InSAR-derived displacement parameters over agricultural land using multi-frequency SAR

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17 June 2026

TU Delft lpdp

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descriptive displacement model

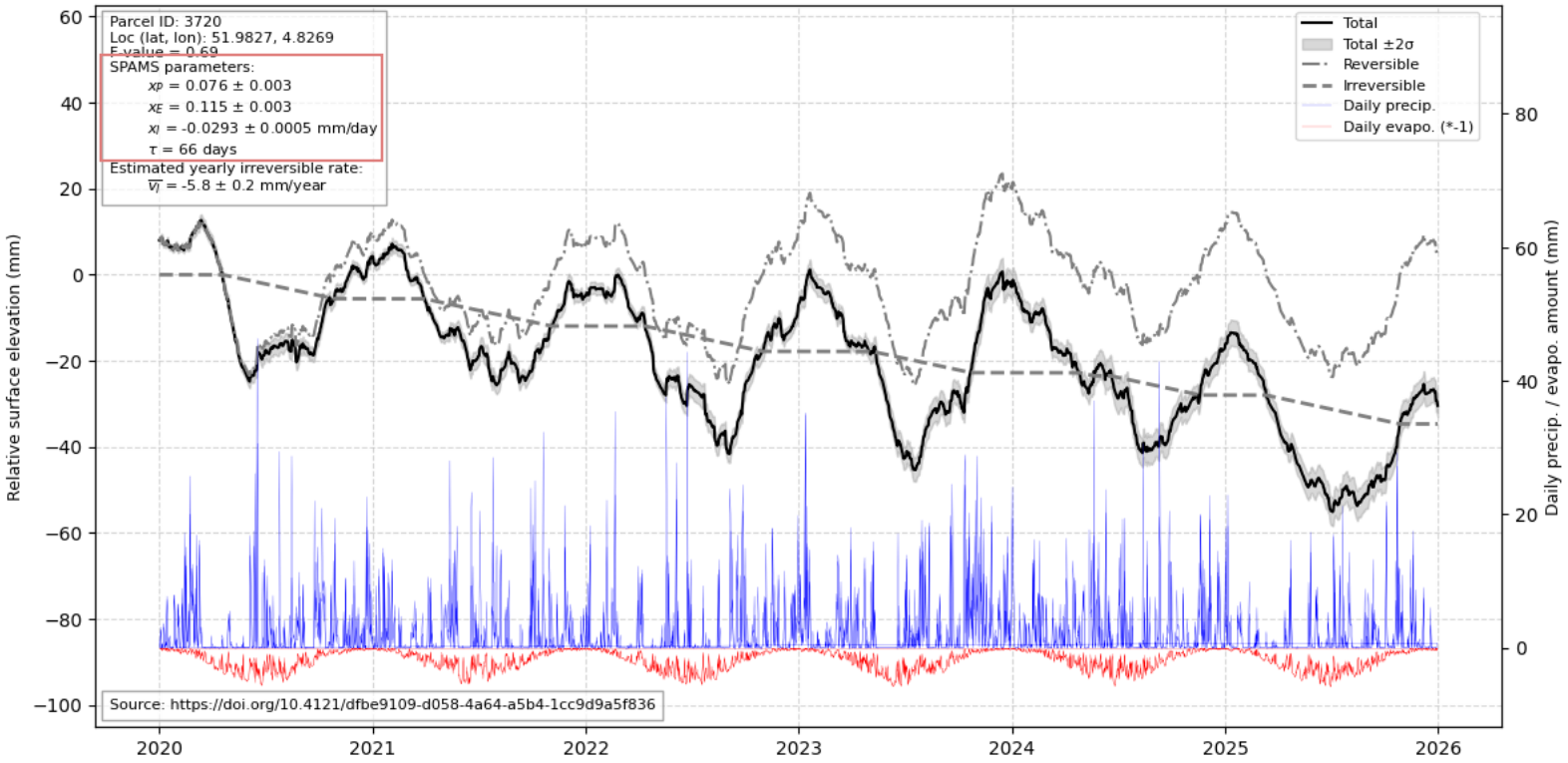
the number of parameters

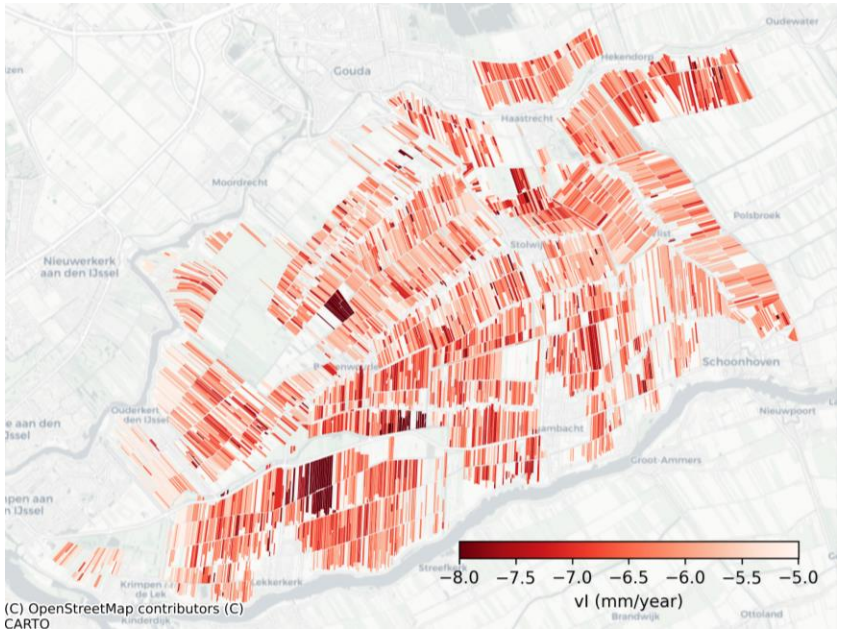
displacement parameters

+

half-vectorized covariance matrix

SPAMS10





Sentinel-1
Peat grassland

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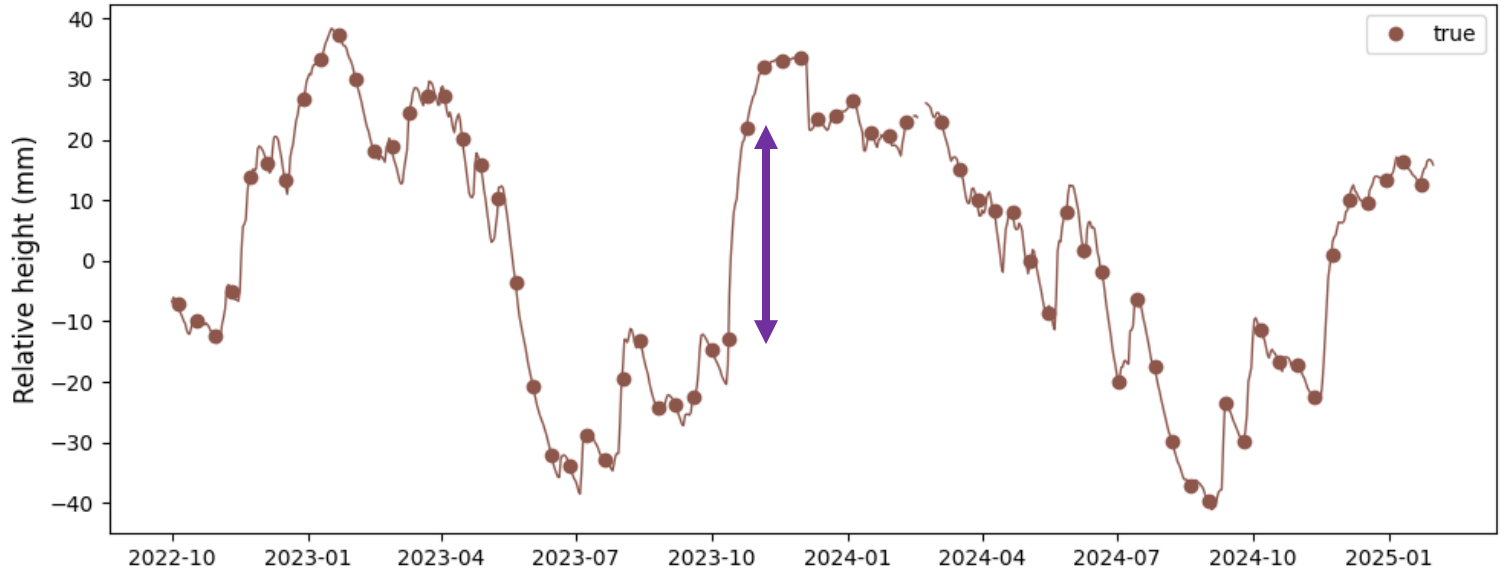
Problems

- Phase ambiguities



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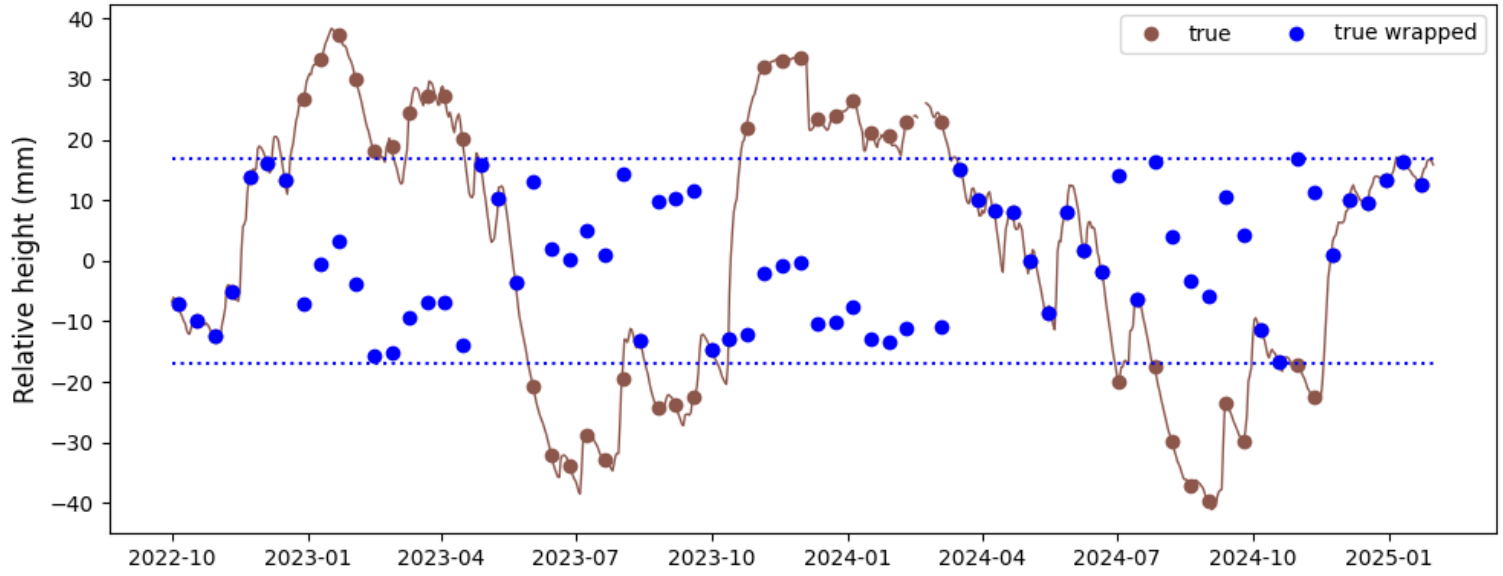
Problems

- Phase ambiguities



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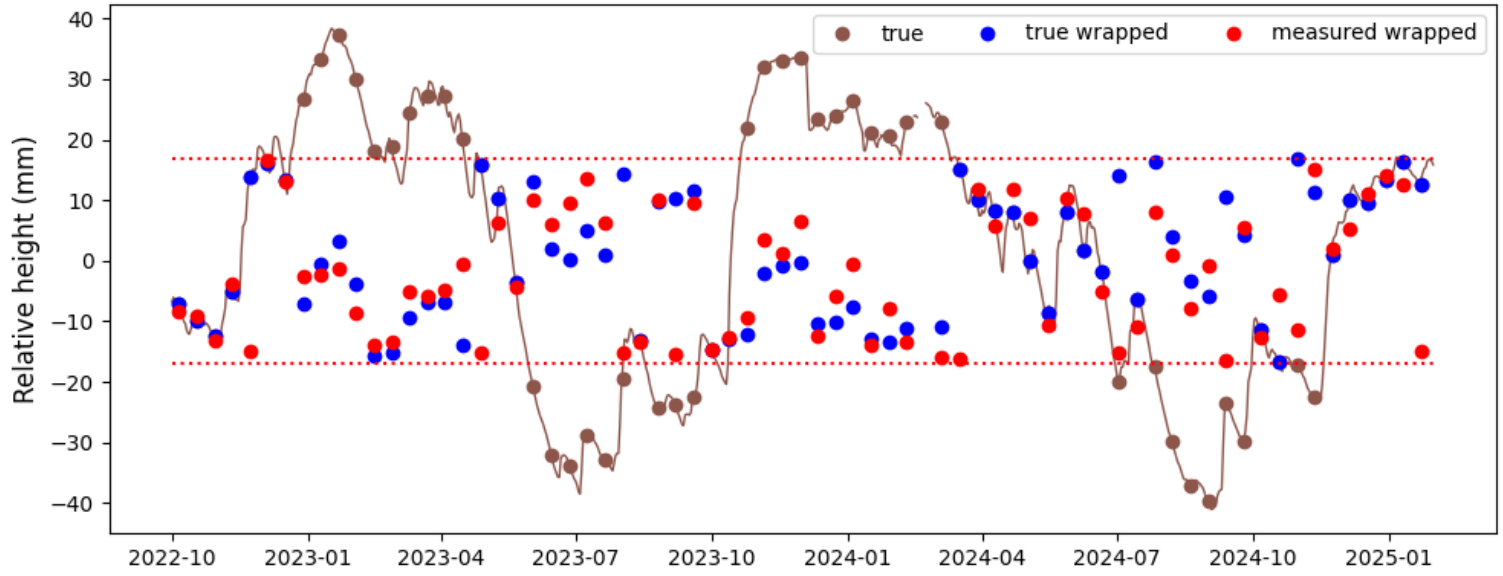
Problems

- Phase ambiguities



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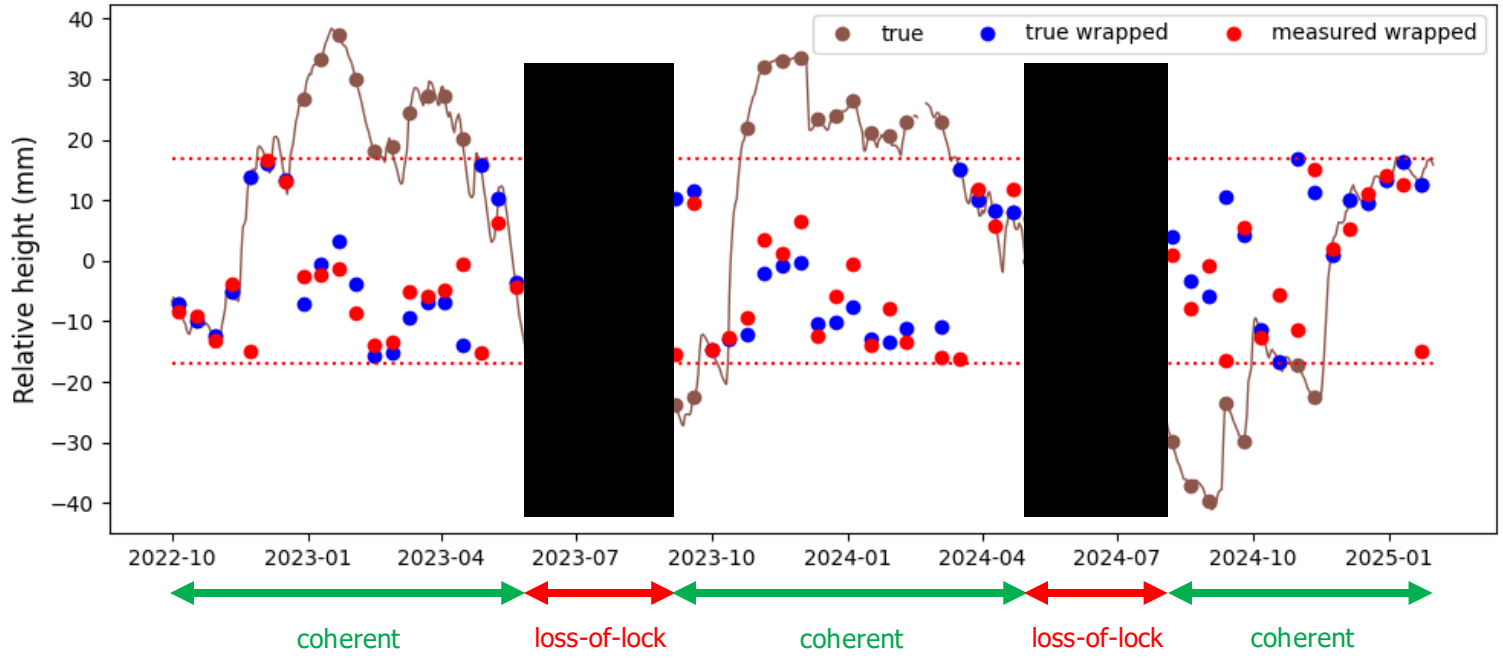
Problems

