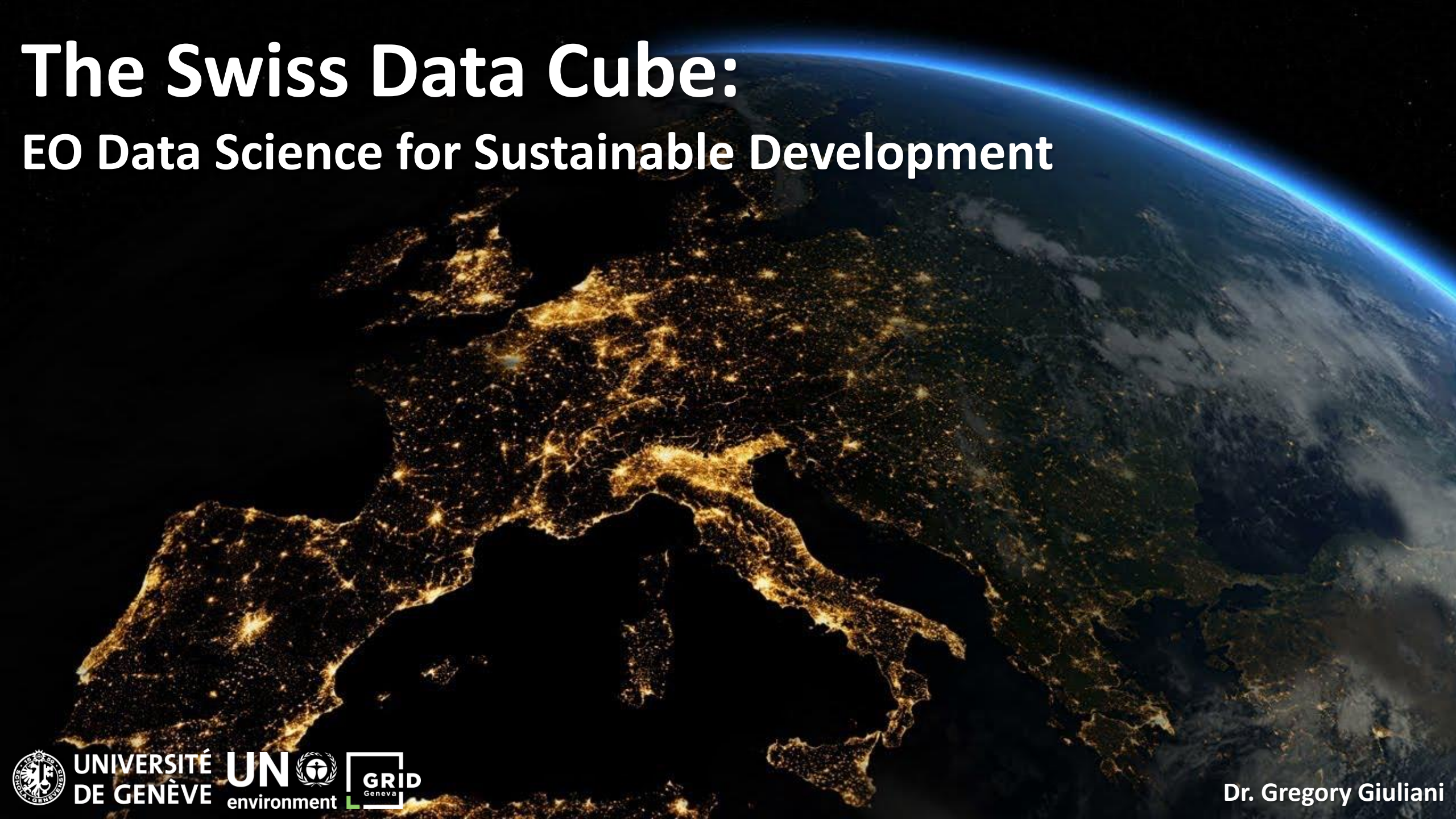
The Swiss Data Cube:

EO Data Science for Sustainable Development

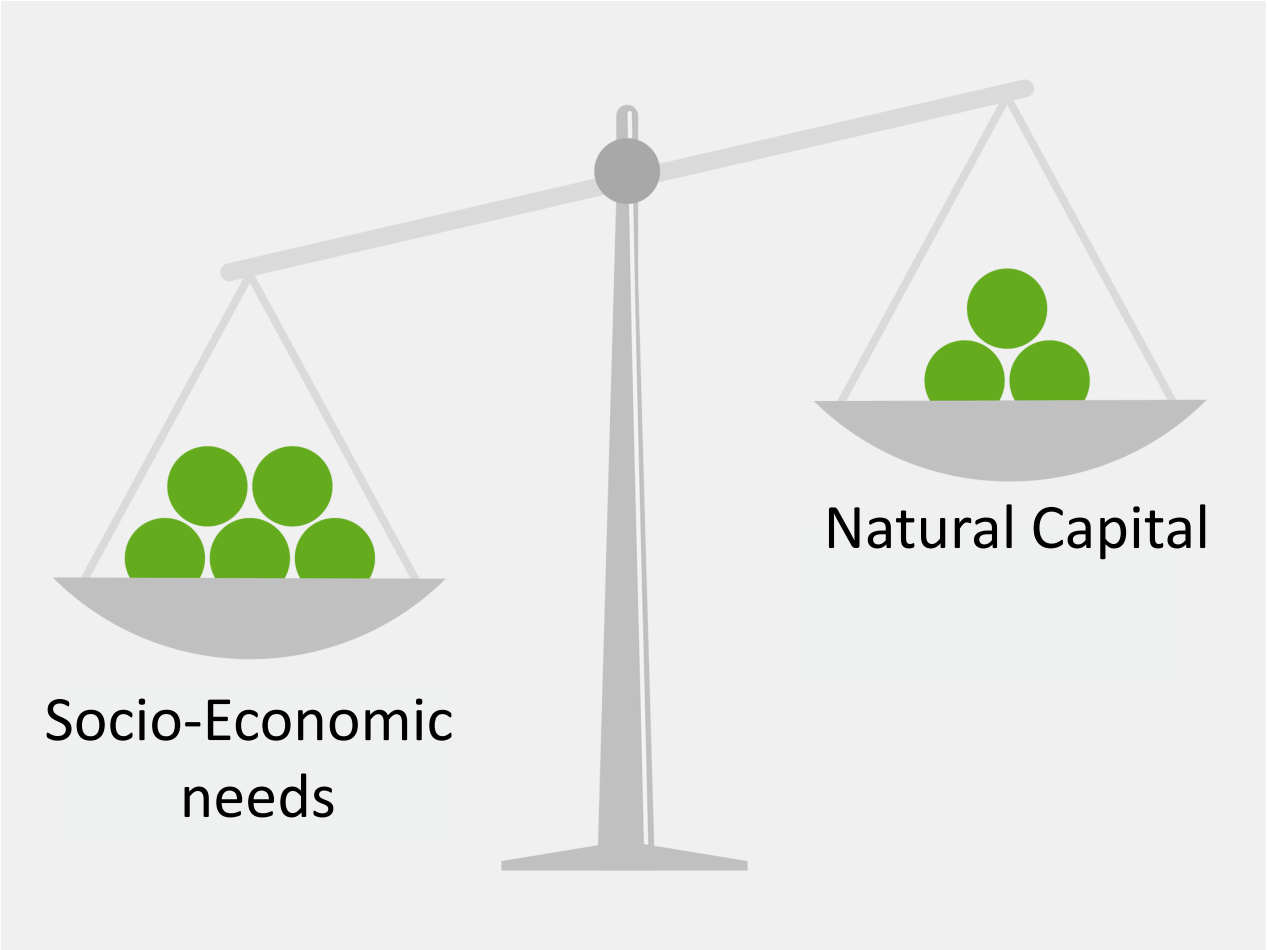


UNIVERSITÉ DE GENÈVE UN environment GRID Geneva

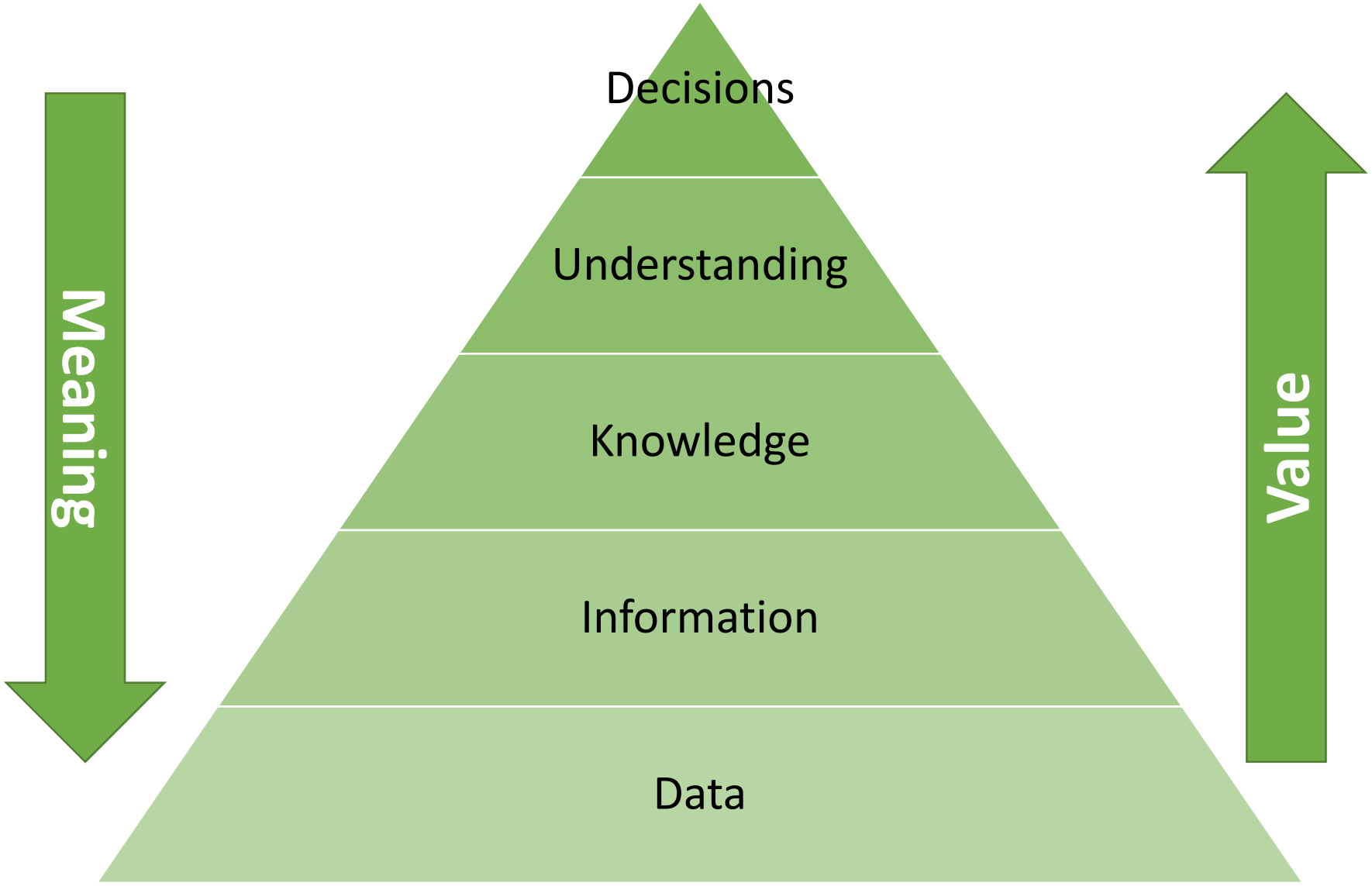
Dr. Gregory Giuliani

The key to sustainable development…

…is achieving a **balance between the exploitation of natural resources for socio-economic development**, and conserving ecosystem services that are critical to everyone' s wellbeing and livelihoods.



The Challenge: Evidence-based policy-making

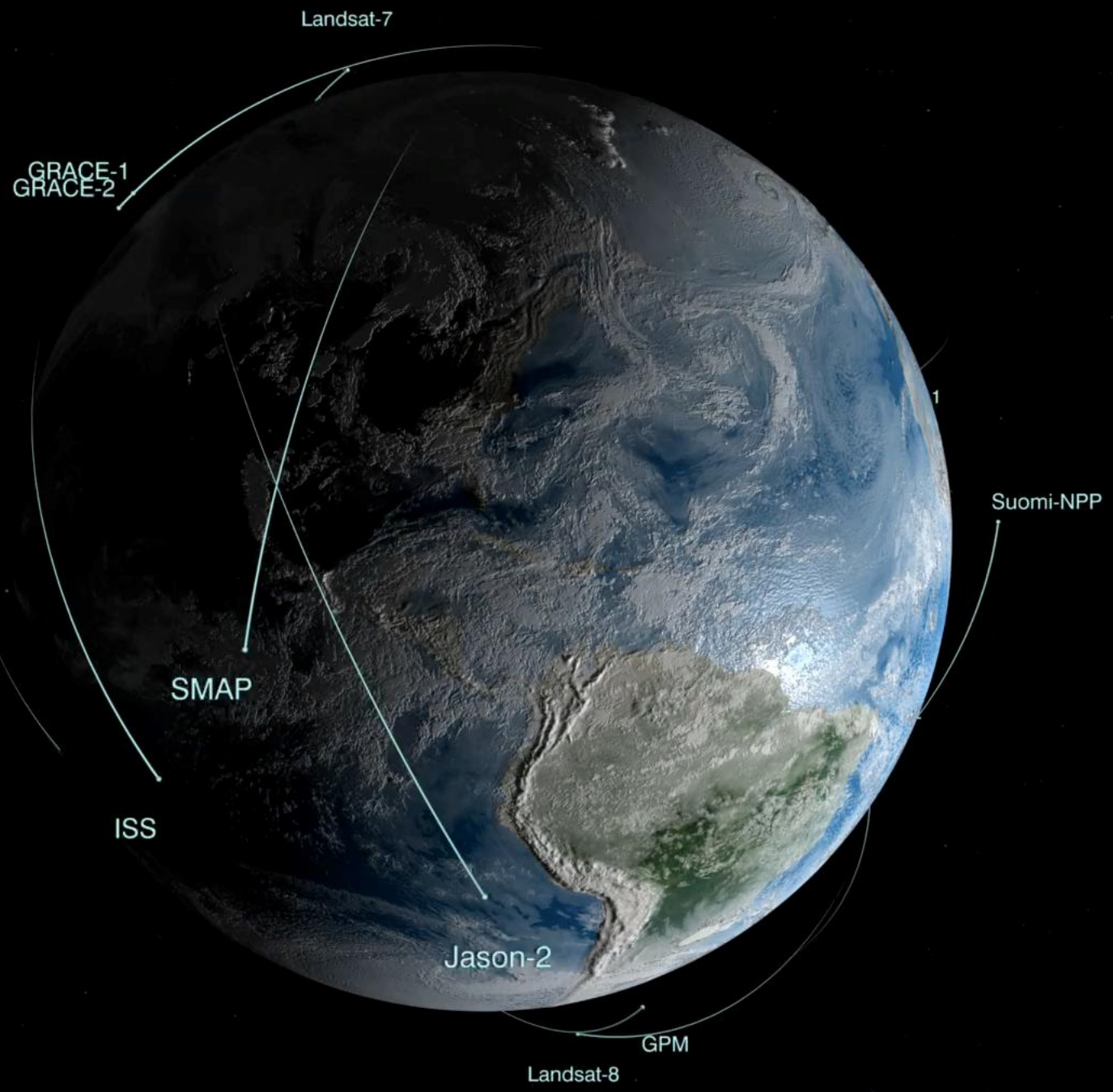


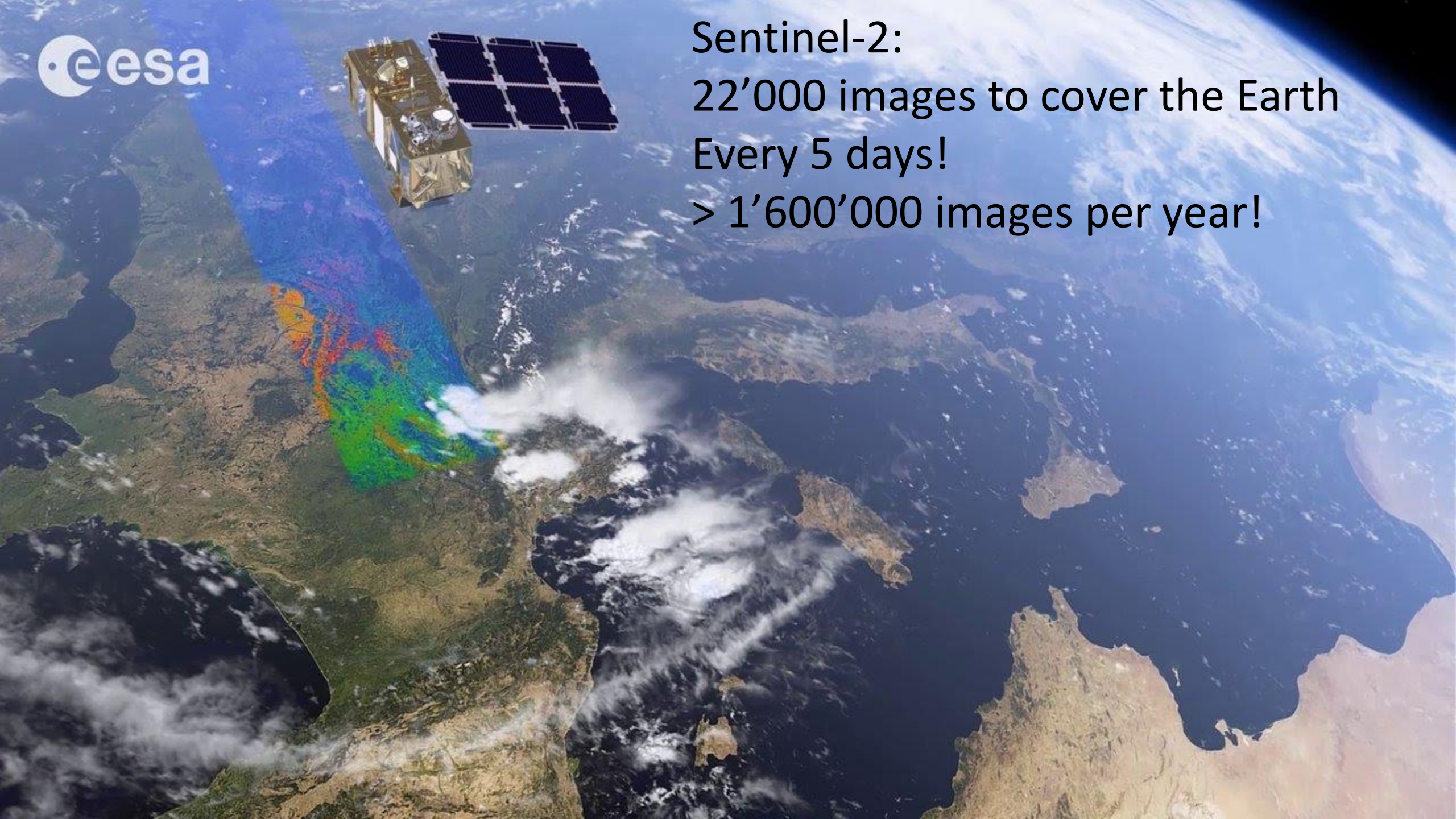
Action:
Societies decide how to use resources of our planet

Knowledge:
inform us about the limits of the planet

To better understand these changes…

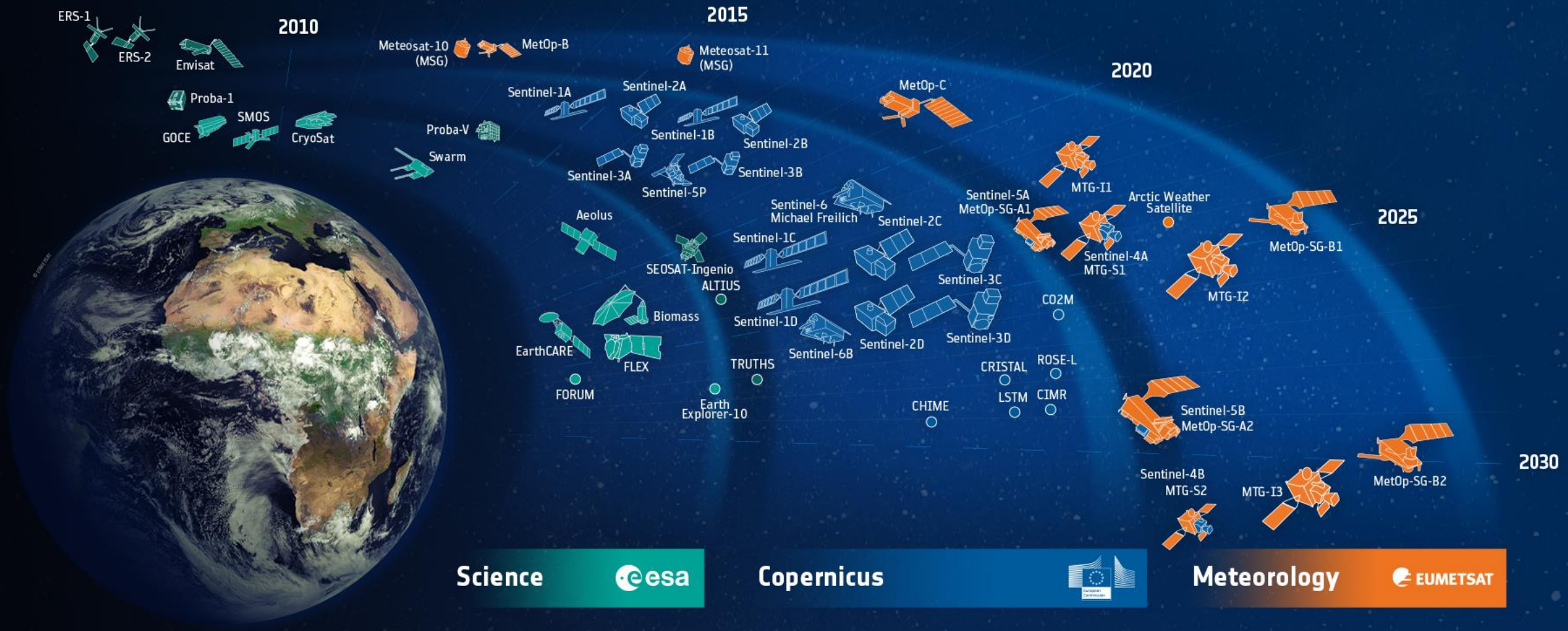
Our planet is under continuous observation from satellites





Sentinel-2:
22’000 images to cover the Earth
Every 5 days!
> 1’600’000 images per year!

