C-band microwave sensors reflect the spring water uptake of temperate deciduous broadleaf trees

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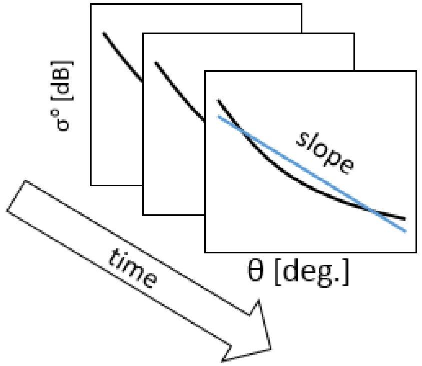
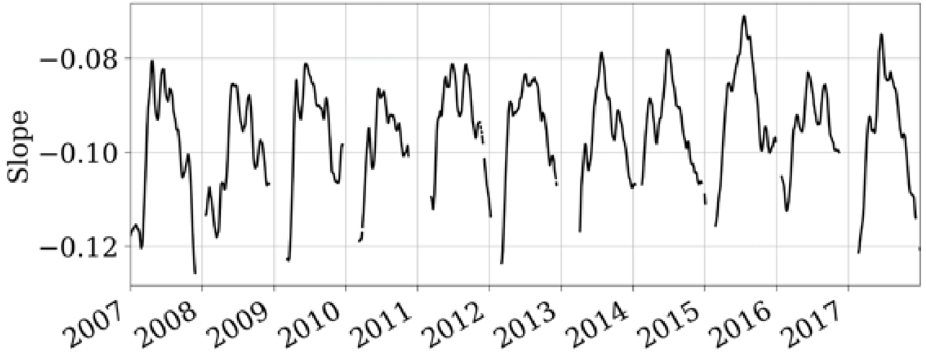
Pitch

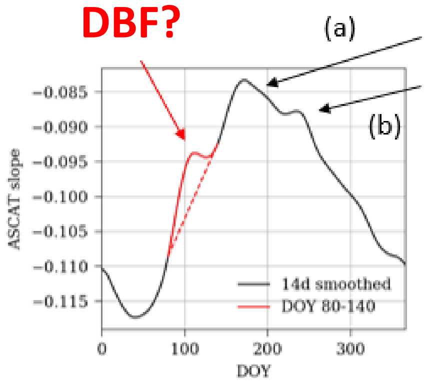
Summary I

- ASCAT backscatter is dependent on the incidence angle. This dependency is weaker if scattering due to vegetation water content or structure occurs in the sensor footprint



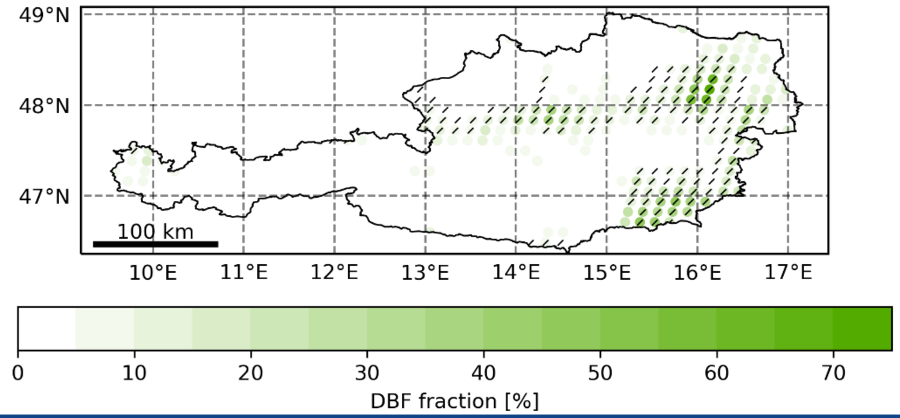


- We detected a period of weak incidence angle dependency in spring, predominantly over regions covered by deciduous broadleaf forest (DBF)



