Evolution of BOKU's Sentinel-2 processing line

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With contributions from our team

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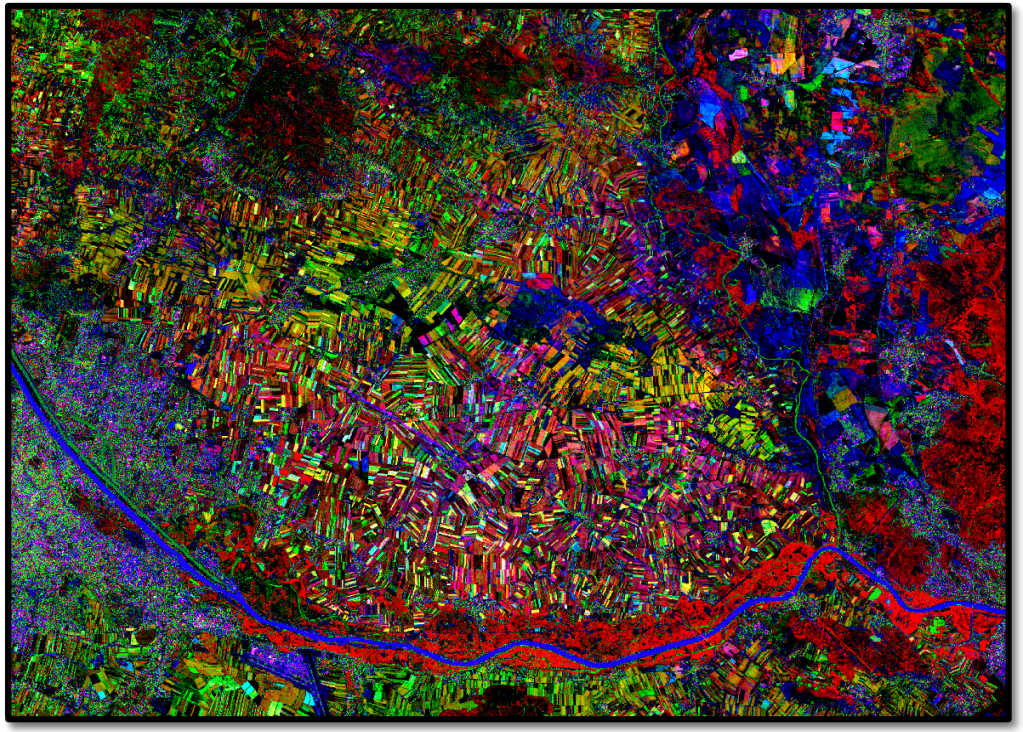
Institute of Surveying, Remote Sensing and Land Information (IVFL)

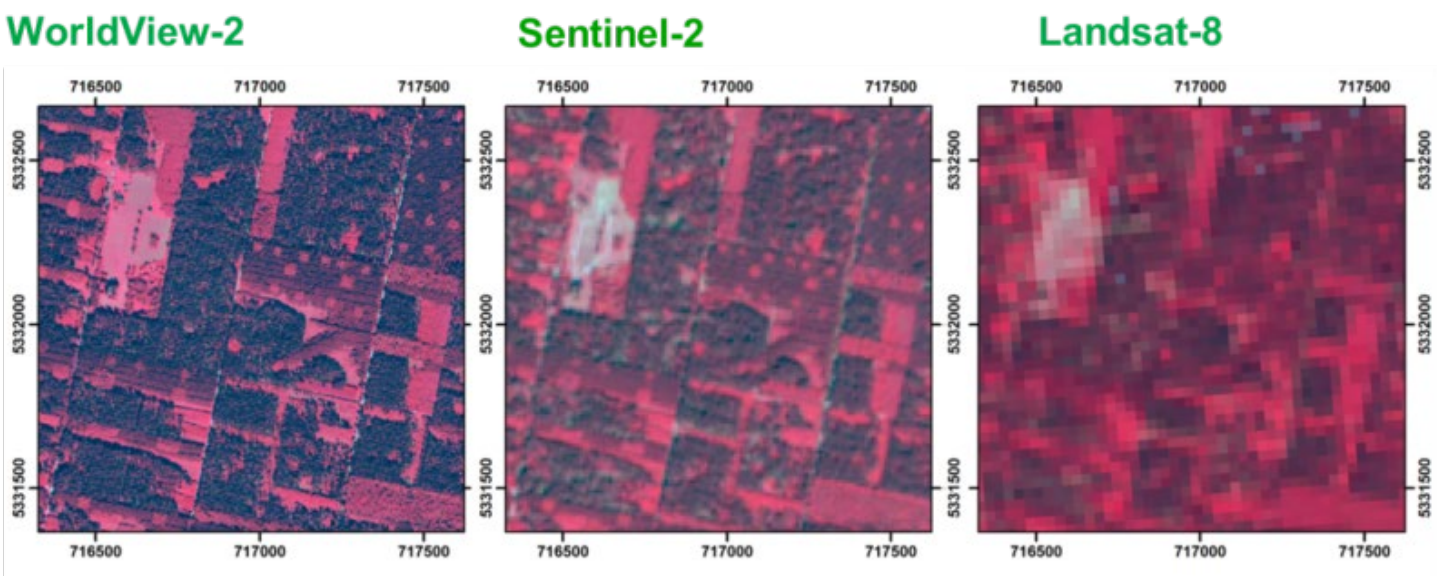
sentinel-2

- Sentinel-2
  - 10 spectral bands (+3)
  - 10-20 m spatial resolution
  - wide swath width (290 km)
  - high revisit time (~5 days)



PCs: 1-2-3: 30/08/2015

PCs: 5-6-7: 30/08/2015



Sentinel-2 Level 2-A processor (2016)

on-demand atmospheric correction & higher level products

Open Access | Technical Note

Data Service Platform for Sentinel-2 Surface Reflectance and Value-Added Products: System Use and Examples

by Francesco Vuolo, Mateusz Żółtak, Claudia Pipitone, Luca Zappa, Hannah Wenng, Markus Immitzer, Marie Weiss, Frederic Baret and Clement Atzberger

Remote Sens. **2016**, *8*(11), 938; https://doi.org/10.3390/rs8110938

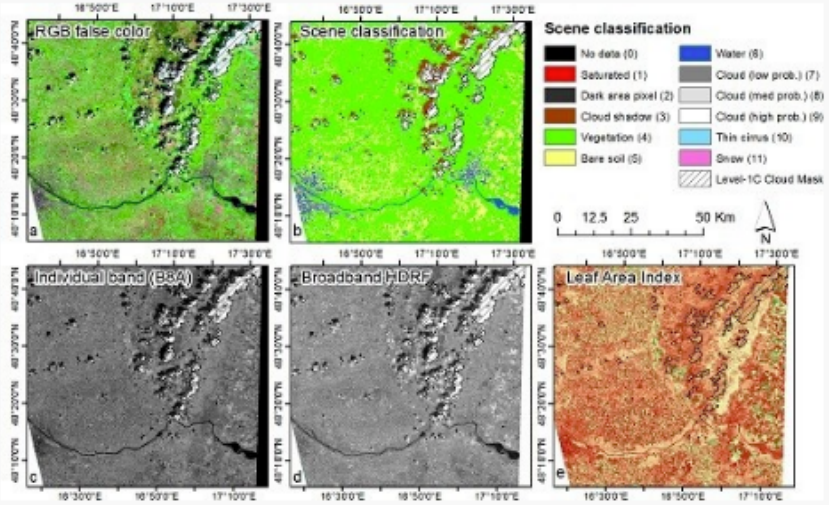
Received: 1 August 2016 / Revised: 12 October 2016 / Accepted: 6 November 2016 / Published: 11 November 2016

Cited by 36 | Viewed by 4346 | PDF Full-text (13665 KB) | HTML Full-text | XML Full-text

Abstract This technical note presents the first Sentinel-2 data service platform for obtaining atmospherically-corrected images and generating the corresponding value-added products for any land surface on Earth. Using the European Space Agency's (ESA) *Sen2Cor* algorithm, the platform processes ESA's Level-1C top-of-atmosphere reflectance to atmospherically-corrected [...] Read more.

(This article belongs to the Special Issue First Experiences with European Sentinel-2 Multi-Spectral Imager (MSI))

▼ Figures



Graphical abstract

First data processing infrastructure for Sentinel-2 data

Sentinel-2 Level 2-A processor (2017)

on-demand atmospheric correction & higher level products

Sentinel2 Data Portal Wiki

- 2019-03-12 Service maintenance
- 2018-12-13 Ndvi endpoint added
- 2018-11-26 Service maintenance
- 2018-10-25 Data loss
- 2018-10-16 Scheduled m
- 2018-10-16 Normal oper resumed
- 2018-08-15 EODC infras problems
- 2018-10-11 Topographic
- 2018-10-08 Granules de
- 2018-08-14 EODC Maint
- 2018-06-22 New DEMs

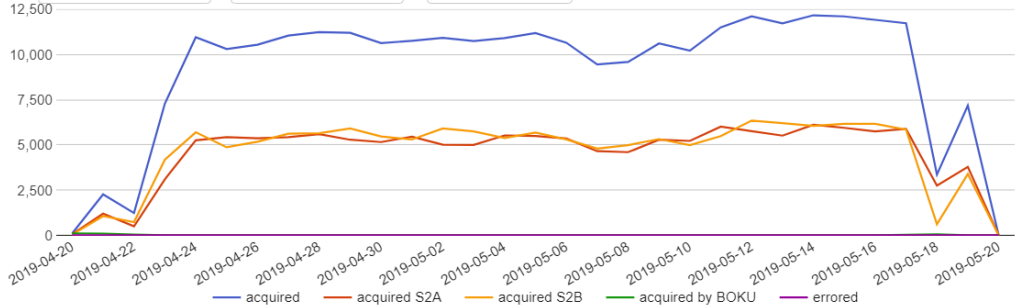
As RSS feed

2019-03-12 Service maintenance

Due to our infrastructure provide maintenance the service will be down between 12th March 5pm and 13th Match 8pm.

Granules provided by EODC

from 04/20/2019 to 05/20/2019 by acquisition date



Last check: 2019-05-20 20:05:00

Angle

download	OK	0.481476 s
getCollection	OK	0.318161 s
getCollectionFilters	OK	16.510115 s

Calc

granuleNdvi	OK	527.190824 s
granuleNdviTransform	OK	15.011104 s

Granule

download	OK	0.322291 s
getCollection	OK	1.35662 s

DATA ACCESS

Need a single Sentinel-2A image ?

Use our web-interface after a one-step registration proces

https://s2.boku.eodc.eu

Need bulk Sentinel-2A data access ?

Get our **sentinel2 R package** on github.com

https://github.com/IVFL-BOKU/sentinel2

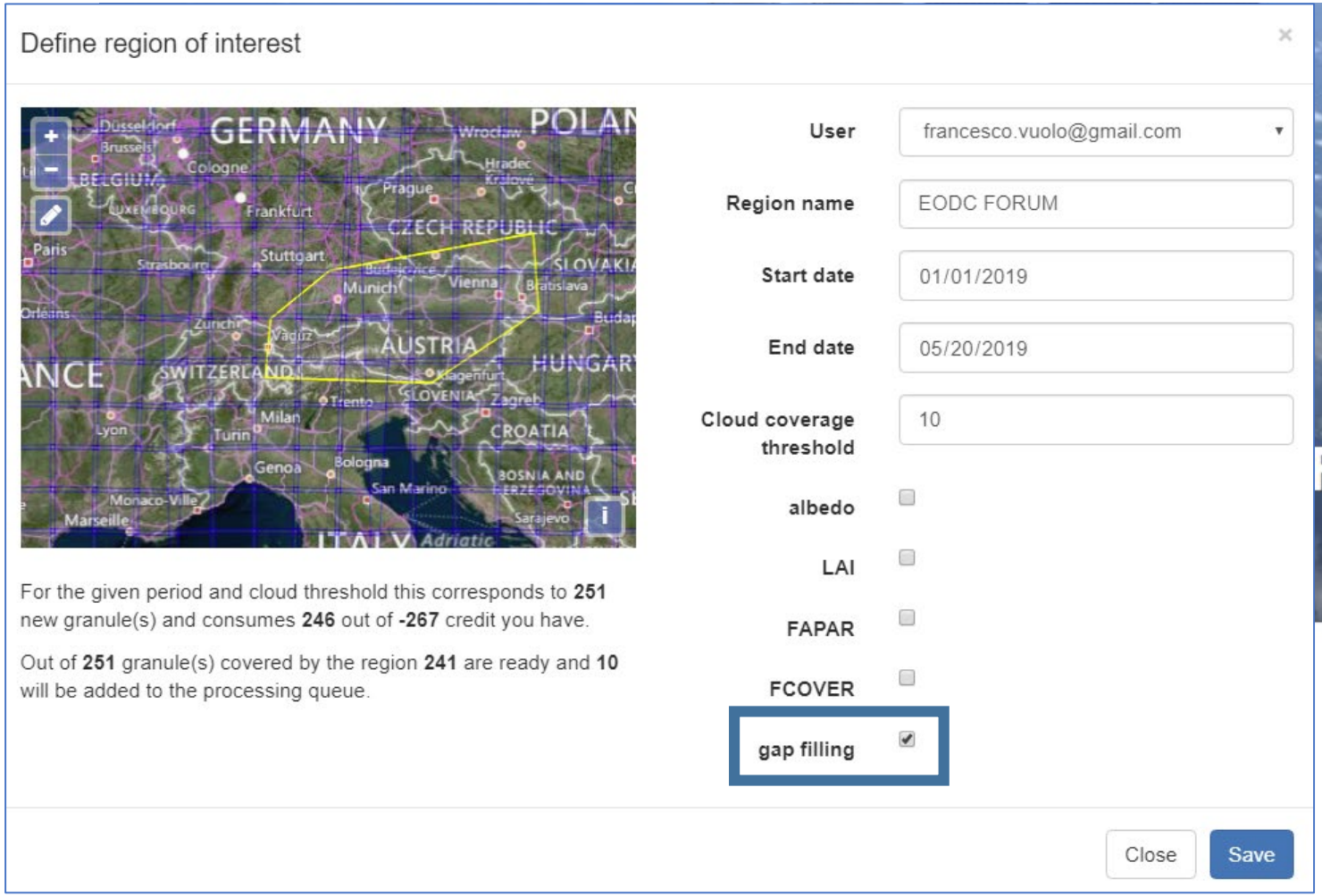
Need more flexibility?

Explore our application programming interface (API):

Wiki API https://s2.boku.eodc.eu/wiki/

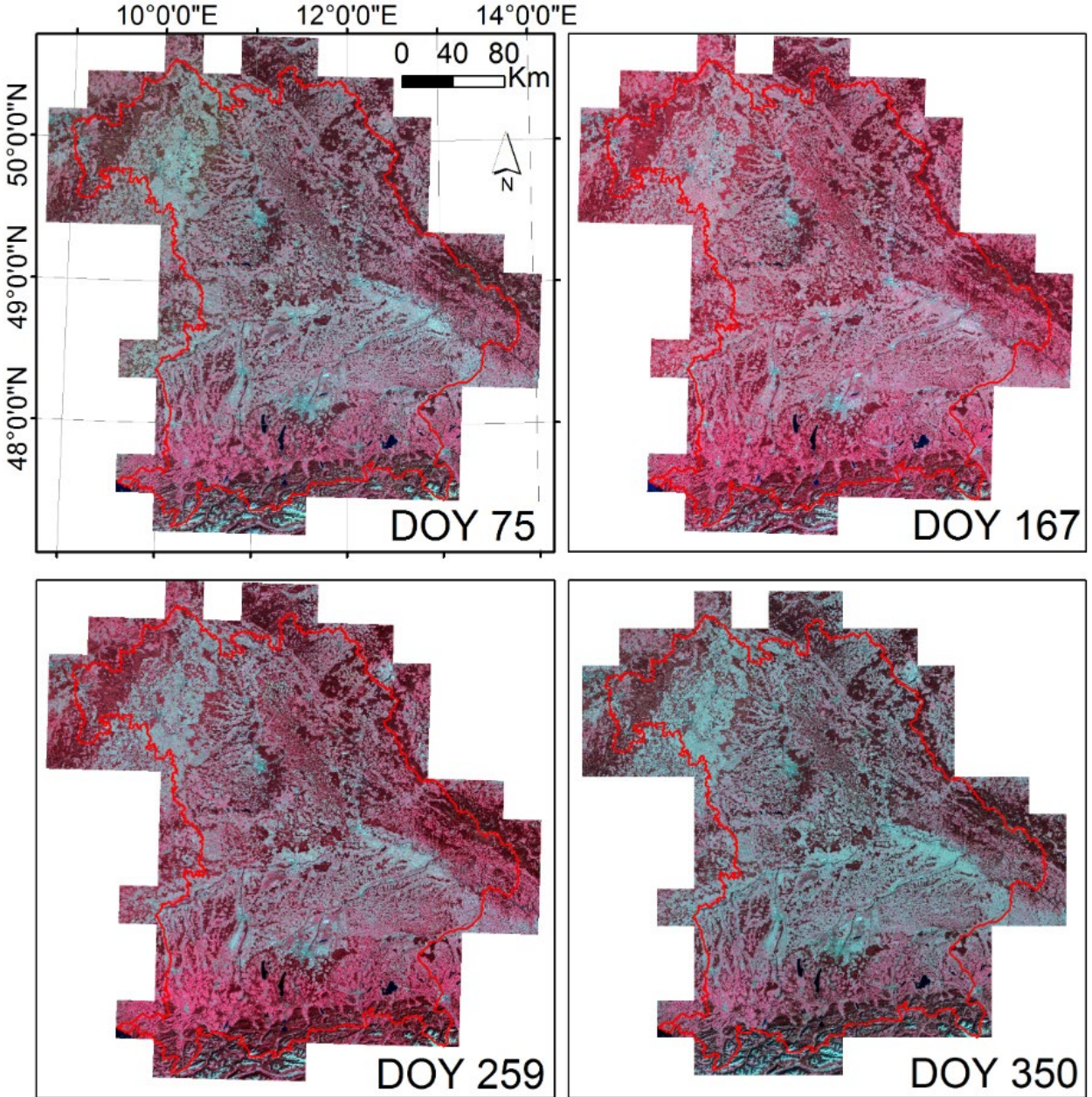
Sentinel-2 Level 2-A processor (2018)

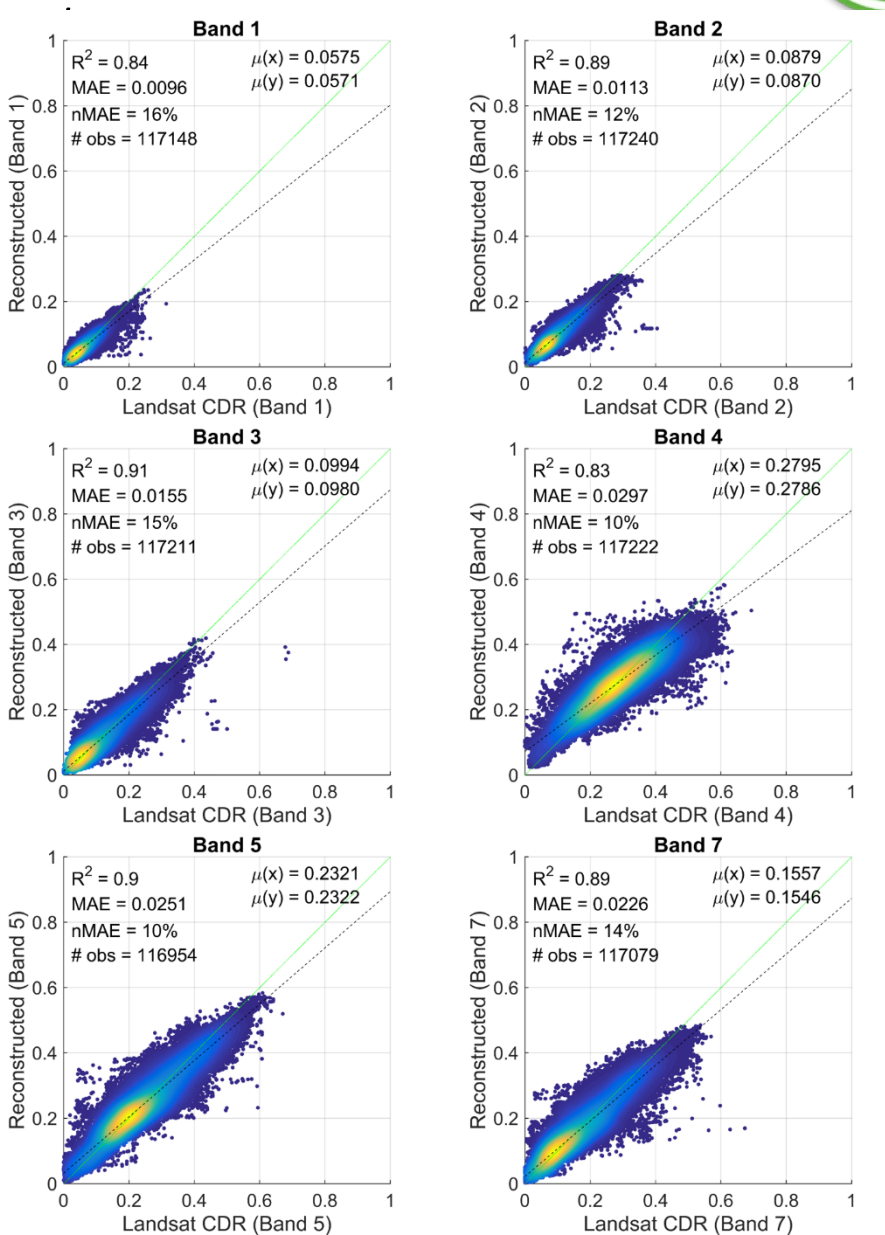
on-demand atmospheric correction & higher level products



On-demand smoothing and gap-filling

Sentinel-2 Level 2-A processor (2018)





Sentinel-2 Level 2-A processor (2016-2018)

