Satellite imagery analysis for coastal erosion assessment in Latvia

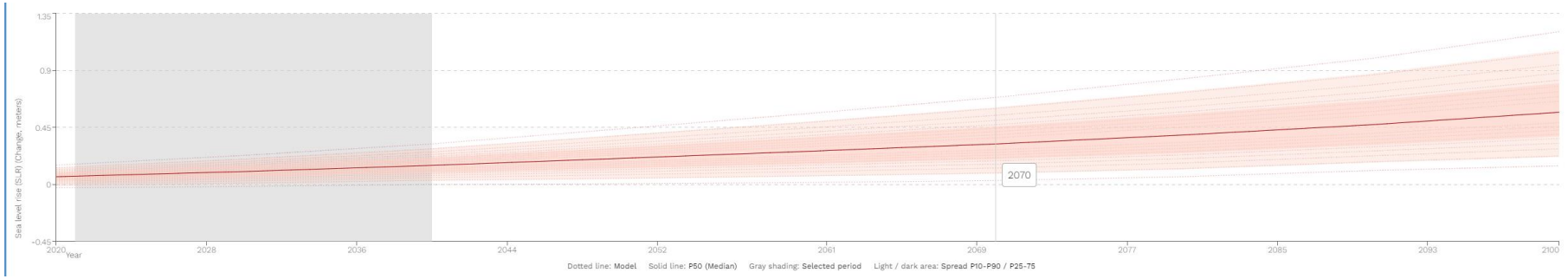
Riga, 2023

Viesturs Zandersons
viesturs.zandersons@lvgmc.lv
Latvian Environment, Geology and Meteorology Centre

Actuality

- **Latvian coastline is more than 500 km long**
- It is composed mainly of **loose, sandy sediments** which are especially **vulnerable to coastal erosion**
- Climate projections outline that **sea level** will **increase in near future,** which likely will **intensify erosion processes**
- Almost **<u>no</u> state-wide monitoring** of the **coastline change has been performed since 2009**

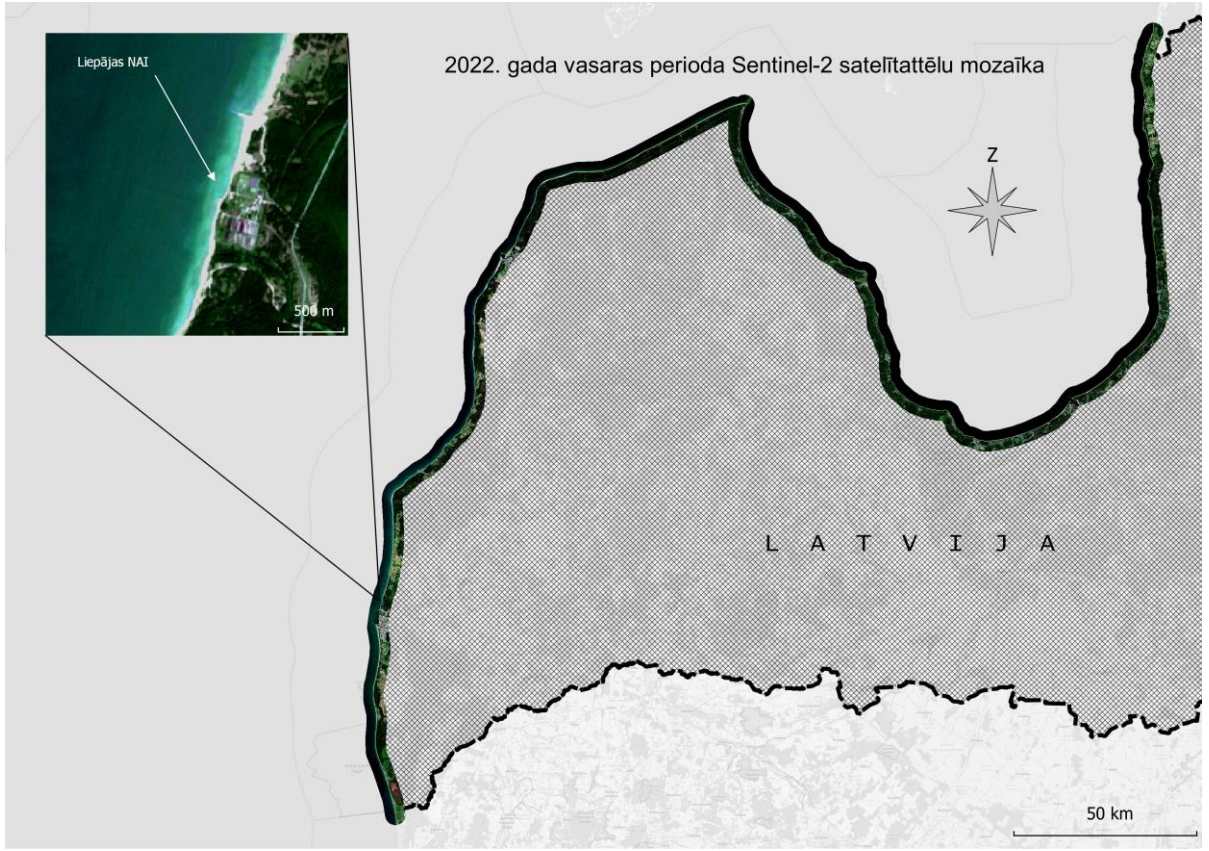
Coastal erosion outlined after storm surge (2018, LSM)



Climate change scenarios (SSP) projected sea level increase until 2100 in the Baltic Sea region

