Session 3

Spectral compositing of Sentinel-2 data using SCMaP as input for soil parameter mapping

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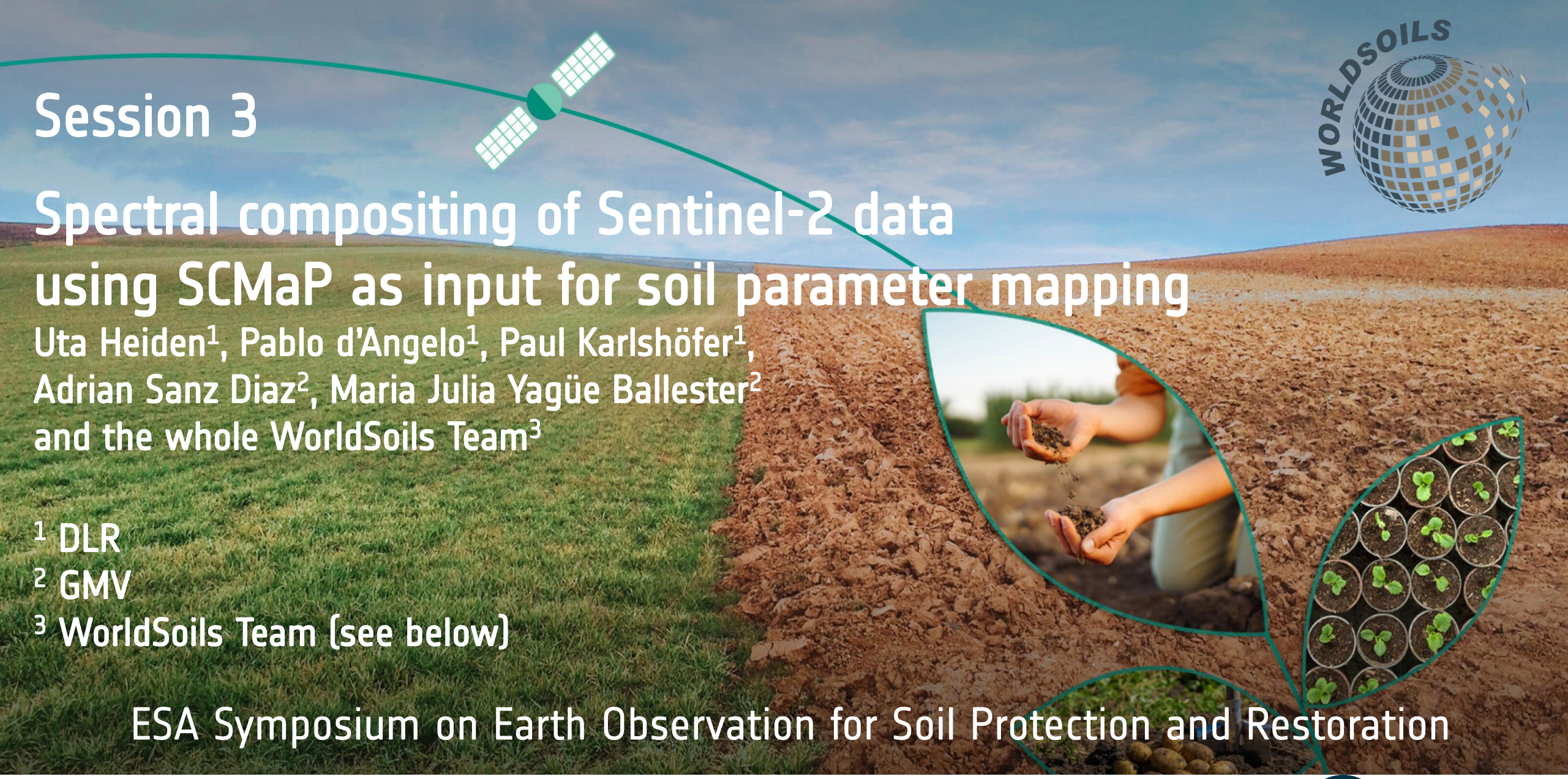

