for trees reaching a height of 5 meters at maturity, or with a combined cover of shrubs, bushes, and trees above 10 percent. Also, OWLs must span a minimum land area of 0.5 hectares and exclude predominantly agricultural or urban land uses. Three diverse landscapes were chosen based on expert input, encompassing natural regions globally and representing the three main land cover classes of interest: forest, OWL, and grassland. The selected areas were (1) Cheringoma, Sofala, Mozambique; (2) Cerrado biome, Goiás, Brazil; and (3) Albacete and Jaén, Spain. For each Area of Interest (AOI), we selected a Sentinel-2 MGRS tile that entirely covered the area. A stratified random sampling approach ensured robust sample collection across all land cover classes within each scene, resulting in over 1.7 million samples per scene. High-resolution imagery from Google Earth/Bing was utilized for visual interpretation. The mapping utilized data from 2022, encompassing a six-month window before and after the year of interest (totaling two years). A total of 174 metrics were calculated on data from various sources to characterize land cover for OWL modeling. Data processing was conducted using Google Earth Engine (GEE), and a Random Forest algorithm was employed for OWL land cover modeling. The resulting maps exhibited a global accuracy of 74.5% (Mozambique) and 76.5% (Brazil), Spain is currently under analysis. In Mozambique, the producer accuracy for OWL was 42.4%, with omissions associated with grasslands and forests at 34.5% and 21.5%, respectively. For the Cerrado region, both user and producer accuracies were notably higher, at 71.6% and 74.7% respectively. Mapping results were combined with ICESat-2 satellite lidar, where available, to investigate the vegetation height and structure of land cover classes. Top of canopy heights, median heights, and percent forest cover decreased between forest, OWL, and grassland classes. This methodology offers a scalable approach for mapping OWLs, contributing to improved deforestation monitoring and environmental protection efforts.

Multi-decadal trend analysis and forest disturbance assessment of European tree species: concerning signs of a subtle shift by Carmelo Bonannella (OGH)

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101059548.

Climate change poses a significant threat to the distribution and composition of forest tree species worldwide. European forest tree species' range is expected to shift to cope with the increasing frequency and intensity of extreme weather events, pests and diseases caused by climate change. Despite numerous regional studies, a continental scale assessment of current changes in species distributions in Europe is missing due to the difficult task of modeling a species realized distribution and to quantify the influence of forest disturbances on each species. In this study we conducted a trend analysis on the realized distribution of 6 main European forest tree species (Abies alba Mill., Fagus sylvatica L., Picea abies L. H. Karst., Pinus nigra J. F. Arnold, Pinus sylvestris L. and Quercus robur L.) to capture and map the prevalent trends in probability of occurrence for the period 2000–2020. We also analyzed the impact of forest disturbances on each species' range and identified the dominant disturbance drivers. Our results revealed an overall trend of stability in species' distributions (85% of the pixels are considered stable by 2020 for all species) but we also identified some hot spots characterized by negative trends in probability of occurrence, mostly at the edges of each species' latitudinal range. Additionally, we identified a steady increase in disturbance events in each species' range by disturbance (affected range doubled by 2020, from 3.5% to 7% on average) and highlighted species-specific responses to forest disturbance drivers such as wind and fire. Overall, our study provides insights into distribution trends and disturbance patterns for the main European forest tree species. The identification of range shifts and the intensifying impacts of disturbances call for proactive conservation efforts and long-term planning to ensure the resilience and sustainability of European forests.

SEEA carbon accounting using Earth Observation datasets and its comparison with carbon accounts following the UNFCCC framework by Arnan Araza (WUR)

Earth Observation (EO) biomass and carbon datasets are increasing and their potential as inputs to the environmental-economic accounting framework based on SEEA was assessed in this study toward accounting for all carbon pools: above-ground, below-ground, deadwood, litter and soil carbon. This demonstration allowed the compilation of carbon accounts in four accounting periods 2010-2017, 2017-2018, 2018-2019 and 2019-2020 for six case countries namely Brazil, Mozambique, the Netherlands, the Philippines, Sweden and USA, and later on compared with the accounts from a counterpart carbon accounting framework based on UNFCCC. The compiled carbon accounts revealed the above-ground component being the dominant carbon pool in Brazil and the Philippines, while soil organic carbon outweighs other carbon pools in the Netherlands, Sweden and surprisingly Mozambique. We found decreasing carbon stocks especially for Brazil even in shorter accounting periods i.e., 2018-2019 captured by the EO dataset. This is in contrast to what has been reported by countries to UNFCCC mostly reporting stability in the carbon flows over the years. Part of the discrepancy is the country definitions of managed forests which can be inconsistent with forest management datasets from EO (this study). Another reason is the dependency of countries on national forest inventories which are rarely updated on an annual