Project aims

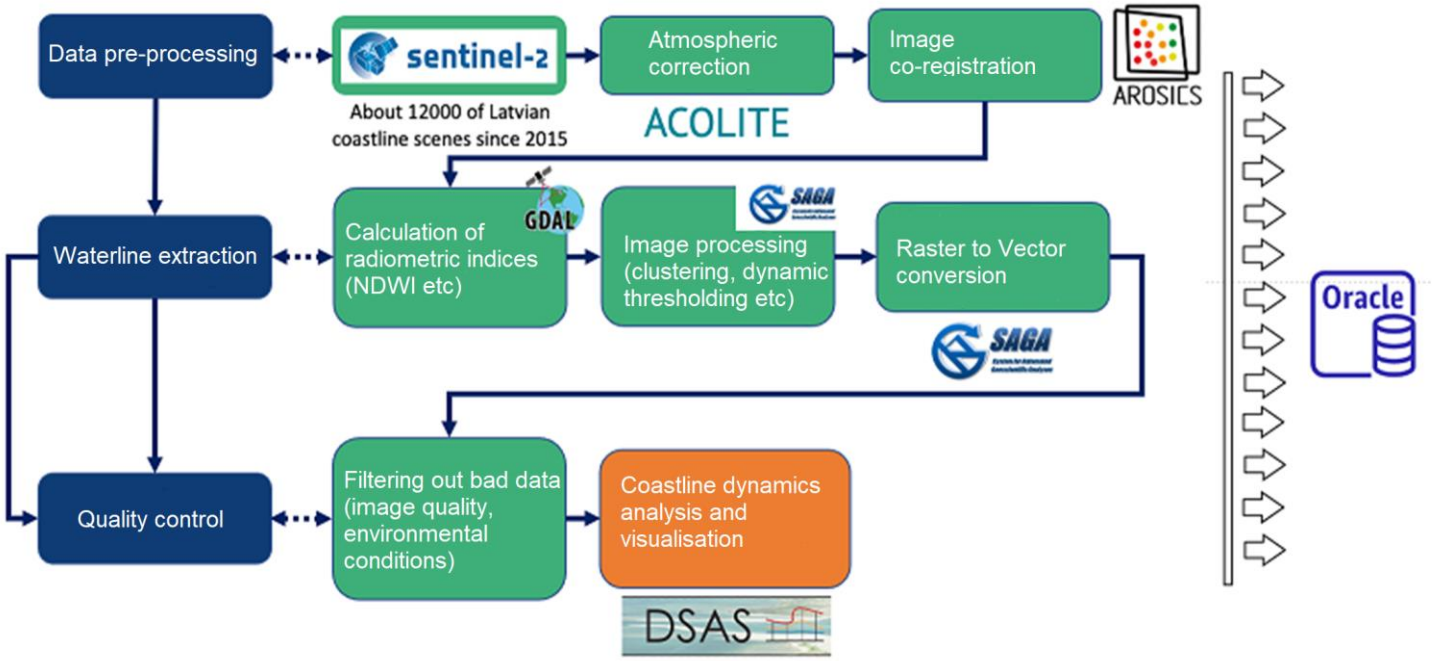
- Main project goal is to **develop a methodology for coastline change monitoring** using **open-source satellite data**
- **Sentinel-2 data** – main source of information, along with **high-resolution commercial satellite data** and measurements from **unmanned aerial vehicles** for result verification
- Methodology and datasets should be **extensible** in the future for **continued monitoring of the coastline**
- Project takes place from **2021** to **2023**



Latvian coastline outlined in Sentinel-2 composite (summer 2022)

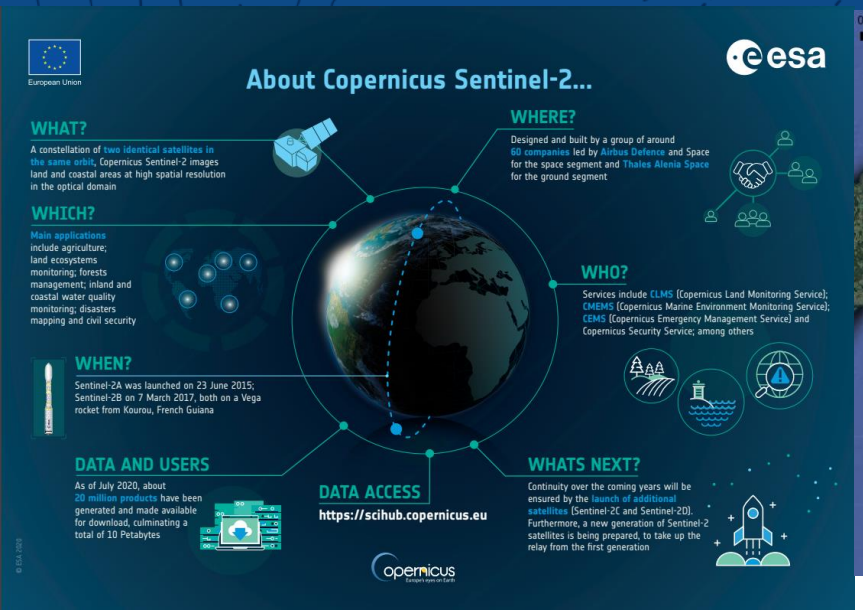
Project outline

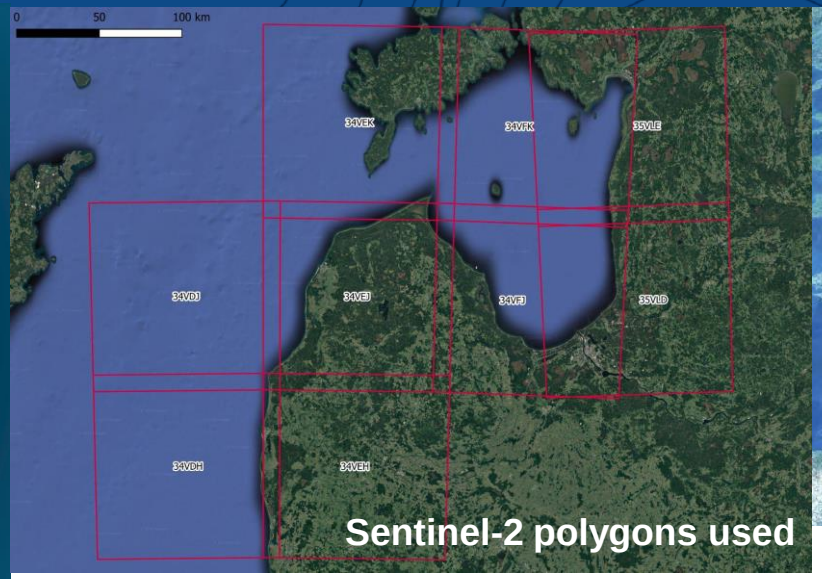
1. Sentinel-2 data (L1C) gathering
2. Data pre-processing
3. Radiometric index calculation
4. Waterline detection
5. Coastline change analysis
6. Result validation
7. Data publication