- Phase ambiguities
- Loss-of-lock



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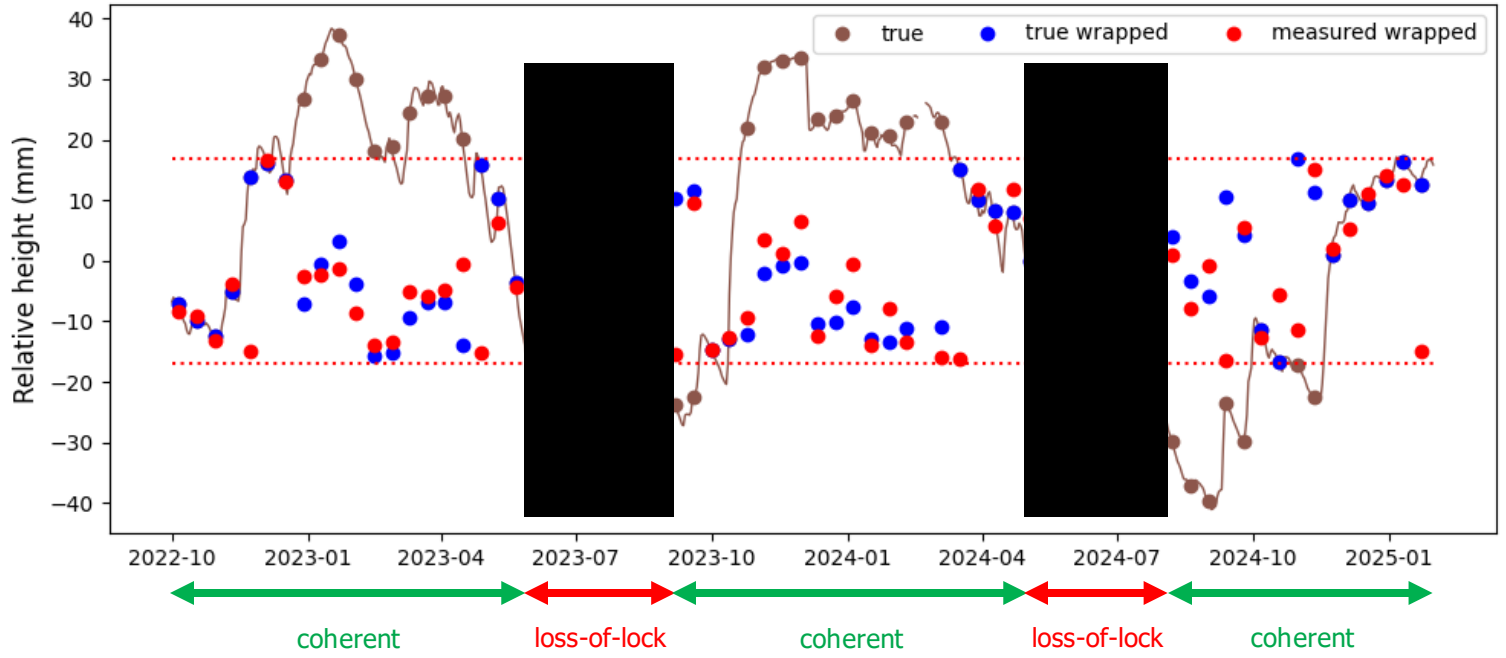
Problems

- Phase ambiguities
- Loss-of-lock
- We don’t know the truth



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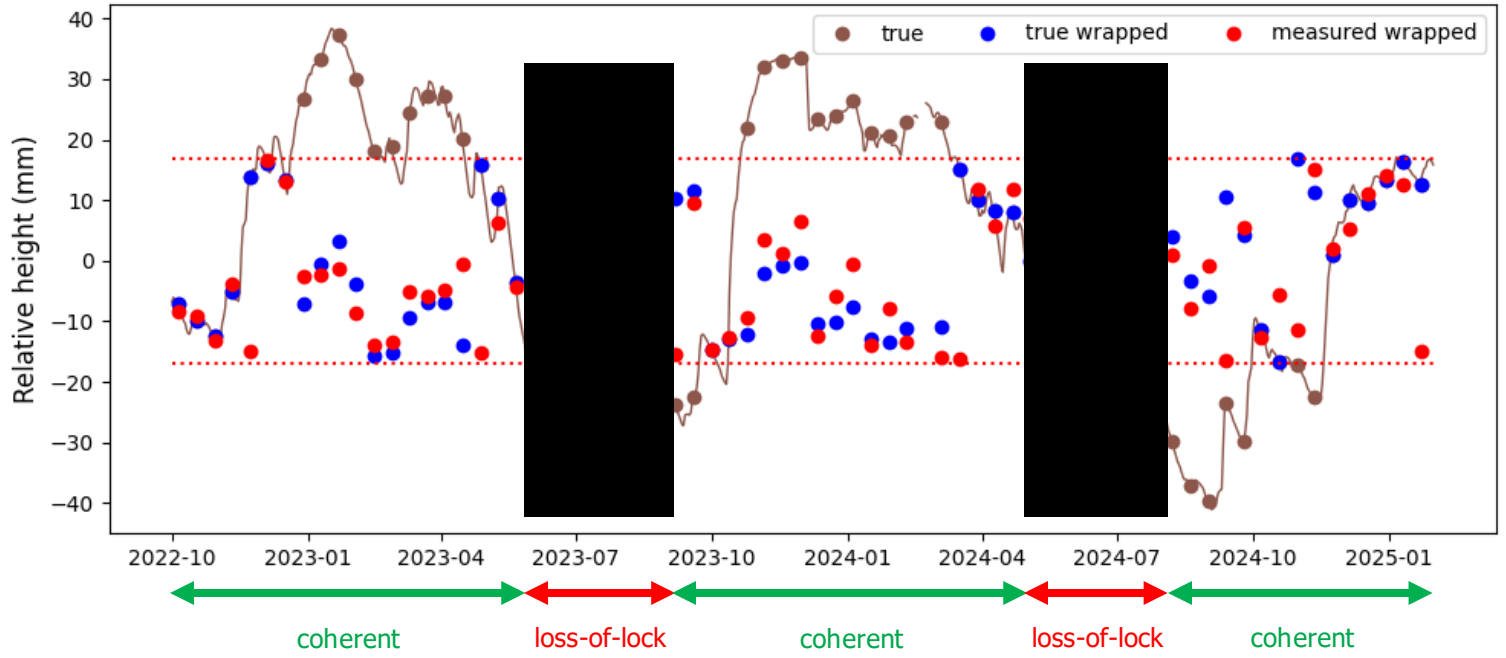
Problems

- Phase ambiguities
- Loss-of-lock
- We don’t know the truth
- Arable areas



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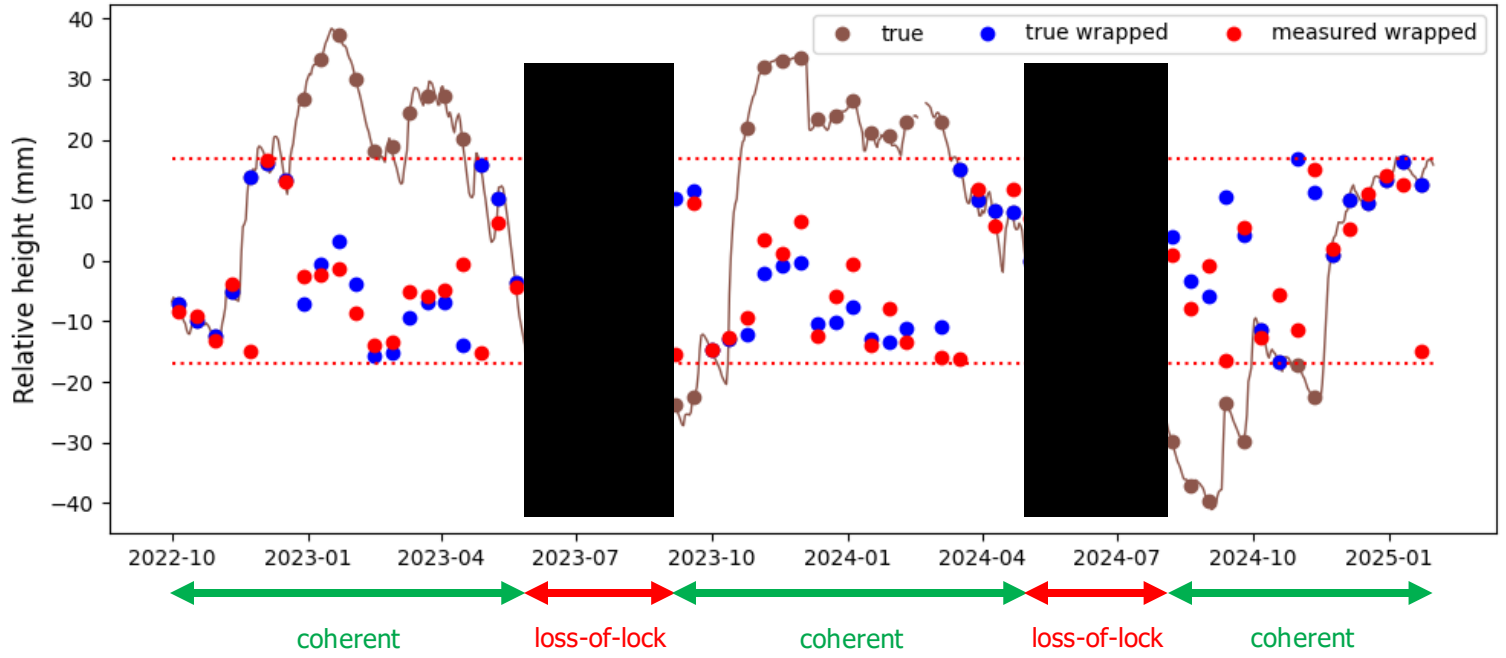
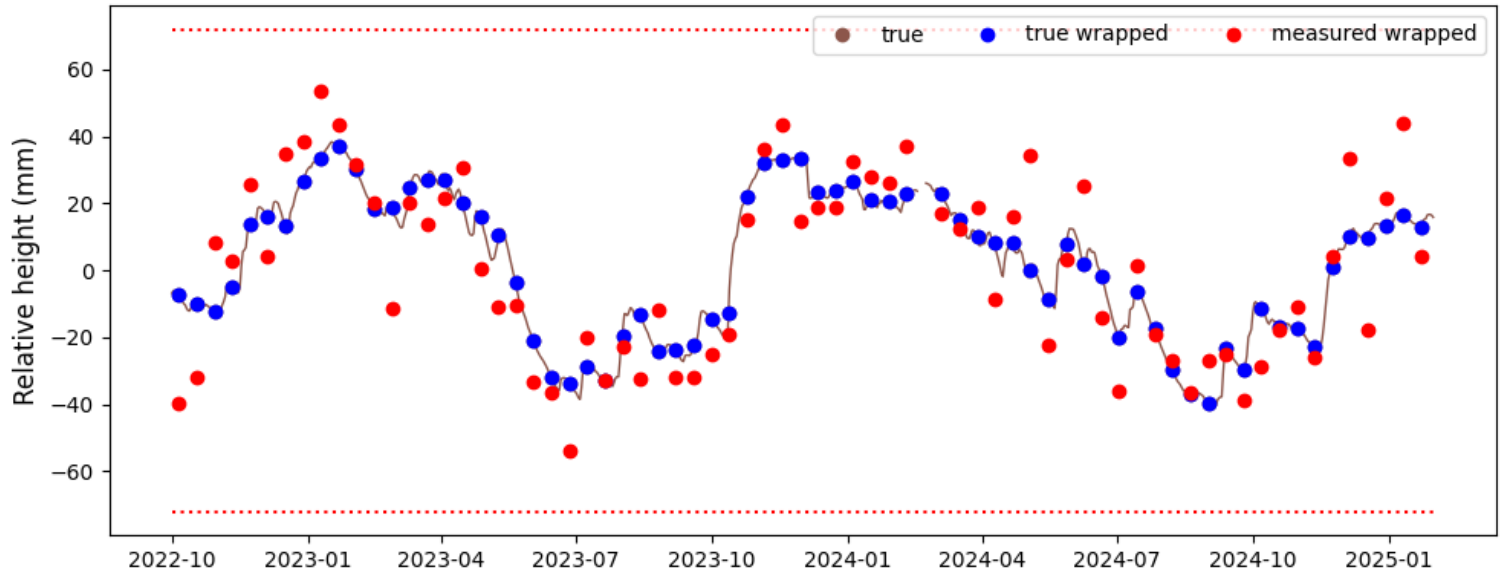
Problems

- Phase ambiguities
- Loss-of-lock
- We don’t know the truth
- Arable areas

L-band ?





