Validation of the Copernicus Sentinel-2 Collection-1 and Operational Scene Classification (SCL) Products

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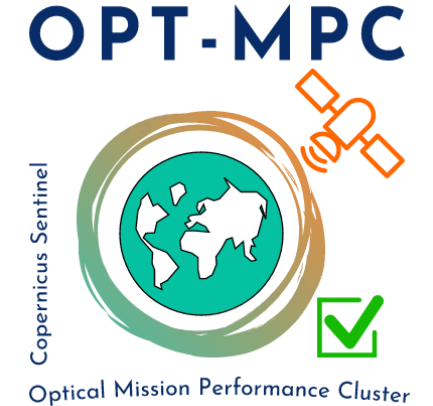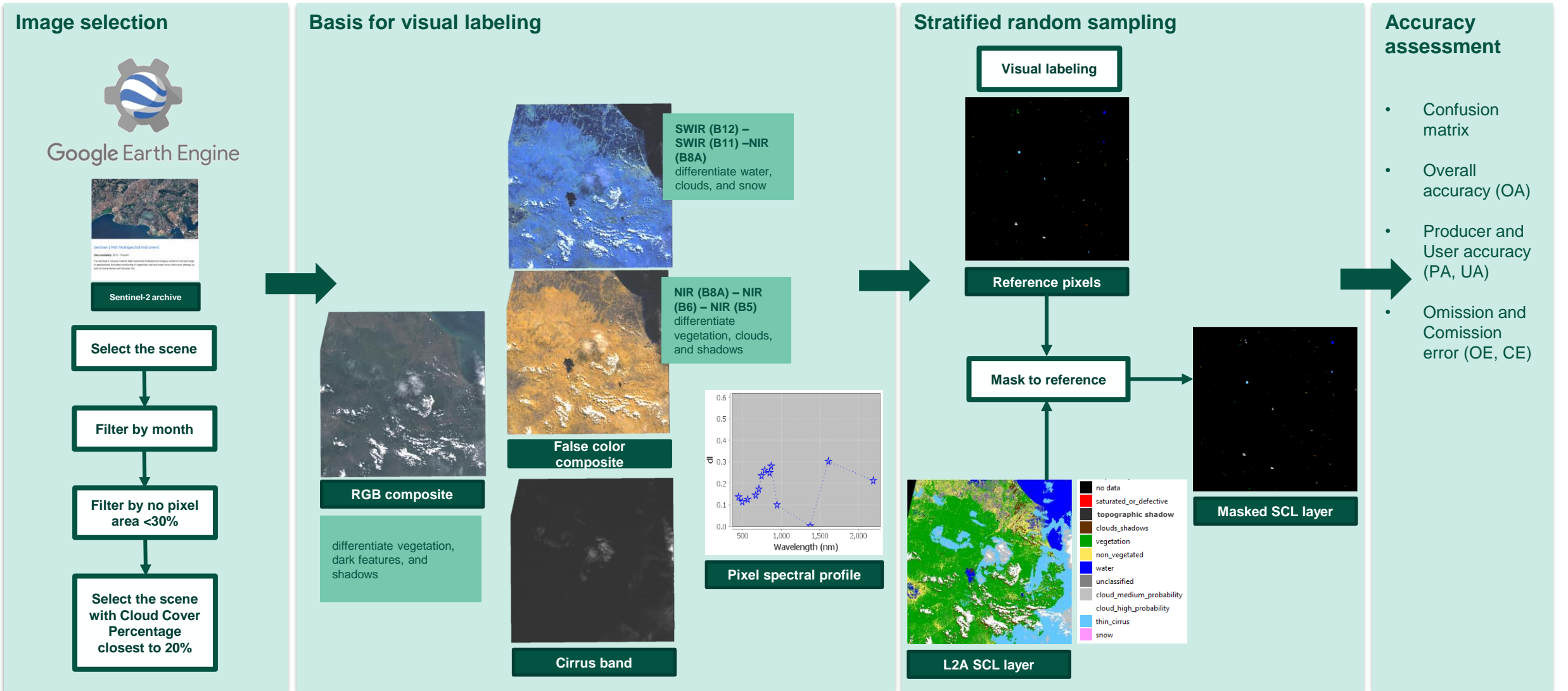
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Introduction

