From the Swiss Data Cube
To Digital Earth Switzerland | Dr. G. Giuliani
The Big Challenge...

The Asteroid was easy.

Now how can we change the trajectory of this planet?
Actionable Insights based on evidence

Each step up the pyramid answers questions about and adds value to the initial data.
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!
Global Volumes of EO data

**Landsat:** 600 images/day | 10+ million images | 4+ petabytes

**Sentinels:** 30’000 images/day | 54+ million of images | 320 petabytes

... and many other satellites (~70) are continuously observing the Earth
5 V’s of Big Data

- **Volume**: Amount of Data
- **Velocity**: Speed of Data Generation
- **Variety**: Diversity of Data types & sources
- **Value**: Extracting meaningful information
- **Veracity**: Accuracy of Data
Landsat acquisitions since 1972

https://www.usgs.gov/landsat-missions/landsat-project-statistics
https://landsat.usgs.gov/landsat-archive-dashboard
“The Landsat satellite is capable of taking a complete photograph of the entire planet every two weeks, and it's been collecting data for more than 20 years. In spite of the great need for that information, the vast majority of those images have never fired a single neuron in a single human brain. Instead, they are stored in electronic silos of data.”

Increasing demand for free & open satellite data

Data delivered to 186 countries;
Download: 53 images/day (2001) - 220'000 images/day (2017)
User shift to multi-year scenes at same location
Primary usage of Landsat Data

As of August 2022

https://www.usgs.gov/landsat-missions/landsat-project-statistics
Positive impact of scientific production

As of August 2022

https://www.usgs.gov/landsat-missions/landsat-project-statistics
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:

- 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.

Millions of individual scenes. Tape store accessed by robot.
Various users need the same data for various purposes...

...investing in the entire value chain!
Analysis Ready Data are key to reduce the burden on EO data users! Spending more time in analyzing data than searching & pre-processing data...

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.
Proven concept in Australia
... to observe permanent and temporary water bodies
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.
## SWISS DATA CUBE in Numbers

A unique Analysis Ready Data Archive

<table>
<thead>
<tr>
<th>39 years</th>
<th>10 sensors</th>
<th>Official gov. data</th>
<th>EO data products</th>
</tr>
</thead>
<tbody>
<tr>
<td>FROM 1984 to 2023</td>
<td>LANDSAT 5/7/8/9; SENTINEL-1AB/2AB/3/5P</td>
<td>DEM; Climate models; Land Cover,...</td>
<td>NDVI, NDWI, EVI, LAI, ... time-series</td>
</tr>
</tbody>
</table>

- **> 450 million** PIXELS
- **> 3000 billion** OBSERVATIONS
- **10-30-90m** PIXEL RESOLUTION
- **~ 80’000** images INGESTED
- **~30 TB** ANALYSIS READY DATA
- **~40 millions CHF** COST OF DATA WITHOUT OPEN DATA ACCESS POLICY

*Updated every week!*

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Our vision

The Swiss Data Cube (operated by the University of Geneva and the United Nations Environment Programme/GRID-Geneva together with the University of Zurich and the Federal Institute for Forest, Snow and Landscape Research) is aiming at **providing a routine, reliable and operational service, using satellite Earth Observations (EO) to deliver decision-ready products** enabling policy makers, scientists, the private sector and civil society to address social, environmental and economic changes at the national scale and develop an ecosystem for innovation across sectors.

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**The Swiss Data Cube - Insight for action**

The SDC will **improve our understanding of Switzerland’s changing landscape**, providing much needed insights, knowledge and analysis for more informed, strategic and inclusive decision making across the country. This information will **benefit policy makers and public officials**, enabling them to make better decisions, and will **increase commercial efficiency and economic growth** for businesses and entrepreneurs across the country.
Our mission

The Swiss Data Cube will **process openly accessible and freely available data** to produce decision-ready products. **Working closely with different stakeholders’ communities** (administrations, industry, scientists…), the Swiss Data Cube will be responsive to the information needs, challenges, and priorities of the Swiss institutions. It will ultimately leverage and build on existing capacity to enable the use of EO data to address key challenges across the country.
Environmental monitoring
Supporting national & cantonal monitoring activities
- Snow cover change over the last 35+ years
- Impact of droughts on vegetation and rivers
- Identifying new protection areas with high archeological potential
- Identifying impervious areas to support climate action plans
- Contribution to air quality monitoring
- Identifying dust to better predict concentration of pollutants

