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SMODEX

... a python package for understanding the
evolution of soil moisture anomalies

Rufai Omowunmi Balogun, Peter James Zellner and Felix Greifeneder

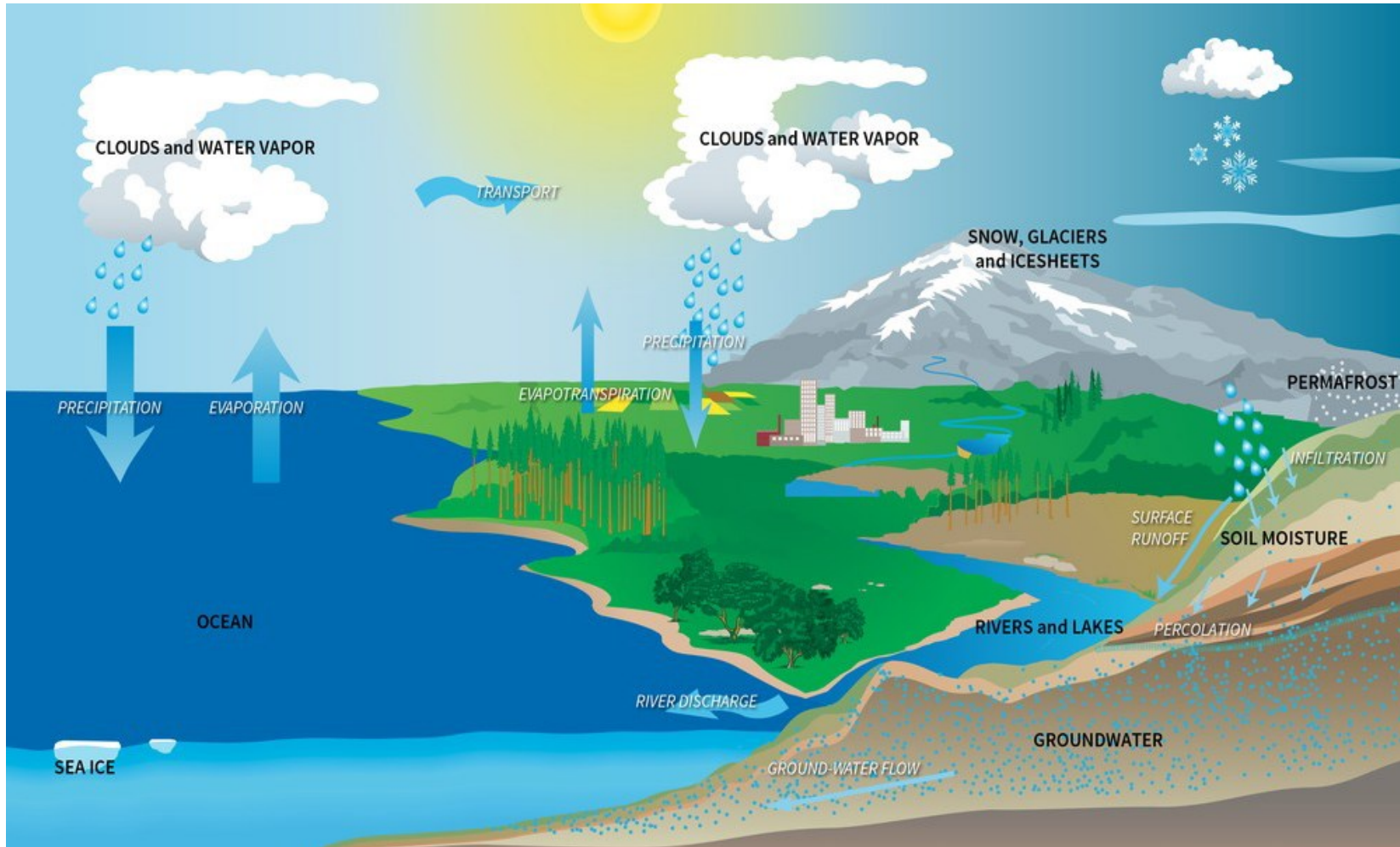
11.11.2023

Presentation outline

- **Background**
- **Motivation**
- **SMODEX**
- **Use case**
- **Conclusion**
- **What next?**

1. Background

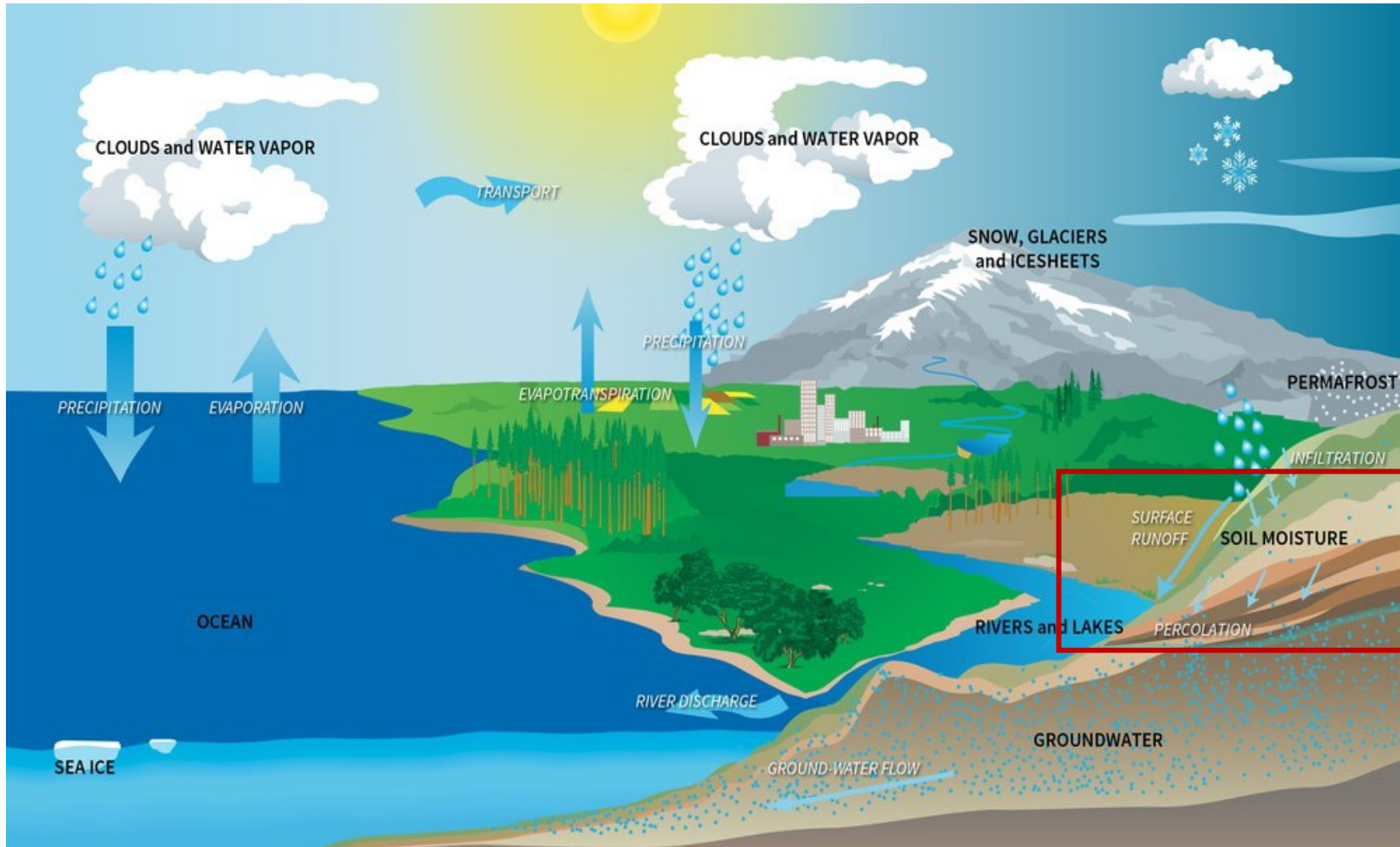
The Global Water Budget



The global water budget is under pressure with significant effects on many downstream sectors (FAO, 2021).

Source: Modeling the Water Budget, NASA JPL:
<https://www.jpl.nasa.gov/edu/teach/activity/modeling-the-water-budget/>

The Global Water Budget



The global water budget is under pressure with significant effects on many downstream sectors (FAO, 2021).