Near real time access

Essential Climate Terrestrial Variables

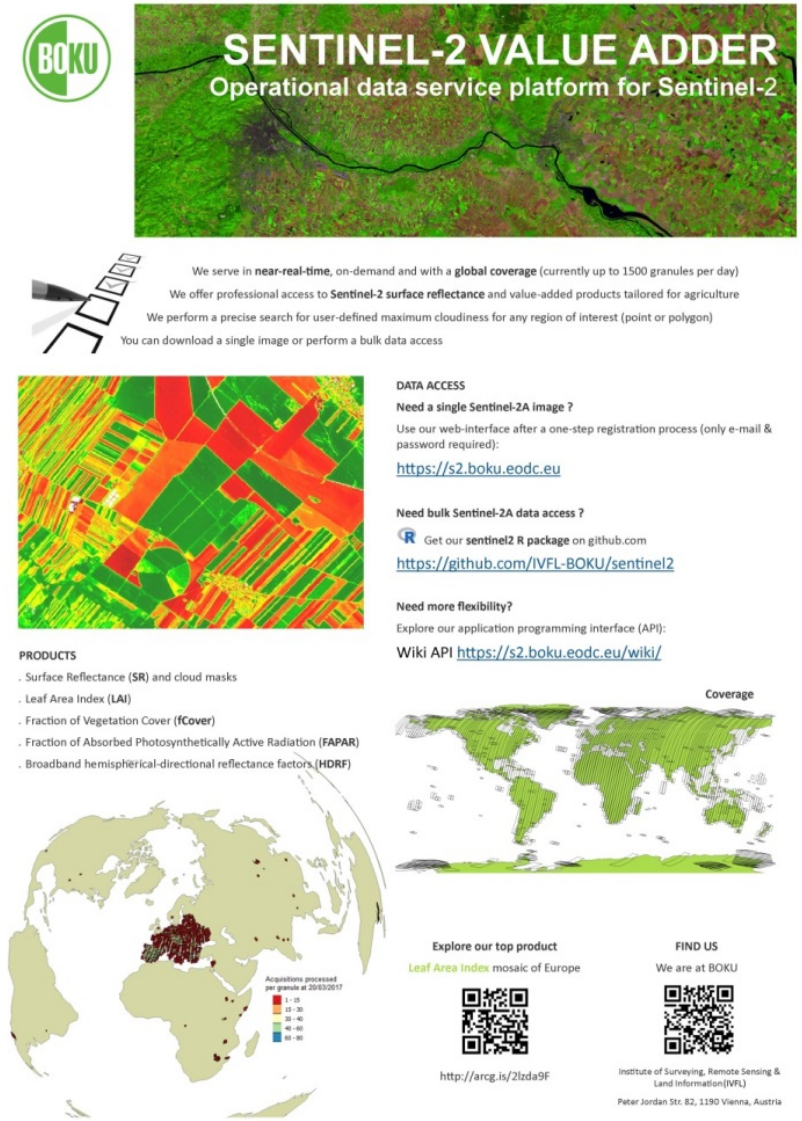
Richest metadata catalogue

Global coverage

1500+ per day

Regular processing of EU

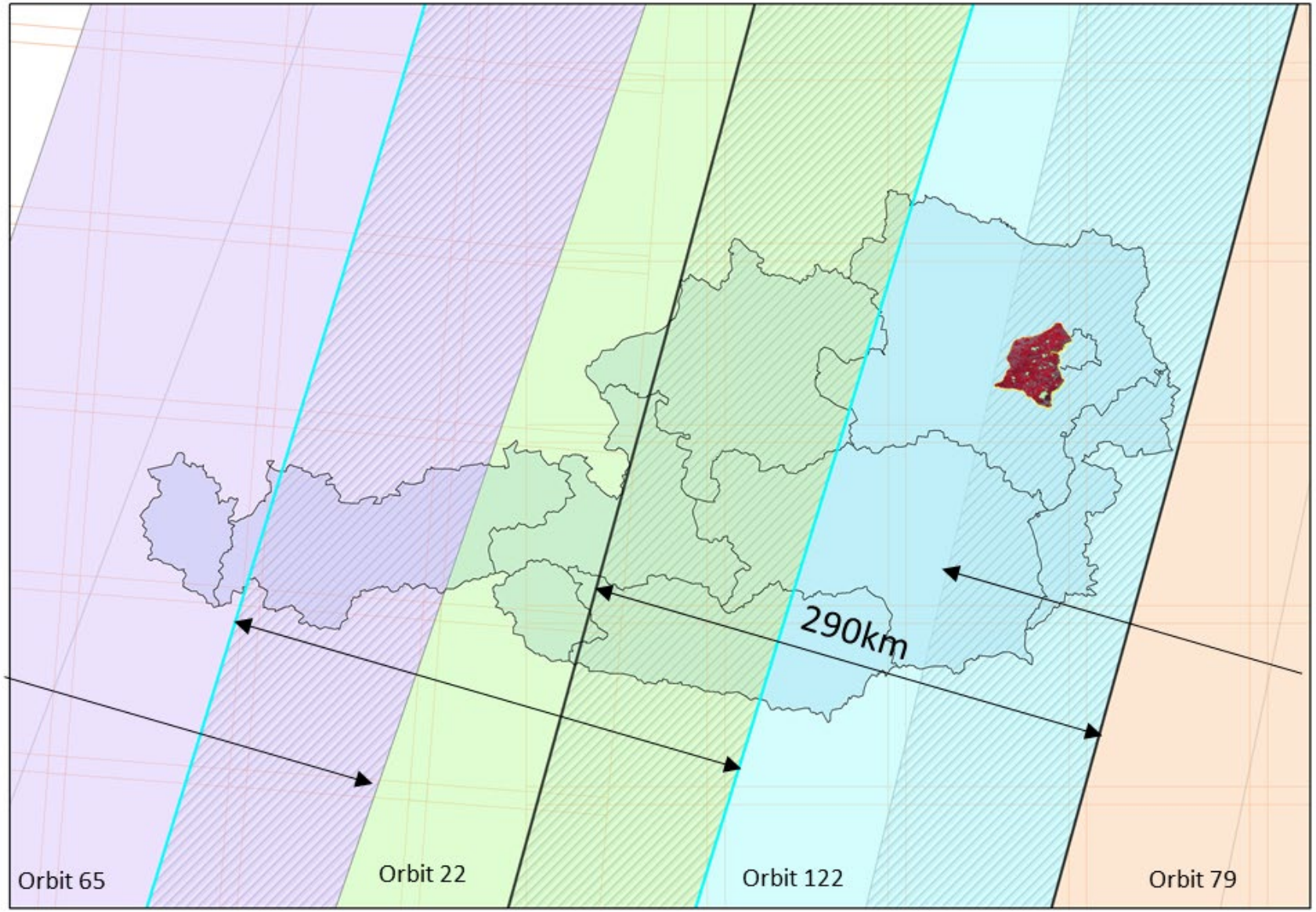
pre-DIAS example



Challenge 1: data granularity

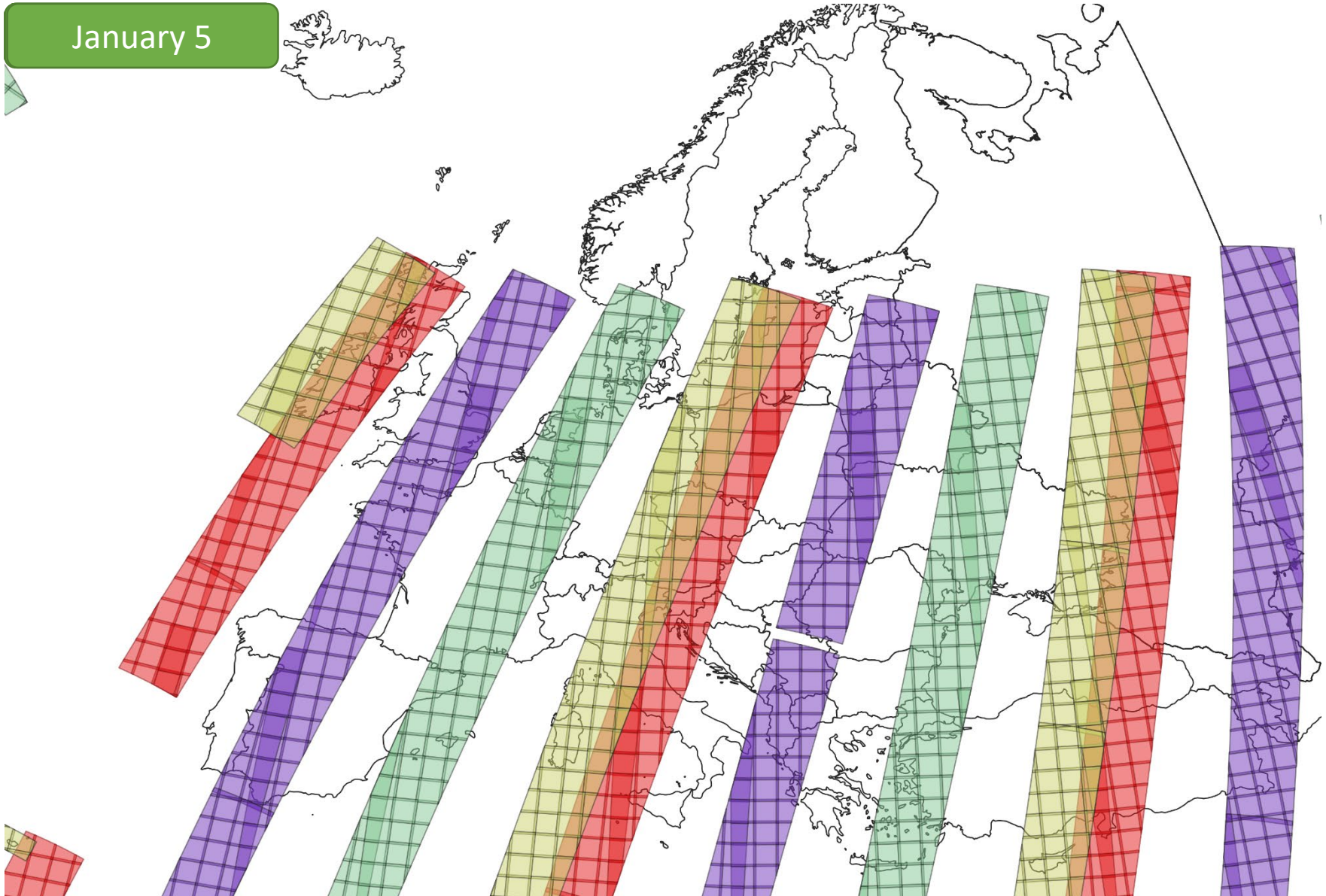
spatially and temporally fragmented EO data

A datacube is needed to facilitate the exploitation of multi-temporal and multi-satellite datasets



Challenge 1: data granularity

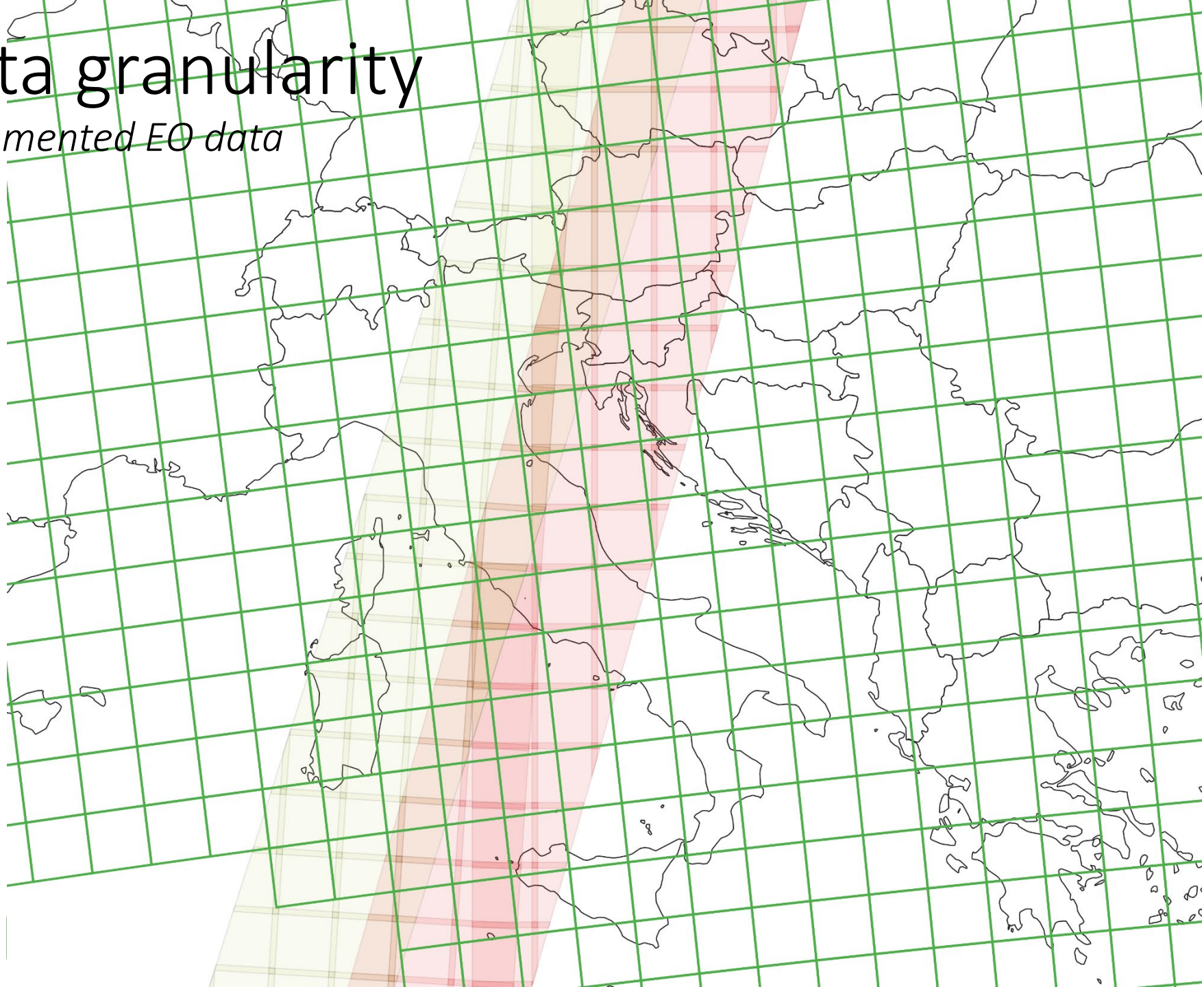
spatially and temporally fragmented EO data



All observations, only 1 of the 2 S-2 missing

Challenge 1: data granularity

spatially and temporally fragmented EO data



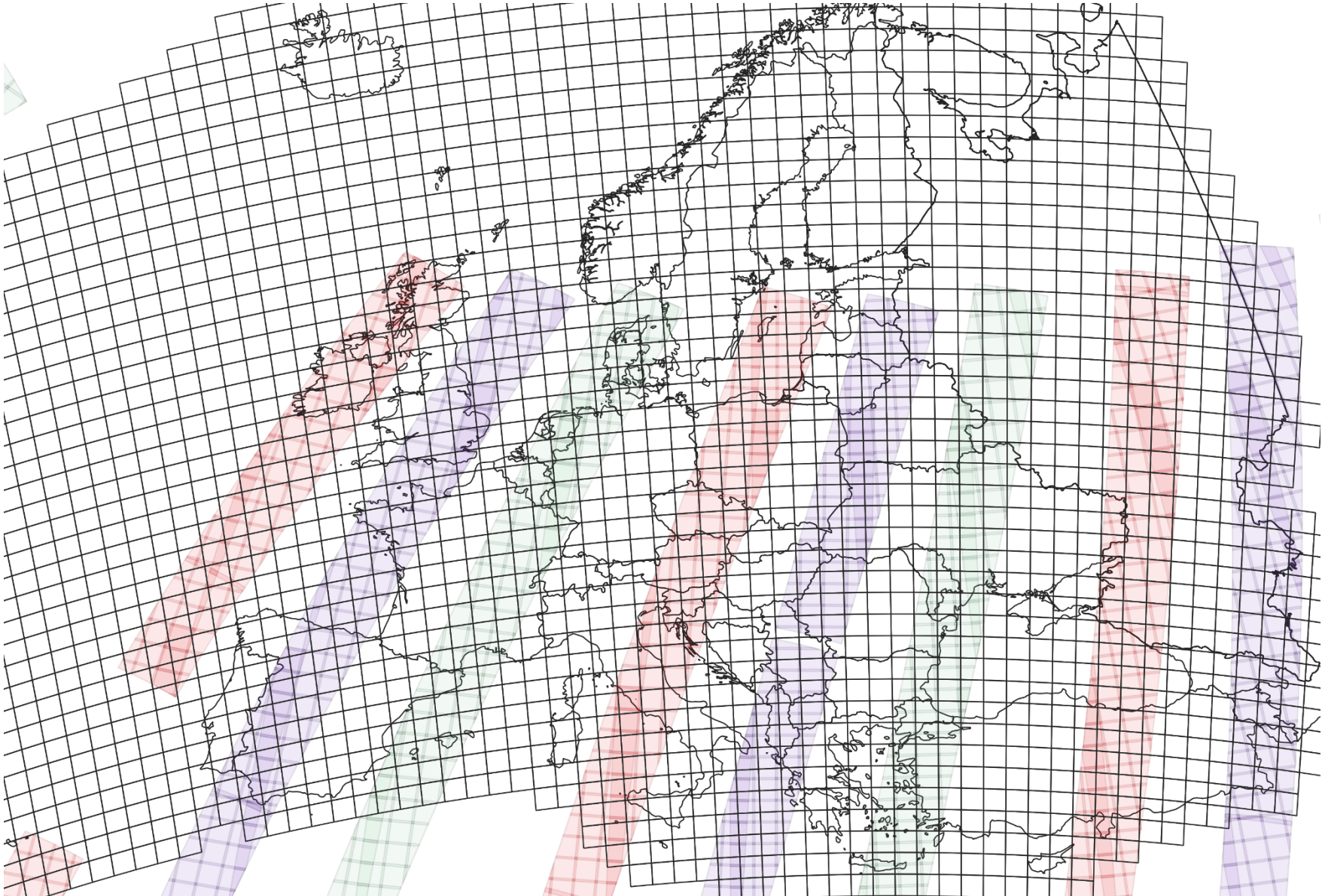
Re-project to **Equi7Grid**

Challenge 1: data granularity

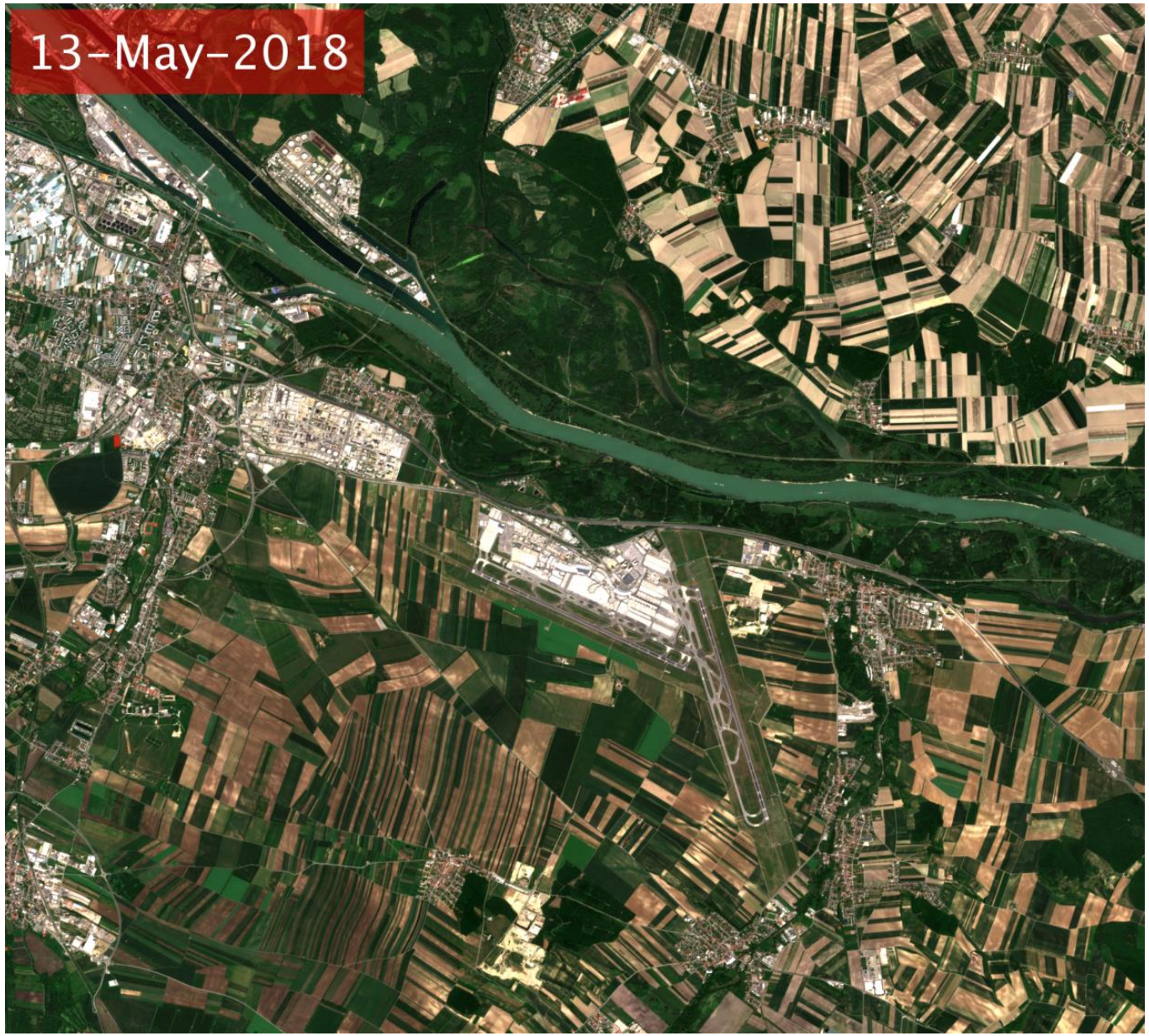
spatially and temporally fragmented EO data

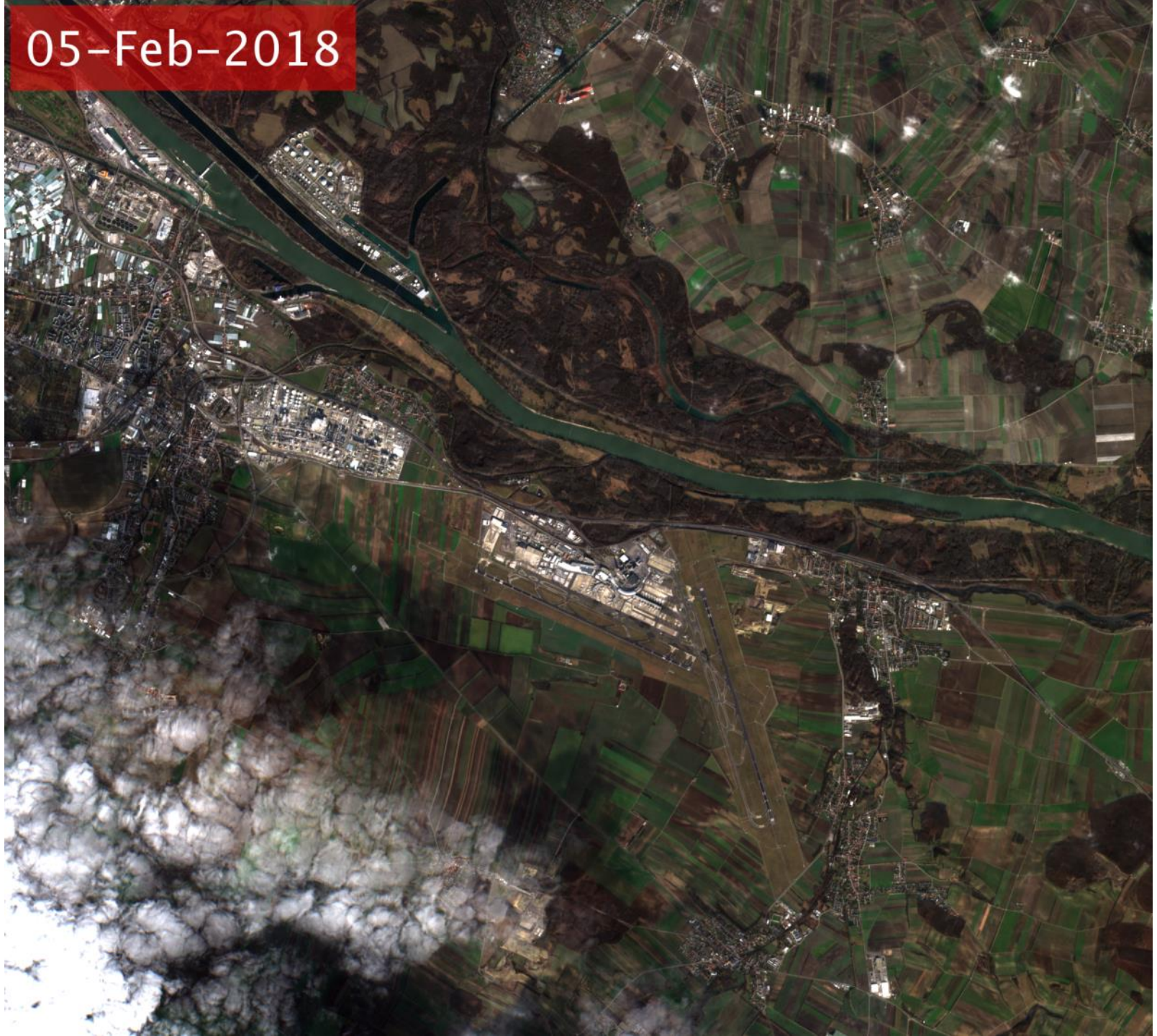
Equi7Grid
European Coverage

Compatible with other available data cubes (S-1)