Copernicus – Europe's Eye on Earth
Largest EO data provider in the World: 250TB/day data
Archive: 250PB of data stored, daily growth rate: 220TB

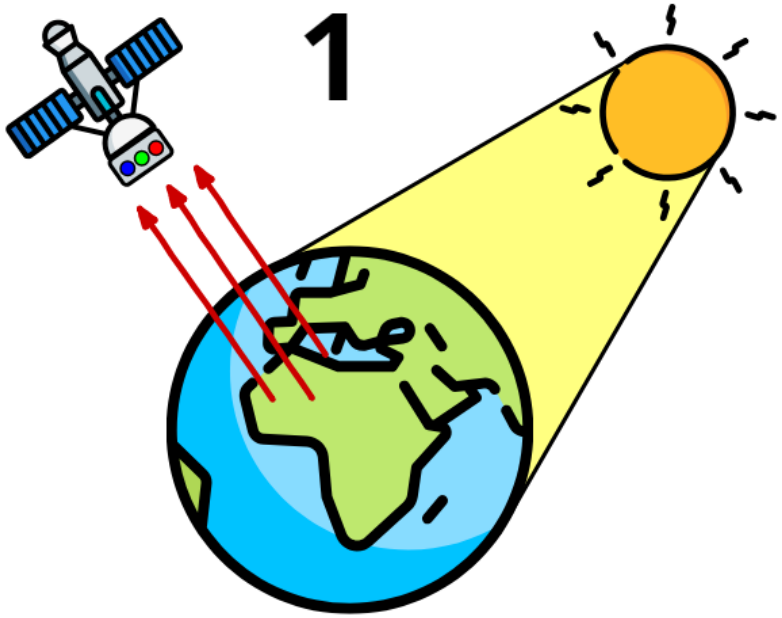


Types of satellites

Passive

radiation from sunlight

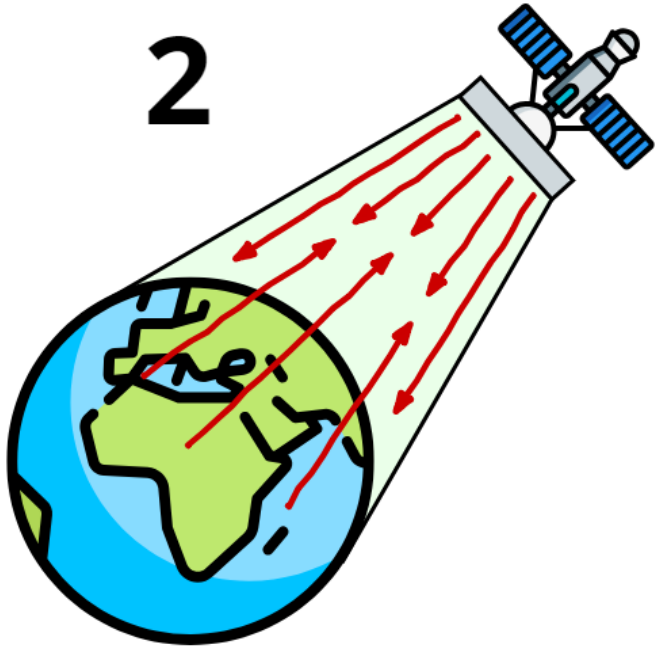
(Sentinel-2&-3, Landsat, MODIS…)



Active

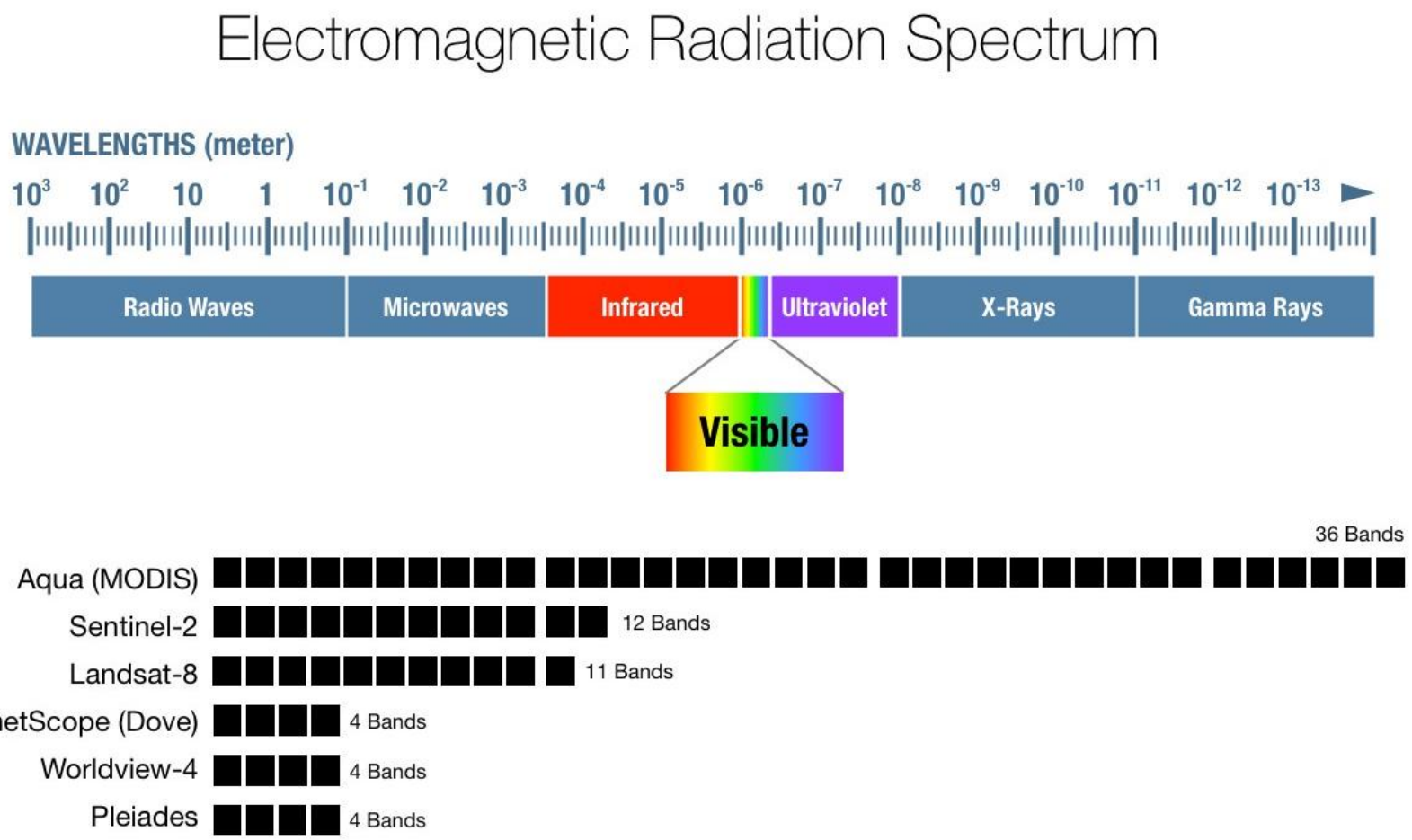
transmit radiation

(Sentinel-1&-6, Jason, Tandem-X…)



Not just photos…

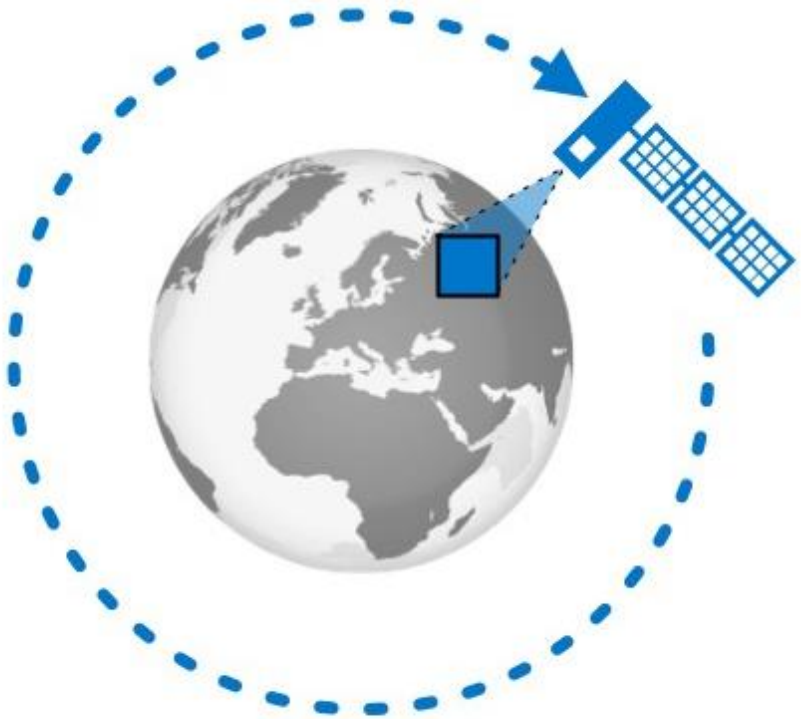
The number of bands of radiation in the electromagnetic spectrum that a satellite can sample (visible, infrared, ultraviolet, microwave, x-ray, etc.)



Radiant.Earth
Earth Imagery for Impact

Temporal resolution

Temporal resolution varies by satellite and describes the time it takes for an individual satellite to orbit and revisit a specific area. Some satellites operate as a constellation with multiple satellites working together to increase their global coverage daily.

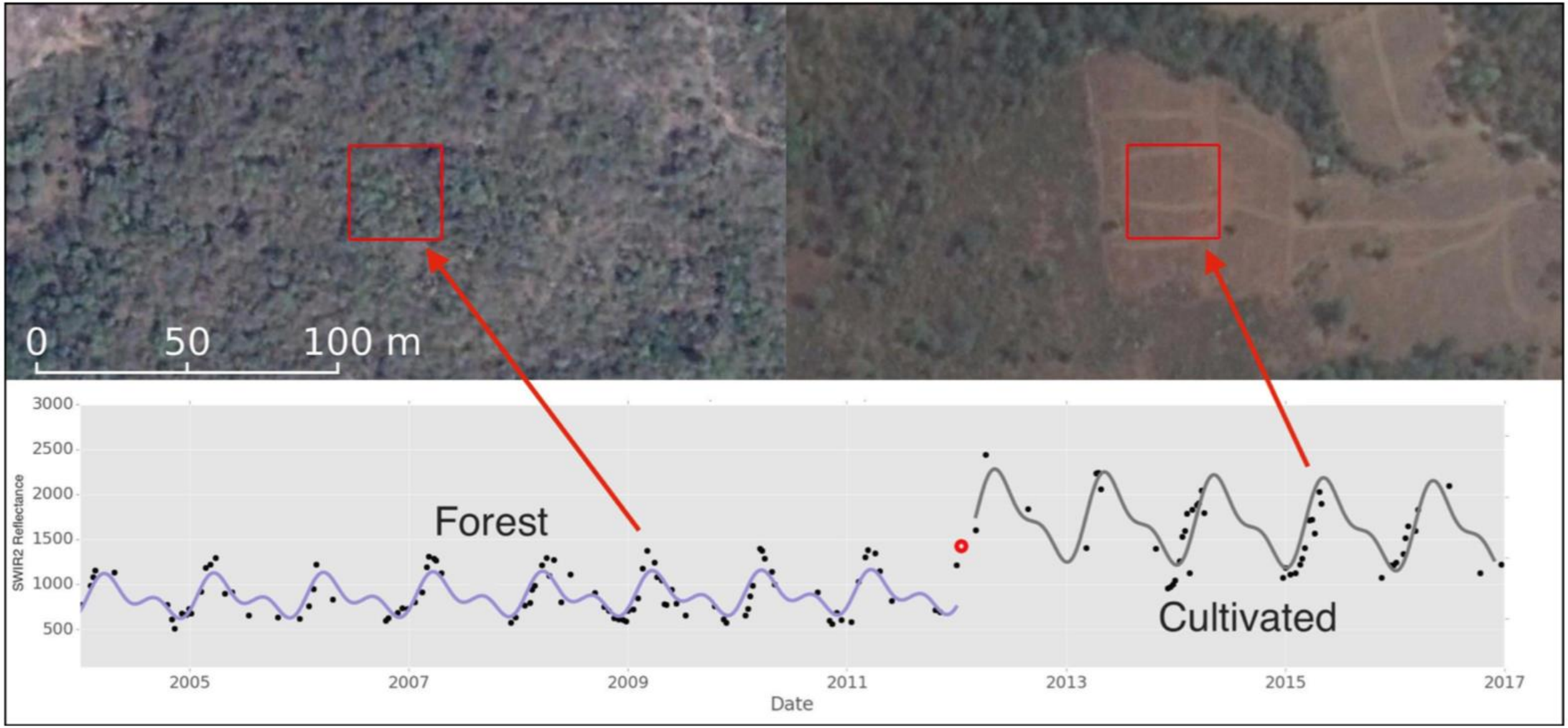


	(#)	Days between images
Aqua (MODIS)	(1)	
PlanetScope (Dove)	(172)	
Worldview-4	(1)	(When requested)
Pleiades	(2)	(When requested)
Sentinel-2	(2)	5 Days
Landsat-8	(1)	16 Days

Radiant.Earth
Earth Imagery for Impact

Temporal resolution…

…A game changer



Monitoring the Earth in (near) real-time is now a reality!

Big Data Challenges in EO Science…

- Data Volume
- Data Variety/Heterogeneity (e.g., sensors, spatial-temporal-spectral resolution)
- It requires scientific knowledge to understand what data is needed… optical (which resolution?), radar (which type?)
- It is hard to access or download
- It is hard to prepare… atmospheric correction, grid formats, pixel alignment, speckle filtering
- It requires capacity building and training

How to transform this large amount of data in useful information and support evidence-based decisions?

Traditional remote sensing product process

Petabyte heirarchical archive:

Millions of individual scenes. Tape store accessed by robot.

Orthorectification calibration, cloud masking, atmospheric correction, mosaicing.

Search catalogue order scenes.

Identify footprint of product in space or time.

Client requests product.

Feature extraction, algorithm application spectral unmixing.

Product packaging and delivery.

Courtesy of Geoscience Australia

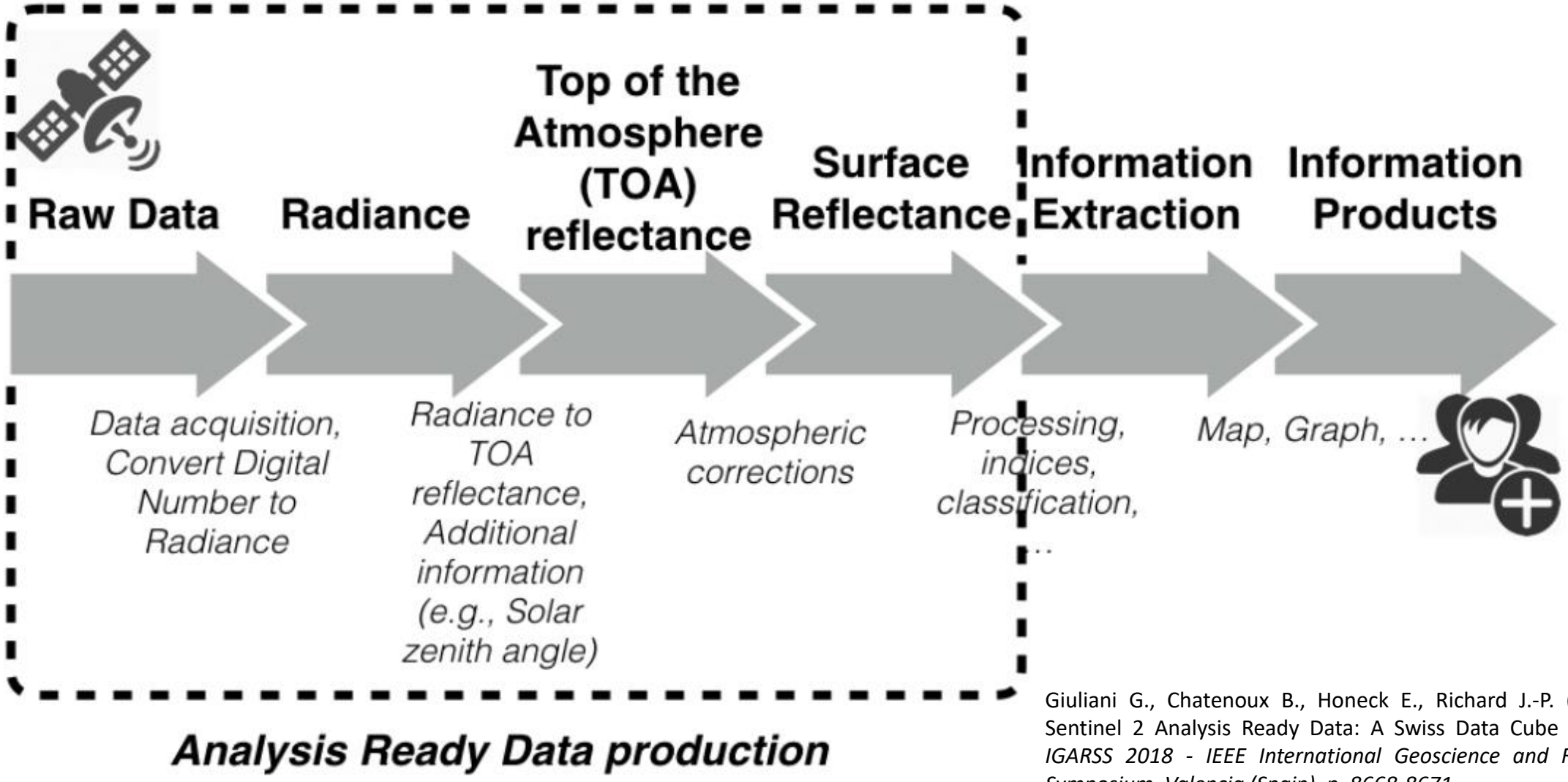
Various users needs the same data for various purposes…

…investing in the entire value chain!

Courtesy of GeoScience Australia

Analysis Ready Data are key to reduce the burden on EO data users!

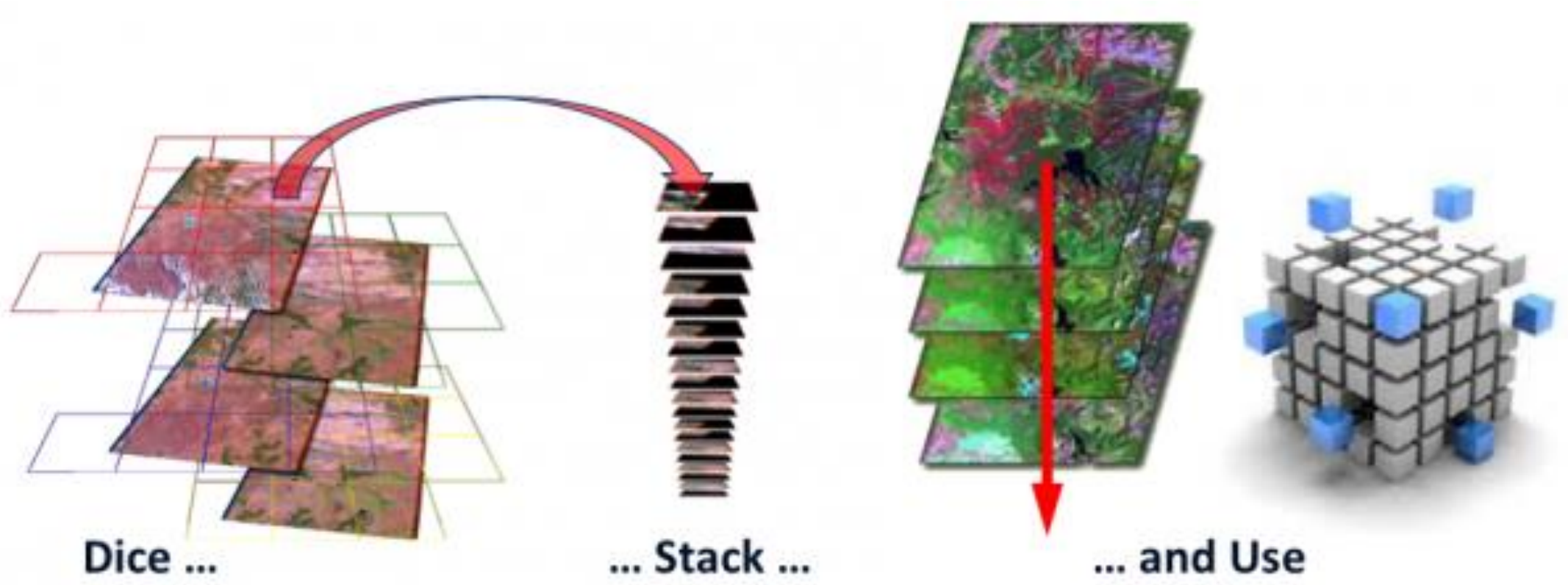
Spending more time in analyzing data than searching & pre-processing data…



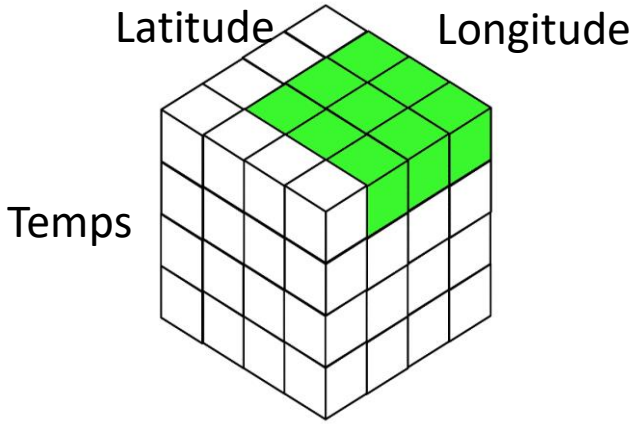
Giuliani G., Chatenoux B., Honeck E., Richard J.-P. (2018) Towards Sentinel 2 Analysis Ready Data: A Swiss Data Cube Perspective. *In: IGARSS 2018 - IEEE International Geoscience and Remote Sensing Symposium. Valencia (Spain). p. 8668-8671*

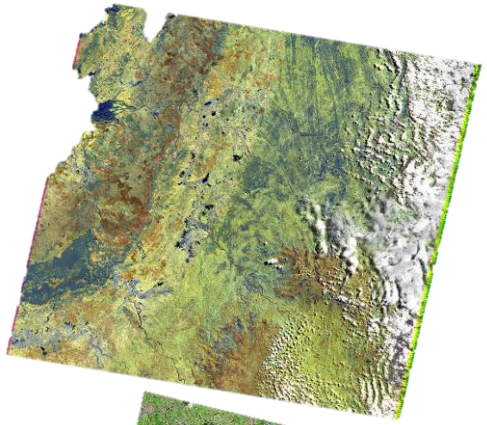
What are Data Cubes?

