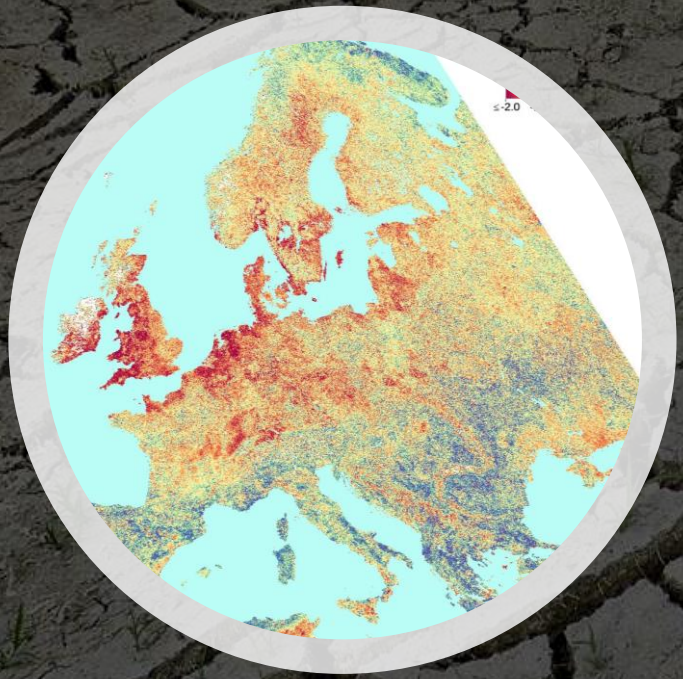

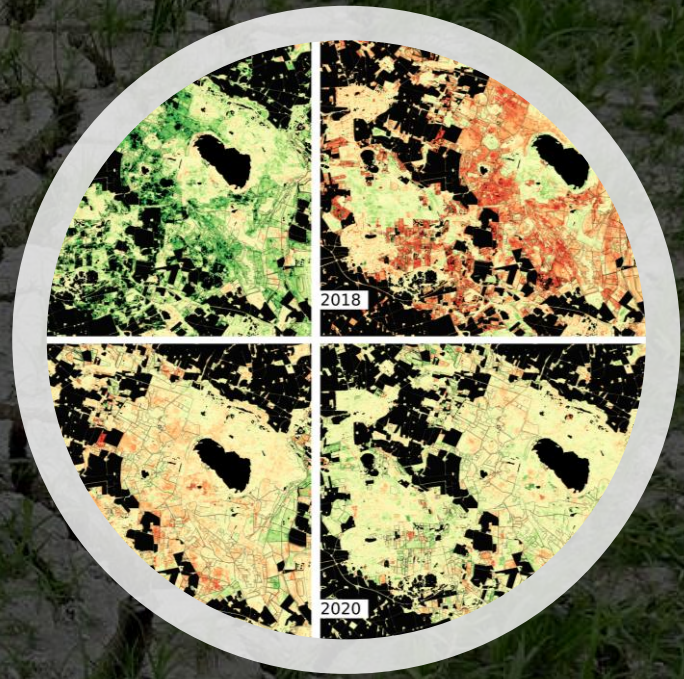

Drought impact monitoring using an EO spatio-temporal data-cube

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Copernicus
Europe's eyes on Earth

What is drought and what are impacts?

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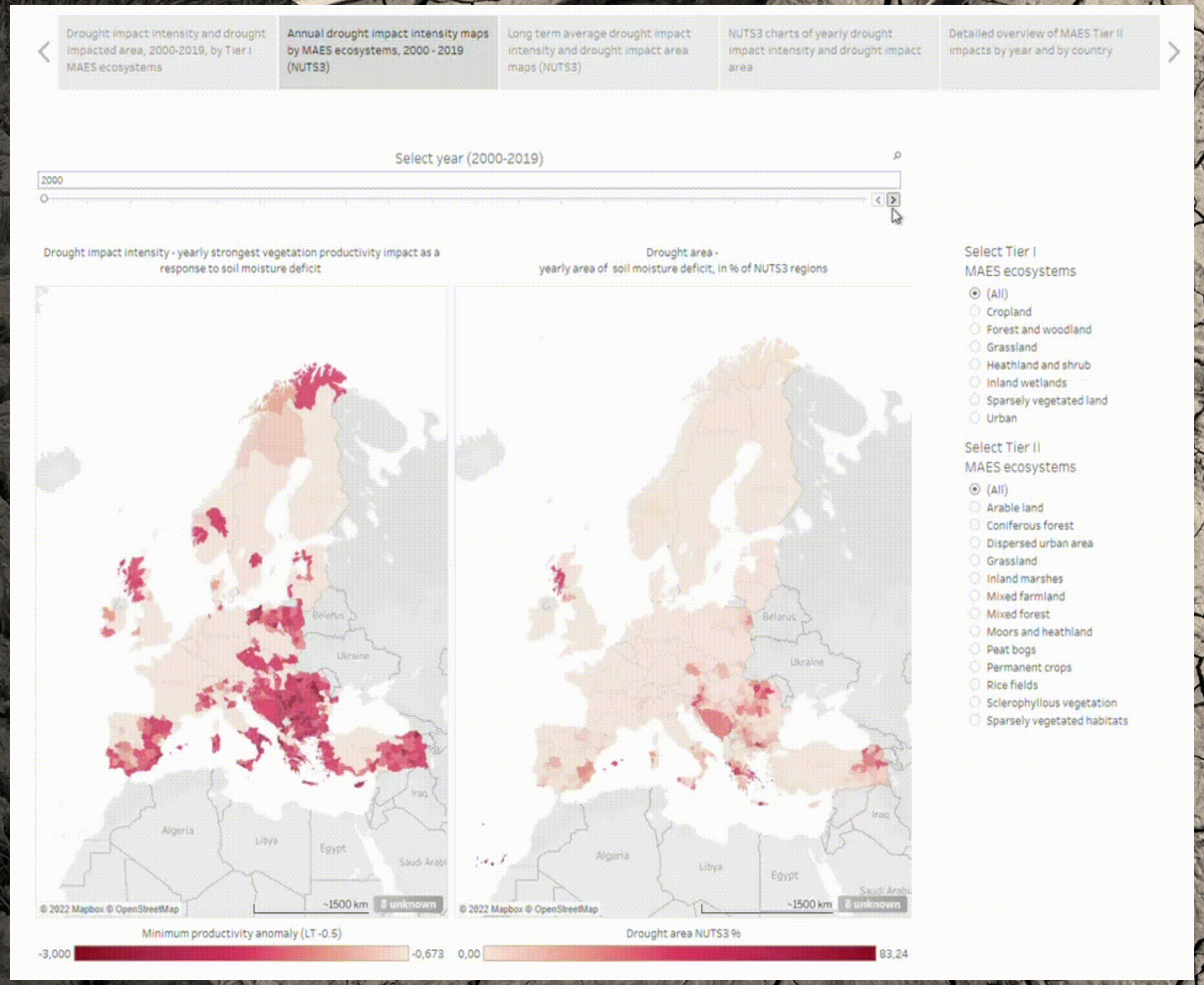
- Recurring natural hazard which can occur anywhere in Europe.
- Propagates through the water cycle, e.g. soil moisture deficit, vegetation water stress, low groundwater levels, etc.
- Lack of precipitation as compared to average conditions/normal climatology.