Challenge 2: Cloud masking & temporal composite

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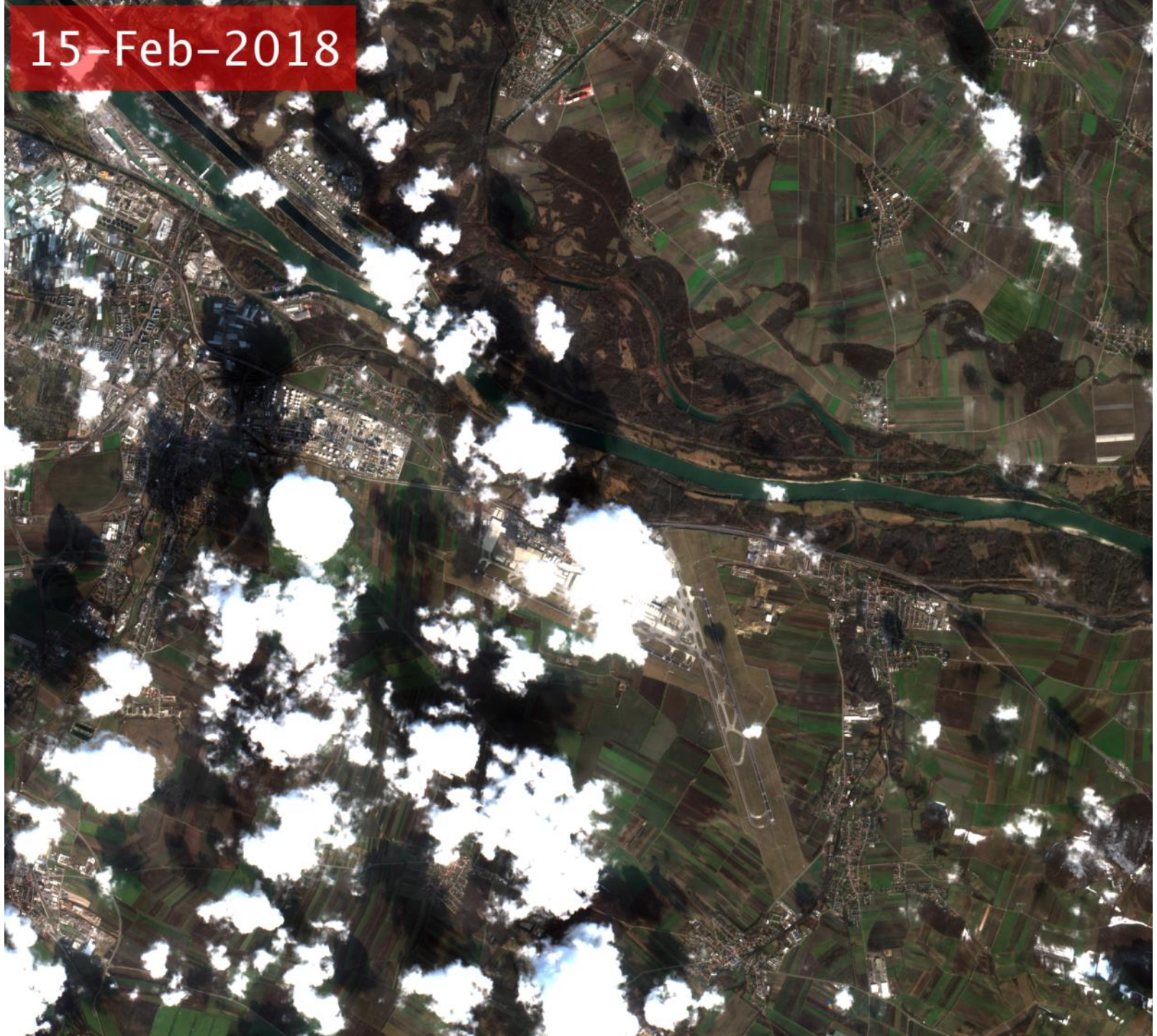
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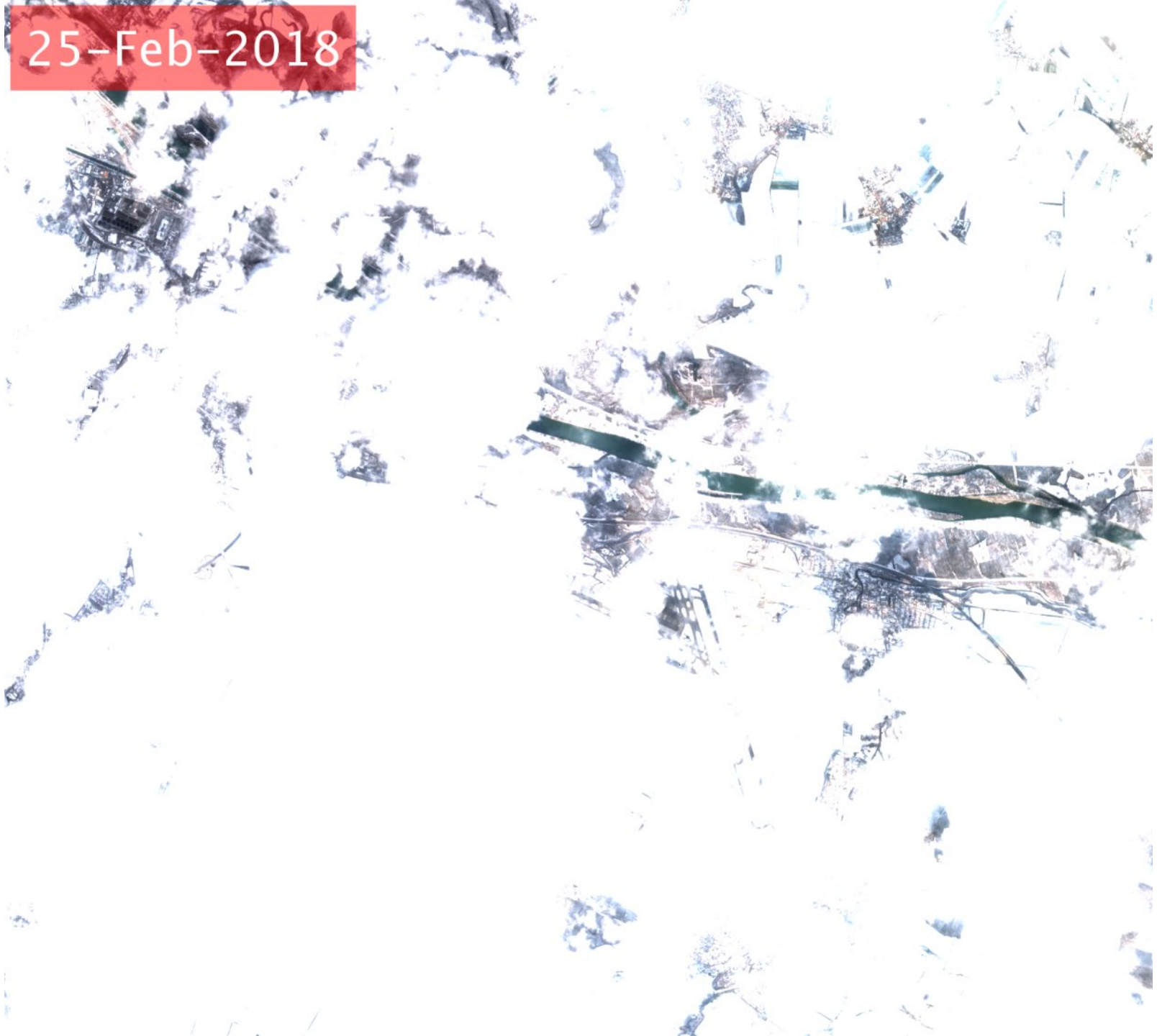
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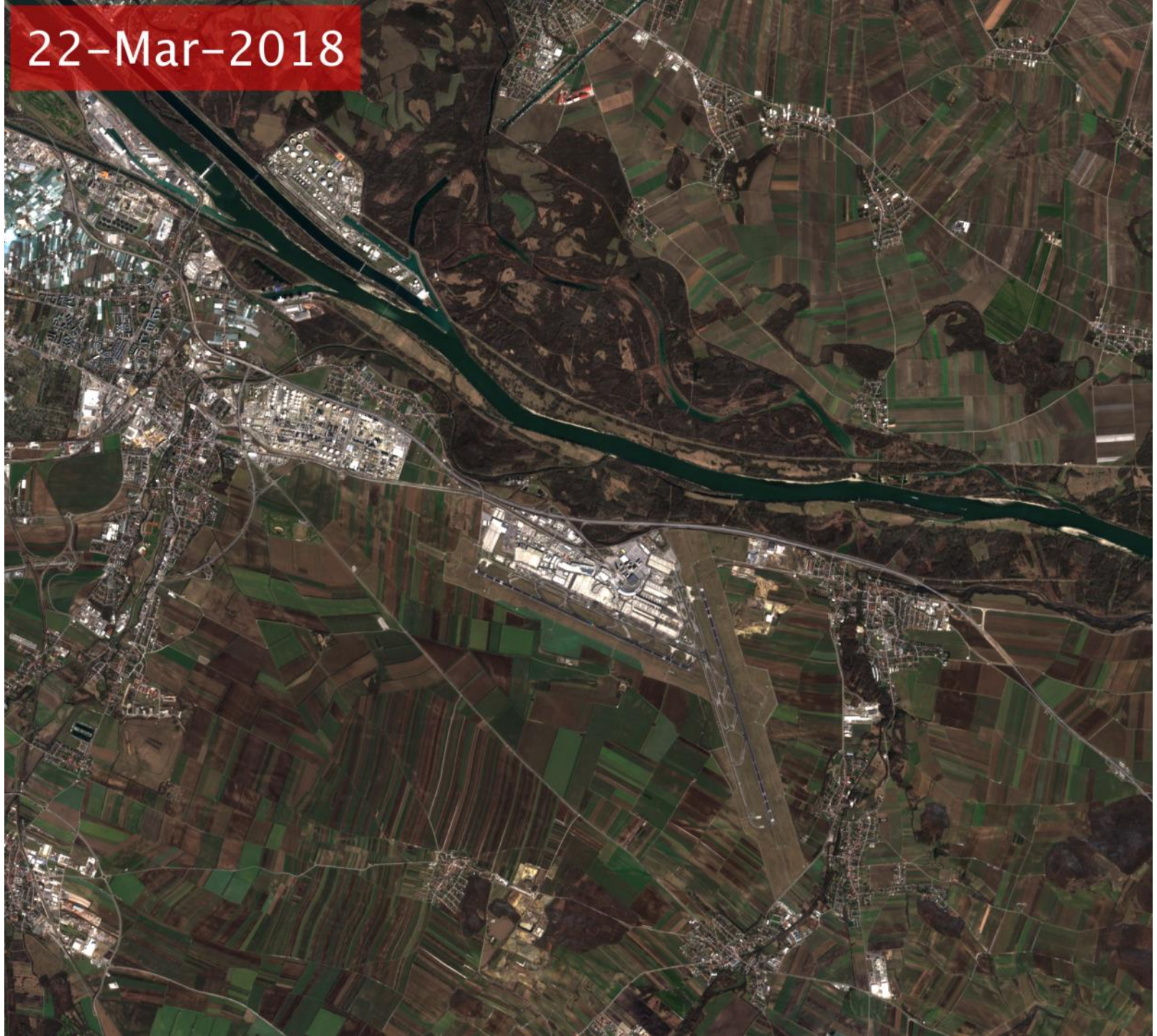
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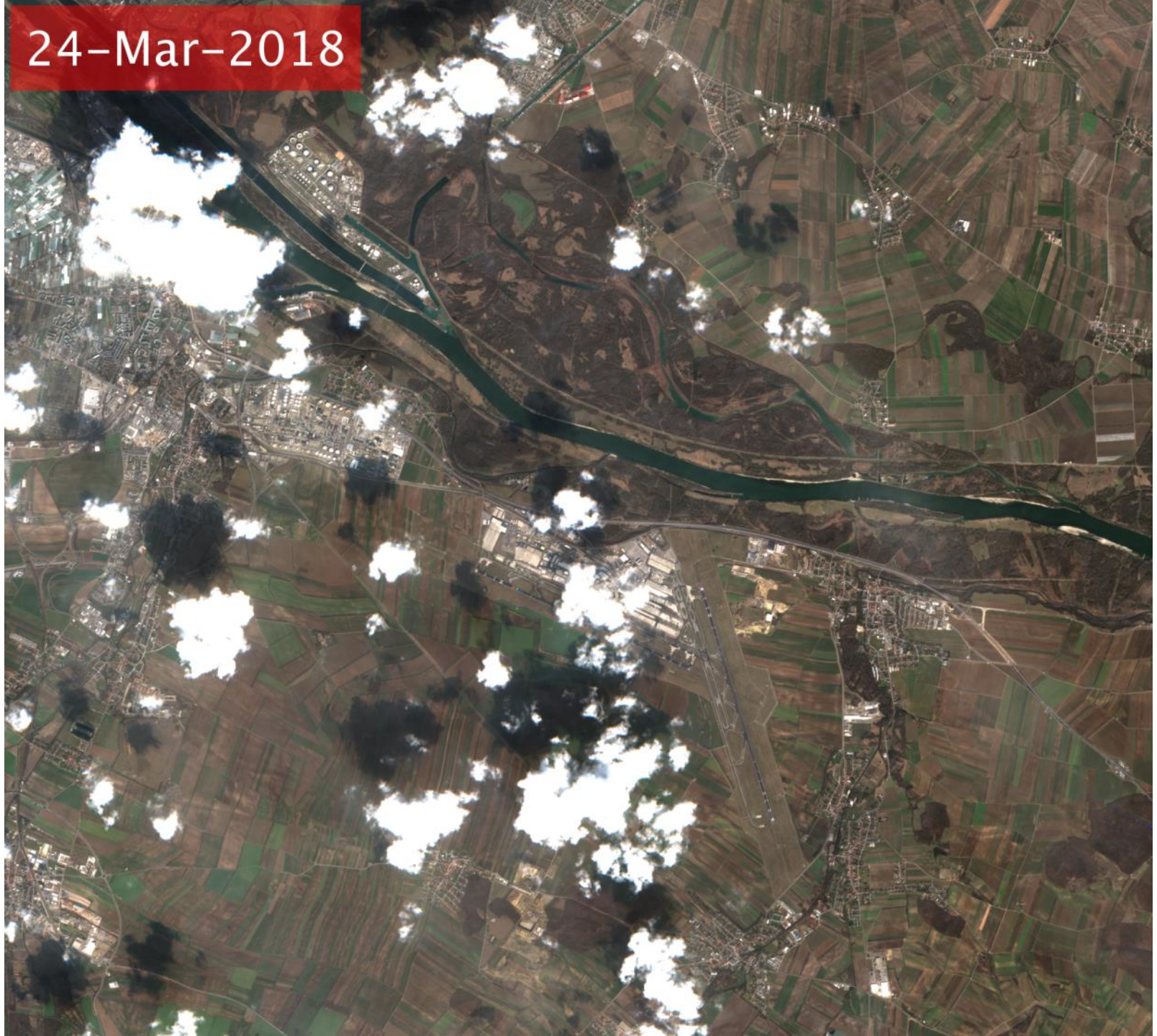
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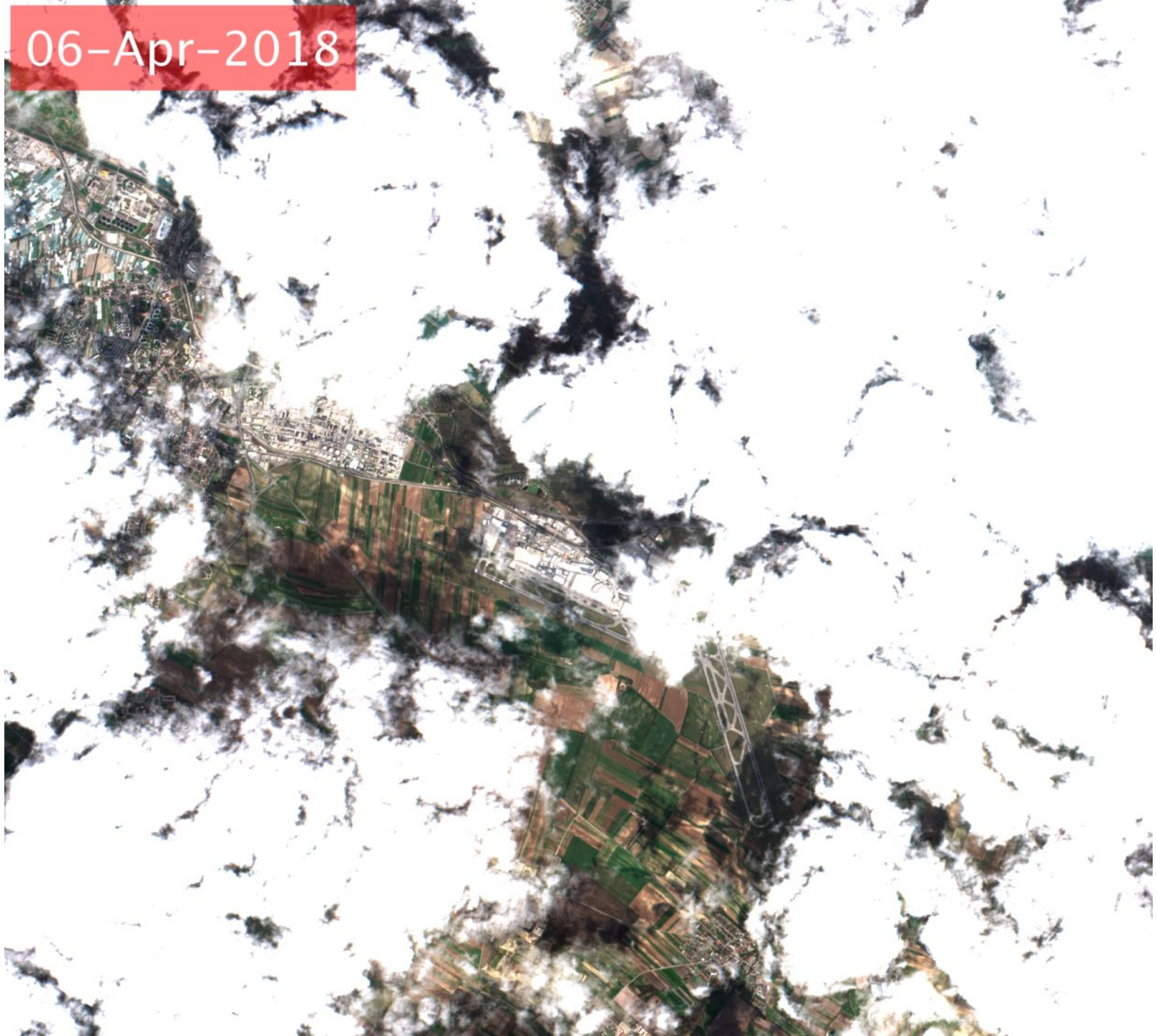
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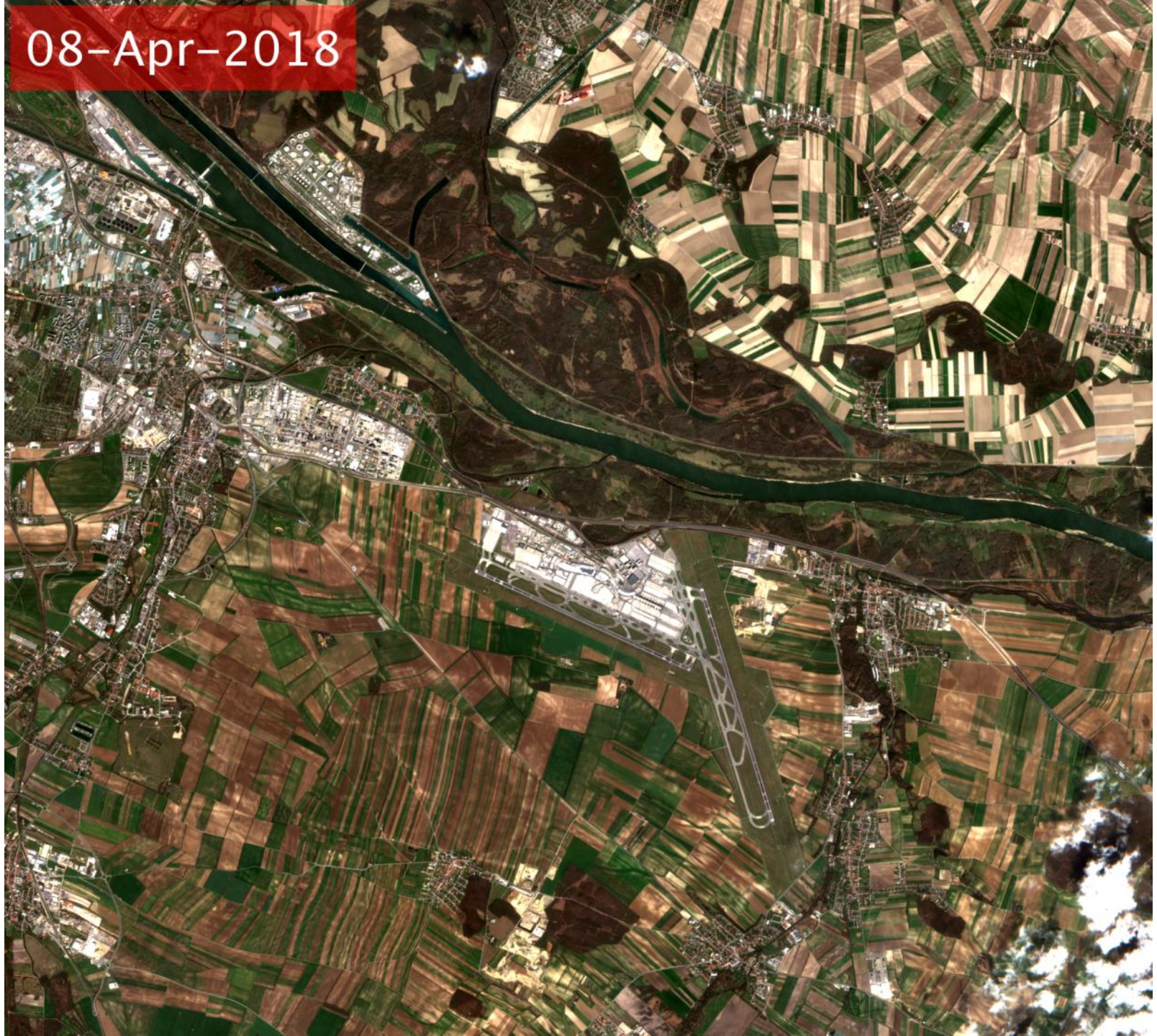
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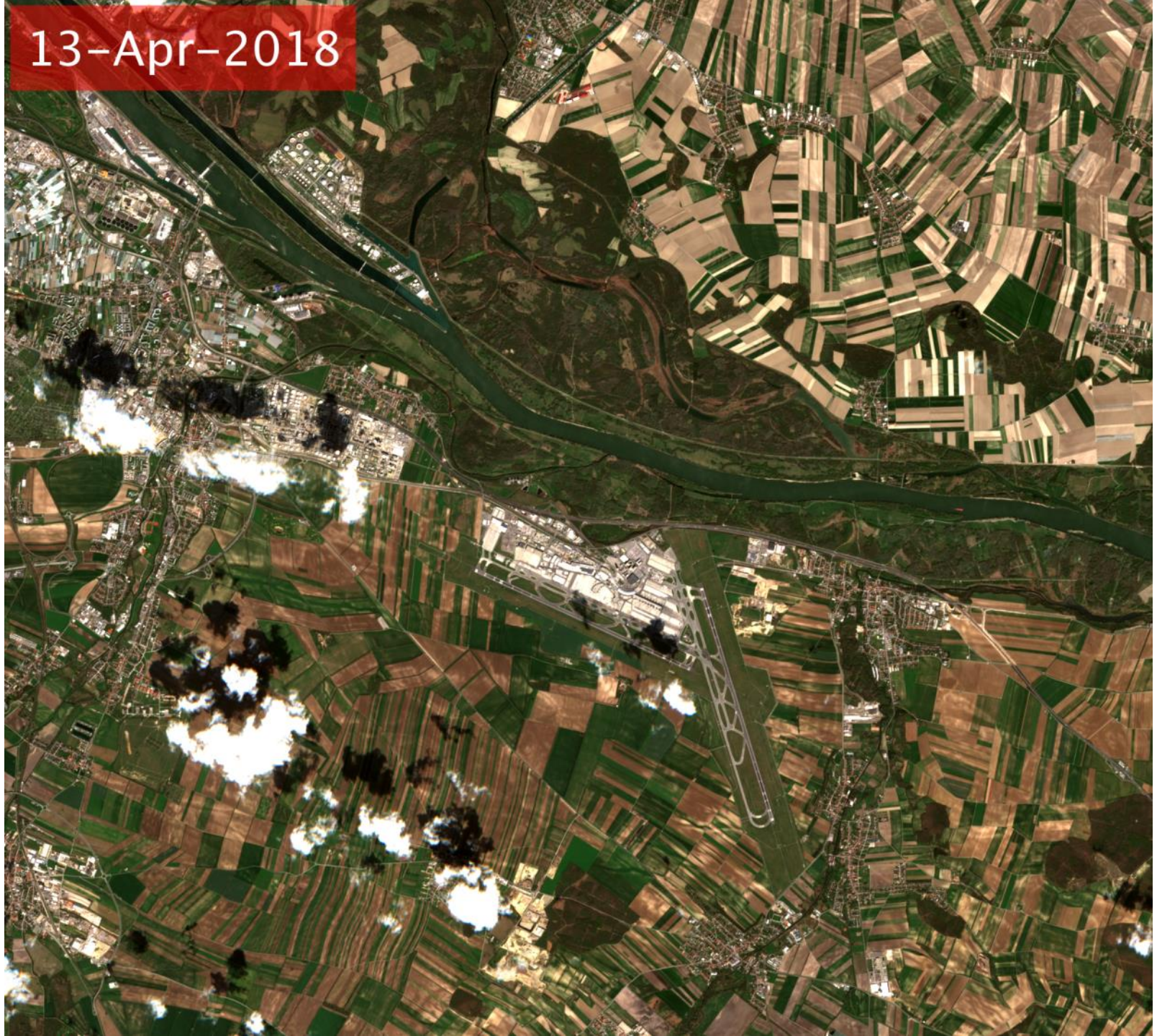
