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15 Soil Moisture Products: Microwaves vs. Cosmic Rays

Intercomparison of current soil moisture products from remote sensing and modeling over COSMOS-Europe field sites in Germany

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Background

Coarse-scale soil moisture (SM) products

Spaceborne microwave sensors
and models

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Field-scale SM data

Cosmic-Ray Soil Moisture Observation System
(COSMOS-Europe)

Mismatch

Retrieval algorithm
Vertical representation
Grid size
Revisit time
Sensor frequency

Benefits

Intrinsically average out spatial heterogeneity of environmental properties and cover surface SM (SSM) and root-zone SM (RZSM)

Value and challenge

Horizontally → large footprint is a valuable ground reference for validating coarse-scale SM products

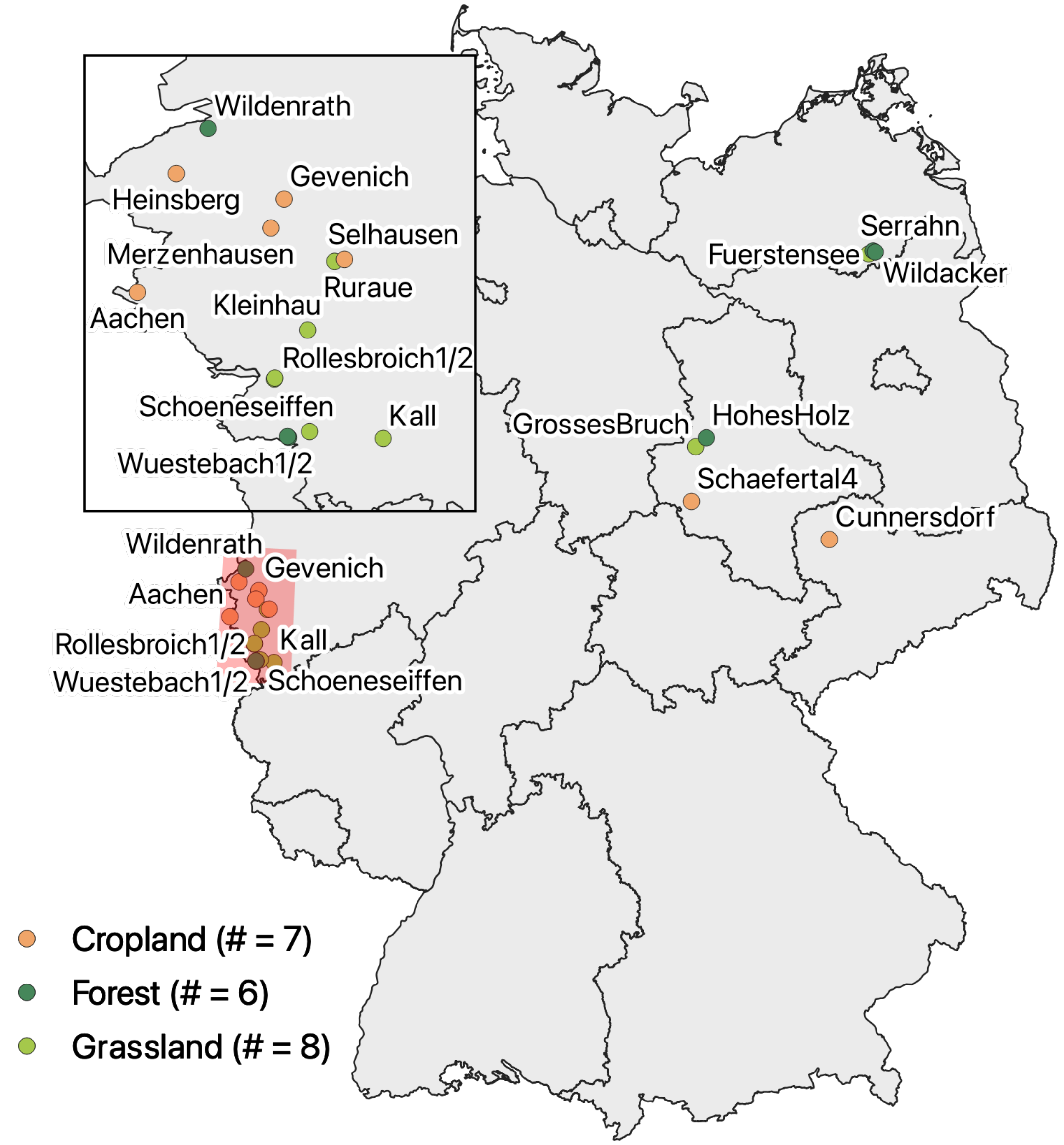
Vertically → deep representation is a challenge for validating SSM products