Soil moisture is a critical parameter used in understanding the hydrological cycle.

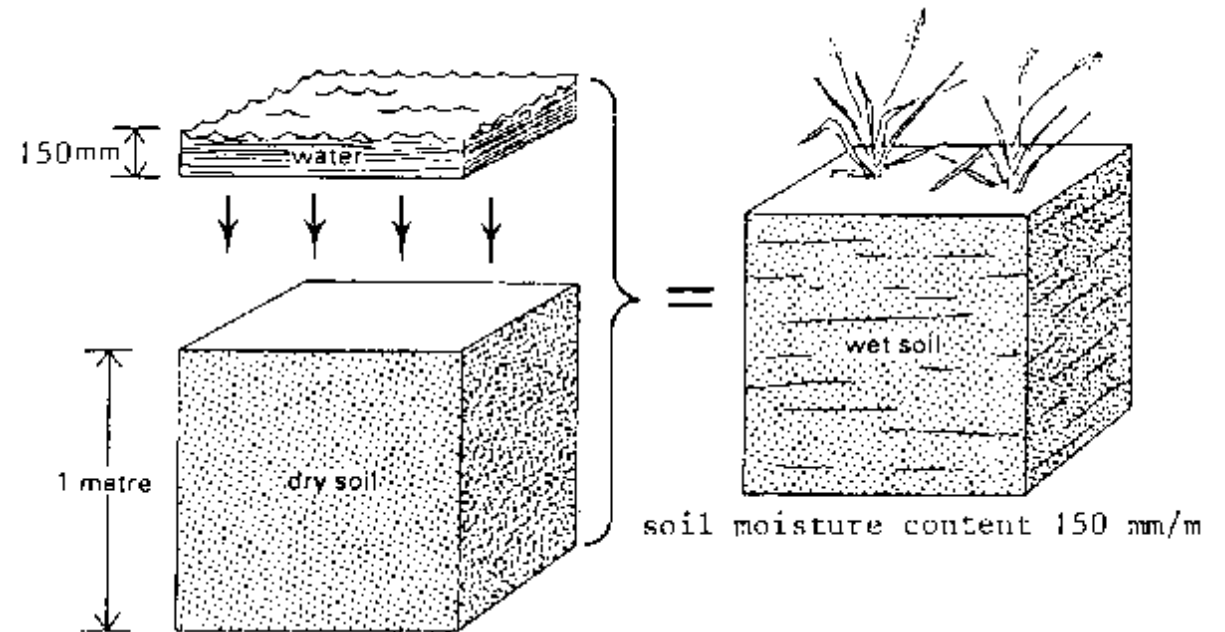
Source: Modeling the Water Budget, NASA JPL:
<https://www.jpl.nasa.gov/edu/teach/activity/modeling-the-water-budget/>

Soil Moisture

Soil moisture content is the measurement of the amount of water held in soil expressed in mm of water depth.

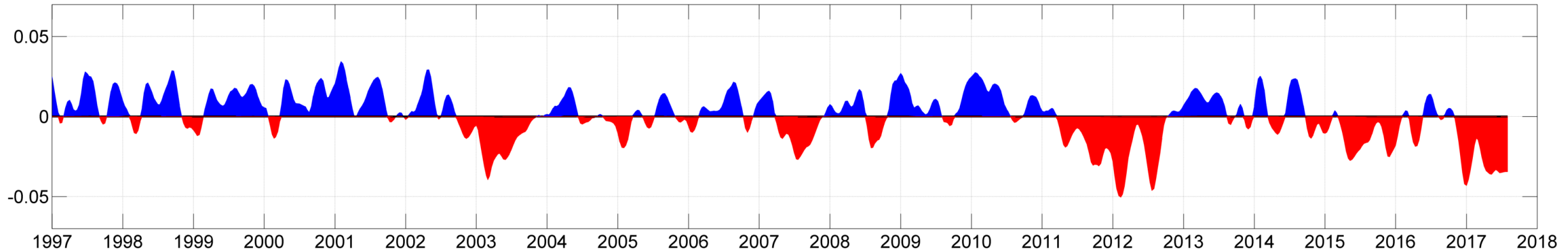
Useful application in:

- Sustainable farming and agricultural practices,
- Flood and erosion control, and
- Drought monitoring and prediction.



Source: Irrigation Water Management: Training Manual, Food and Agricultural Organization (FAO). Chapter 2: Soil and Water: <https://www.fao.org/3/r4082e/r4082e03.htm>

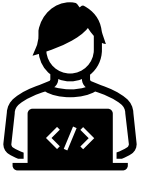
Soil Moisture Anomalies



Source: Annual Soil Moisture Anomalies over Italy (1997 to 2018), European Space Agency, https://www.esa.int/ESA_Multimedia/Images/2017/09/Italy_soil_moisture_anomalies

“Soil Moisture Anomaly is a climatic indicator used to detect and monitor the start and duration of agricultural drought and other dryness/wetness conditions”

2. Motivation

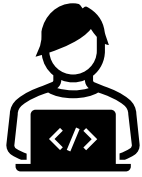


Why smodex?

- ❑ Soil moisture and soil moisture anomalies are reliable predictors for dryness/ wetness conditions,
- ❑ Climatic analysis can involve multiple steps and processing chains,
- ❑ Climatic analysis are often computationally demanding,

3. smodex package

pip install smodex



smodex

smodex – an acronym for soil moisture indices.

A tool for accessing, analyzing and sharing soil moisture data and information.

Data Access

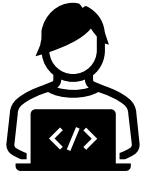
Computation

Visualization

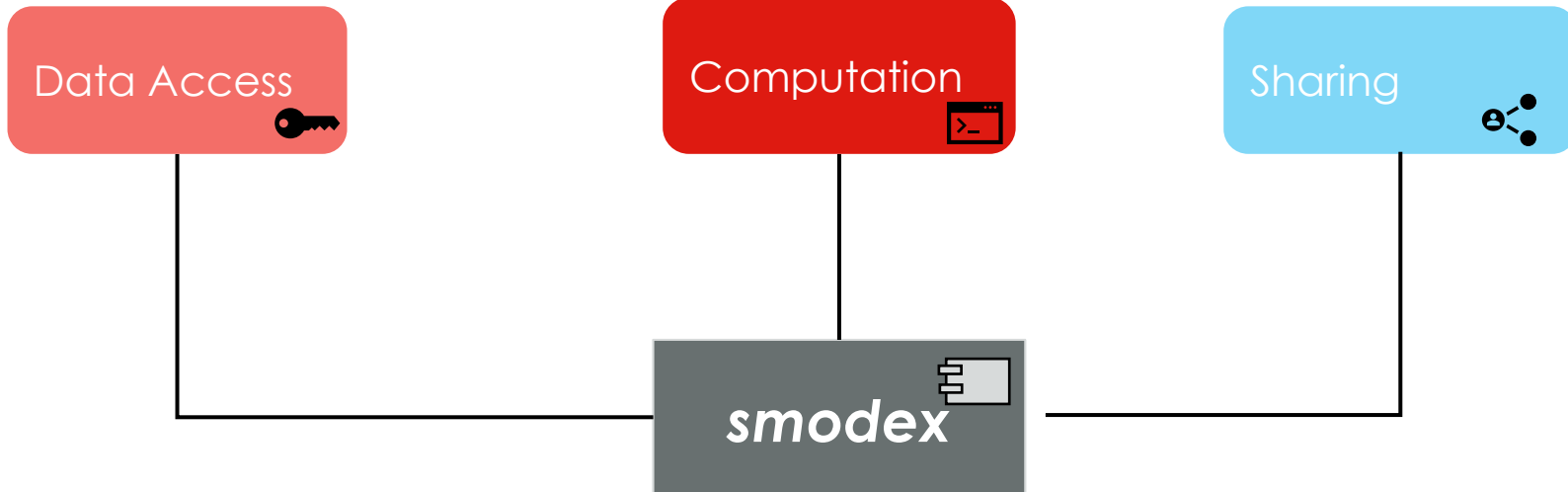
Sharing

The screenshot shows the PyPI page for the smodex package. At the top, there's a search bar and navigation links for Help, Sponsors, Log In, and Register. The package name 'smodex 1.0.1b0' is prominently displayed, along with a 'Latest version' badge and a 'Released: Oct 30, 2023' date. A 'pip install smodex' button is visible. Below this, the project description states: 'SMODEX Package: A Python package for understanding the evolution of soil moisture anomalies.' It includes metadata such as license (MIT), coverage (62%), and python version (>=3.6). The 'Package Usage' section lists three user categories: Researchers, Students, and Open-source and Open-science scientists. The 'Installation' section provides the command 'pip install smodex'. The 'Project description' section details the package's purpose: to enhance the performance of soil moisture and soil moisture anomalies analysis using climate datasets, following FAIR and Open Science principles.