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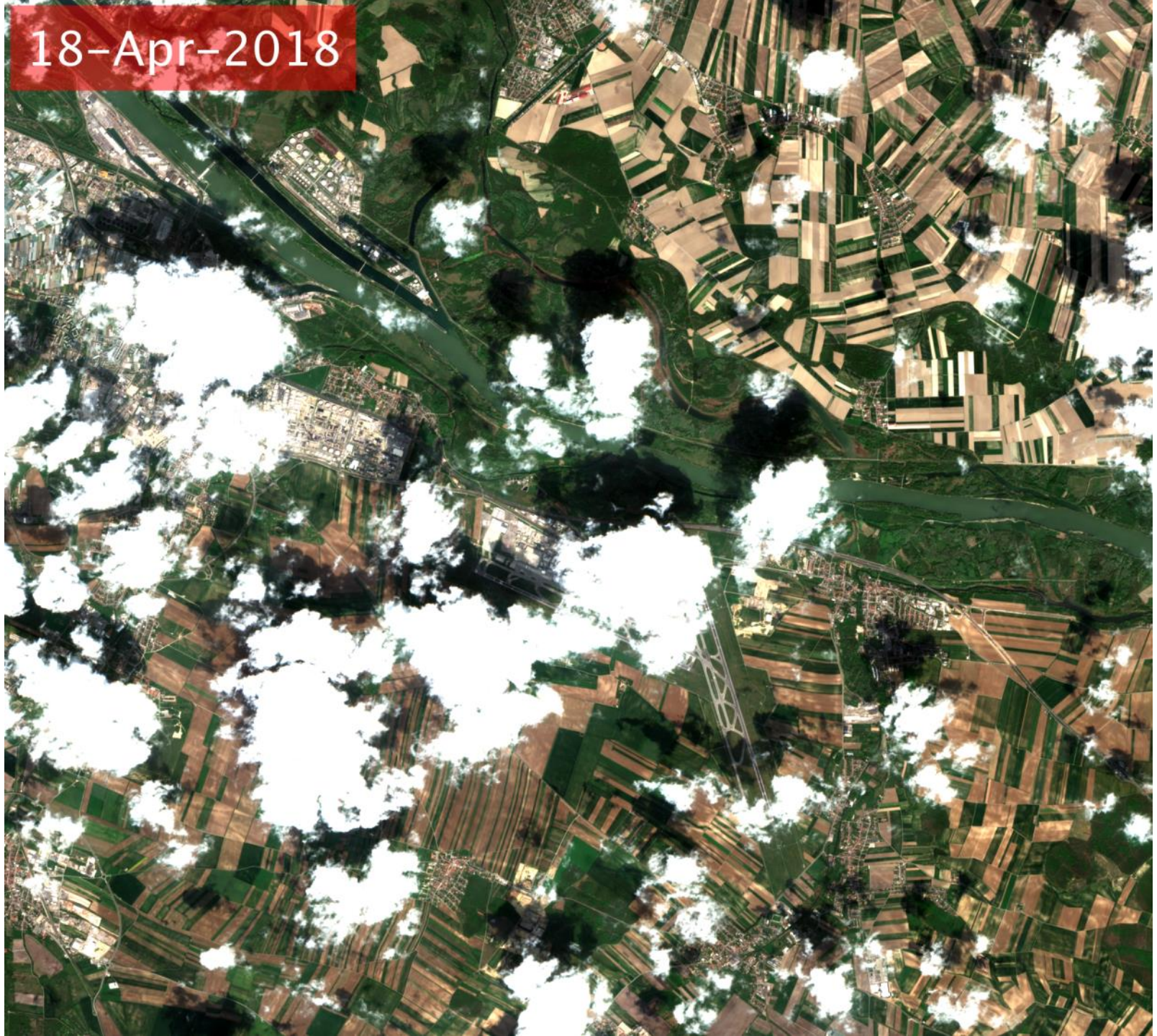
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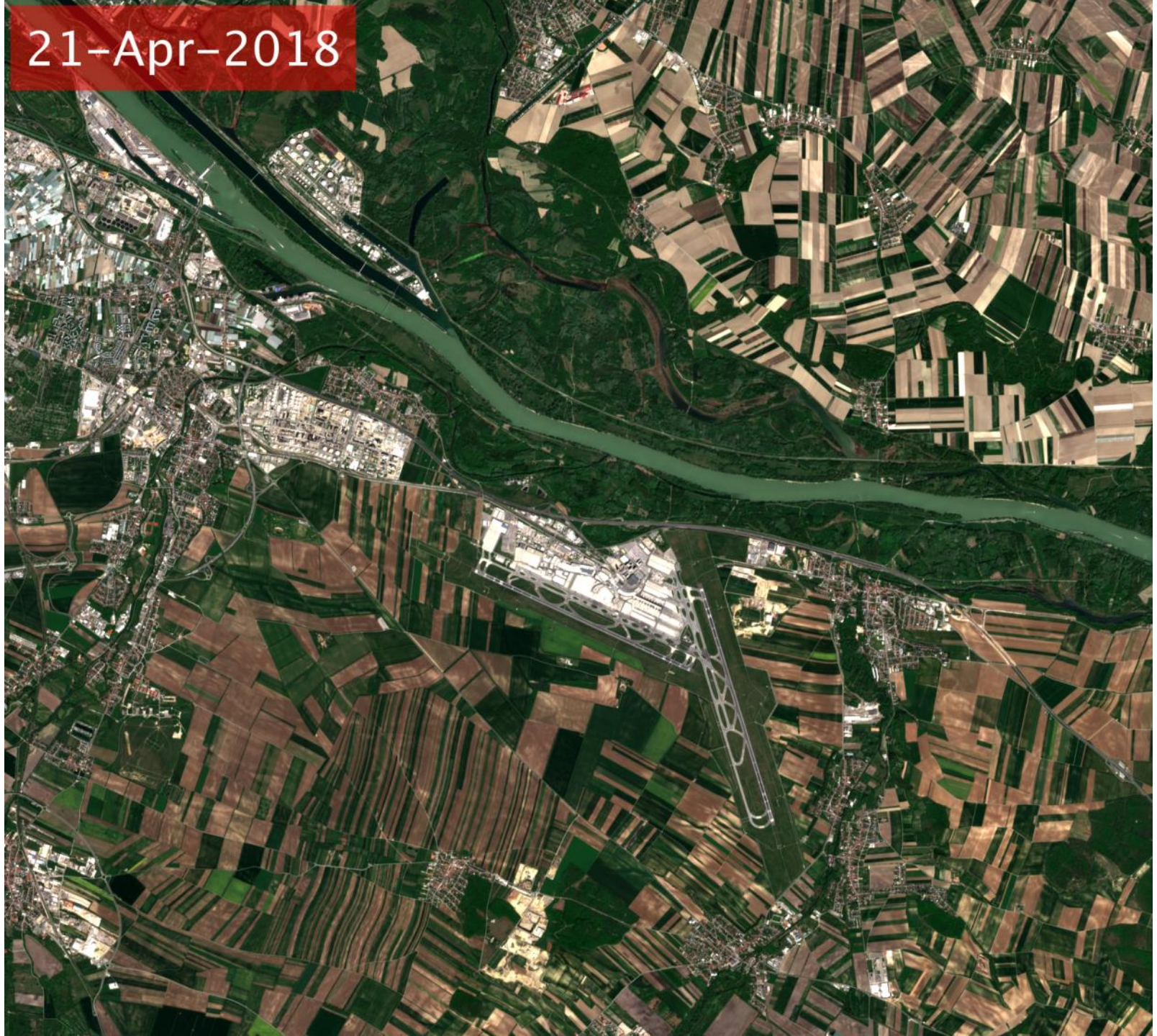
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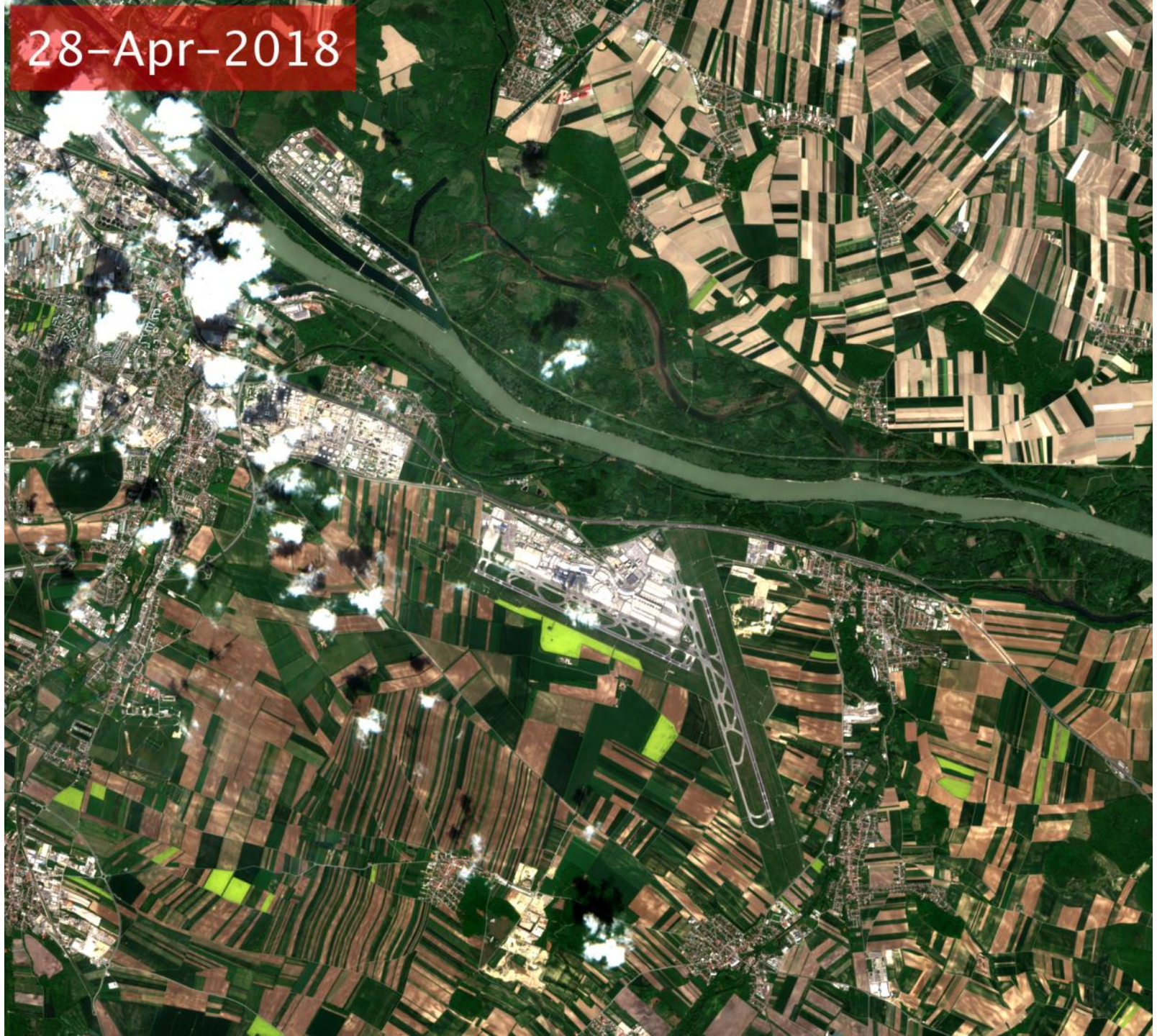
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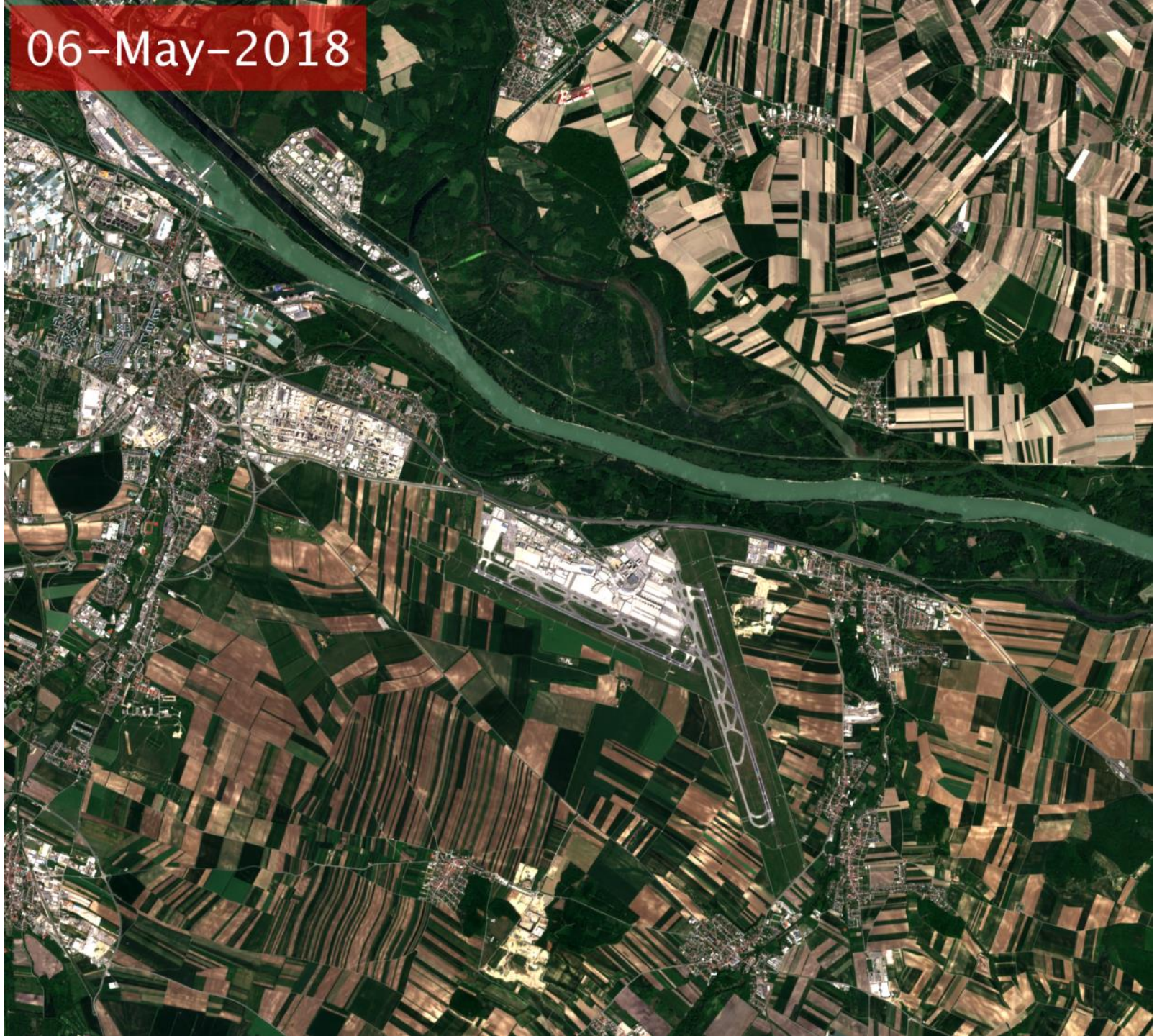
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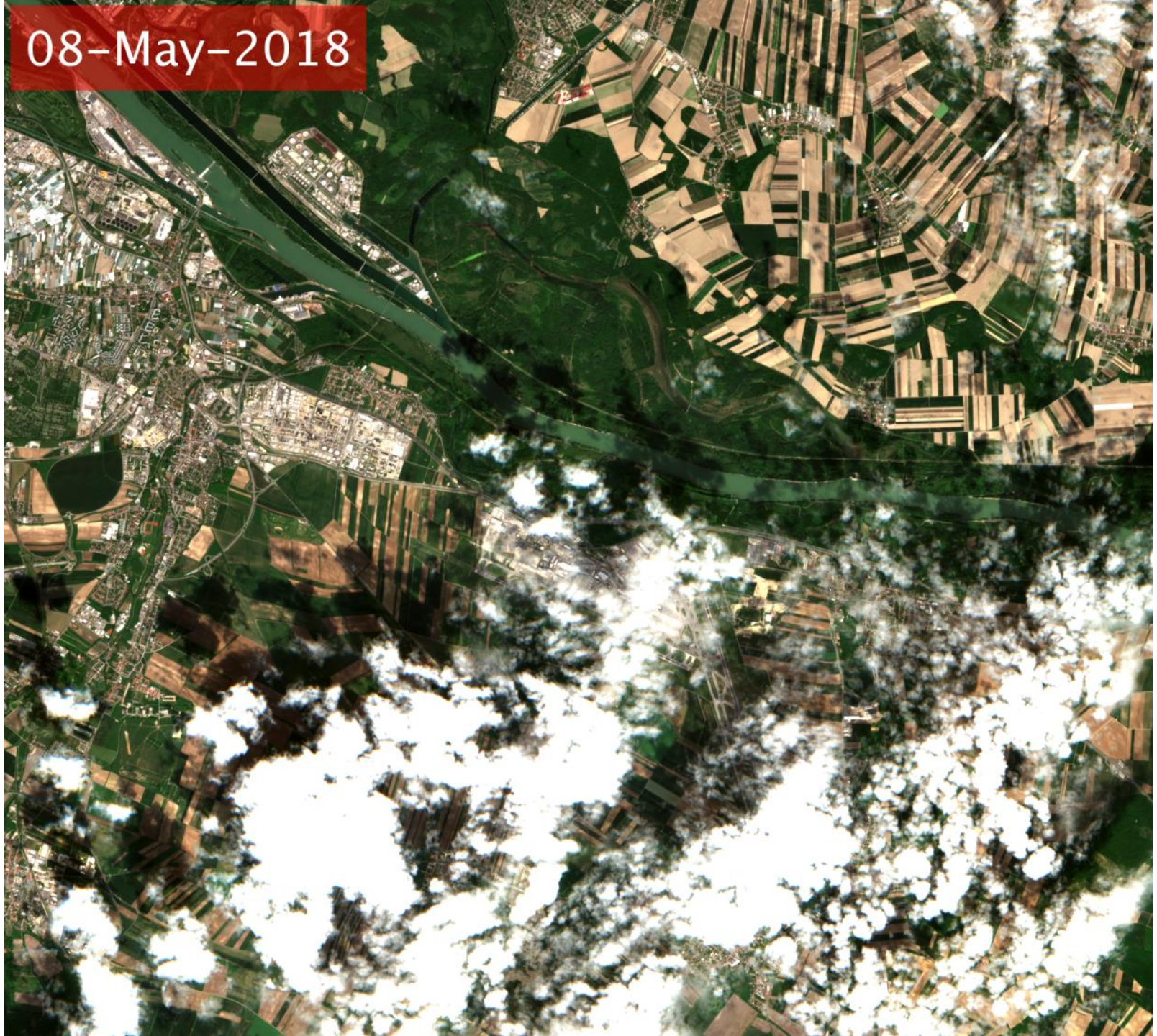
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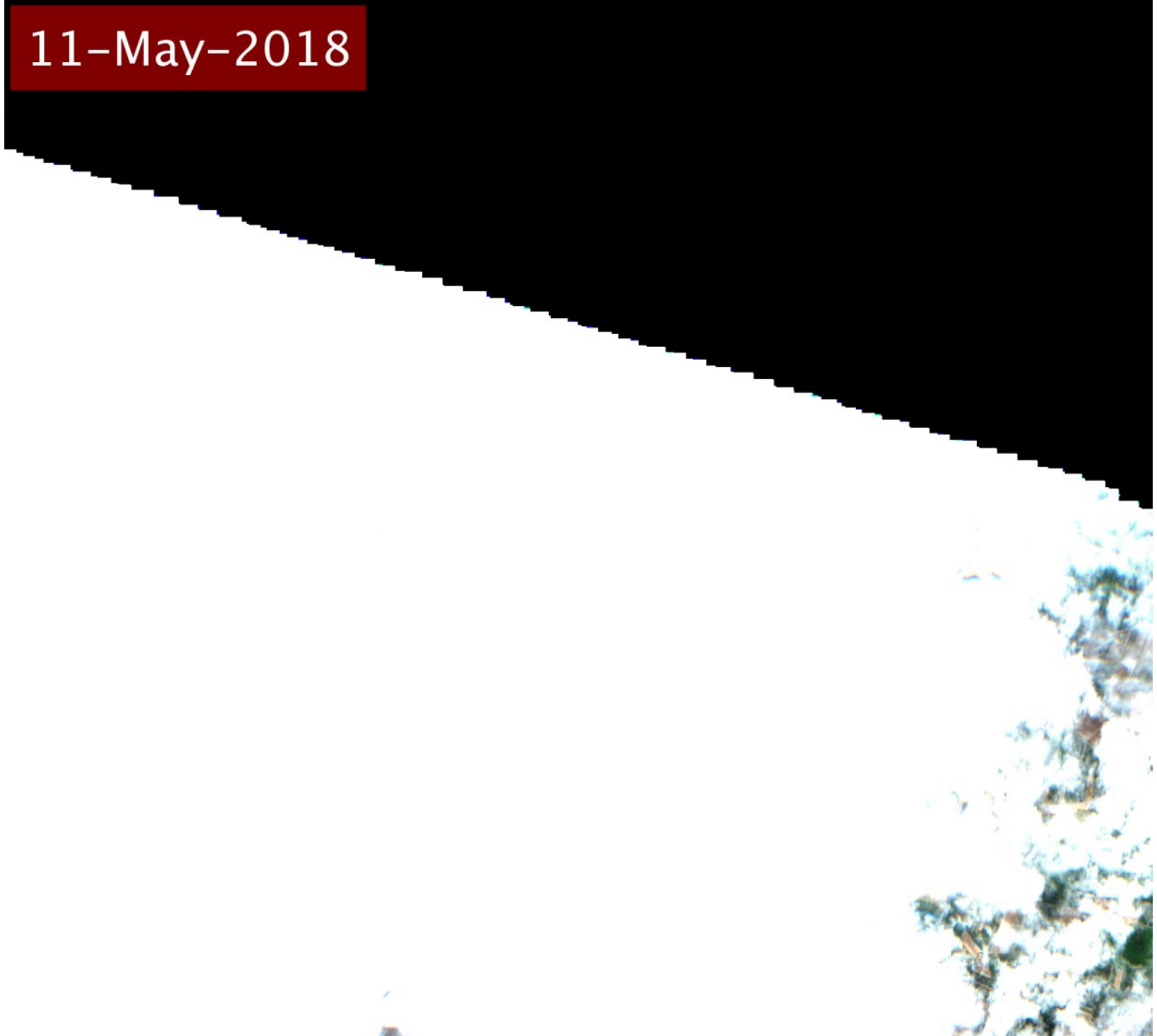
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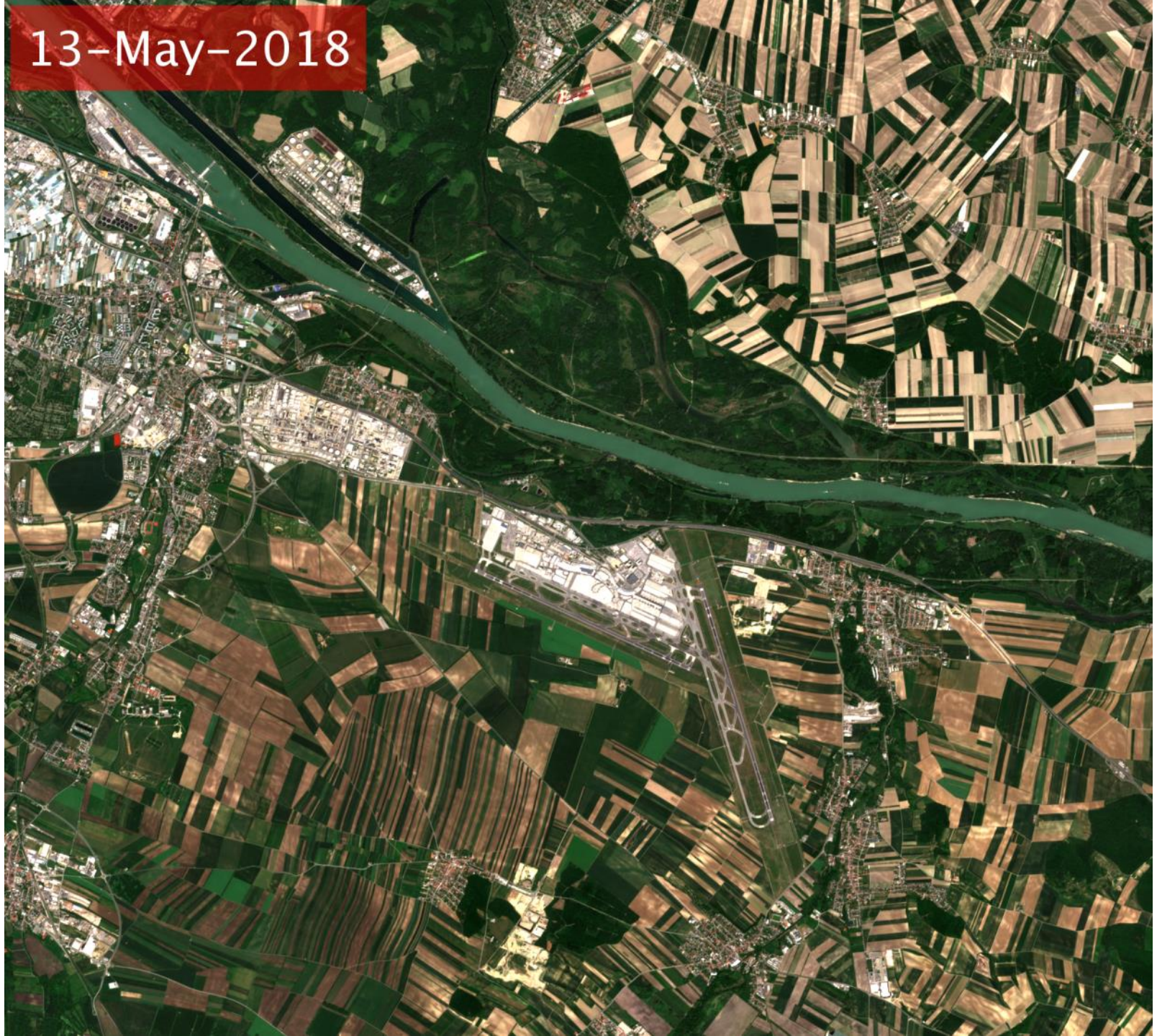
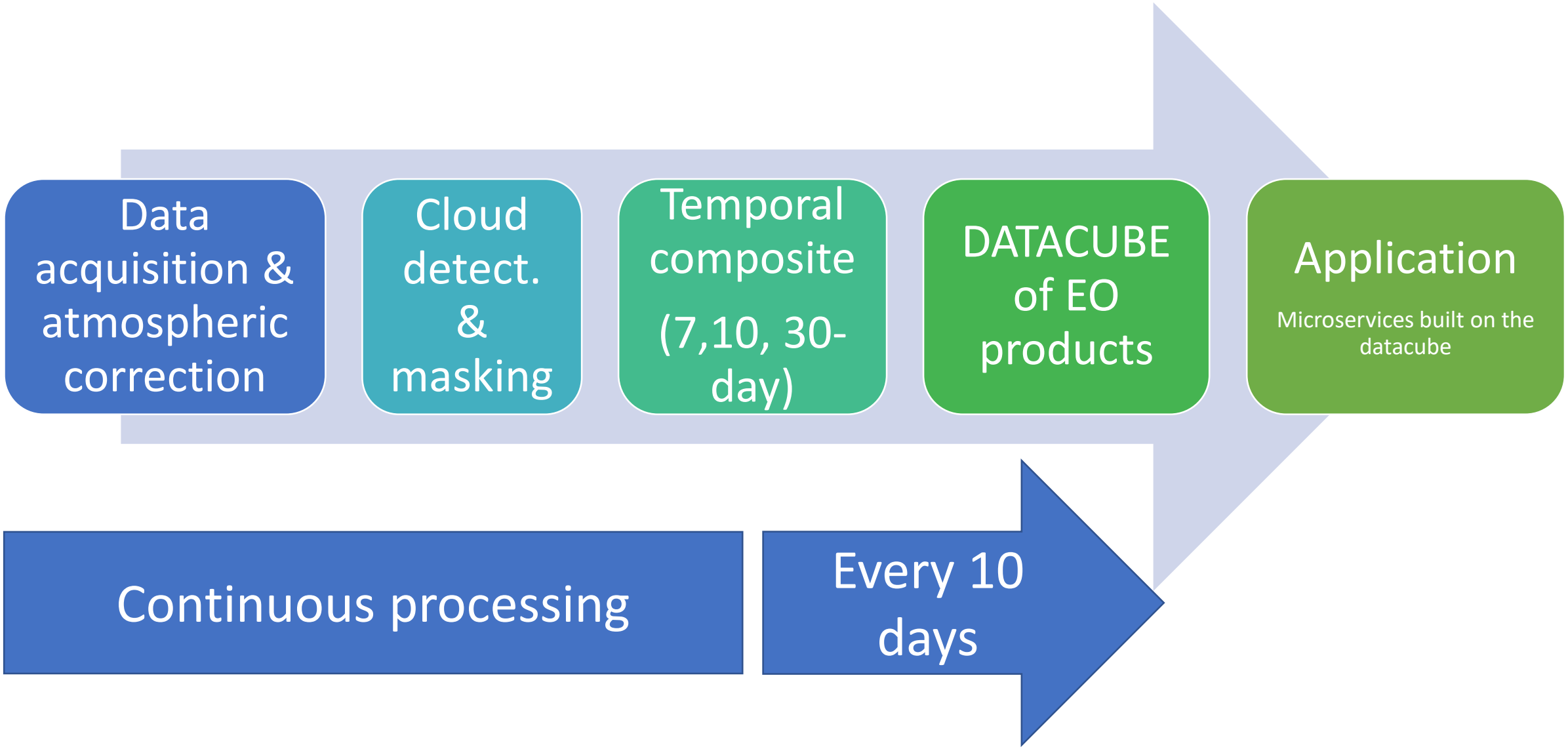
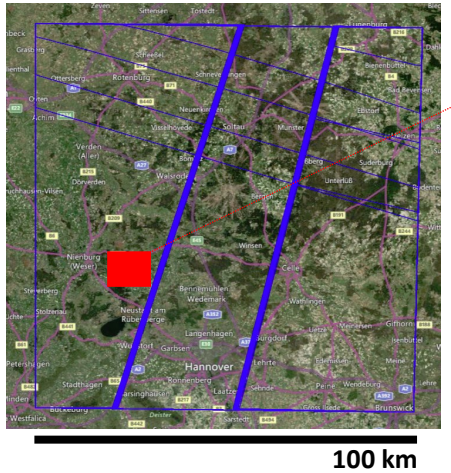