Data and Methods

Selected SM products

Type	Sensor (Satellite)/Model	Product	Layers	Grid
Single	AMSR2 (SHIZUKU)	LPRM	1	25 km
	ASCAT (Metop-A/B/C)	HSAF H115/H116	1	12.5 km
		HSAF H141/H142	4	10 km
	C-SAR (Sentinel-1)	CGLS SSM	1	1 km
	Radiometer (SMAP)	NASA L3E	1	9 km
		NASA L4	3	9 km
	MIRAS (SMOS)	CATDS L3	1	15 km
		CATDS L4	1	25 km
Dual	Sentinel-1/ASCAT	CGLS SWI	8	1 km
	SMAP/Sentinel-1	NASA L2	1	3 km
Multiple	AMSR2, ASCAT, GMI, MIRAS, SMAP	ESA CCI combined	1	0.25°
	AMSR2, ASCAT, GMI, MIRAS, SMAP	NASA SMOPS blended	1	0.25°
Models	ERA5-Land	ERA5-Land	4	0.1°
	GLDAS-Noah	NOAH025	4	0.25°
	GLEAM	GLEAM	2	0.25°

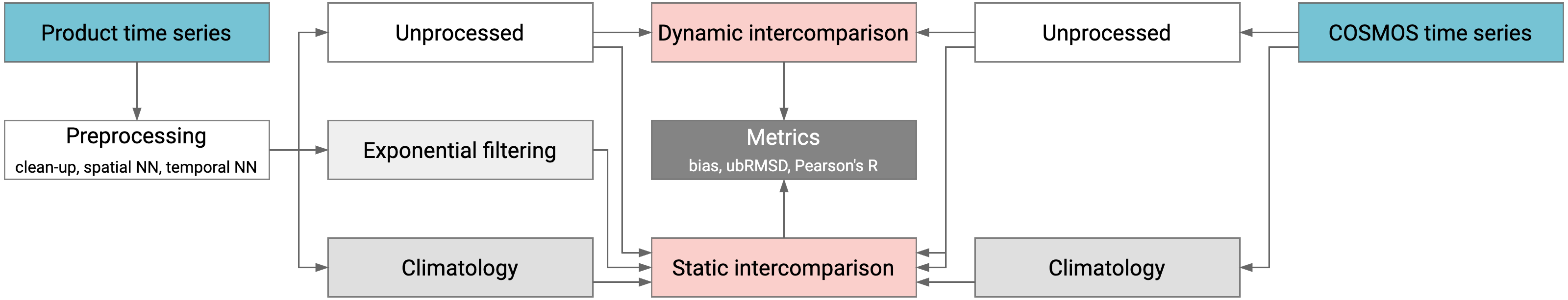
Selected COSMOS-Europe stations



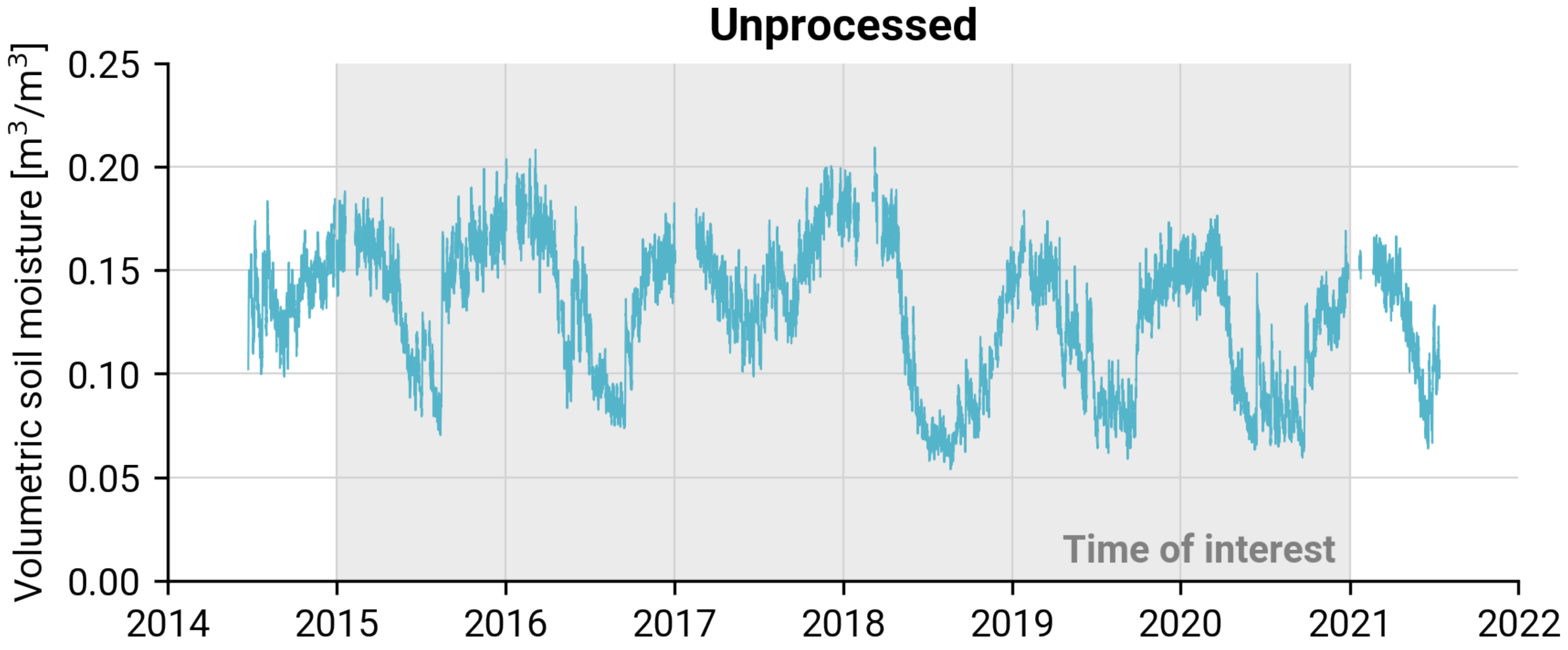
Data and Methods

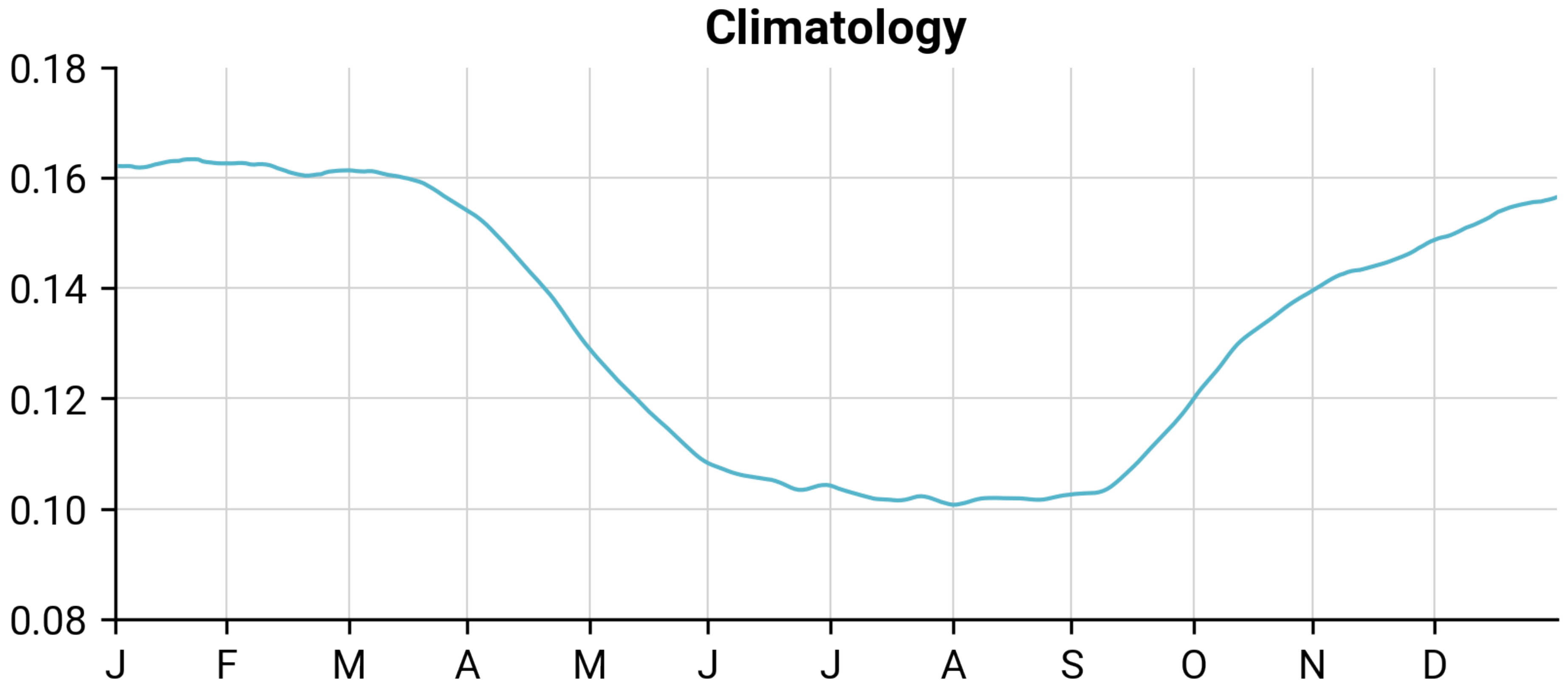
Study design flowchart

(NN – nearest neighbor, ubRMSD – unbiased root-mean-square difference)



