Session 3

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

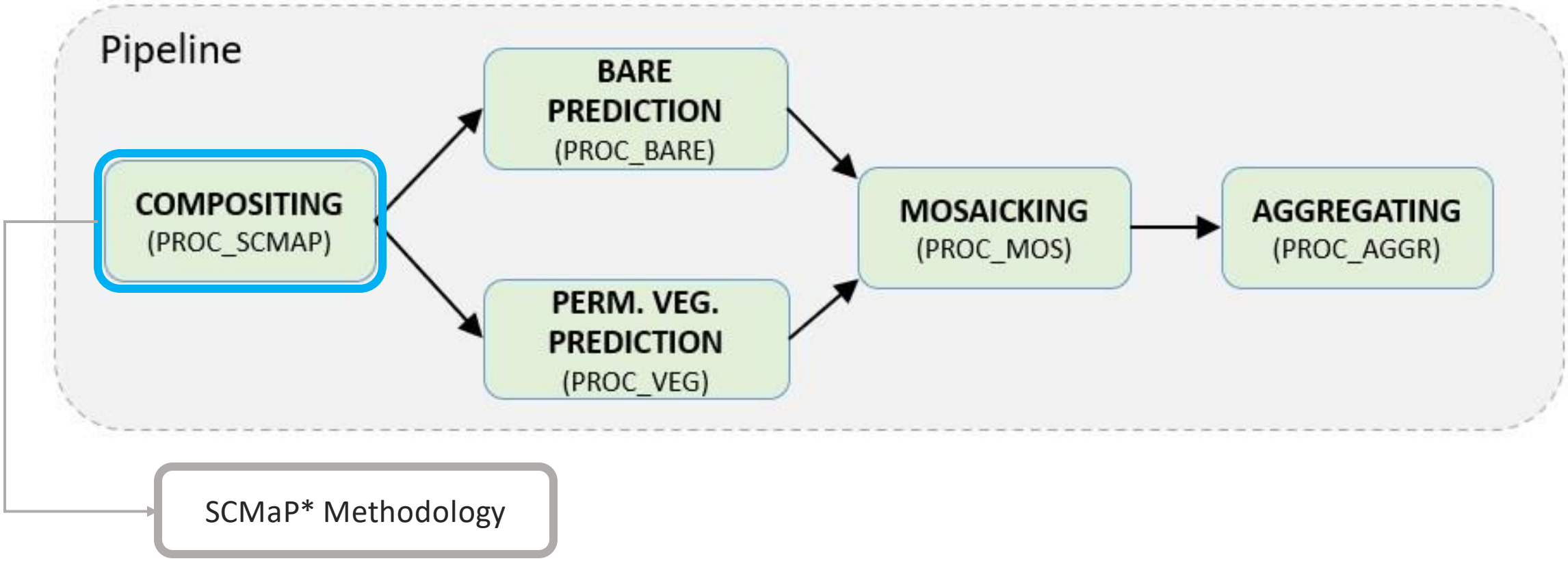
Uta Heiden[1], Pablo d'Angelo[1], Paul Karlshöfer[1],
Adrian Sanz Diaz[2], Maria Julia Yagüe Ballester[2]
and the whole WorldSoils Team[3]

[1] DLR
[2] GMV
[3] WorldSoils Team (see below)