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Mission summary

Parameters	Sentinel-1 (IW)	SAOCOM (Stripmap)
Constellation	Sentinel-1 A, C, D	SAOCOM-1 A, B
Repeat cycle	12 / 6 (days)	16 / 8 (days)
Central frequency	5.405 GHz (C-band)	1.275 GHz (L-band)
Wavelength	~5.55 cm	~23.51 cm
Orbit altitude	~693 km	~620 km
Orientation	Right looking	Right looking
Processing product	Level 1A SLC	Level 1A SLC
NESZ	-22 dB	-28 dB
Spatial resolution	~20 x 5 m	~4 x 10 m (az x rg)

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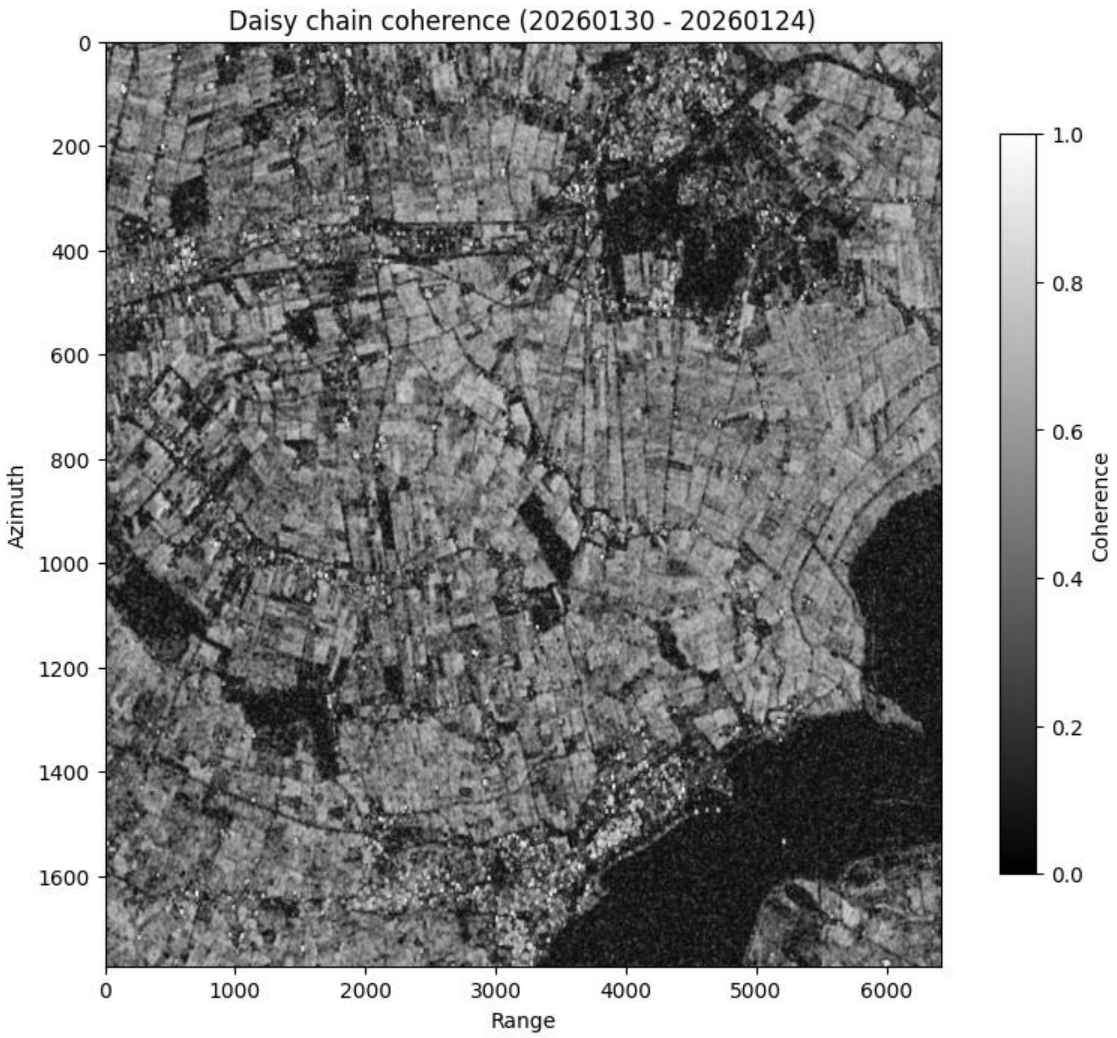
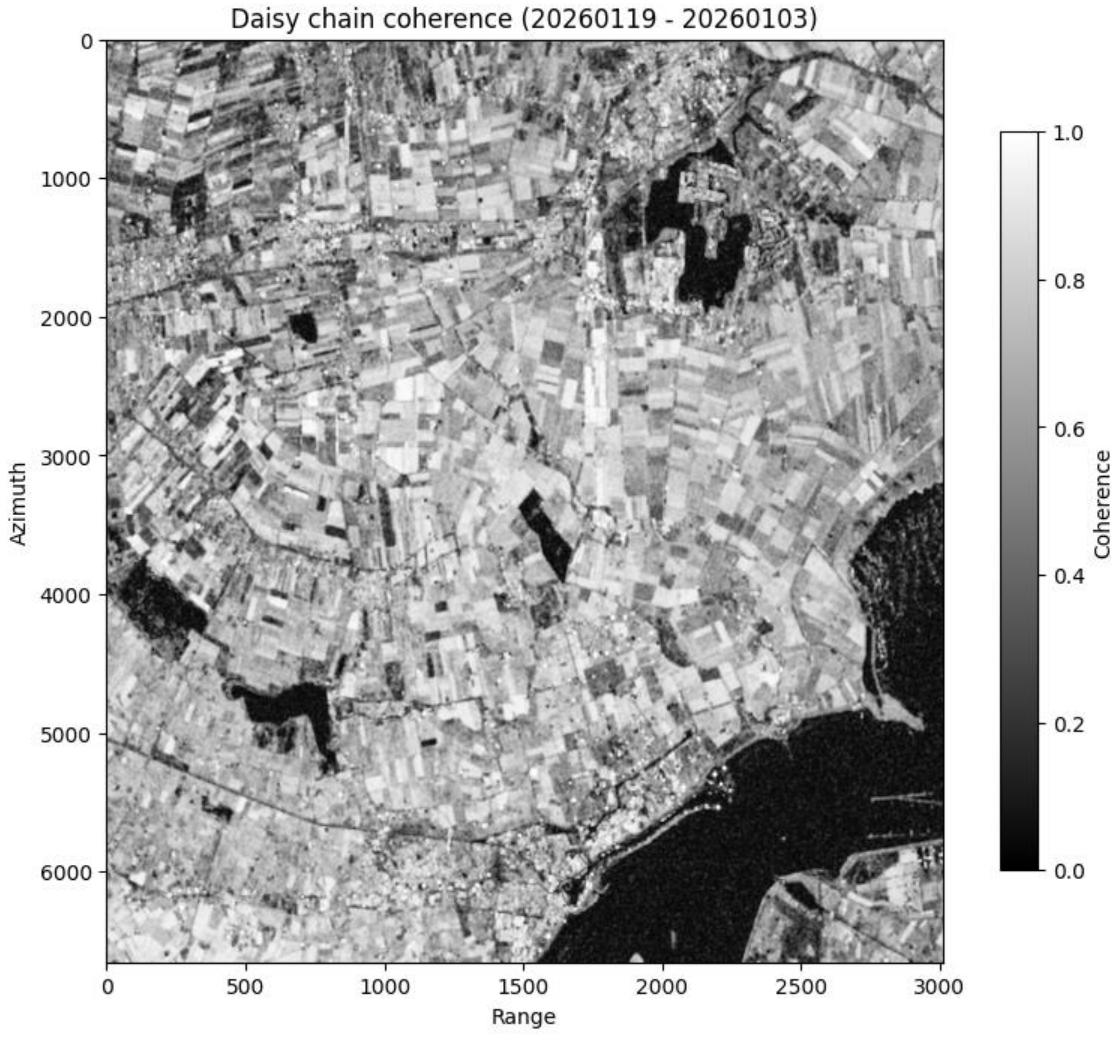
Daisy chain coherence estimates