- This work is part of **Sentinel-2 Optical Mission Performance Cluster (OPT-MPC)**

- **Sen2cor** processed Sentinel-2 from the Level 1C products to Level 2A products:
  - surface reflectance (Bottom-of-Atmosphere, BOA)
  - Scene Classification (SCL)
  - Aerosol Optical Thickness (AOT) and Water Vapor (WV)

- We investigated the performance of **Sen2Cor 2.11** SCL on Collection-1 (PB 05.00) and operational products (PB 05.09) in separating clear pixels from cloudy pixels

- Collection-1 products were evaluated and compared to their corresponding pre-Collection products from previous baselines (PB 02.08, 02.09, 03.00, and 03.01).

- We utilized **Sen2val** tools to generate the reference pixels for validation.

Selected sites and scenes

World map with selected sites: Potsdam, **Germany**; Yakutsk, **Russia**; Rimrock, **USA**; Murcia, **Spain**; Bandung, **Indonesia**

Year	Processing Baseline	Type	Products
2020	PB 05.00	Collection-1	12 products
2021	PB05.00	Collection-1	12 products
2023	PB 05.09	Operational	7 products

Collection-1 products (PB 05.00)

	Northern latitude season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Yakutsk	T52VEP	Jan.			April		June			Sept.		Nov.	
Potsdam	T33UUU		Febr.			May		July			Oct.		Dec.
Rimrock	T11TMM	Jan.		March			June		August			Nov.	
Barrax	T30SWH		Febr.		April			July		Sept.			Dec.
Manila	T51PTS			March		May			August		Oct.		

Season groupings: winter (Jan–Feb), spring (Apr–May), summer (Jun–Aug), fall (Sep–Oct), winter (Nov–Dec)

Operational products (PB 05.09)

	Northern latitude season	Jan	Feb	Mar	Apr	May	Jun	Jul
Yakutsk	T52VEP					May		
Potsdam	T33UUU	Jan.					June	
Rimrock	T11TMM		Febr.					July
Barrax	T30SWH			March				
Manila	T51PTS				April			

Methodology

Image selection

Google Earth Engine

Sentinel-2 archive

Select the scene

↓

Filter by month

↓

Filter by no pixel area <30%

↓

Select the scene with Cloud Cover Percentage closest to 20%

Basis for visual labeling

RGB composite

differentiate vegetation, dark features, and shadows

SWIR (B12) – SWIR (B11) –NIR (B8A) differentiate water, clouds, and snow

NIR (B8A) – NIR (B6) – NIR (B5) differentiate vegetation, clouds, and shadows

False color composite

Pixel spectral profile

Cirrus band

Stratified random sampling

Visual labeling

Reference pixels

↓

Mask to reference →

Masked SCL layer

L2A SCL layer

- no data
- saturated_or_defective
- topographic shadow
- clouds_shadows
- vegetation
- non_vegetated
- water
- unclassified
- cloud_medium_probability
- cloud_high_probability
- thin_cirrus
- snow

Accuracy assessment

- Confusion matrix
- Overall accuracy (OA)
- Producer and User accuracy (PA, UA)
- Omission and Comission error (OE, CE)

Results: Collection-1

Scenes without snow (snow cover < 50%)

	Clear pixels	Cloud pixels	sum	UA	CE	OA
Clear pixels	57%	7%	64%	89%	11%	**92%**
Cloud pixels	1%	35%	36%	98%	2%	
sum	58%	42%	100%			
PA	99%	83%				Balanced OA
OE	1.4%	17.2%				**94%**

Scenes with snow (snow cover > 50%)