ESA Symposium on Earth Observation for Soil Protection and Restoration

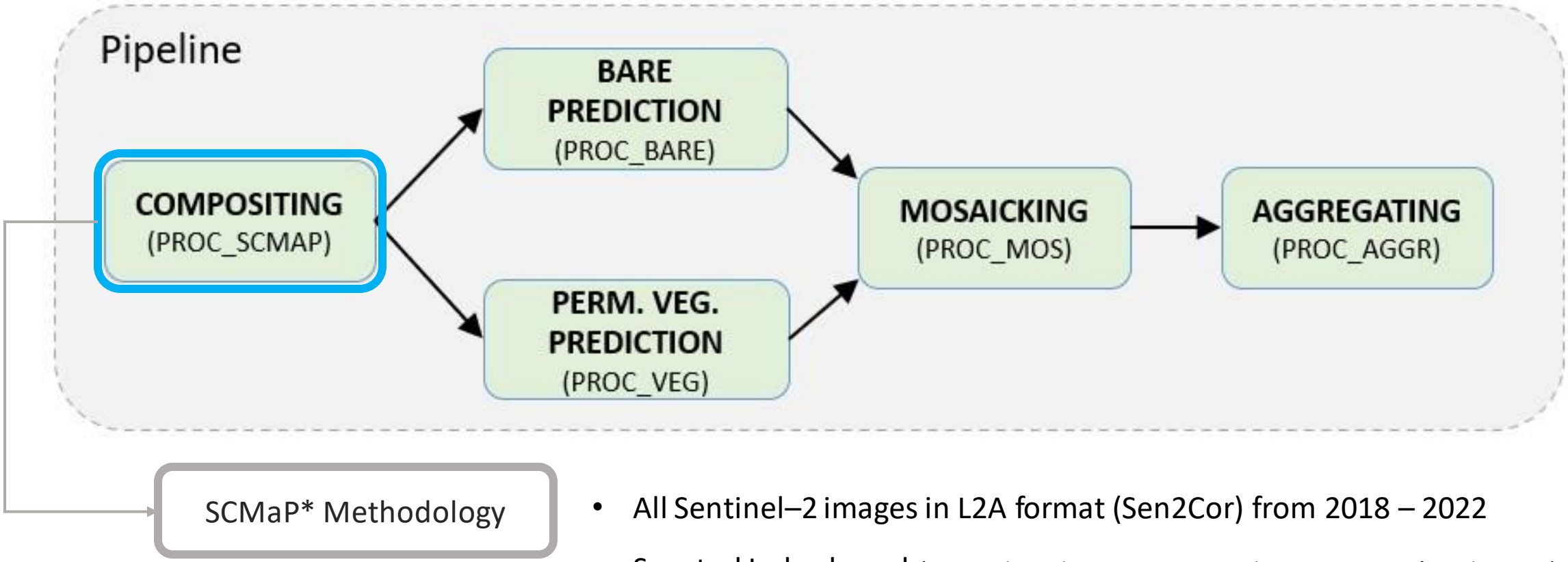
Contract 400131273/20/I-NB

WorldSoils processing system overview



* Soil Composite Mapping Processor

WorldSoils processing system overview

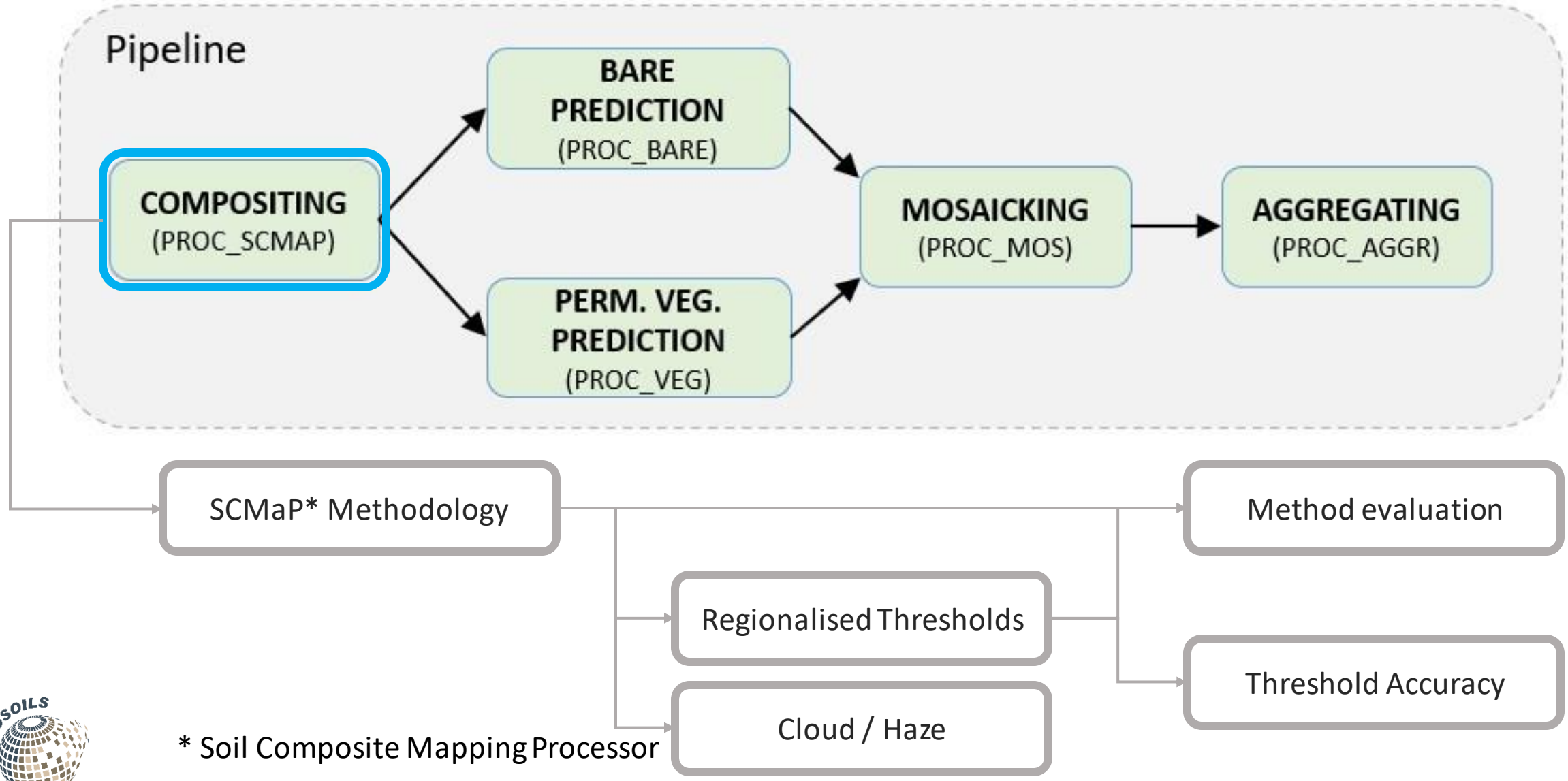


- All Sentinel–2 images in L2A format (Sen2Cor) from 2018 – 2022
- Spectral Index based *(e.g. Diek et al. 2017, Rogge et al. 2018, Dematte et al., 2018)*
- Used index: PV+IR2 *(Heiden et al. 2022, Möller, M. et al. 2022, Dvorakova, K., et al., 2023)*