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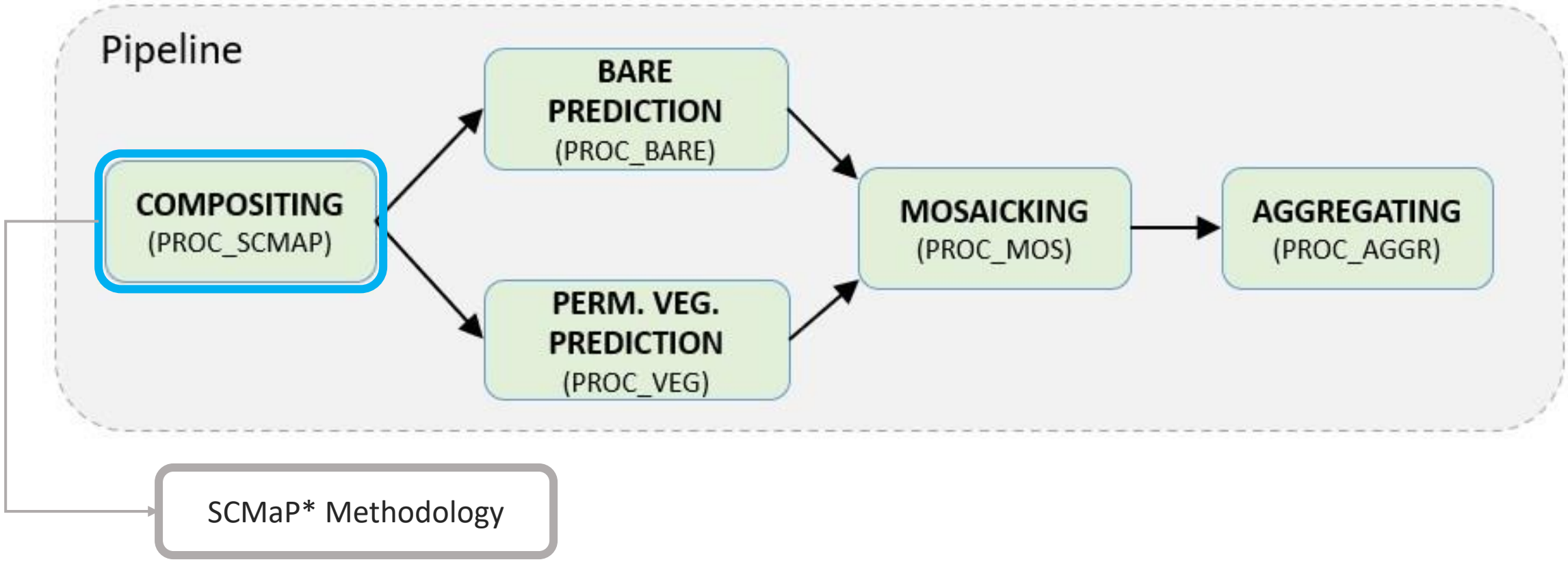
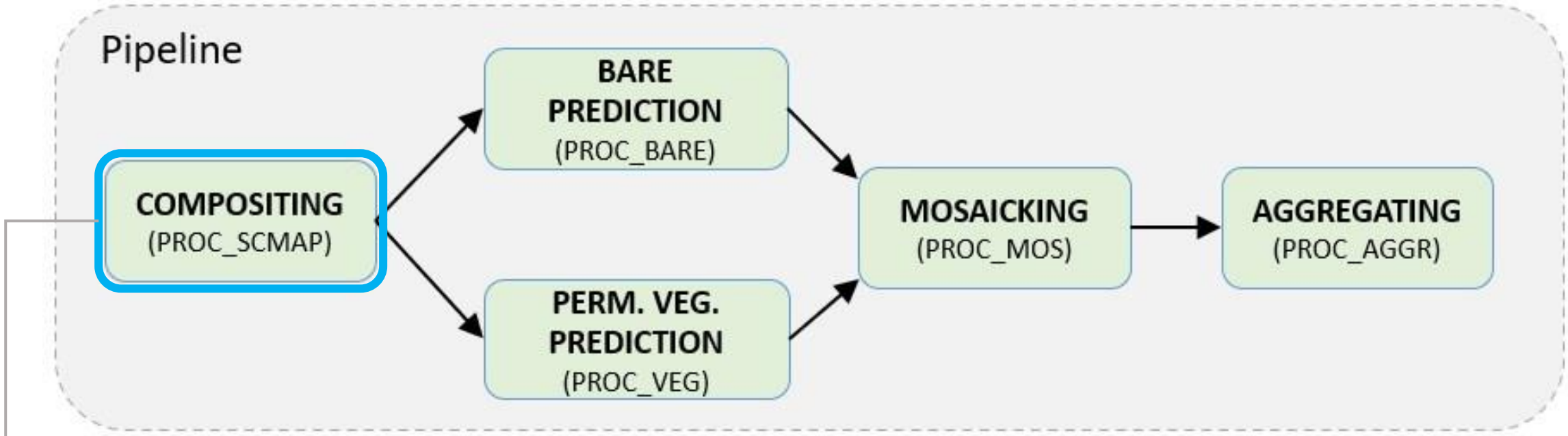
WorldSoils processing system overview