	Clear pixels	Clouds pixels	sum	UA	CE	OA
Clear pixels	49%	19%	69%	72%	28%	**71%**
Clouds pixels	9%	22%	31%	70%	30%	
sum	58%	42%	100%			
PA	84%	53%				Balanced OA
OE	15.9%	46.9%				**78%**

Overall Accuracy difference of SCL products between pre-Collection-1 and Collection-1 products

	1	2	3	4	5	6	7	8	9	10	11	12
2021	-0,14	-0,53	0,10	0,53	-0,08	-0,42	-0,61	-0,16	-0,03	2,24	-0,02	1,02
2020	-0,12	0,00	0,00	0,03	-0,08	0,06	3,24	-1,21	0,10	-0,08	0,20	0,27

Overall Accuracy difference (%)
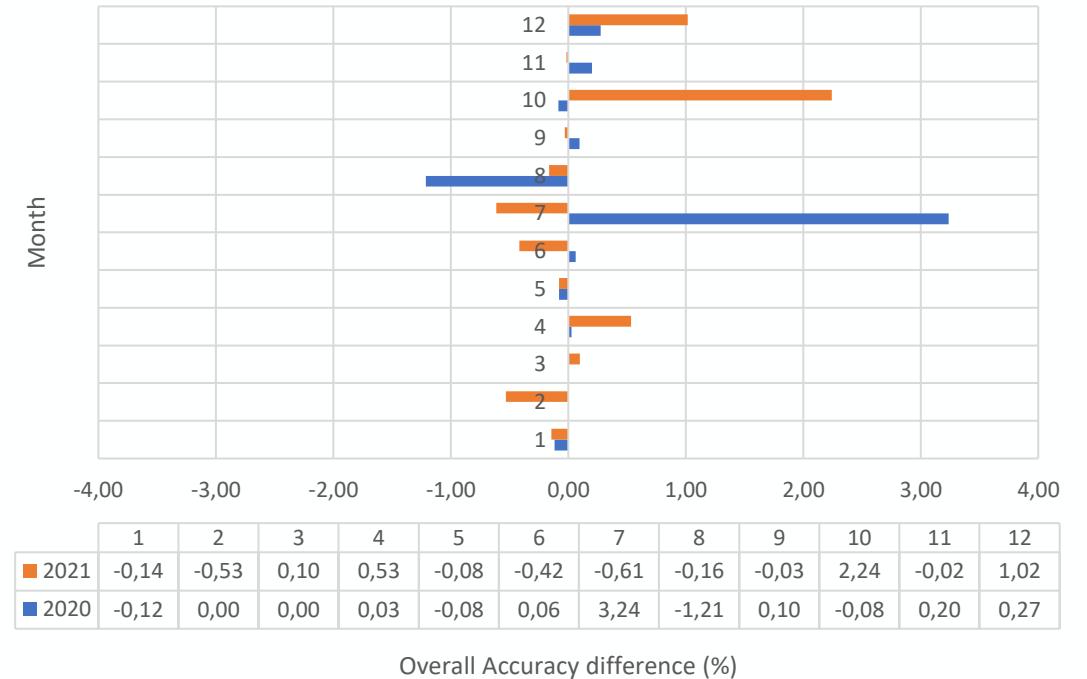
$$\Delta OA = OA_{Collection-1} - OA_{pre-Collection-1}$$

- OA differences are small (-1.21 to 3.24%)
- Improvements in detecting topographic shadows on scenes in Yakutsk and Rimrock
- Overestimation of topographic shadows on scenes in Potsdam