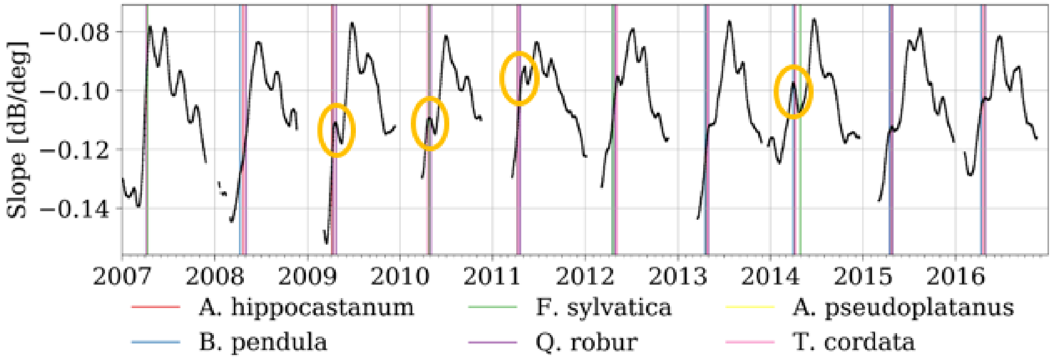
Peaks from winter crops (a) and summer crops (b)

Occurrence of spring peaks and DBF cover in Austria



Summary II

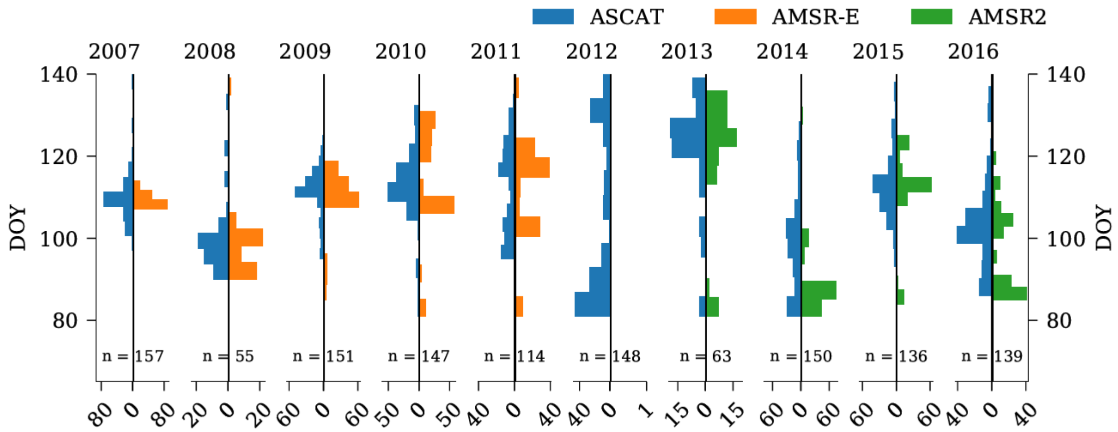
- Comparison with phenological observations, leaf area index and temperature suggests that this is due to increasing water uptake by deciduous broadleaf trees before leaf emergence



DOY of ASCAT spring peak (detection of relative maximum)

DOY of spring leaf-out from reference dataset

- Peaks in vegetation optical depth (AMSR-E, AMSR2) agree very well with ASCAT peaks



y-axis: Day of year (DOY) when spring peak occurs

Study area: moderate flatlands in Austria

...and if you would like to see more:

Motivation, background & results

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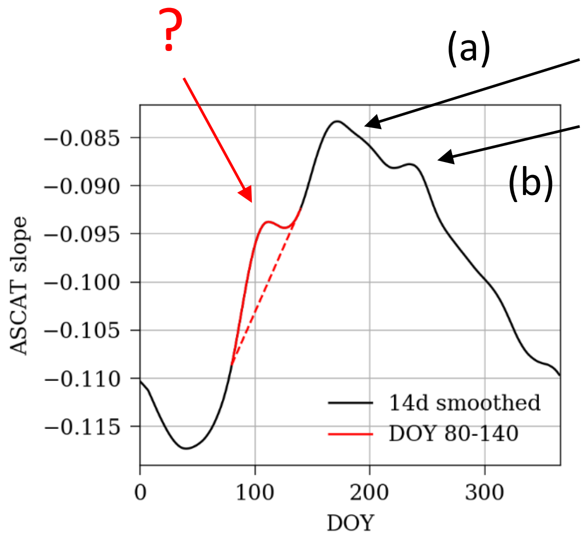
Motivation

- Previous study: Evaluation of **ASCAT vegetation characterisation** over an agricultural area in Austria *(Pfeil et al., 2018)*
- Observation of a **„peak“** around March/April
  - Cannot be explained by typical crop phenology

Slope climatology

(grid cell located in agricultural area, lower Austria)