* Soil Composite Mapping Processor

WorldSoils processing system overview

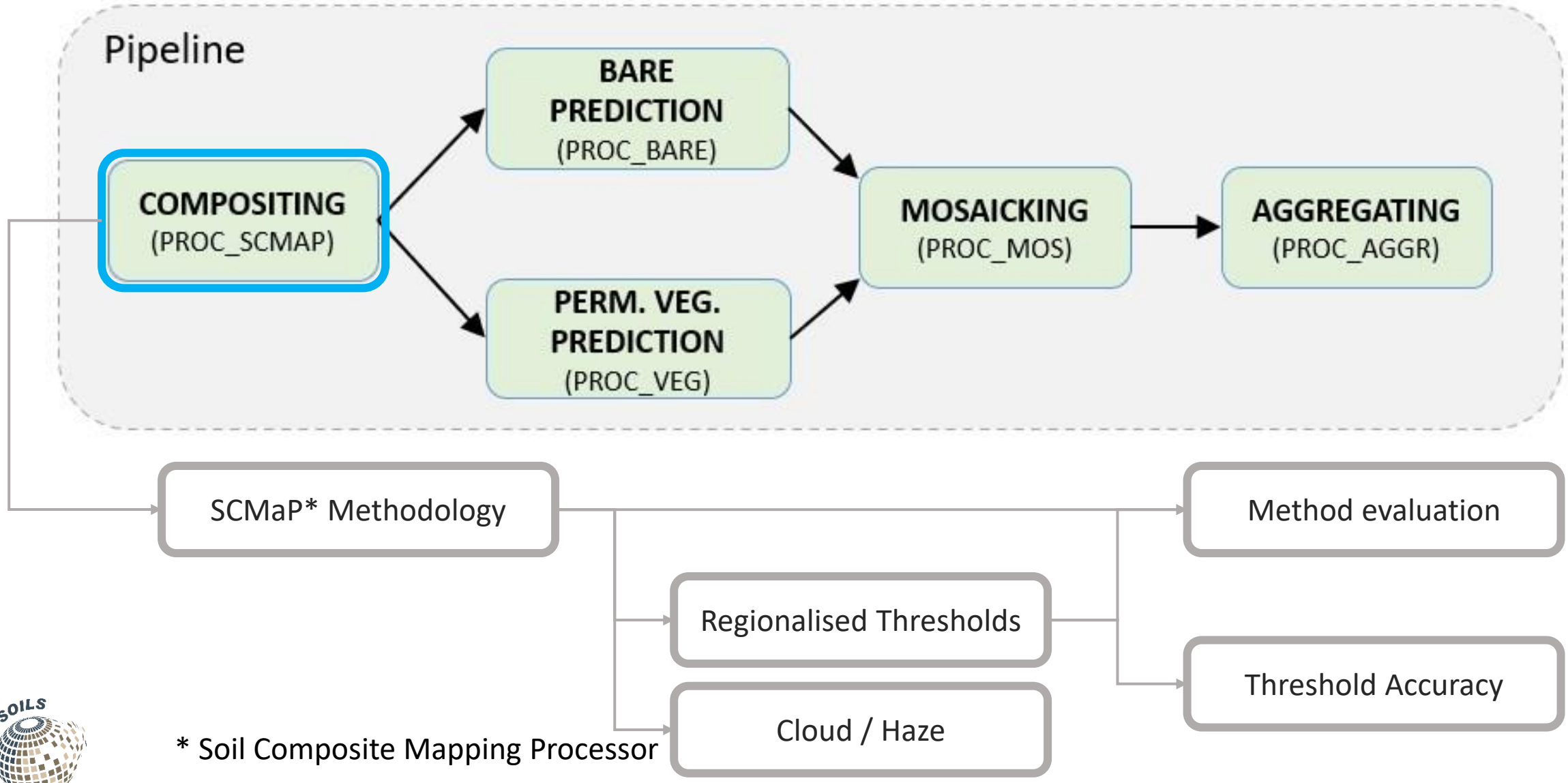


- All Sentinel–2 images in L2A format (Sen2Cor) from 2018 – 2022
- Spectral Index based *(e.g. Diek et al. 2017, Rogge et al. 2018, Demattê et al., 2018)*
- Used index: PV+IR2 *(Heiden et al. 2022, Möller, M. et al. 2022, Dvorakova, K., et al., 2023)*

$$PV+IR2 = \frac{B8 - B4}{B8 + B4} + \frac{B8 - B12}{B8 + B12}$$

* Soil Composite Mapping Processor

WorldSoils processing system overview



* Soil Composite Mapping Processor

SCMaP Methodology

Flowchart

Input data

Sentinel-2 Reflectances + Cloud Masks

ESA WorldCover

HISET

European Threshold Database

Threshold definition

SCMaP Compositing

Index calc. + thresholding

Bare soil detection

Cloud and haze filter

Averaging

Landcover Masking

Averaging

Statistics

Output products

Mean + STD reflectance composite

MEAN + STD Bare surface reflectance composite (SRC)

Bare surface pixel count

Valid pixel count

Bare surface frequency

Bare surface mask

Method Evaluation

Threshold Validation

Threshold Definition Criteria

Criteria for large scale areas

- Generic and globally applicable
- Allows for regionalized threshold derivation
- Accounts especially for spectral similarity between bare soils (crops) and non-photosynthetic vegetation (grassland)
- Spectral index independent
- Fully automated

Regionalised Thresholds

Threshold Definition Concept - HISET

*described in Heiden et al., 2022

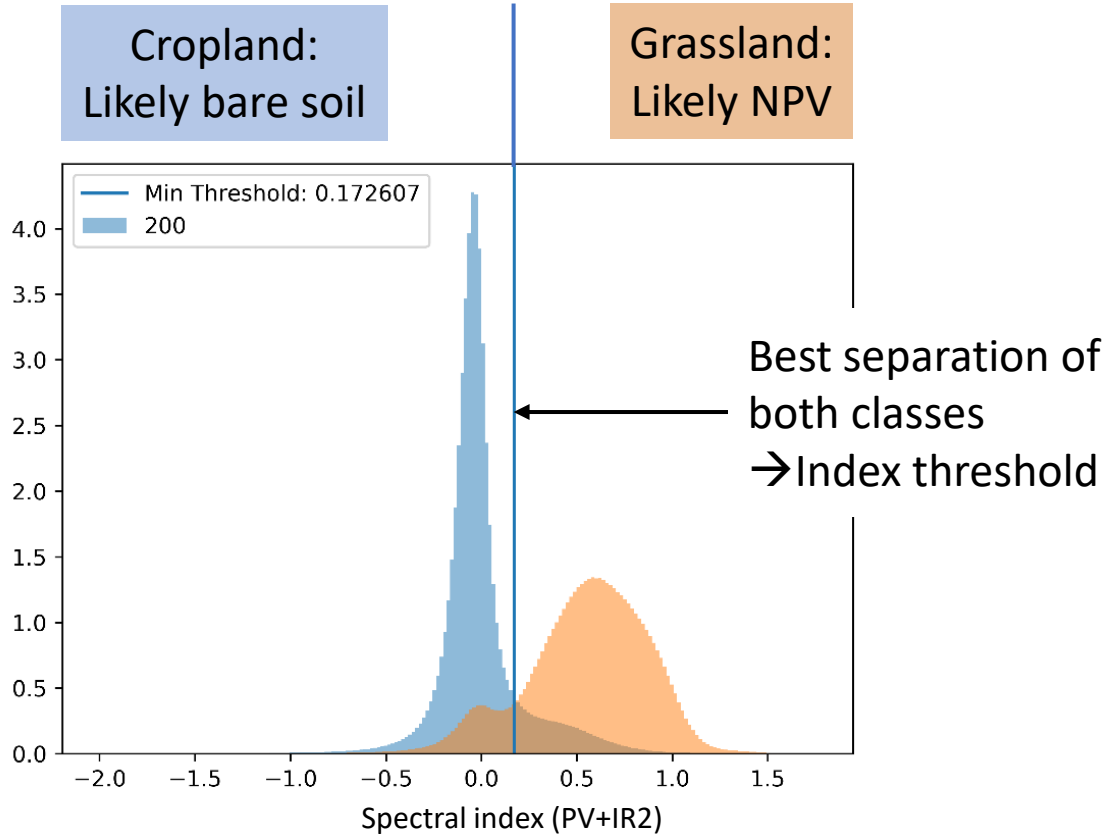
1. Index calculation -> Index minimum composite
2. Selection of specific LC classes (e.g. WorldCover - 10m)
3. Temporal behaviour of LC classes (normalised histogram)
4. Threshold definition