Time-series multi-dimensional (space, time, data type) stack of spatially aligned pixels used for efficient and effective access and analysis.

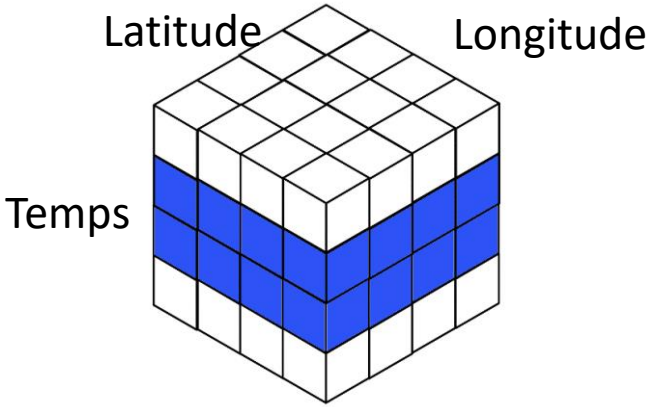


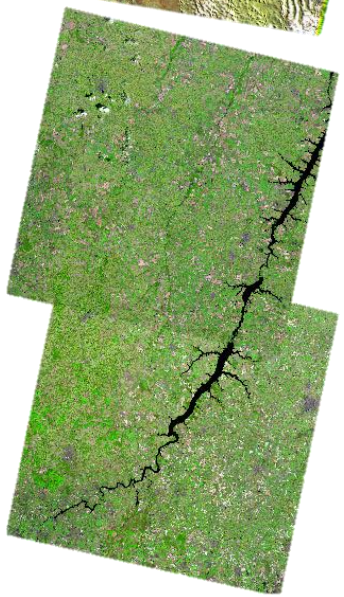
Courtesy of GeoScience Australia



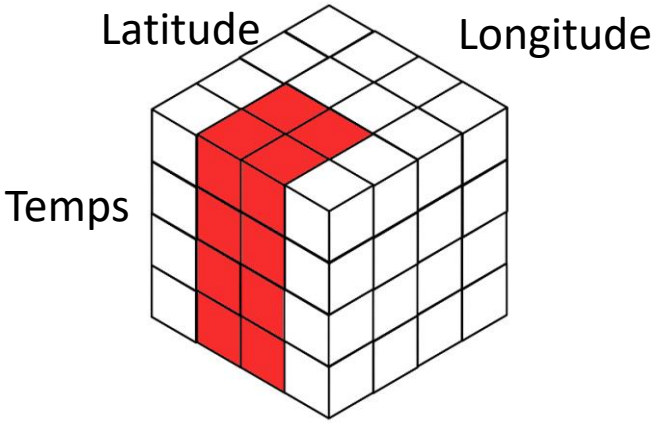


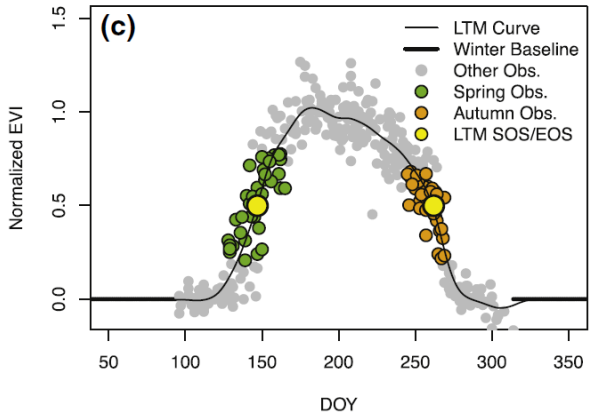
A single time slice, similar to a standard **“scene”** can be used to assess a single point in time





Several time slices can be combined into one to form a “**Mosaic**”. This is often used to reduce clouds or create seasonal or annual images.





Time Series analyses consider the variation of data over time to assess change

Adapted from CEOS

Governments have **national and international reporting commitments** and obligations as well as national environmental programs.

They all **need information that is synoptic, consistent, spatially explicit**, sufficiently detailed to **capture anthropogenic impacts**, and national in scope.

EO Data Cubes can provide the **long baseline required to determine trends, define present, and inform future**. This can fit these interests to inform programs and communities.

Plan directeur de recherche Environnement 2021-2024

Domaines et thèmes de recherche prioritaires

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Office fédéral de l'environnement OFEV

Thèmes de recherche prioritaires 2021-2024

1 Perspectives d'avenir : relevé de données et modélisation fondée sur celles-ci

1.1 Étude et modélisation quantitatives de l'incidence des grandes tendances globales sur l'environnement en Suisse.

1.2 Modélisation de tendances et de perspectives pour divers domaines environnementaux, à partir de données rétrospectives, en particulier de séries chronologiques spatialement distribuées.

1.3 Élaboration de méthodes pour la prise en compte des aspects écologiques et régionaux dans l'élaboration d'une vue d'ensemble systémique servant de base à la prise de décision.

1.4 Optimisation des réseaux et des méthodes de mesure, en particulier en ce qui concerne la combinaison de la télédétection et des mesures in situ, le développement des méthodes de télédétection des changements, l'analyse des opportunités et des risques des nouvelles méthodes d'observation environnementale.

1.5 Élaboration de bases pour le monitoring systématique à long terme des polluants persistants et des métaux lourds dans les organismes et les milieux environnementaux.

1.6 Détermination des facteurs pertinents pour l'examen des indicateurs utilisés actuellement dans le cadre des comptes rendus sur l'environnement et mise au point d'un système de veille (radar) pour les questions environnementales qui devraient être étudiées à l'avenir.

1.7 Développement de la bibliothèque de données environnementales et de la science ouverte (« open science ») : analyse des effets des stratégies de libre accès (« open access ») et de transparence des données gouvernementales (« open government data ») sur la recherche dans le secteur environnemental.

2 Diffusion d'informations, communication et mutation des valeurs

2.1 Évaluation et optimisation du système de rapports sur l'environnement pour chaque média (supports imprimés, voie électronique) et public cible, et étude de la manière dont les groupes cibles pertinents peuvent être identifiés et atteints.

2.2 Élaboration de méthodes d'agrégation et de regroupement des informations pour une communication optimale des données environnementales.

2.3 Élaboration d'approches pour communiquer les impacts environnementaux invisibles, intangibles et imperceptibles, tels que la perte de biodiversité ou la micropollution.

2.4 Analyses de l'efficacité des mesures de communication (médias sociaux, campagnes, etc. et élaboration d'un modèle d'impact pour la communication sur les questions environnementales complexes.

2.5 Enregistrement des paramètres démographiques pertinents (connaissances, attitudes, etc.) pour une communication axée sur les groupes cibles.

2.6 Étude des possibilités d'influencer la mutation des valeurs en vue d'une transformation sociale.

3 Promotion des compétences environnementales chez les professionnels

3.1 Identification des facteurs pertinents pour l'acquisition et l'application des compétences environnementales chez les professionnels.

3.2 Mesure de l'efficacité des actions choisies dans les domaines professionnels pertinents en matière environnementale.

3.3 Étude de la contribution possible de la numérisation à la promotion des compétences environnementales.

4 Transformation numérique

4.1 Étude des opportunités et des risques de la numérisation en termes d'impact sur l'environnement et les ressources, et identification des conditions-cadres nécessaires pour que la numérisation puisse exercer un effet majoritairement positif sur l'environnement.

4.2 Étude du potentiel de la transformation numérique de la société et de l'économie pour l'observation de l'environnement (monitoring, programme Copernicus), l'exécution de la législation environnementale et la communication environnementale.

SWISS DATA CUBE *in Numbers*

A unique Analysis Ready Data Archive

Updated every week!

37 years
FROM 1984 to 2021

7 sensors
LANDSAT 5/7/8;
SENTINEL-1/2 A-B

10-30-90m
PIXEL RESOLUTION

> 450 million
PIXELS

> 1000 billion
OBSERVATIONS

~ 15000 images
INGESTED

~7 TB
ANALYSIS READY DATA

~10 millions CHF
COST OF DATA WITHOUT OPEN DATA ACCESS POLICY

GRID Genève · UNIVERSITÉ DE GENÈVE · University of Zurich[UZH] · WSL

Giuliani G., Chatenoux B., De Bono A., Rodila D., Richard J.-P., Allenbach K., Dao H., Peduzzi P. (2017) Building an Earth Observations Data Cube: lessons learned from the Swiss Data Cube (SDC) on generating Analysis Ready Data (ARD). *Big Earth Data 1(1):1-18*

Open Data Cube - https://www.opendatacube.org

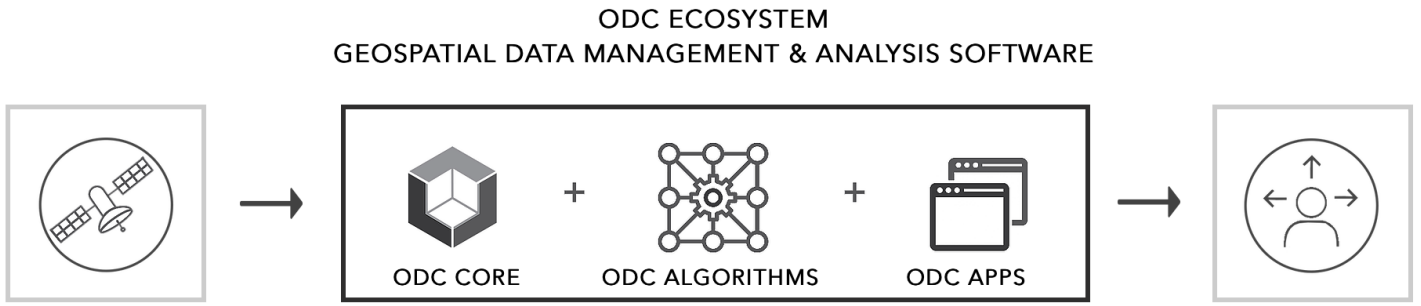
OPEN DATA CUBE

About Overview Install Applications Resources News Contact

Open Data Cube

The Open Data Cube (ODC) is an Open Source Geospatial Data Management and Analysis Software project that helps you harness the power of Satellite data. At its core, the ODC is a set of Python libraries and PostgreSQL database that helps you work with geospatial raster data. See our GitHub repository here>>.

The ODC seeks to increase the value and impact of global Earth observation satellite data by providing an open and freely accessible exploitation architecture. The ODC project seeks to foster a community to develop, sustain, and grow the technology and the breadth and depth of its applications for societal benefit.



SATELLITE DATA
Examples:
- *Landsat*
- *Sentinel*
- *MODIS*

FLEXIBLE DEPLOYMENT
Depending on your application, the Open Data Cube can be deployed on HPC, Cloud, and local installations. Typical installations run on Linux, MacOS, and Windows.

INFORMED DECISIONS
Examples:
- *Deforestation*
- *Water Quality*
- *Illegal Mining*

Learn More

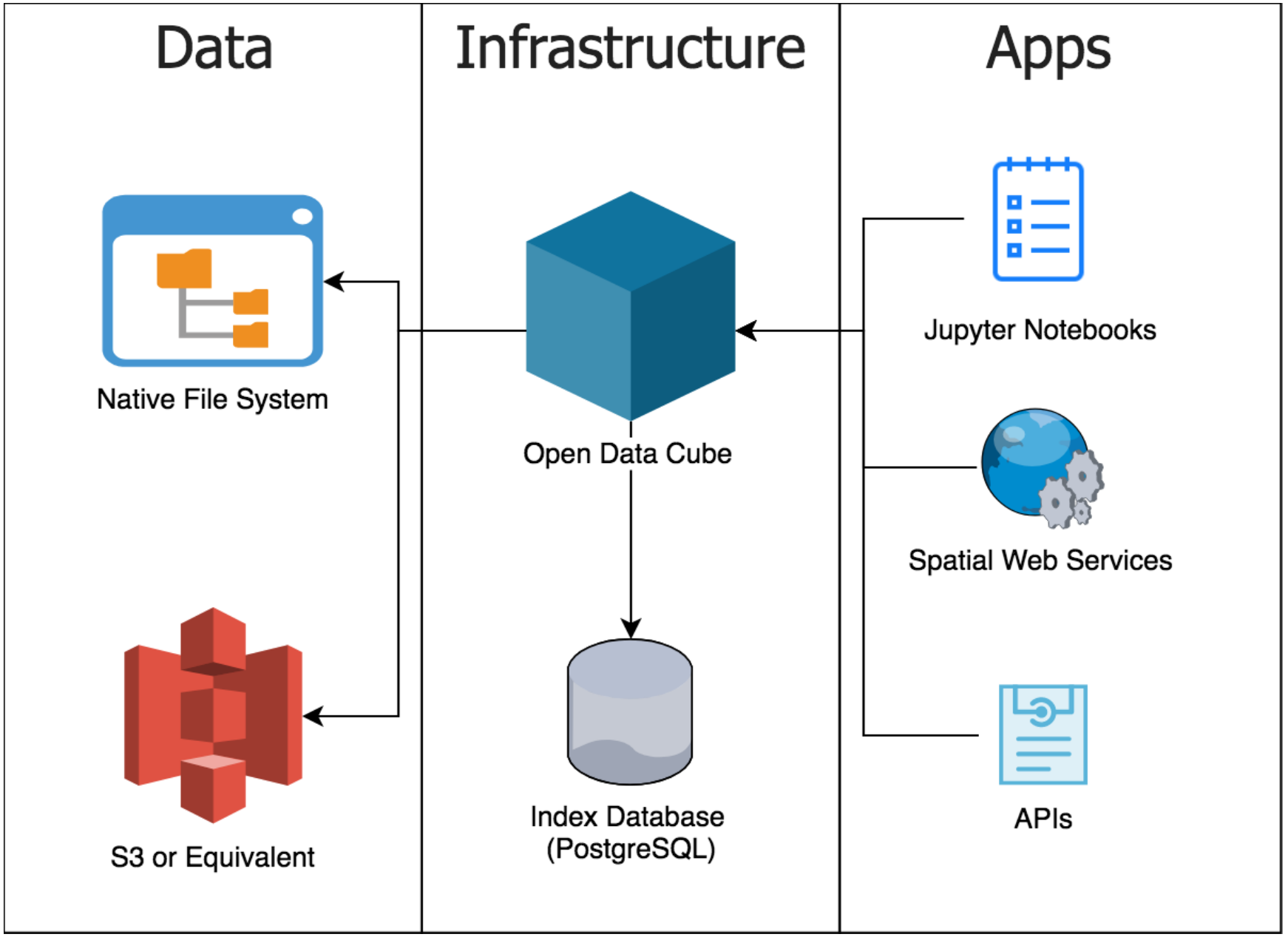
Australian Government Geoscience Australia · CEOS · USGS science for a changing world · CSIRO · CATAPULT Satellite Applications · AMA ANALYTICAL MECHANICS ASSOCIATES

What is the Open Data Cube?

A Python Library that facilitates working with raster data

Courtesy UK Catapult

Technical components



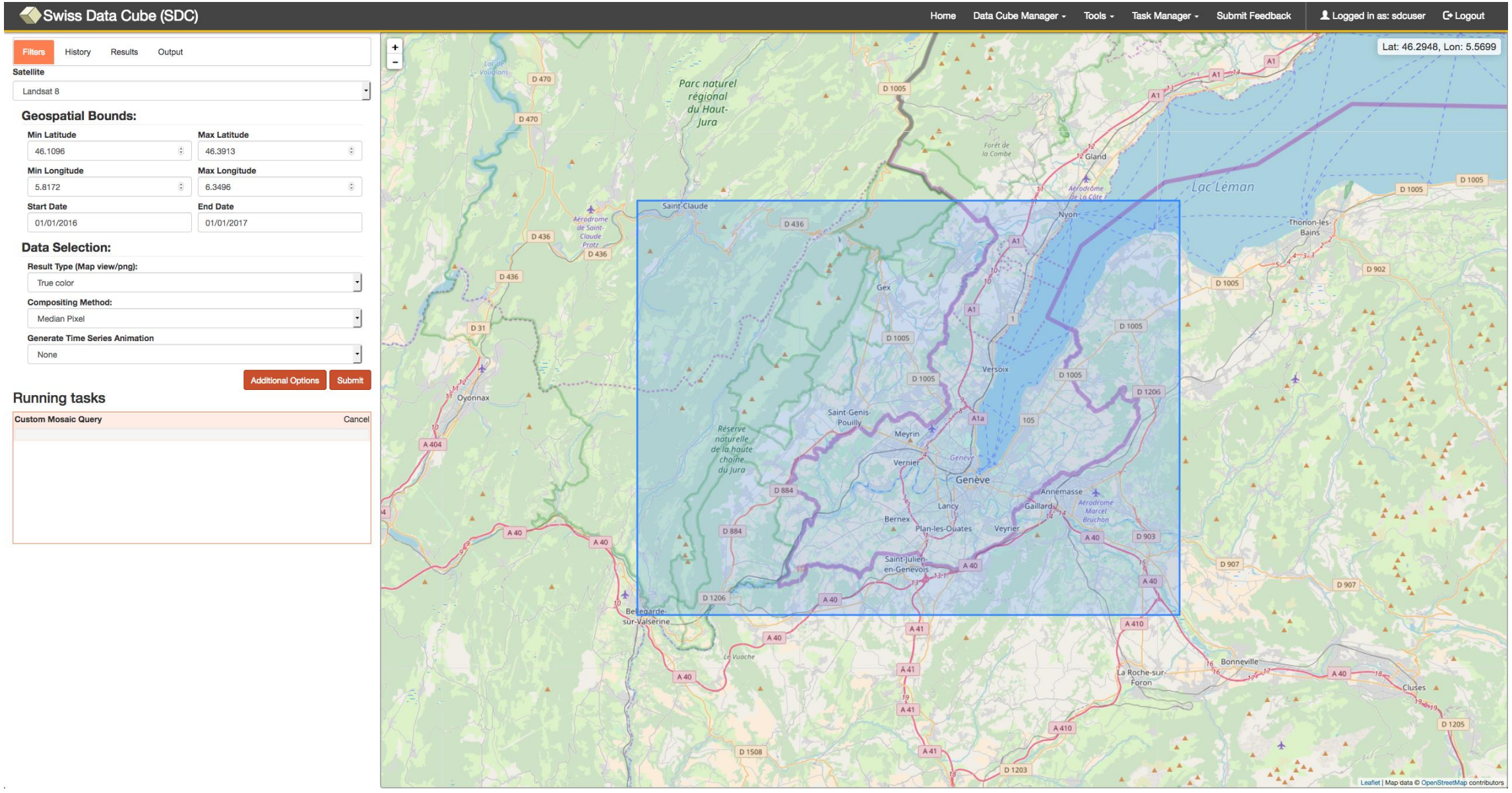
In a nutshell:

- Data
- An Index
- Software

Courtesy UK Catapult

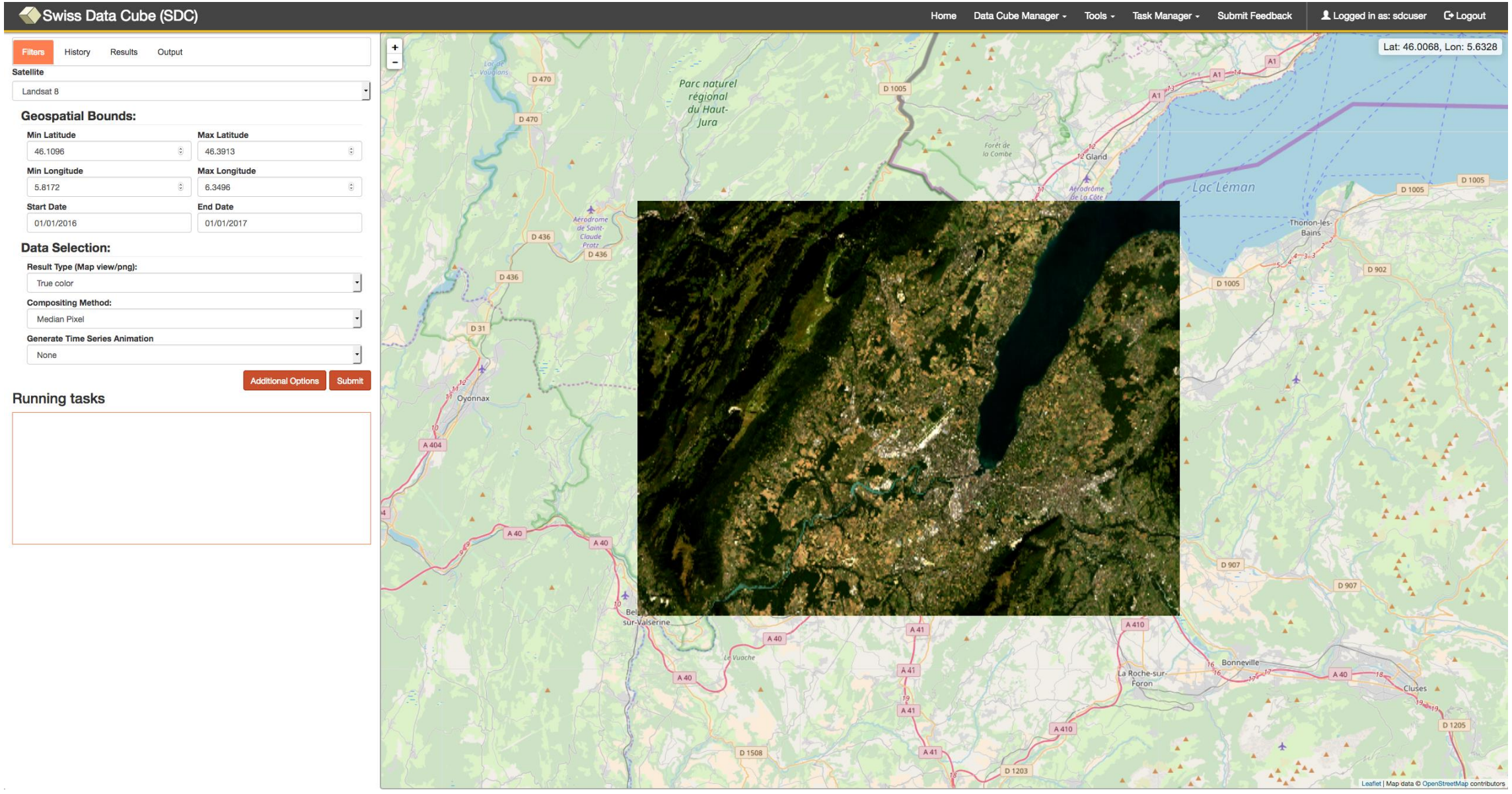
How to use the Swiss Data Cube?