August 2022 – Jan 2026

Sentinel-1



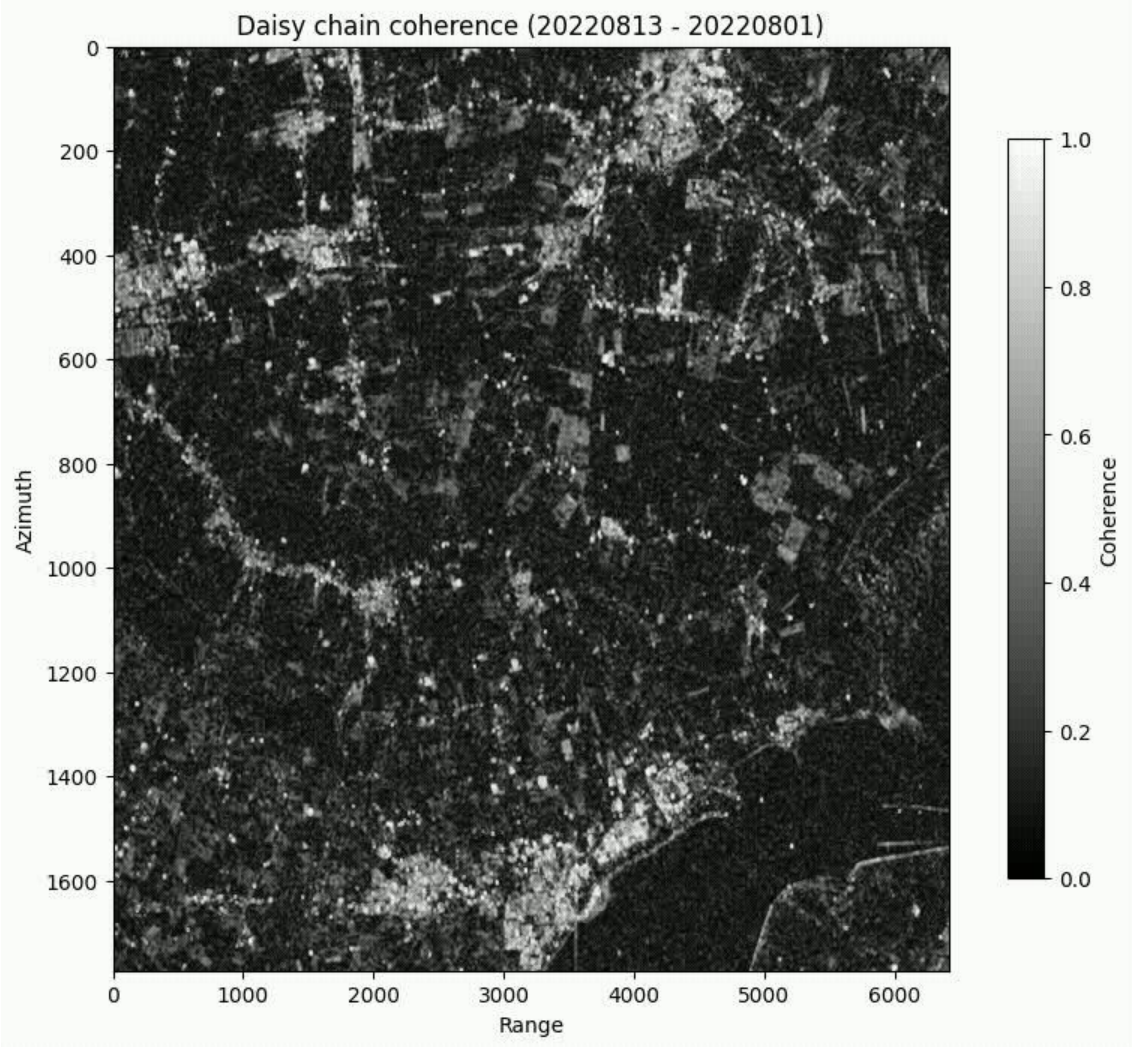
SAOCOM



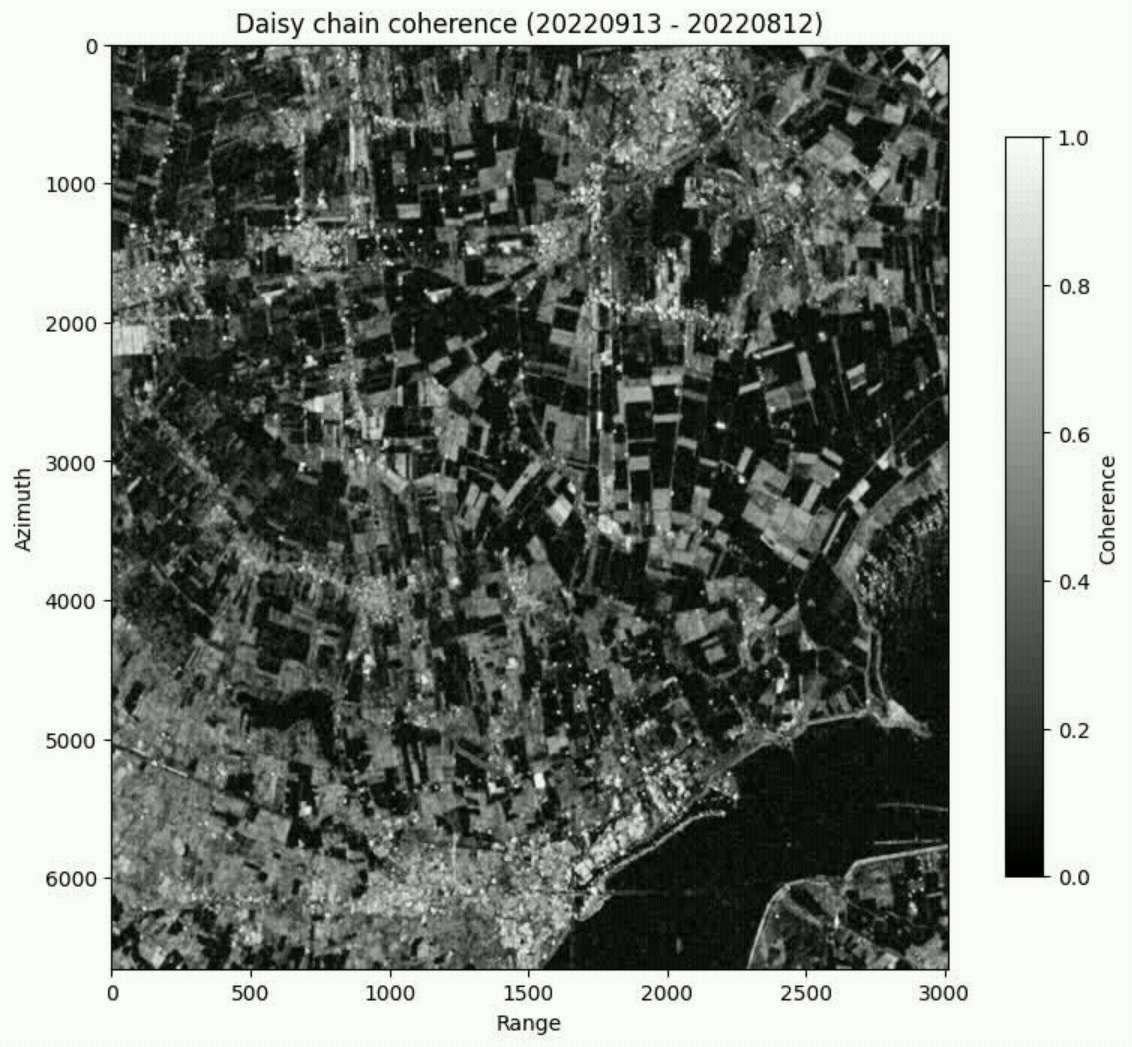
Daisy chain coherence estimates

August 2022 – Jan 2026

Sentinel-1



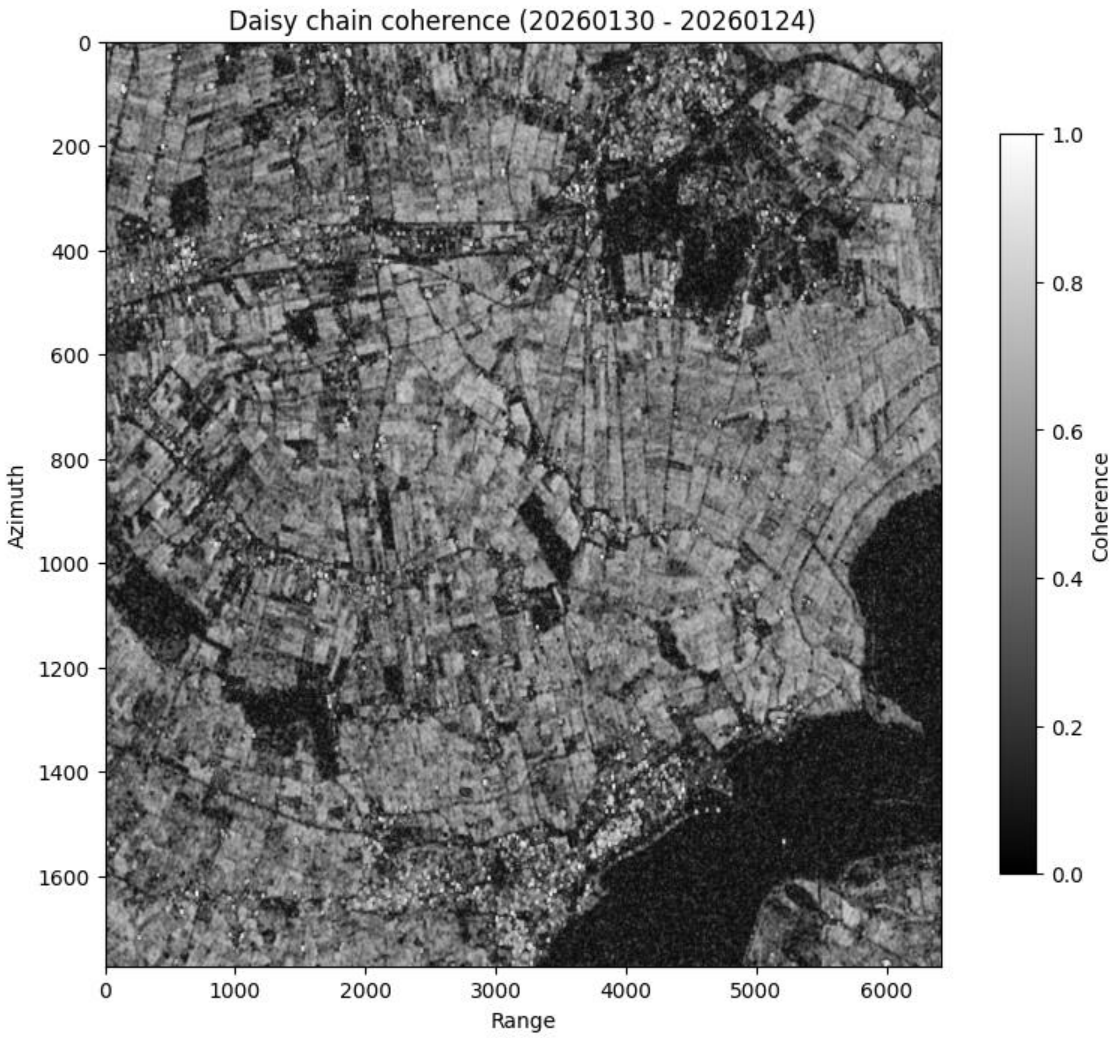
SAOCOM



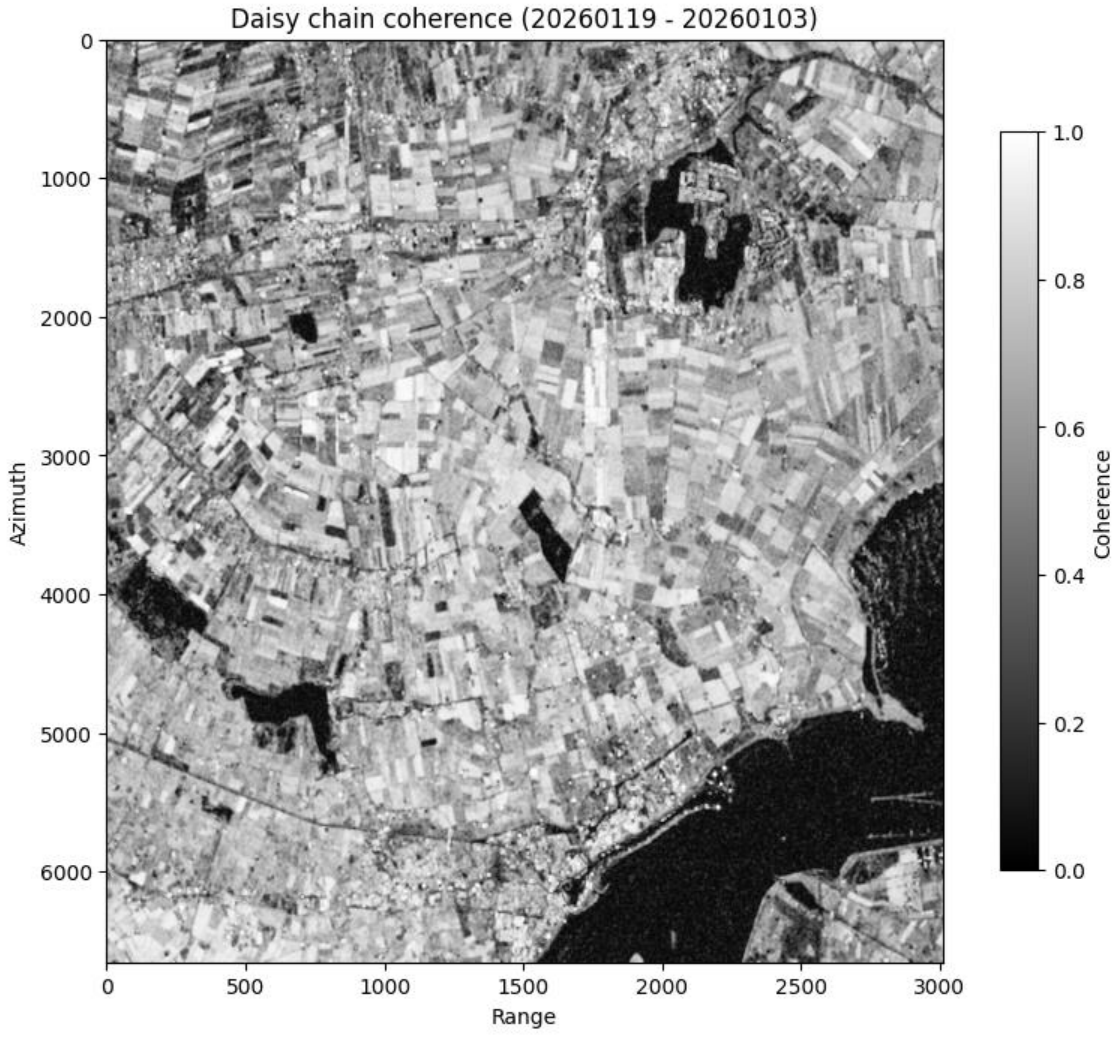
Daisy chain coherence estimates

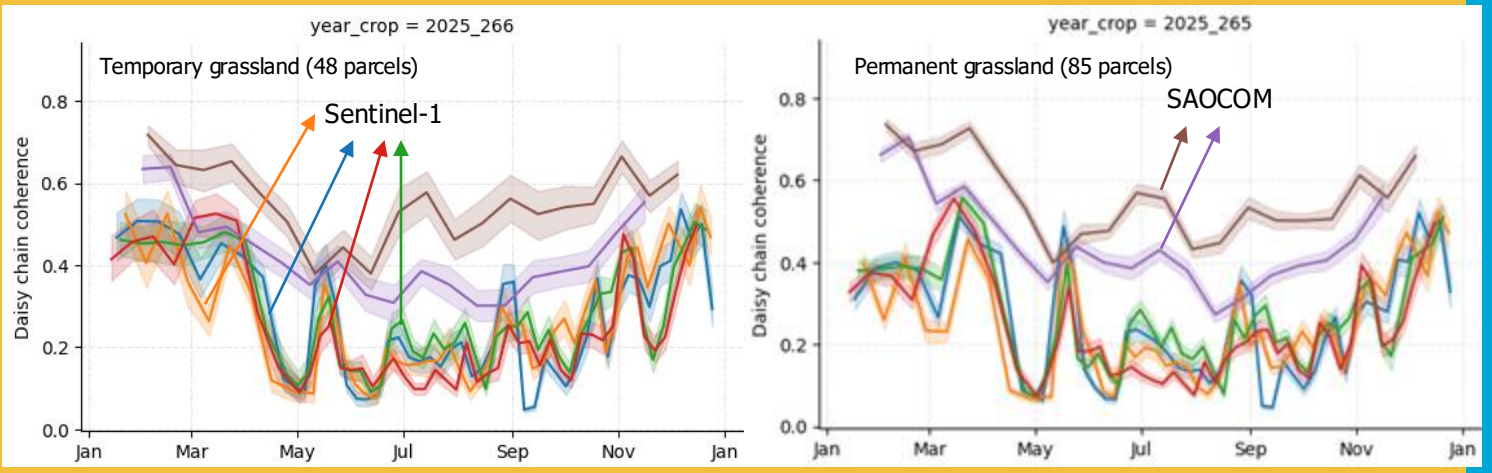
August 2022 – Jan 2026

Sentinel-1

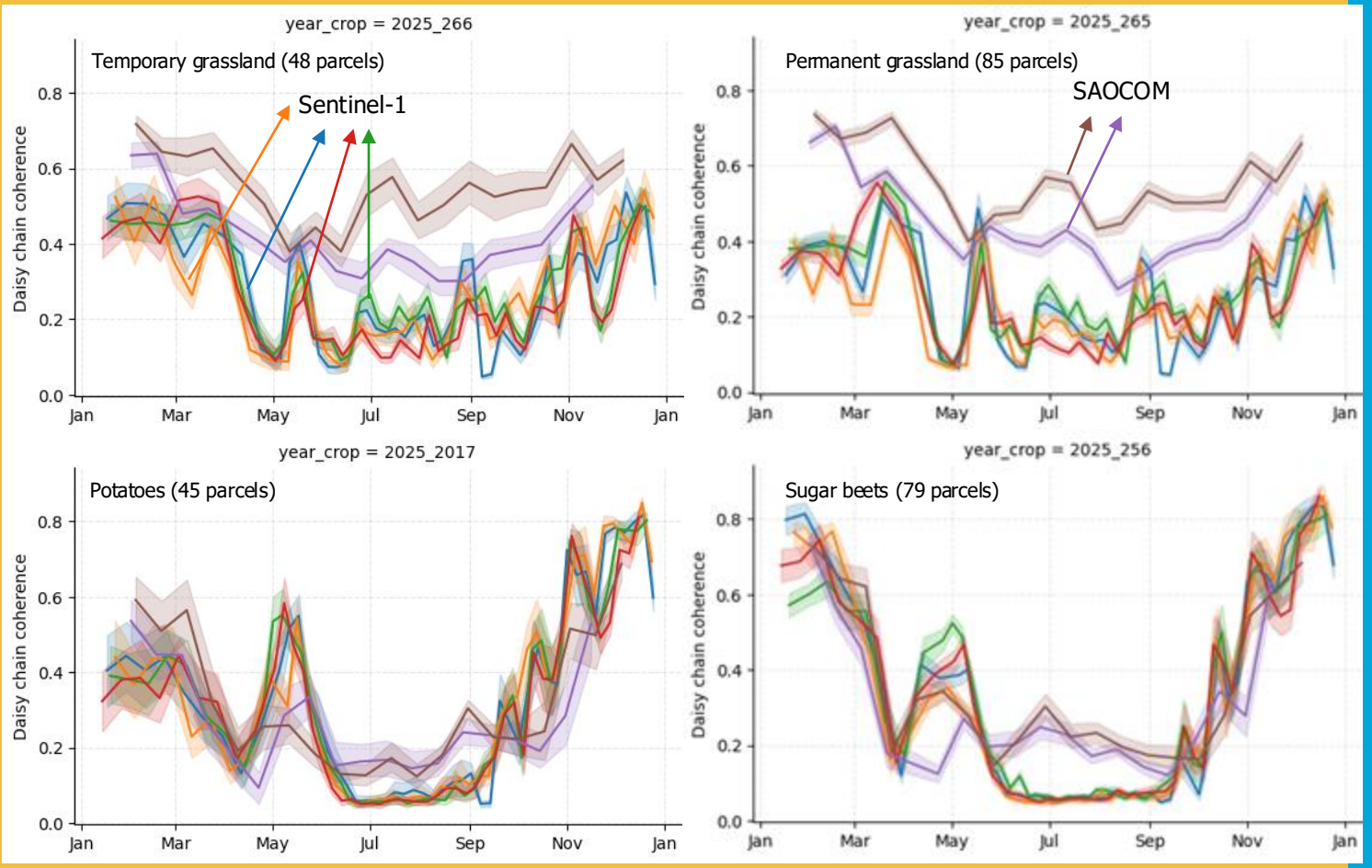


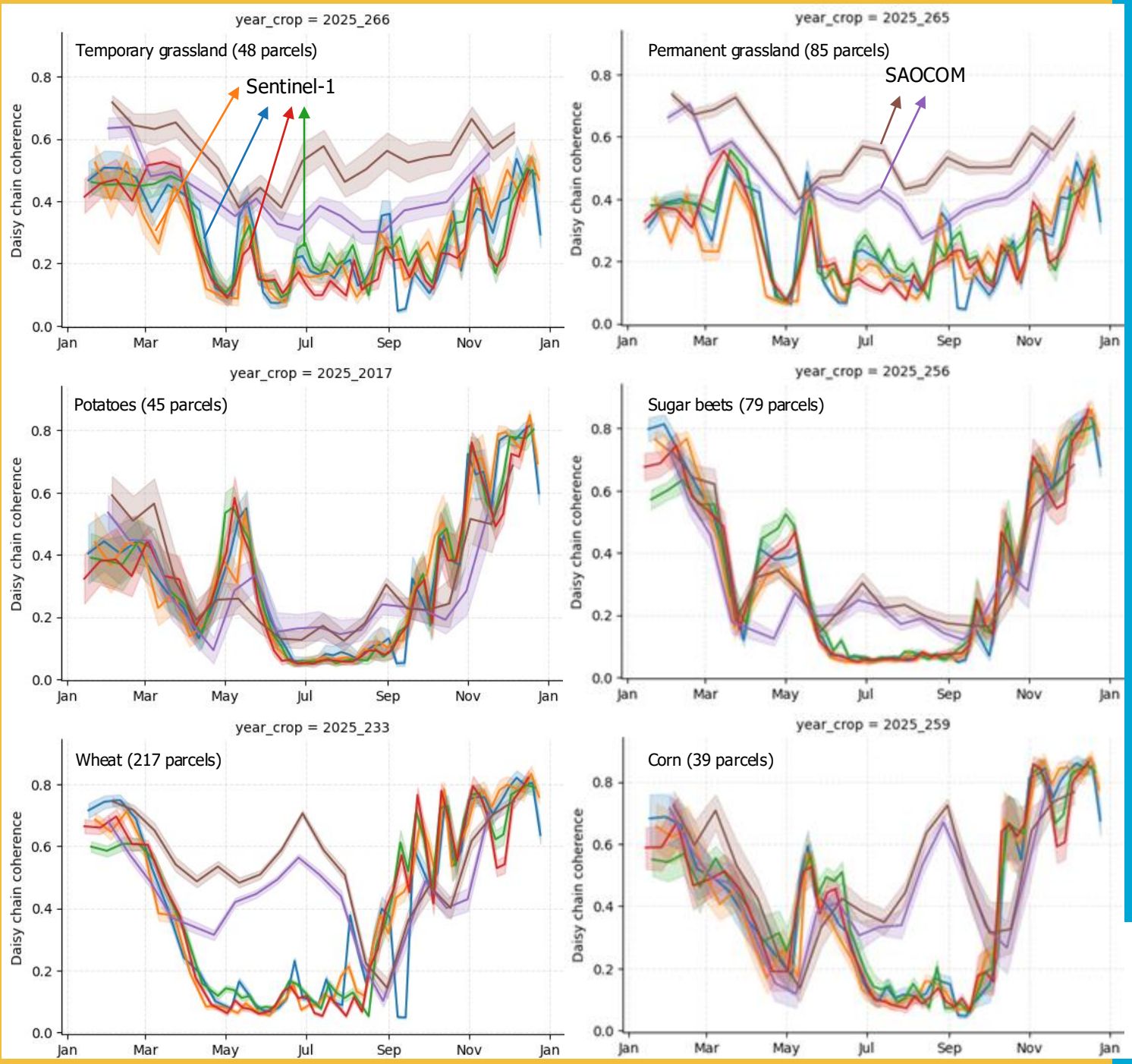
SAOCOM



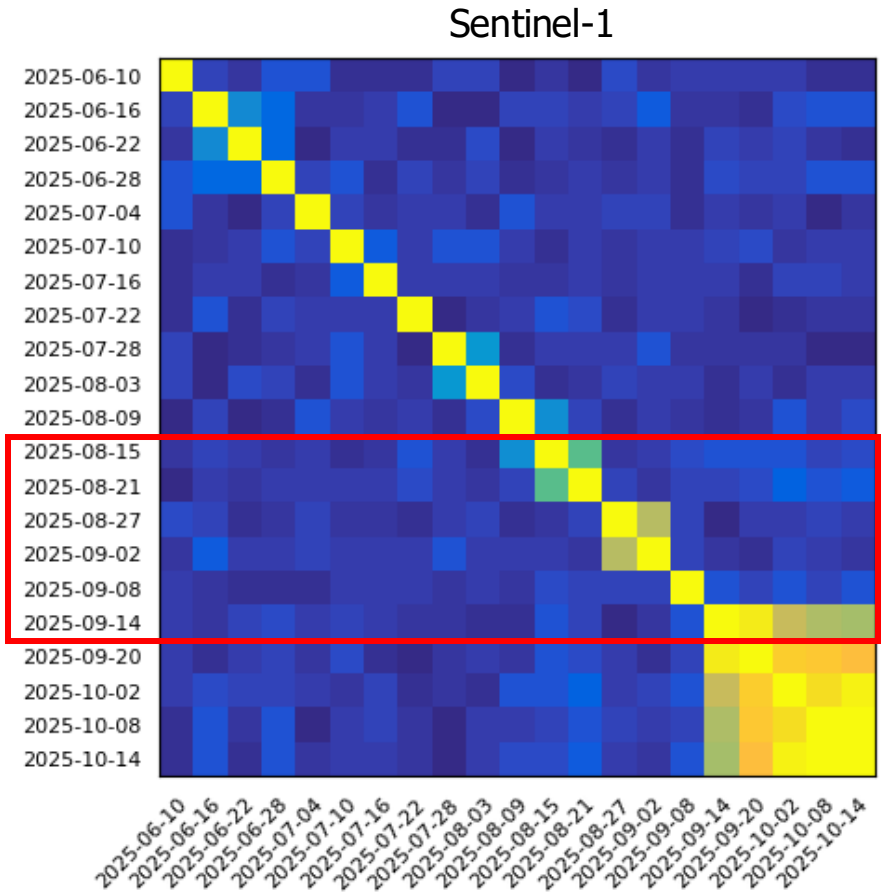

year_crop = 2025_266
Temporary grassland (48 parcels)
Sentinel-1
Daisy chain coherence
0.0
0.2
0.4
0.6
0.8
Jan
Mar
May
Jul
Sep
Nov
Jan