Index Minimum Composite

HISET*

Histogram SEparation Threshold

Temporal minimum of a vegetation index



Regionalised Thresholds

Underlying LC database

Challenges – Land Cover/Use Map

1. Areas with limited or missing pixels of the two LC types ⟶ interpolation and extrapolation

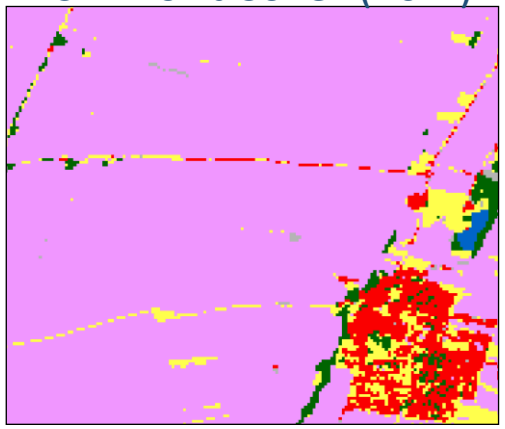
2. Refinement of LC cropland
   - LC class includes spectral mixtures (border pixels)
   - LC definition – pasture land not actively managed, do not show bare soils
   - Assessment of activity of surfaces

Temporal Variability Index $:= \sum_{i=0}^{N} \left| \frac{M_{i+1} - M_i}{d_{i+1} - d_i} \right|$, M_i is a i-th of N bimonthly, minimum index composites, that is centered at date d_i.

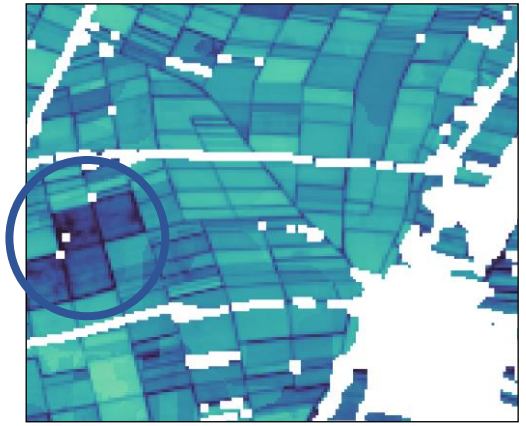
- Activity map is used to clean up the crop layer

Sentinel-2 Reflectance

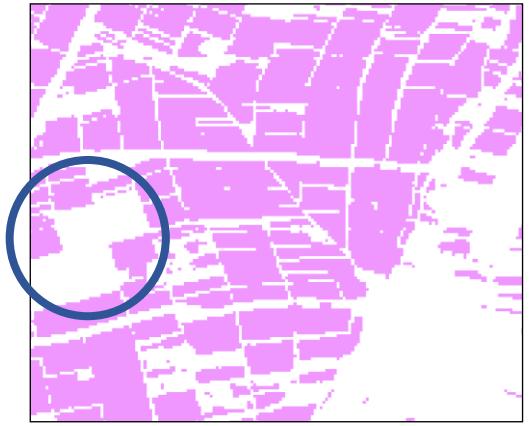
ESA WorldCover (10m)