13-May-2018

Sentinel-2 Level 2-A processor (2019)

on-demand atmospheric correction & higher level products



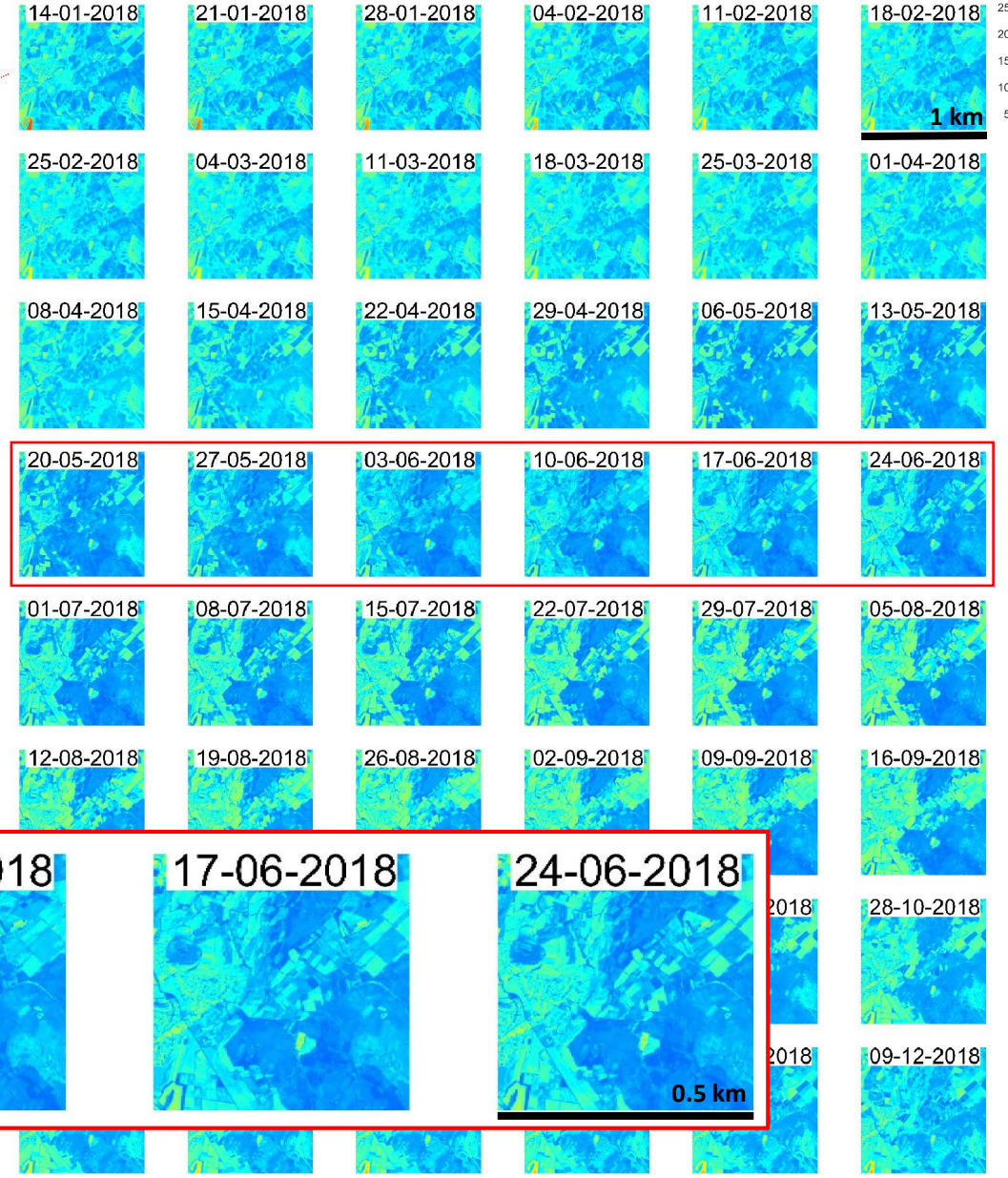


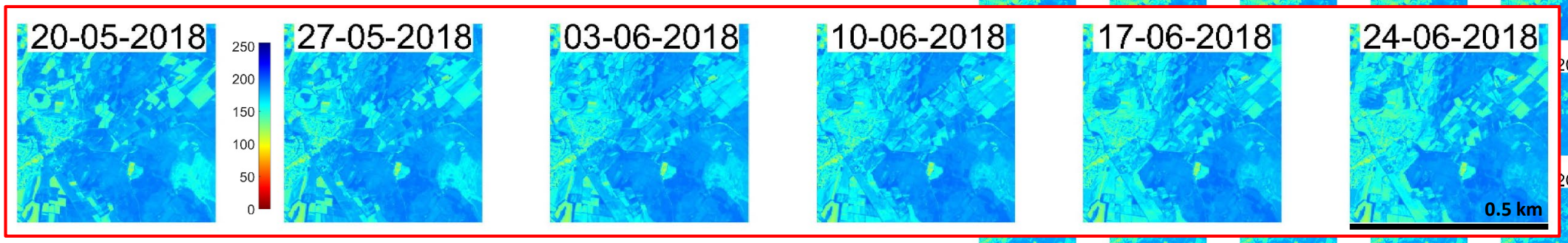
Sentinel-2 granule "32UND"

Time series

- starting **01-01-2018**
- ending **31-12-2018**

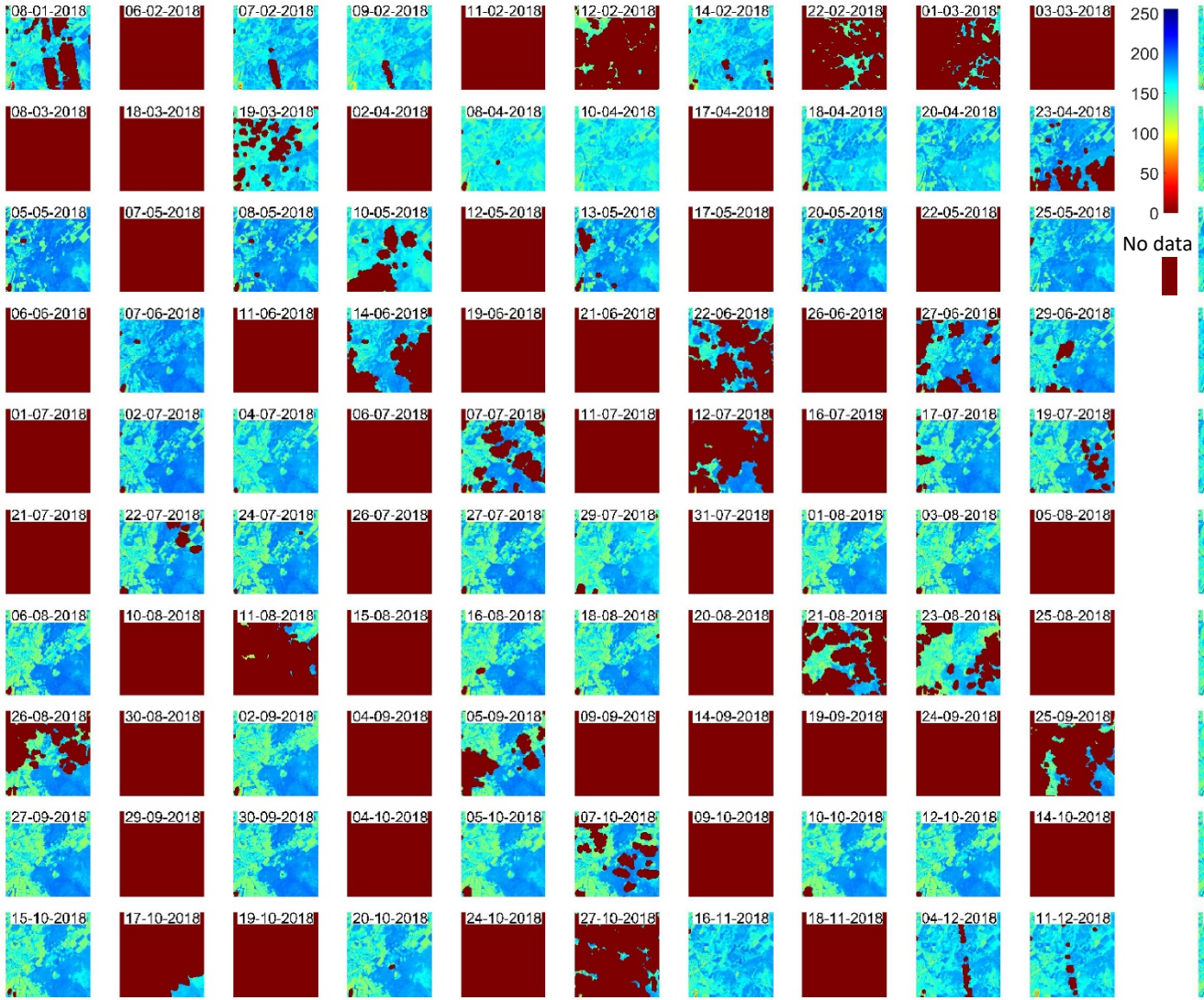
Cloud cover max **50%**





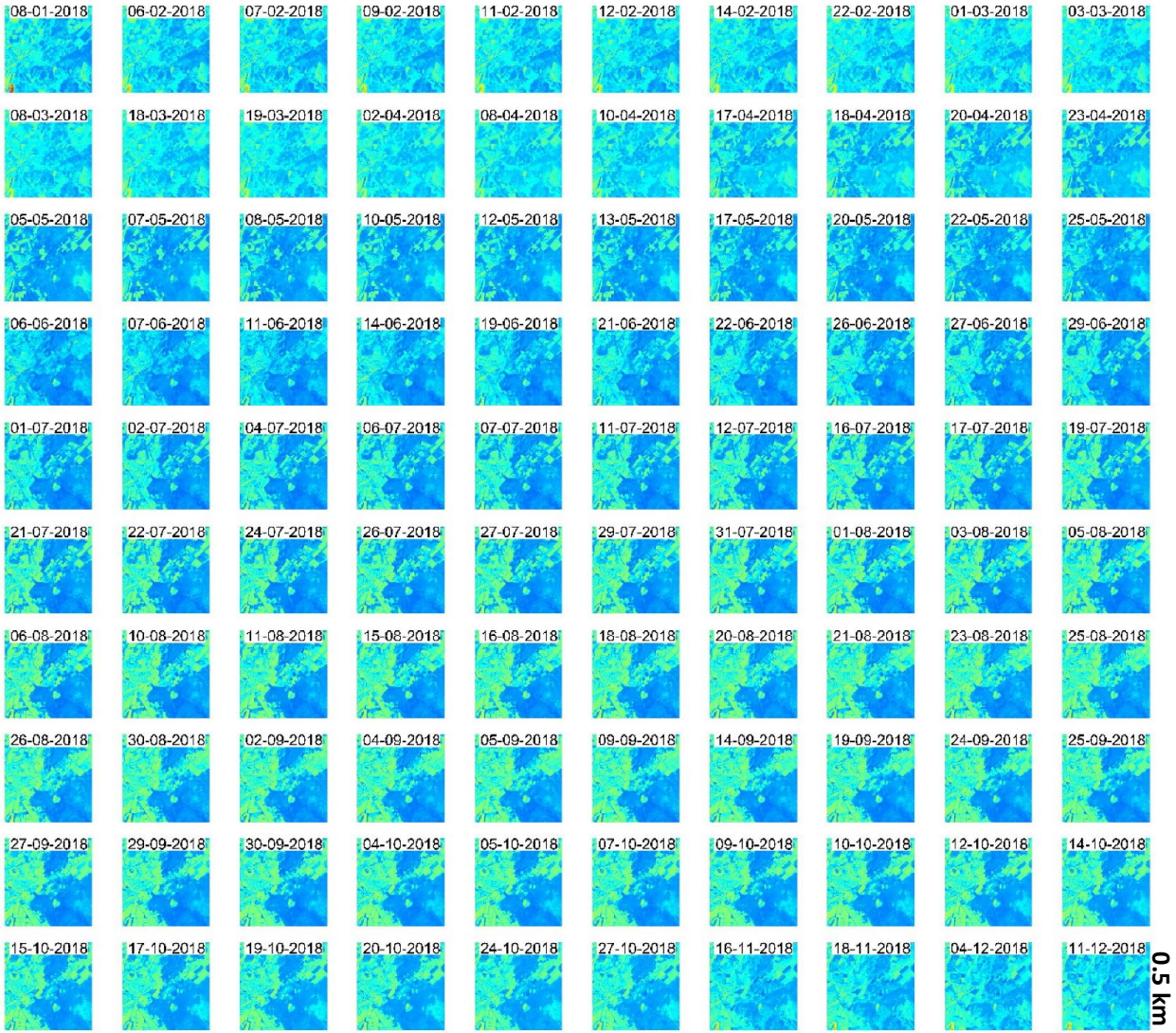
Smoothed and gap-filled NDVI time series – regularly spaced "Every Sunday"

Original data



Original Sentinel-2 NDVI data, Granule "32UND"
starting **01-01-2018 -** ending **31-12-2018** Cloud cover max **50%**