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

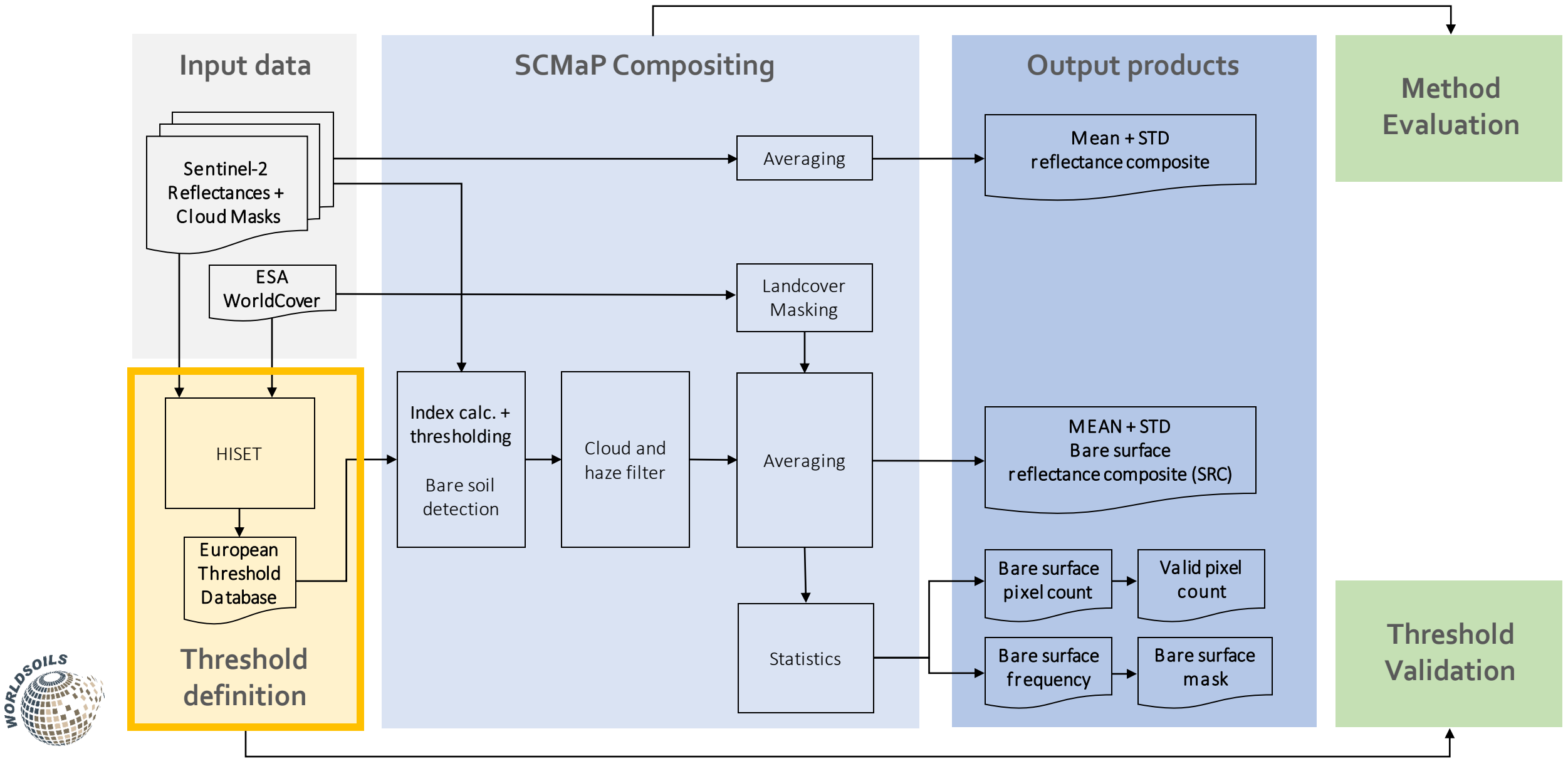
* Soil Composite Mapping Processor

WorldSoils processing system overview



SCMaP Methodology

Flowchart



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

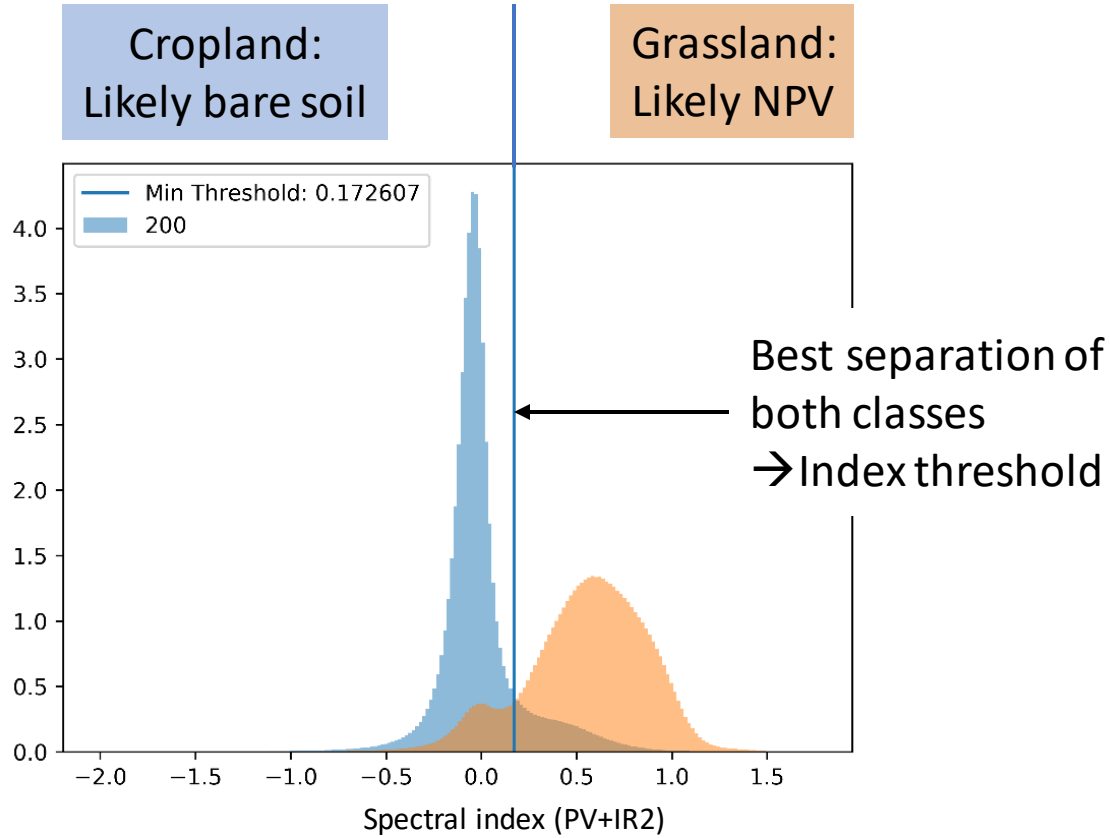
1. Index calculation -> Index minimum composite
2. Selection of specific LC classes (e.g. WorldCover - 10m)
3. Temporal behaviour of LC classes (normalised histogram)
4. Threshold definition