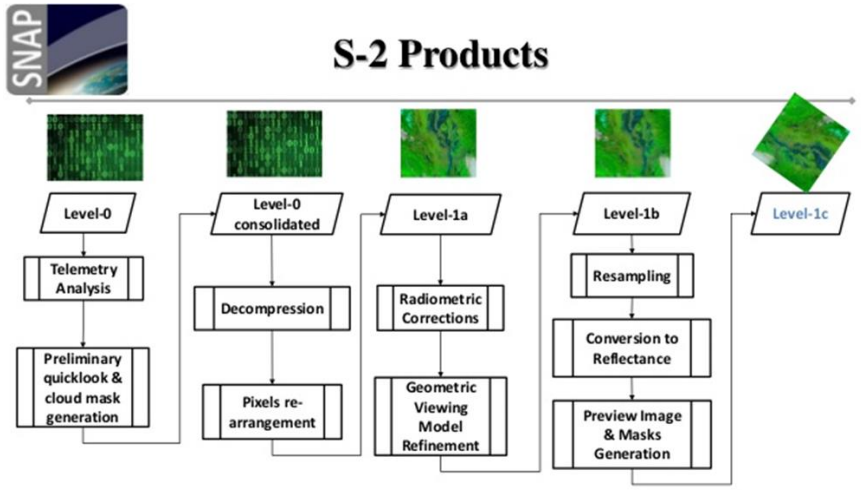


Data processing scheme

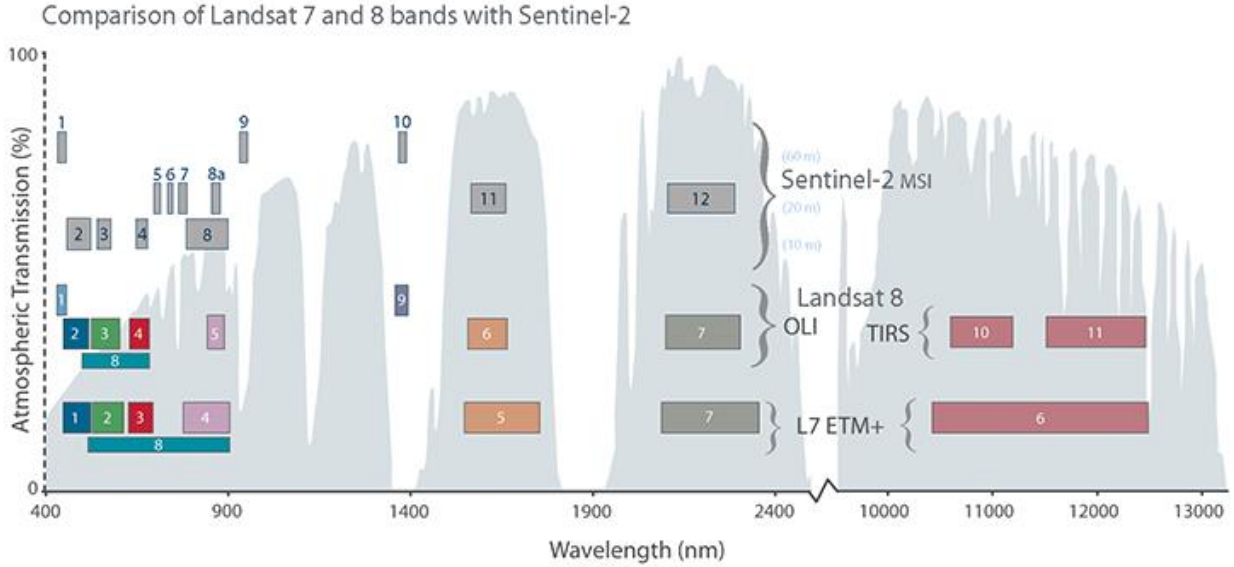
Sentinel-2 mission





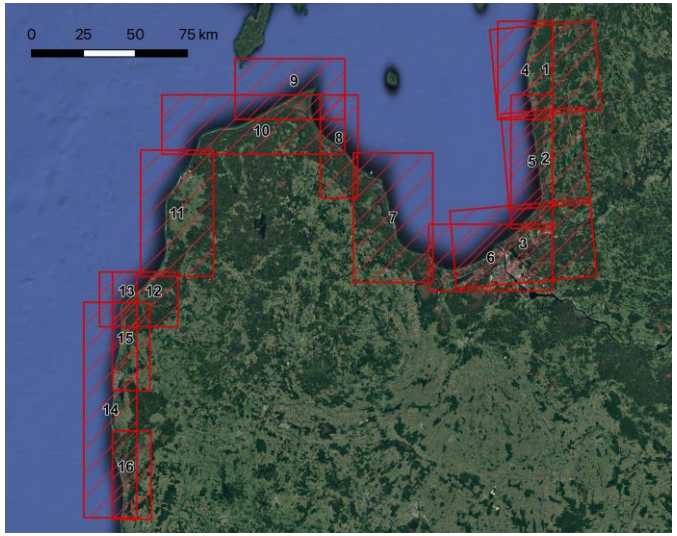


Sentinel-2 product description



Data pre-processing
Atmospheric correction

1. Atmospheric correction and cropping
2. Accurate georeferencing - *coregistration*
3. Cloud masking
4. Median scene creation



Subpolygons used in the project

Atmospheric correction

Data from 15th august, 2020, before (left side) and after (right side) atmospheric correction (11th *subpolygon*)

ACOLITE* processor

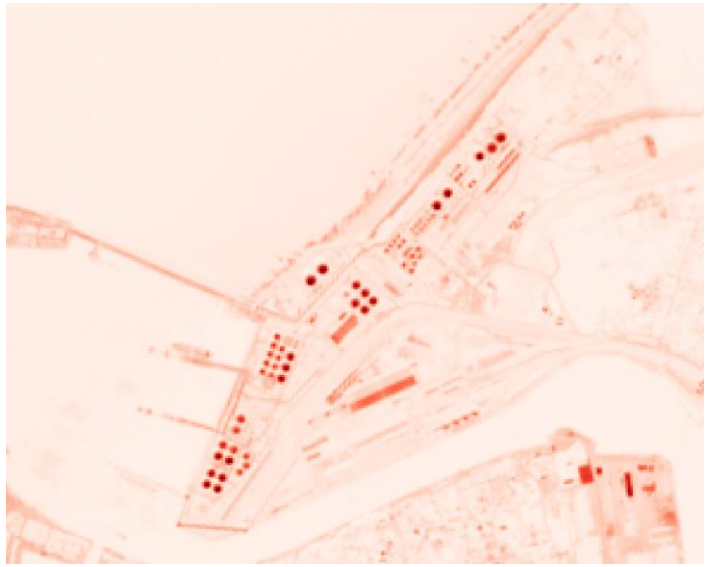
Dark spectrum mapping

Based on the darkest pixels in the scene to calculate ***aerosol optical depth***