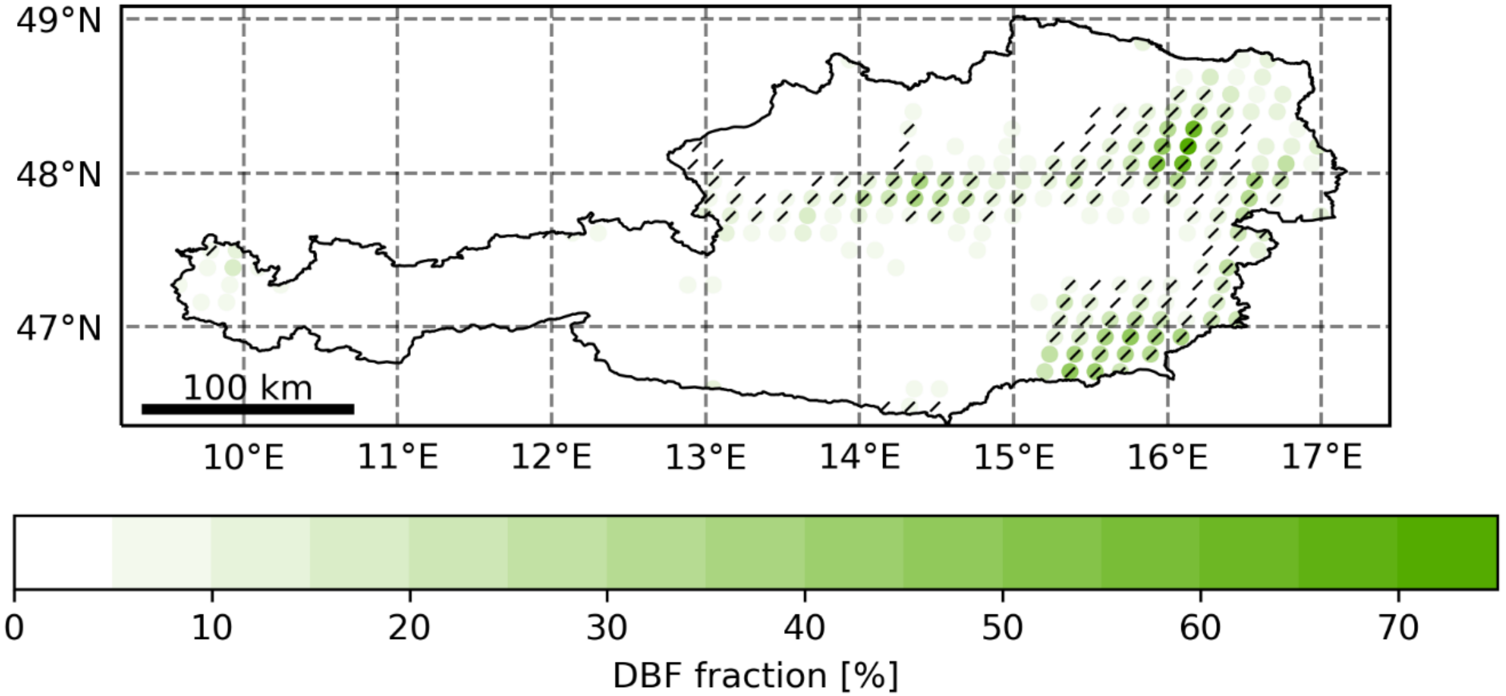


Peaks from winter crops (a) and summer crops (b)

Spatial distribution of spring peaks

ASCAT grid cell without peak

ASCAT grid cell with peak



→ Can leaf emergence in DBF be the cause of the spring peaks in the ASCAT slope?

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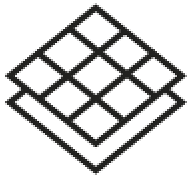
Study area & data sets

- **Austria (AT)**
  - Very good availability of reference data
  - We know the climate, vegetation cycles, topography etc. well

Sensor name	Variable	Spatiotemp. resolution
ASCAT	Slope	25x25 km, 1-3 daily
AMSR-E	Vegetation optical depth (VOD)	75x43 km, 1-3 daily
AMSR2	Vegetation optical depth (VOD)	62x35 km, 1-3 daily