COSMOS time series for station *GrossesBruch*

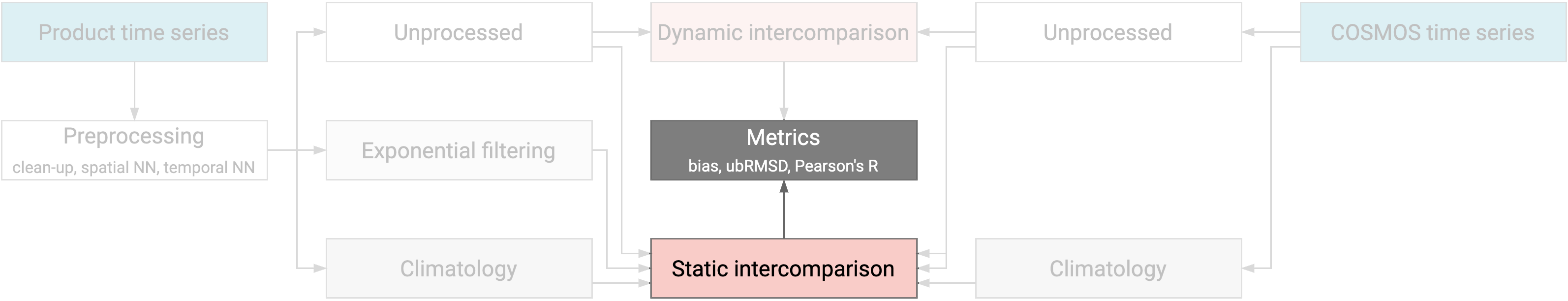




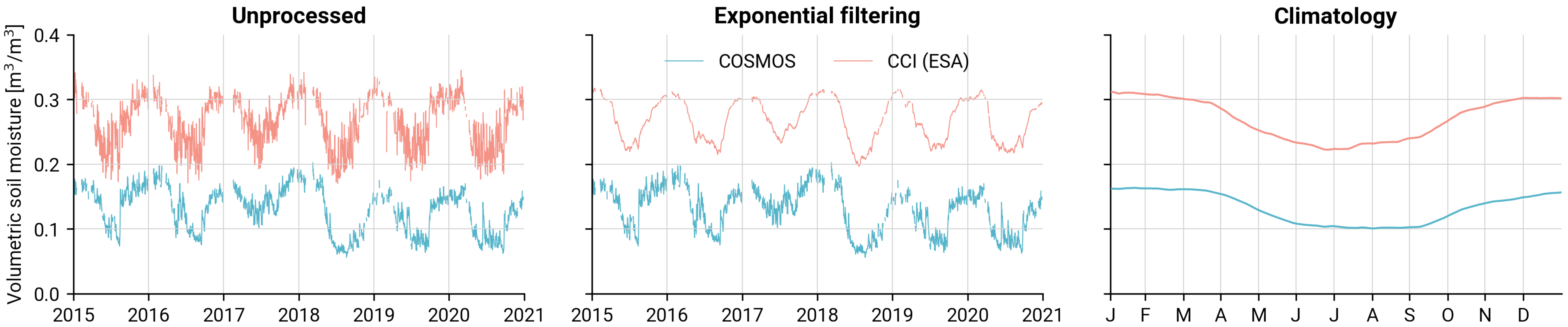
Data and Methods

Study design flowchart

Static intercomparison



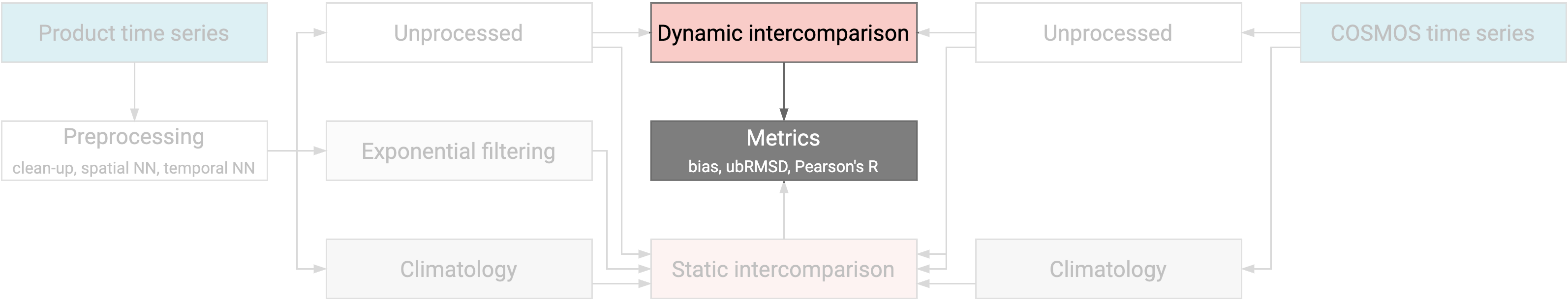
COSMOS and CCI time series for station *GrossesBruch*