Define your area of interest, your algorithm and your time-frame



How to use the Swiss Data Cube?

And get the result!



Or use the Python API

Jupyter Notebook

jupyter test2_Aletsch_LB_RGB Last Checkpoint: 09/26/2017 (autosaved)

Logout

File Edit View Insert Cell Kernel Widgets Help

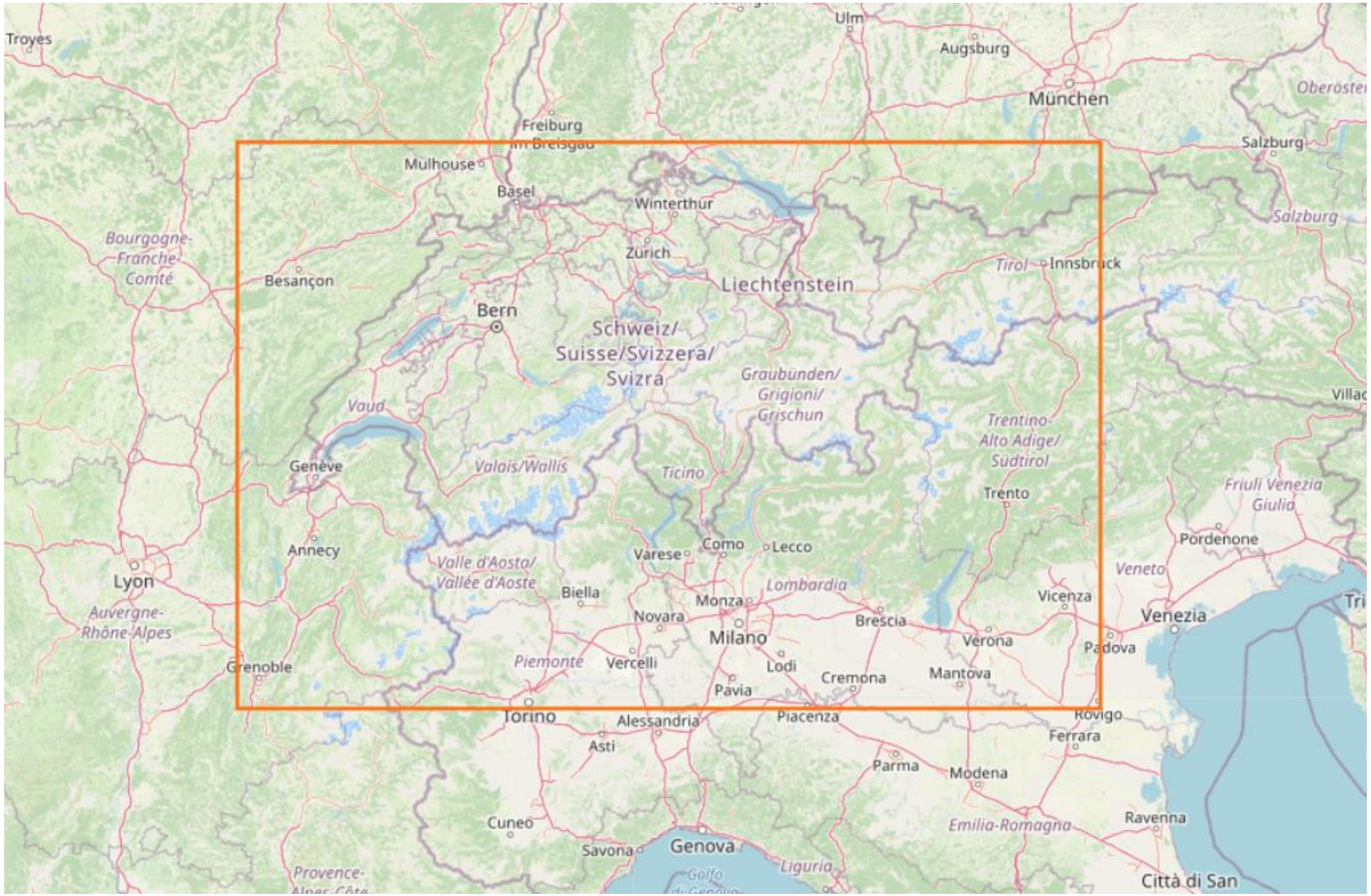
Trusted Python 3

Code

Out[8]: <matplotlib.text.Text at 0x7f19aff47b00>

In [7]:
```
max_time = 18
for i in range(0,max_time):
    plt.figure(figsize=(6, 6))
    sel = scaled2.isel(time=i)
    plt.imshow(sel)
    plt.axis('off')
    t = pd.to_datetime(str(sel['time'].values))
    plt.title(t.strftime('%d %m %Y'),loc='right')
    plt.title('RGB Glacier Aletsch',loc='left')
```

Covering more than Switzerland…



Bondo Landslide – 23 august 2017

NATURAL CATASTROPHE

Bondo landslide damage estimated at CHF41 million

By swissinfo.ch and agencies

DEC 14, 2017 - 21:29

A total of 99 buildings were damaged in Bondo, a third of them were destroyed

(Keystone)

The massive landslide that swept through Bondo, a small village in canton Graubünden, in August caused damage of around CHF41 million ($41.5 million), the municipality of Bregaglia said on Thursday.

The municipality faced known costs of CHF20 million – half for damage to infrastructure and half for immediate action taken, such as the evacuation of the surrounding area. The cantonal building insurance will cover CHF12.5 million of that since 99 buildings were damaged, a third of them destroyed.

The rest of the CHF41 million is the estimated cost of ongoing work to fix the damage. The municipal authorities said the area around the Piz Cengalo mountain and the

Leuk forest fire – 13 august 2003

Huge fire rages near alpine resort

AUG 14, 2003 - 14:02

The biggest single forest fire in Switzerland for three decades has forced emergency services to draft in the Swiss army to help battle the flames.

Dry conditions and winds of around 45kmh fuelled the blaze near the spa resort of Leukerbad.

Some 125 soldiers were mobilised to help firefighters tackle the blaze which ravaged 450 hectares of forest in canton Valais.

Around 450 hectares of forest went up in smoke around Leuk.

(Keystone)

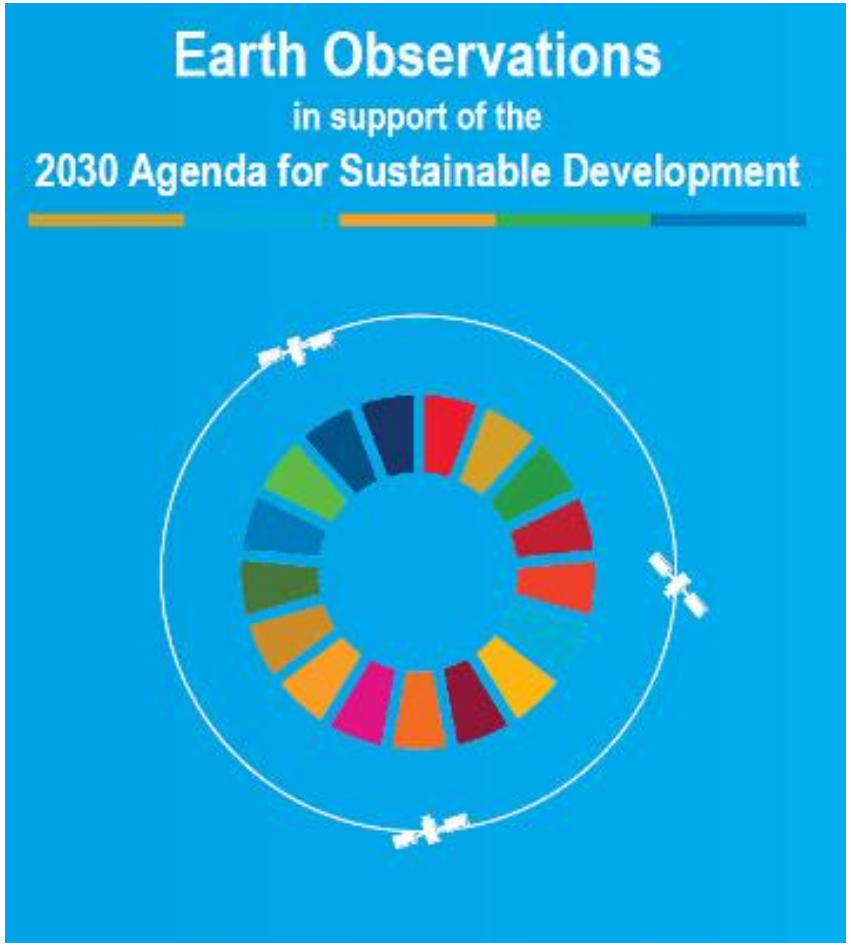
Seven helicopters – including two army Superpumas - and more than 300 firefighters were drafted in to contain the fire, which cantonal police believe could have been ignited by a cigarette. One worker was admitted to hospital with slight injuries.

The blaze began on Wednesday evening and rapidly spread to an altitude of 2,000 metres. Shortly before midnight, hundreds of people living in the nearby towns of Leuk, Wyler and Albinen had to be evacuated.

They were able to return home late on Thursday even though the fire continued to burn in patches.

Earth Observations is useful for monitoring SDG's

GEO GROUP ON EARTH OBSERVATIONS



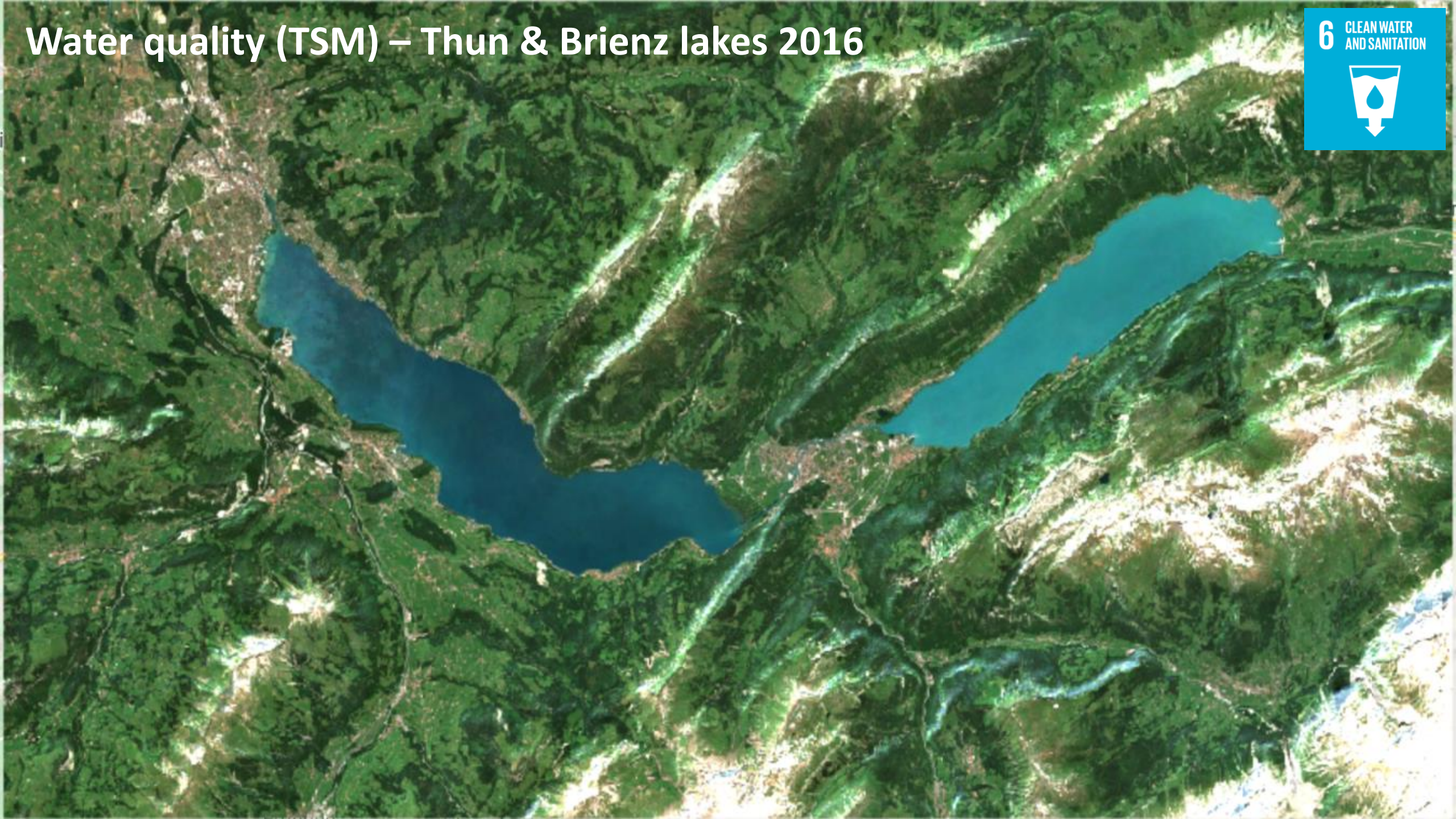
http://earthobservations.org/geo_sdgs.php

EARTH OBSERVATION AND GEOSPATIAL INFORMATION LINKAGES TO SDG GOALS, TARGETS AND INDICATORS

SUSTAINABLE DEVELOPMENT GOALS

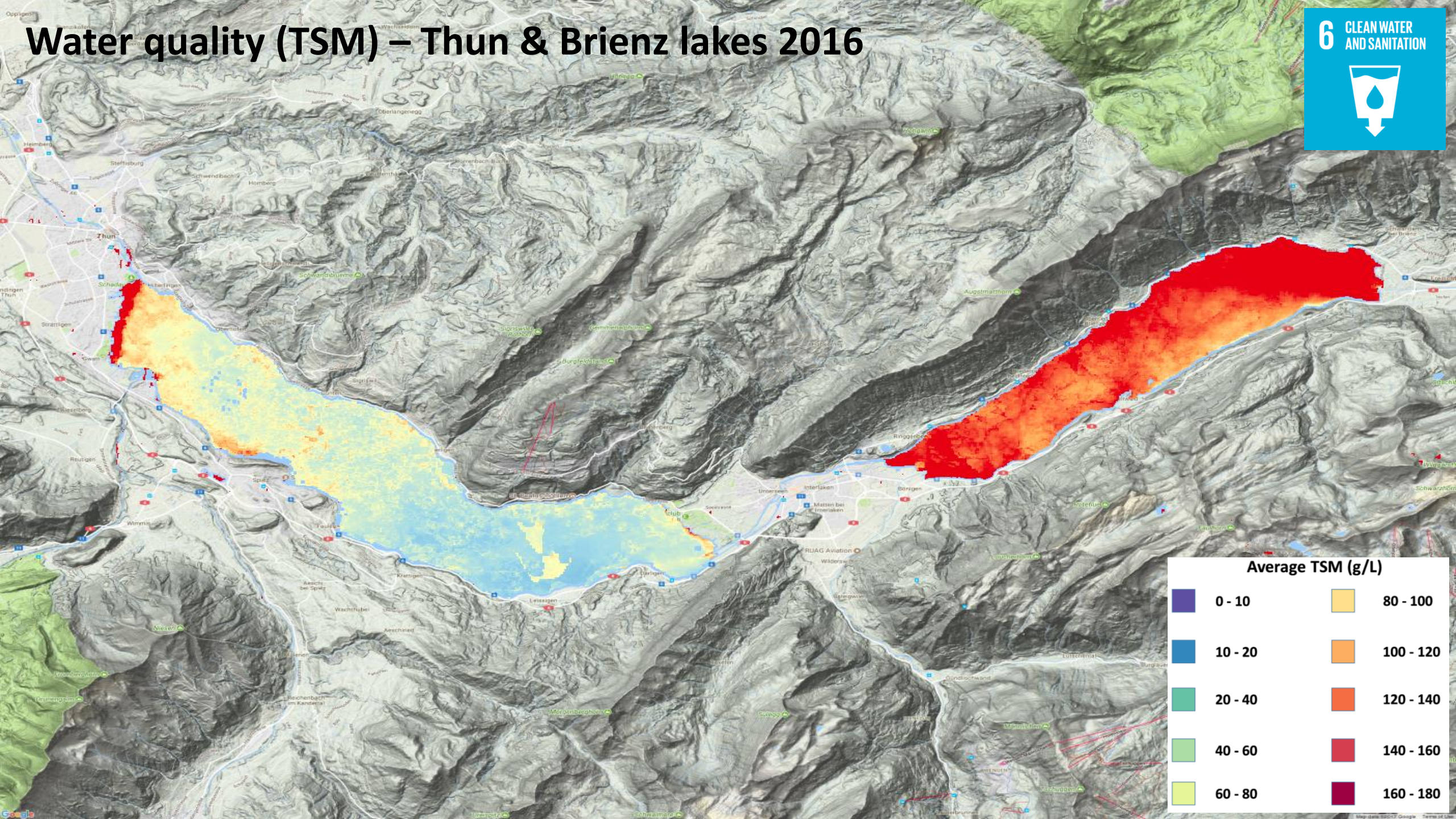
Target (Contribute to progress on the Target, not necessarily the Indicator)									Goal	Indicator (Direct measure or indirect support to the Indicator)					
							1.4	1.5	1 No poverty	1.4.2					
						2.3	2.4	2.c	2 Zero hunger	2.4.1					
					3.3	3.4	3.9	3.d	3 Good health and well-being	3.9.1					
									4 Quality education						
								5.a	5 Gender equality	5.a.1					
		6.1	6.3	6.4	6.5	6.6	6.a	6.b	6 Clean water and sanitation	6.3.1	6.3.2	6.4.2	6.5.1	6.6.1	
					7.2	7.3	7.a	7.b	7 Affordable and clean energy	7.1.1					
								8.4	8 Decent work and economic growth						
					9.1	9.4	9.5	9.a	9 Industry, innovation and infrastructure	9.1.1	9.4.1				
						10.6	10.7	10.a	10 Reduced inequalities						
	11.1	11.3	11.4	11.5	11.6	11.7	11.b	11.c	11 Sustainable cities and communities	11.1.1	11.2.1	11.3.1	11.6.2	11.7.1	
				12.2	12.4	12.8	12.a	12.b	12 Responsible consumption and production	12.a.1					
					13.1	13.2	13.3	13.b	13 Climate action	13.1.1					
		14.1	14.2	14.3	14.4	14.6	14.7	14.a	14 Life below water	14.3.1	14.4.1	14.5.1			
	15.1	15.2	15.3	15.4	15.5	15.7	15.8	15.9	15 Life on land	15.1.1	15.2.1	15.3.1	15.4.1	15.4.2	
								16.8	16 Peace, justice and strong institutions						
17.2	17.3	17.6	17.7	17.8	17.9	17.16	17.17	17.18	17 Partnerships for the goals	17.6.1	17.18.1				

Water quality (TSM) – Thun & Brienz lakes 2016



6 CLEAN WATER AND SANITATION

Water quality (TSM) – Thun & Brienz lakes 2016



6 CLEAN WATER AND SANITATION

Water Observations

Water observations / Maximum observations

0% - 0.5%	25% - 37.5%
0.5% - 1.25%	37.5% - 50%
1.25% - 2.5%	50% - 62.5%
2.5% - 6.25%	62.5% - 75%
6.25% - 12.5%	75% - 87.5%
12.5% - 25%	87.5% - 100%

Water detection – Drought impact (2018)

11 SUSTAINABLE CITIES AND COMMUNITIES

Modelling Accessibility to Urban Green Areas Using Open Earth Observations Data: A Novel Approach to Support the Urban SDG in Four European Cities