Source: SMODEX, Python Package Index (PyPI), <https://pypi.org/project/smodex/>



smodex



smodex latest

Search docs

Installation

Getting Started

1. Data Loading
2. Climatology computation
3. Anomalies computation
4. Data visualization
5. Data sharing

API Documentation

Contributing

Getting Started

The goal of the smodex package is to ensure the seamless computation of soil moisture anomalies from climate datasets. Hence, the main steps involved in this computation have been simplified to:

1. Data Loading,
2. Climatology computation,
3. Anomalies computation,
4. Data visualization, and
5. Data sharing

In this page, we walk you through how to utilize the main functionalities of the `smodex` package to perform these actions. Ensure you have the smodex package, you can consult the installation guide for the different ways of installing the package in your development environment.

1. Data Loading

The smodex downloader module provides functionalities that enables you access datasets from the ERA5 Climate Data Store by specifying the details of the requested datasets in a JSON file and providing all the necessary information for downloading the datasets you need. To do this, follow the following steps:

1. Step 1. Ensure you have the ERA5 CDS API installed in your development environment. This can be done by:

```
pip install cdsapi
```

This provides all the necessary functionalities and backends for accessing the CDS datasets.

Next to this, create a configuration file (JSON file) that contains all the data specification for the data you would like to request, example:

```
{  "product_type": "reanalysis",  "variable": [    "volumetric_soil_water_layer_1",    "volumetric_soil_water_layer_2",    "volumetric_soil_water_layer_3",    "volumetric_soil_water_layer_4"  ],  "year": 1981,  "month": [ "01", "02", "03" ],  "day": [ "03", "08", "16", "24", "30" ],  "time": [ "08:00", "06:00", "12:00", "18:00" ],  "area": [ 47.148, 18.255, 46.297, 12.542 ],  "format": "netcdf"}
```

This JSON file in general should contain the information on your Area of Interest and other specific information on the datasets you would like to download.

1. Step 2. Specify the time range (start date and end date) and download your data to the specified path:

API 3

ERA5 CDS API

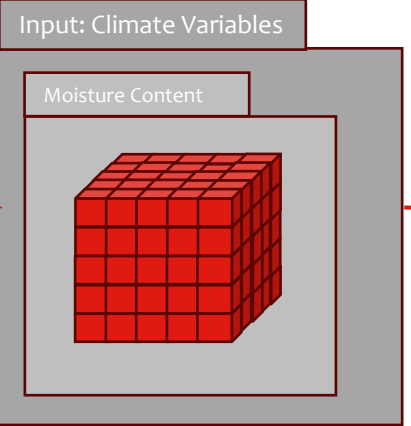
API 2

Data Access

conf

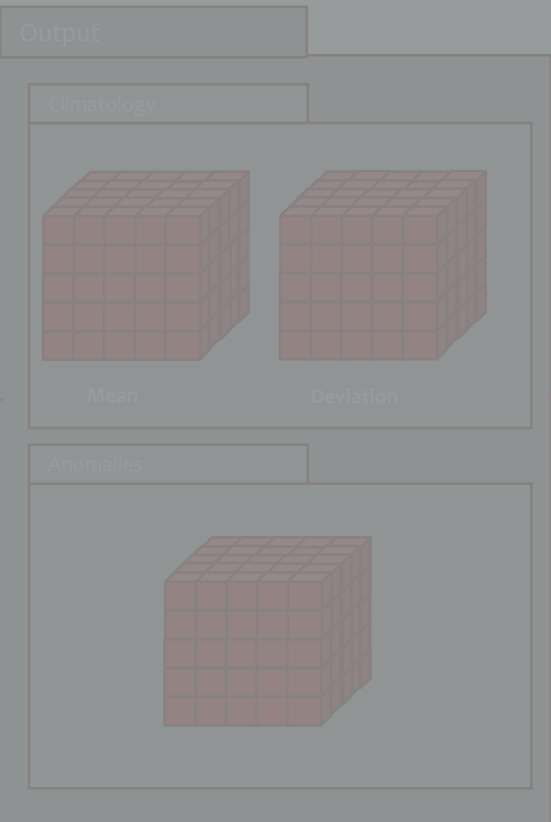


downloader

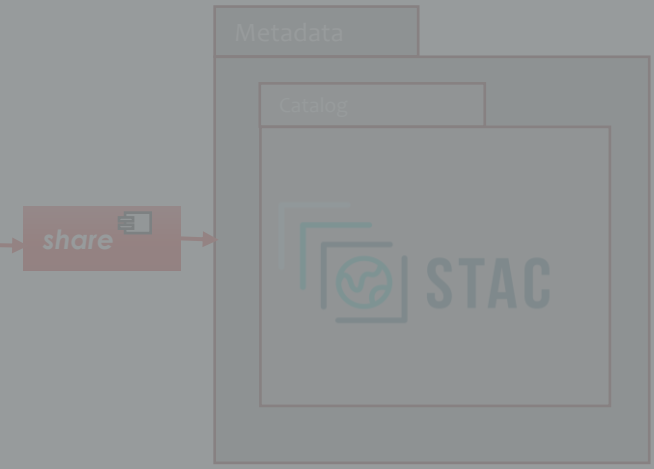


High dimensional datasets:
 30 years × 365 days × 4 synoptic hours × x_dim × y_dim