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basis. Moreover, our compiled accounts showed minimal carbon emissions from forest degradation mainly driven by the choice of ecosystem extent input, and lower soil carbon emissions than UNFCCC reports, potentially underestimating peatland emissions. The findings and outputs from this demonstration echo the potential of EO datasets for carbon accounting especially with the advent of time series biomass data, higher spatial resolution of ecosystem extent maps 5-10 m and online ecosystem accounting tools for efficient use cases.

Workshop: Big Data Analytics in Open Geo Hub Cloud using SITS by Gilberto Camara (INPE), Rolf Simoes (OGH)

The workshop will focus on the analysis of image time series extracted from big Earth observation data cubes available at the Open GEO Hub (OGH). The demonstration will present case studies of land use and land cover classification, including: (a) accessing and visualising data using OGH STAC; (b) building data cubes; (c) generating composite indexes; (d) combining multi-source data; (e) controlling the quality of training samples; (f) creating models using machine learning and deep learning algorithms; (g) tuning deep learning models; (h) parallel image classification using GPUs and CPUs; (i) removing outliers by post-processing; (j) using best practices for accuracy assessment. The workshop will use the open-source R package SITS, which is one of the technologies whose development is being supported by the OEMC project.

Workshop: Global Forest Watch: the latest data and tools to better protect forests by Myroslava Lesiv (IIASA), Elise Mazur (WRI), Elizabeth Goldman (WRI)

The workshop aims to present new data sets related to tree management available on the GFW website and tools for collecting feedback on these data sets and tools to collect training and validation data.
The list of new data sets includes the new version of Spatial Database of Planted Trees, the Natural Lands Map, and a new version of the Forest management layer for the year 2020. Discussion will focus on current challenges data producers face such as dataset definitions, data gaps, and quality assurance of the presented datasets.

Workshop: Geo-AutoML with Scikit-map by Leandro Leal Parente (OGH)

In this workshop, the participants will apply an automated machine learning framework suitable for EO data able to:

- Define an optimum number of models to produce per-pixel values and prediction interval considering the mapping requirements and computational resources available
- Evaluate the computation efficiency and model performance for several ML models considering specific input EO data and target variable

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- Establish the model hyper-parameters able to reduce the computation time without significantly reducing the model performance - Establish a plan for distributing the processing in a multi-node high performance computing (HPC) environment.

Large-scale EO processing with xcube on CDSE by Davide Consoli (OGH)

xcube is a mature and capable Python software package and framework for EO data ingestion, processing, analysis, visualization, and dissemination. In the scope of the Open Earth Monitor project, xcube is being updated and expanded to support new data sources, improve on-demand cluster processing capabilities, and run seamlessly on the new Copernicus Data Space Ecosystem. Recent work also focuses on providing a maximally preconfigured turnkey distribution of xcube, increasing its suitability as a drop-in compute engine for cloud infrastructures such as CDSE. xcube's features are complemented by the new zappend tool, which provides robust creation and updating of large, slice-structured Zarr datasets.
This talk will describe and demonstrate a typical large-scale processing workflow using the xcube framework in the CDSE ecosystem – running the gamut through data ingestion from multiple sources through the xcube data store subsystem, data cube construction and normalization, data synthesis and processing to export, dissemination, and seamless visualization via the server and viewer components. Scalability and big data capability is accounted for throughout through approaches such as object storage, parallelization, on-demand cluster processing, dataset pyramidization, and lazy computation. The newly implemented components and improved integration make xcube an ideal tool for the realization of typical Open Earth Monitor workflows.