Results: Collection-1 (PB 05.00)
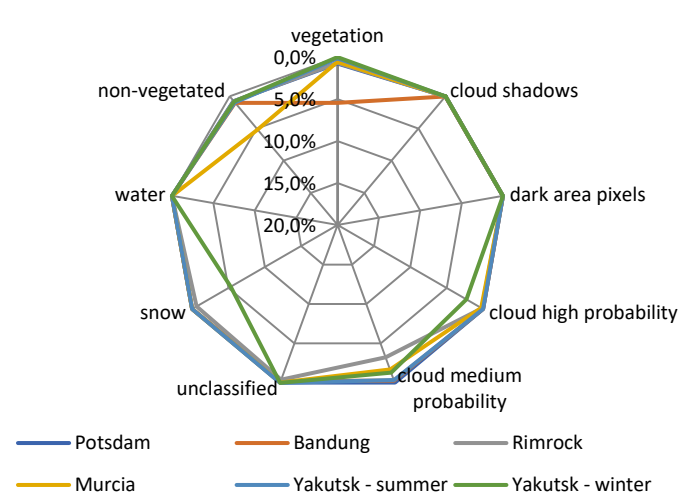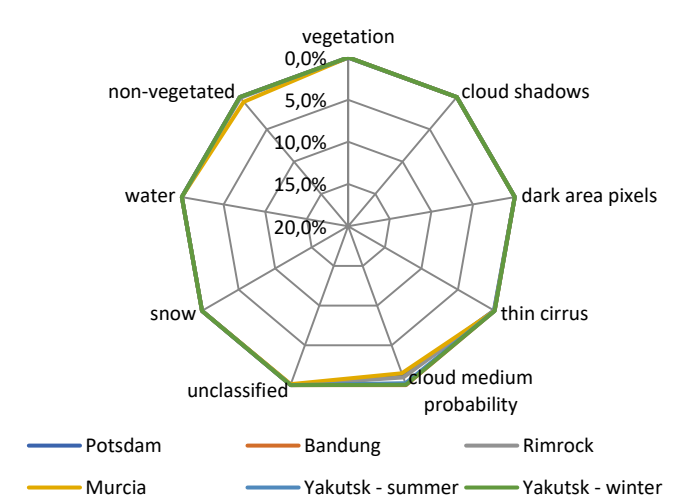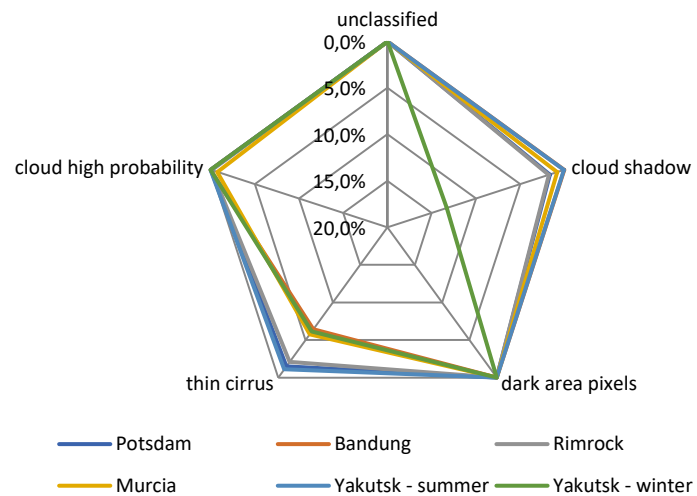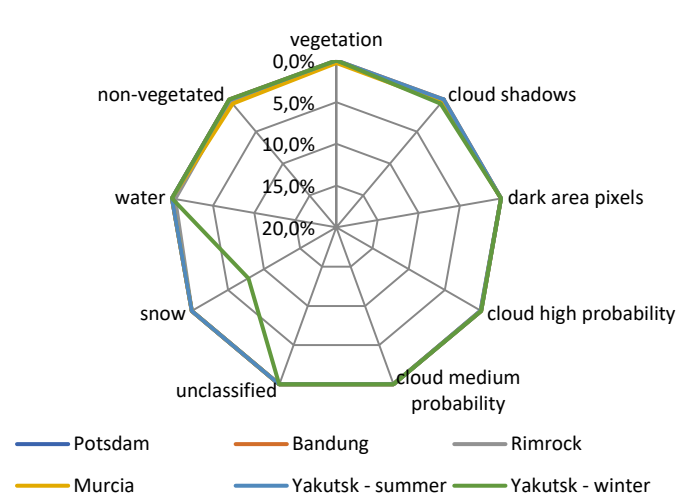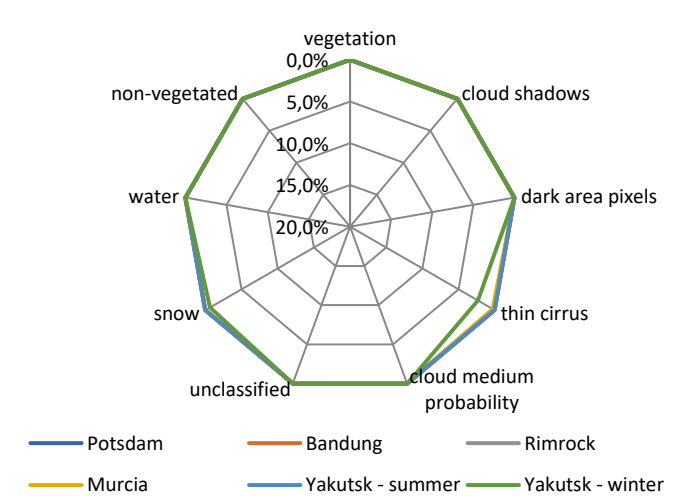
Results: Collection-1 (PB 05.00)