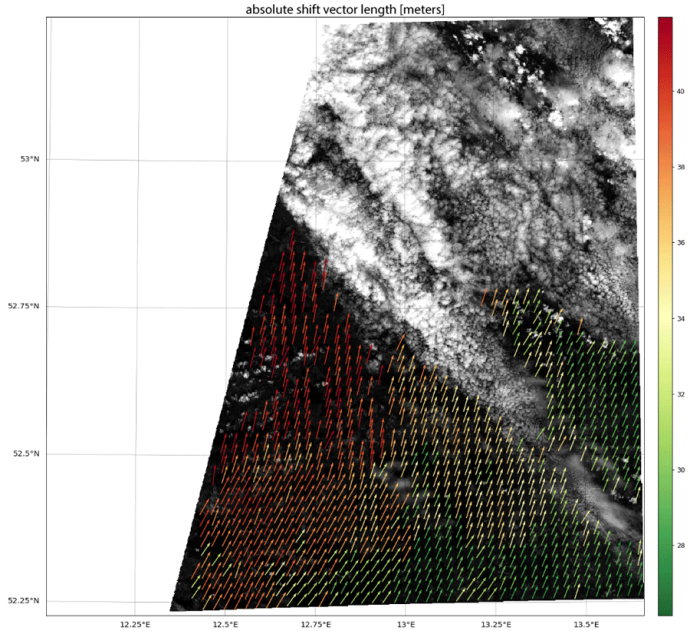
Substracts ***aerosol optical depth*** from data

*Vanhellemont, Q., and Ruddick, K., 2018

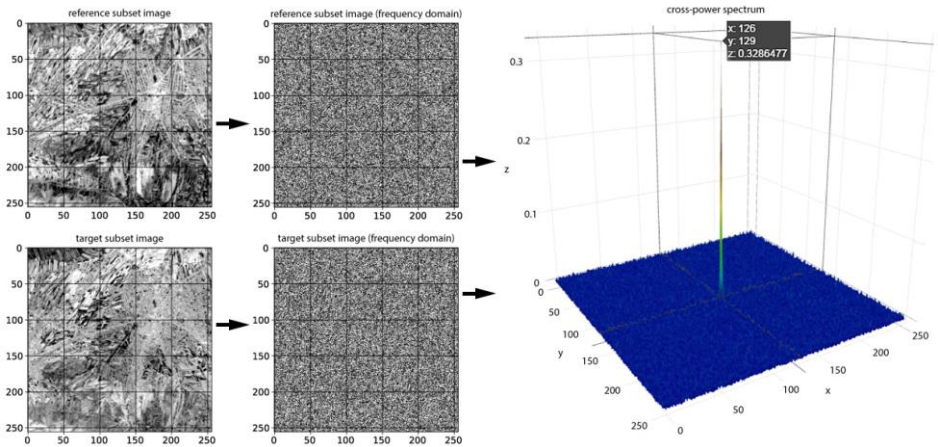
Data pre-processing
Coregistration



15th august 2020, Ventspils harbour
B2 channel before and after coregistration



Scene georeferencing visualized



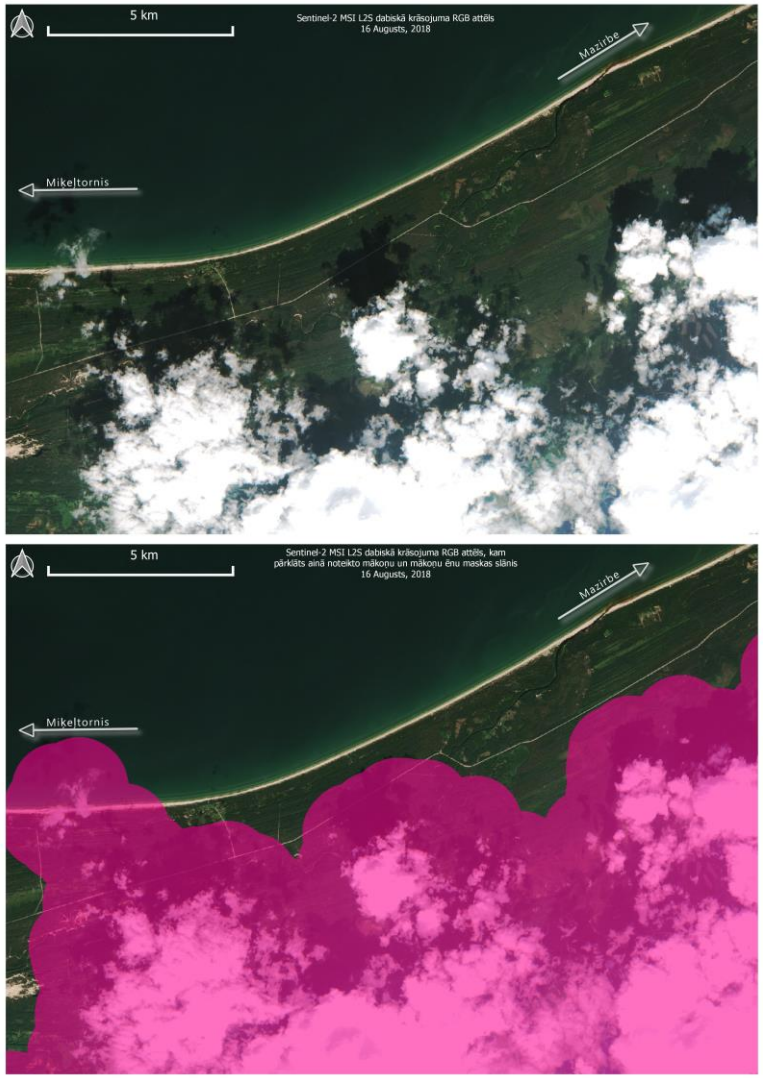
Arosics processor visualized

Arosics* processor

- Measuring small shoreline changes requires good **spatial accuracy** and **georeferencing**
- Satellite measurements (***slave***) are «*shifted*» against reference (***master***), so the pixel information spatially matches
- **Arosics** is based on Fourier spectrum phase correlation differences between *slave* and *master* files
- We use one good scene for each subpolygon as a **master**