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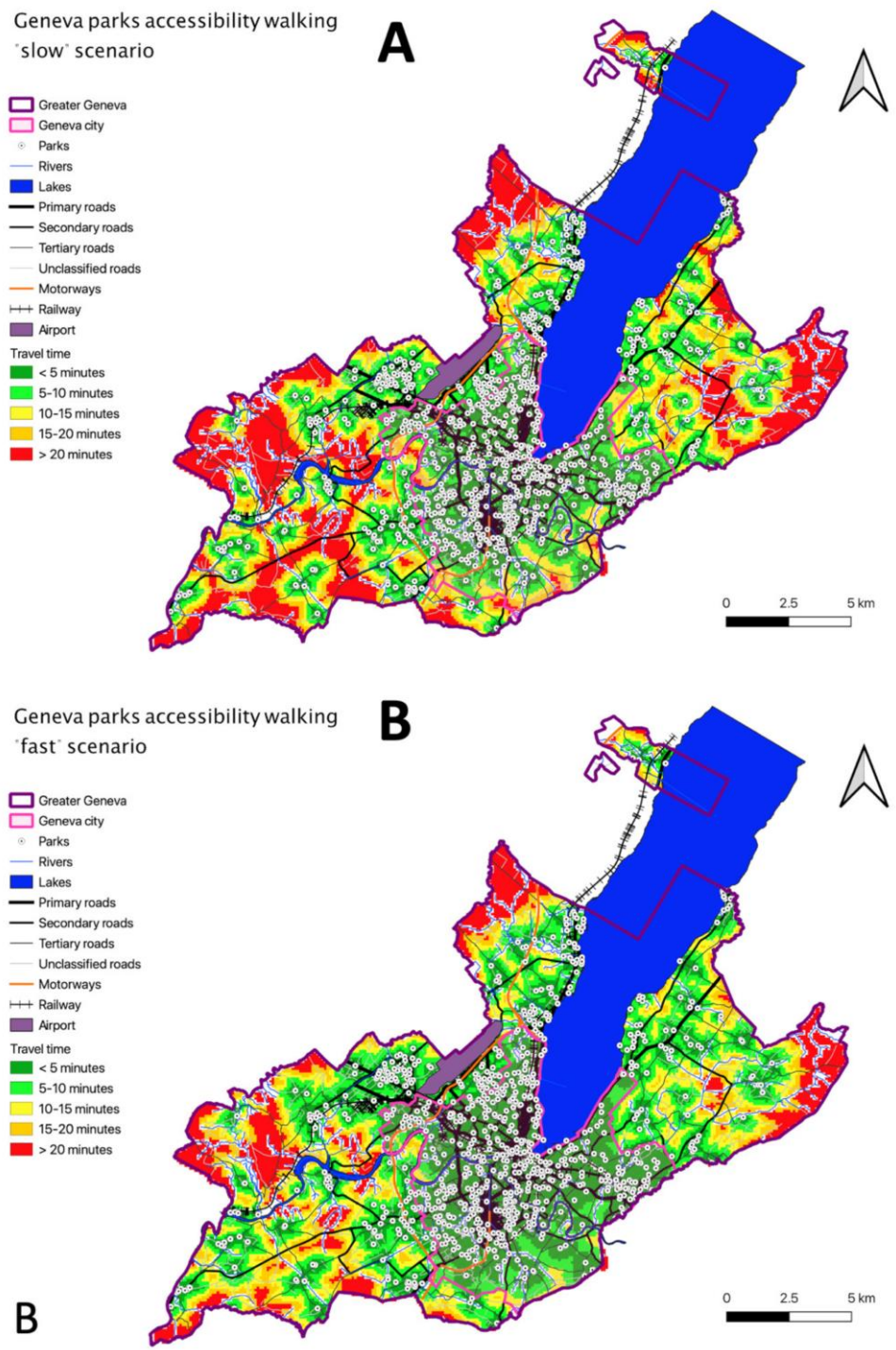
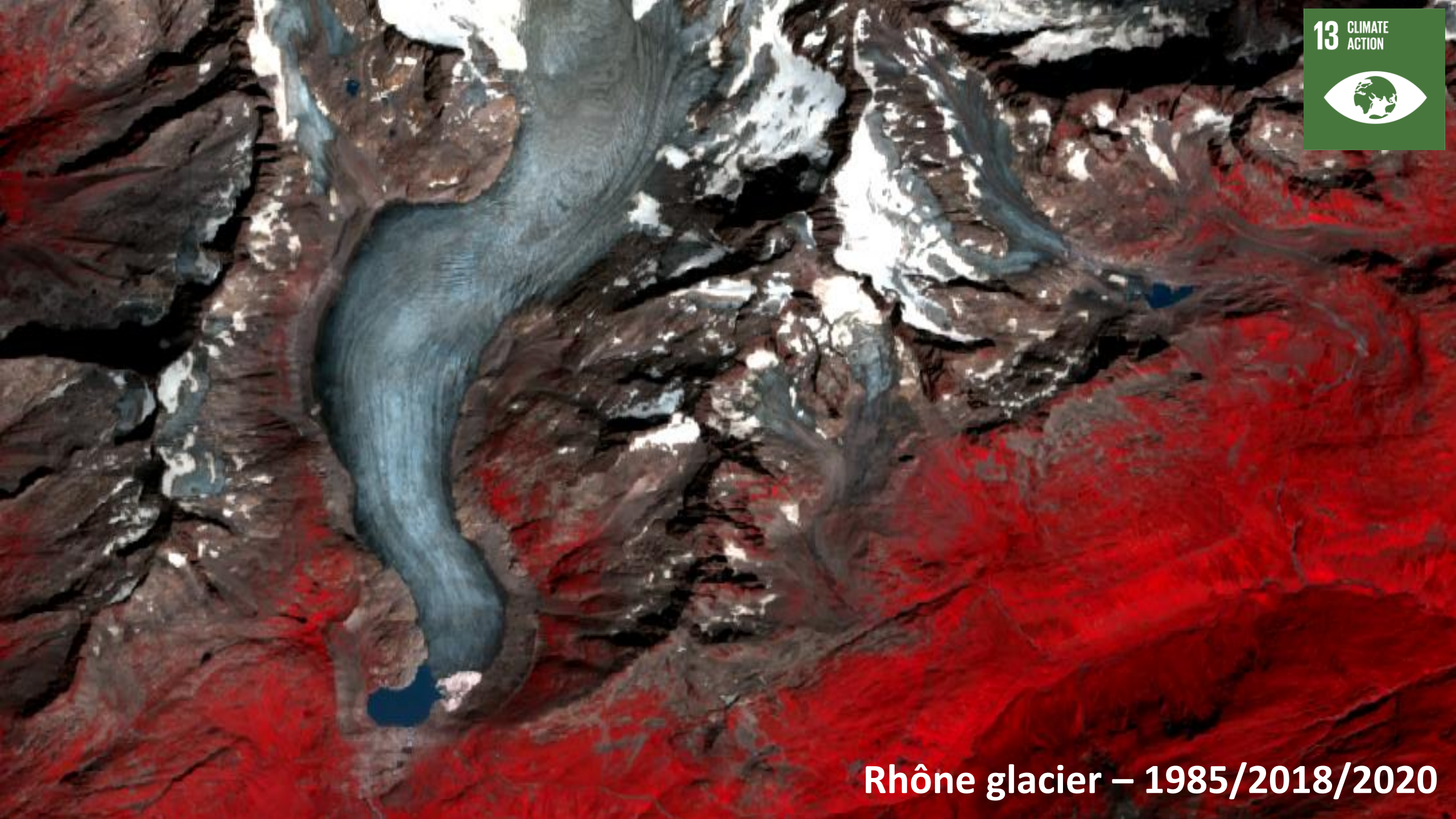
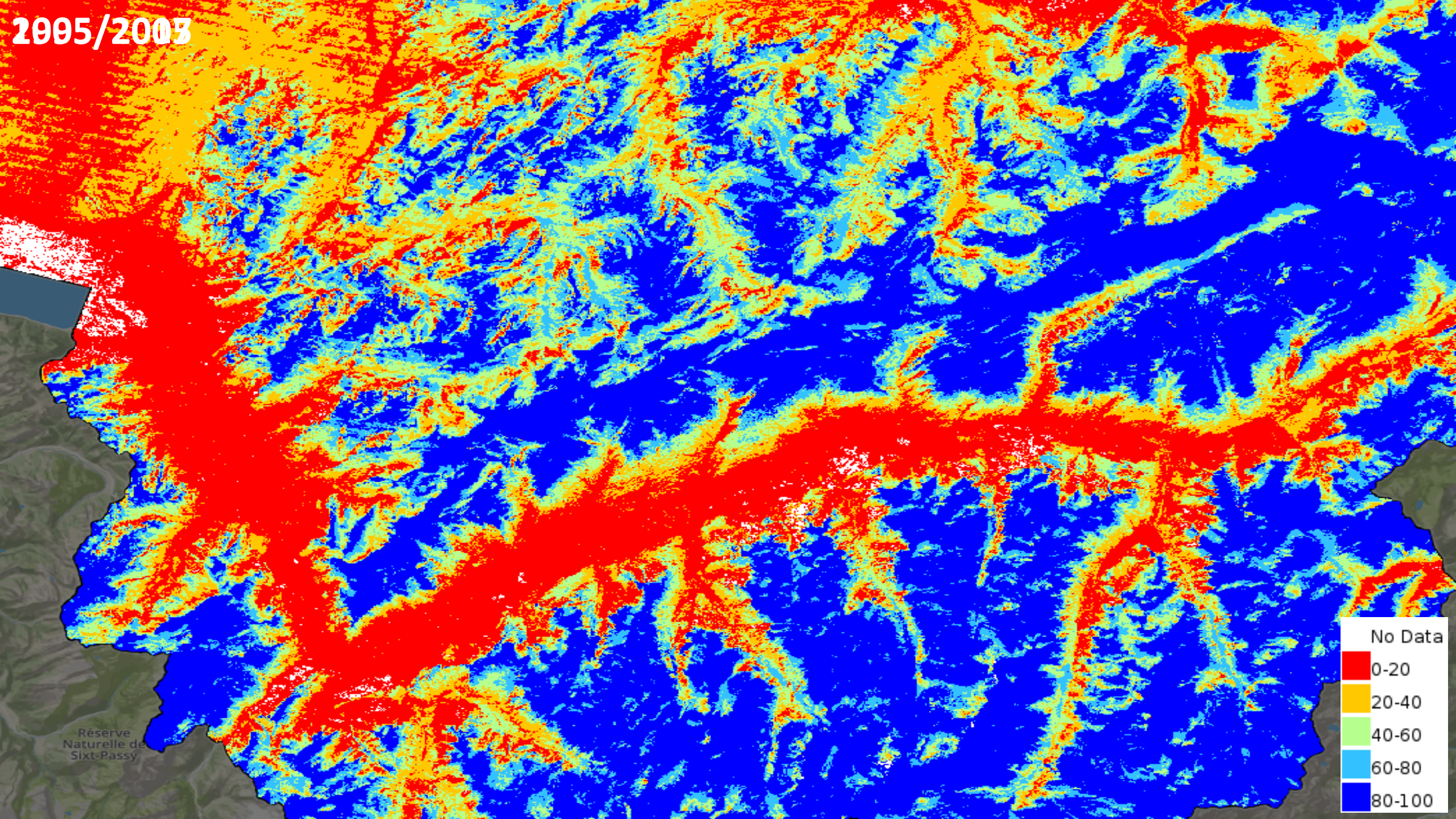
Remote Sens. **2021**, *13*(3), 422; https://doi.org/10.3390/rs13030422



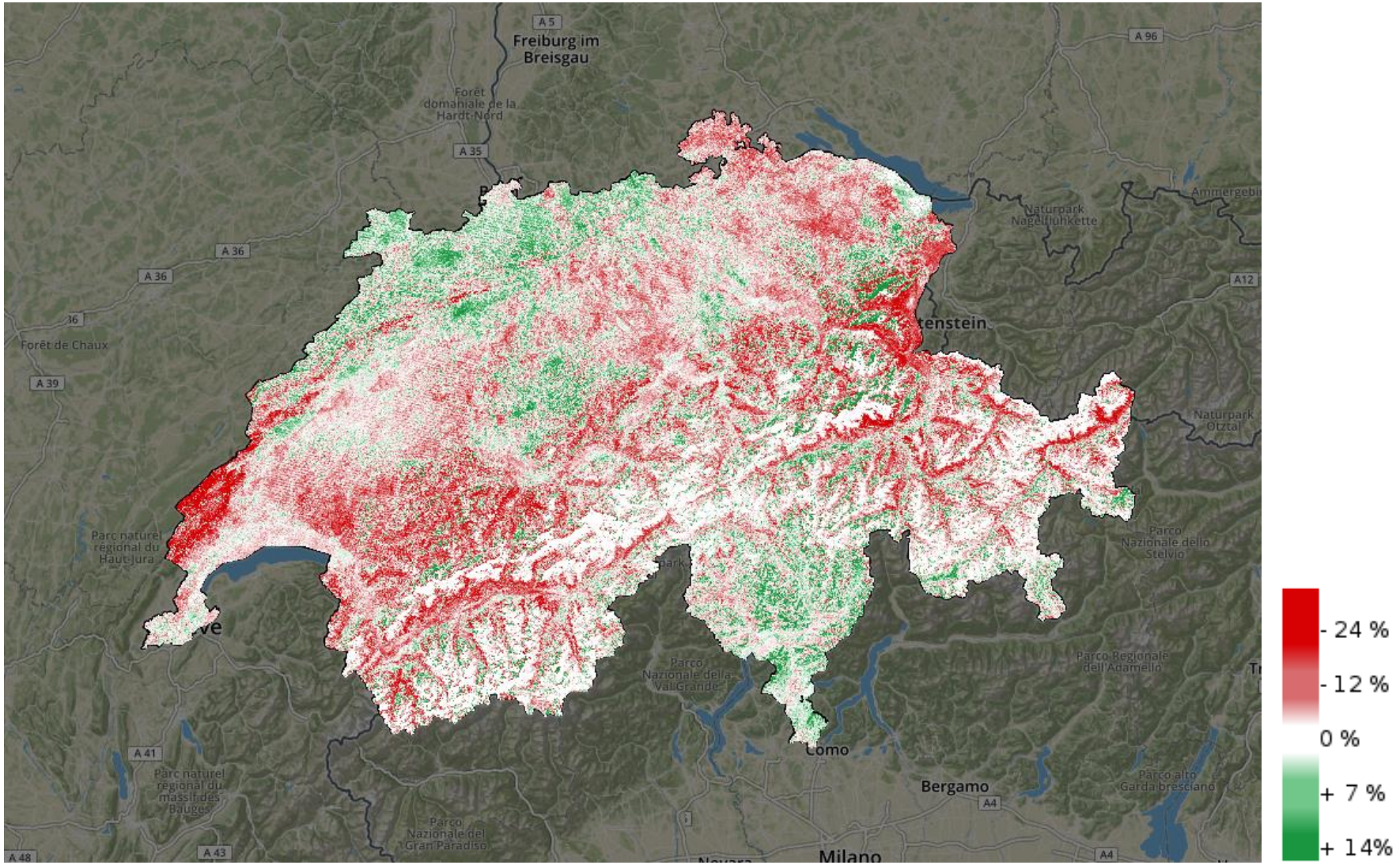


Rhône glacier – 1985/2018/2020

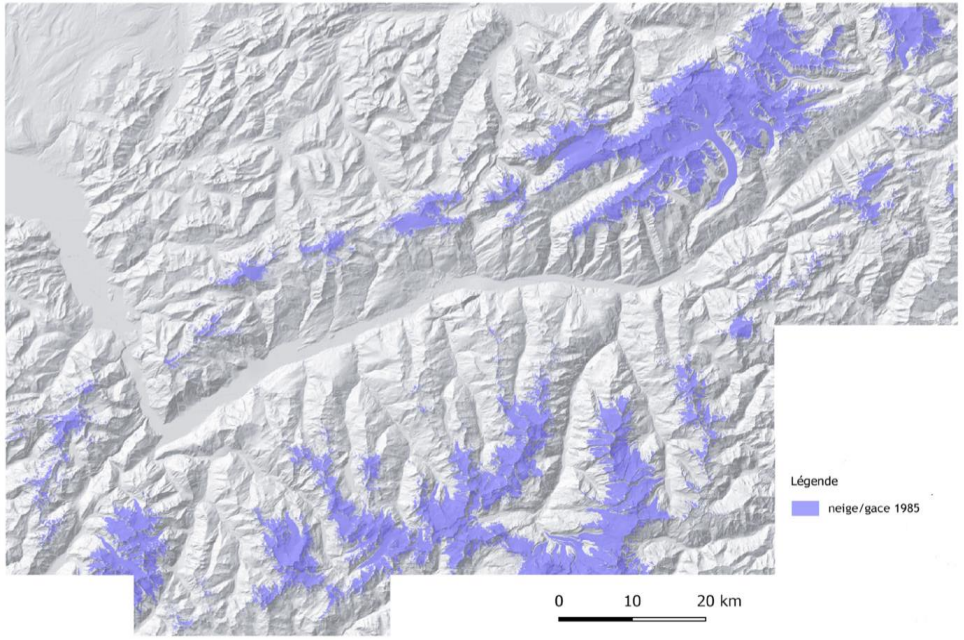

2005/2007
Réserve
Naturelle de
Sixt-Passy
No Data
0-20
20-40
40-60
60-80
80-100

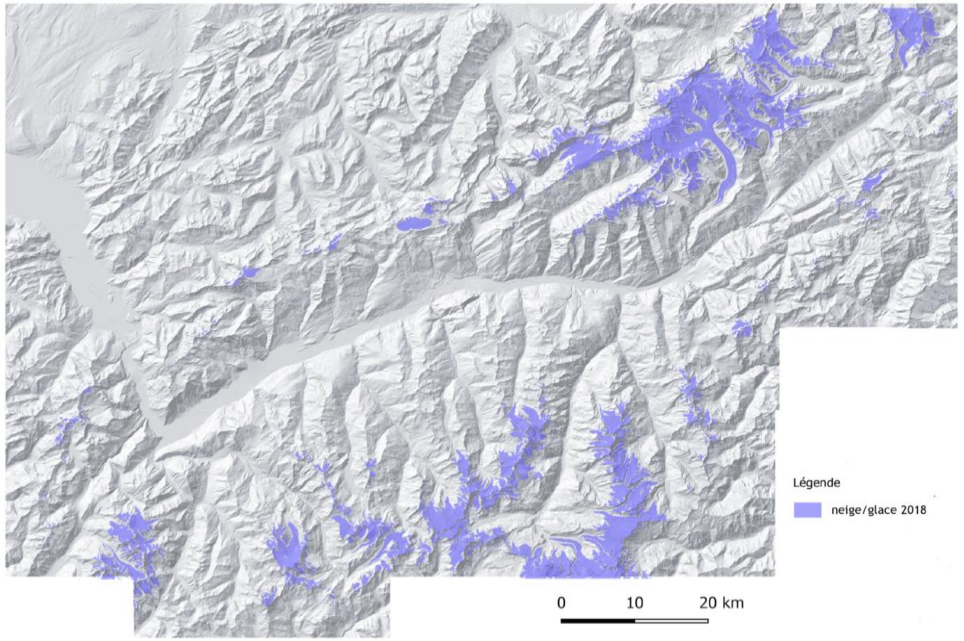
Snow Cover changes for the last 20 years!

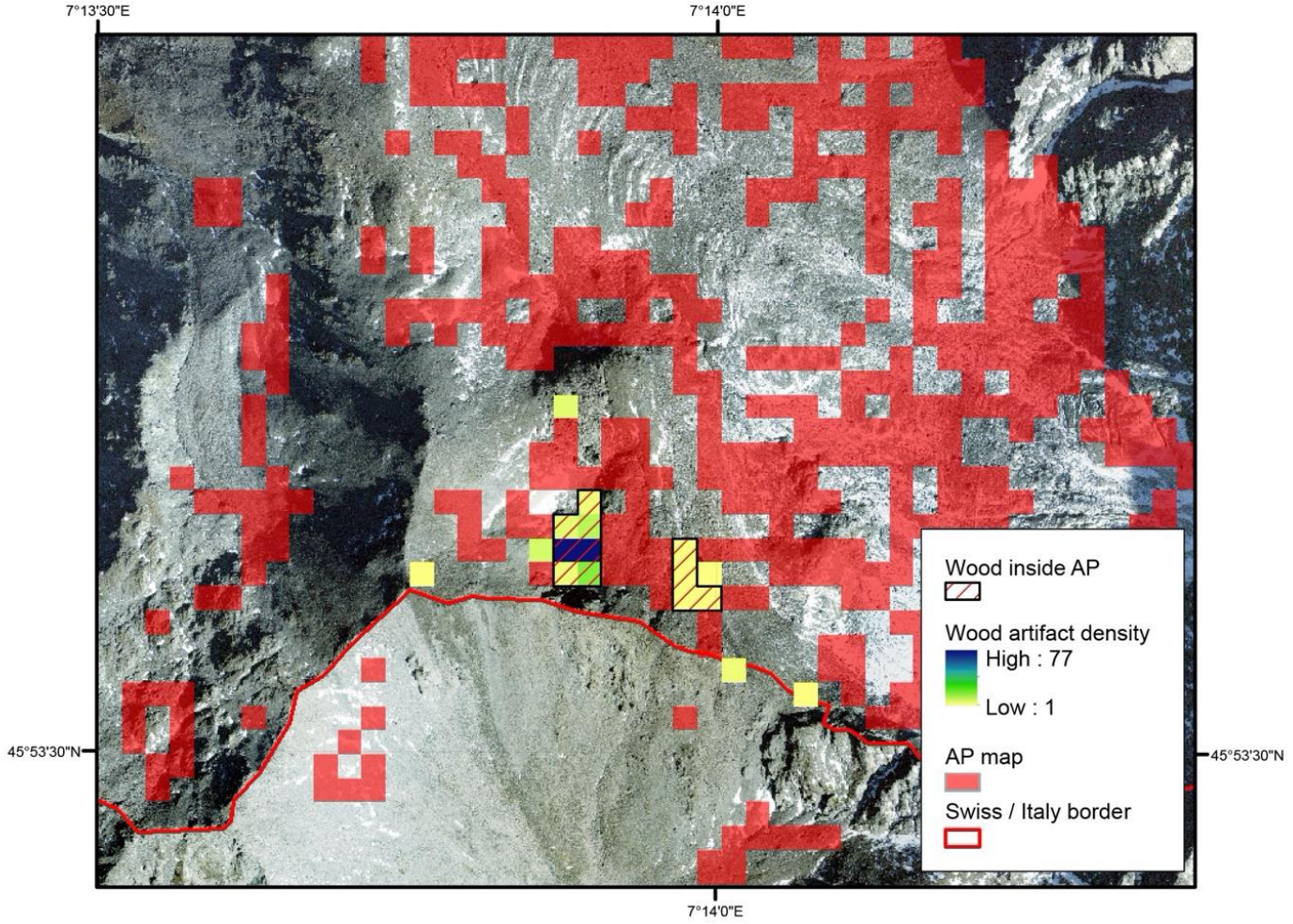
Permanent snow area decreased of 4% (2100km^2) while surface where snow is rare has increased of 8% (5200km^2).