Observed differences: Topographic Shadows

Improved — Rimrock T11TMM 10 Nov 2021: Pre-collection-1 (RGB, SCL) and Collection-1 (RGB, SCL)
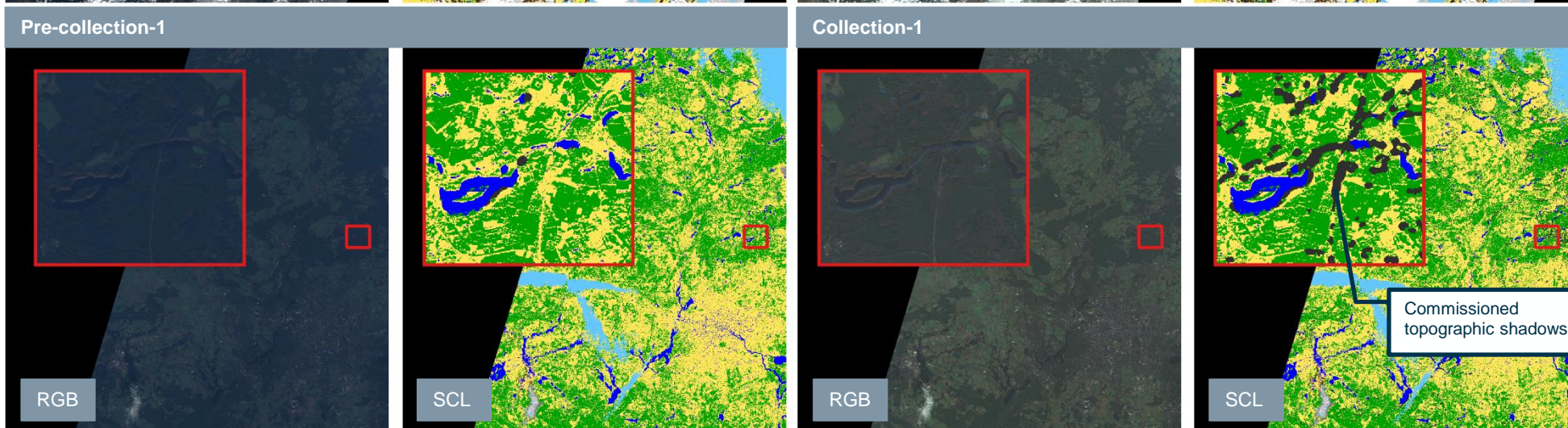
Overestimated — Potsdam T33UUU 19 Dec 2020: Pre-collection-1 (RGB, SCL) and Collection-1 (RGB, SCL)