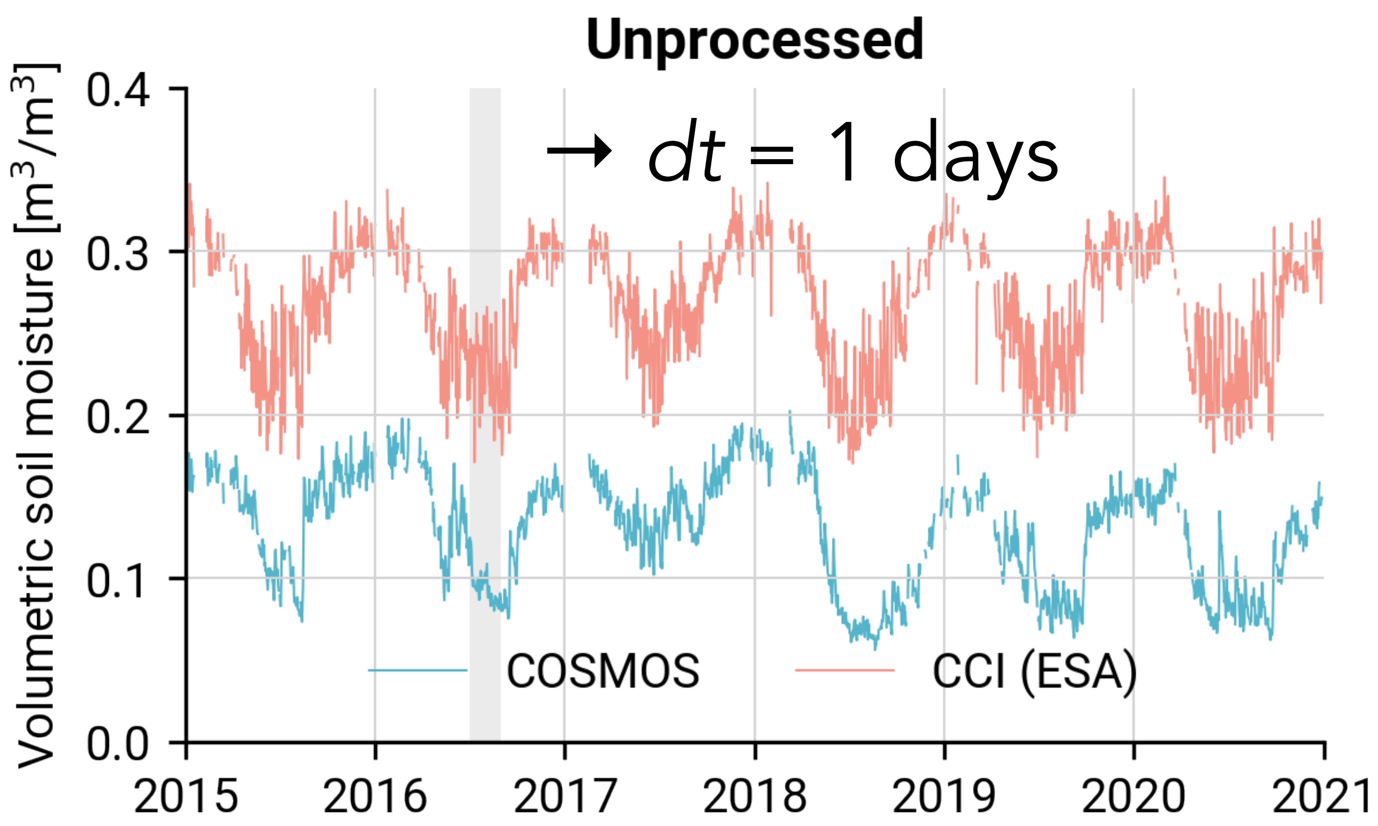
Data and Methods

Study design flowchart

Dynamic intercomparison