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

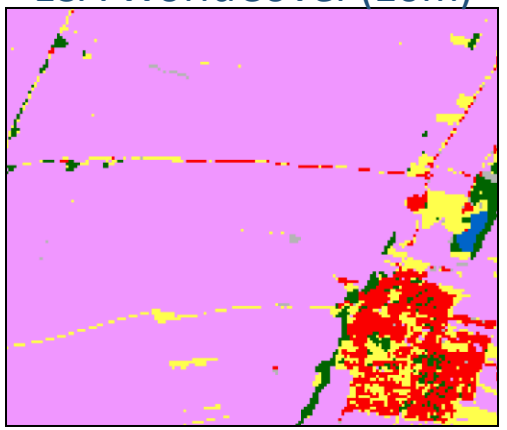
2. Refinement of LC cropland
   - LC class includes spectral mixtures (border pixels)
   - LC definition – pasture land not actively managed, do not show bare soils
   - Assessment of activity of surfaces

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.

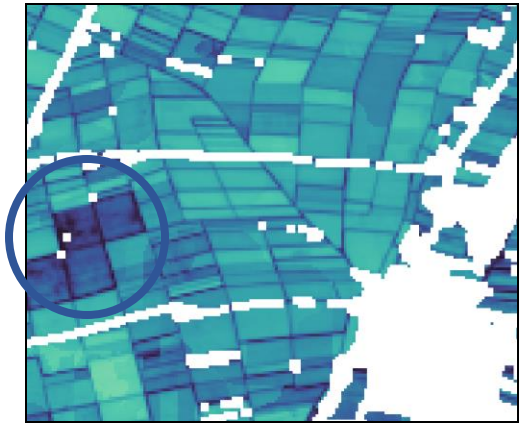
- Activity map is used to clean up the crop layer

Sentinel-2 Reflectance

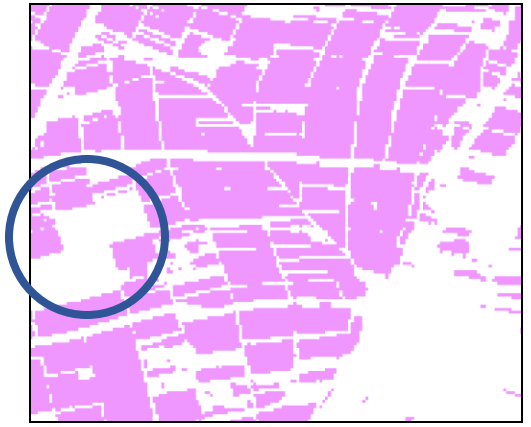
ESA WorldCover (10m)