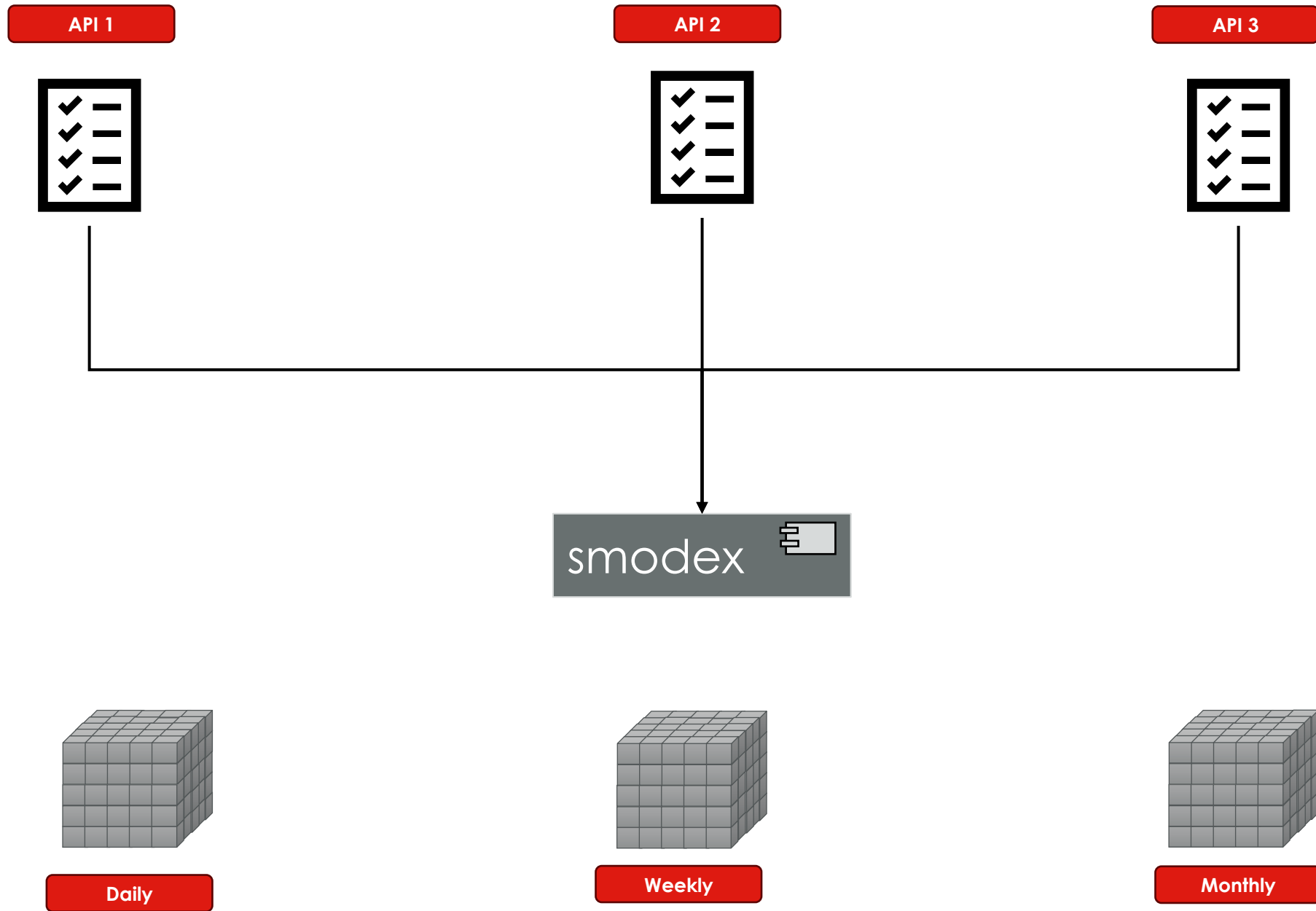
Compute



Share



data access



API 3

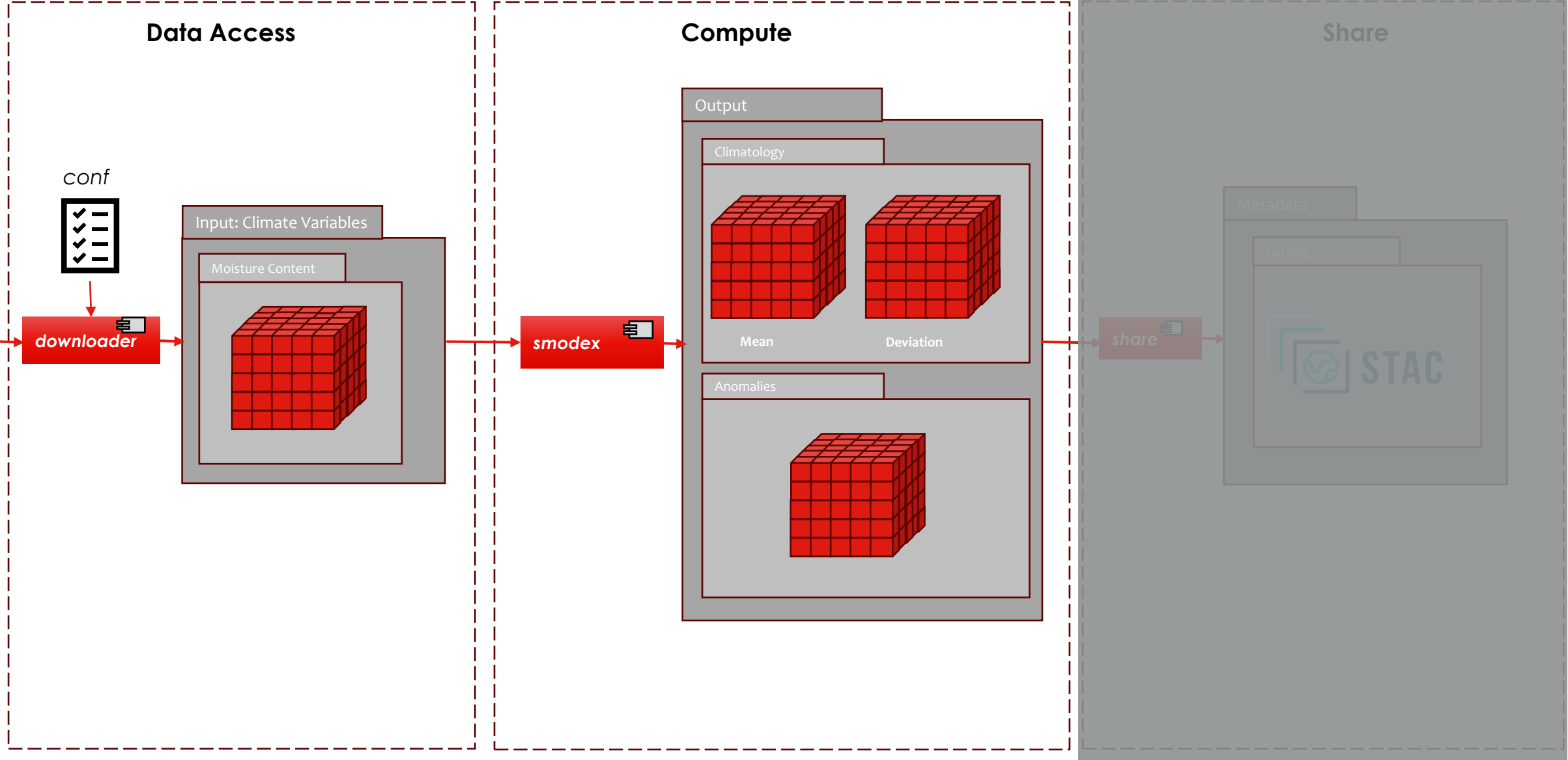
ERA5 CDS API

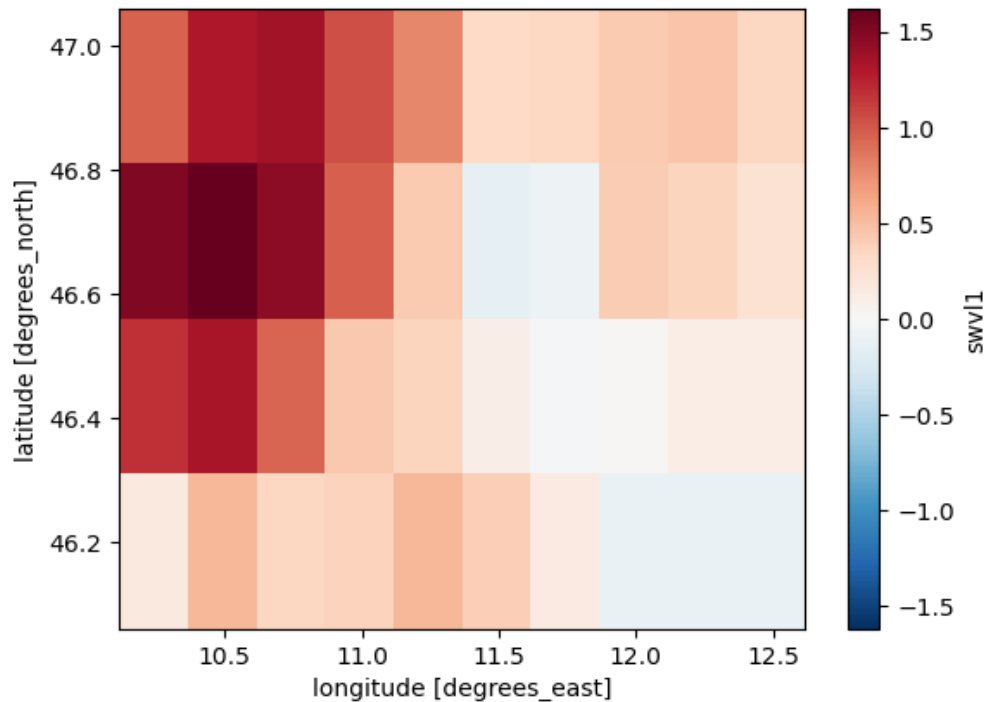
API 2

Data Access

Compute

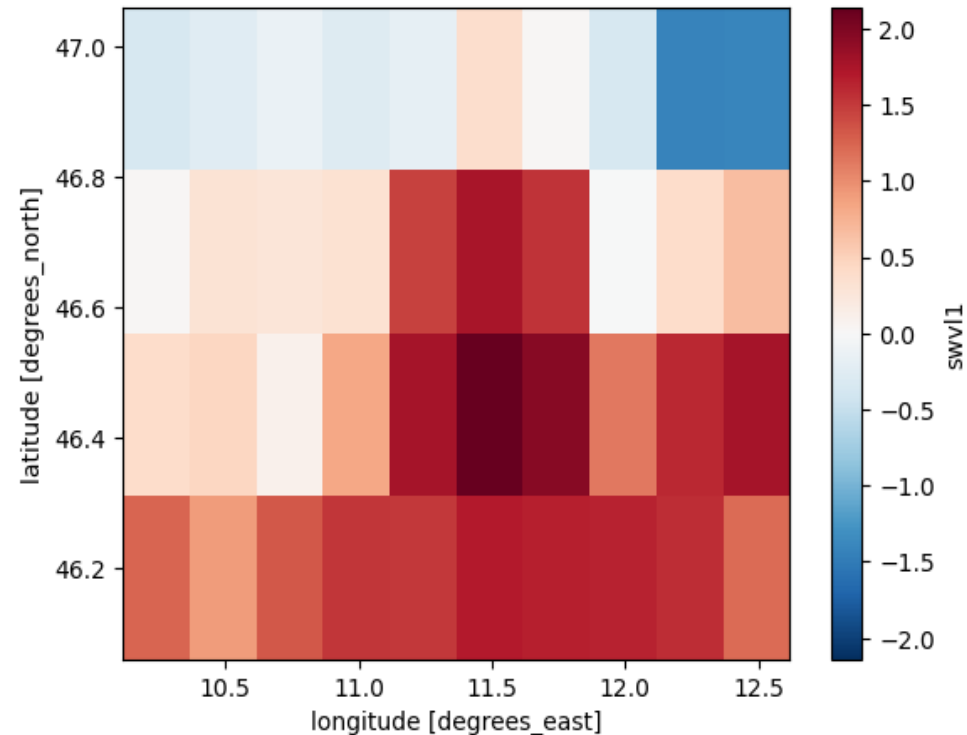
Share





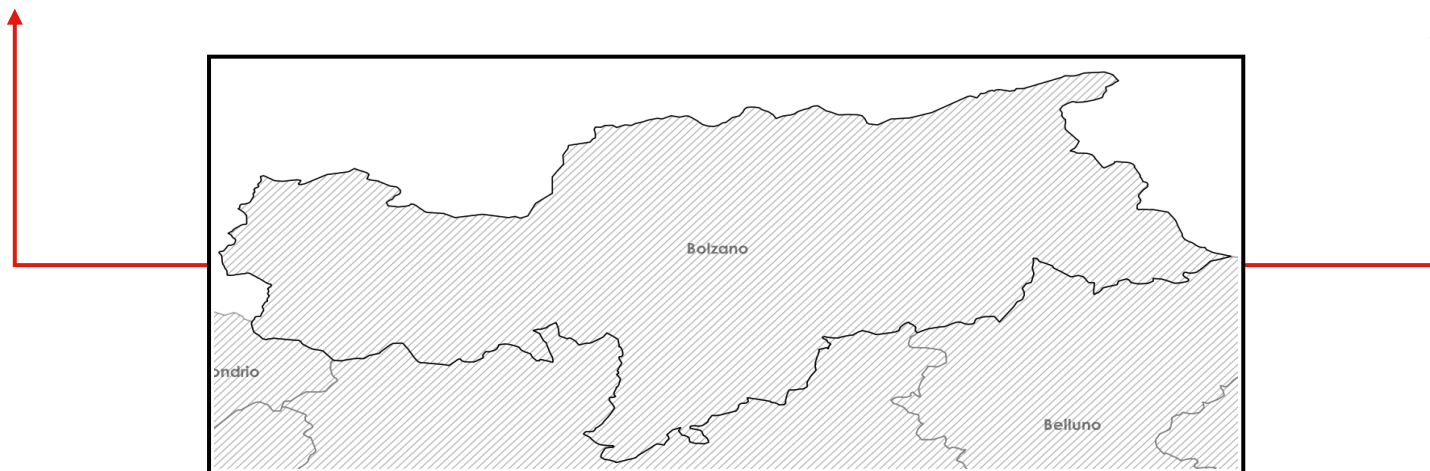
Soil moisture anomaly for September 2011 over South Tyrol