- It causes:
  - Losses or destruction of wildlife habitats, increased stress on endangered species, loss of wetlands
  - Increased number of wildfires
  - Wind and water erosion of soils
  - Loss of harvest, poor soil quality, biodiversity and ecosystem service decline, loss of C sequestration

-> **land degradation**

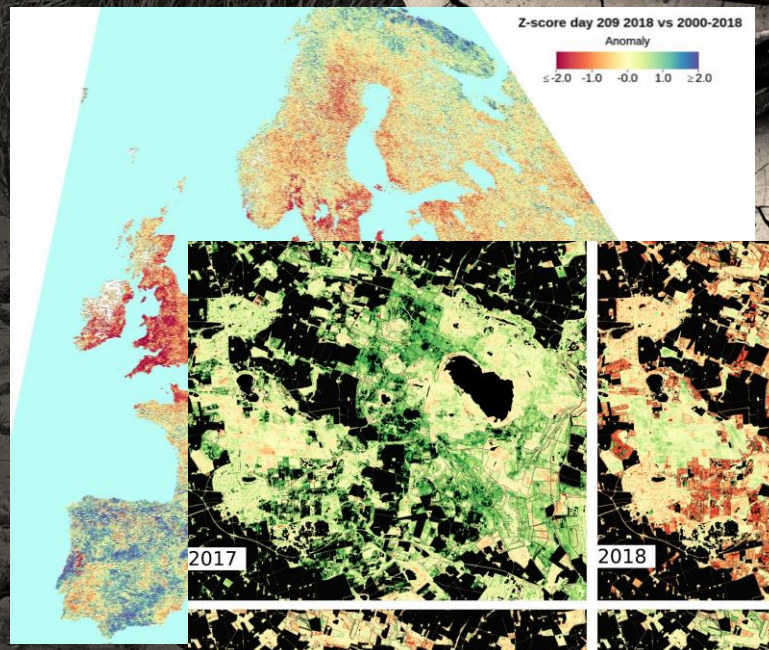


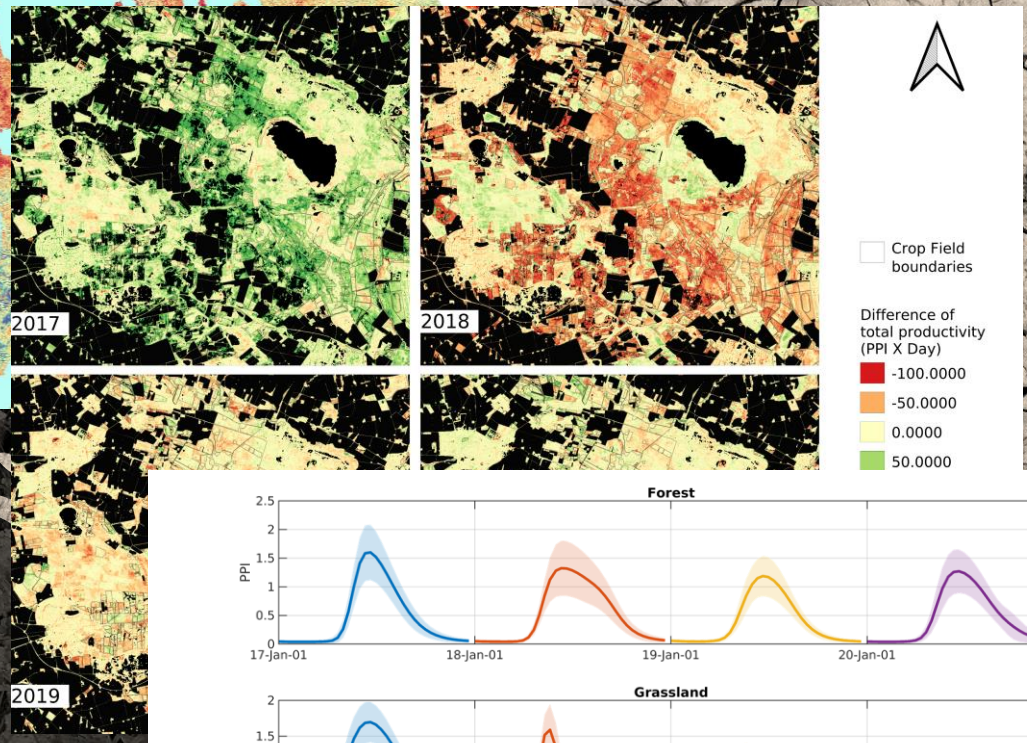
Challenges

Impacts occur on a continental/global scale – but manifest locally.

Need to identify nature restoration options.