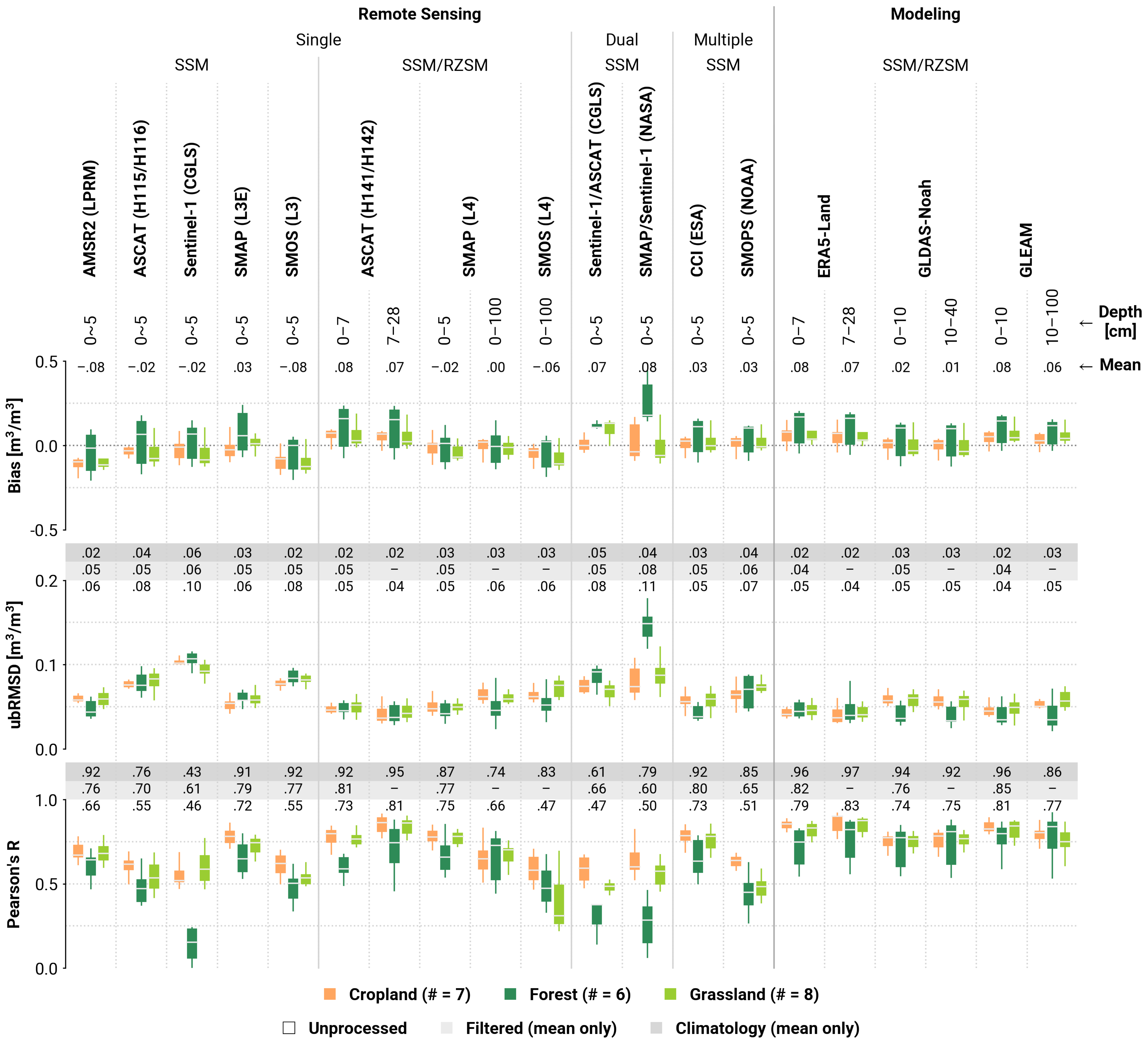
COSMOS and CCI time series for station *GrossesBruch*