Temporal scale: monthly

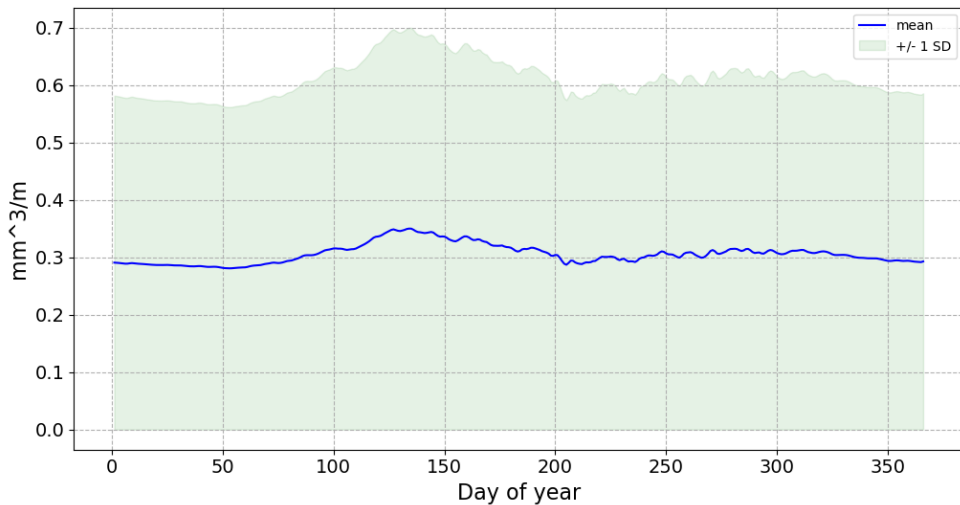


Soil moisture anomaly for 2nd week of 2011 over South Tyrol

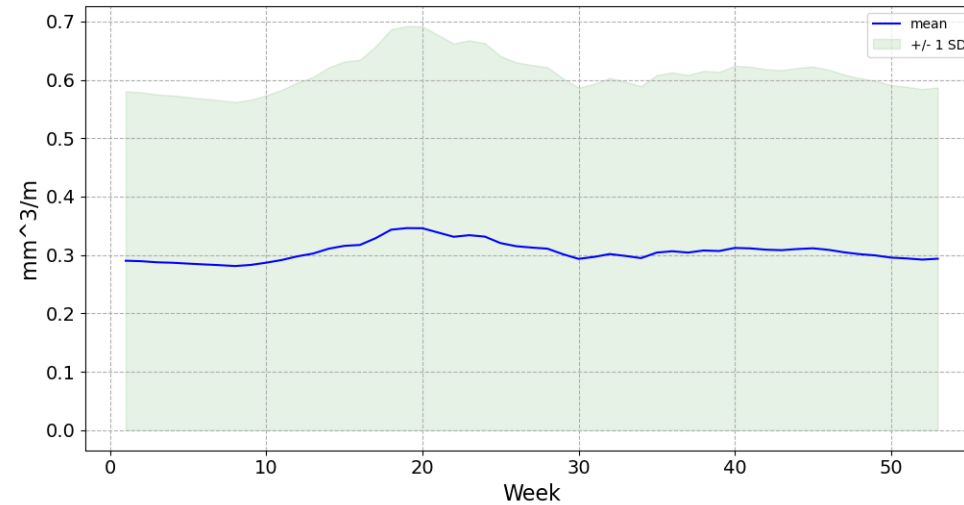
Temporal scale: weekly



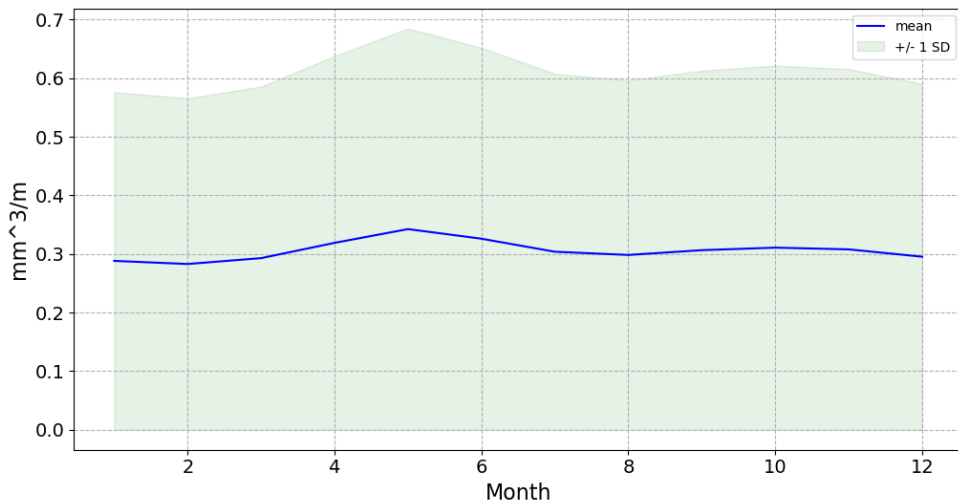
Daily climatology of soil moisture (1981 to 2010) over the South Tyrol region