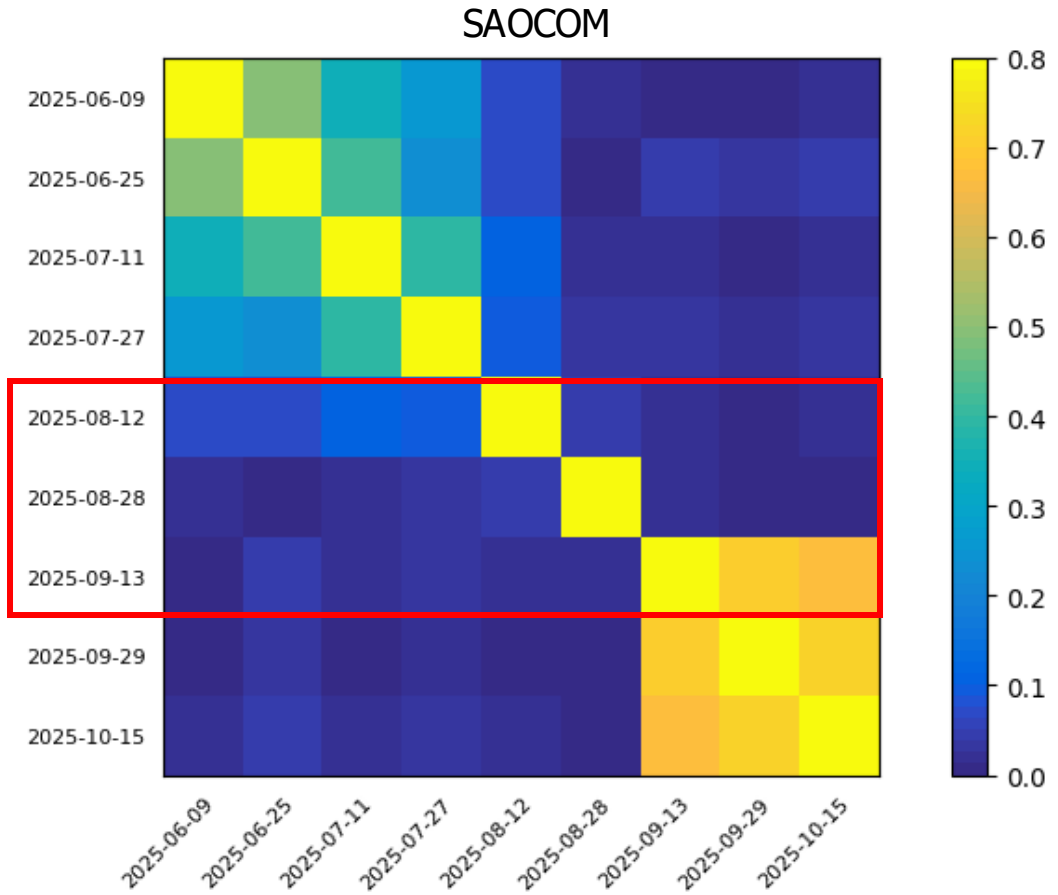
year_crop = 2025_265
Permanent grassland (85 parcels)
SAOCOM
Daisy chain coherence
0.0
0.2
0.4
0.6
0.8
Jan
Mar
May
Jul
Sep
Nov
Jan


year_crop = 2025_266
Temporary grassland (48 parcels)
Sentinel-1
year_crop = 2025_265
Permanent grassland (85 parcels)
SAOCOM
year_crop = 2025_2017
Potatoes (45 parcels)
year_crop = 2025_256
Sugar beets (79 parcels)
Daisy chain coherence
0.0
0.2
0.4
0.6
0.8
Jan
Mar
May
Jul
Sep
Nov
Jan


year_crop = 2025_266
Temporary grassland (48 parcels)
Sentinel-1
year_crop = 2025_265
Permanent grassland (85 parcels)
SAOCOM
year_crop = 2025_2017
Potatoes (45 parcels)
year_crop = 2025_256
Sugar beets (79 parcels)
year_crop = 2025_233
Wheat (217 parcels)
year_crop = 2025_259
Corn (39 parcels)
Daisy chain coherence
0.0
0.2
0.4
0.6
0.8
Jan
Mar
May
Jul
Sep
Nov
Jan
stack_id
s1_asc_t015
s1_asc_t088
s1_dsc_t037
s1_dsc_t139
sao_asc_t215
sao_dsc_t115

Loss-of-lock: harvesting





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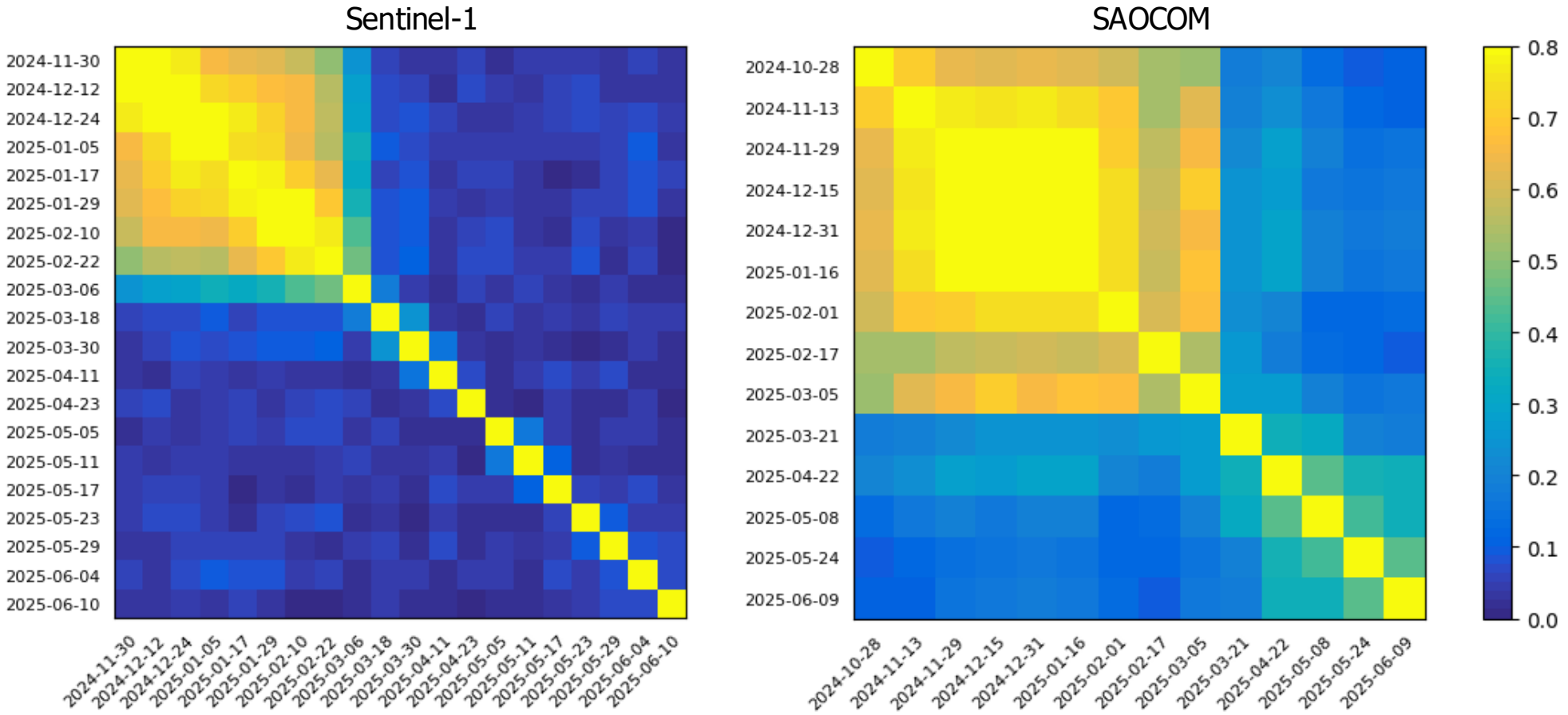
Loss-of-lock: plowing



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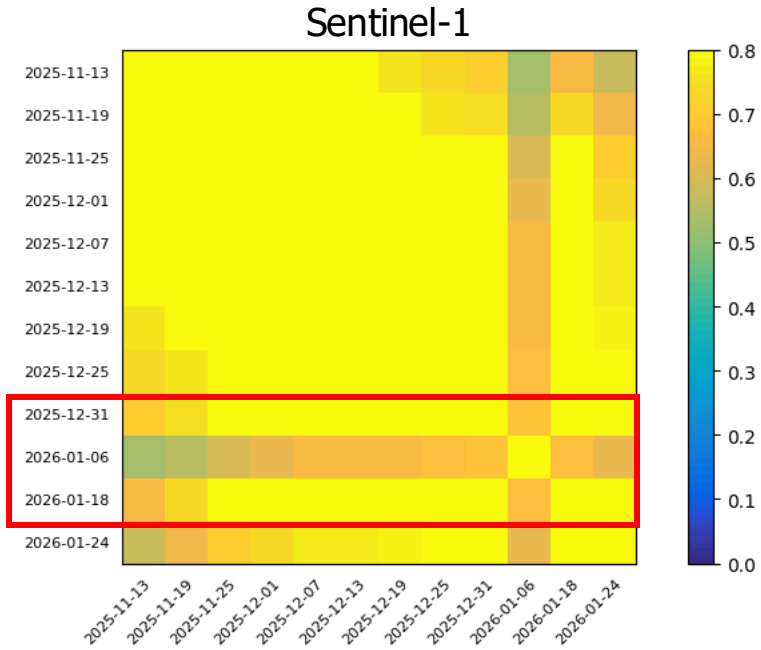
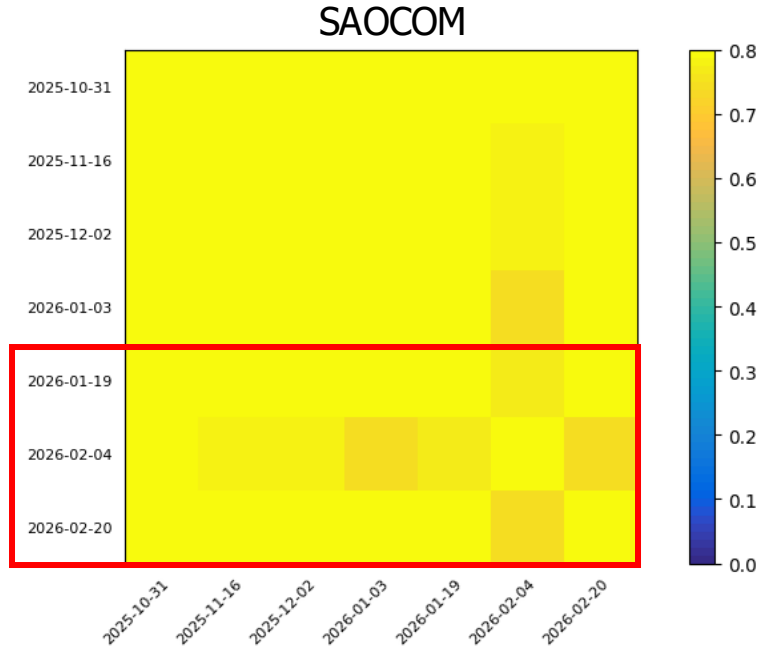
Intermittent loss of coherence: snow





31-Dec-2025

6-Jan-2026

17-Jan-2026

19-Jan-2026

1-Feb-2026

20-Feb-2026

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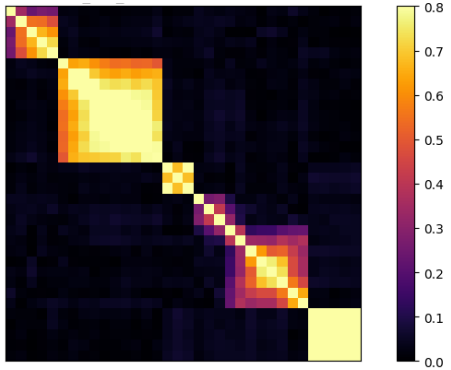
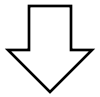
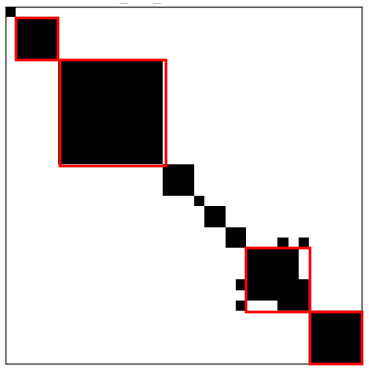
Coherent segment block identification