Time-series reconstruction of global scale historical Earth observation data by seasonally weighted average by Davide Consoli (OGH)

While various imputation methods are available to reconstruct gappy time series of images, most of them are inadequate for large datasets like the full Landsat archive.
To address this need, this work proposes a new methodology called seasonally weighted average generalization (SWAG). SWAG works solely on the time dimension, reconstructing images by employing a weighted average of available samples in the original time series. It prioritizes images collected at integer multiples of a year to enforce annual seasonality and gives higher weights to more recent images to avoid propagating land cover changes. The method is implemented as part of the open-source Python package scikit-map and optimized for computational efficiency.

Systemic human-biosphere-atmosphere monitoring and diagnostics by Gregory Duveiller (MPG)

Here we propose a planetary health diagnostic framework, which aims to track, understand, and characterize the Earth system during the onset and progression of both chronic change (such as climate change) and abrupt disruptions (stemming from climate extremes and socio-economic

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shocks). However, monitoring a single component of the Earth system to guide policy, but ignoring other essential components, could lead to misleading diagnostics and maladaptation of global sustainability. To gain insights into the integration of climate, biosphere, and society, we apply an interactive dimensionality reduction to the annual variability of multi-stream global data from 2003-2022, including data representing the biosphere and climate combined with national socio-economic indicators.
We find that the interactions between biosphere, atmosphere and socio-economy can be captured by three principal axes, which cumulatively explain 17.3%, 22.8% and 24.5% of the variability condensed by non-interactive dimensionality reduction in each individual domain, respectively. The 1st and 2rd pairs of Biosphere-atmosphere-socioeconomic interactive axes describe terrestrial vegetation and land surface water syndromes. The first axes positively correlate to terrestrial vegetation productivity, air temperature, and technology and public health. The second axes negatively correlate to soil moisture, potential evaporation, and reflect several combined socioeconomic aspects such as land use and inequality. We find distinct trajectories across countries with high-income countries more resistant COVID-19-induced economic shock. High and low income groups show contrasting trajectories that are related to poverty reduction and methane emission in the low-income country group. This study advocates for a data-driven paradigm to jointly monitor the recent trajectories of the biosphere, atmosphere, and society that could provide a better understanding and early warning of the state of the Earth system for human well-being.

Workshop: Monitoring Deforestation-related land use change and Carbon Emissions for EUDR and climate policies by Robert Masolele (WUR)

The workshop aims to exchange on recent policy requirements, progress in providing EO-based data and products and equip participants with better knowledge and skills to analyze the drivers of deforestation and associated carbon emissions using remote sensing and Machine learning. The workshop aligns with recent European Union (EU) regulations to curb the EU market's impact on global deforestation and provides valuable information for monitoring land use following deforestation, crucial for environmental initiatives and carbon neutrality goals.

Workshop: Playing the water cycle game: data from space for flood risk mitigation and better managing water resources by Luca Brocca (CNR)

Climate change is profoundly affecting the global water cycle, increasing the likelihood and severity of extreme water-related events. Droughts are becoming more frequent and intense. Extreme precipitation events are more localized and of unprecedented magnitude, causing widespread flooding and severe impacts on our lives and assets. Accurately predicting and monitoring water-related environmental disasters, as well as optimal water resource management, require better decision support systems. These systems should integrate remote sensing, in-situ and citizen observations with high-resolution Earth system

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modelling, artificial intelligence, information and communication technologies, and high-performance computing.
Within the Digital Twin Earth for Hydrology and the Open Earth Monitor Cyberinfrastructure projects, we have developed advanced interactive tools for building what-if scenarios for flood risk assessment, drought monitoring and water resources management. The workshop will describe the developed tools (current version here: https://explorer.dte-hydro.adamplatform.eu/) and the recent advances developed within the Open Earth Monitor Cyberinfrastructure and related projects. An interactive session will be held to demonstrate the potential and limitations of the developed what-if scenarios.

Exploring the biophysical impacts of potential changes in tree cover in Africa by Gregory Duveiller (MPG)

The UN has declared this to be the Decade of Ecosystem Restoration, which should foster the development of restoration projects in many parts of the world suffering from land degradation. In parallel, there is growing demand for deforestation-free and sustainably produced products, as reflected partly by the establishment of the new EU Regulation on Deforestation-free products. The combination of these trends will likely lead to local land use changes resulting in increases in landscape heterogeneity. Here we place an interest in the effects that such changes have on biophysical variables that directly impact the Earth system and the local climate, such as short-wave radiation, land surface temperature and evapotranspiration, as estimated diurnally from geostationary satellite observations. In this study, we explore how the tree density and tree spatial arrangement in different ecosystems of the African continent have an impact on the energetic budget at local and regional scales. We perform a space for time analysis where local changes on vegetation are used to disentangle the effect of land cover transitions on biophysical variables. We expect the results of the study to provide insights into where increasing landscape complexity may provide additional benefits in terms of ecosystem services and thereby contribute towards guidelines in sustainable land planning.