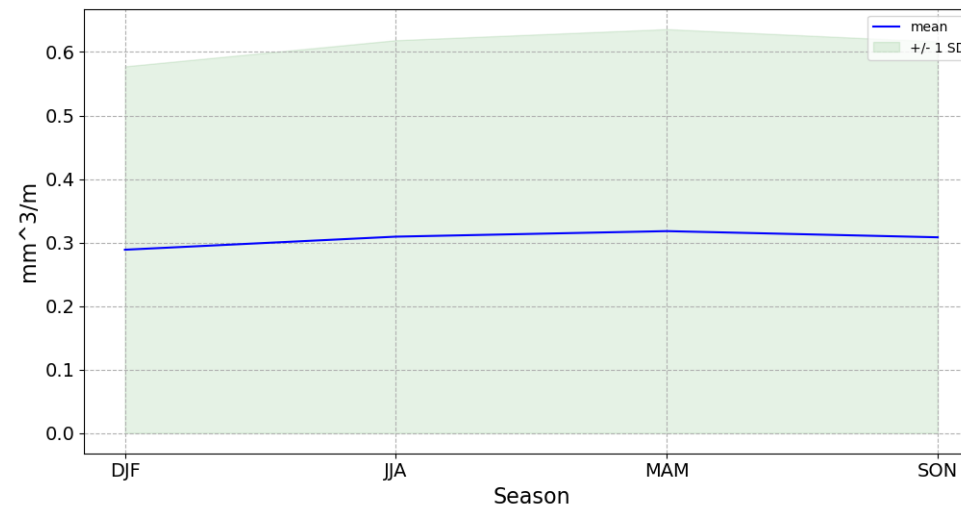
Weekly climatology of soil moisture (1981 to 2010) over the South Tyrol region

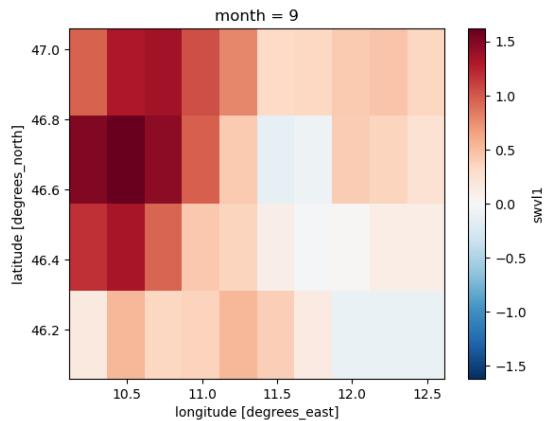


Monthly climatology of soil moisture (1981 to 2010) over the South Tyrol region

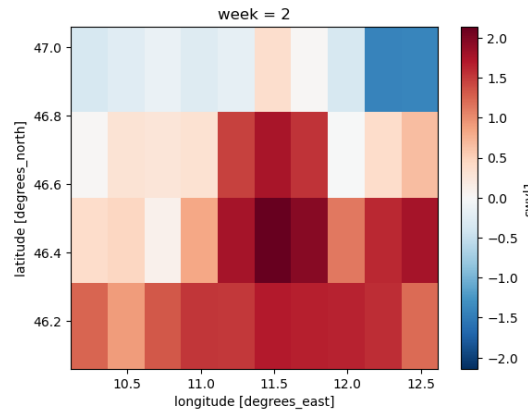


Seasonal climatology of soil moisture (1981 to 2010) over the South Tyrol region

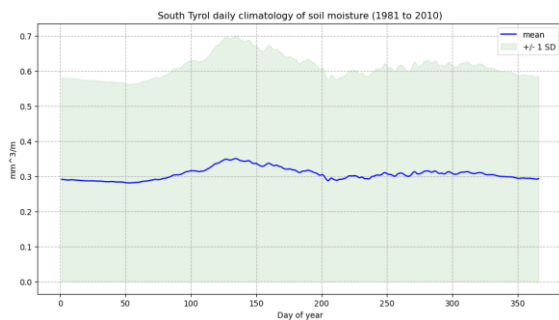




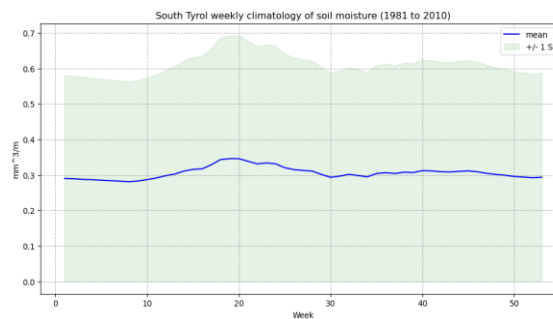
Monthly anomalies



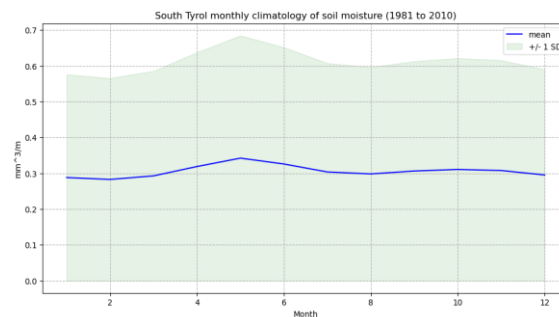
Weekly anomalies



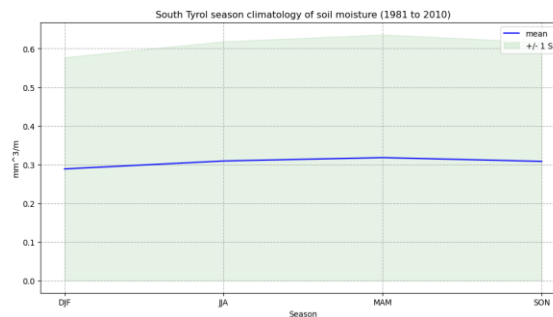
Daily Climatology



Weekly Climatology



Monthly Climatology



Seasonal Climatology

- Spatial resampling,
- Temporal resampling,
- Climatology at different time scales,
- Temporal trends,