Cropland



Temporal variability



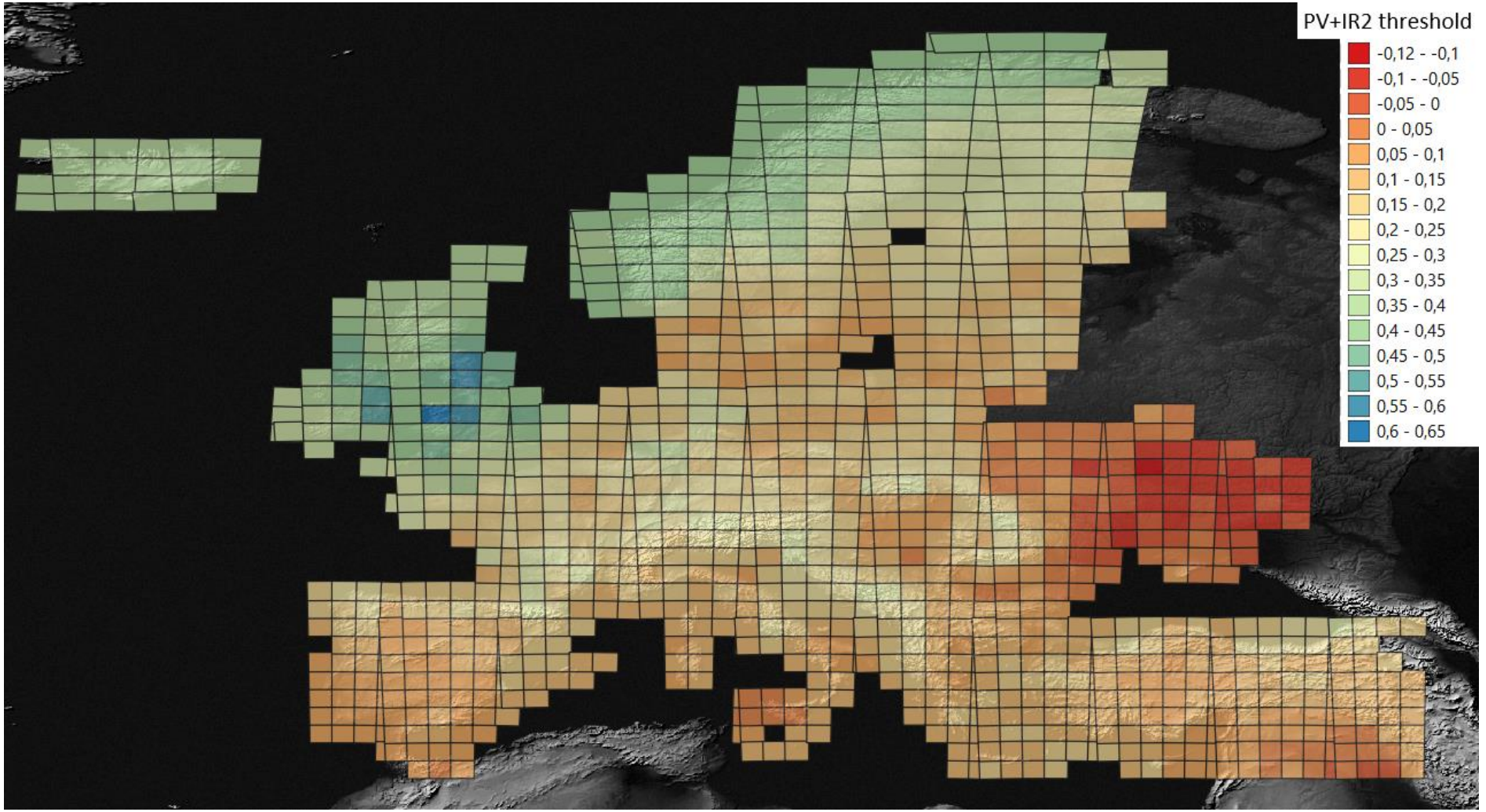
Active cropland

Regionalised Thresholds

European Threshold Database

- PV+IR2 thresholds range between – 0.1 and 0.6
- Correlated with bioclimatic zones

- Karlshöfer et al., in preparation



Cloud and Haze Handling

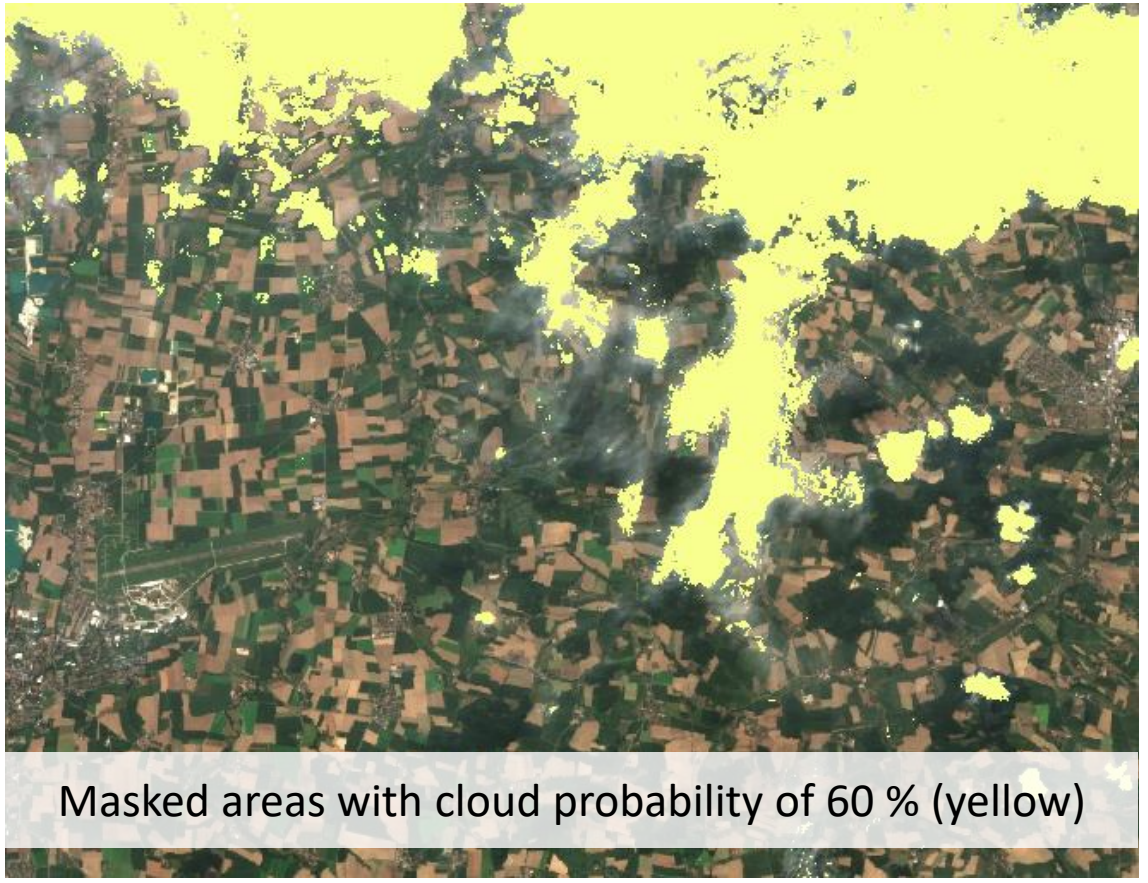
Problem definition

Multiple steps:

1. Selection of single scenes with < 80 % cloud cover
2. Masking of clouds, haze, snow etc. using Scene Classification Layer (SCL 4/5/6) of Sen2Cor processing
3. Bare soil specific cloud and haze masking

↓

Noticed remaining clouds and haze



Masked areas with cloud probability of 60 % (yellow)

Bare soil specific detection

NIR – SWIR difference (clouds)

Distinct difference in NIR and SWIR behavior between clouds and almost all soils

- Soils: B11 > B8, Clouds: B11 < B8
- (B11-B8A)/(B11+B8A) > 0.02
- Only very few misclassifications: 0.1% of all LUCAS spectra (some nut tree orchards in southern Spain)

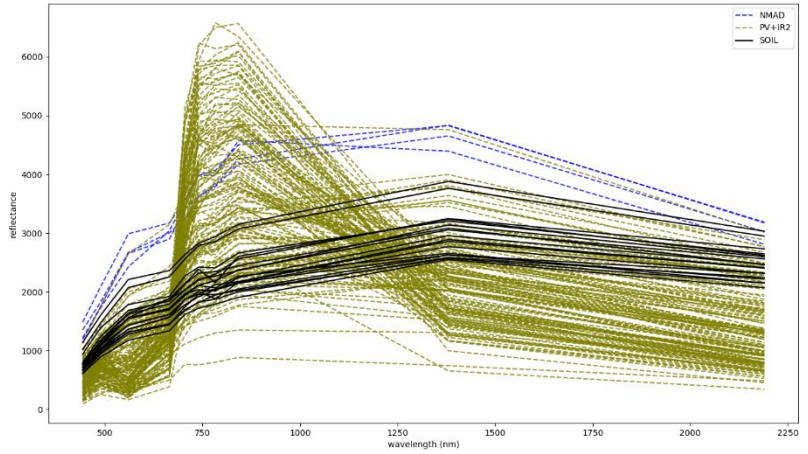
"Blue outliers" (haze / thin clouds)