Deviation from normal condition needs long-term observations





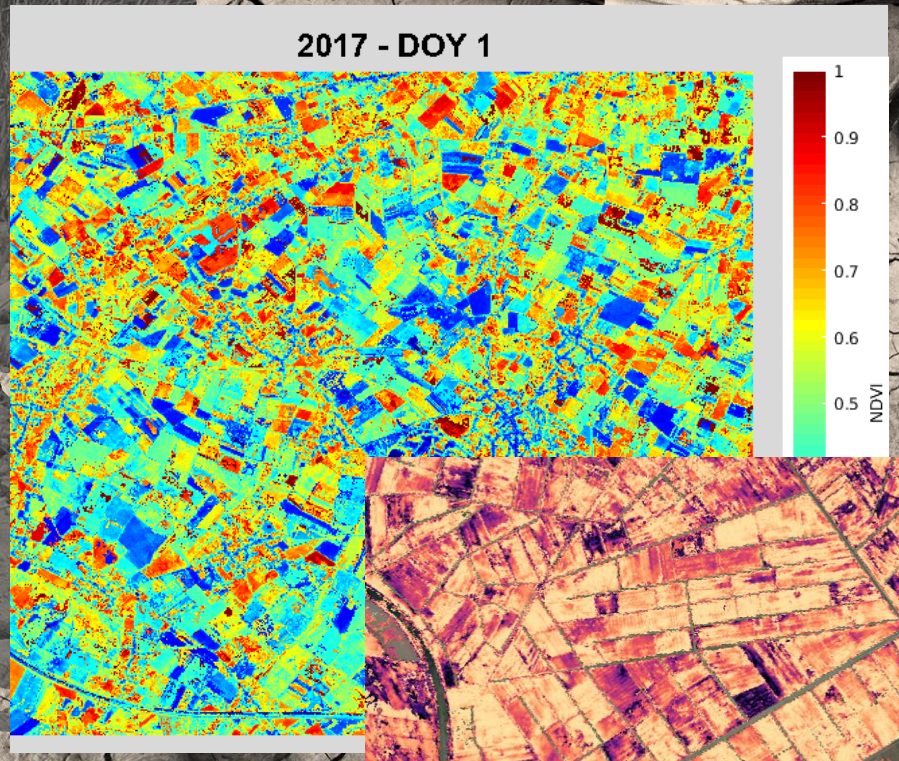
Challenges

Impacts occur on a continental/global scale – but manifest locally

Impacts have to be monitored with high spatial and temporal resolution.

Copernicus Land Monitoring Service: **High Resolution Vegetation Phenology and Productivity** (10m resolution, every 10 days, from 2017 on).

- Handling > 1 Million Sentinel-2 input files (totals ~350 TB)
- Generating > 6 Million output files (totals 750 TB) on the WEkEO DIAS
- ~~Bring the data to the user -~~ > bring the user to the data

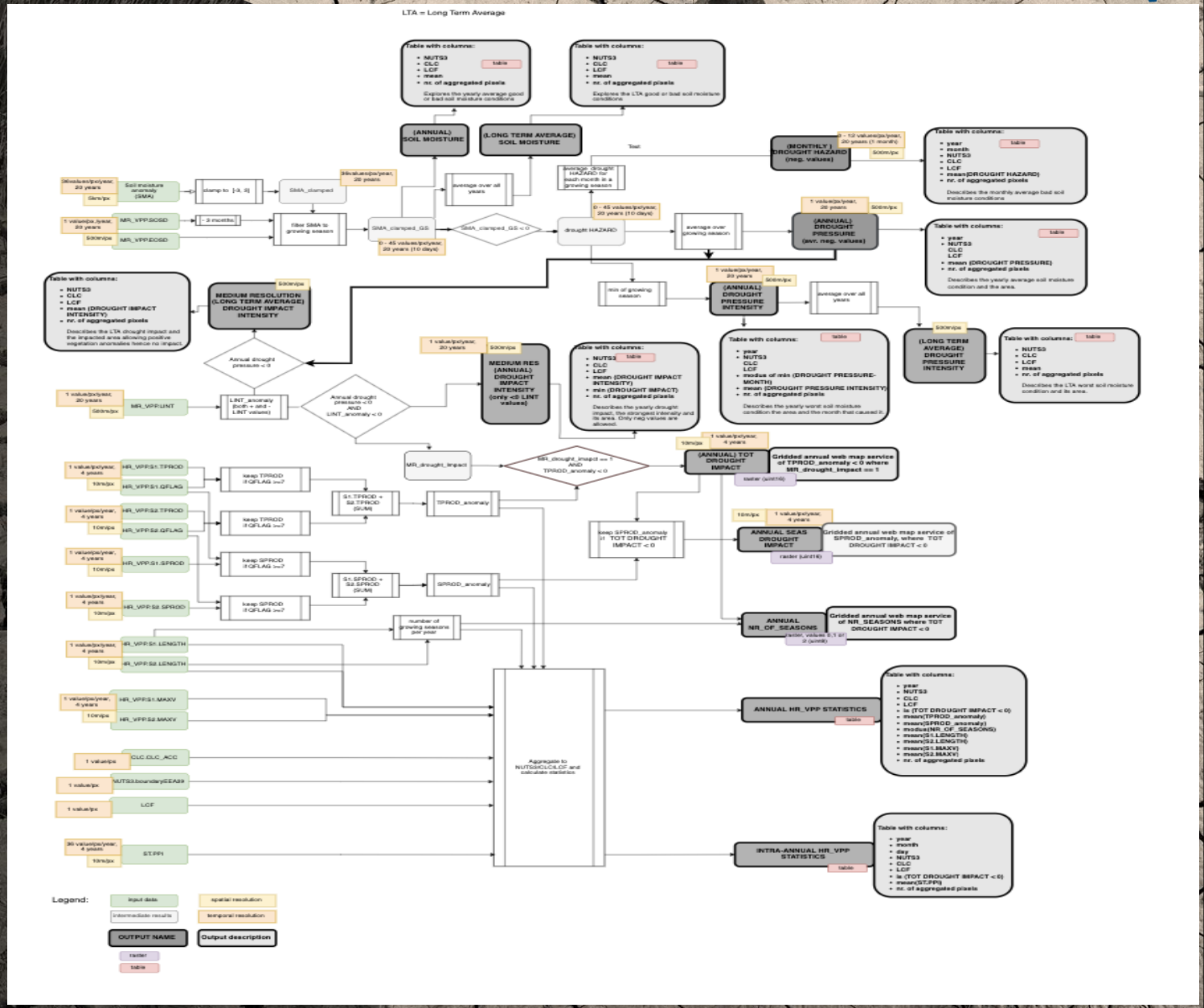


Continental scale analytics of impacts is not “business as usual” exercise

Challenges

Processing

- Need to flexibly apply ML algorithms, statistics, aggregation of results
- Test assumptions, adjust thresholds
- Explore results: charts and images
- Need to reiterate various parts of the workflow
- Where are my data???



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OGC

python

API

DATA SERVICES

sentinelhub

on-the-fly & batch processing

xcube

multi-temporal analysis (xarray)

GeoDB

vector data service

EOxHub

hosted app engine

jupyterhub

jupyter Notebooks

Algorithms

Apps

Data

Access to full archives

Analysis Ready Data

CLOUD

CREODIAS powered by CloudFerro

mundi WEB SERVICES

WEkEO by COPERNICUS

aws

Copernicus Europe's eyes on Earth

USGS science for a changing world

EO commercial in-situ sensor GIS data

Thematic data

SINERGISE

Brockmann Consult GmbH

EOX

gisat

planet.

sentinelhub

Approach

- Past approach
  - Drought assessment done on medium resolution (500 m)
  - Could be done on a work station, with several hours of processing
- Upscaling to 10-meter resolution
  - 500m -> 10m = 2500 x more data
  - input volume – PB-level (Soil Moisture, MR-VPP, HR-VPP, auxiliary)
  - processing time should be in the order of one day
    - how to iterate?