Identifying areas of archaeological potential in the Alps



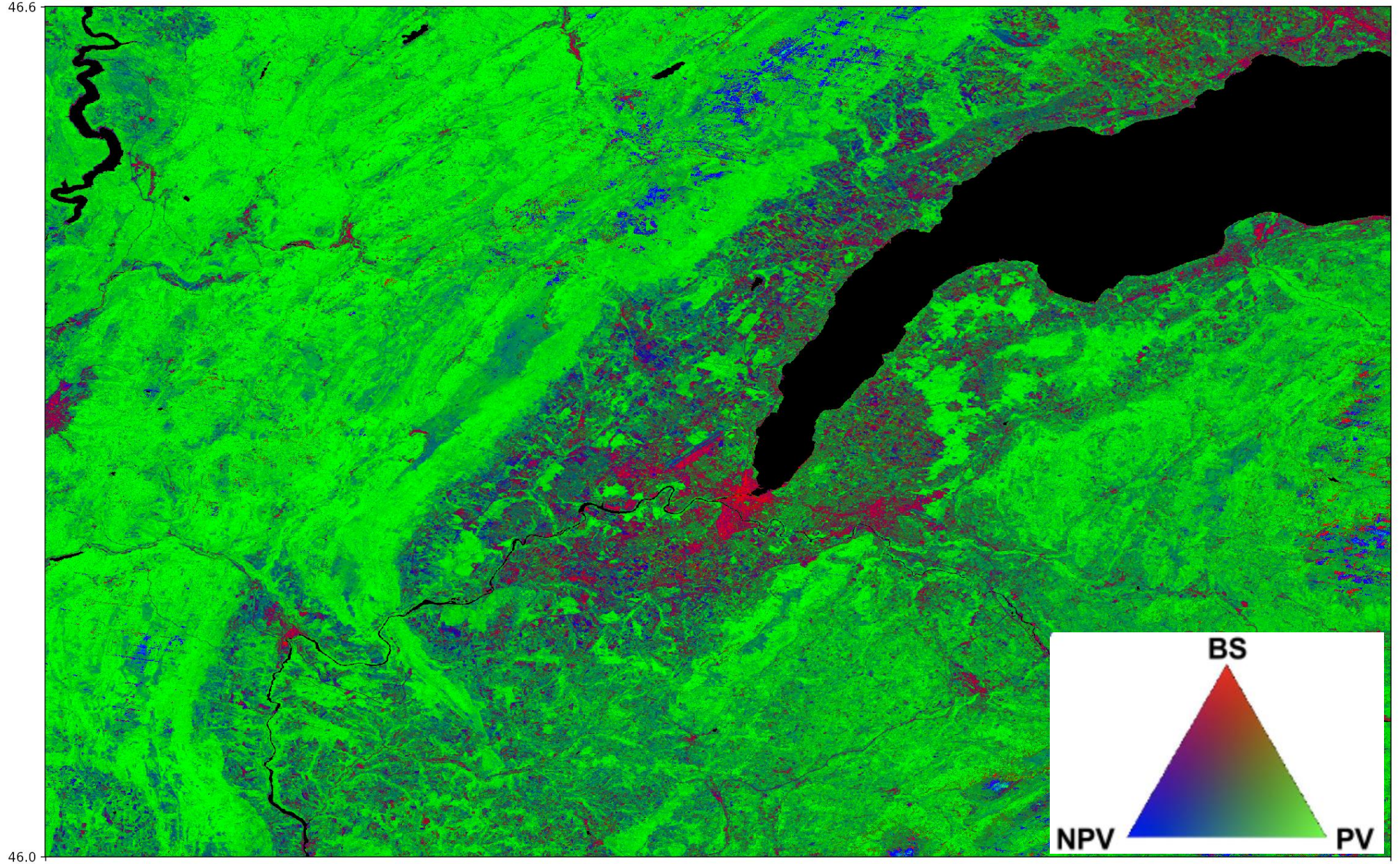




Cornut C., Ozainne S., Poussin C., Andenmatten R., Giuliani G., Identifying areas of archaeological potential in the Swiss Alps using satellite-derived time-series of snow cover estimates, Submitted to Remote Sensing Applications: Society and Environment

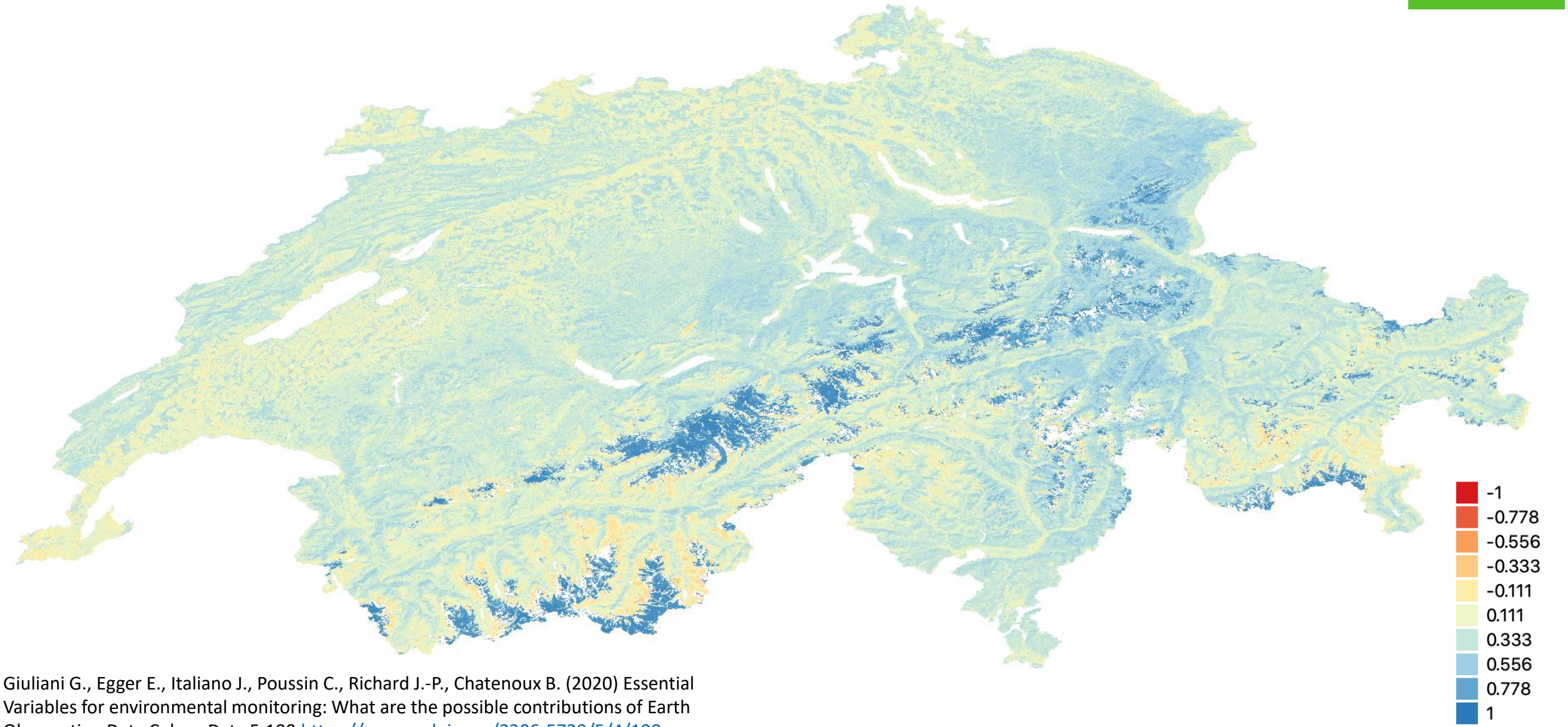

Composite RGB - Landsat 2003
46.6
46.0
5.7
6.6

Fractional cover - Landsat 2003



Normalized Difference Water Index (NDWI)…

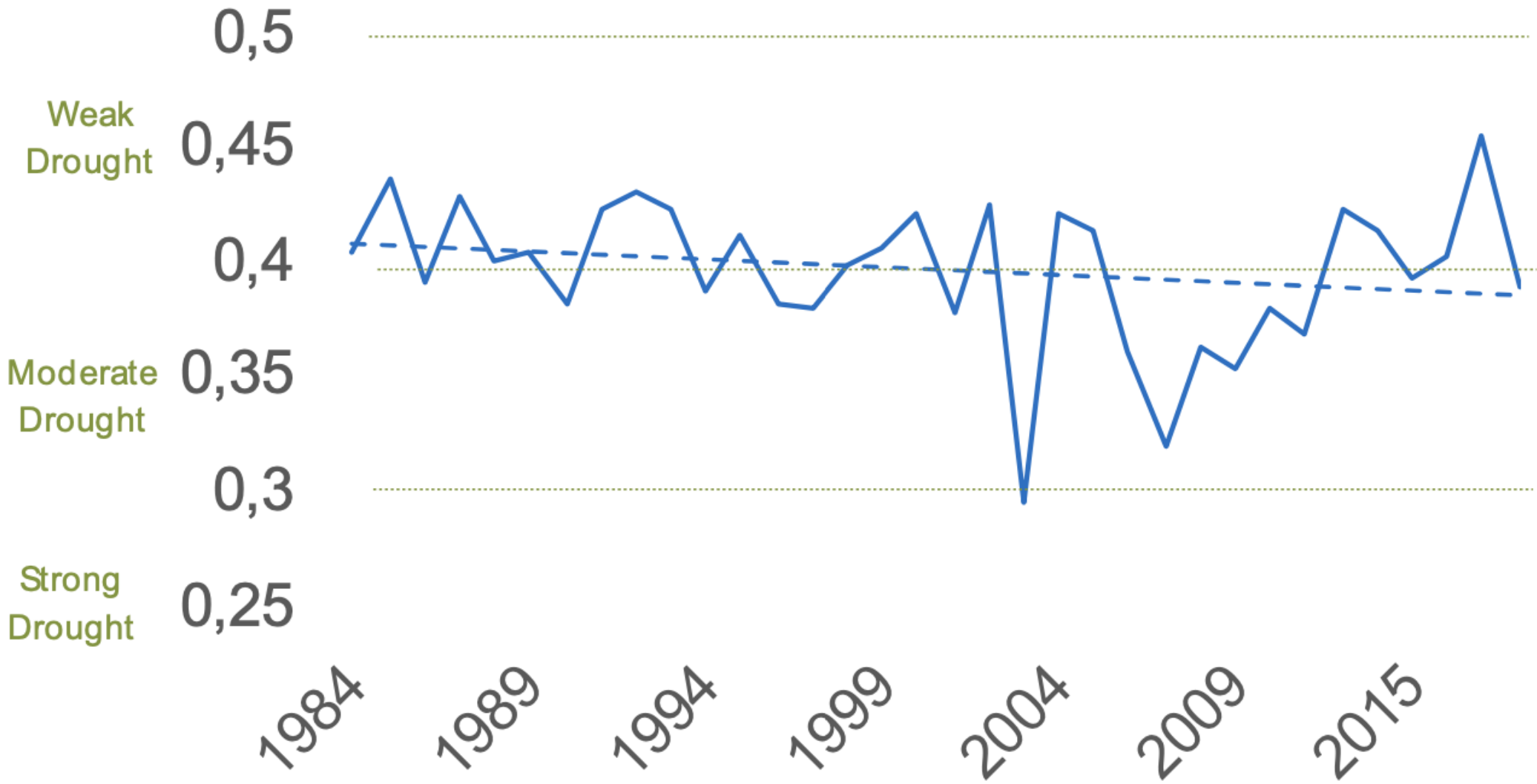
Water content of vegetation (2014 vs. 2003)



Giuliani G., Egger E., Italiano J., Poussin C., Richard J.-P., Chatenoux B. (2020) Essential Variables for environmental monitoring: What are the possible contributions of Earth Observation Data Cubes, Data 5:100 https://www.mdpi.com/2306-5729/5/4/100

Trends in vegetation water content

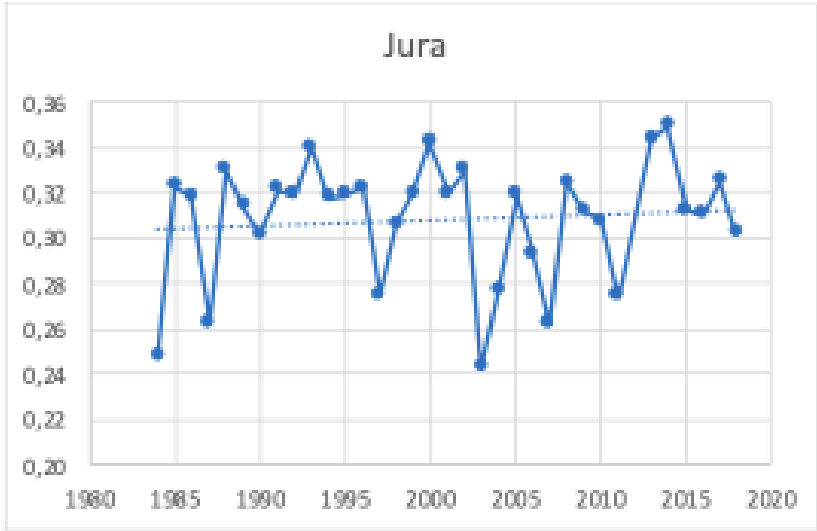
NDWI time-series from 35 years of Landsat observations – Annual mean

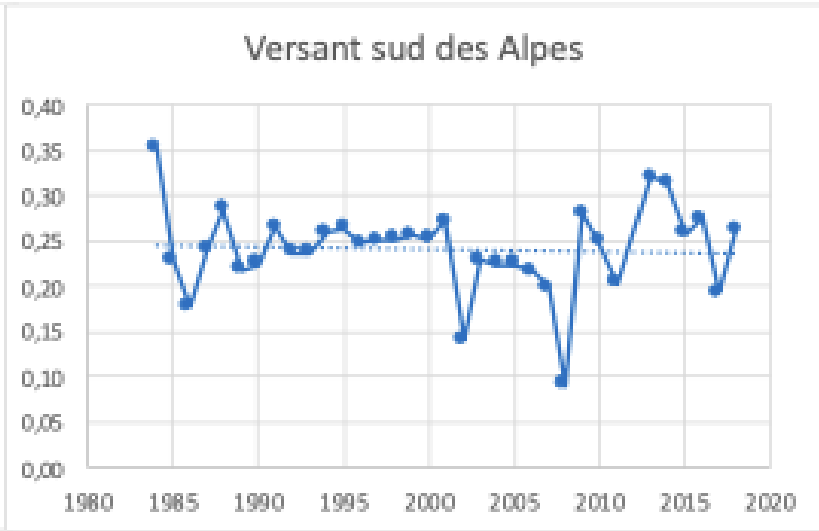


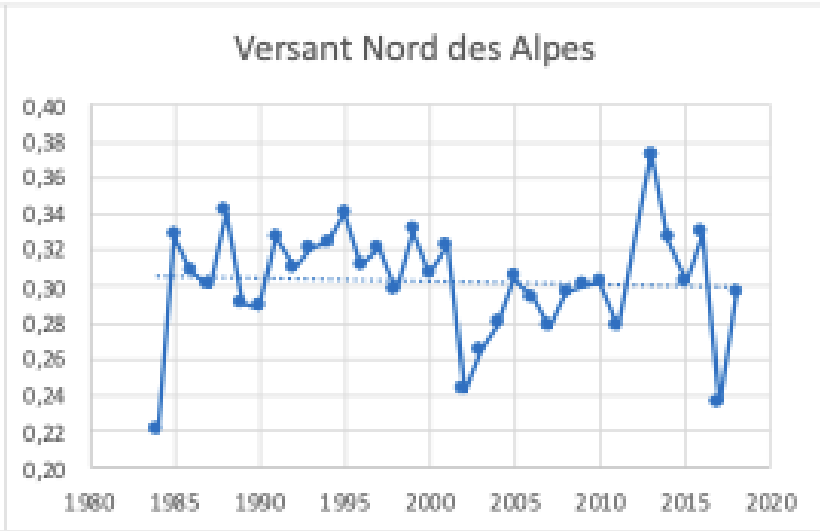
Poussin C., Massot A., Ginzler C., Weber D., Chatenoux B., Lacroix P., Piller T., Nguyen L., Giuliani G., Drying conditions in Switzerland - Indication from a 35-year Landsat trend analysis of vegetation water content estimates to support SDG15, *Submitted to* ***Big Earth Data***

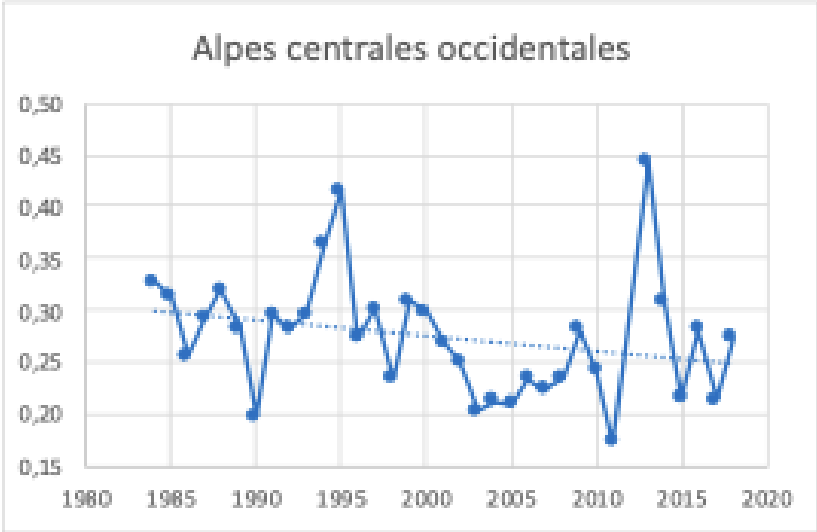
Trends in vegetation water content

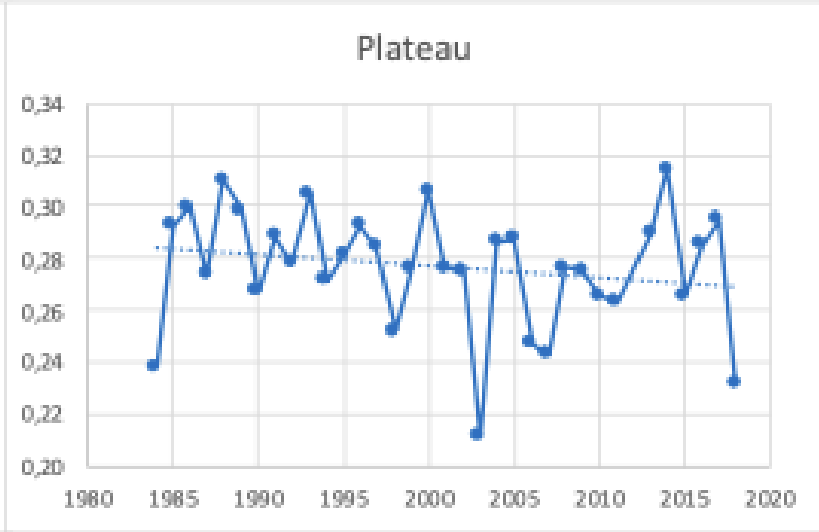
Statistics by biogeographical zones – mean summer season

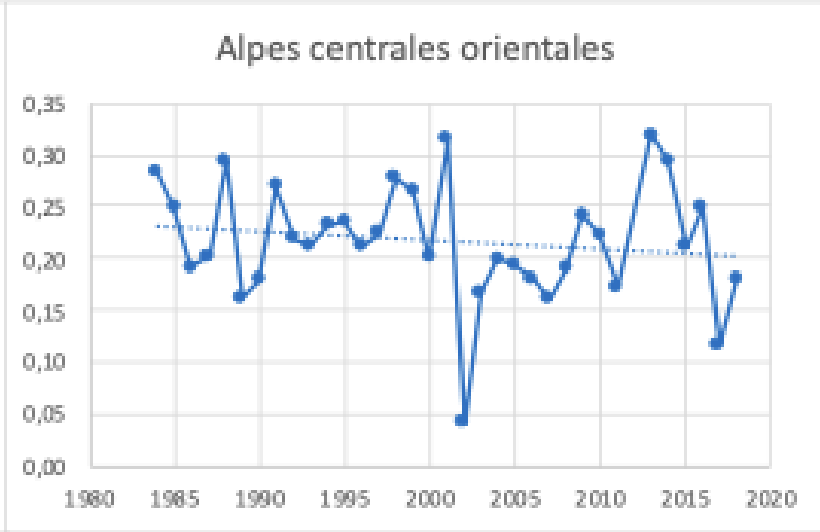






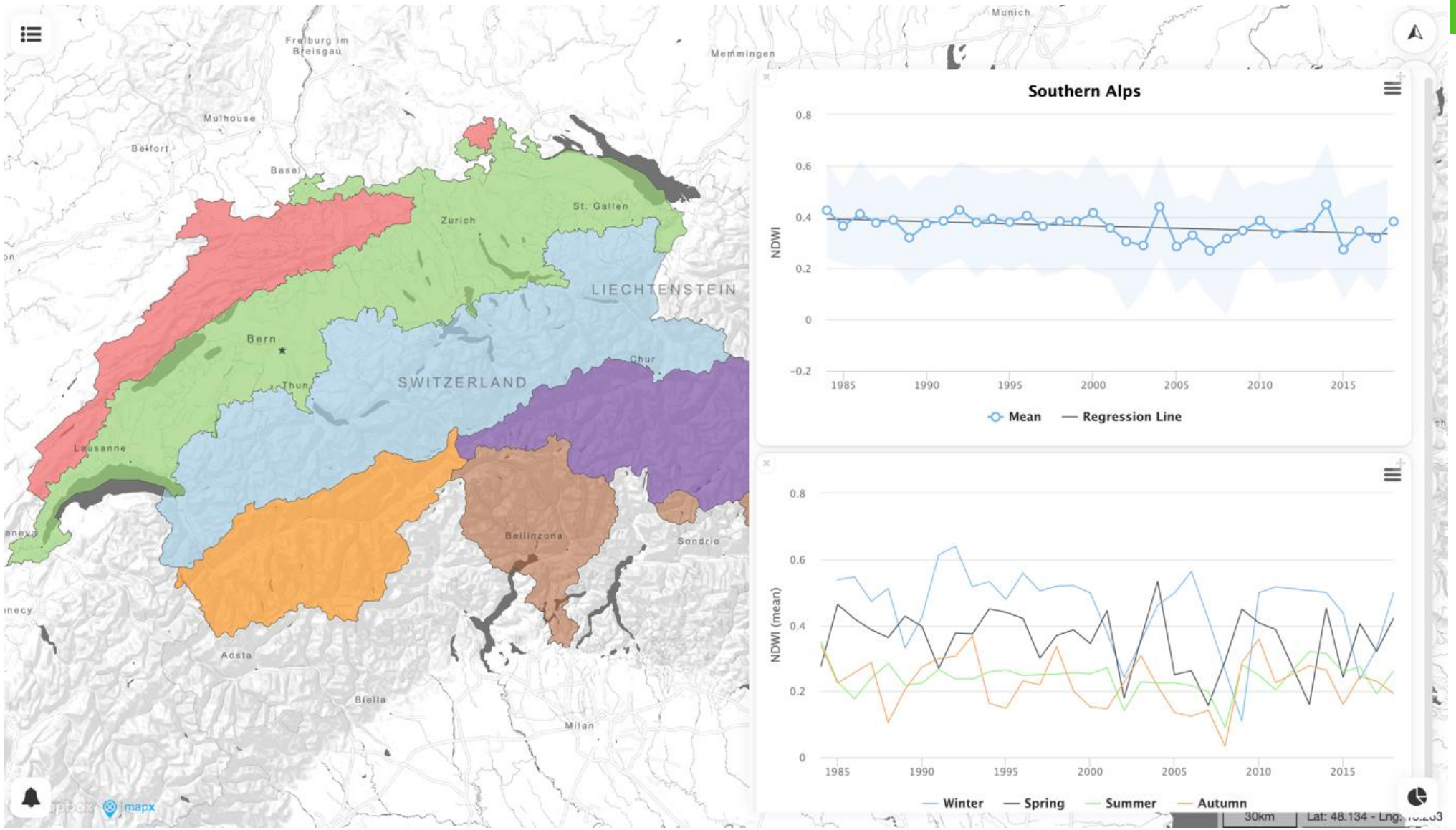






Soon…

A dedicated service/dashboard to follow trends by regions & cantons

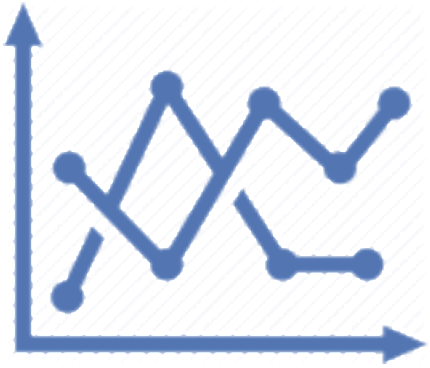


SDG 15.3.1 Land Degradation…

…is undermining the well-being of 3.2 billion people (IPBES)