Workshop: Spatiotemporal Machine Learning: fitting models and generating predictions using time-series data by Tom Hengl (OGH)

Machine Learning is commonly used to map environmental variables in 2D, but what about generating predictions of dynamic variables such as above ground biomass, forest species, soil carbon and similar? The difference between spatiotemporal vs purely 2D / 3D mapping is in the three main aspects: (1) points and covariate layers are matched in spacetime (usually month-year period or at least year), (2) covariate layers are based on time-series data and include also accumulative indices (e.g. cumulative rainfall, cumulative snow cover, cumulative cropping fraction and similar) and derivatives, (3) during model training and validation, points are subset in both spacetime to avoid overfitting and bias in predictions. The rationale for using spatiotemporal machine learning is fitness of data for reliable time-series analysis: the predictions for anywhere

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in the spacetime cube need to be unbiased, with objectively quantified prediction errors (uncertainty), so that hence changes can be derived without a risk for serious over-/under-estimation. We have tested this framework on local and regional data sets (e.g. LUCAS soil samples covering 2009, 2012, 2015, 2018 for Europe) and can be now potentially applied using global compilations of soil points (https://opengeohub.github.io/SoilSamples/). Spatiotemporal machine learning could also potentially be used for predicting future states of soil, e.g. by extrapolating models to future climate scenarios and future land use systems (Bonannella et al., 2023).

Workshop: Accessing global scale, historical and complete Landsat data by Davide Consoli (OGH)

The first part of the workshop will describe the processing pipeline applied to produce the Landsat bi-monthly, complete (gaps free) and cloud optimized collection derived from the GLAD Landsat ARD-2 collection, from 1997 to 2022. The second part of the workshop will be focused on how to access the collection and its derived biophysical parameters, such as fraction of absorbed photosynthetically active radiation (FAPAR), normalized difference water index (NDWI) and bare soil fraction (BSF). All the data and the code presented will open source and freely available.

ForestNavigator: combining forest monitoring and modelling for assessing policy pathways towards EU climate neutrality by Fulvio Di Fulvio (IIASA), Andrey Lessa Derci Augustynczik (IIASA), Petr Havlik (IIASA)

The achievement of ambitious LULUCF mitigation targets for 2030 and the EU 2050 climate neutrality goals strongly rely on forests. Currently, there is a large discrepancy in data for monitoring the status of EU forests with large differences across sources of information. In particular, remote sensing data and national statistics are not sufficiently detailed and consistently integrated to allow for comprehensive monitoring of forest status and consistently modelling biomass and carbon over time, by showing a latency in capturing changes in forest cover and forest biomass.
ForestNavigator aims at modelling a series of forest sector policy pathways aligned to EU climate neutrality goals. These pathways rely on integrating various data sources, including high resolution remote sensing derived datasets (forest area, disturbances), ground data sources (NFI structural data) and national statistics (forest harvest and products). In ForestNavigator, we consistently combine these sources allowing for for a consistent representation of forests and forest sector status featured in forest biophysical and socioeconomic models. Additionally, ForestNavigator develops workflows that enable to timely update mitigation pathways according to near-real time detection of changes in forests and in the forest bioeconomy. This near-real time update of policy pathways, according to the continuously changing conditions, enables to timely correct efforts for achieving policy mitigation targets. We present recent developments ongoing in

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ForestNavigator project for a model-data fusion towards the assessment of EU consistent forest policy pathways.