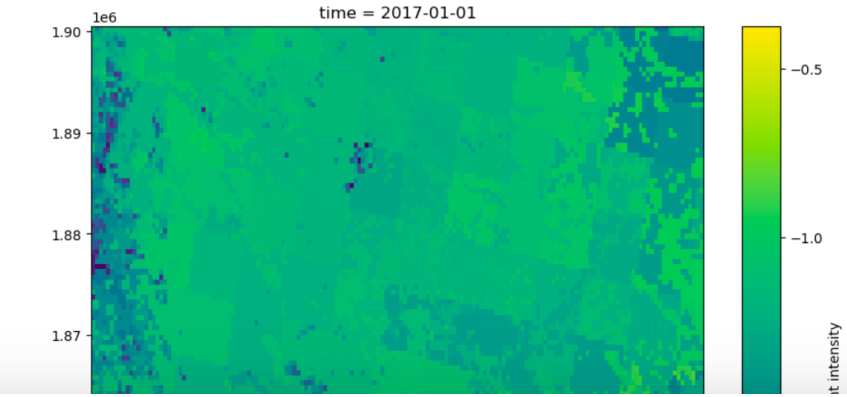
1.2 ANNUAL AND LONG-TERM AVERAGE DROUGHT INTENSITY

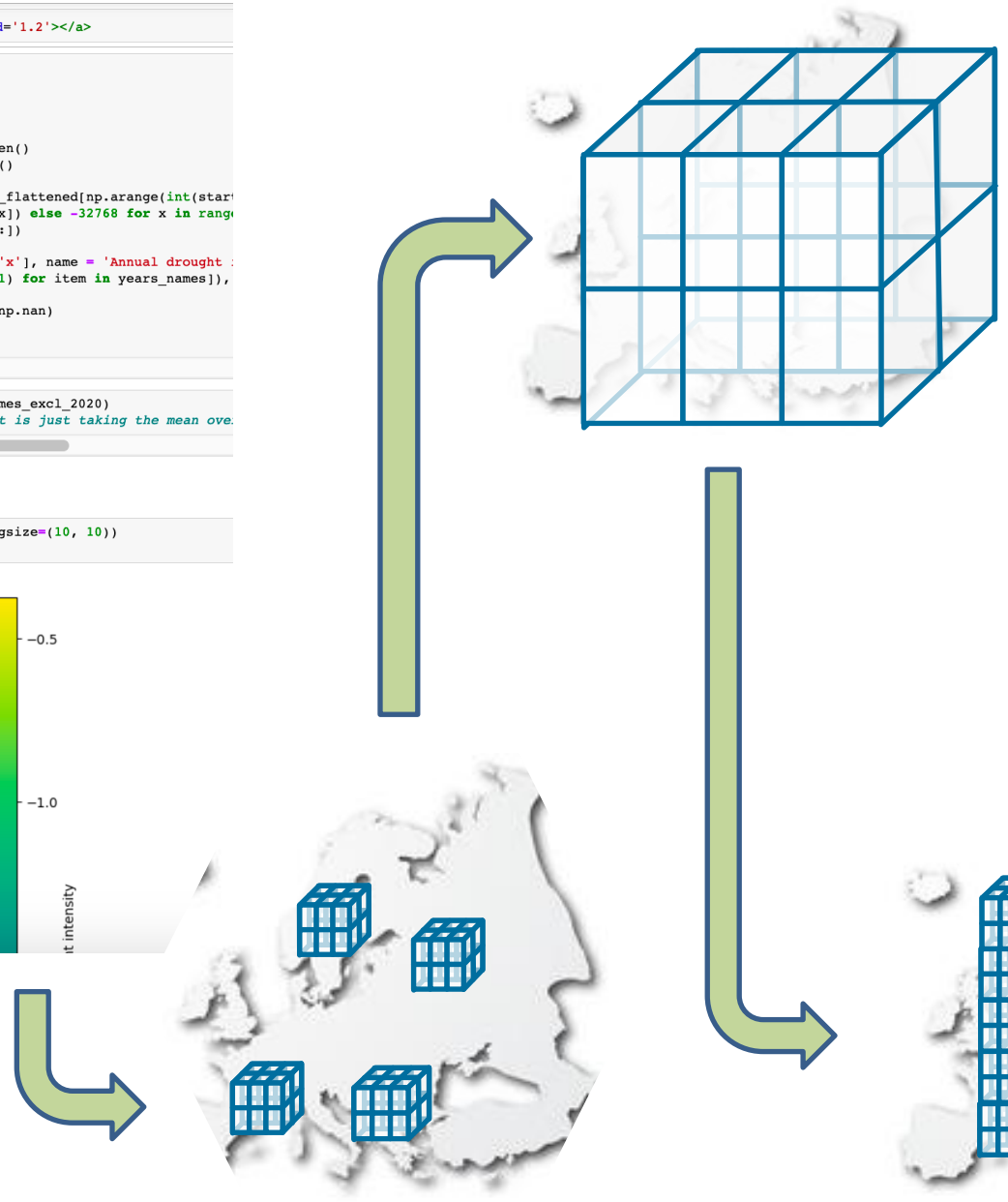
```
def calc_annual_drought_intensity(cube_moisture, cube_phenology, years_names):

    drought_intensity_values = np.zeros_like(cube_phenology['sos_doy_3m'].compute().data)
    cube_moisture_flattened = cube_moisture['anomaly_filtered'].values.flatten()
    for time in range(len(cube_phenology.time.data)):
        start_ind_season = cube_phenology.isel(time = time)['SOS_start_ind'].values.flatten()
        end_ind_season = cube_phenology.isel(time = time)['EOS_start_ind'].values.flatten()

        drought_intensity_values[time,:,:] = np.reshape(np.array([np.nanmin(cube_moisture_flattened[np.arange(int(star
                                                  if not np.isnan(start_ind_season[x]) else -32768 for x in range
                                                 , drought_intensity_values.shape[1:])

    cube_drought_intensity = xr.DataArray(drought_intensity_values, dims = ['time', 'y', 'x'], name = 'Annual drought
                                          coords = {'time': np.array([dt.datetime(item, 1, 1) for item in years_names]),
    cube_drought_intensity = cube_drought_intensity.where(cube_drought_intensity<=0,0)
    cube_drought_intensity = cube_drought_intensity.where(cube_drought_intensity!=-32768,np.nan)

    return cube_drought_intensity
```