*Shcheffler et al 2017

Data pre-processing
Cloud Masking



Cloud masking for 16th august, 2018

sen2cloudless algorithm*

Algorithm used by SentinelHub but also available in github

- LightGBM *random-forest* scene classification

Our addition:

- Strict cloud classification of >10%
  (more *false-positive* clouds but cleaner results)
- **Buffering** according to the sun angle
  from zenith

*https://github.com/sentinel-hub/sentinel2-cloud-detector

Median scene creation

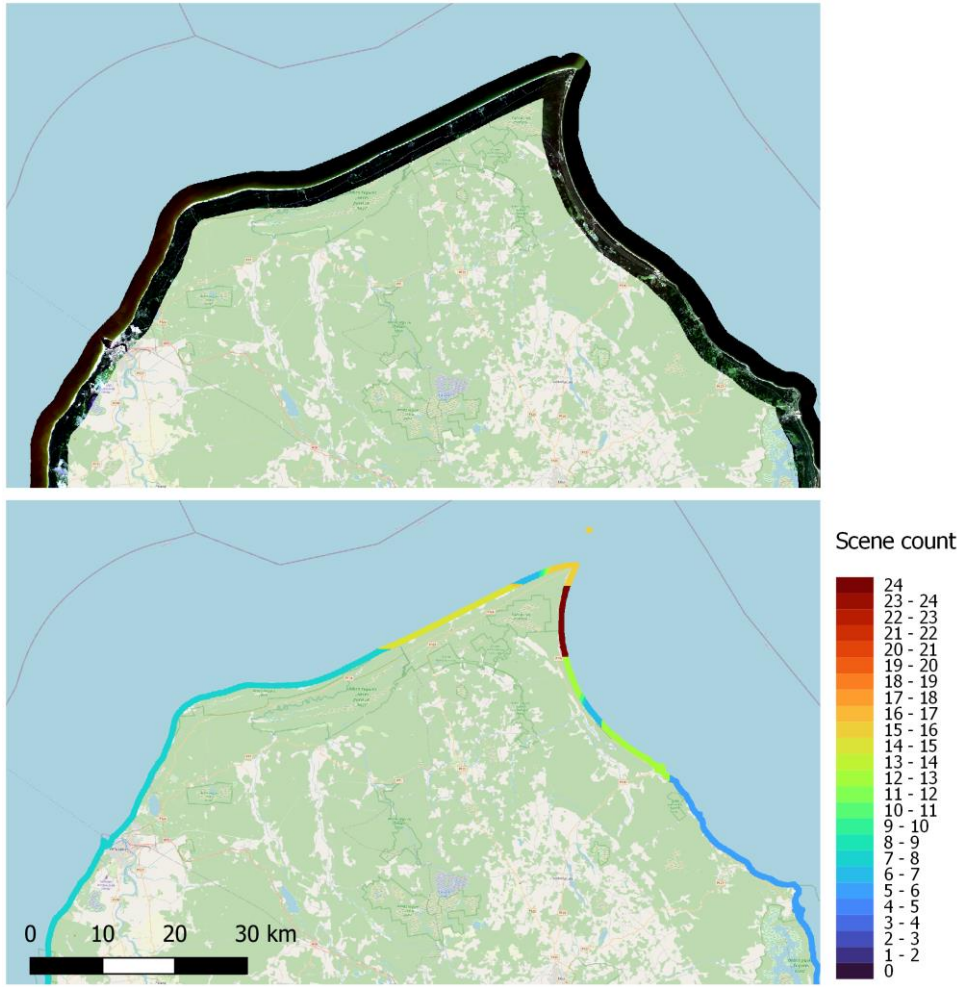
We extracted waterlines in **two different ways**

1. From each **individual scene separately** (~**5000 different lines**)

2. From the **season median scene mosaics**

Individual scenes represent variability of results

Median scenes represent long term change

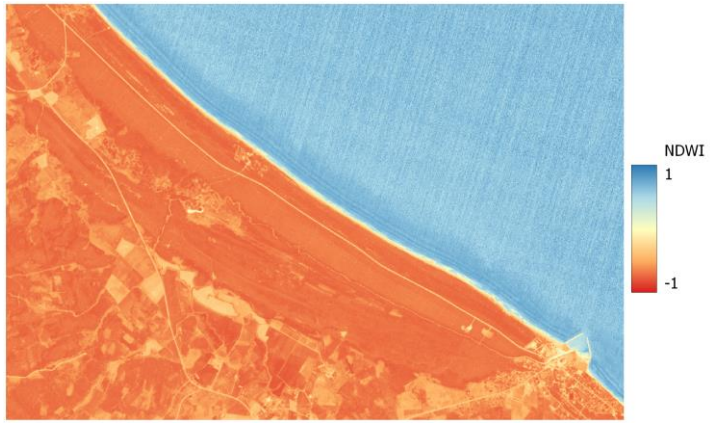


Top – median scene for may-september 2022.
Bottom – count of individual cloudless scenes used in median creation

Waterline detection
Radiometric indices calculation

Normalized difference water index *(NDWI)*

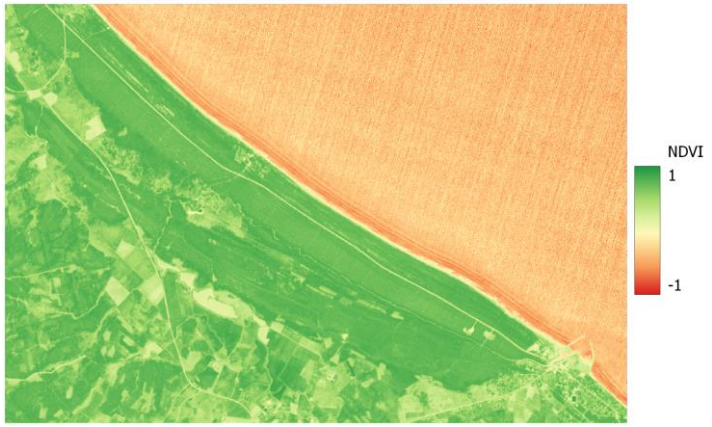
› Sentinel-2 NDWI = **(B03 - B08) / (B03 + B08)**



NDWI near Roja 22.04.2020.