→ Validation metrics were calculated for a **61-days moving window**

Static Intercomparison

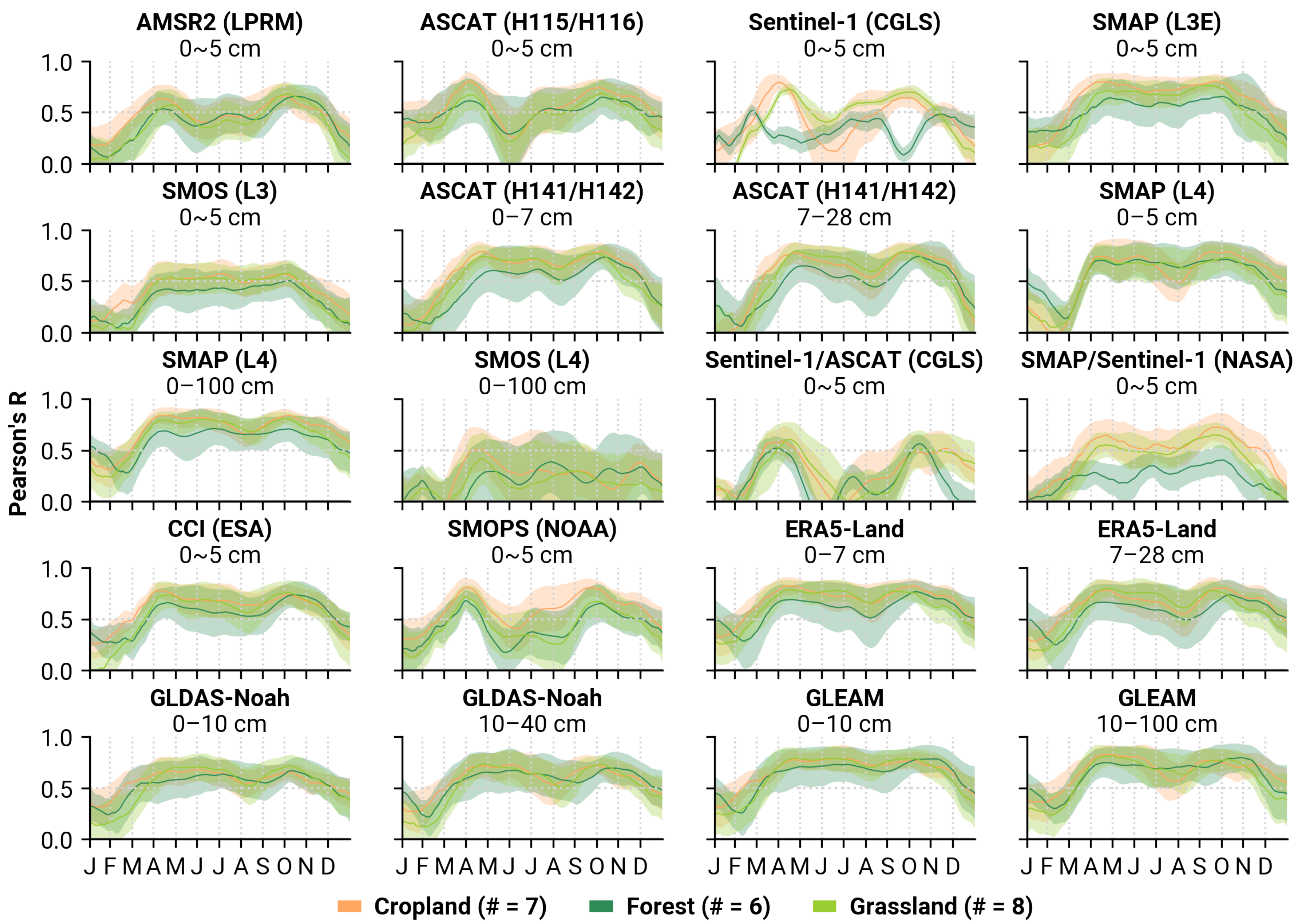
Performance metrics for all products



- Largest range and lowest mean performance over **forests**, due to strong biomass signals. Over **croplands**, mean performances are highest, due to bare-soil seasons.
- **Exponential filtering** of SSM time series decreases ubRMSD and increases R when comparing to COSMOS time series. This underlines the potential to derive RZSM dynamics from SSM products.
- **Climatologies** of product time series decreases ubRMSD and increases R (except for Sentinel-1) when comparing to COSMOS climatologies. This quantifies similarities of large-scale SM dynamics.