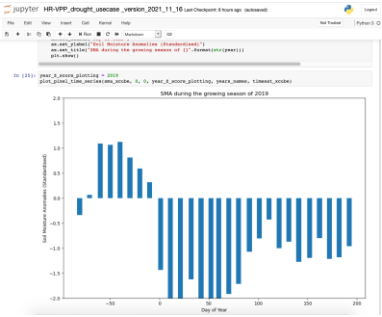
```
annual_drought_intensity = calc_annual_drought_intensity(sma_xcube, MRVPP_xcube, years_names_excl_2020)
long_term_drought_intensity  = annual_drought_intensity.mean(axis = 0) # long-term drought is just taking the mean ove
```

Visualize annual drought intensity

```
annual_drought_intensity.sel(time='2017-01-01 12:00:00', method='nearest').plot.imshow(figsize=(10, 10))
plt.show()
```







Tools used

- Wekeo @ CreoDIAS
  - HR-VPP data as generated by Copernicus Services
  - Storage of derived data
- Sentinel Hub @ CreoDIAS
  - Bring your own data (HR-VPP, MR-VPP, AUX) – no duplication!
  - Batch Processing
- EOxHub Workspace + xcube
  - Management of the process, analysis of results
- EO Browser
  - Visualisation of results, quick analysis

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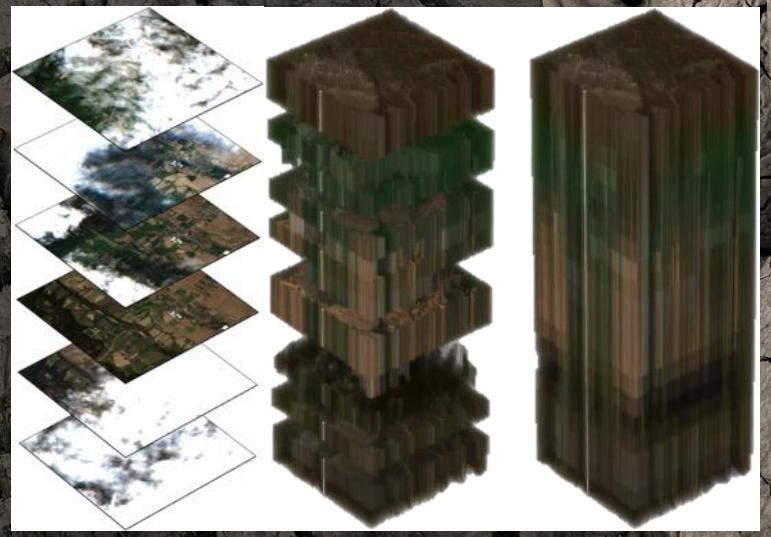
Sentinel Hub Batch Processing

- Request data at large scale – either spatial or temporal.
- Run your algorithm for a whole continent.
- Pre-process vast amount of data.
- Execute, monitor for updates, follow-up processes



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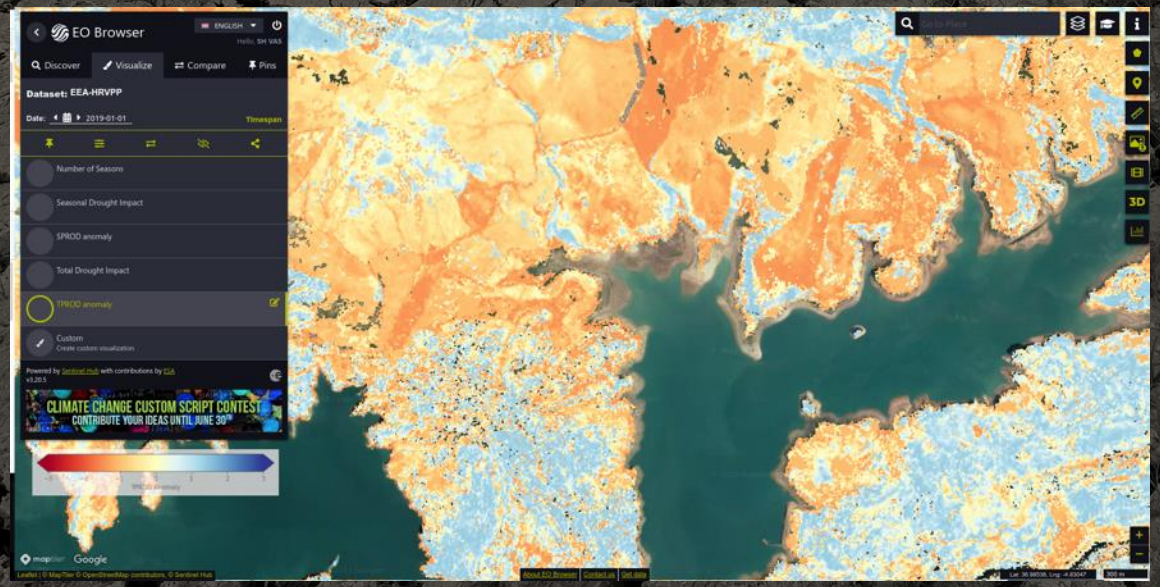
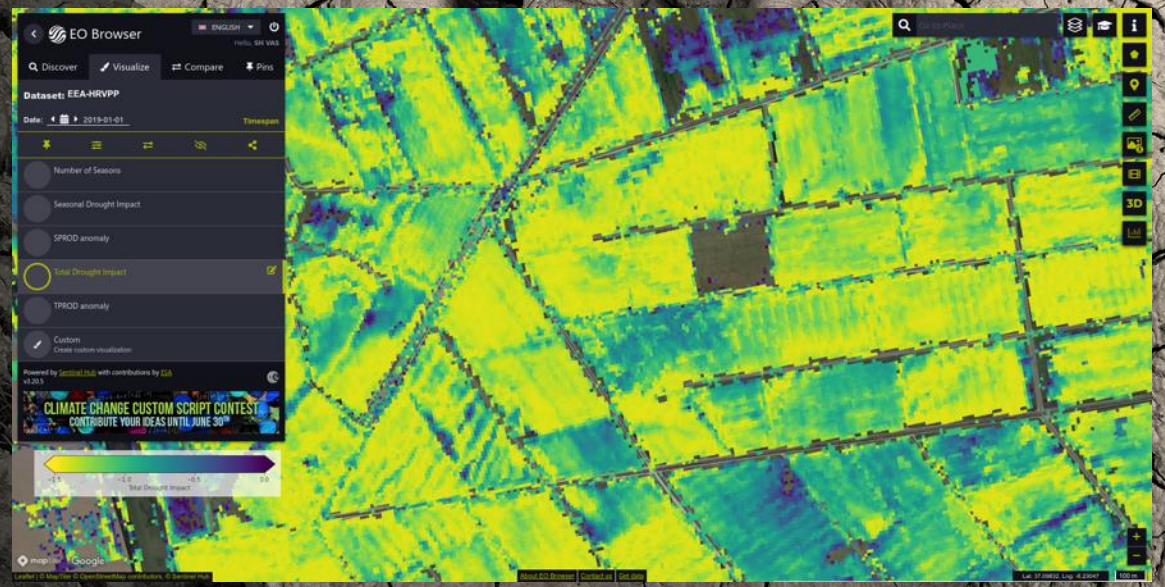
EO Browser