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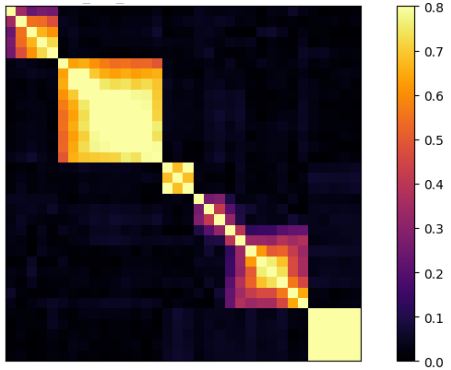
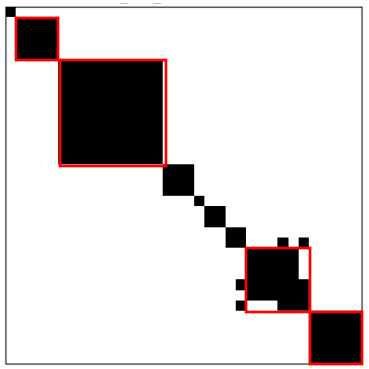
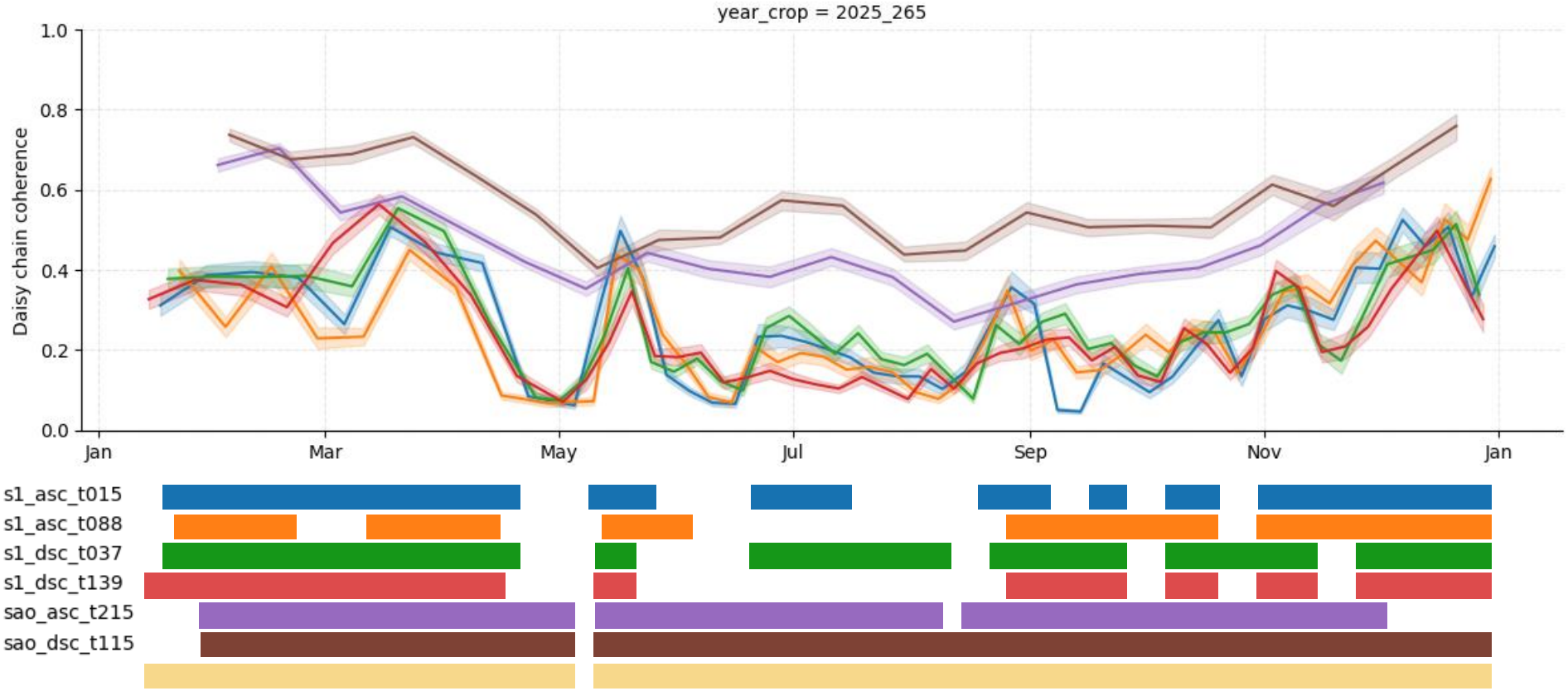
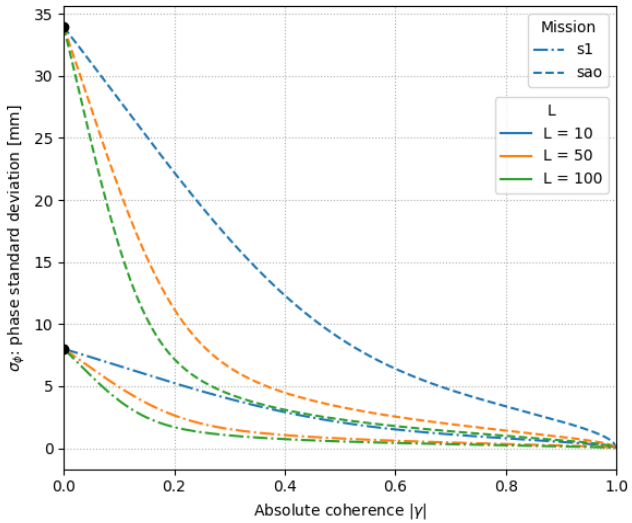

0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0




year_crop = 2025_265
Daisy chain coherence
1.0
0.8
0.6
0.4
0.2
0.0
Jan
Mar
May
Jul
Sep
Nov
Jan
s1_asc_t015
s1_asc_t088
s1_dsc_t037
s1_dsc_t139
sao_asc_t215
sao_dsc_t115


Mission
s1
sao
L
L = 10
L = 50
L = 100
σφ: phase standard deviation [mm]
Absolute coherence |γ|
35
30
25
20
15
10
5
0
0.0
0.2
0.4
0.6
0.8
1.0

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The Netherlands

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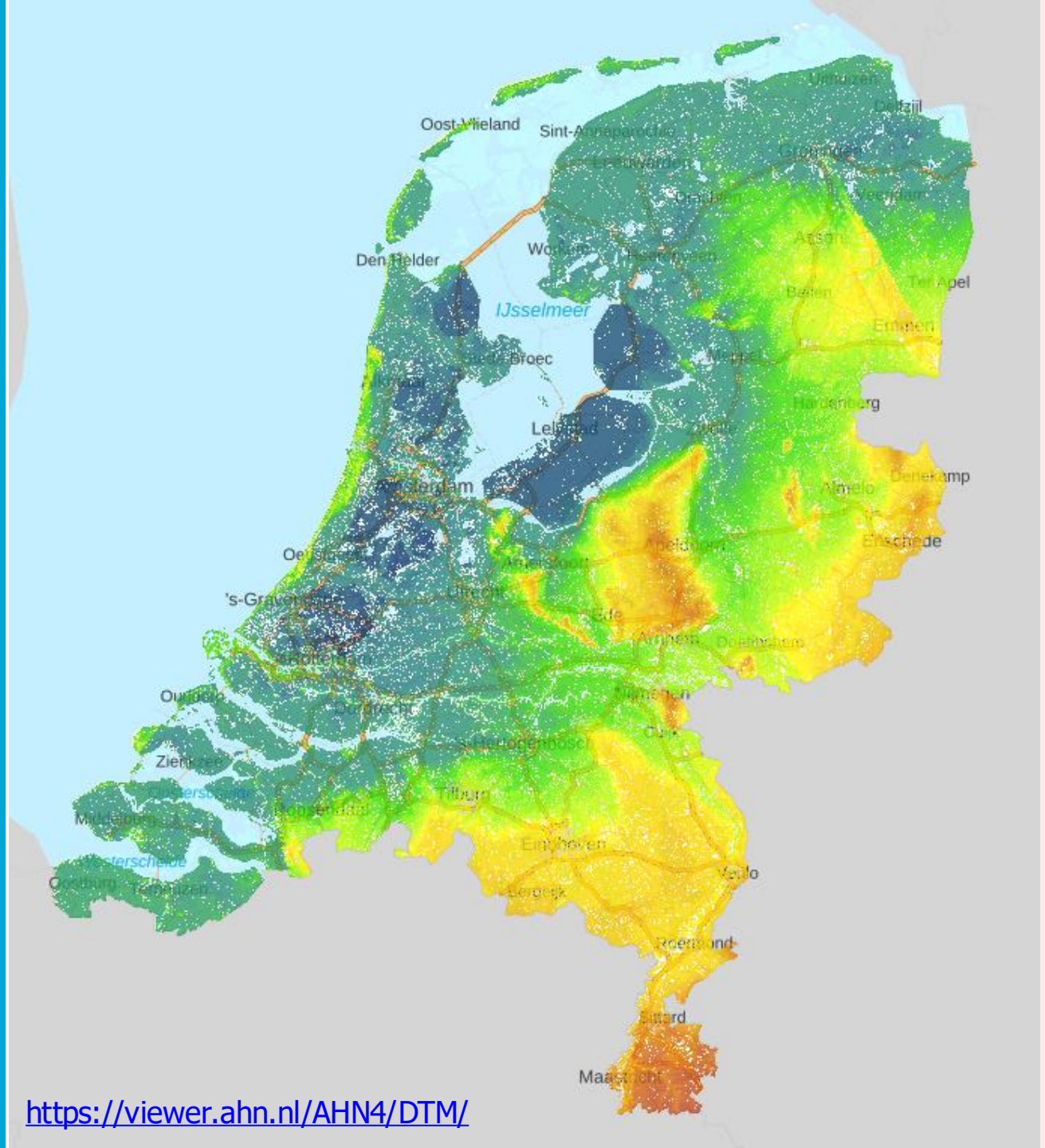
The Netherlands

- Low land



https://viewer.ahn.nl/AHN4/DTM/

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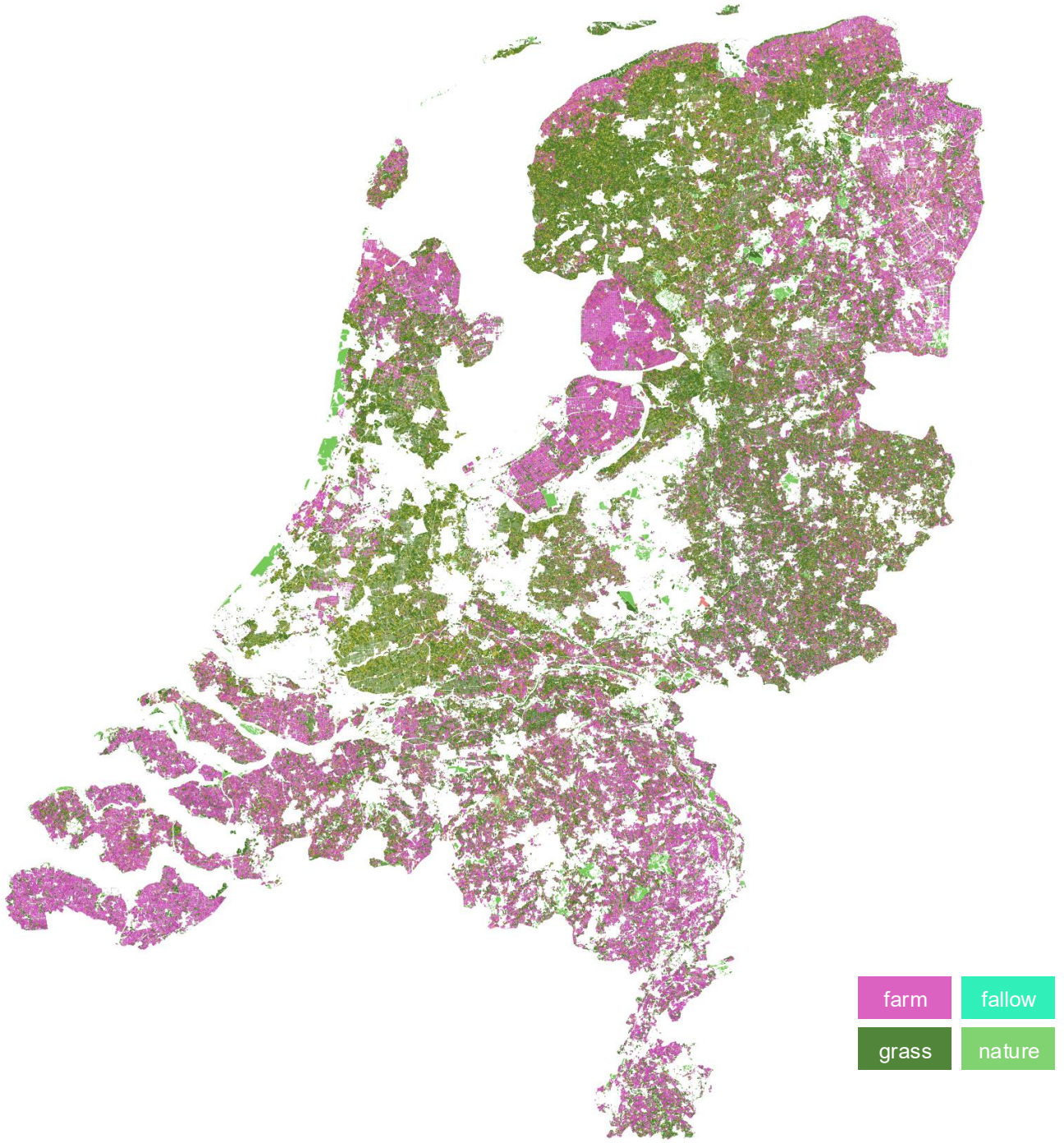
The Netherlands

- Low land
- Agricultural producers



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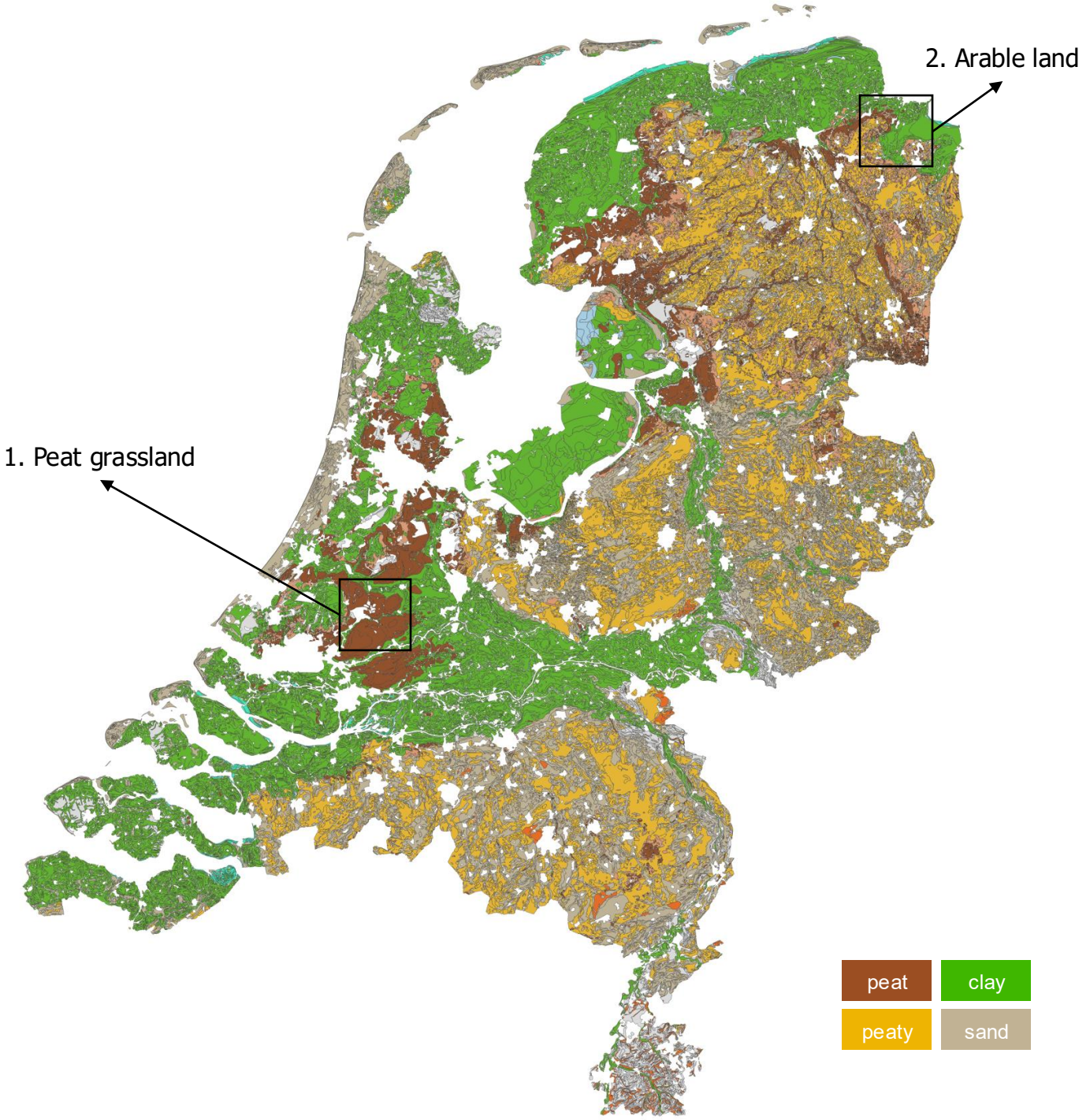
The Netherlands