Cropland



Temporal variability



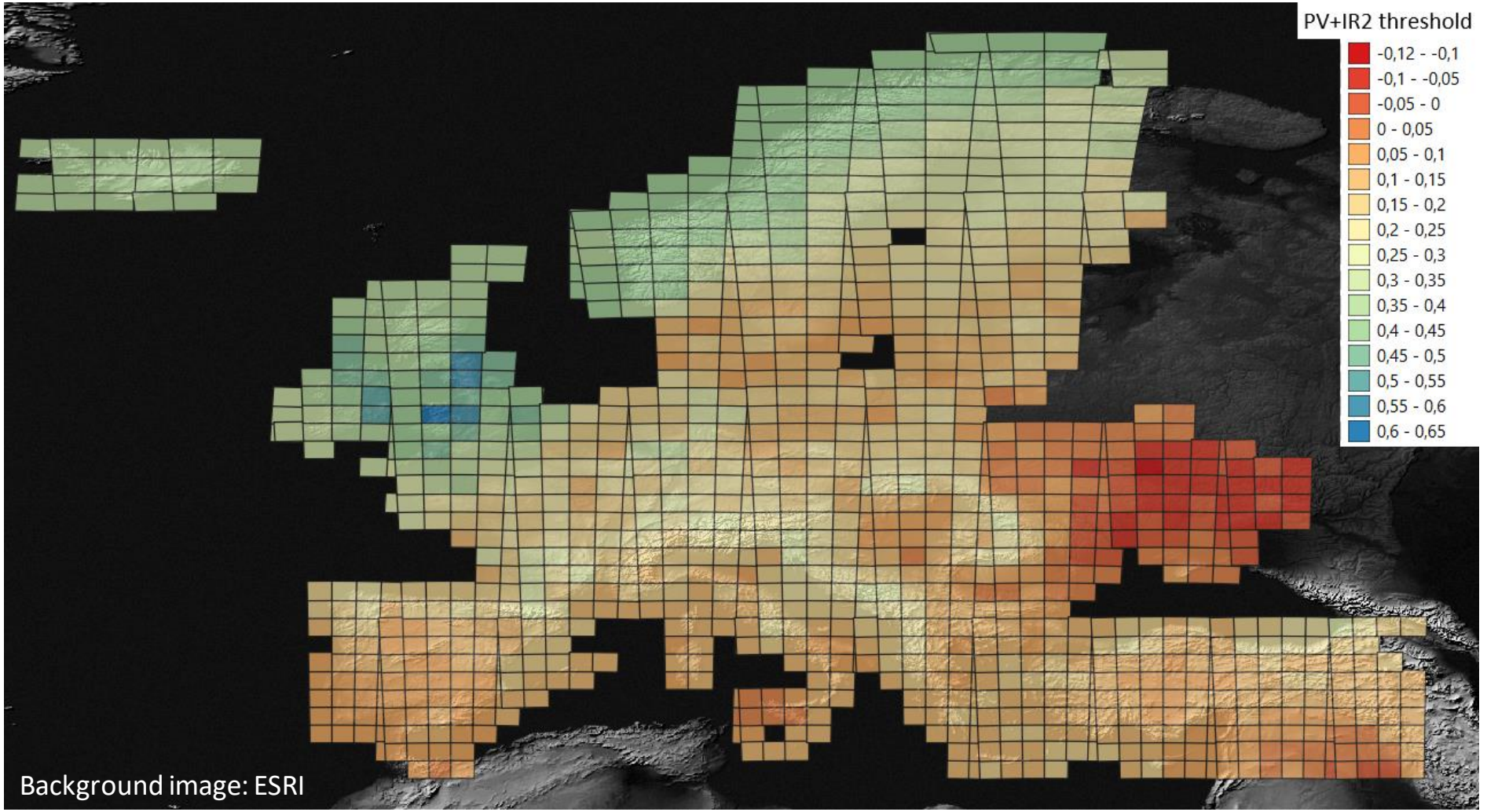
Active cropland

Regionalised Thresholds

European Threshold Database

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

- Karlshöfer et al., in preparation



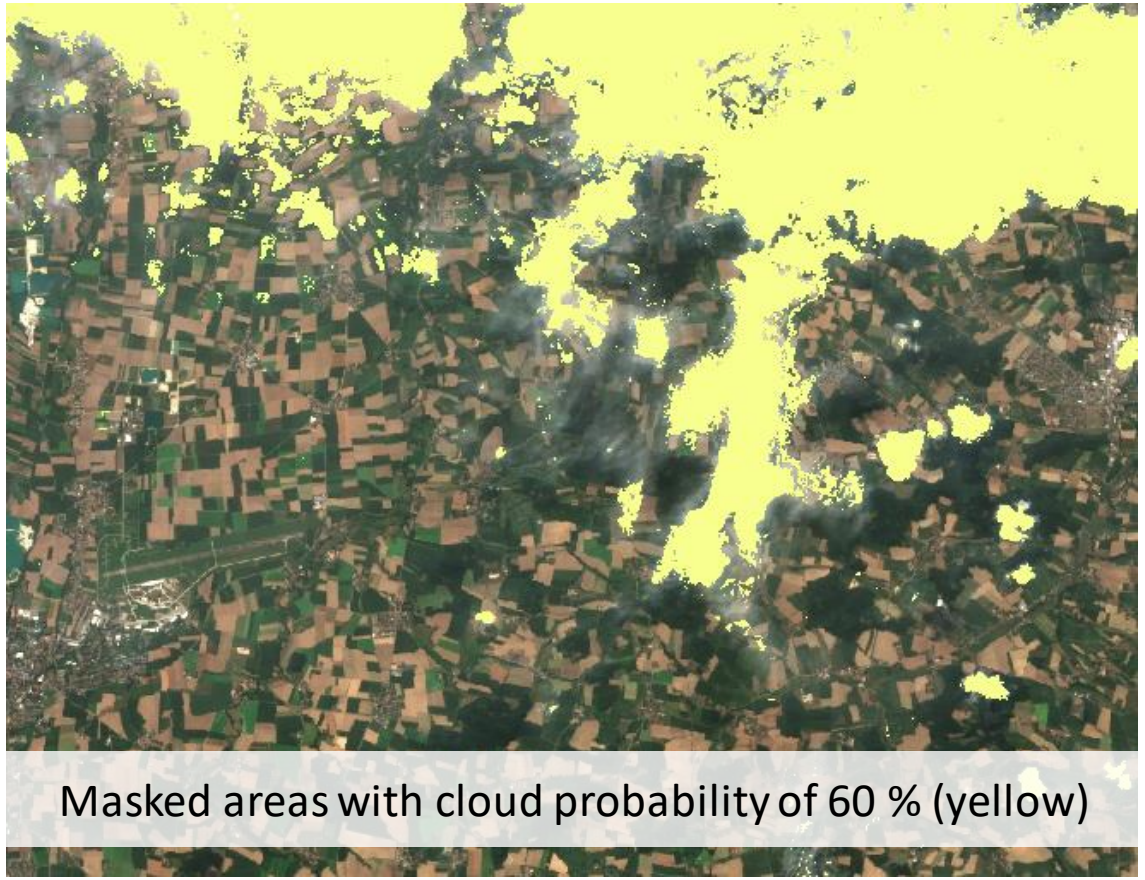