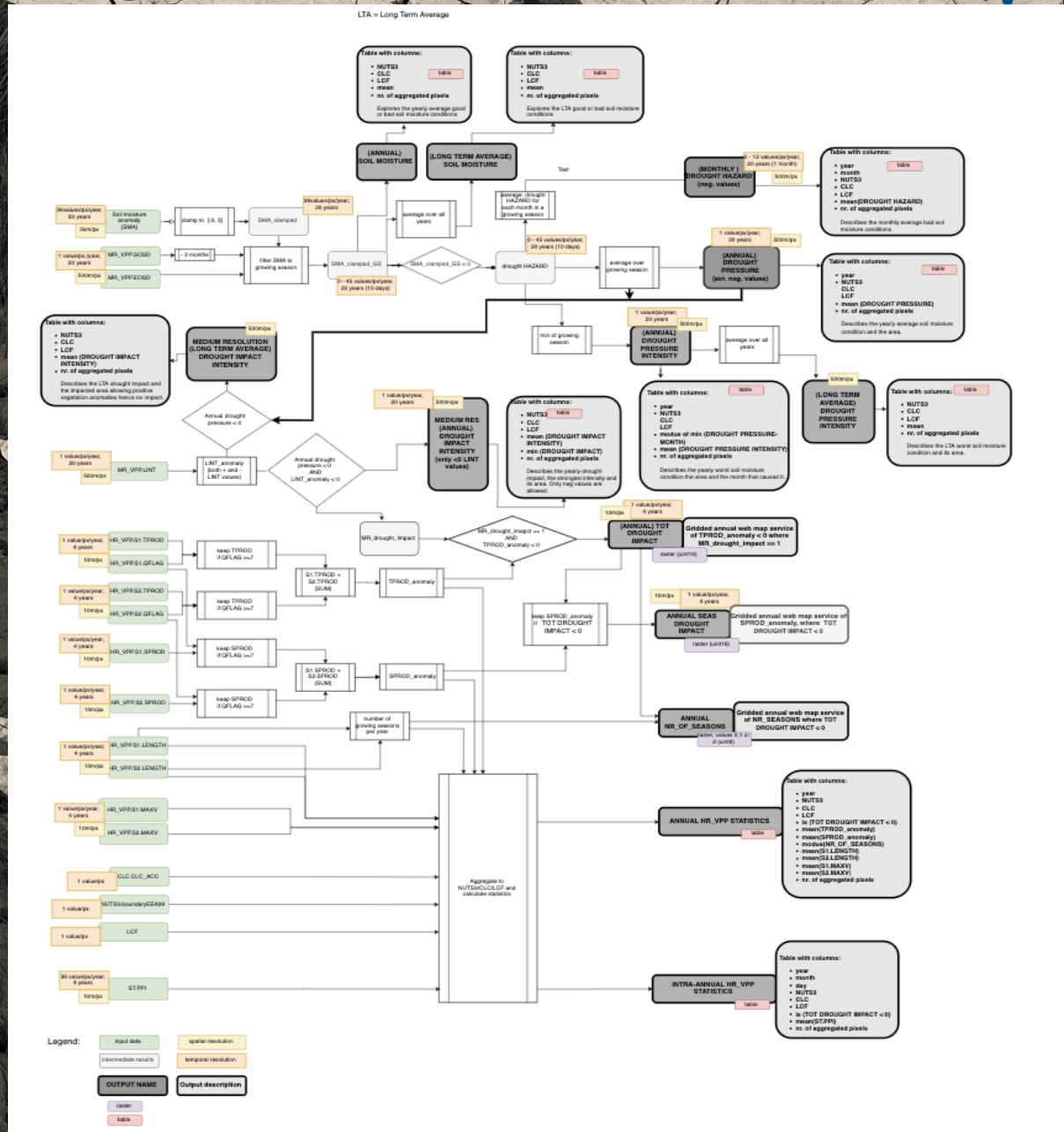


Processing at continental scale

- 0.75 PB of data
- 50.000 processing hours (@500 VMs)
  - 10s of thousands of S3 requests per second
- 10-15.000 EUR per run

Technical challenges

- Overall diagram not overly complicated but devil is in details
- Each element represents a rule based on data from different sources, different time periods (current/annual/multi-annual) – difficult to contemplate, in mind, what is happening – how to debug?
- How to convert diagram into Python/Evalscript
- Impossible to have all pixels in memory – how to grid to not corrupt spatial/temporal statistics
- How to efficiently mix MR and HR data