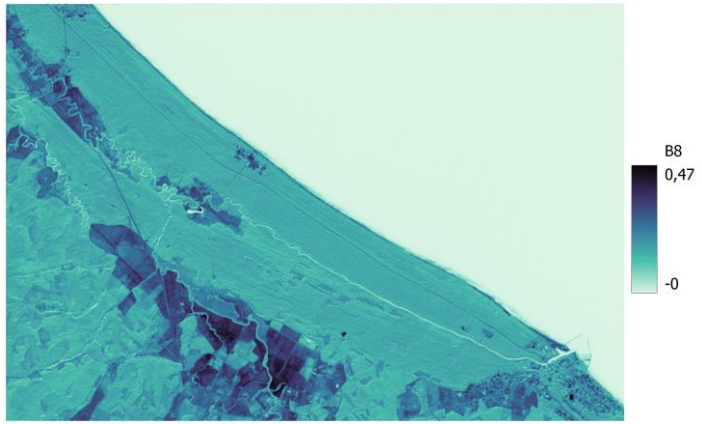
Normalized difference vegetation index *(NDVI)*

$$NDVI := \texttt{Index}(B8, B4) = \frac{B8 - B4}{B8 + B4}.$$



NDVI near Roja 22.04.2020.

NIR channel (Sentinel-2 B8)
22.04.2020.



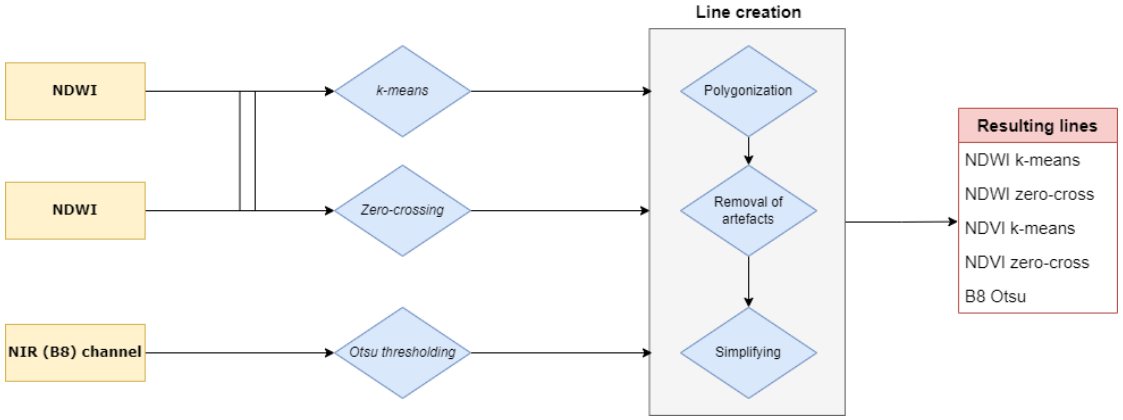
Waterline extraction

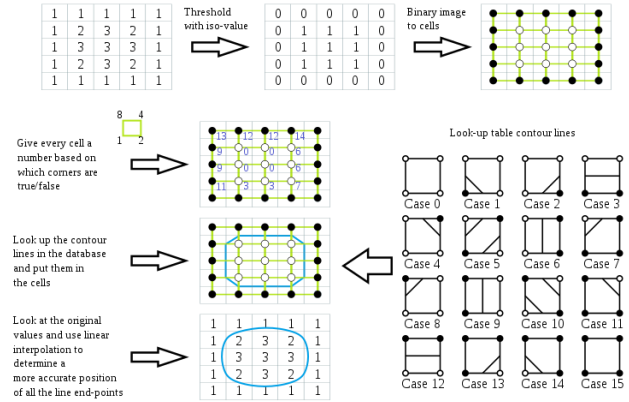
Three different methods

1. K-means
2. Otsu thresholding
3. Zero crossing

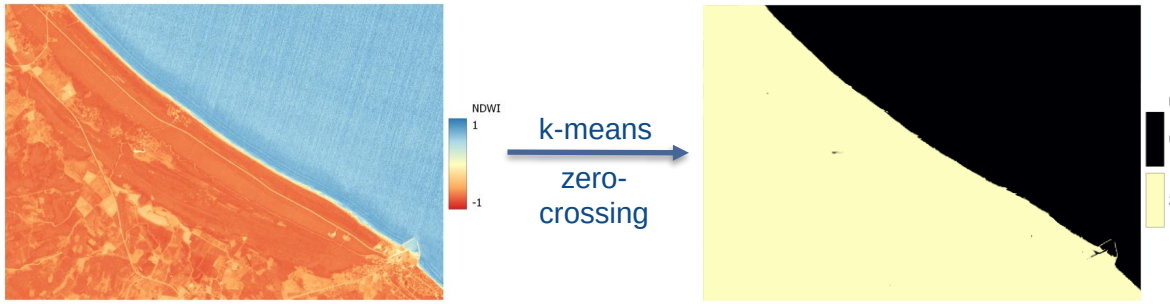
Otsu works best, but at some coastal areas **other methods work better**

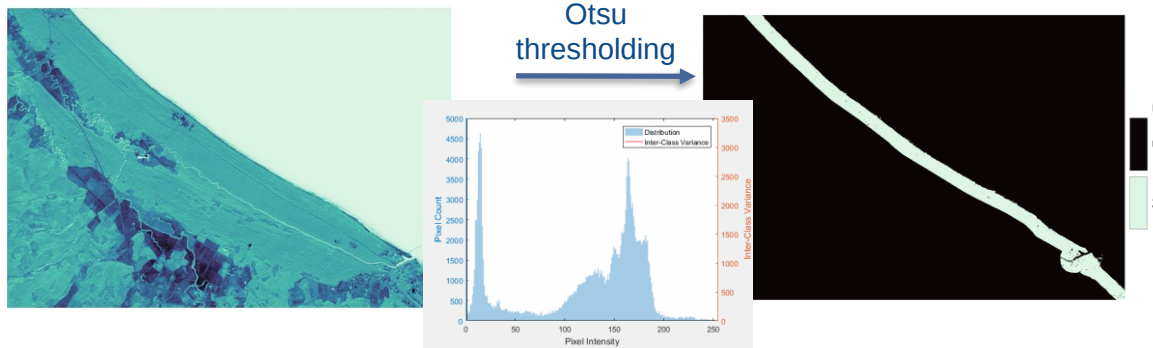
Each waterline is **combined** from the three methods