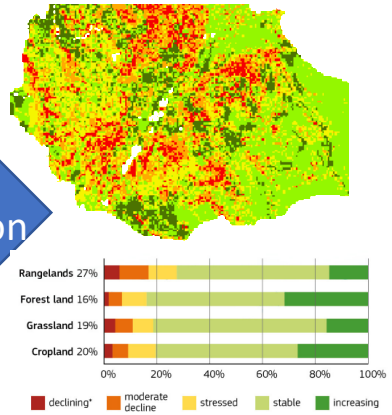
DATA → **INFORMATION** → **KNOWLEDGE**

Model



Model

Interpretation & representation



EO Data

- MODIS/AVRRR
- ESA CCI Land Cover
- SoilGrids

Sub-indicators

- Land Productivity Dynamics
- Land Cover Change
- Soil Organic Carbon Stocks

SDG15.3.1

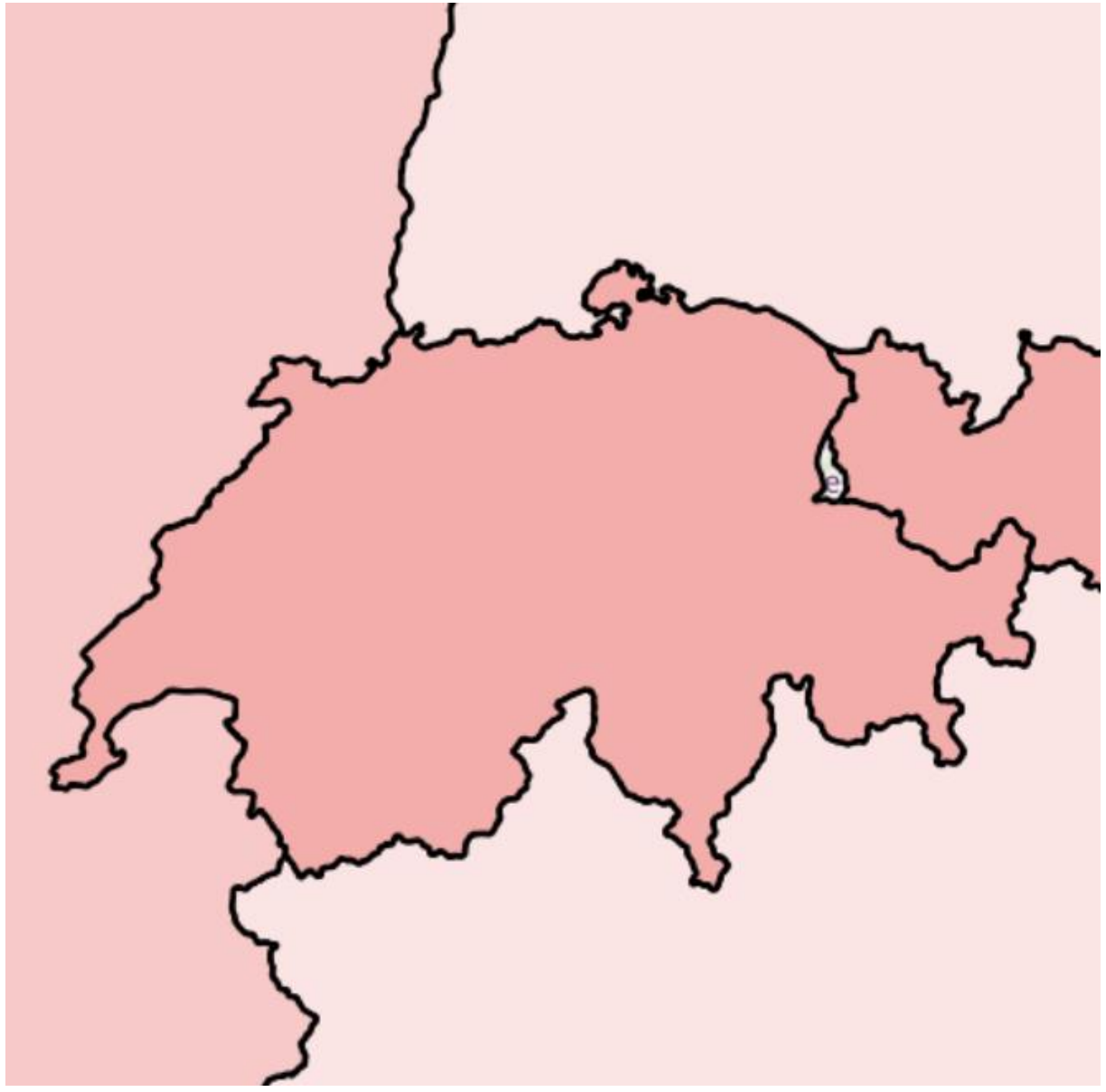
Proportion of land that is degraded over total land area

Collaboration: UNIGE, GEO, ESA, CNR, JRC, UNEP

Giuliani G., Mazzetti P., Santoro M., Nativi S., Van Bemmelen J., Colangeli G., Lehmann A. (2020) Knowledge generation using satellite Earth Observations to support Sustainable Development Goals (SDG): a use case on Land Degradation, International Journal of Applied Earth Observation and Geoinformation 88:102068 https://doi.org/10.1016/j.jag.2020.102068

Aggregated indicators…

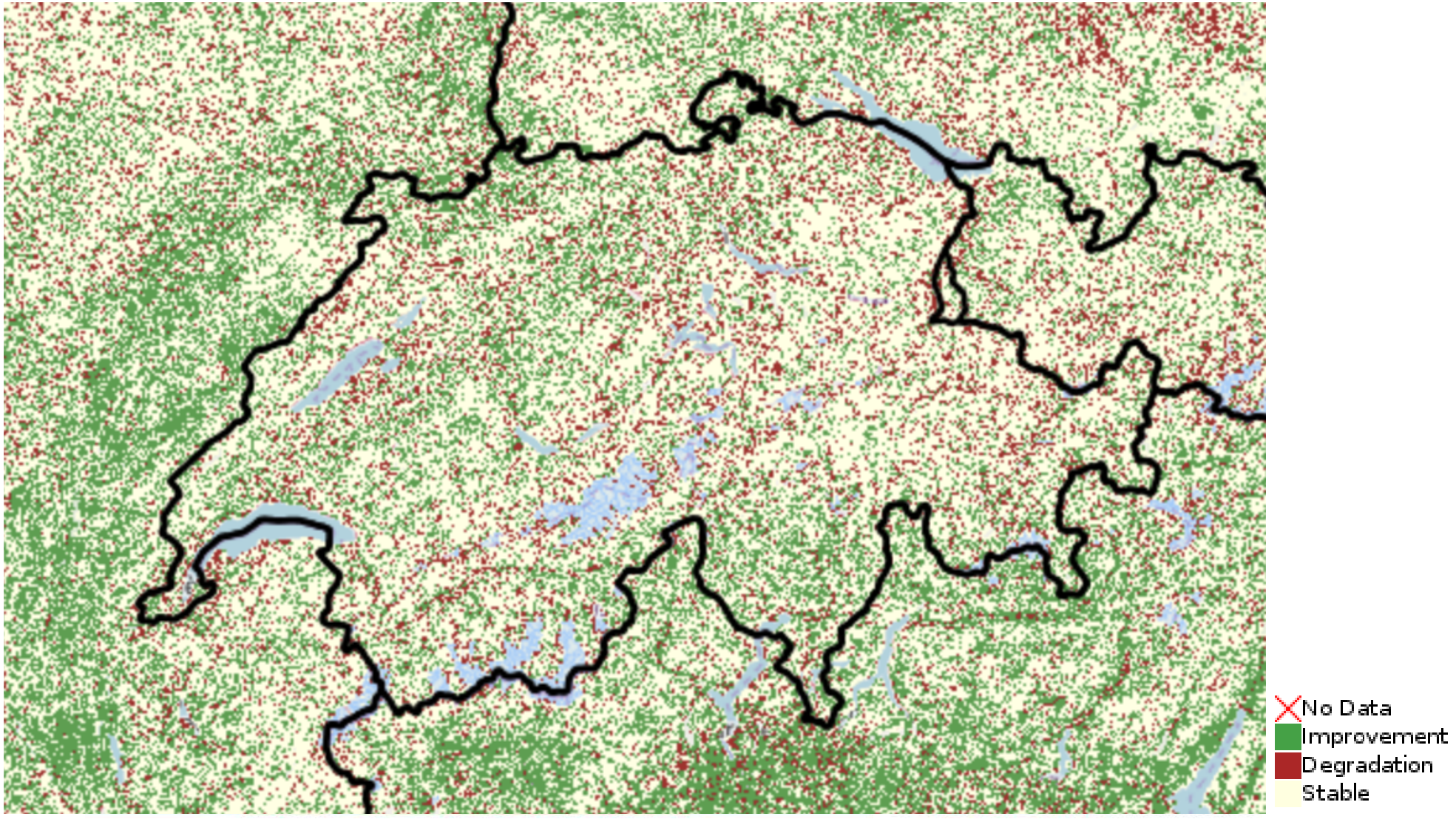
… are not enough for public policy!



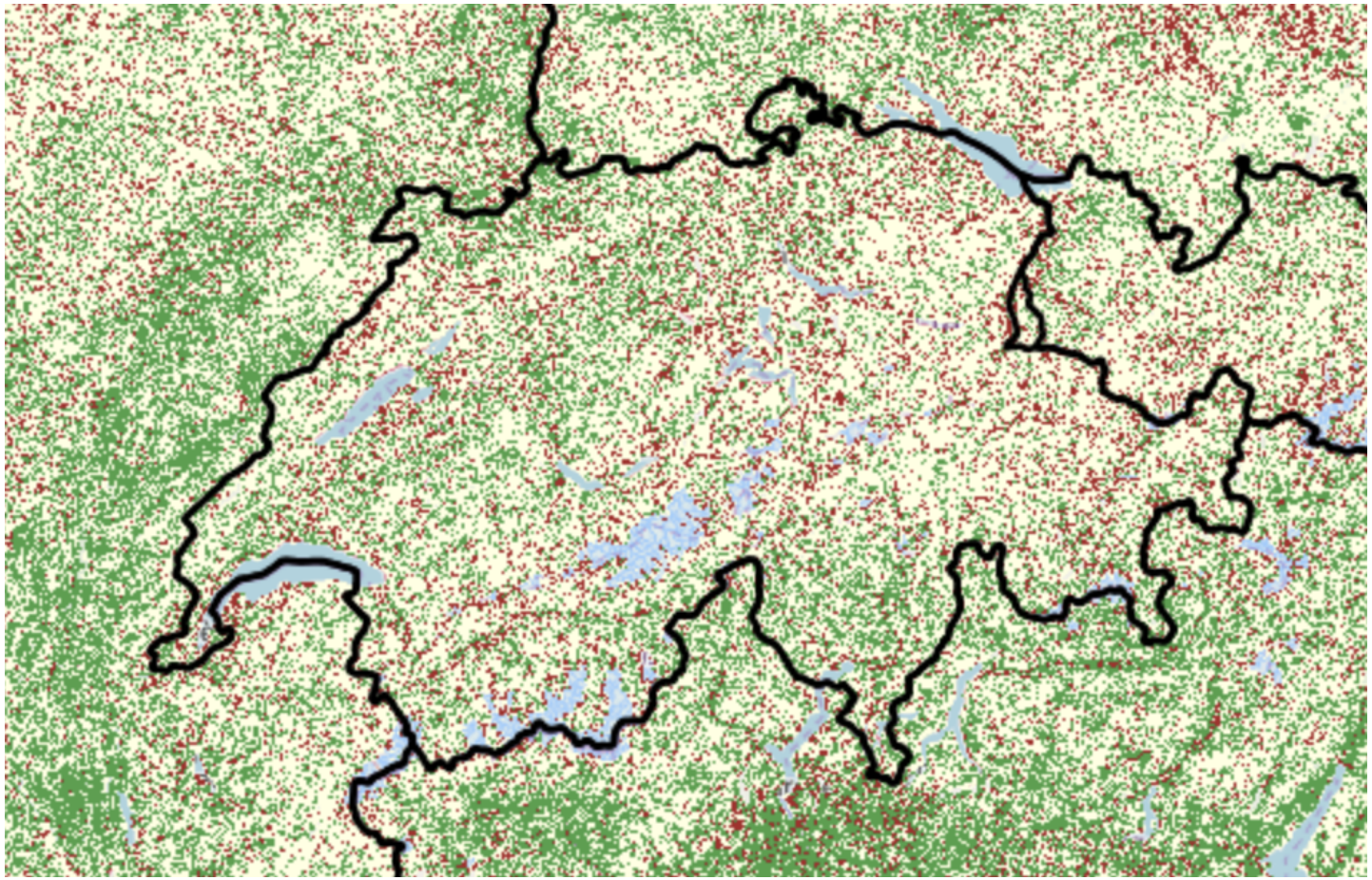
Disaggregation of indicators…

… to capture spatial (maps) and temporal dynamics (graphs)

How much? Where? When? Who?



SDG15.3.1 – Results from Switzerland



No data
Degradation
Stable
Improvement

Official value: 4.7%

SDC value: 9.7%

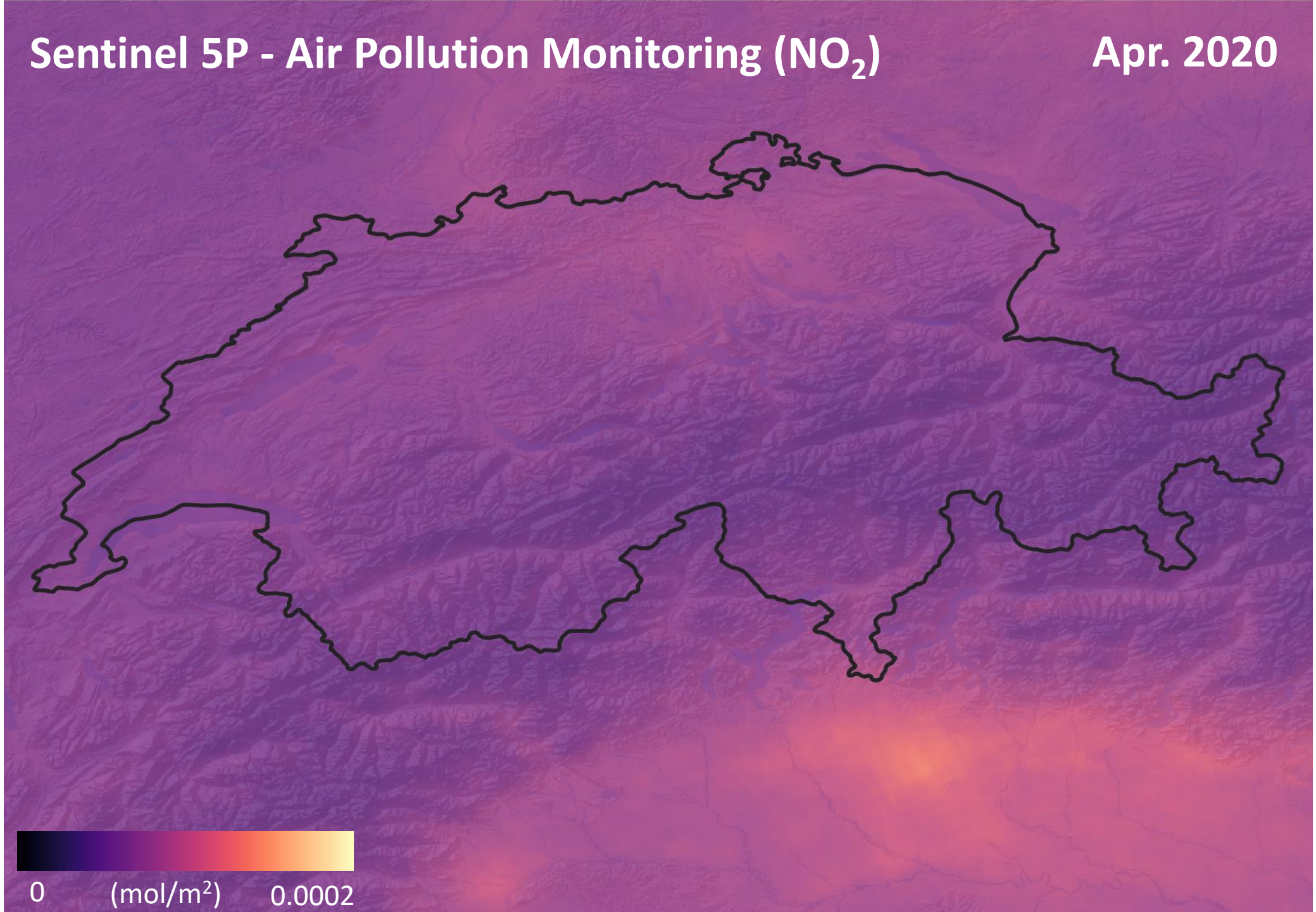
Official definition in Switzerland is based only on soil sealing and do not consider land productivity!

Do not comply with the official UN definition!

Giuliani G., Chatenoux B., Benvenuti A., Lacroix P., Santoro M., Mazzetti P., Monitoring Land Degradation at national level using satellite EO time-series data to support SDG15 – Exploring the potentiation of Data Cube, Big Earth Data, https://doi.org/10.1080/20964471.2020.1711633

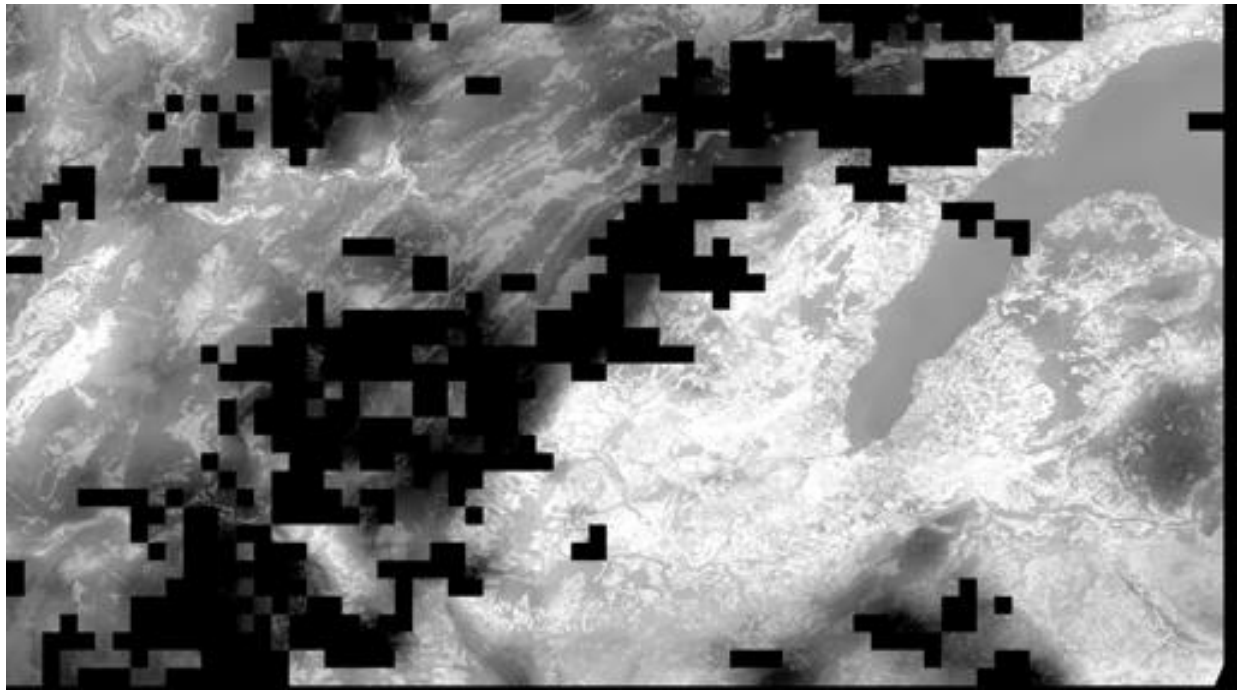
Potential (other) applications

- Monitoring land cover change
- Glacier monitoring, ice extent mapping, snow cover monitoring
- Agricultural applications: crop monitoring, food security
- Vegetation and forest monitoring, parameter generation (chlorophyll concentration, carbon mass estimations)
- Water quality monitoring
- Flood mapping and management
- Urban mapping & monitoring


Sentinel 5P - Air Pollution Monitoring (NO_2)
Apr. 2020
0
(mol/m²)
0.0002

Sentinel-2/Sentinel-3 Data fusion

Land Surface Temperature



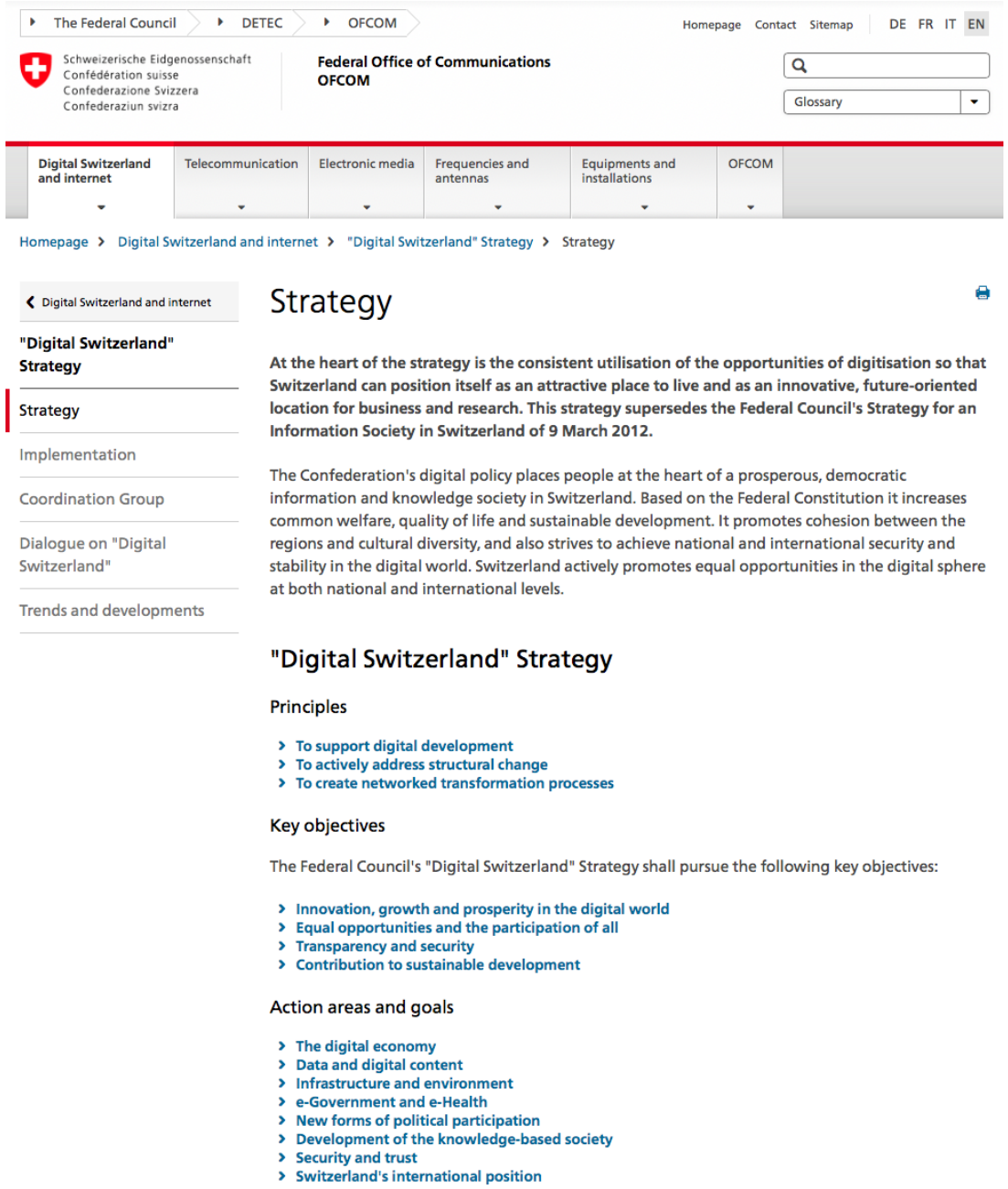
The black pixels represent locations with unreliable surface temperature measurements in the original, low-resolution LST map

Pena et al., in prep

Implemented standards in the Swiss Data Cube

- **Upstream services**
  - *Discovery:* ISO19115-2 and ISO19139-2; OGC CSW, STAC (under evaluation)
  - *View & Download:* OGC WMS & WCS
  - *Processing:* Python API; OGC WPS (under test)
- **Downstream services**
  - *Discovery:* CSW; OpenSearch; OAI
  - *View:* WMS with EO extension, WMTS, TMS, WMS-C, ncWMS
  - *Download:* WCS with EO extension

The SDC supports the « Digital Switzerland » strategy



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Federal Office of Communications OFCOM

Glossary

Digital Switzerland and internet | Telecommunication | Electronic media | Frequencies and antennas | Equipments and installations | OFCOM

Homepage › Digital Switzerland and internet › "Digital Switzerland" Strategy › Strategy

Digital Switzerland and internet

"Digital Switzerland" Strategy

Strategy

Implementation

Coordination Group

Dialogue on "Digital Switzerland"

Trends and developments

Strategy

At the heart of the strategy is the consistent utilisation of the opportunities of digitisation so that Switzerland can position itself as an attractive place to live and as an innovative, future-oriented location for business and research. This strategy supersedes the Federal Council's Strategy for an Information Society in Switzerland of 9 March 2012.