API 3

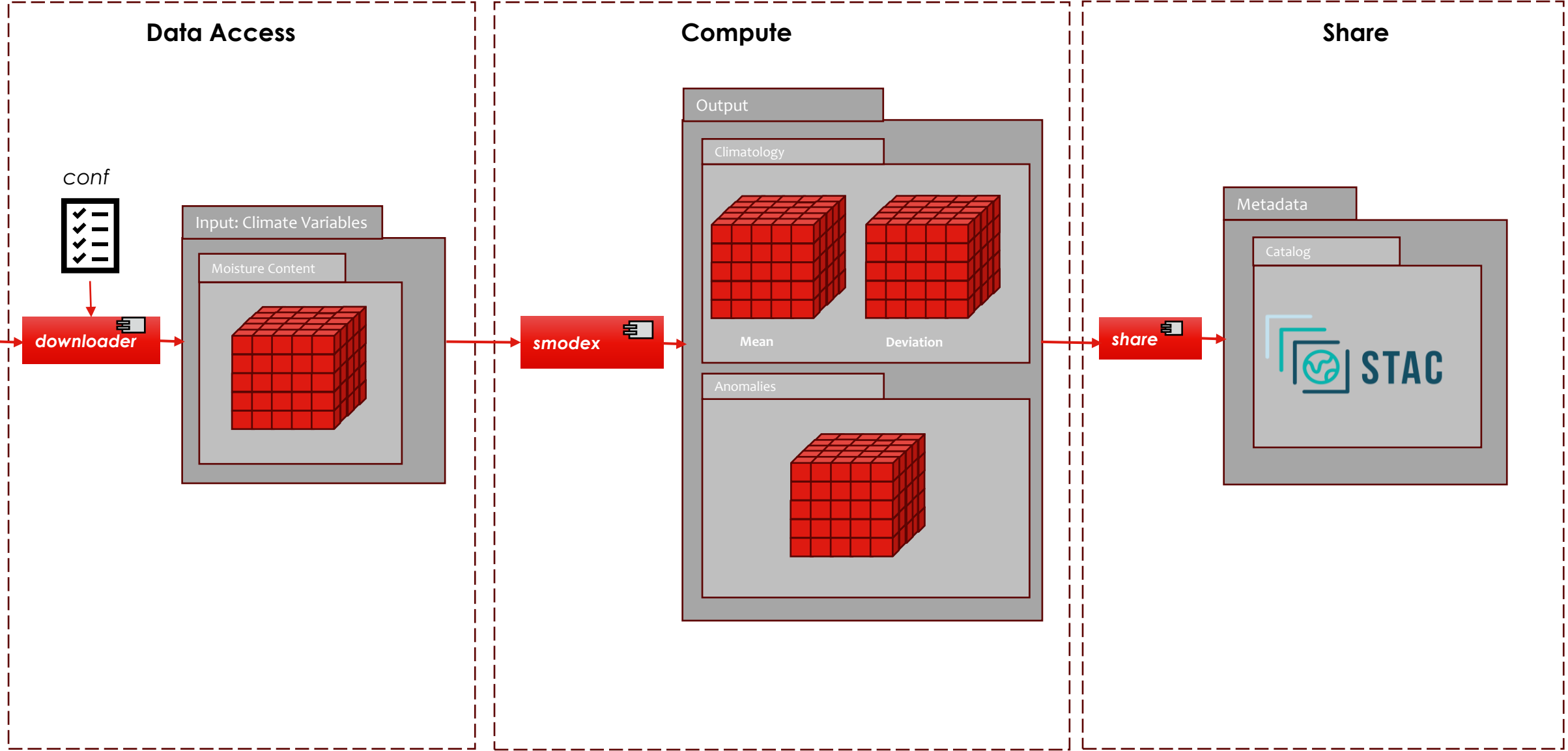
ERA5 CDS API

API 2

Data Access

Compute

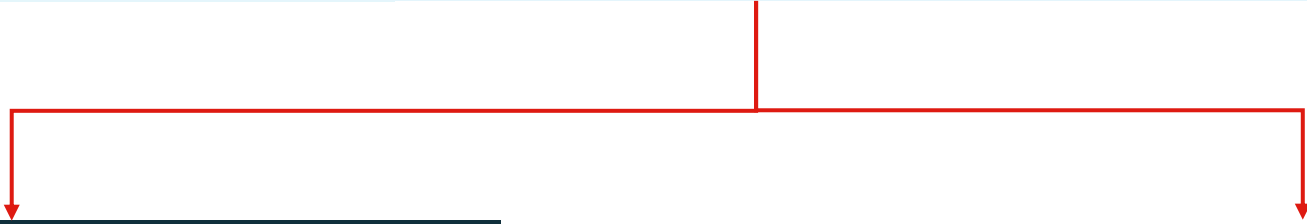
Share



STAC

SpatioTemporal Asset Catalogs

The STAC specification is a **common language to describe geospatial information**, so it can more easily be worked with, indexed, and discovered.



```
{  
  "stac_version": "1.0.0",  
  "type": "Feature",  
  "id": "20201211_223832_CS2",  
  "bbox": [],  
  "geometry": {},  
  "properties": {},  
  "collection": "simple-collection",  
  "links": [],  
  "assets": {}  
}
```

STAC Browser

Share Language: English

Please specify a STAC Catalog or API...

https://...

Load

... or select one from STAC Index:

Imagery acquired by the China-Brazil Earth Resources (CBERS) and Amazonia-1 satellites. The image files are recorded and processed by INPE and are converted to Cloud Optimized Geotiff format in order to optimize its use for cloud based applications. Daily updated and hosted on AWS.

Copernicus Data Space Ecosystem (openEO)

Catalog

This openEO service runs on the Copernicus Data Space Ecosystem and offers data access and processing on full archives of Copernicus data, such as the Sentinels.

CREODIAS

Catalog

Release post: [https://creodias.eu/forum/-/message_boards/message/291442]

data.geo.admin.ch

API

Data Catalog of the Swiss Federal Spatial Data Infrastructure

Data Access

Compute

Share

Expanding to meet user's needs

> smodex > **Issues**

Open 4 Closed 1 All 5

Search or filter results...

- Add STAC data sharing**
#5 · created 1 week ago by RufaiOmowunmi.Balogun · Data Sharing functionalities · Nov 30, 2023
dev
- Notebook example for Data Download for different areas**
#4 · created 1 week ago by RufaiOmowunmi.Balogun · Create Package Usage Examples · Nov 7, 2023
dev
- SMODEX Package Main Notebook example**
#3 · created 1 week ago by RufaiOmowunmi.Balogun · Create Package Usage Examples · Nov 7, 2023
dev
- Time-scale functionality**
#2 · created 1 week ago by RufaiOmowunmi.Balogun · Extend time-scale of anomalies ... · Nov 3, 2023
dev