Cloud and Haze Handling

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)

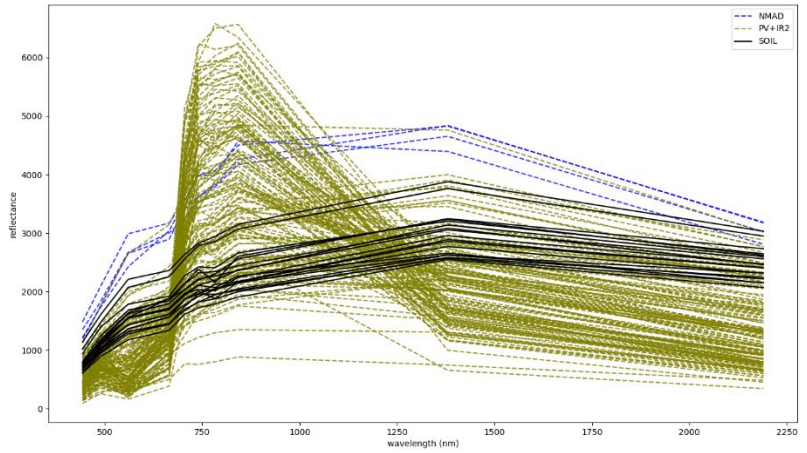
"Blue outliers" (haze / thin clouds)

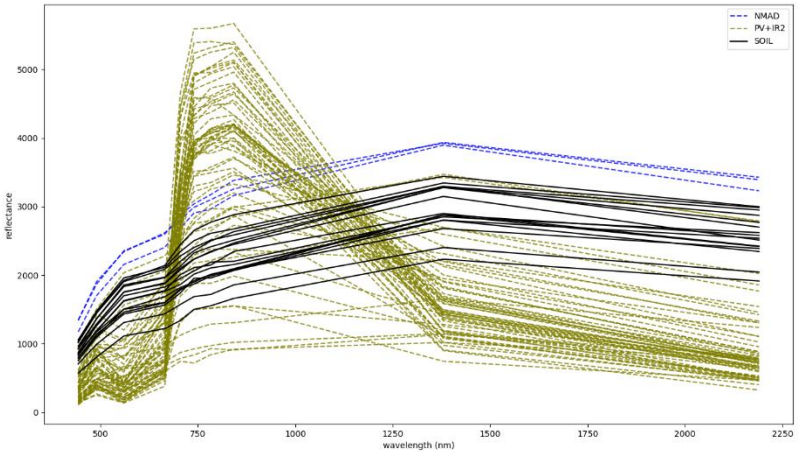
Atmospheric effect strongest in blue band