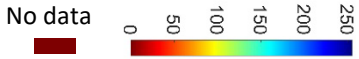
Gap-filled data

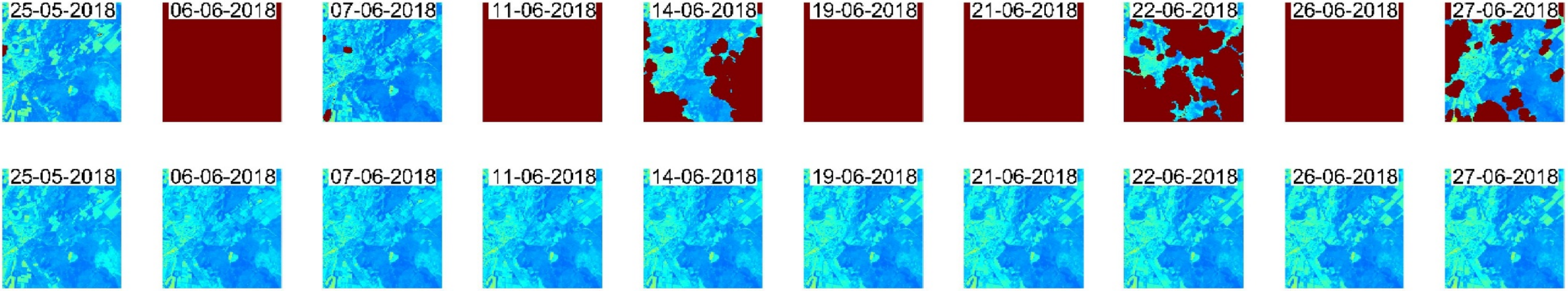


Gap-filled Sentinel-2 NDVI data, Granule "32UND"
starting **01-01-2018 -** ending **31-12-2018**

0.5 km

Original Sentinel-2 NDVI data, Granule “32UND”
starting **01-01-2018 -** ending **31-12-2018** Cloud cover max **50%**

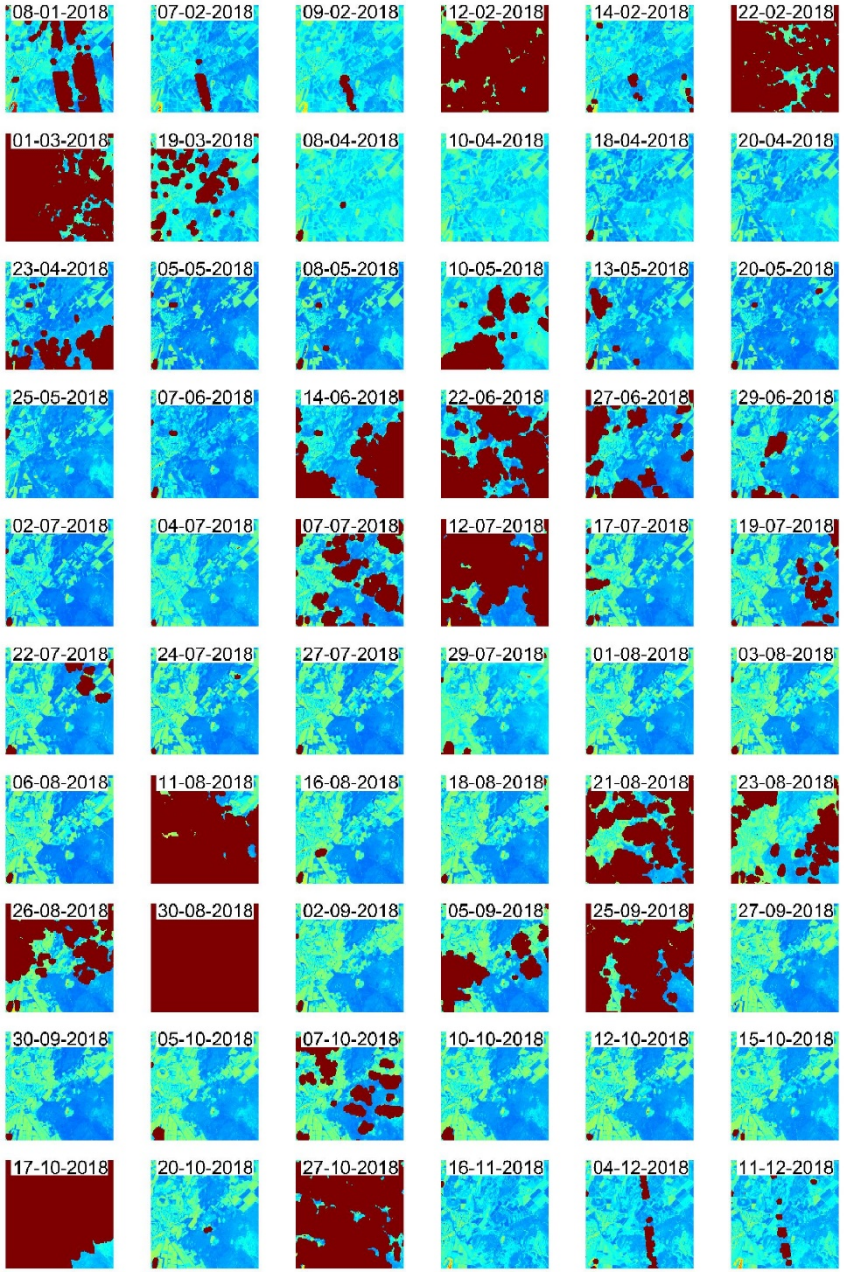




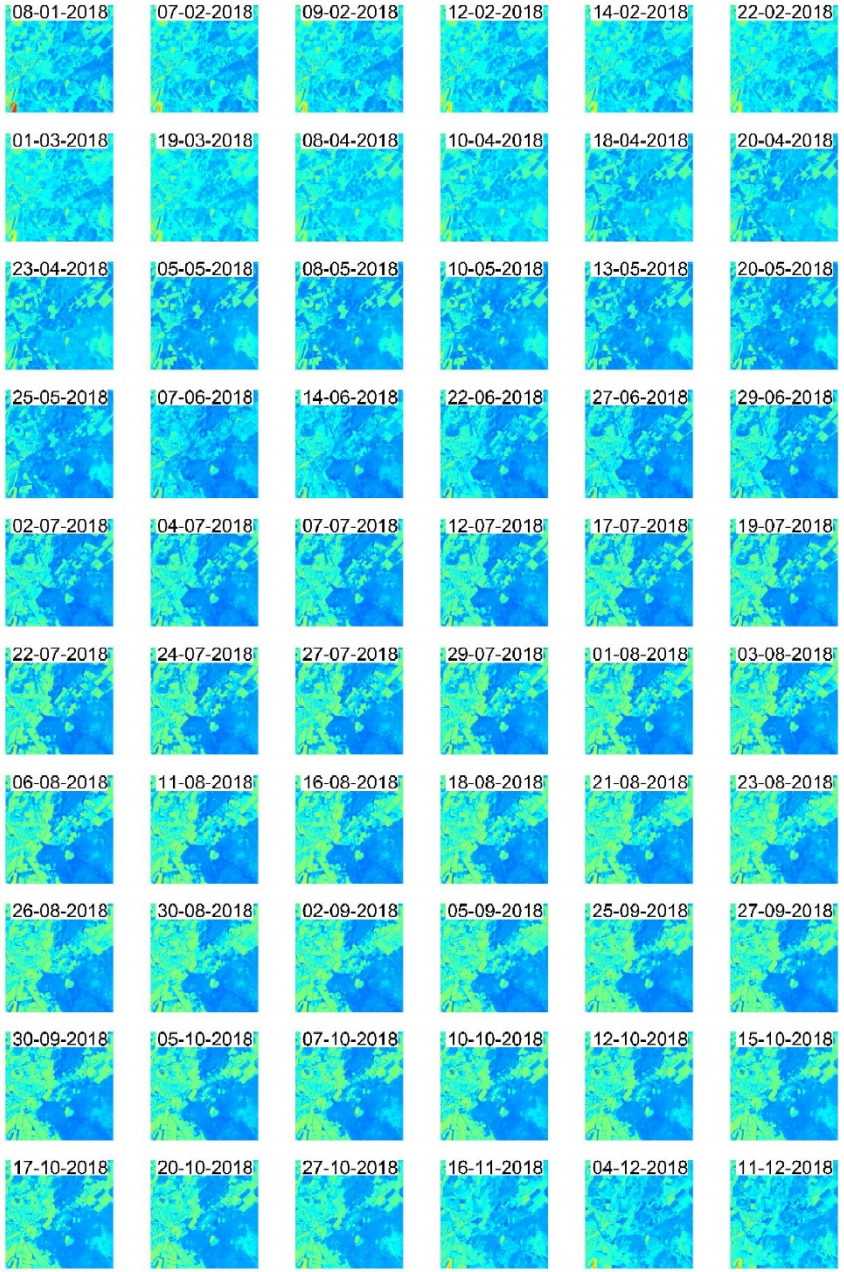
0.5 km

Gap-filled Sentinel-2 NDVI data, Granule “32UND”
starting **01-01-2018 -** ending **31-12-2018**

Original Sentinel-2 NDVI data, Granule “32UND”
starting **01-01-2018** - ending **31-12-2018** Cloud cover max **50%**



Gap-filled Sentinel-2 NDVI data, Granule “32UND”
starting **01-01-2018** - ending **31-12-2018**



Multi-temporal **Sentinel-2** data, how it helps in monitoring:

Crop types & rotations

REGIONMARCHFELD

Potential productivity of crops

Forest types and changes

Lebensregion
Biosphärenpark
Wienerwald

Example study: crop type classification

Altitude / Topography: Flat topography with an altitude of ~ 160-180m above sea level

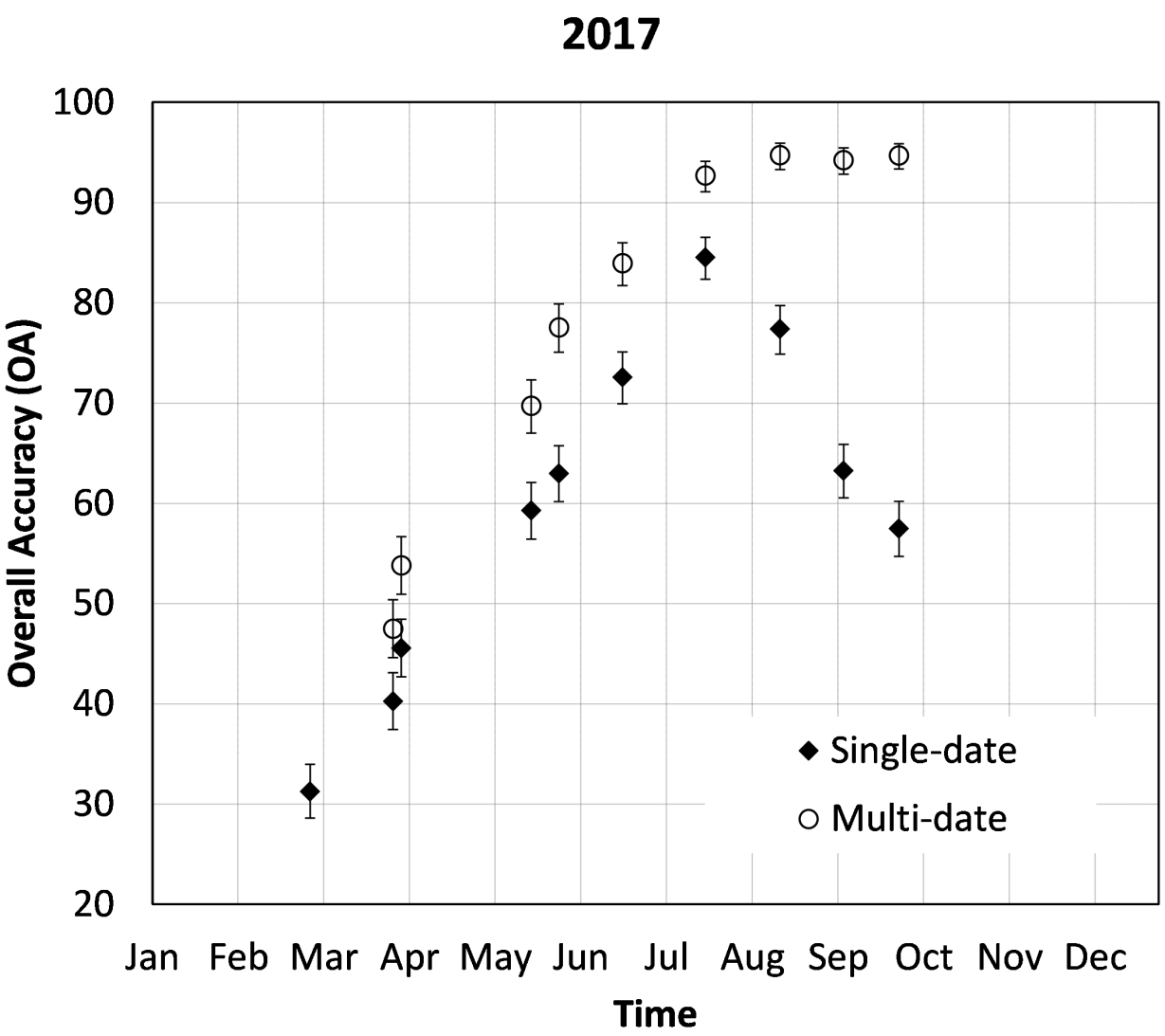
Climate type: Continental
Average annual rainfall: ~550 mm

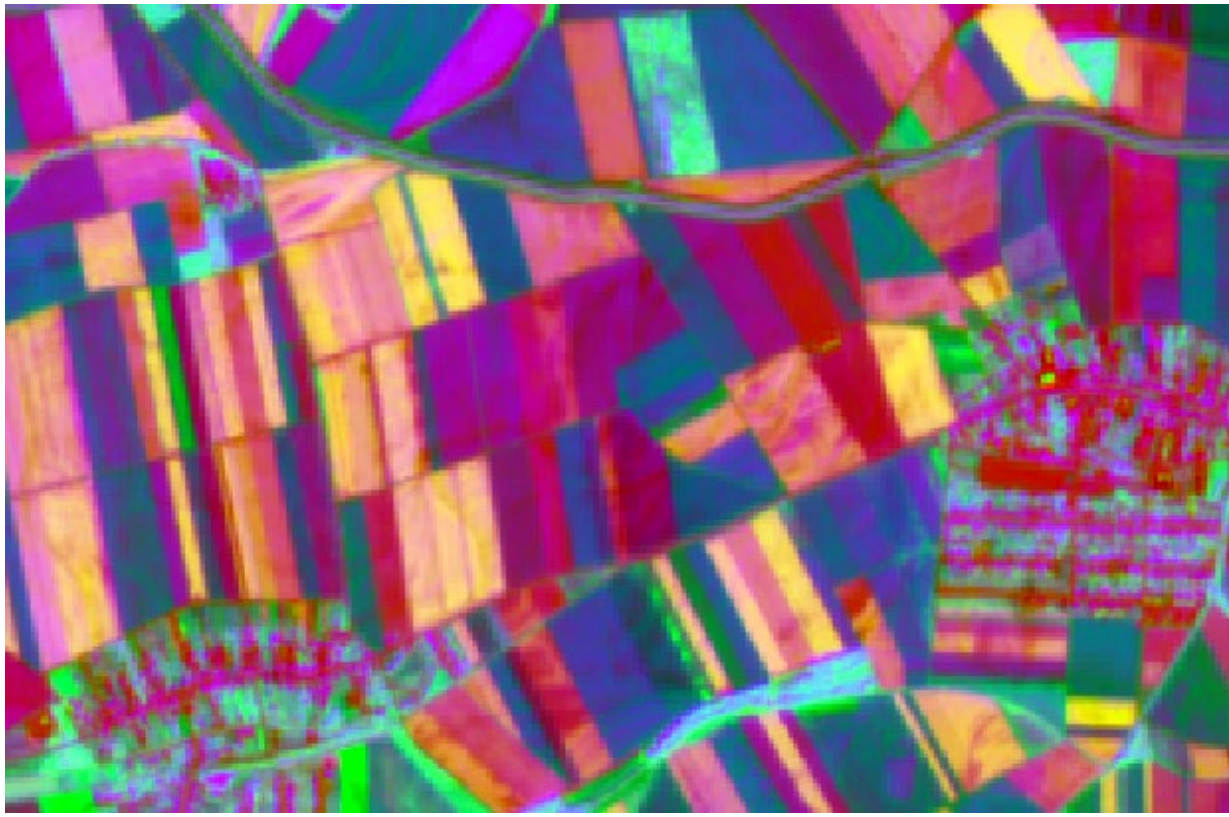
Average annual ET: ~640 mm

REGIONMARCHFELD

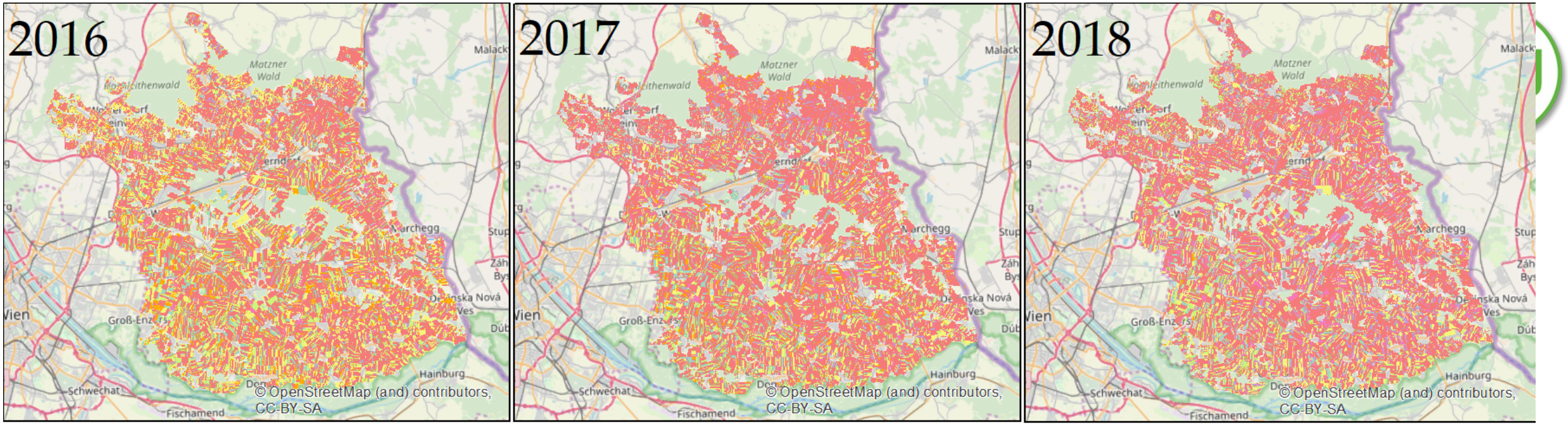
Main crops include durum wheat, grain maize, soybean, sunflower and various vegetables

How much does multi-temporal Sentinel-2 data improve crop type classification?





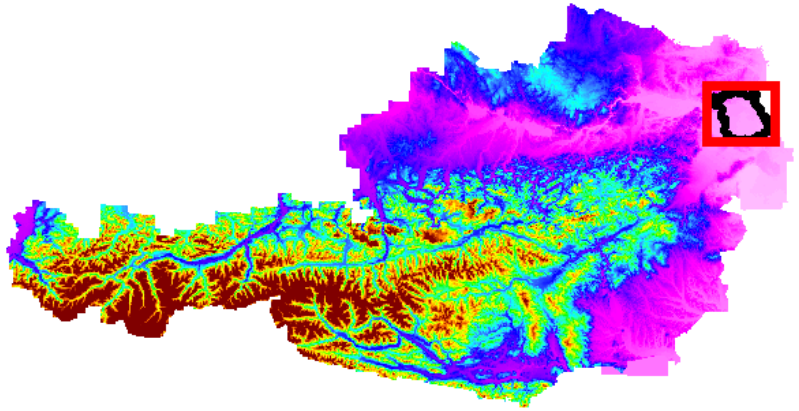
PCs of the spectral-temporal data stack



0 10 20 40 Km

Maize
Sugarbeet
Winter cereal
Onion
Potato
Carrot
Soybean
Pumpkin
Sunflower
Other vegetable
Alfalfa
Asparagus
Pea

in gray:
only present in 2018



Marchfeld region

DEM

Value

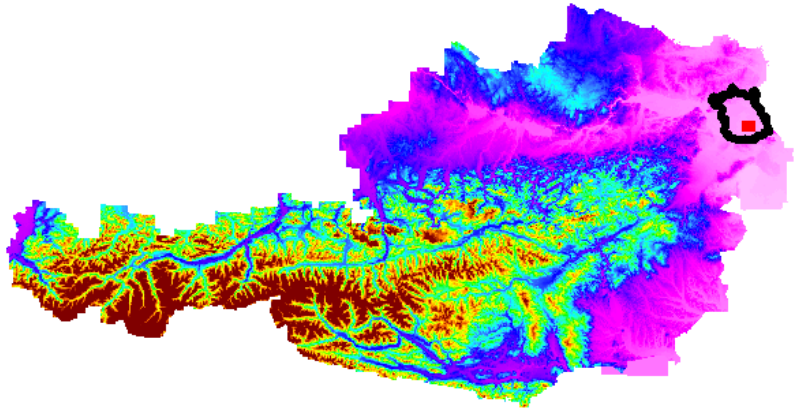
High : 3793

Low : 0

0 0.5 1 2 Km

Maize
Sugarbeet
Winter cereal
Onion
Potato
Carrot
Soybean
Pumpkin
Sunflower
Other vegetable
Alfalfa
Asparagus
Pea