Marching squares algorithm for shoreline extraction

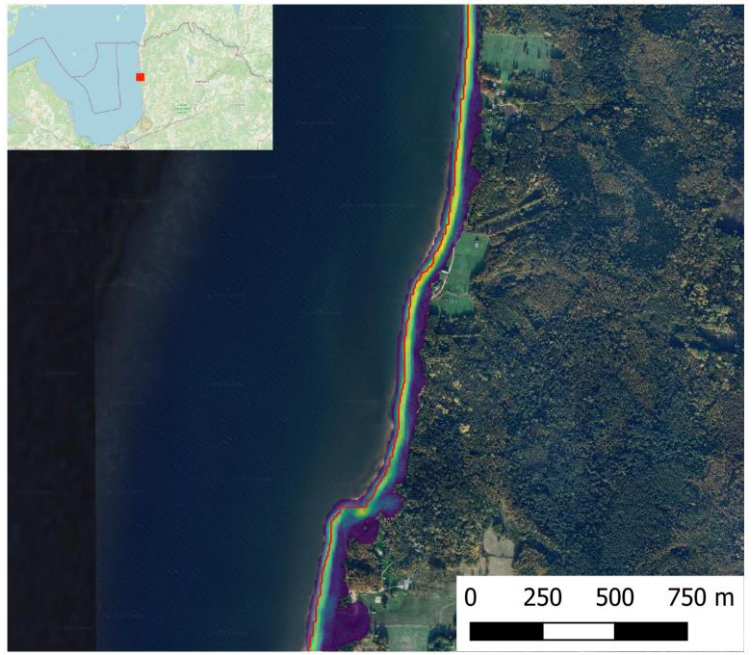




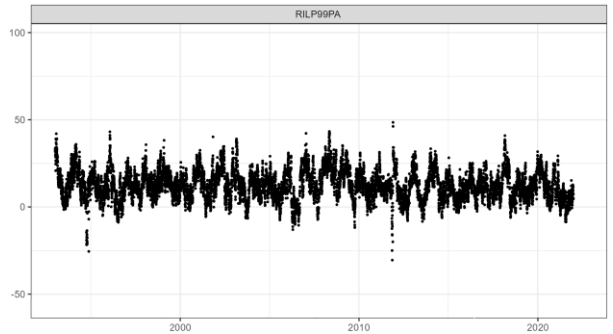
Individual waterline quality control

Comparison of individual lines with sea level measurements

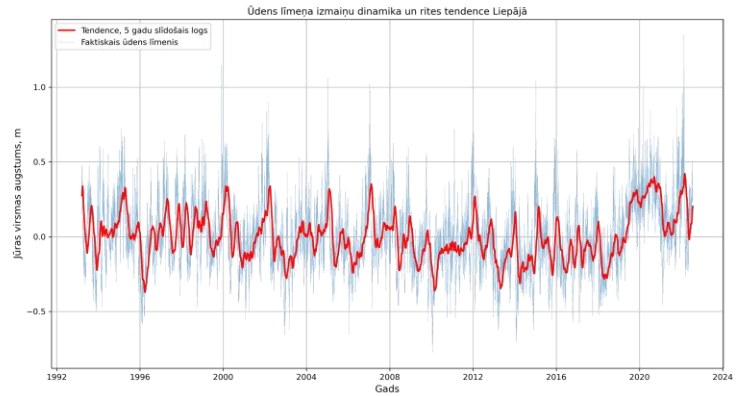
- Sentinel-2 overflight time comparison with **Copernicus CMEMS sea level reanalysis**
- Removed the lines from overflights during sea level state of **+-0.2 m** from the **long-term average**
- Around **~200 quality controlled waterlines available** anywhere in Latvia (in period 2015-2023)
- **Heatmap** to represent the waterline variability



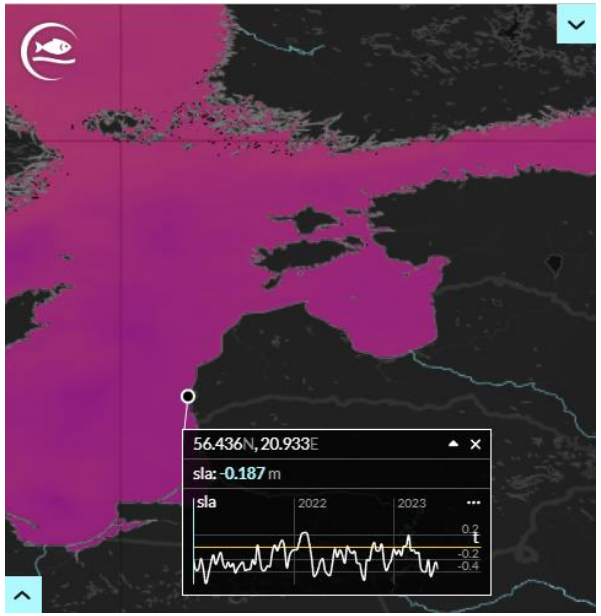
Coastline near Veczemju cliffs in 2020.
Red line represents median results.
Brighter colours - more frequent coastal position