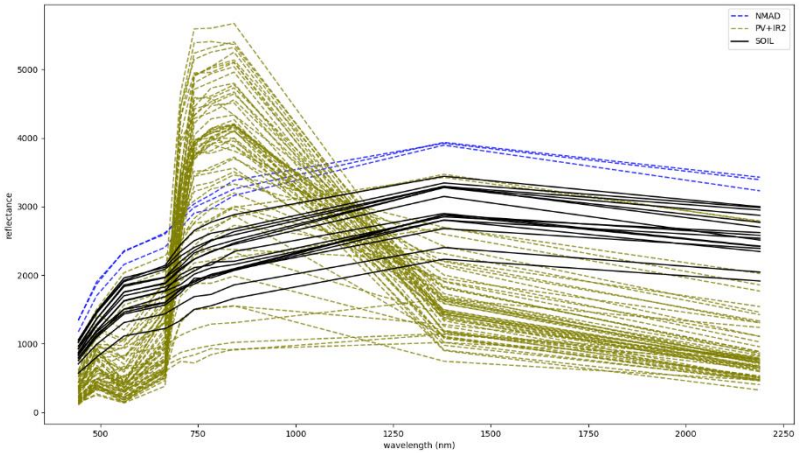
Atmospheric effect strongest in blue band

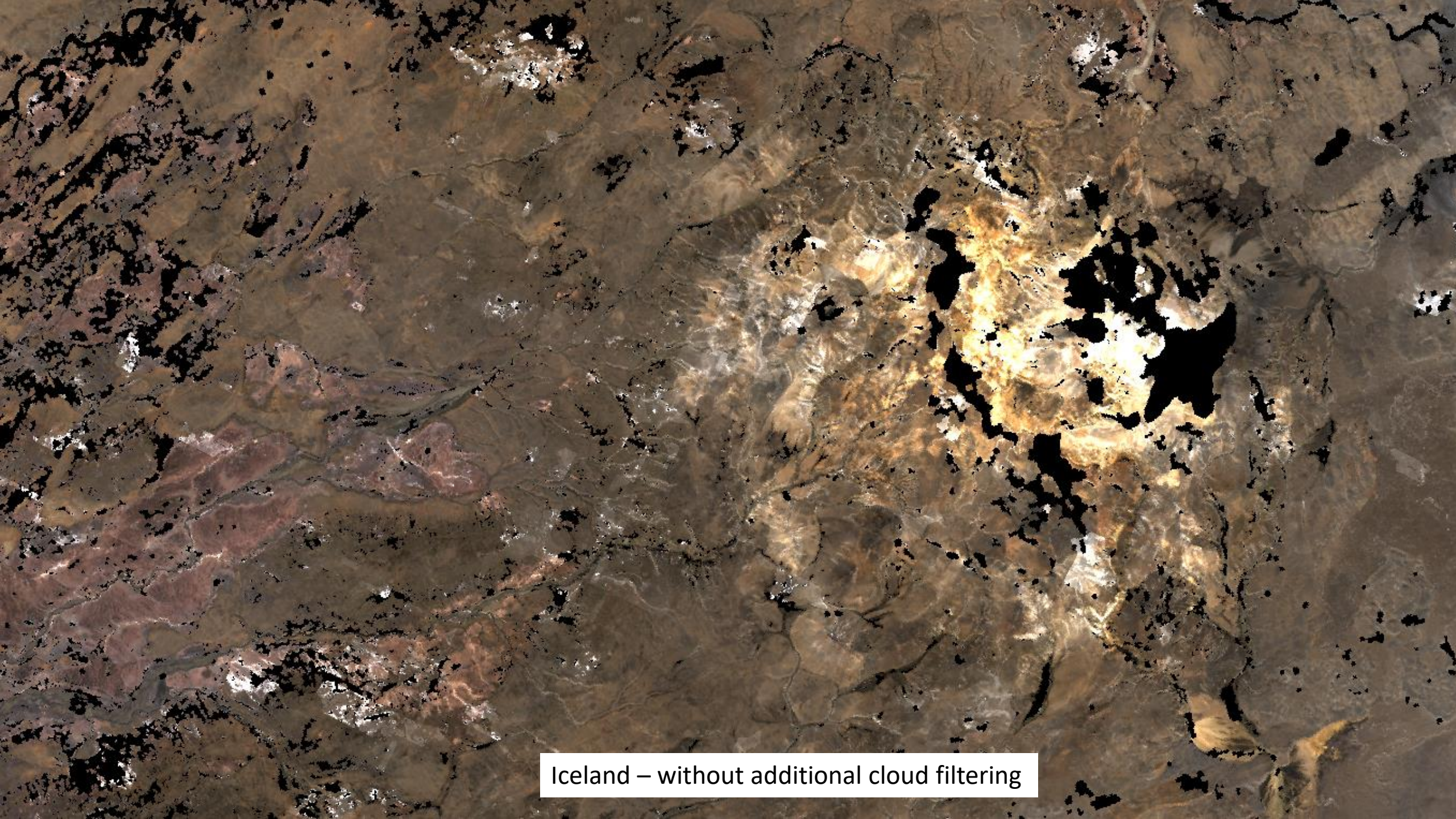
- detect remaining haze and thin cloud contamination based on higher blue reflectance
- Local statistics based outlier filter:

$$b \leq median(B) + 3\sigma$$

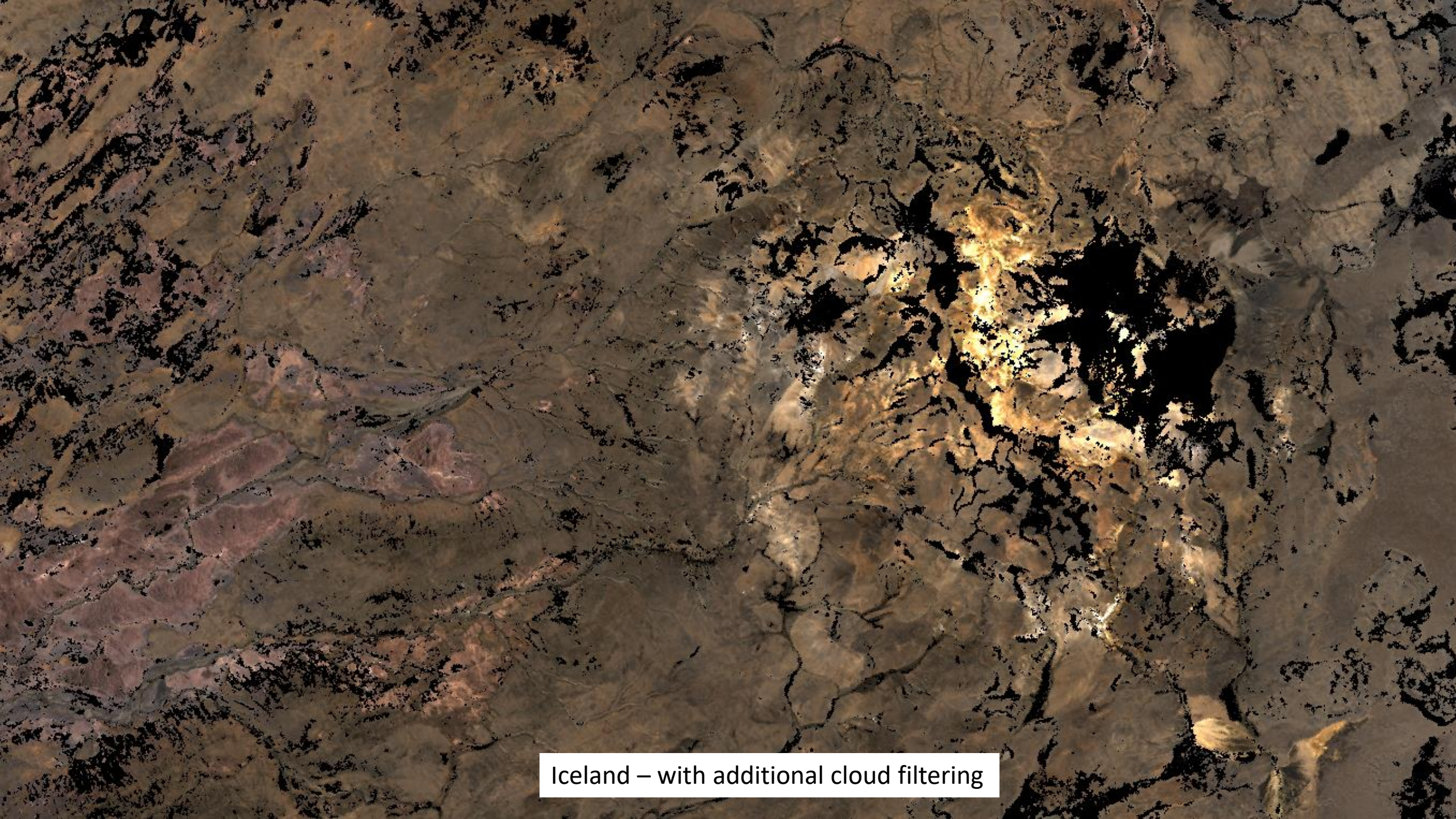
$$\sigma = 1.48\, median(|B - median(B)|)$$