in gray:
only present in 2018



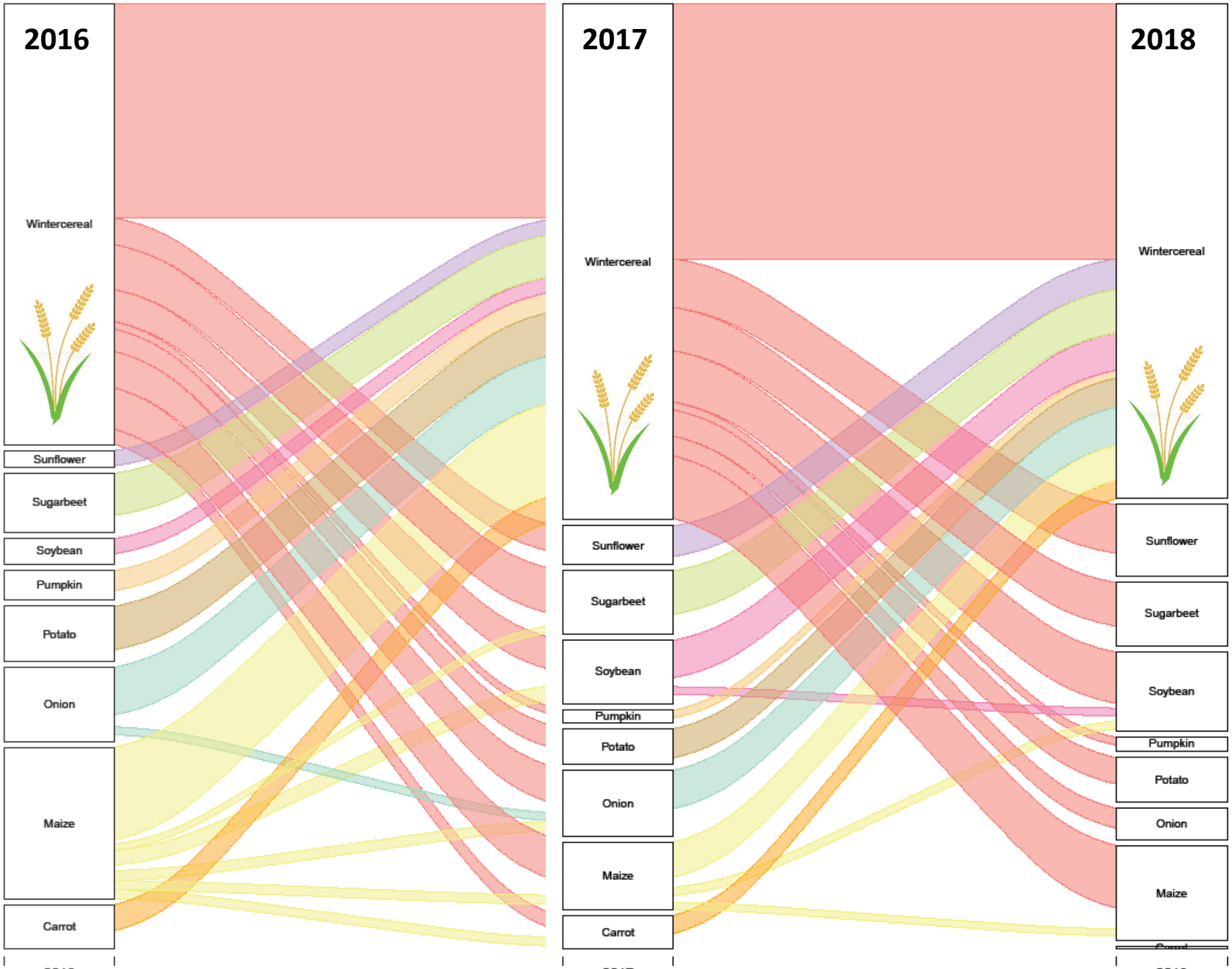
Marchfeld region

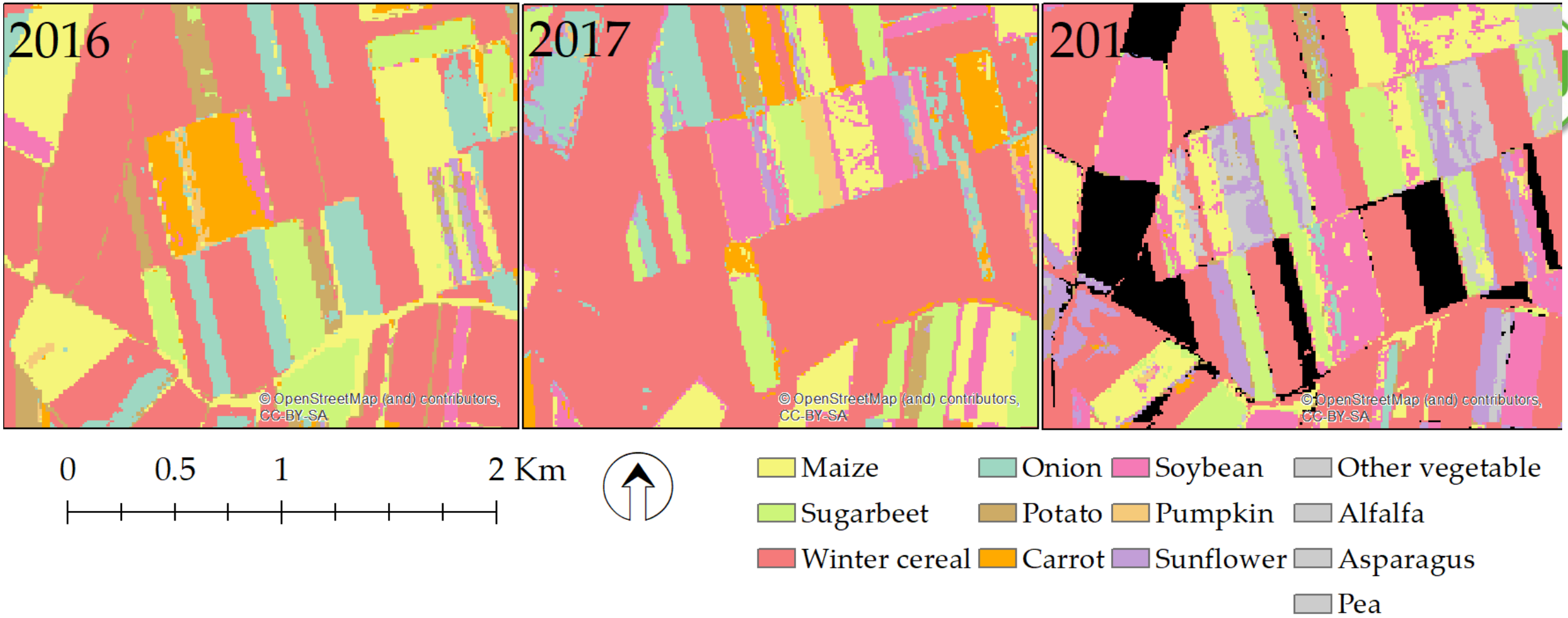
DEM

Value

High : 3793

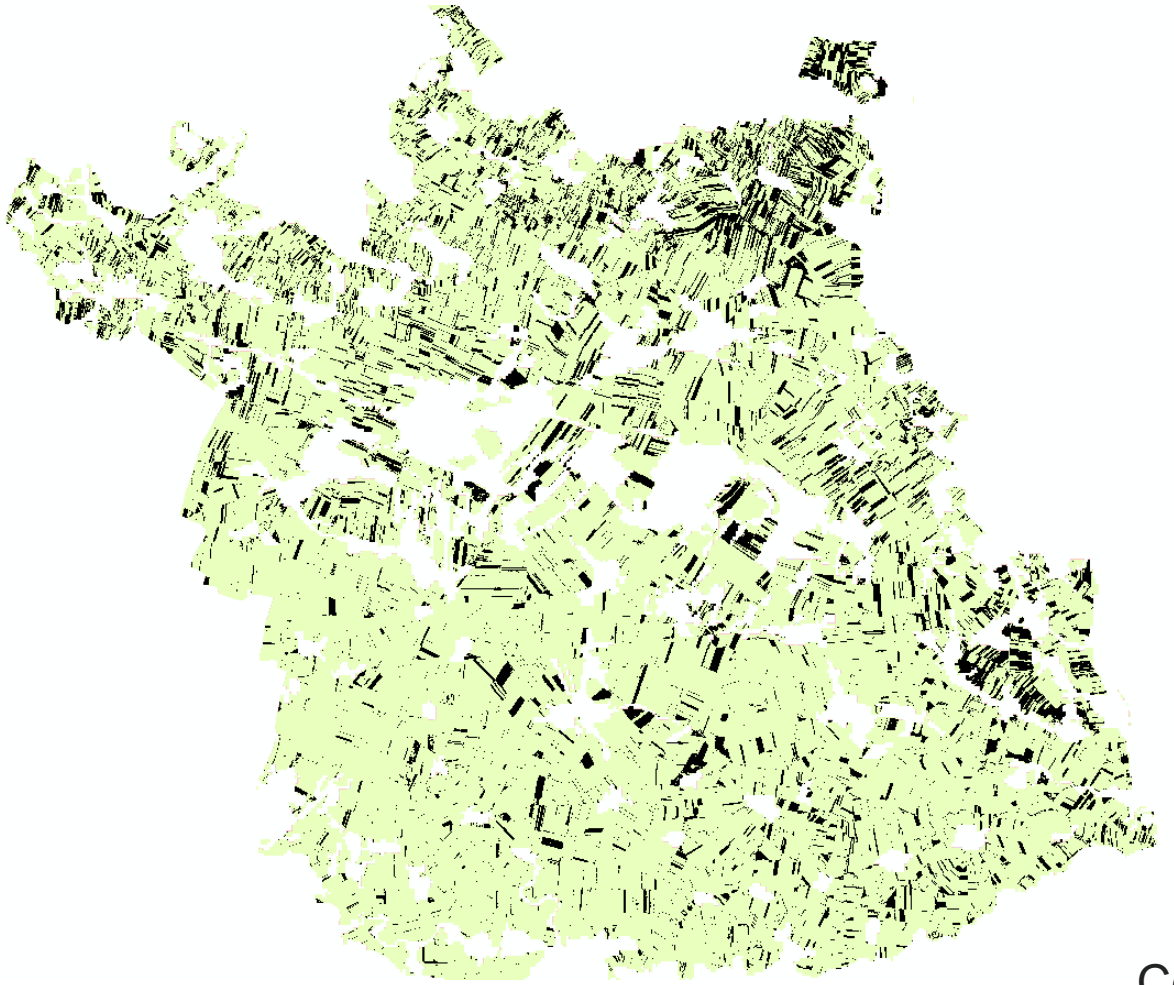
Low : 0


2016
Wintercereal
Sunflower
Sugarbeet
Soybean
Pumpkin
Potato
Onion
Maize
Carrot
2017
Wintercereal
Sunflower
Sugarbeet
Soybean
Pumpkin
Potato
Onion
Maize
Carrot
2018
Wintercereal
Sunflower
Sugarbeet
Soybean
Pumpkin
Potato
Onion
Maize



Single crop production systems (over the period 2016-2018) are marked in **black in 2018**

Crop rotations: Single- vs multi-crop rotation



14 % of total crop land was under a single crop production system in the years 2016-2018 (**in black**)

Comparison 2016 vs 2017: https://arcg.is/XOmDq
Comparison 2017 vs 2018: https://arcg.is/0bSeyX

Error matrix (RF OOB) 2016 & 2017

2016	Carrot	Maize	Onion	Potato	Pumpkin	Soybean	Sugar beet	Sunflower	Winter cereal	User's accuracy
Carrot	95	1	0	1	0	0	0	0	0	0.979
Maize	3	160	0	2	1	3	0	1	0	0.941
Onion	2	6	110	1	1	0	0	3	2	0.880
Potato	2	0	0	98	0	0	2	3	0	0.933
Pumpkin	0	1	0	0	61	0	0	1	0	0.968
Soybean	0	0	0	1	0	78	0	0	0	0.987
Sugar beet	0	3	0	4	0	3	169	0	0	0.944
Sunflower	0	0	0	0	0	0	0	55	0	1.000
Winter cereal	0	0	4	1	0	0	0	0	352	0.986
Producer's accuracy	0.931	0.936	0.965	0.907	0.968	0.929	0.988	0.873	0.994	0.958

2017	Carrot	Maize	Onion	Potato	Pumpkin	Soybean	Sugar beet	Sunflower	Winter cereal	User's accuracy
Carrot	63	1	0	0	0	2	0	0	0	0.955
Maize	1	210	1	0	0	18	0	0	0	0.913
Onion	0	5	116	1	0	3	0	0	0	0.928
Potato	2	1	0	97	1	0	2	1	0	0.933
Pumpkin	1	0	0	0	49	0	0	1	0	0.961
Soybean	4	2	0	0	0	94	5	1	0	0.887
Sugar beet	0	3	0	1	0	2	178	0	0	0.967
Sunflower	1	0	0	0	1	1	1	42	0	0.913
Winter cereal	1	0	0	0	0	0	0	0	276	0.996
Producer's accuracy	0.863	0.946	0.991	0.980	0.961	0.783	0.957	0.933	1.000	0.946

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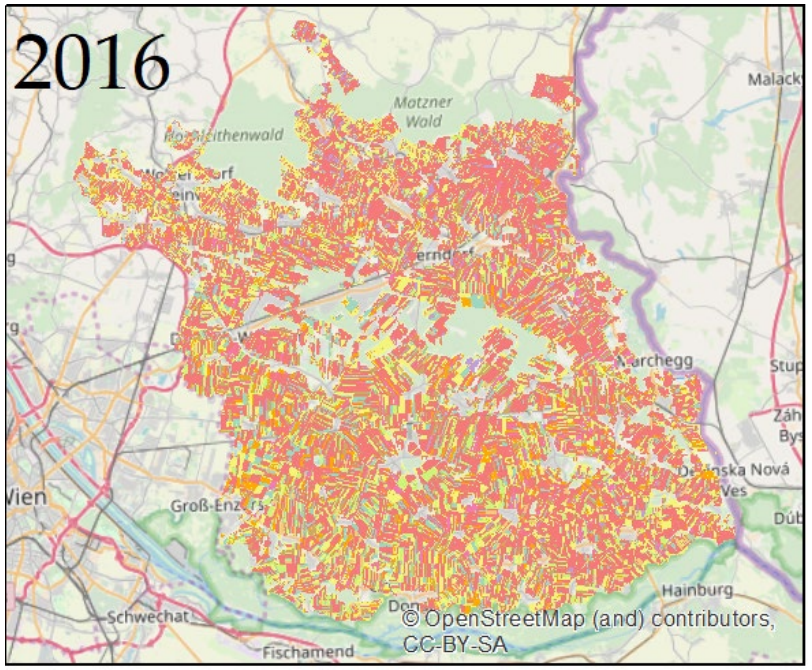
How much does multi-temporal Sentinel-2 data improve crop type classification?

Francesco Vuolo, Martin Neuwirth, Markus Immitzer, Clement Atzberger, Wai-Tim Ng

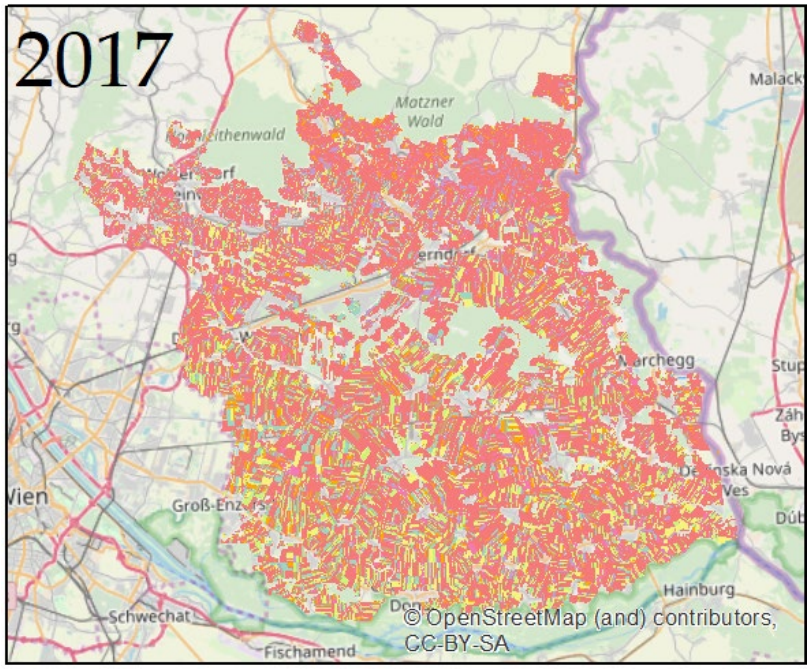
https://doi.org/10.1016/j.jag.2018.06.007



BOKU vs Invekos (Integriertes Verwaltung- und Kontrollsystem)

n = 5219

2016	Maize	Vegetable	Potato	Pumpkin	Soybean	Sugar beet	Sunflower	Winter cereal	User's accuracy
Maize	559	12	0	2	0	6	0	1	0.964
Onion & Carrot	82	384	16	3	1	0	0	20	0.759
Potato	2	15	218	2	0	15	5	1	0.845
Pumpkin	1	8	9	126	0	0	6	1	0.834
Soybean	5	9	3	1	230	3	0	1	0.913
Sugar beet	10	2	8	1	0	599	0	2	0.963
Sunflower	0	2	6	0	0	0	126	2	0.926
Winter cereal	10	10	1	1	1	1	0	2690	0.991
Producer's accuracy	0.836	0.869	0.835	0.926	0.991	0.960	0.920	0.990	0.945

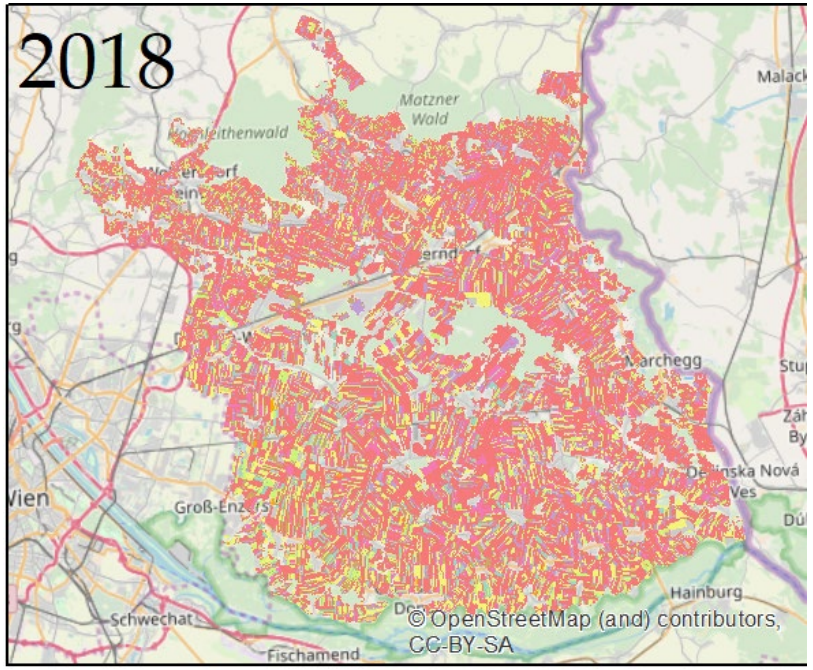


BOKU vs Invekos (Integriertes Verwaltung- und Kontrollsystem)

n = 5085

2017	Maize	Vegetable	Potato	Pumpkin	Soybean	Sugar beet	Sunflower	Winter cereal	User's accuracy
Maize	545	21	3	0	49	0	16	8	0.849
Onion & Carrot	45	372	6	7	26	9	13	38	0.721
Potato	2	7	256	2	9	10	8	7	0.850
Pumpkin	0	12	0	70	4	0	4	0	0.778
Soybean	36	10	1	1	205	0	0	2	0.804
Sugar beet	3	15	2	4	6	543	10	10	0.916
Sunflower	1	9	14	0	2	10	138	12	0.742
Winter cereal	1	7	0	0	1	1	0	2492	0.996
Producer's accuracy	0.861	0.821	0.908	0.833	0.679	0.948	0.730	0.970	0.909

Error matrix (based on RF OOB) n = 1149

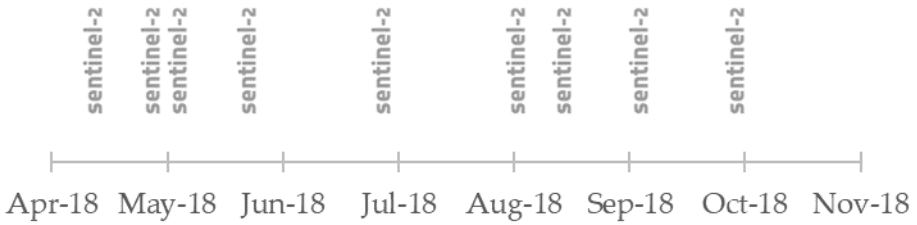


Classification algorithm: Random Forest

Features: S2A&B L2A data in visible, Red-Edge, NIR and SWIR

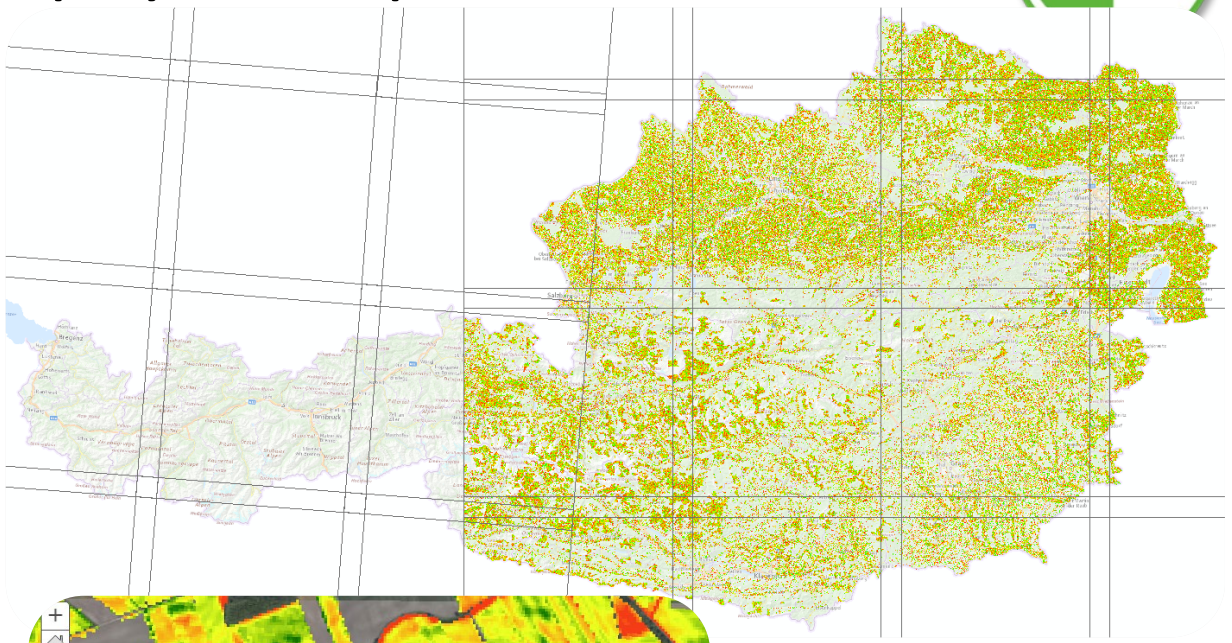
Error matrix: out of bag error (OOB)

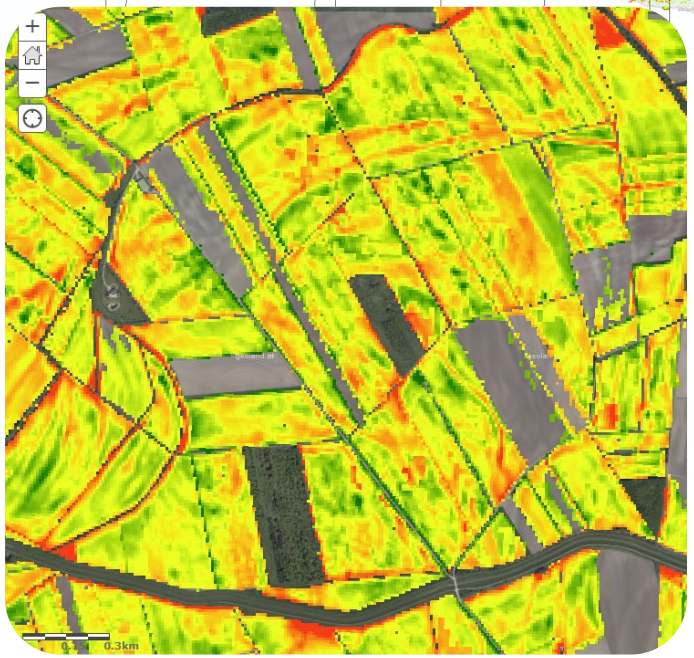
Temporal distribution of S2 acquisitions:



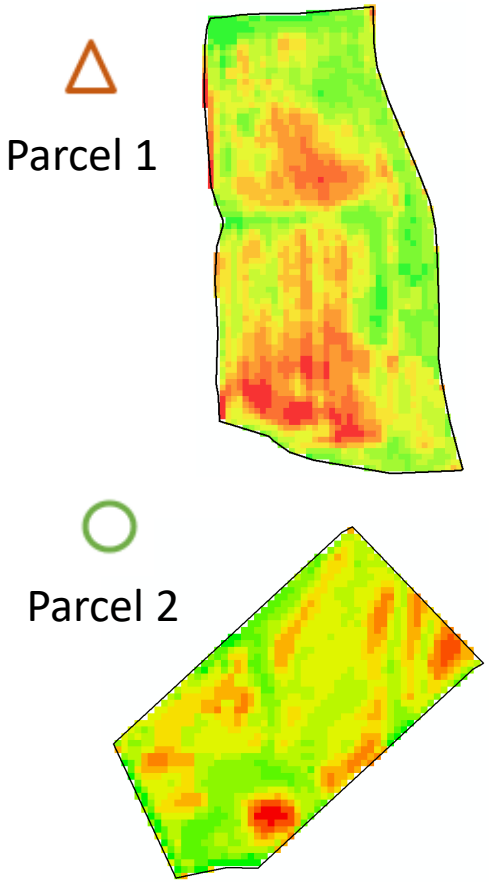
2018	Alfalfa	Asparagus	Carrot	Mais	Onion	Pea	Potato	Pumpkin	Sugarbeet	Sunflower	Soybean	Vegetable	Winter cereal	User's accuracy
Alfalfa	15	0	0	0	0	0	0	0	0	0	0	0	0	1
Asparagus	0	2	0	1	0	0	0	0	0	0	0	0	0	0.667
Carrot	0	0	5	0	1	0	0	0	0	0	3	0	0	0.556
Mais	0	0	0	166	0	3	0	0	1	0	4	0	3	0.938
Onion	0	0	0	0	80	0	0	0	0	0	1	0	0	0.988
Pea	0	0	0	0	1	38	0	0	3	3	0	0	0	0.844
Potato	0	0	0	0	0	0	76	0	0	3	6	0	5	0.844
Pumpkin	0	0	0	0	1	0	0	35	0	0	3	0	0	0.897
Sugarbeet	0	0	0	0	1	0	1	0	94	0	0	0	0	0.979
Sunflower	0	0	0	2	0	0	0	0	0	142	3	0	0	0.966
Soybean	0	0	0	3	0	0	1	0	0	8	208	0	2	0.937
Vegetable	0	0	0	1	1	1	0	0	1	0	1	16	0	0.762
Winter cereal	0	0	0	1	0	0	0	0	0	0	0	0	203	0.995
Producer's accuracy	1	1	1	0.95	0.94	0.9	0.97	1	0.95	0.91	0.9083	1	0.95	0.940