Drought monitoring across scales with open soil moisture remote sensing data by Jaime Gaona (CNR)

Drought monitoring across scales is increasingly feasible with the use of open data. Multiple missions dedicated to monitor specific variables as indicators of the status of the earth system contribute to the growing availability of earth observation datasets. Soil moisture is one of these key indicators to monitor the status of drought.
However, drought, as a process dependent on multiple conditions from the atmospheric scale to the local land surface scale, expresses itself as a pattern of patterns. This nested nature consisting of vast anomalies conditioned in fragments, frequently complicates the characterization of drought from only one type of observations (e.g. ground data or only certain scale of remote sensing observations). Therefore, soil moisture data at multiple spatial scales are needed.
Currently, soil moisture datasets cover a reasonably wide range of scales to enable the monitoring of drought from continental to local scale. Multiple products exist to cover the monitoring of soil moisture anomalies with resolutions in the order of tens of kilometres either from active and passive radiometric technologies like ASCAT (Advanced SCATterometer) and the European Space Agency - Climate Change Initiative (ESA-CCI) products. Similarly, the pursuit of high-resolution observations is already evidencing the advantage of high-resolution data such as that of Sentinel-1 mission for dealing with the small-scale heterogeneity. Evaluation of these two scales of available data over Europe and Italy serve as examples of their suitability for multiple drought applications, also in an operational context
For this study we benefit from the Open Earth Monitoring Cyberinfrastructure project aiming to democratize the use of earth observations open the path to generalize the integration of open datasets across scales. Overall, our goal is to support this initiative and improve the comparison and combination of open data sources. This is crucial for addressing the multi-scale challenges of earth system sciences.

Implementing Open EO Knowledge and the journey towards users engagement by Paola De Salvo (GEO)

GEO now since 2 decades has been working, to advocate Earth Observations Open data and Open knowledge, it is urgent to make sure that users are able to discover, access and re-use the available open applications, enhance knowledge sharing and solve most urgent countries socio environmental issues. The GEO Knowledge Hub is a promising tool to enhance knowledge sharing among the scientific community and accelerate the impact that EO Data and EO Knowledge can have.

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Rethinking the grid: Towards less distorted imagery and AI by Daniel Loos (MPG)

Satellite imagery is traditionally stored and processed on rectangular grids. However, the widespread usage of such grids has normalized their inherent distortions, particularly near the poles. Previous attempts to address this issue, such as employing multiple local projections like the UTM-based Sentinel 2 L1C grid, have led to inefficiencies, including a significant increase in data volume (~30%) due to overlaps that need to be stored, downloaded, and processed. Additionally, there is a lack of a unified global indexing system and the choice of pixel cell shape, which further complicate the analysis.
In this keynote talk, we advocate for a paradigm shift towards Discrete Global Grid Systems (DGGS) to mitigate these challenges. DGGS tessellate the Earth's surface with hierarchical cells of equal area, minimizing distortion and reducing loading time of large geospatial datasets. This approach would greatly improve spatial statistics and convolutional Machine Learning models, where accurate representation of global phenomena is paramount at a global scale.

Deriving policy-relevant geodata from satellite images: lessons learned in the GEO.INFORMED project by Stien Heremans (KU Leuven)

Evidence-based policy is gaining importance, also in the environmental policy domain in Flanders, Belgium. However, the most prevalent source of policy-relevant information still remains ground sampling, with limited spatial and temporal detail and coverage. The ease of access to freely available (Sentinel) satellite imagery from the Copernicus program through the new OpenEO API provides a golden opportunity for filling this information gap. During the GEO.INFORMED project, remote sensing and deep learning researchers engaged in a co-creation trajectory with regional environmental policy makers to develop machine learning workflows for transforming Copernicus satellite data into policy-relevant geodata. The main challenges encountered in the project where associated with ensuring mutual understanding between scientists and policy-makers; and with the technical implications of non-standard model inputs and limited reference data availability. Within the project, a range of strategies for overcoming these challenges were tested, and the lessons learned will be the main focus of this talk.

Global Trait-Based Vegetation Monitoring by Felix Specker (ETH Zurich)

Restoration projects are crucial for ecosystem recovery and biodiversity conservation, but their large-scale monitoring poses significant challenges. Conventional approaches often rely on intensive manual work, incur high costs and need help with standardisation, making monitoring on a global scale impossible. Public satellite missions such as Sentinel-2 have great potential to transform ecosystem monitoring due to their high spatial and temporal resolution when linked directly to ecosystem characteristics. Here, we present several global, high-resolution (20m) maps of vegetation traits derived from Sentinel-2 multispectral imagery, reflecting the mean trait value during the vegetation period at annual intervals from 2019 onwards. Using a hybrid

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inversion approach of the physically-based radiative transfer model PROSAIL, we estimate leaf functional traits (e.g. chlorophyll content, equivalent water thickness, or leaf mass per area) and canopy structural traits (e.g. leaf area index). Validation using in-situ data suggests that the trait maps can effectively track local temporal changes. Further, we show how the generated trait maps can map functional trait diversity at a coarser resolution. Altogether, these products provide deeper insights into ecosystem health, biodiversity status and restoration efforts.