Challenges

Need to bring the right message to the right user

The overall message

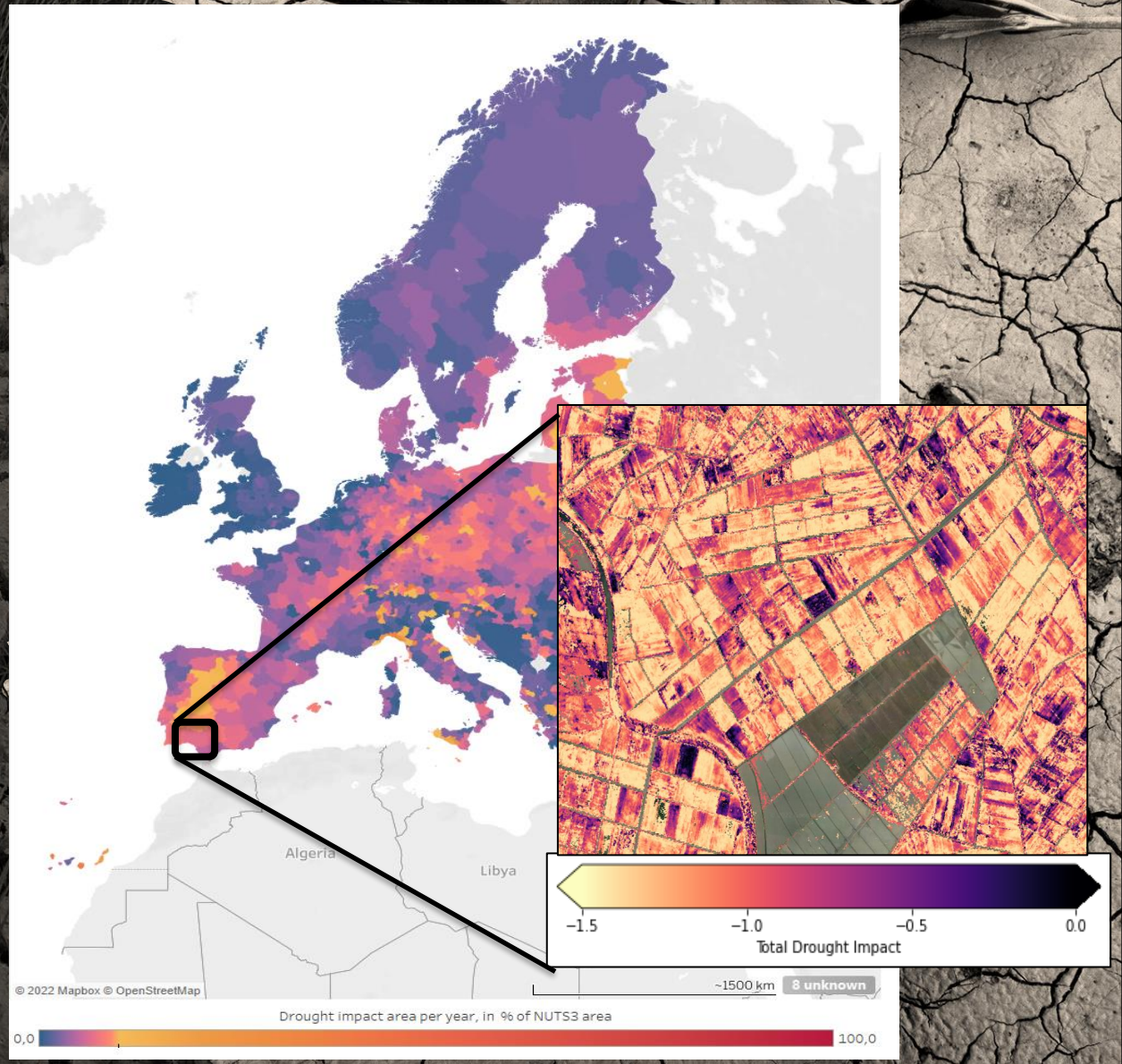
- The last decade saw the most intense droughts, forest area impacted increased continuously from 60,000 km^2 in 2017 to 160,000 km^2 in 2019.

The detailed message

- Croplands were most impacted in Portugal, forest productivity decline was highest in Sweden, grasslands were mostly affected in Austria.

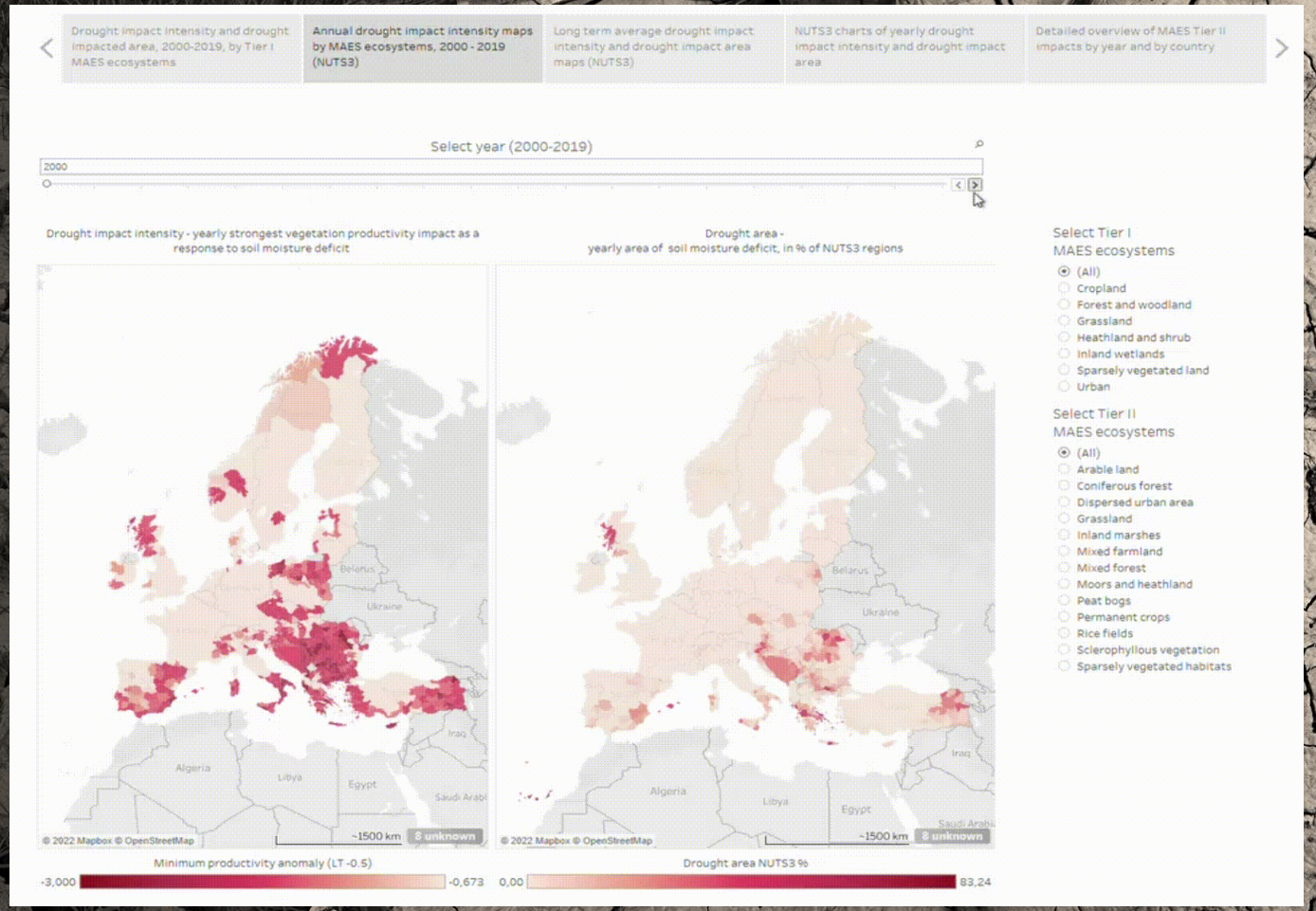
The very detailed message

- Which region do we need to support most financially?