Dynamic Intercomparison

Climatology of R using a 61-days moving window



- R increases with the onset of the year and peaks during **spring**, due to most optimal conditions for SM estimation between winter months and vegetation period.
- R of SM products from modeling most **constant** compared to that of pure remote sensing products.

Conclusions

Ranking using mean Pearson's R

Pearson's R Rank	All stations	Cropland	Forest	Grassland
1	ERA5-Land 7–28 cm	ERA5-Land 7–28 cm	GLEAM 10–100 cm	ERA5-Land 7–28 cm
2	GLEAM 0–10 cm	ASCAT (H141/H142) 7–28 cm	GLEAM 0–10 cm	ASCAT (H141/H142) 7–28 cm
3	ASCAT (H141/H142) 7–28 cm	ERA5-Land 0–7 cm	ERA5-Land 7–28 cm	GLEAM 0–10 cm
4	ERA5-Land 0–7 cm	GLEAM 0–10 cm	GLDAS-Noah 10–40 cm	ERA5-Land 0–7 cm
5	GLEAM 10–100 cm	GLEAM 10–100 cm	GLDAS-Noah 0–10 cm	SMAP (L4) 0–100 cm
6	GLDAS-Noah 10–40 cm	SMAP (L3E) 0~5 cm	ERA5-Land 0–7 cm	ASCAT (H141/H142) 0–7 cm
7	SMAP (L4) 0–100 cm	CCI (ESA) 0~5 cm	ASCAT (H141/H142) 7–28 cm	GLDAS-Noah 10–40 cm
8	GLDAS-Noah 0–10 cm	SMAP (L4) 0–100 cm	SMAP (L4) 0–100 cm	CCI (ESA) 0~5 cm
9	CCI (ESA) 0~5 cm	ASCAT (H141/H142) 0–7 cm	SMAP (L4) 0–5 cm	GLDAS-Noah 0–10 cm
10	ASCAT (H141/H142) 0–7 cm	GLDAS-Noah 10–40 cm	SMAP (L3E) 0~5 cm	GLEAM 10–100 cm
11	SMAP (L3E) 0~5 cm	GLDAS-Noah 0–10 cm	CCI (ESA) 0~5 cm	SMAP (L3E) 0~5 cm
12	AMSR2 (LPRM) 0~5 cm	AMSR2 (LPRM) 0~5 cm	ASCAT (H141/H142) 0–7 cm	AMSR2 (LPRM) 0~5 cm
13	SMAP (L4) 0–5 cm	SMAP (L4) 0–5 cm	AMSR2 (LPRM) 0~5 cm	SMAP (L4) 0–5 cm
14	SMOS (L3) 0~5 cm	SMAP/Sentinel-1 (NASA) 0~5 cm	SMOS (L4) 0–100 cm	Sentinel-1 (CGLS) 0~5 cm
15	ASCAT (H115/H116) 0~5 cm	SMOS (L3) 0~5 cm	SMOS (L3) 0~5 cm	SMAP/Sentinel-1 (NASA) 0~5 cm
16	SMOPS (NOAA) 0~5 cm	SMOPS (NOAA) 0~5 cm	ASCAT (H115/H116) 0~5 cm	ASCAT (H115/H116) 0~5 cm
17	SMAP/Sentinel-1 (NASA) 0~5 cm	ASCAT (H115/H116) 0~5 cm	SMOPS (NOAA) 0~5 cm	SMOS (L3) 0~5 cm
18	SMOS (L4) 0–100 cm	Sentinel-1/ASCAT (CGLS) 0~5 cm	Sentinel-1/ASCAT (CGLS) 0~5 cm	Sentinel-1/ASCAT (CGLS) 0~5 cm
19	Sentinel-1/ASCAT (CGLS) 0~5 cm	SMOS (L4) 0–100 cm	SMAP/Sentinel-1 (NASA) 0~5 cm	SMOPS (NOAA) 0~5 cm
20	Sentinel-1 (CGLS) 0~5 cm	Sentinel-1 (CGLS) 0~5 cm	Sentinel-1 (CGLS) 0~5 cm	SMOS (L4) 0–100 cm

- **Modeling-involved** SM products outperform.
- **ASCAT (H141/H142)**, **SMAP (L4)**, **CCI (ESA)**, **SMAP (L3E)** perform best among selected remote sensing products.
- Next steps are extending to **European scale** to increase field sites complexity.

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Abstract + Contact → Project Website

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