SDG monitoring
Following progresses towards policy framework
- SDG 6.6.1: change in water extent
- SDG 11.7.1: urban green areas
- SDG 15.3.1: land degradation

Collaborations
Who already benefits (or is interested) by the SDC?
- National: BAFU, swisstopo, FSO, …
- Cantons: Geneva, Vaud, Valais, Neuchâtel, Zurich, Ticino
- International: Australia, Brazil, Chile, UK, Greece, Israel, Armenia, …
- Private sector: Litix, WeGaw, PicTerra
- Universities: Bern, Basel, ETHZ, Lausanne, Geneva

SwissEnvEO
http://geonetwork.swissdatacube.org
2TB of freely available satellite-derived national time-series data products (NDVI, LAI, …) – FAIR compliant

Scientific impact
Enhancing environmental monitoring
- 26 publications
- > 60 presentations
- > 20 interviews, newspaper, …
- > 10 scientific projects supported

Data & Analysis services
Seamless access to the SDC content
- OGC: https://ows.swissdatacube.org/
- STAC: https://explorer.swissdatacube.org/stac
- Jupyter Hub: https://jupyterhub.swissdatacube.org/
Value proposition

The Swiss Data Cube (SDC) will **deliver a unique capability to track changes across Switzerland** to process, interrogate, and present Earth observation satellite data in response to environmental issues of Switzerland. This near real-time information can be **readily used as an evidence** base for the design, implementation, and evaluation of national policies. It will also support innovation and growth in the digital economy; improve the management of natural resources; and improve efficiency and effectiveness of government investments.
Open Data Cube - https://www.opendatacube.org

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.

ODC ECOSYSTEM
GEOSPATIAL DATA MANAGEMENT & ANALYSIS SOFTWARE

SATELITE 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
"Digital Earth can play an insightful role to provide the basis for reliable and responsible scientific understanding and knowledge to support informed decisions and evidence-based policy advice. It can help to integrate different data describing the three dimensions of sustainability (economic, social, and environmental)"
EO for SDG Monitoring

ADVANTAGES

- Regular and repeatable observations
- Multi-annual time series of observations
- Cost-effective to monitor remote areas

IMPROVEMENTS

1. Better integrate EOs data with national statistics
2. Improve capacity to analyse EO data
3. Increase use of cloud computing facility to analyse data

Source: https://eo4society.esa.int/wp-content/uploads/2021/01/EO_Compendium-for-SDGs.pdf
Based on the evaluation of ECV, EBV and EBW, approximately 67 from a total number of 89 variables can be fully or partially measured using remote sensing. This corresponds to a percentage of 75%. By domain, this corresponds to 79% of ECV (41 of 52), 57% of EBV (12 of 21) and 88% of EWV (14 of 16). This shows that remote sensing can provide a substantial contribution to measure this EVs.
Water quality (TSM) – Thun & Brienz lakes 2016
Water quality (TSM) – Thun & Brienz lakes 2016
Le lac des Brenets (NE) n'est plus navigable à cause de la sécheresse
Modelling Accessibility to Urban Green Areas Using Open Earth Observations Data: A Novel Approach to Support the Urban SDG in Four European Cities

by Gregory Giuliani 1,2,*, Ekkehard Petri 3, Eduard Interiews 4, Veronika Vysna 3, Yaniss Guigoz 1,2,5, Nicolas Ray 1,5 6, and Ian Dickie 6

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Remote Sens. 2021, 13(3), 422; https://doi.org/10.3390/rs13030422
Modelling Physical Accessibility to Public Green Spaces in Switzerland to Support the SDG11

Figure 3. Travel time to reach centroids of urban green spaces, using a walking and motorized model: (A) nationally, (C) for the canton of Zurich, (E) for the canton of Vaud; and using a walking-only model: (B) nationally, (D) for the canton of Zurich, (F) for the canton of Vaud.

Figure 5. (A) percentage of the population, per municipality, that have access within 15 min (walking and motorized scenario) to (A) the centroid of the nearest urban green space, and to (B) the nearest forest patch.
Greening vegetation in Switzerland

Obuchowicz C., Poussin C., Giuliani G., Change in observed long-term greening across Switzerland – Evidence from a three decades NDVI time-series and its relationship with climate and land cover factors, Submitted to Big Earth Data.
Normalized Difference Water Index (NDWI)...