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

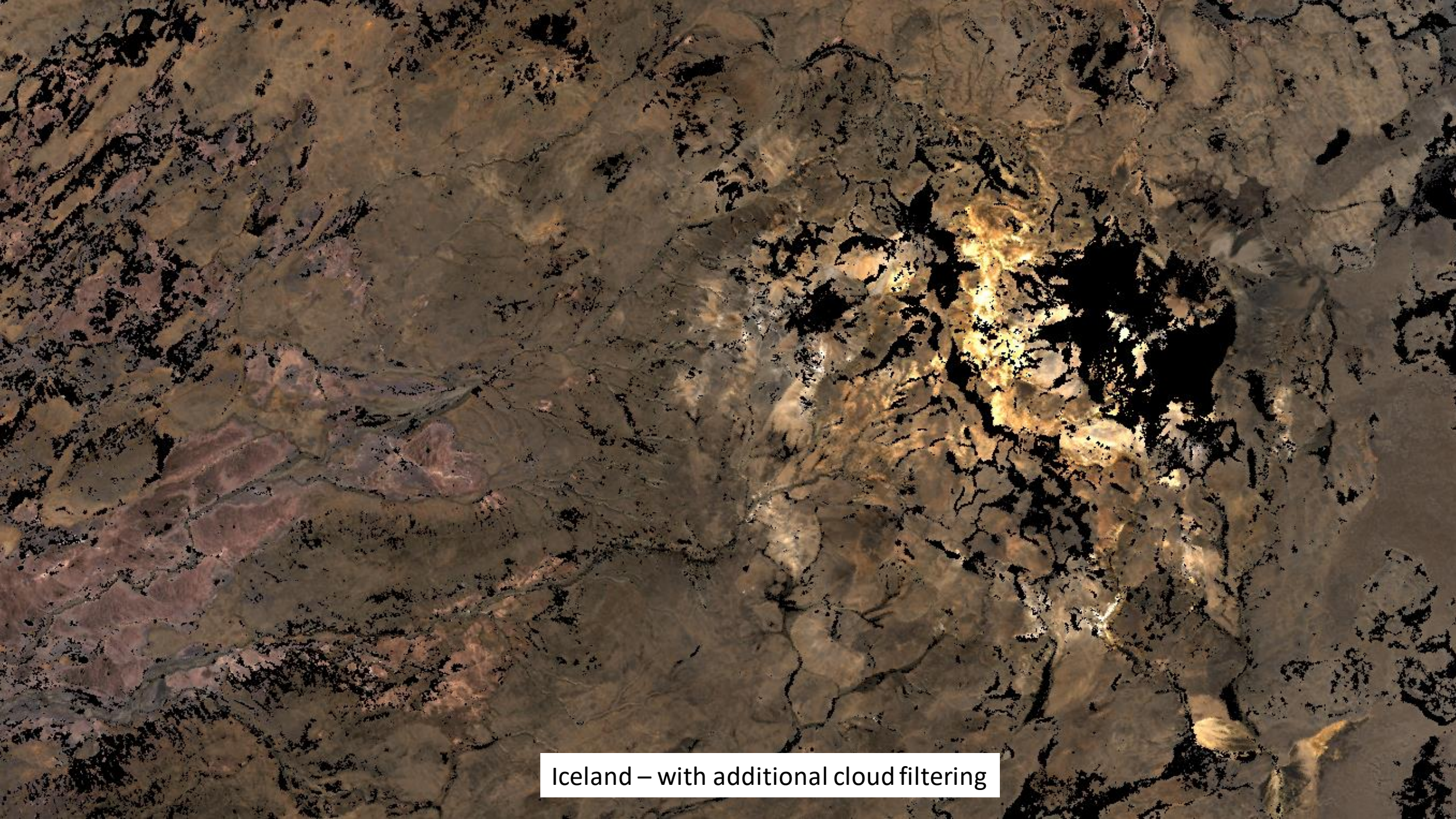
$$b \leq median(B) + 3\sigma$$

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






Iceland – without additional cloud filtering

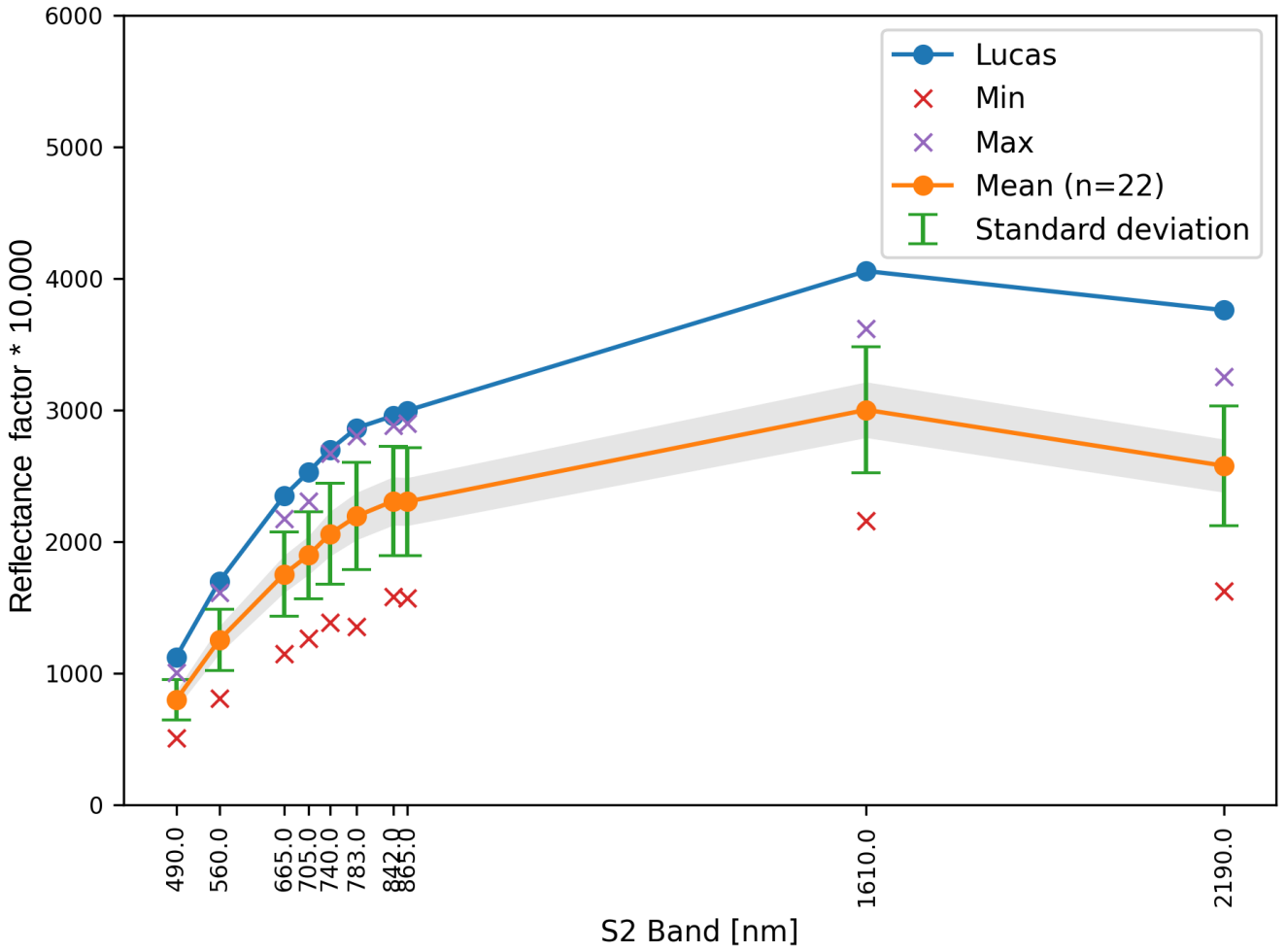


Iceland – with additional cloud filtering

Method Evaluation

Evaluating the soil reflectance composite product

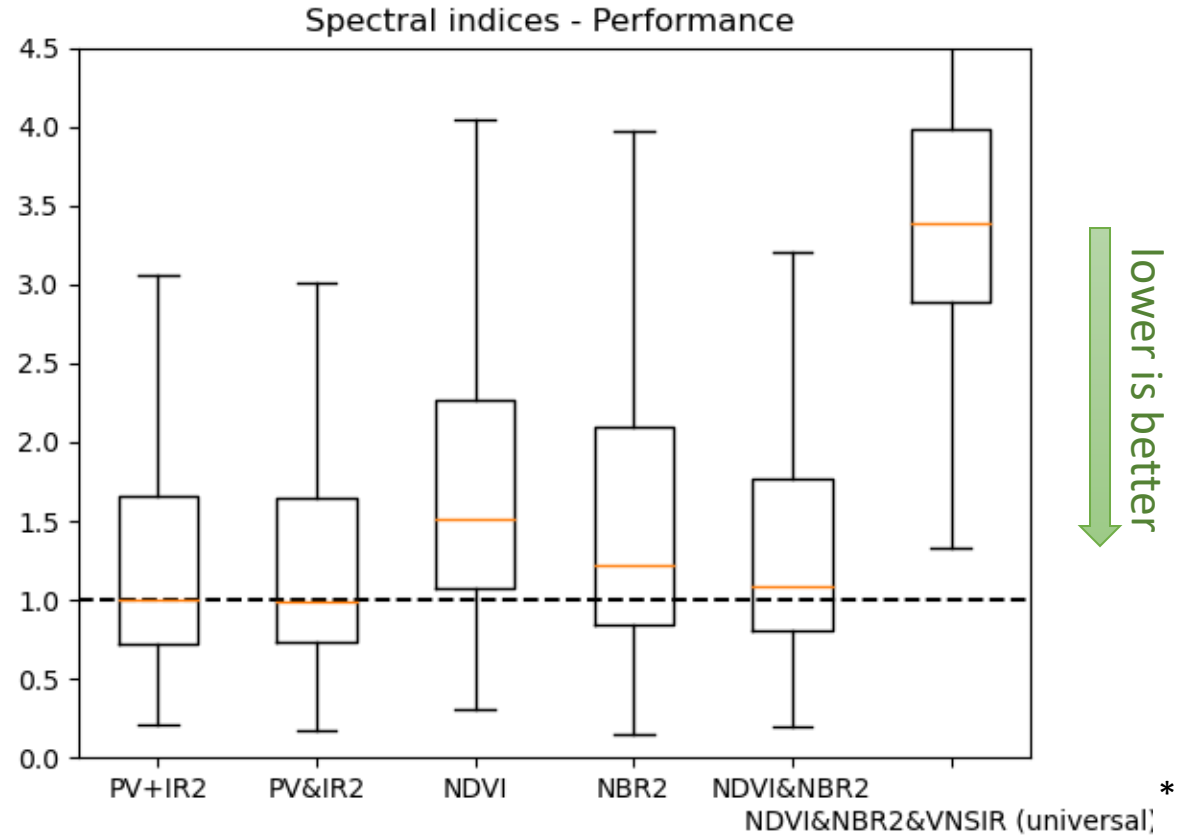
- How to evaluate the used compositing methodology:
  - Selection of indices
  - Thresholds
  - Universal versus regional approach?
- What is the reference for the soil composite spectra?
- Can we evaluate for large areas (e.g. Europe) instead of small test areas?



Method 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!

uta.heiden@dlr.de

ESA Symposium on Earth Observation for Soil Protection and Restoration