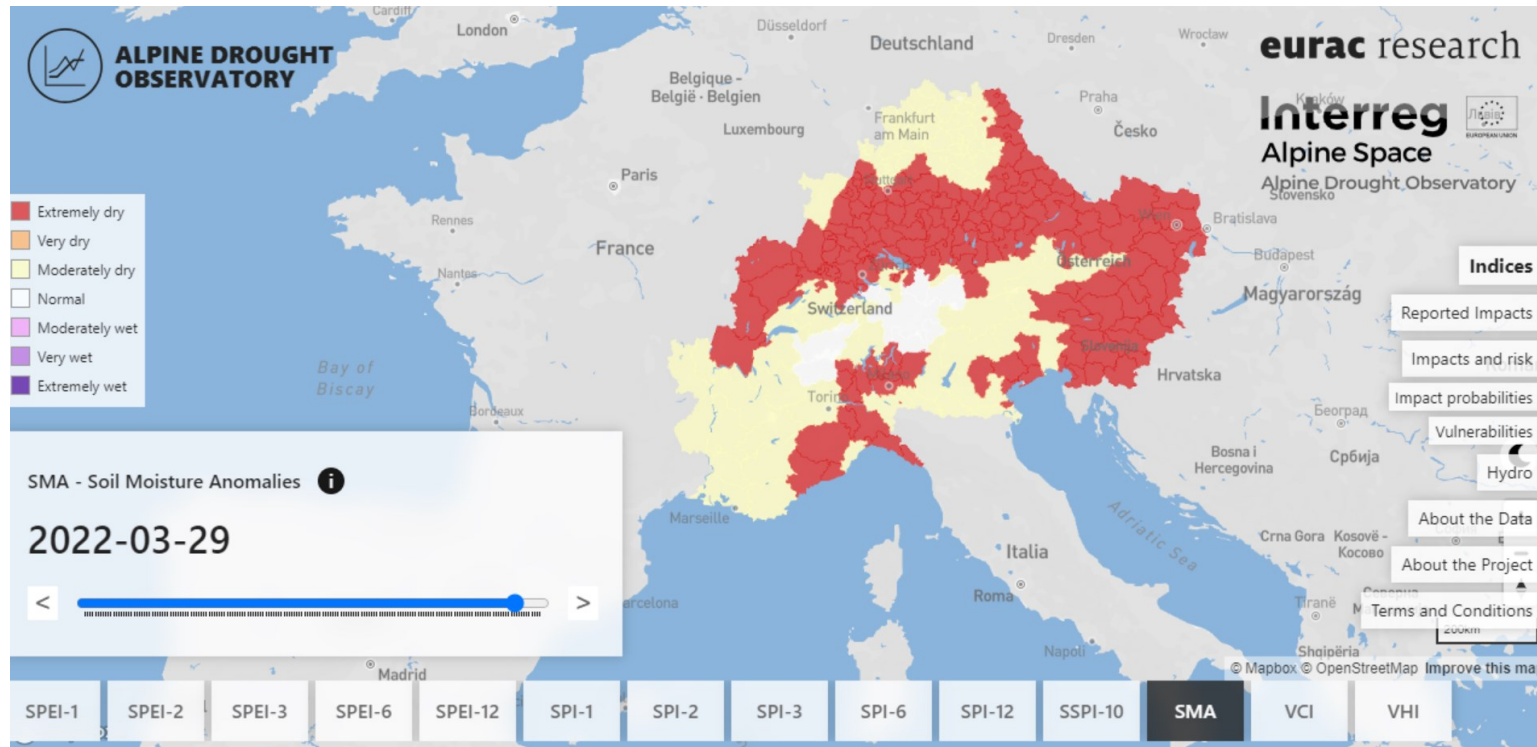
ERA5 CDS API

downloader

share



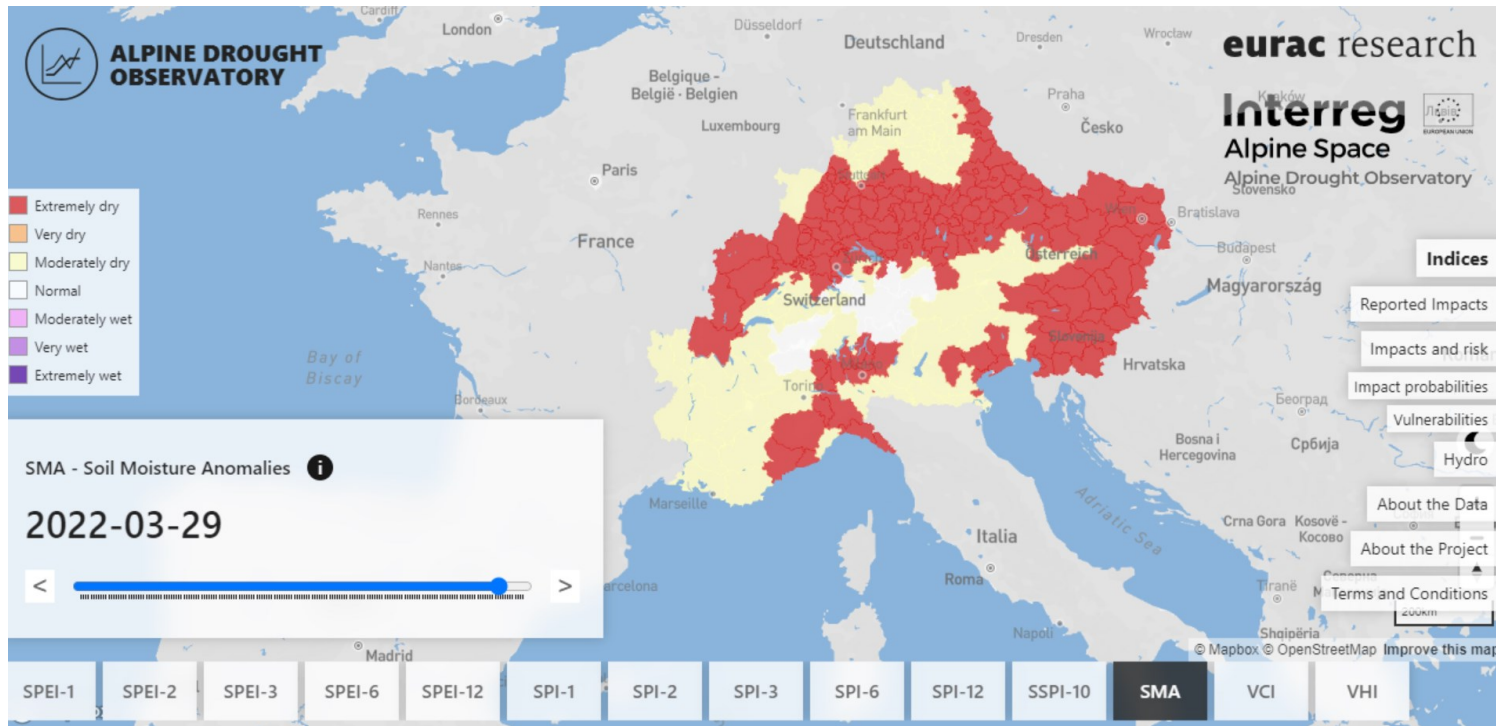
The Alpine Drought Observatory



- ❑ Soil moisture anomalies products on the ADO portal,
- ❑ Used in **CI pipeline** to produce data in a simple way

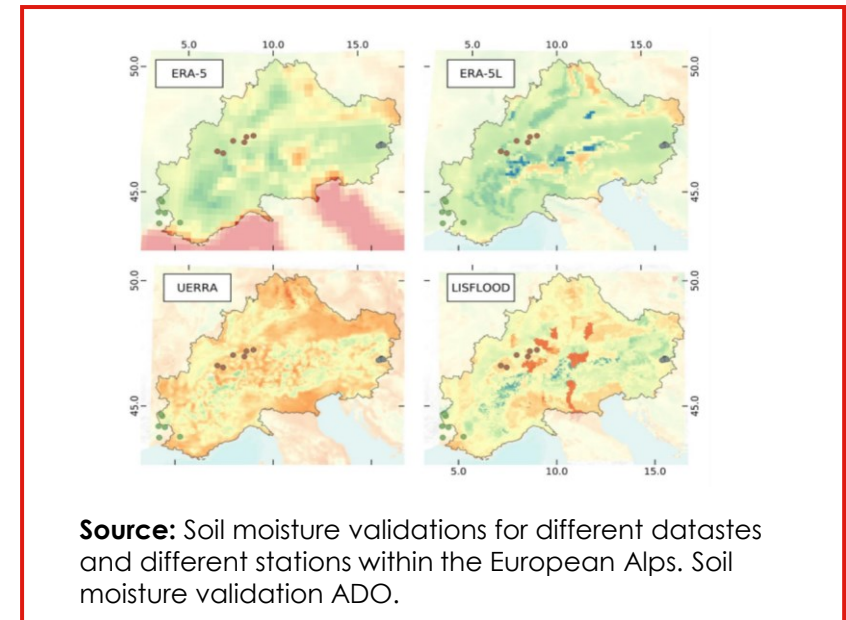
Source: Spatial Distribution of Soil Moisture Anomalies over the European Alps for 29th of March, 2022. The Alpine Drought Observatory. <https://ado.eurac.edu/sma>

The Alpine Drought Observatory



Source: Spatial Distribution of Soil Moisture Anomalies over the European Alps for 29th of March 2022. The Alpine Drought Observatory. <https://ado.eurac.edu/sma>

- ❑ Soil moisture anomalies products on the ADO portal,
- ❑ Used in **CI pipeline** to produce data in a simple way
- ❑ Additional data validation for downstream uses



Source: Soil moisture validations for different datasets and different stations within the European Alps. Soil moisture validation ADO.

4. Conclusion

smodex is:

- ❑ an **open-source** python tool for:
 - i.) accessing climate datasets,
 - ii.) computing soil moisture indicators, and
 - iii.) sharing generated datasets with other scientists in an open-source standard-compliant way
- ❑ provides **functionalities** for
 - i.) spatial and temporal analysis,
 - ii.) data resampling, and
 - iii.) sharing (accessible metadata)
- ❑ **Extensible** to:
 - i.) accessing data from other earth observation/climate data APIs, and
 - ii.) computing new indicators

What next?

- Extend **data access** to other earth observation APIs,
- Extend **data computation** to workflow for soil moisture estimation and anomalies from other high-resolution earth observation datasets,
- Provide a **CLI tool** to enable easy adoption of computations in high-performance computing environment,
- Extend tools based on user's requests for specific downstream functionalities

Useful links

- ❑ **SMODEX package on PyPI**

<https://pypi.org/project/smodex/>

- ❑ **Getting started with SMODEX**

<https://smodex.readthedocs.io/en/latest/guide/quickstart.html>

- ❑ **The Alpine Drought Observatory**

<https://ado.eurac.edu/>

- ❑ **EU Alpine region' Soil Moisture Anomalies on EDP Portal**

<https://edp-portal.eurac.edu/discovery/ea665ca2-0ceb-11ed-86c5-02000a08f4e5>

eurac research

 <https://ror.org/01xt1w755>



Link to this presentation:

<https://www.sfscon.it/talks/smodex-a-python-package-for-understanding-the-evolution-of-soil-moisture-anomalies/>



Code repository:

https://gitlab.inf.unibz.it/earth_observation_public/smodex