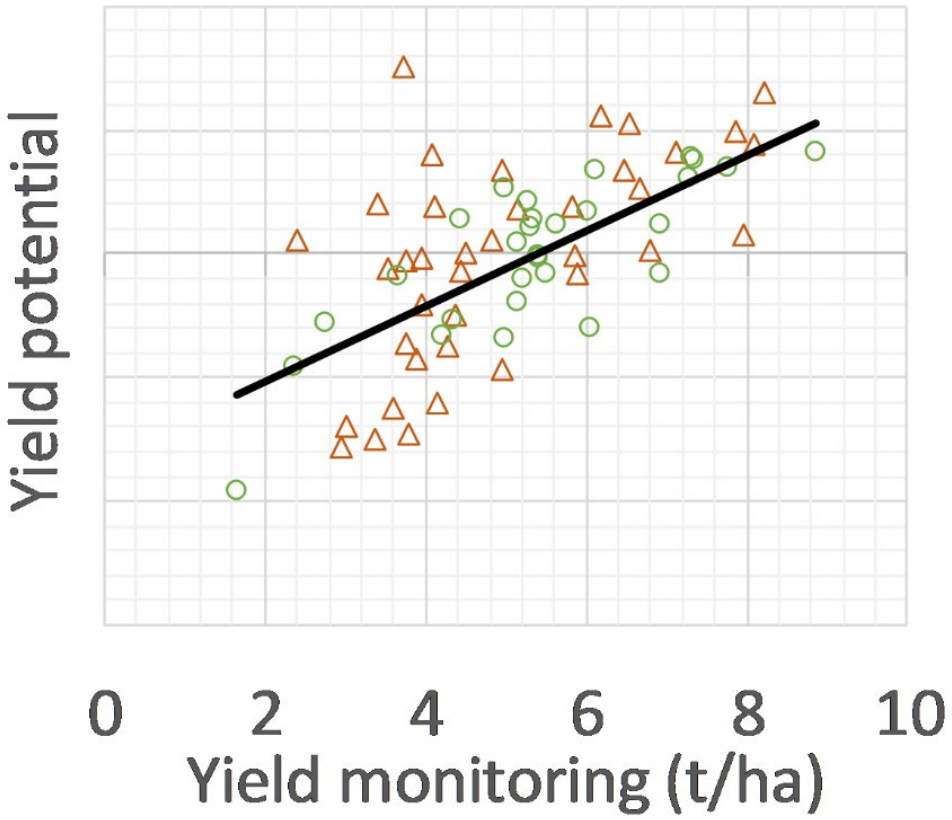
Example study: crop yield potential



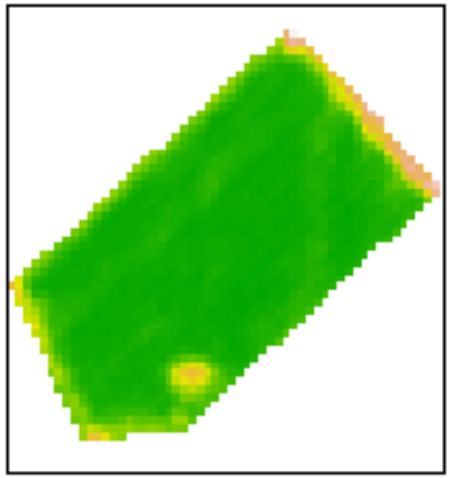


Yield potential vs Actual Yield (yield monitor)

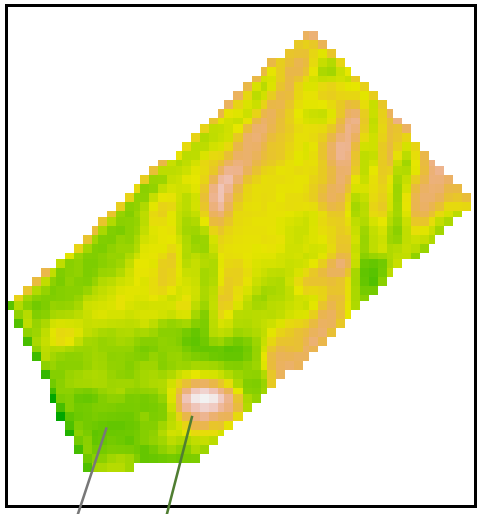




Calculation:
Integrates **crop development over multiple years** and local **climate**



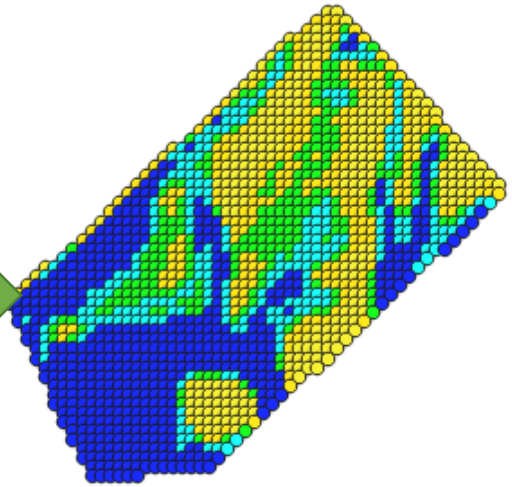
Yield potential map

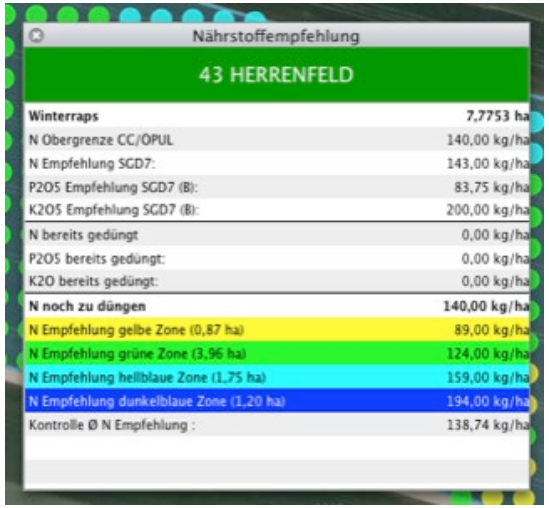


Low

High

N application zones





Nährstoffempfehlung

43 HERRENFELD

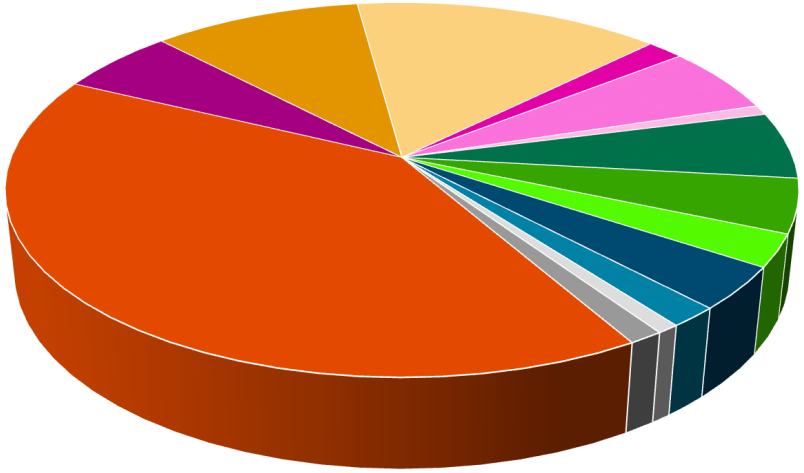
Winterraps	**7,7753 ha**
N Obergrenze CC/OPUL	140,00 kg/ha
N Empfehlung SGD7:	143,00 kg/ha
P2O5 Empfehlung SGD7 (B):	83,75 kg/ha
K2O5 Empfehlung SGD7 (B):	200,00 kg/ha
N bereits gedüngt	0,00 kg/ha
P2O5 bereits gedüngt:	0,00 kg/ha
K2O bereits gedüngt:	0,00 kg/ha
N noch zu düngen	**140,00 kg/ha**
N Empfehlung gelbe Zone (0,87 ha)	89,00 kg/ha
N Empfehlung grüne Zone (3,96 ha)	124,00 kg/ha
N Empfehlung hellblaue Zone (1,75 ha)	159,00 kg/ha
N Empfehlung dunkelblaue Zone (1,20 ha)	194,00 kg/ha
Kontrolle Ø N Empfehlung :	138,74 kg/ha

Example study: **Wienerwald Biosphere Reserve**

- Established: 2005
- Located between the Northern Alps and the Pannonic Basin next to Vienna (Austria)
- 105.645 ha, lower Austria + Vienna
- > 60% of the area are forest - largest contiguous deciduous beech forest in Central Europe
- Important biodiversity hot spot throughout Europe
- Wooded hills alternates with meadows, pastures, vineyards and dry grasslands
- Aim: Ecological, sustainable economic and social development of the region

Results tree species

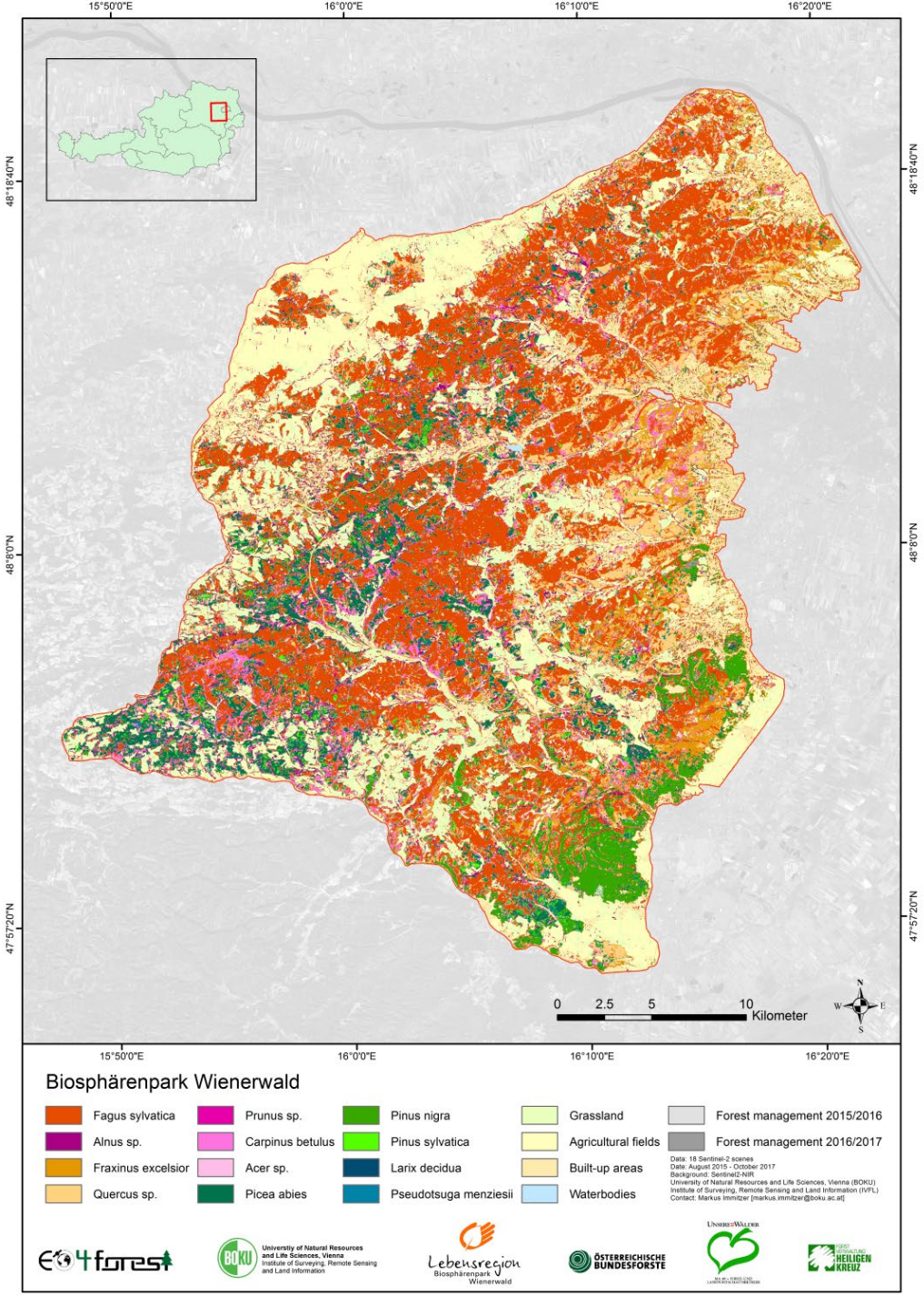
- Land cover classification combined with best tree groups models
- Forest changes masked out



Fagus sylvatica	Prunus sp.	Pinus nigra
Alnus sp.	Carpinus betulus	Pinus sylvatica
Fraxinus excelsior	Acer sp.	Larix decidua
Quercus sp.	Picea abies	Pseudotsuga menziesii

Forest management 2015/2016

Forest management 2016/2017



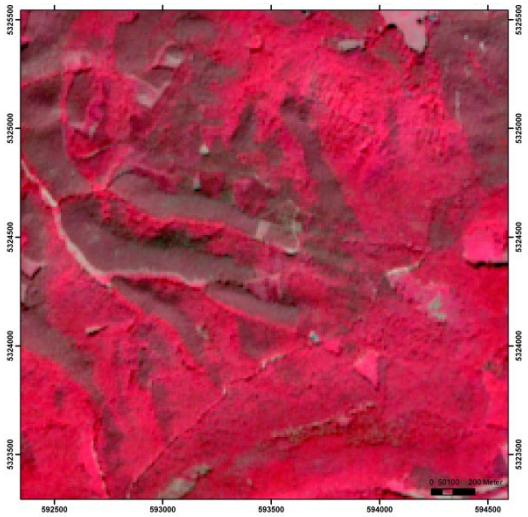
Results - tree species

- Best tree group models aggregated

Classification	Reference												
	FS	AG	FE	QU	PR	CP	AC	PA	PN	PS	LD	PM	UA
Fagus sylvatica	**211**	4	7	7	4	12	8						**83.4%**
Alnus glutinosa	0	**44**	0	1	0	0	0						**97.8%**
Fraxinus excelsior	0	0	**44**	3	0	0	7						**81.5%**
Quercus sp.	0	1	5	**117**	1	4	2						**90.0%**
Prunus sp.	0	0	0	0	**18**	0	0						**100.0%**
Carpinus betulus	4	2	3	1	1	**48**	0						**81.4%**
Acer sp.	0	1	1	1	1	1	**16**						**76.2%**
Picea Abies								**132**	0	3	1	1	**96.4%**
Pinus nigra								1	**101**	1	1	2	**95.3%**
Pinus sylvestris								1	4	**75**	0	0	**93.8%**
Larix decidua								1	1	0	**46**	1	**93.9%**
Pseudotsuga menziesii								0	1	0	1	**52**	**96.3%**
∑ reference data	215	52	60	130	25	65	33	135	107	79	49	56	1006
PA	**98.1%**	**84.6%**	**73.3%**	**90.0%**	**72.0%**	**73.8%**	**48.5%**	**97.8%**	**94.4%**	**94.9%**	**93.9%**	**92.9%**	
							OA	**89.9%**		Kappa	**0.885**		

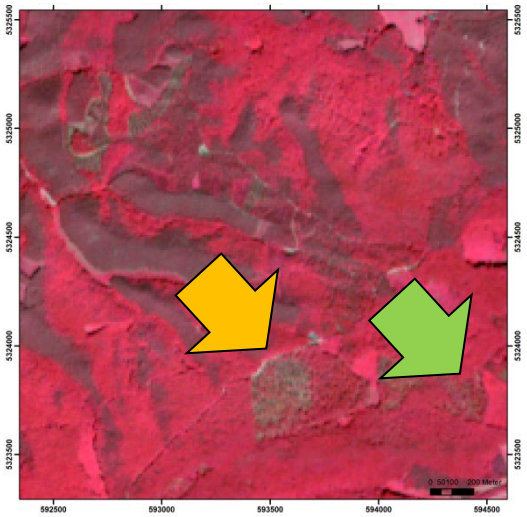
Change detection – Forest management activities

August 2015



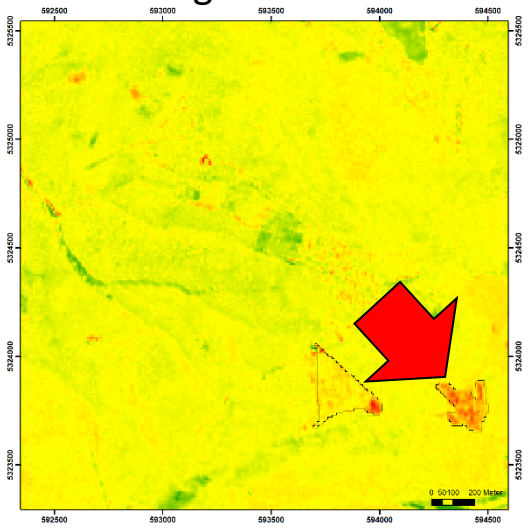
August 2016

August 2017

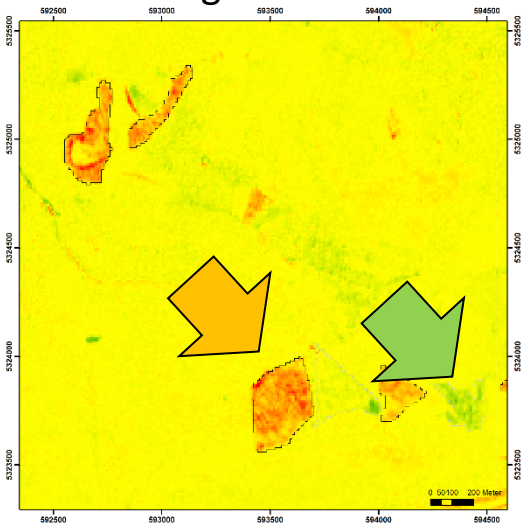


Difference
Actual year –
previous year

Change 2015-2016



Change 2016-2017



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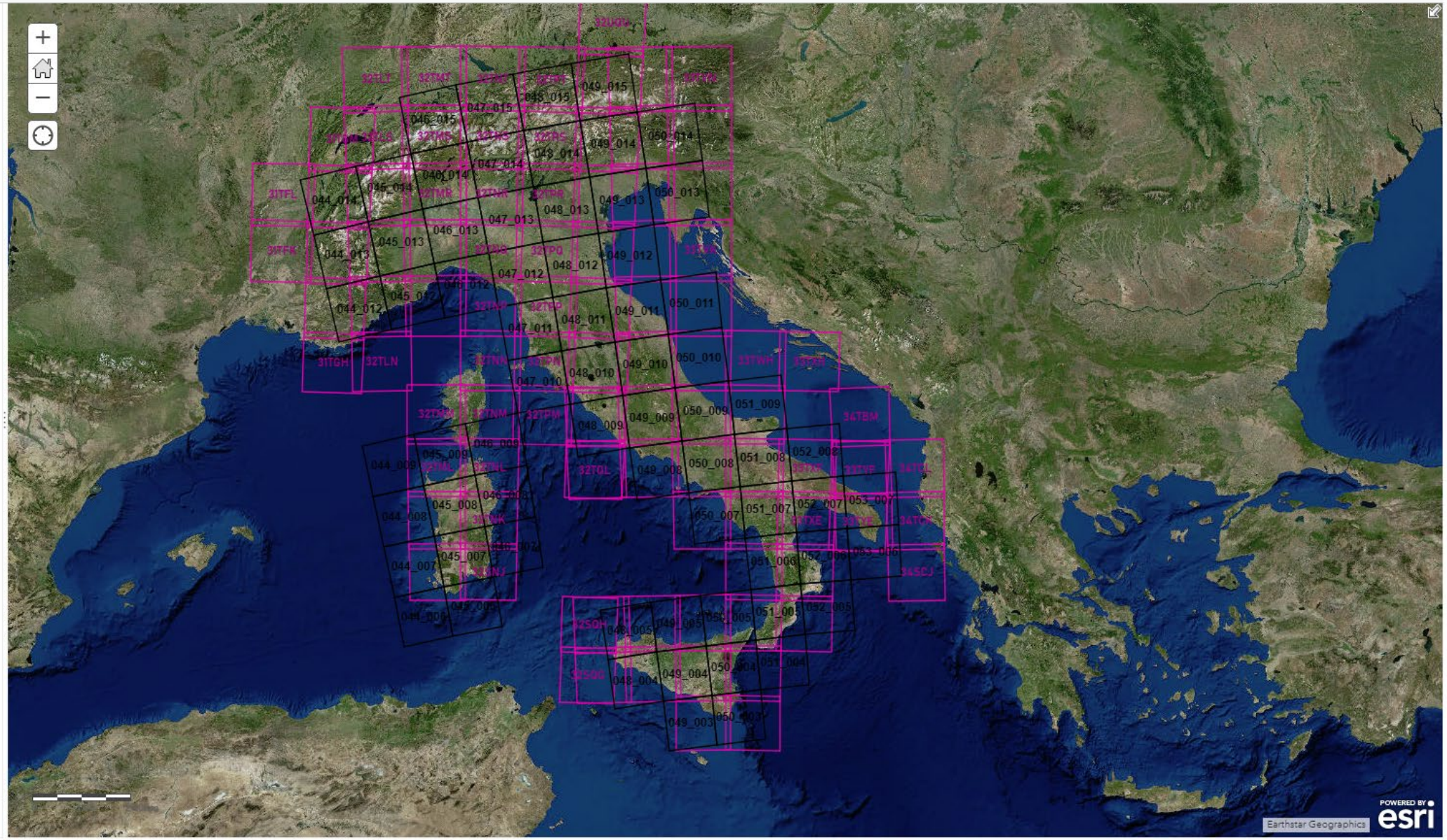
gend



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Problematic areas (data)
Sparce urban
Sparce urban (- data)
Low density Urban?
Low density Urban? (- data)
Urban
Other built up areas
Urban with low inter annual variations
problematic areas (data)
Water
Water (- data)
Water with low inter annual variations
crosoft

… CONCLUSIONS …

Huge potential of Sentinel-2 for agriculture/ forestry/ natural resource management … we have nowadays the necessary resolution, data policy, information content, timeliness, revisit frequency which is needed

We can handle (EODC) huge data volumes & pre-processing tasks… using cloud solution (plus supercomputing) … at fair price …

Information matters – not data … transformation of added-value data in usuable information is key challenge – this requires expertise in data mining, pattern recognition, image classification … business requirements

Thank you for your attention

Francesco Vuolo & Clement Atzberger
& team contribution

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