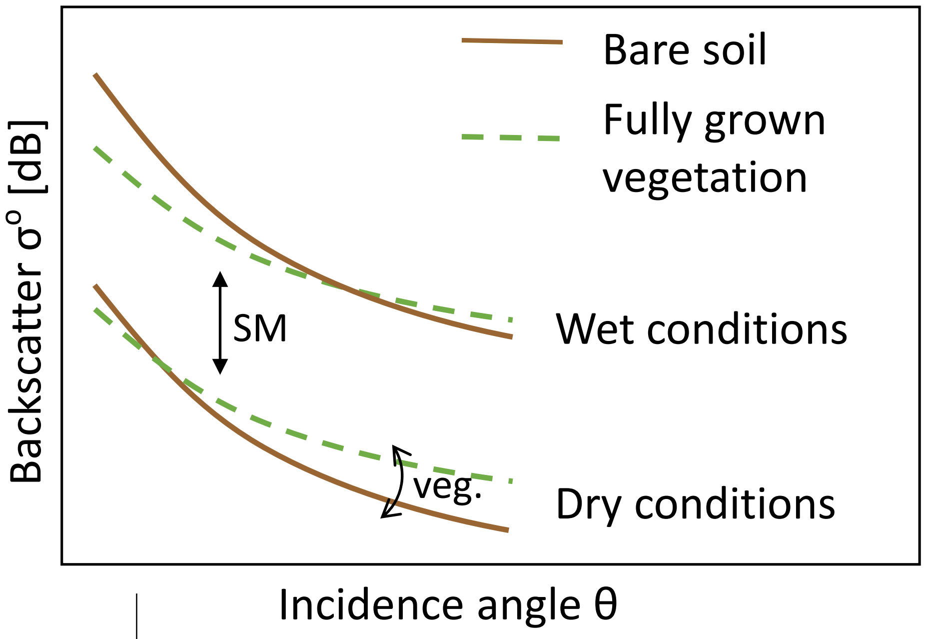
- Pan-European Phenology (PEP725) database (Templ et al., 2018)
  - Leaf-unfold dates for 188 sites in AT
  - Up to six species per site