- Low land
- Agricultural producers
- Soft soils



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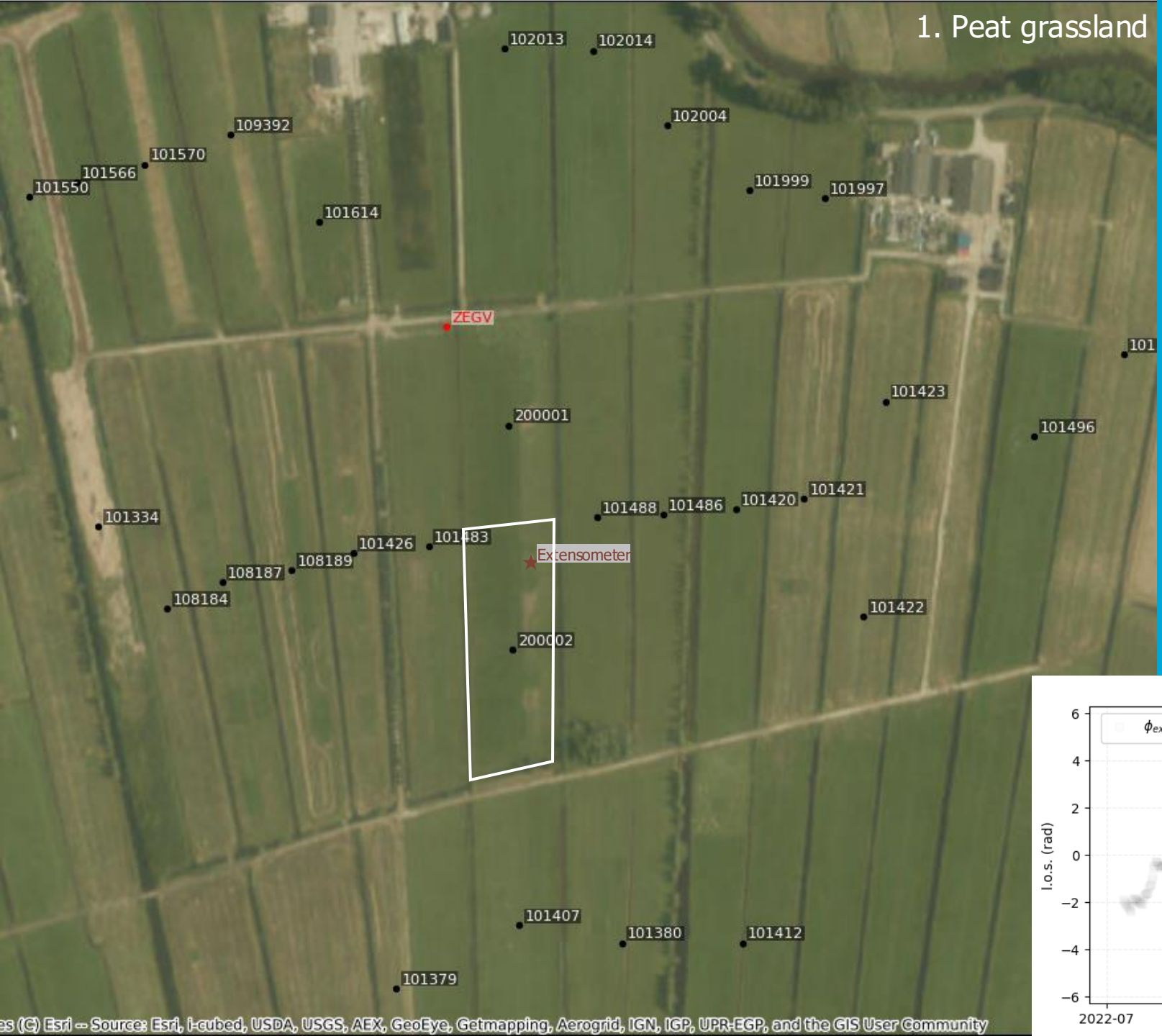
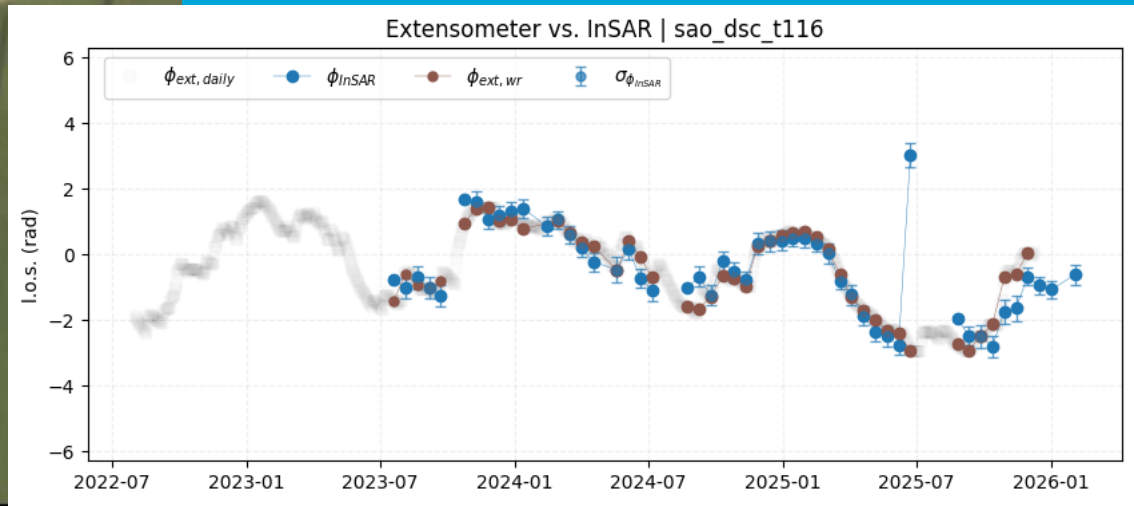


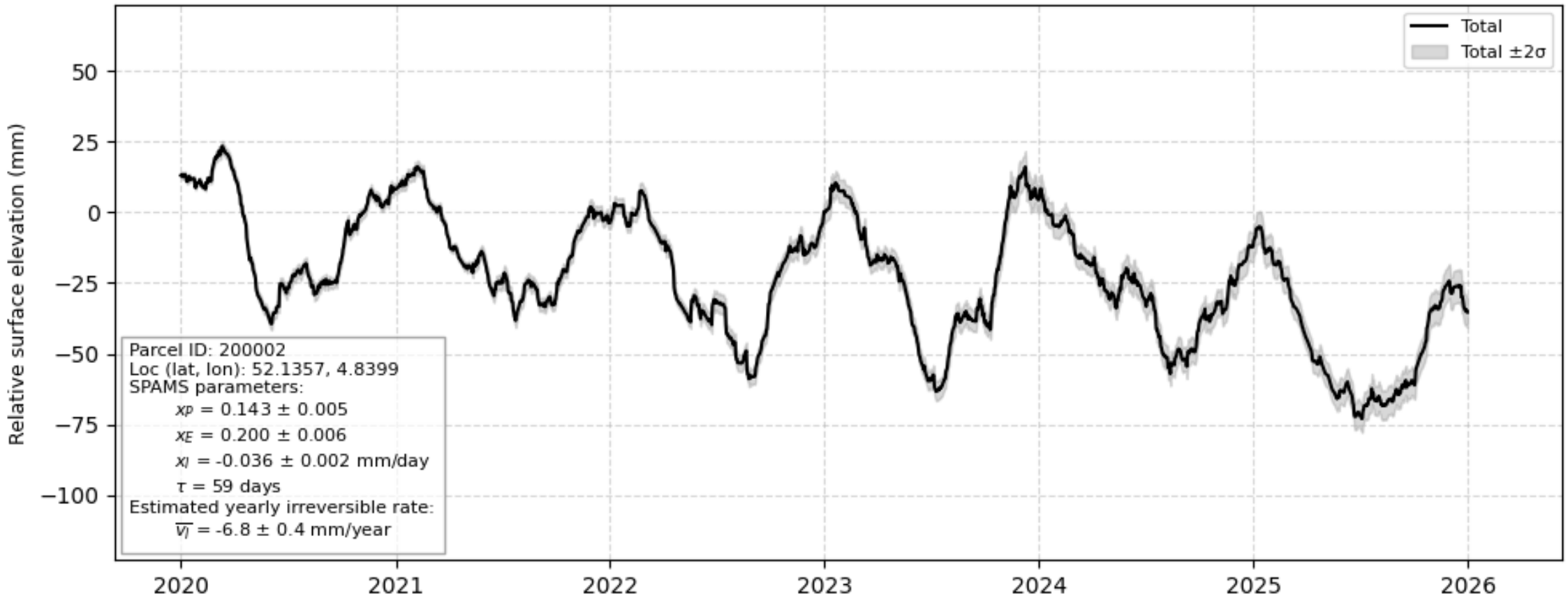
Experiment setup

- Observation period:

  Aug 2022 – Jan 2026
- Reference point: IGRS
- Parcel geometry as boundary for multilooking
- Contextual grouping

  Soil type + ground water zone
- Short arcs (< 500 m)




Total
Total ±2σ
Relative surface elevation (mm)
50
25
0
−25
−50
−75
−100
2020
2021
2022
2023
2024
2025
2026
Parcel ID: 200002
Loc (lat, lon): 52.1357, 4.8399
SPAMS parameters:
x_P = 0.143 ± 0.005
x_E = 0.200 ± 0.006
x_I = -0.036 ± 0.002 mm/day
τ = 59 days
Estimated yearly irreversible rate:
$\overline{v_I}$ = -6.8 ± 0.4 mm/year

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Total
Total ±2σ
Extensometer
Observation
Relative surface elevation (mm)
50
25
0
−25
−50
−75
−100
2020
2021
2022
2023
2024
2025
2026
Parcel ID: 200002
Loc (lat, lon): 52.1357, 4.8399
SPAMS parameters:
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$\overline{v_I}$ = -6.8 ± 0.4 mm/year

TU Delft

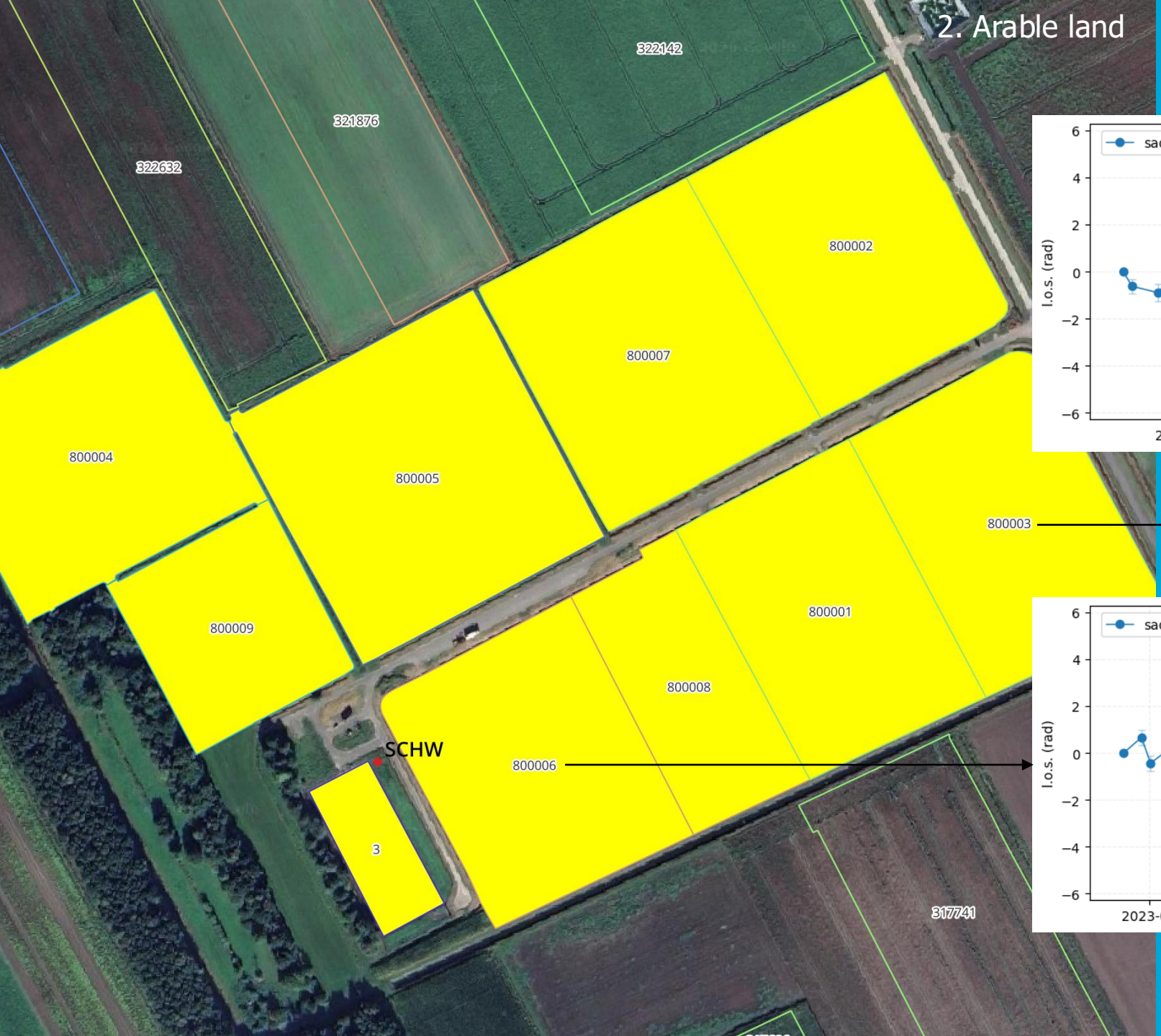
Experiment setup

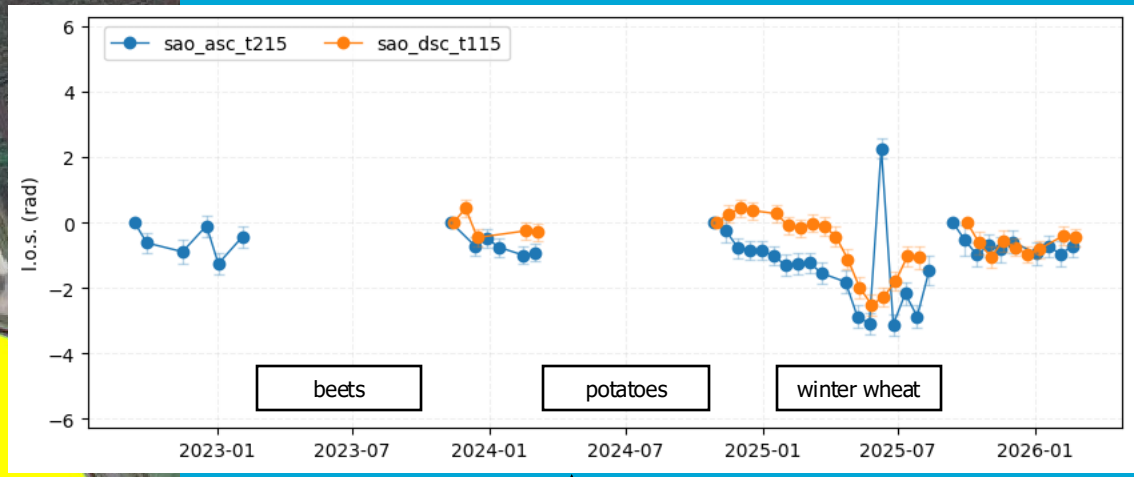
- Observation period:

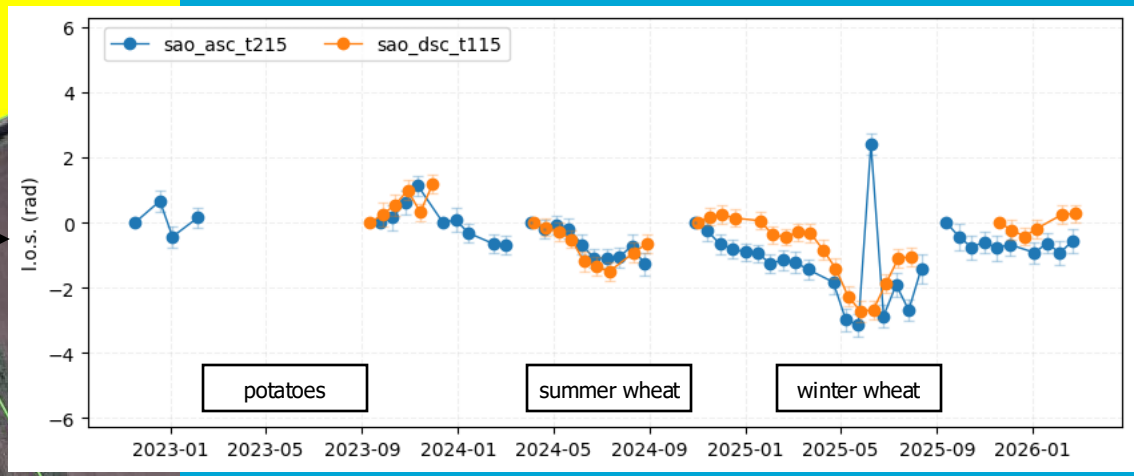
  Aug 2022 – Mar 2026
- Reference point: IGRS
- Parcel geometry as boundary for multilooking
- Contextual grouping

  Soil type + ground water zone
- Short arcs (< 500 m)

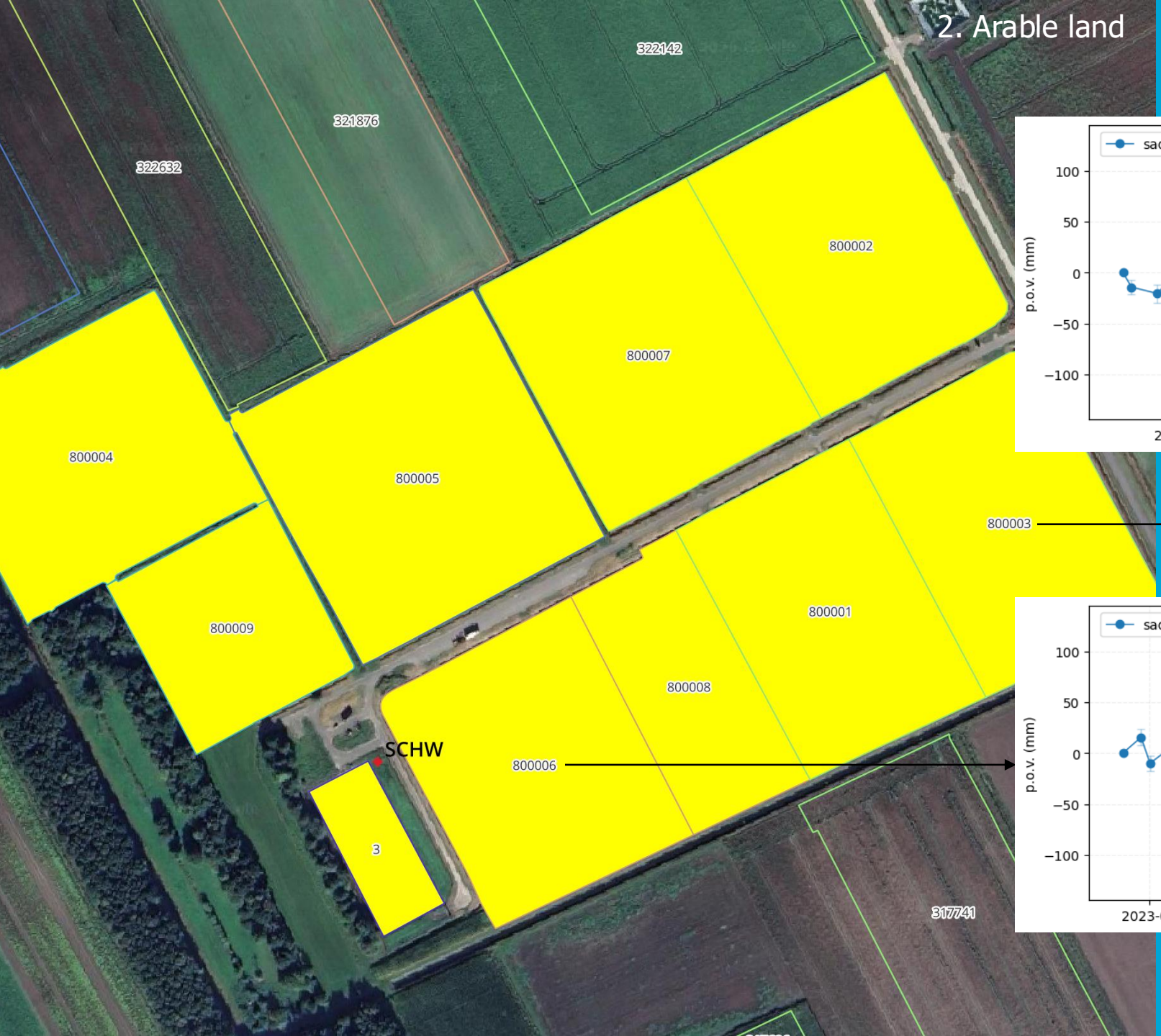
2. Arable land

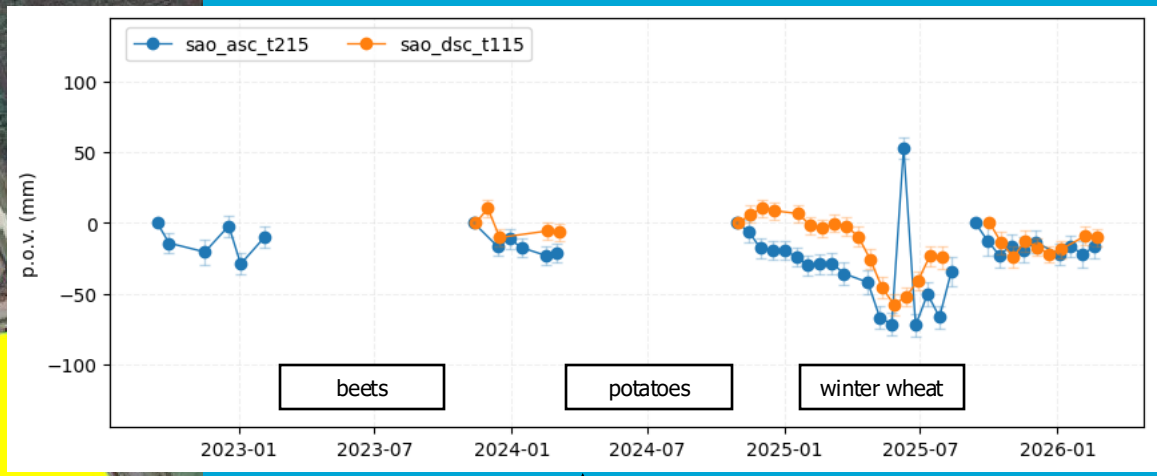


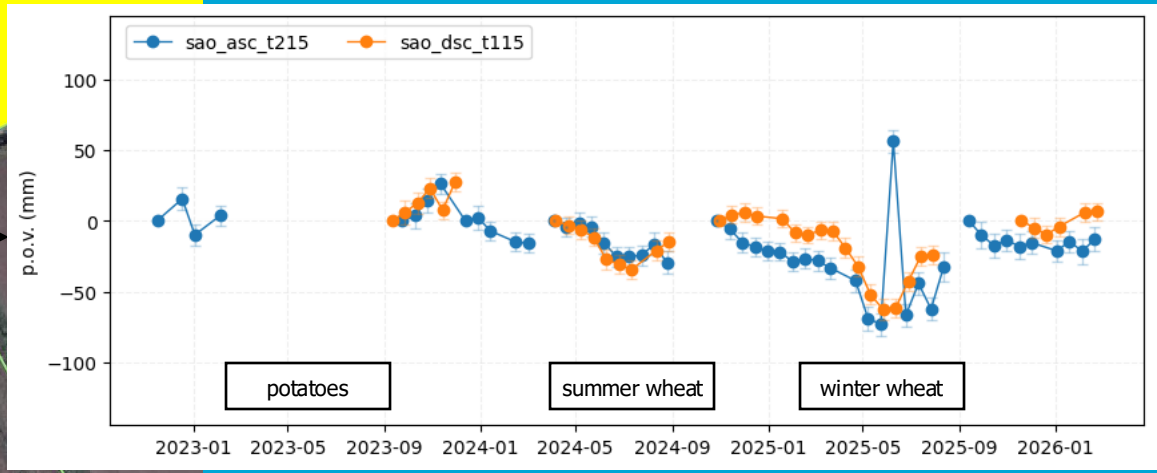


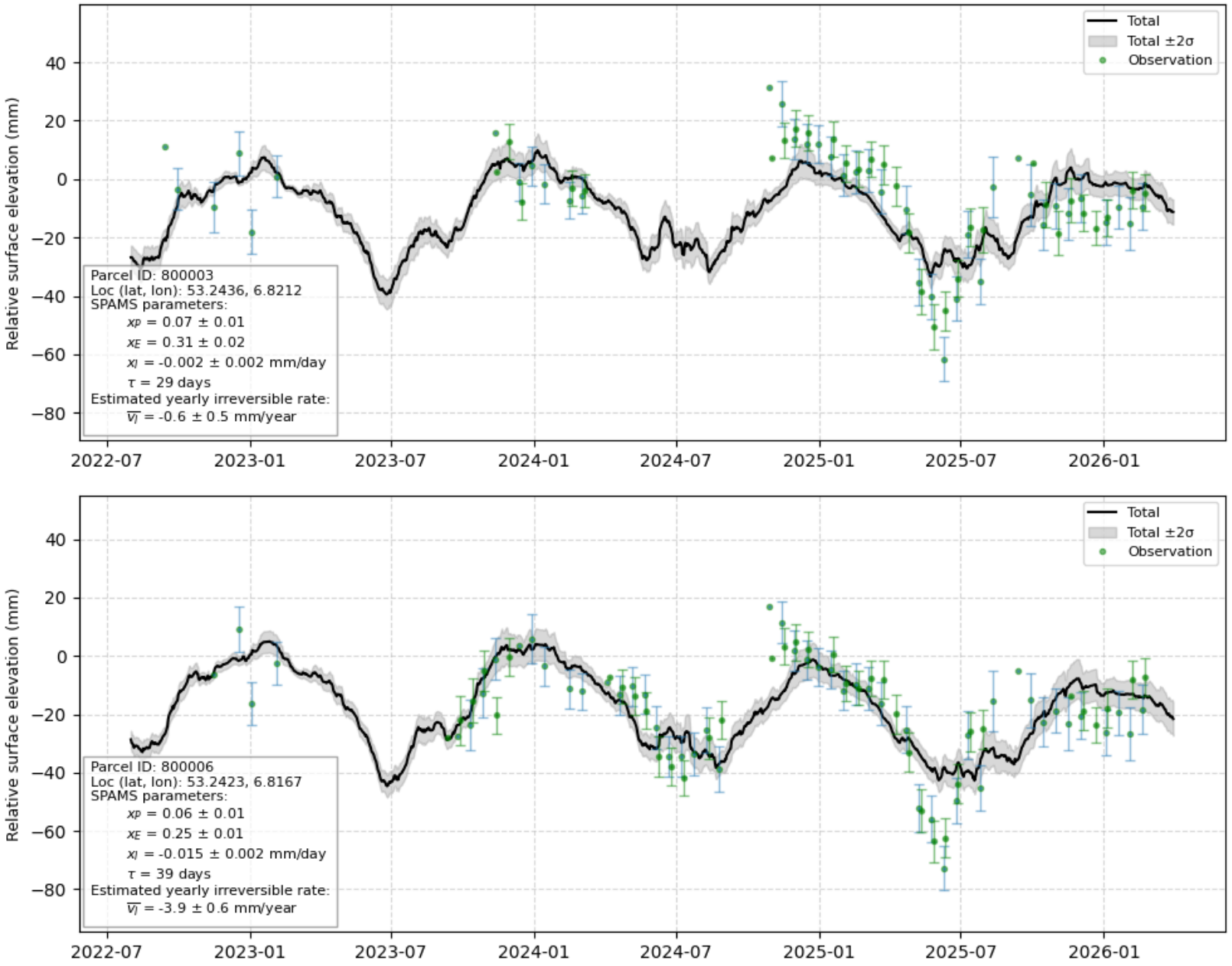


2. Arable land








Total
Total ±2σ
Observation
Relative surface elevation (mm)
40
20
0
−20
−40
−60
−80
2022-07
2023-01
2023-07
2024-01
2024-07
2025-01
2025-07
2026-01
Parcel ID: 800003
Loc (lat, lon): 53.2436, 6.8212
SPAMS parameters:
x_P = 0.07 ± 0.01
x_E = 0.31 ± 0.02
x_I = -0.002 ± 0.002 mm/day
τ = 29 days
Estimated yearly irreversible rate:
$\overline{v_I}$ = -0.6 ± 0.5 mm/year
Total
Total ±2σ
Observation
Relative surface elevation (mm)
40
20
0
−20
−40
−60
−80
2022-07
2023-01
2023-07
2024-01
2024-07
2025-01
2025-07
2026-01
Parcel ID: 800006
Loc (lat, lon): 53.2423, 6.8167
SPAMS parameters:
x_P = 0.06 ± 0.01
x_E = 0.25 ± 0.01
x_I = -0.015 ± 0.002 mm/day
τ = 39 days
Estimated yearly irreversible rate:
$\overline{v_I}$ = -3.9 ± 0.6 mm/year

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Conclusions

Longer wavelengths can provide longer and higher coherent intervals, but the associated standard deviation must be considered

In peat grassland, L-band observations can be treated as ground truth, provided surface motion magnitudes remain within the wavelength range

Multi-band and multi-mission InSAR observations open new opportunities for surface motion modeling by leveraging the strengths of each configuration

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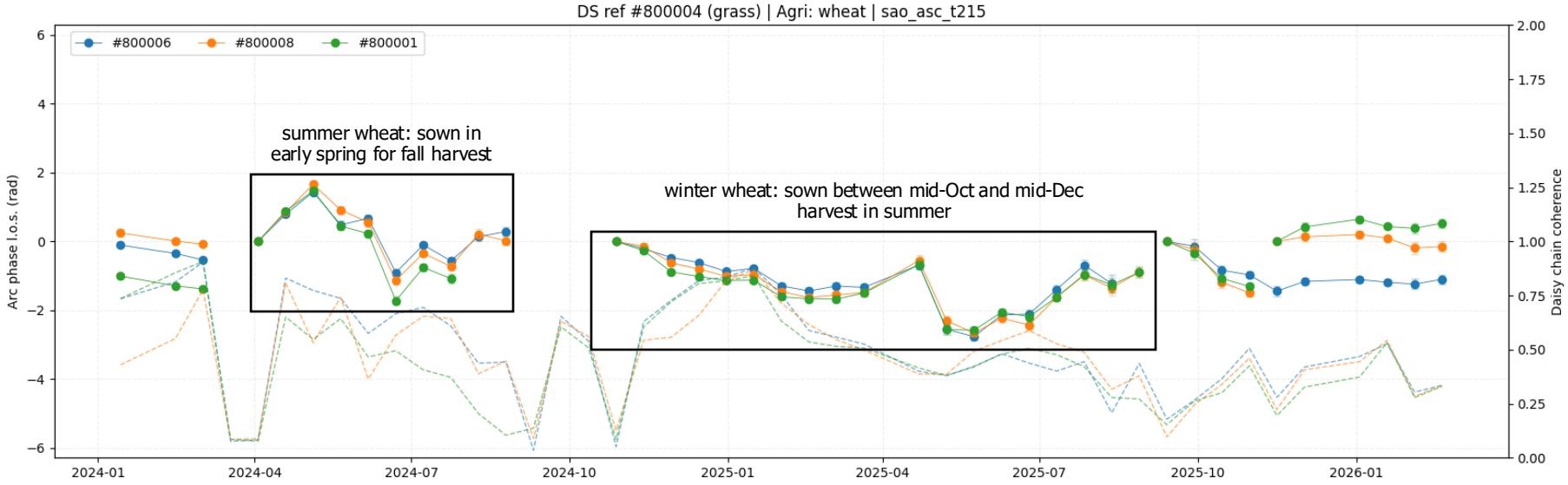
Vegetation-induced bias?



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