Future potential

- Empowering EEA (and other) users to do these steps alone
- Flexibly ingest new datasets (e.g. GPP, ESAs biomass mission)
- Integration of results in dashboards (LISE, Explore Europe, EEA website)
- Offer a platform for policy, academia and industry to work together
- Facilitate nature restoration investments
- Monitor impacts near-real-time and near-real-detail
- Digital Twin!

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More info
https://eurodatacube.com
https://sentinel-hub.com/
https://apps.sentinel-hub.com/eo-browser/
Thank you for your attention
esa
opernicus
Europe's eyes on Earth
USGS
science for a changing world
Horizon 2020
amazon
web services
opernicus
Europe's eyes on Earth
European Environment Agency

Challenges

- Impacts occur on global scale, but manifest based on local conditions

- Data needs:

  - deviation from normal condition needs long-term observations

  – coverage, temporal frequency, spatial resolution

- Modelling needs – additional explanatory variables

- Need to flexibly apply ML algorithms, statistics, aggregation of results

- Need to reiterate various parts of the workflow

- Need to bring the right message to the right user

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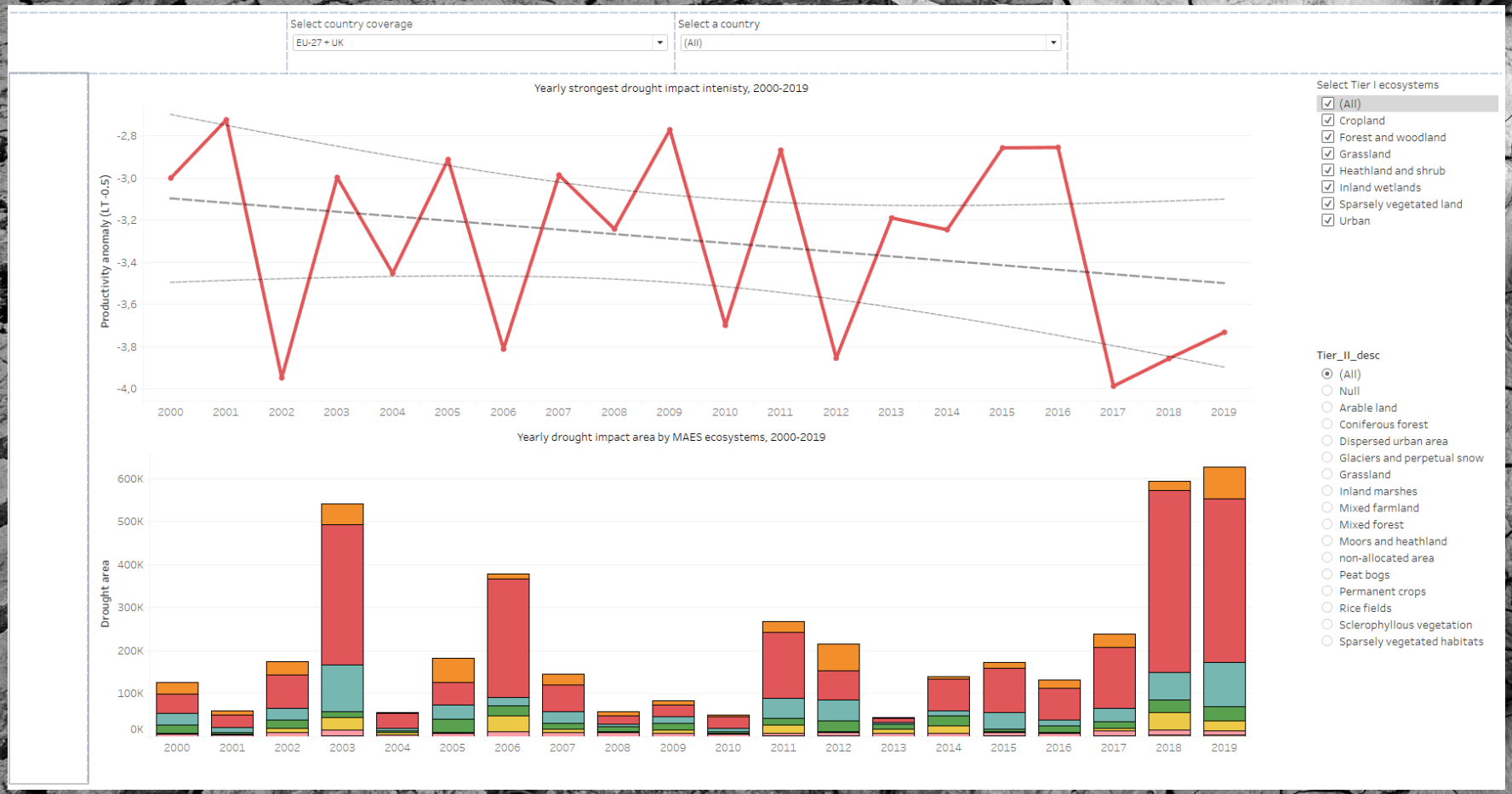
Challenges

Impacts depend on local conditions -



Challenges

Need to bring the right message to the right user

The big picture

- Between 2000 and 2019, Europe was affected by severe droughts
- The last decade saw the most intense drought years
- The annual vegetation productivity loss was 3%
- forest area impacted increased continuously from 60,000 km^2 in 2017 to 160,000 km^2 in 2019.

The detailed picture

- In proportion of its territory Malta, Cyprus, Lithuania, Portugal, Czechia, Bulgaria and Spain was impacted the most

The more detailed picture

- Between 2000 and 2019, Europe was affected by severe droughts
- The last decade saw the most intense drought years
- The annual vegetation productivity loss was 3%
- forest area impacted increased continuously from 60,000 km^2 in 2017 to 160,000 km^2 in 2019.

Challenges

- Volume of data, cost of data storage
- Long processing time makes it inefficient/impossible to iterate
- Difficult to even review the results
- Difficult to find errors, to fix errors