Iceland – without additional cloud filtering

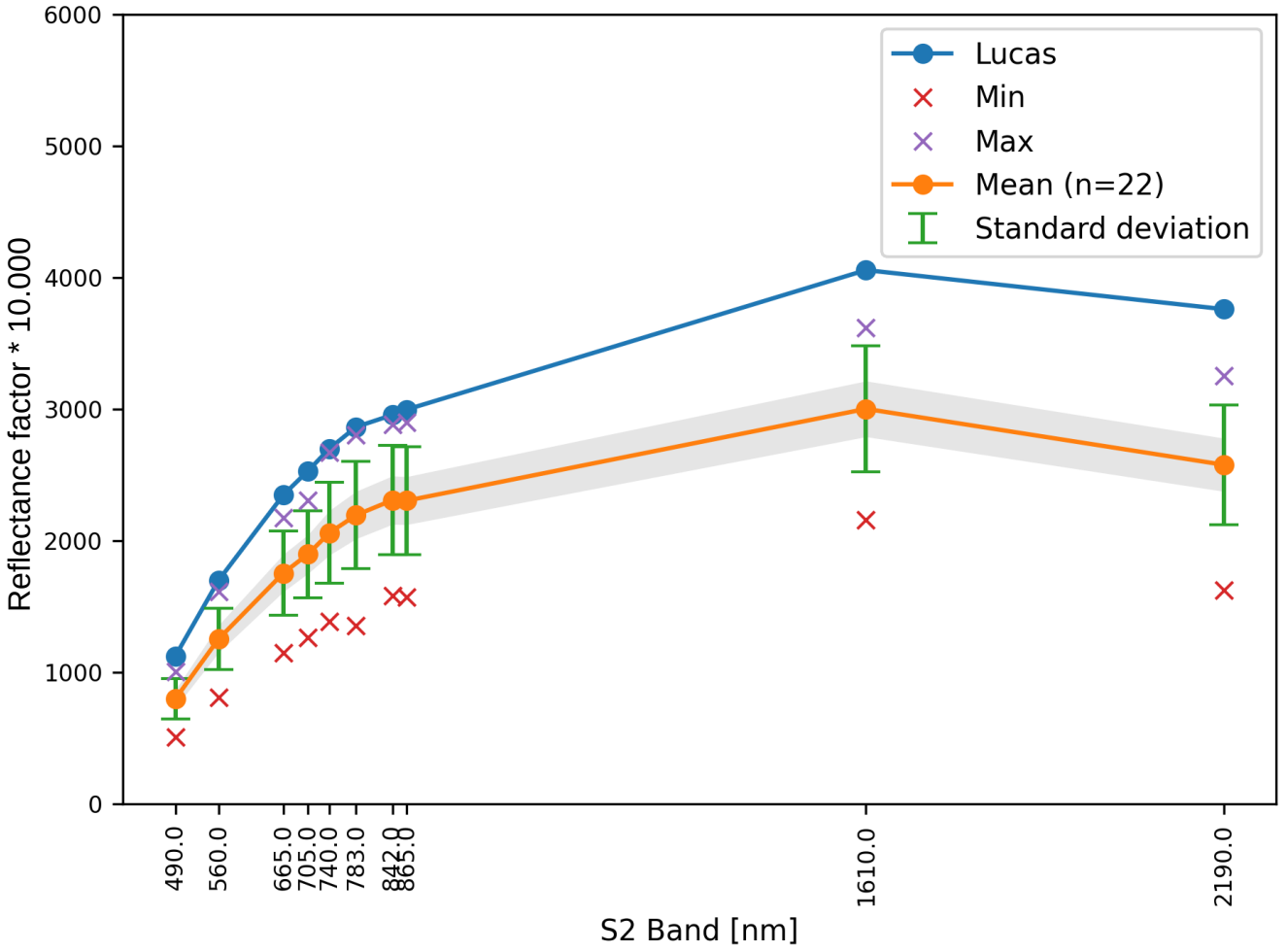


Iceland – with additional cloud filtering

Method Evaluation

Evaluating the soil reflectance composite product

- How to evaluate the used compositing methodology:
  - Selection of indices
  - Thresholds
  - Universal versus regional approach?
- What is the reference for the soil composite spectra?
- Can we evaluate for large areas (e.g. Europe) instead of small test areas?

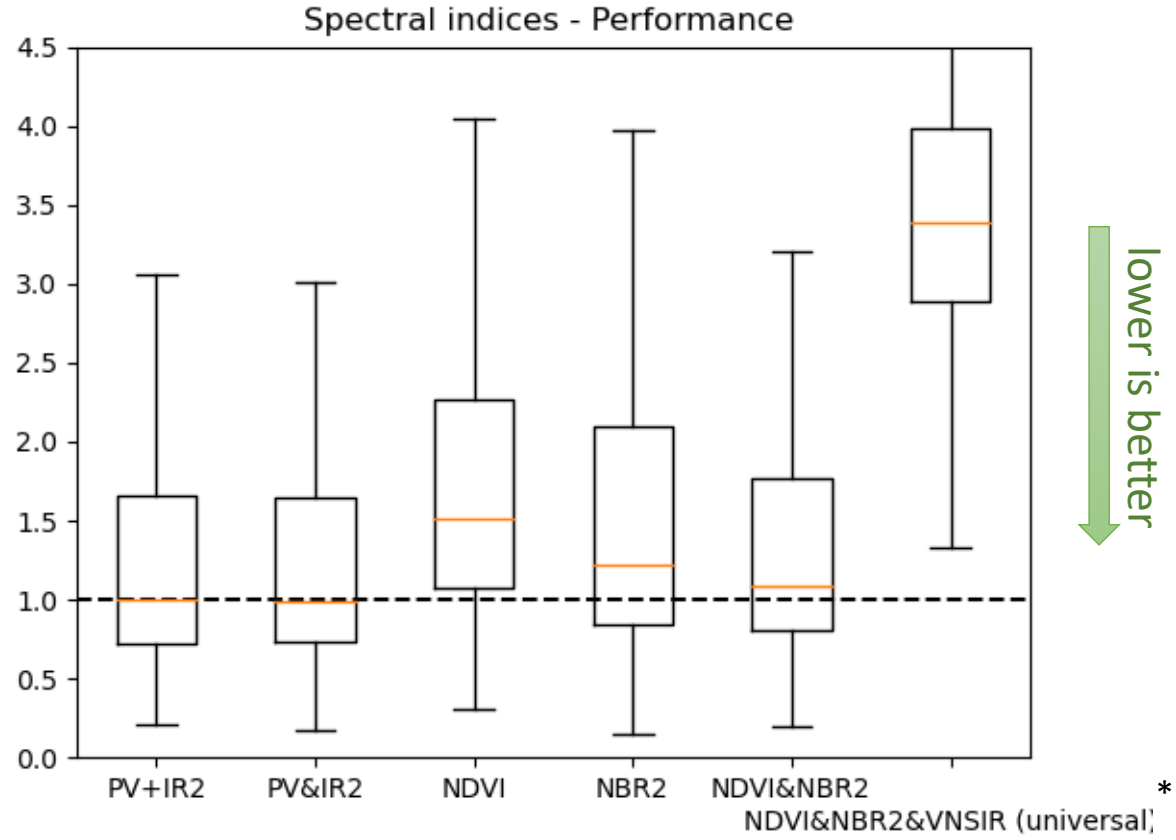


Method Evaluation

Method Comparison

- At each LUCAS points, **ideal thresholds** can be computed, that minimize angular distance
- Performance: $\min_t \frac{1}{N} \sum_{i=0}^{N} SAM\left(l_i, C_i(t)\right)$, for N LUCAS points and the Composite C based on thresholds t
- **PV+IR2 outperforms** established indices
- Significant range [-0.05, 0.4] of ideal thresholds and local patterns indicate that a **regionalized** thresholds is crucial
  - Also evident by the bad performance of universal thresholds

→ Regional PV+IR2 good choice for an index



* Universal thresholds taken from literature: -0.25 < NDVI < 0.25, -0.1 < NBR2 < 0.3, VNSIR < 0.9

Summary and Outlook

Summary:

- SCMaP – fully automated processor for enhanced image products for soil mapping
- PV+IR2 suitable to select bare soil surfaces by reducing NPV influence to a minimum
- Technique for regionalised threshold definition developed, tested and evaluated
- Tested at continental scale (Europe)
- Approach evaluated against other soil compositing strategies using LUCAS spectrum as reference

Outlook:

- Reduce dependencies (Land cover map, thresholds)
- Produce pixel-based spectral uncertainty maps

Many thanks for your attention!

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