SCL classes
- no data
- saturated_or_defective
- topographic shadow
- clouds_shadows
- vegetation
- non_vegetated
- water
- unclassified
- cloud_medium_probability
- cloud_high_probability
- thin_cirrus
- snow

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Observed differences: **Topographic Shadows**

Improved

Pre-collection-1 | Collection-1

Rimrock T11TMM 10 Nov 2021

Improved topographic shadows detection

Overestimated

Potsdam T33UUU 19 Dec 2020

Commissioned topographic shadows

SCL classes

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Results: Operational Products (PB 05.09)

Scenes without snow (snow cover < 50%)

	Clear pixels	Cloud pixels	sum	UA	CE	OA
Clear pixels	54%	2%	56%	96%	4%	**95%**
Cloud pixels	3%	41%	44%	94%	6%	
sum	56%	44%	100%			
PA	95%	94%				**Balanced OA**
OE	4.7%	5.6%				**95%**

Scenes with snow (snow cover > 50%)

	Clear pixels	Clouds pixels	sum	UA	CE	OA
Clear pixels	26%	23%	48%	53%	47%	**77%**
Clouds pixels	0%	52%	52%	100%	0%	
sum	26%	74%	100%			
PA	100%	69%				**Balanced OA**
OE	0.0%	30.6%				**77%**