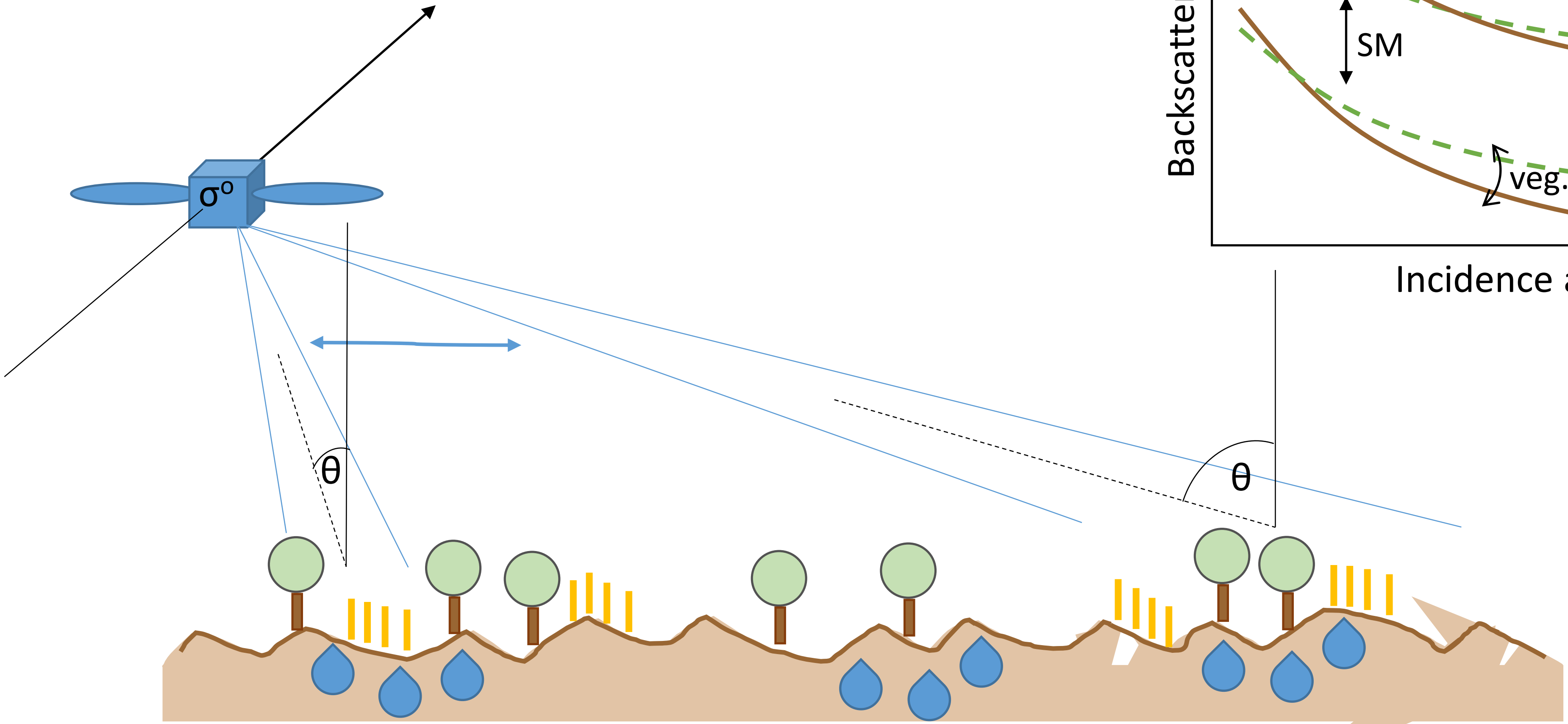


- CCI Land Cover (Bontemps et al., 2012)
- Leaf area index (Dierckx et al., 2014)
- SPARTACUS temperature (Hiebl & Frei, 2016)

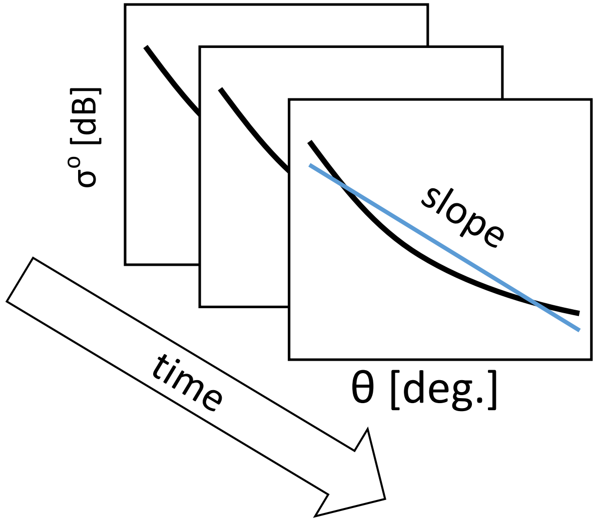
Background

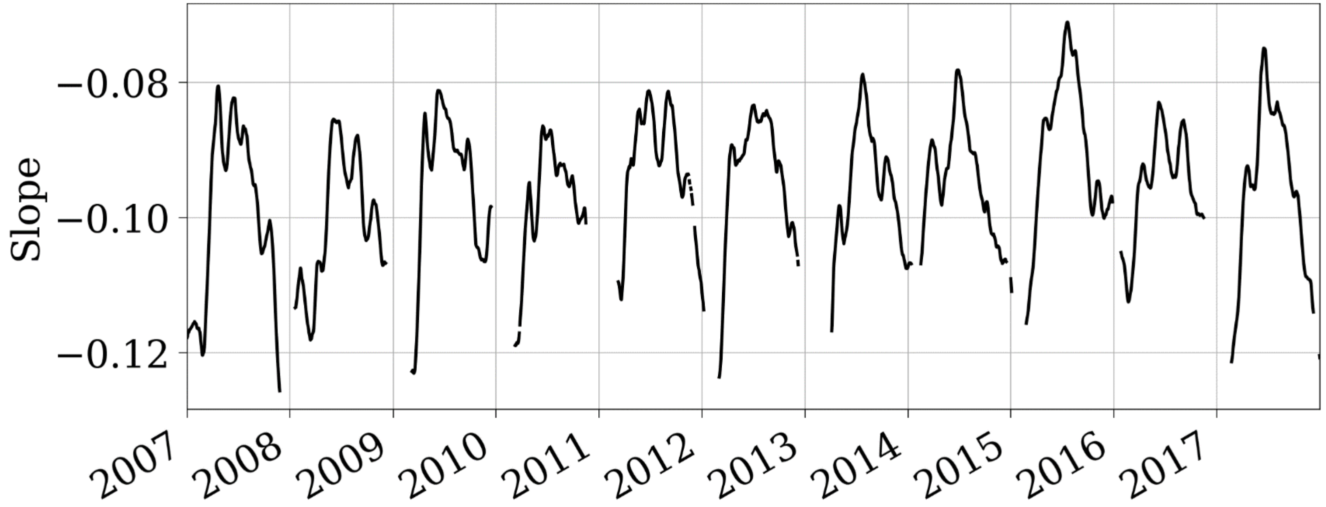
- Advanced Scatterometer (ASCAT)
- C-band VV backscatter
- 25 x 25 km | global coverage in 1-3 days