Comparison of reanalysis with sea-level measurements



Sea level measurements near Liepāja



Sea level reanalysis near Liepāja

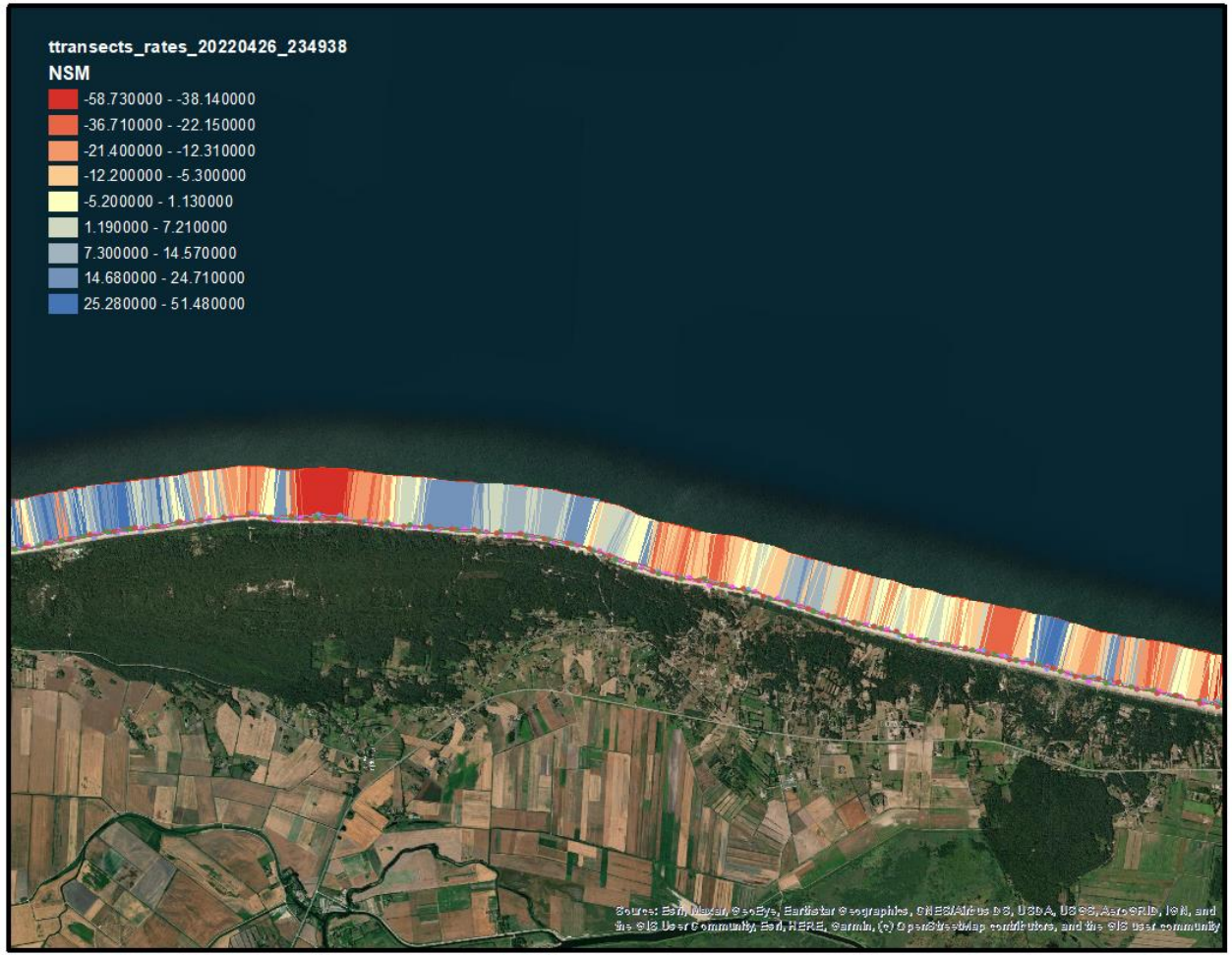
Shoreline change calculation

Work in progress

- Shoreline change is calculated using US Geological Survey tool ***Digital Shoreline Analysis System***

DSAS DIGITAL SHORELINE ANALYSIS SYSTEM

- **Shoreline change** is calculated on perpendiculars from the shore
- **Season median waterlines** are used
- Future shoreline change will also be projected



Shoreline change calculation example near Bernāti

Results verification

Work in progress

Verification uses two multispectral data sets

- Unmanned aerial vehicle (UAV) data
- High definition satellite datasets (Airbus, MaxSAR)

- **Yearly UAV measurements in Bernāti, Latvia**

- Same day as **Sentinel-2 overflights**

- High resolution UAV and satellite data are upscaled and processed similarly as **Sentinel-2 results**

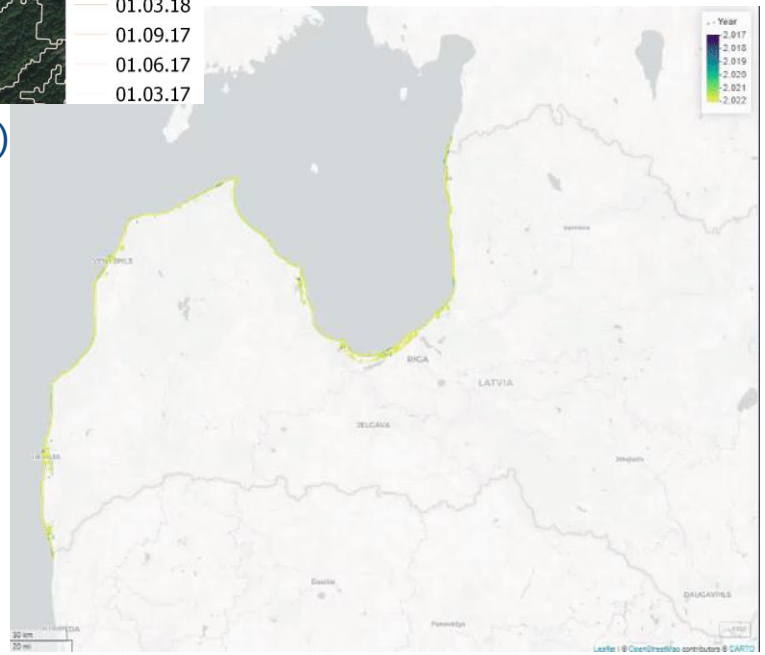
AirBus data Pléiades data from 23.04.2016. near Bernāti

UAV measured RGB composite in 2022 near Bernāti, Latvia

Data publication

- **Results will be published in late 2023 – early 2024**
- Interactive tool online **klimats.meteo.lv**
- **Downloadable data in geospatial data formats** along with methodology and algorithm description
- Data will be **updated yearly** after the end of the project

Coastline change near Ovisi (2017-2022)



Thank you for the attention!
Any questions?

Viesturs Zandersons
viesturs.zandersons@lvgmc.lv
Latvian Environment, Geology and Meteorology Centre