Water content of vegetation (2014 vs. 2003)

Trends in vegetation water content
NDWI time-series from 35 years of Landsat observations – Annual mean

- Weak Drought
- Moderate Drought
- Strong Drought

Building monitoring services
To facilitate the access to information generated with EO data (e.g., Droughts, Land Cover, Urbanization, Air Quality, ...)
Drought Monitoring
Drought Monitoring
Drought Monitoring

NDWI


Legend:

To complete:

NDWI Trend for Switzerland
Land Surface Temperature
Benefiting from the Landsat thermal band
Land Surface Temperature
Benefiting from the Landsat thermal band

Bern City

Monthly median

Seasonal median
Snow cover mapping

Snow is an important form of water storage

Snow cover is an Essential Climate Variable

A natural resource: indicator of climate change; essential for water-resource management; affects various ecosystem services

Using Sentinel-2 data

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$^2$).
Improved Landsat-based snow cover mapping accuracy using a spatiotemporal NDSI and generalized linear mixed model

DOI: 10.1016/j.srs.2023.100078
Identifying areas of archaeological potential in the Alps

SDG 15.3.1 Land Degradation... 
...is undermining the well-being of 3.2 billion people (IPBES)
SDG 15.3.1 Land Degradation...

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

Collaboration: University of Geneva; GEO; ESA, CNR, JRC; UN Environment

Giuliani et al., submitted


Collaboration: UNIGE, GEO, ESA, CNR, JRC, UNEP
Special Issue on EVs
International Journal of Digital Earth, Vol.13(2) - 2020

https://www.tandfonline.com/toc/tjde20/13/2
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
The SDC supports the «Digital Switzerland» strategy

- 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
HAVE YOU FAILED TO REPRODUCE AN EXPERIMENT?

Most scientists have experienced failure to reproduce results.

- Someone else’s
- My own

Chemistry
Biology
Physics and engineering
Medicine
Earth and environment
Other
Reproducible

- Same data
- Same analysis

Replicable

- Different data
- Same analysis

Robust

- Same data
- Different analysis

Generalisable

- Different data
- Different analysis
FAIR COOKBOOK
DATA RECIPES

- 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
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
SwissEnvEO: a FAIR national EO environmental database

http://geonetwork.swissdatacube.org

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

The Swiss data cube, analysis ready data archive using earth observations of Switzerland

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Since the opening of Earth Observation (EO) archives (USGS/NASA Landsat and EC/ESA Sentinels), large collections of EO data are freely available, offering scientists new possibilities to better understand and quantify environmental changes. Fully exploiting these satellite EO data will require new approaches for their acquisition, management, distribution, and analysis. Given rapid environmental changes and the emergence of big data, innovative solutions are needed to support policy frameworks and related actions toward sustainable development. Here we present the Swiss Data Cube (SDC), unleashing the information power of Big Earth Data for monitoring the environment, providing Analysis Ready Data over the geographic extent of Switzerland since 1984, which is updated on a daily basis. Based on a cloud-computing platform allowing to access, visualize and analyse optical (Sentinel-2; Landsat 5, 7, 8) and radar (Sentinel-1) imagery, the SDC minimizes the time and knowledge required
Global Impact...

...but essential to consider the local context!
Think global, cube local: an Earth Observation Data Cube’s contribution to the Digital Earth vision

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\begin{abstract}
The technological landscape for managing big Earth observation (EO) data ranges from global solutions on large cloud infrastructures with web-based access to self-hosted implementations. EO data cubes are a leading technology for facilitating big EO data analysis and can be deployed on different spatial scales: local, national, regional, or global. Several EO data cubes with a geographic focus ("local EO data cubes") have been implemented. However, their alignment with the Digital Earth (DE) vision and the benefits and trade-offs in creating and maintaining them ought to be further examined. We investigate local EO data cubes from five perspectives (science, business and industry, government and policy, education, communities and citizens) and illustrate four examples covering three continents at different geographic scales (Swiss Data Cube, semantic EO data cube for Austria, DE Africa, Virginia Data Cube). A local EO data cube can benefit many stakeholders and players but requires several technical developments. These developments include enabling local EO data cubes based on public, global, and cloud-native EO data streaming and
\end{abstract}

\begin{articleshort}
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\begin{keywords}
Earth Observation data cube; Digital Earth; interoperability; workflows; open data cube
\end{keywords}

EO Data Cubes have the potential...

... to enhance scientific accountability and credibility

Without trust and shared knowledge:

• Doing science can be difficult

• Taking sound decisions can be problematic

• And envisioning a sustainable development can be complicated
Open to collaboration!
Follow us
http://www.swissdatacube.ch

Swiss Data Cube

Earth Observations Analysis Ready Data for Switzerland

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