Conclusions
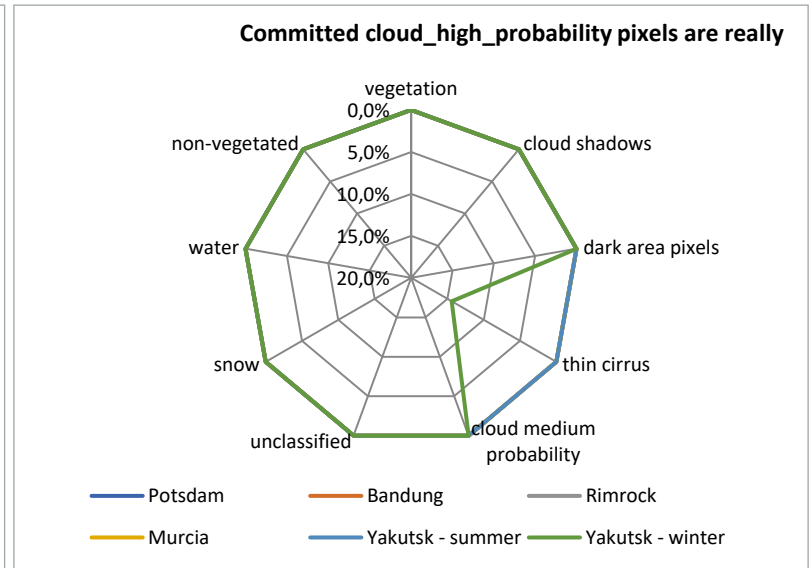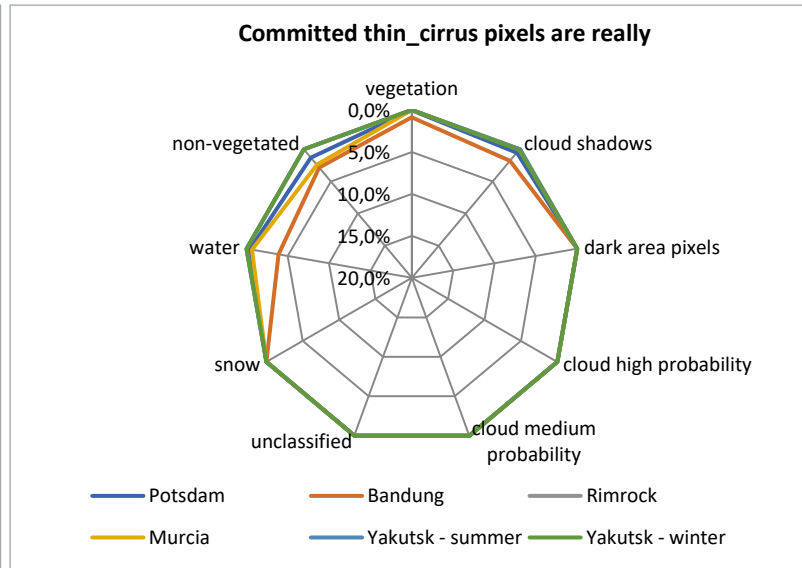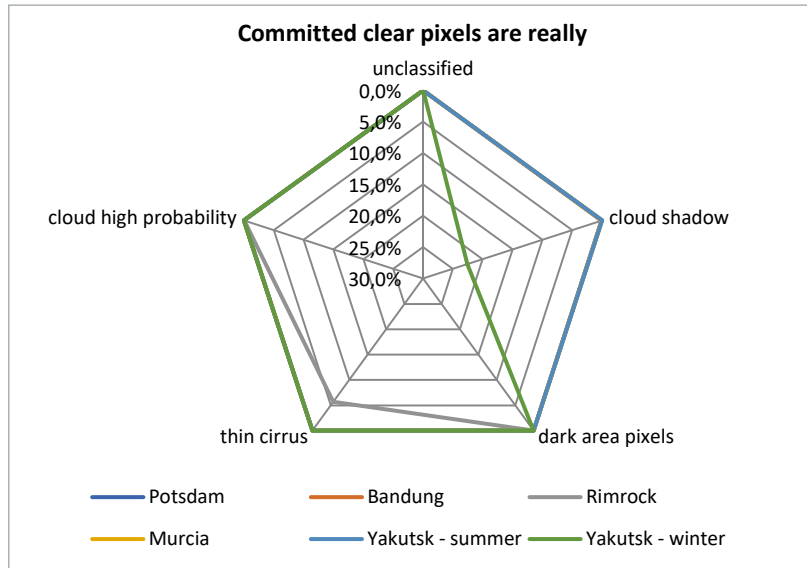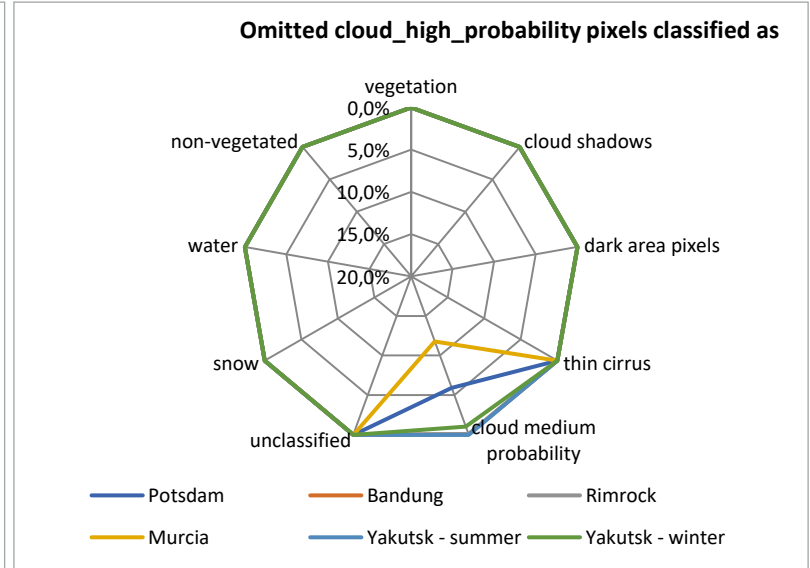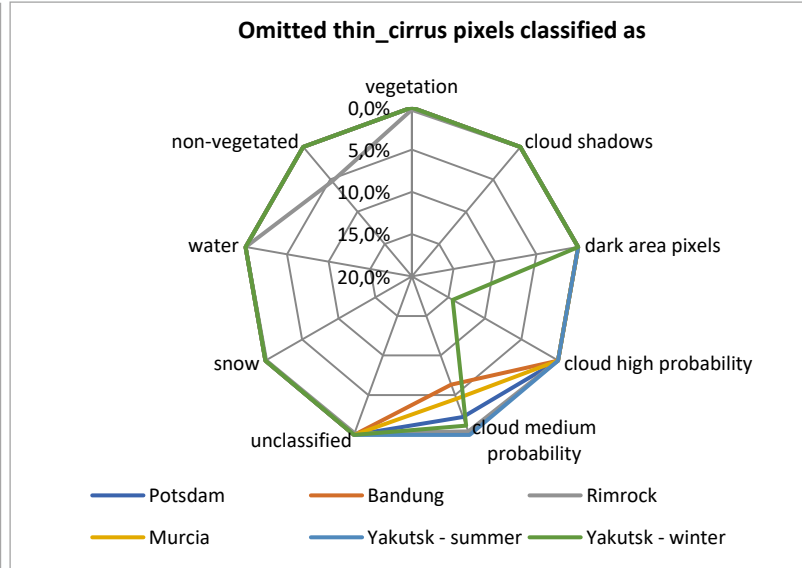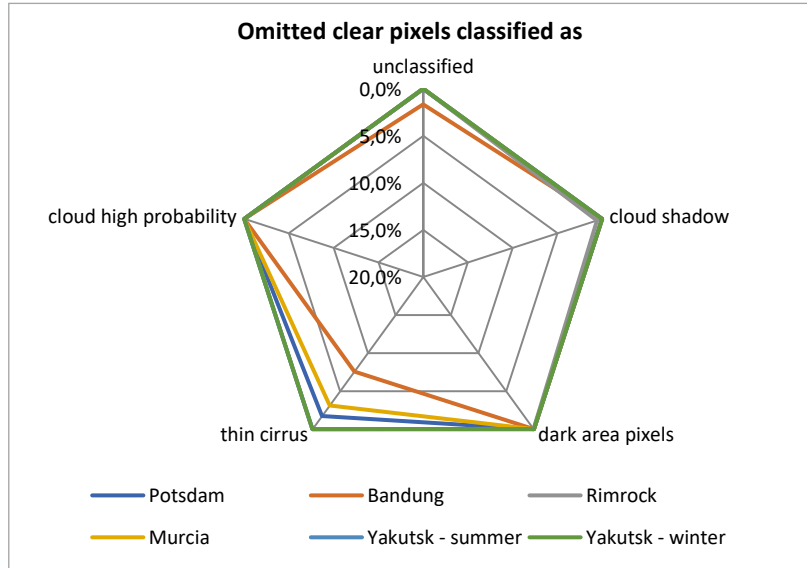
- Collection-1 products (PB 05.00) 2020 - 2021:

  - **Balanced overall accuracy** of scenes without snow is **94%**, as for scenes with snow **78%**

  - **Differences on Overall Accuracies** of pre-Collection-1 and Collection-1 SCL products are small (max **3.24%**)

  - **Improvements on topographic shadow** detection on scenes in Yakutsk and Rimrock

  - **Overpredictions of topographic shadows** over water, vegetation, and non-vegetated pixels in Potsdam

  - **Different Sen2cor versions:** Pre-collection-1 SCL products were processed with **Sen2cor 2.8 and 2.9**, whereas Collection-1 SCL products were processed with **Sen2cor 2.11**

- Operational products (PB 05.09) 2023:

  - **Balanced overall accuracy** of scenes without snow is **95%**, as for scenes with snow **77%**

Conclusions

- **Sen2cor** performed SCL on **scenes without snow cover relatively better** than on scenes with snow cover both on operational and Collection-1 products

- On snow covered scenes, **thin cirrus pixels** are often misclassified as snow and vice versa due to similarity in spectral profiles

- **Cloud shadow pixels on snow** are also often misclassified as clear pixels due to its brighter reflectance compared to cloud shadow on land without snow cover

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Thank you

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