The Confederation's digital policy places people at the heart of a prosperous, democratic information and knowledge society in Switzerland. Based on the Federal Constitution it increases common welfare, quality of life and sustainable development. It promotes cohesion between the regions and cultural diversity, and also strives to achieve national and international security and stability in the digital world. Switzerland actively promotes equal opportunities in the digital sphere at both national and international levels.

"Digital Switzerland" Strategy

Principles

- To support digital development
- To actively address structural change
- To create networked transformation processes

Key objectives

The Federal Council's "Digital Switzerland" Strategy shall pursue the following key objectives:

- Innovation, growth and prosperity in the digital world
- Equal opportunities and the participation of all
- Transparency and security
- Contribution to sustainable development

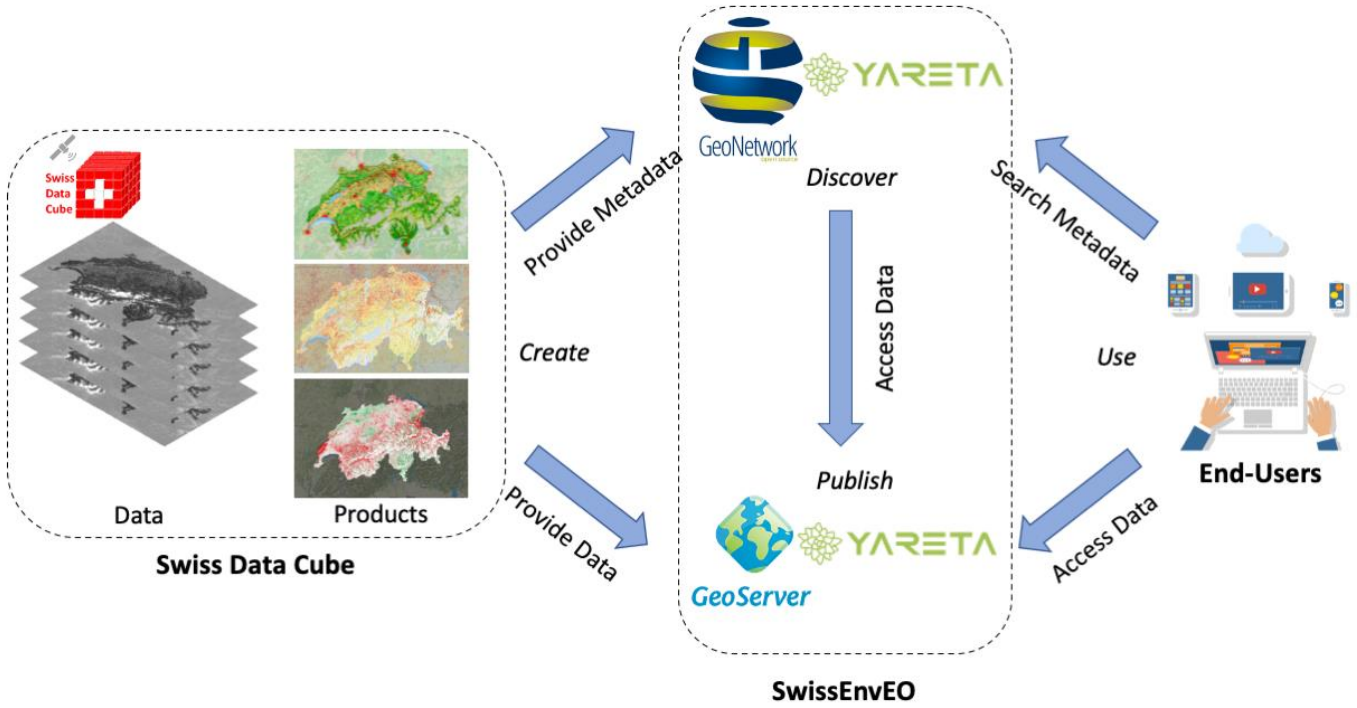
Action areas and goals

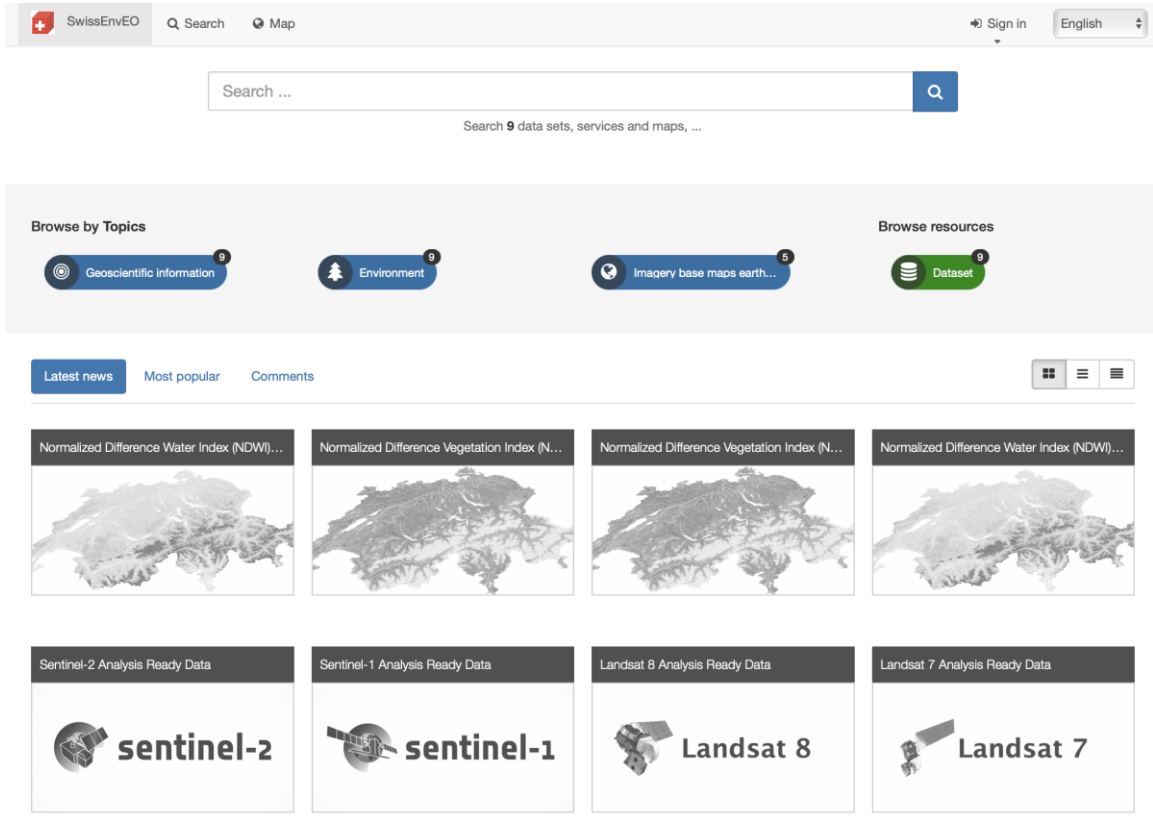
- The digital economy
- Data and digital content
- Infrastructure and environment
- e-Government and e-Health
- New forms of political participation
- Development of the knowledge-based society
- Security and trust
- Switzerland's international position

- Support innovation and growth in the digital economy
- Improve efficiency and effectiveness of government investments
- Improve management of natural resources
- Stimulate research
- Effective monitoring mechanism
- Generate information products
- Improve data access and use & enable new products/services that can transform everyday life

SwissEnvEO: a FAIR national EO environmental database

http://geonetwork.swissdatacube.org





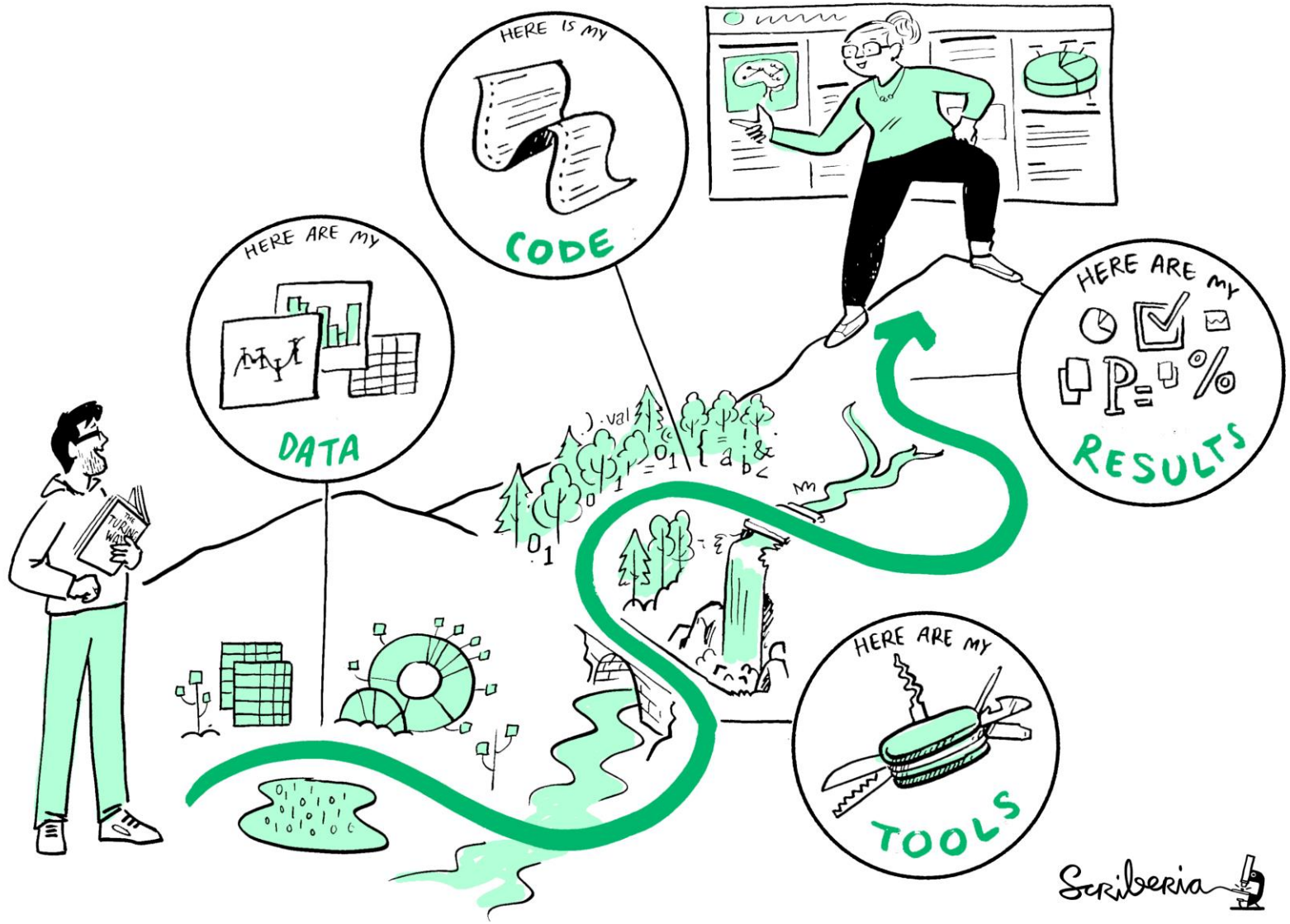
Giuliani G., Cazeaux H. Burgi P.-Y., Poussin C., Richard J.-P., Chatenoux B. (2021) SwissEnvEO: a FAIR national environmental data repository for Earth Observation Open Science, CODATA Data Science Journal 20(1):2 http://doi.org/10.5334/dsj-2021-022

- GIVE PEOPLE THE TOOLS TO MAKE CLEAN DATA
- CLEAN DATA IS MORE REUSABLE AND INTEGRATABLE
- DATA FROM VARIOUS PIPELINES TO BE USED ACROSS DIFFERENT SYSTEMS

Scriberia

Achieving reproducible knowledge…

…exposing all parts of an application



Good application:

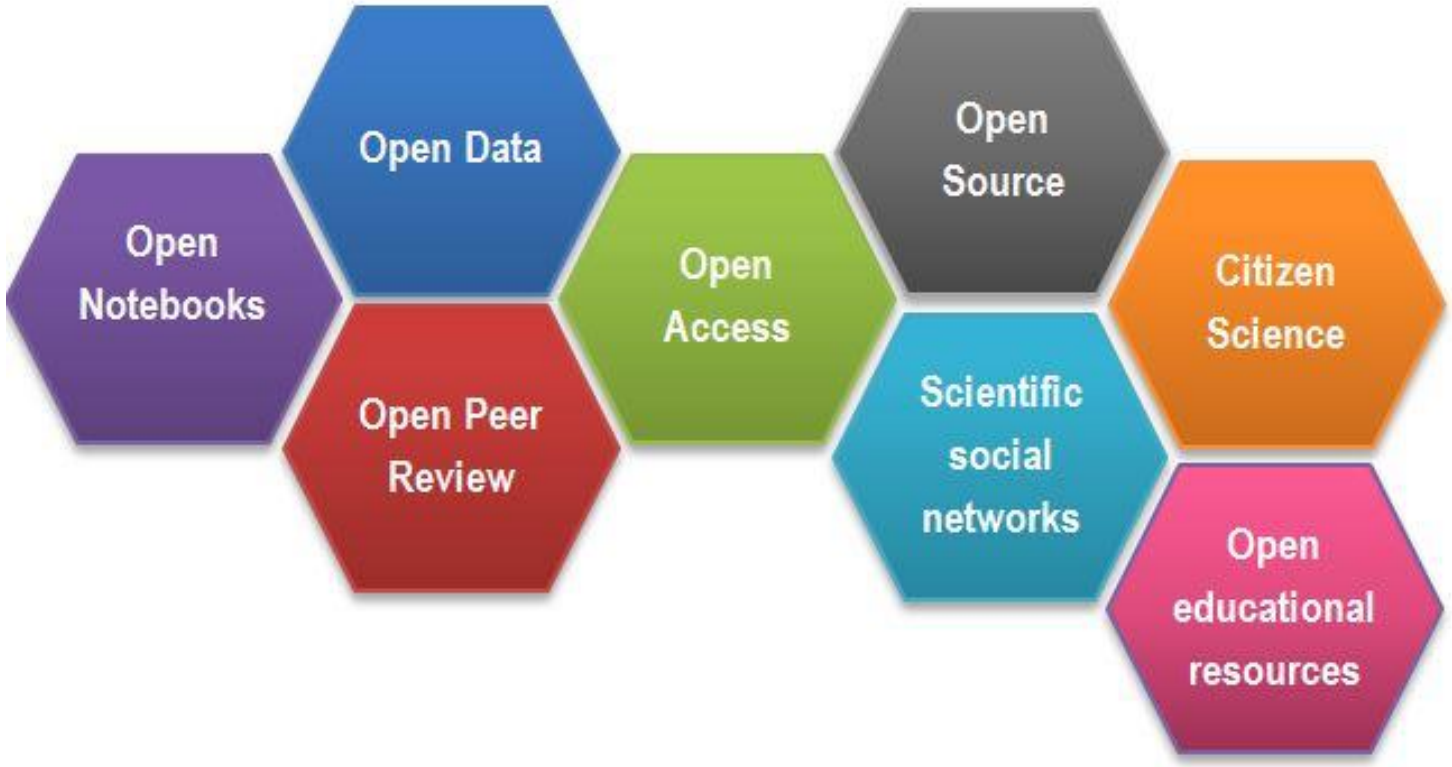
Good in-situ, satellite data & models > produce new knowledge

Trust is the key (data):

For decision makers

SDC Open & Reproducible EO Science

- **Open Data:** Landsat 5,7, 8 ARD; Sentinel 1-2 ARD + All scientific/decision-ready products are freely, openly available & FAIR compliant
- **Open Notebooks:** All algorithms are documented and openly available
- **Open Access:** All publications
- **Open Source:** All applications
- **Open Educational Resources:** Bringing ODC into practice



Open to collaboration!

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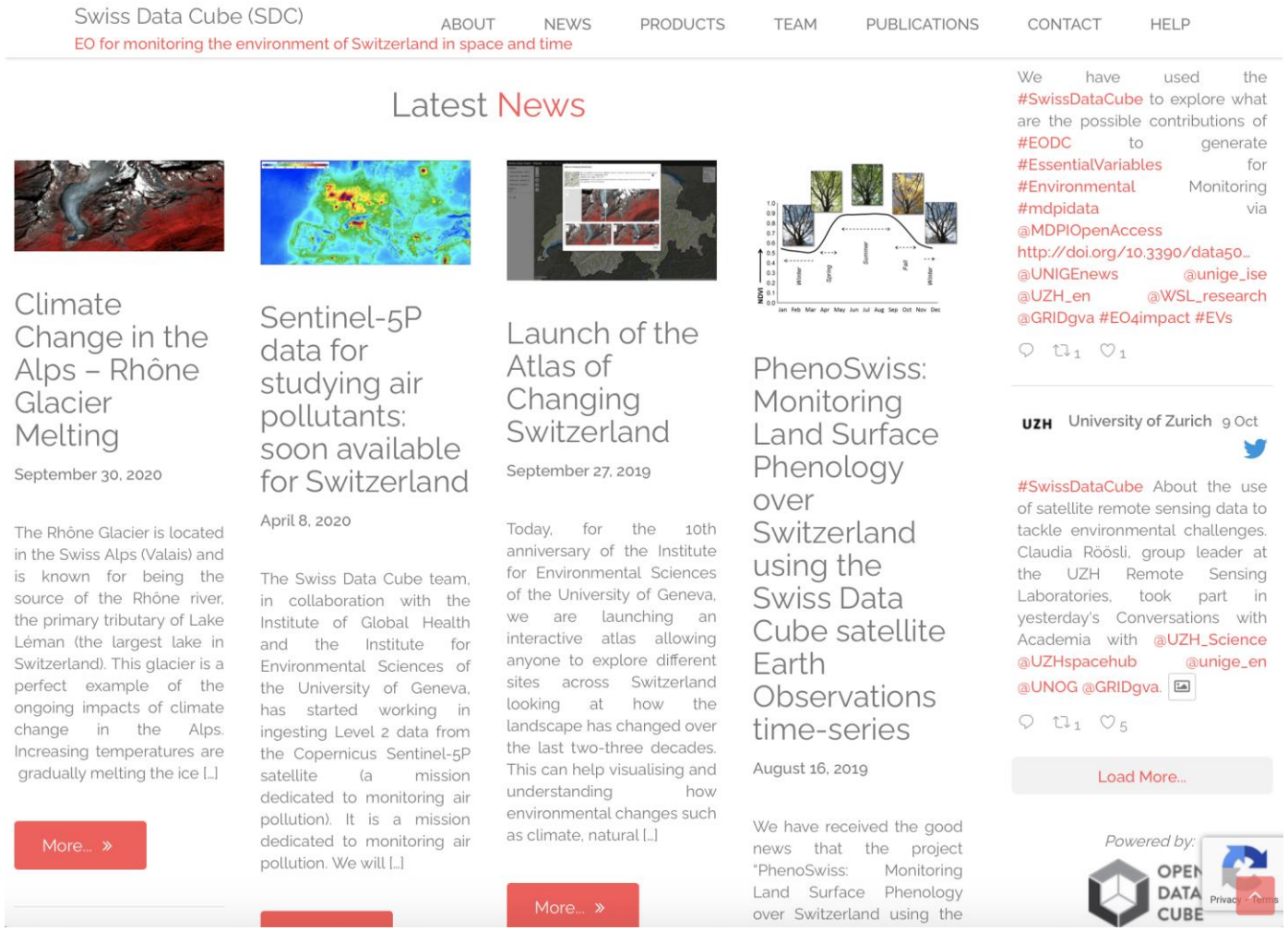

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