Workshop: Citizen Science Mobile App and Data in Support of Forest Mapping: Laxenburg Park Campaign by Milutin Milenković (IIASA)

Policies on opening satellite image archives have shifted earth observation to the big data era. However, due to the associated data-hungry analytics, such as deep learning, satellite observations have to be combined (trained and then validated) with a large amount of in-situ data to get meaningful results. Yet, the collection of in-situ data is often laborious, and the resulting observations are rarely open for others to use. To bridge this in-situ data gap, this workshop will analyze the suitability of a citizen science mobile app for measuring biomass and tree species of individual trees and forest plots, i.e., the TreeQuest and ForestQuest modules, respectively. The app has been developed by the International Institute for Applied Systems Analysis (IIASA) and will be freely available for Android and iOS phones by the workshop. We will first present the app and then initiate a citizen science campaign motivating the conference participants to take part by testing the app and surveying selected trees around the conference center. Members from TU Wien will measure and model selected trees using a terrestrial laser scanner. The resulting 3D point cloud will allow the extraction of detailed information on vegetation structure, which will be used for comparison with the mobile app and forest inventory measurements acquired with traditional forest measurement tools (e.g. caliper, vertex). Finally, we will present the results and discuss the performance and potential further development of the app with workshop participants.

Workshop: Inferring spatiotemporal dynamics of mosquitoes in Italy using machine learning by Carmelo Bonannella (OGH), Daniele Da Re (U.Trento)

Various modelling techniques are available to understand the temporal and spatial variations of the phenology of species. Scientists often rely on correlative models, which establish a statistical relationship between a response variable (such as species abundance or presence-absence) and a set of predominantly abiotic covariates. The choice of the modelling approach, i.e., the algorithm, is a crucial factor in addressing the multiple sources of variability that can lead to disparate outcomes when different models are applied to the same dataset. This inter-model variability has led to the adoption of ensemble modelling techniques, among which stacked generalisation, which has recently demonstrated its capacity to produce robust results. Stacked ensemble modelling incorporates predictions from multiple base learners or models as inputs for a meta-learner. The meta-learner, in turn, assimilates these predictions and generates a final prediction by combining the information from all the base learners. Our study utilized a recently

published dataset documenting egg abundance observations of Aedes albopictus collected using ovitraps. This dataset spans various locations in southern Europe, covering four countries - Albania, France, Italy, and Switzerland- and encompasses multiple seasons from 2010 to 2022. Utilising these ovitrap observations and a set of environmental predictors, we employed a stacked machine learning model to forecast the weekly average number of mosquito eggs. This approach enabled us to i) unearth the seasonal dynamics of Ae. albopictus for 12 years; ii) generate spatio-temporal explicit forecasts of mosquito egg abundance in regions not covered by conventional monitoring initiatives. Beyond its immediate application for public health management, our work presents a versatile modelling framework adaptable to infer the spatio-temporal abundance of various species, extending its relevance beyond the specific case of Ae. Albopictus.

Mapping Cocoa Farms Across Pantropical Regions Using High-Resolution Satellite Imagery and Deep Learning by Robert Masolele (WUR)

Cocoa cultivation serves as a crucial source of income for countless farmers across pantropical regions. However, this agricultural practice often leads to deforestation in tropical forests. While previous studies have highlighted the expansion of cocoa farms, particularly in select African countries, there remains a significant gap in comprehensive data regarding the location of cocoa farms on a pantropical scale. To address this challenge, our study employs deep learning models trained on Sentinel-1 and Sentinel-2 satellite imagery, coupled with annotated reference datasets, to map cocoa farms across pantropical regions.
Our findings provide valuable insights for governments, cocoa companies, consumers, NGOs, and international organizations striving to mitigate the challenges associated with escalating deforestation linked to cocoa production. Of particular significance is the utility of this dataset in addressing the recent European Union Regulation mandating companies to refrain from importing commodity crops associated with deforestation. By providing a comprehensive understanding of cocoa farm distribution across pantropical regions, our research contributes to informed decision-making and sustainable practices in cocoa production and trade.

EarthCODE – A FAIR Open Science environment for the Earth sciences by Garin Smith (Telespazio)

The EarthCODE (Earth Science Collaborative Open Development Environment) vision provides an integrated, cloud-based, user-centric development environment which can be used to support the European Space Agency's (ESA) science activities and projects. Building on activities that developed the European EO open-source ecosystem and the Open Earth System Science community (e.g. EOEPCA - Exploitation Platform Common Architecture, DeepESDL - Deep Earth System Data Lab, openEO Platform, ESA Euro Data Cube, etc.), ESA is implementing EarthCODE as a collaborative platform for conducting Earth System Science sustainably and adhering to FAIR and Open Science Principles. EarthCODE will enable the long-term persistence of research outputs from science activities.

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EarthCODE looks to maximize reproducibility, reuse, and consumption of research outputs by the wider community, promoting a flexible and scalable architecture developed with interoperable open-source blocks, with a long-term vision evolving by incrementally integrating industrially provided services from a portfolio of the Network of Resources. EarthCODE platform collaborators will participate in creating integrated architecture, with interoperable solutions and federated capabilities.
EarthCODE will use EOEPCA Open Standards to help support Open Science and help drive these standards. Open science principles are increasingly being embraced in the field of Earth Sciences, promoting transparency, collaboration, and accessibility of research. This is being done by promoting open access publications, preprints and open review processes, sharing data/methodologies for verification, reproducibility and reuse. In software development, these principles allow inspection, modification, and code contribution, encouraging collaboration among researchers through various platforms (i.e. GitHub, GitLab, etc.). Sharing of educational resources openly allows for global audience, and involvement of the public through citizen science for scientific research.
EarthCODE will provide an Integrated Development Platform, giving developers the tools needed to develop high quality workflows that allow experiments to be executed in the cloud and the reproduced by other scientists, following Open Science principles. Our solution is built around existing open-source solutions and building blocks, primarily the Open Science Catalogue, EOxHub and EOEPCA. With its adopted federated approach, EarthCODE will have the capability to facilitate processing on other platforms, i.e. DeepESDL, ESA EURO Data Cube, Open EO Cloud/Open EO Platform and AIOPEN/AI4DTE.
Collaboration and Federation are at the heart of EarthCODE. As EarthCODE evolves we expect providing solutions allowing allow federation of data and processing. EarthCODE has ambition to deliver a model for a Collaborative Open Development Environment for Earth system science, where researchers can leverage the power of the wide range of EO platform services available to conduct their science, while also making use of FAIR Open Science tools to manage data, code and documentation, create end-to-end reproducible workflows on platforms, and have the opportunity to discover, use, reuse, modify and build upon the research of others in a fair and safe way. EarthCODE thus aims to make possible the eight enabling elements of the EO Open Science and Innovation vision: open data, open-source code, linked data & code, open access documentation, end-to-end workflows reproducible on platforms, open science resources, open science tools, and a healthy community applying all the elements in their practice.

Workshop: High-Resolution Gross Primary Productivity: Modeling and Mapping Dynamics
by Serkan Isik (OGH)

This workshop will explore the high-resolution mapping of gross primary productivity (GPP) using light-use efficiency models. During the workshop, we will cover how to access the bi-monthly GPP maps and assess the accuracy of the maps via eddy covariance flux measurements. Participants will gain insight on how to exploit high-resolution GPP maps across diverse ecosystems.

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Workshop: Using GRASS, SAGA and Whiteboxtool to map global high-resolution land relief parameterization adopting Equi7 projection system by Yu-Feng Ho (OGH)

The workshop starts with accessing a global ensemble digital terrain model, cropping to tile and reprojecting to Equi7 projection system. Secondly, the attendants will set up a docker containing GRASS, SAGA and Whtieboxtool with R/Python that enables to script land relief parameterization process. Lastly, attendant will follow a workflow that produces different land relief parameters by tiles and mosaics with consideration of boundary effect, in order to achieve high-resolution global scale terrain parameter mapping.