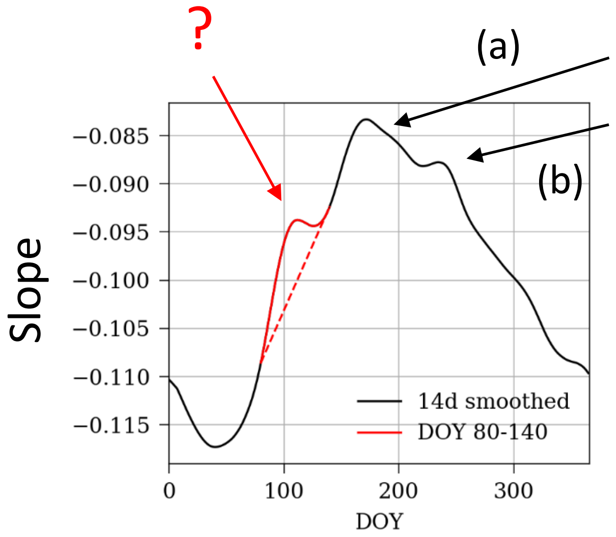
ASCAT slope





Slope climatology

(grid cell located in agricultural area, lower Austria)



Peaks from winter crops (a) and summer crops (b)

1. Is there a spring peak?
2. At which day of year?

Objectives

1. Where does the „up and down“ we see in spring come from?

   – Comparison to ESA CCI **land cover** dataset
   Peaks occur in 100% of grid cells dominated by DBF, to some extent also in grid cells dominated by other land cover → DBF can dominate entire signal in spring

   – Validation with **reference data** (PEP725 database, leaf area index)
   MAD* ASCAT peak – phenological observations of leaf out: 8 days
   MAD* ASCAT peak – maximum increase of LAI: 13 days
   (grid cells with DBF fraction > 10%)

2. Can the variations in timing of the spring peak be explained by **temperature dynamics**?

   – Comparison with SPARTACUS air temperature (growing degree days)
   MAD* ASCAT peak – GDD160 (base temperature 5°C): 7 days

Pfeil et al., in revision

*median absolute difference

Objectives

3. Is this a sensor-dependent phenomenon or do we see it in other C-band sensors as well?

➡ Investigation of AMSR-E and AMSR2 vegetation optical depth (VOD) time series

➡ Detection of potential spring peaks

➡ Comparison with ASCAT spring peaks

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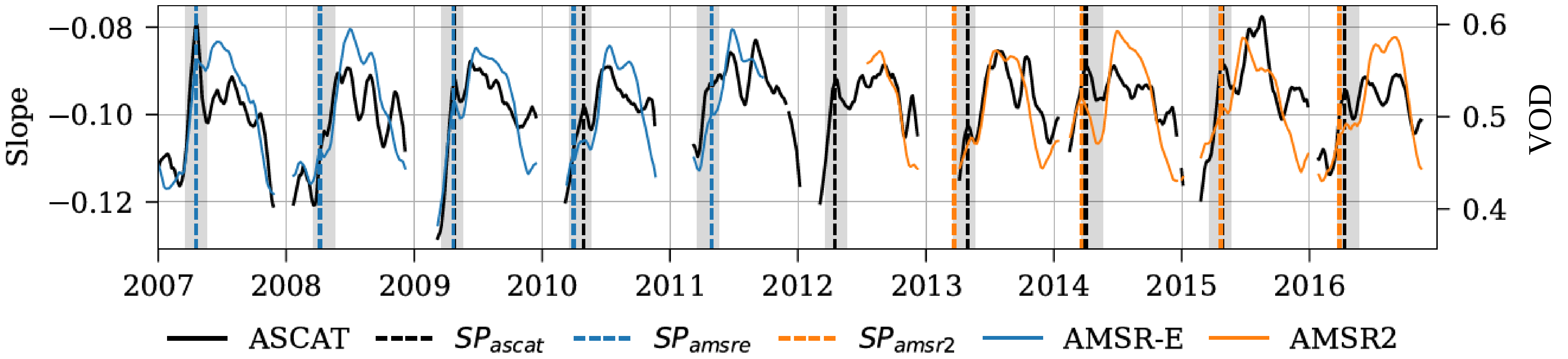
Comparison to C-Band radiometers

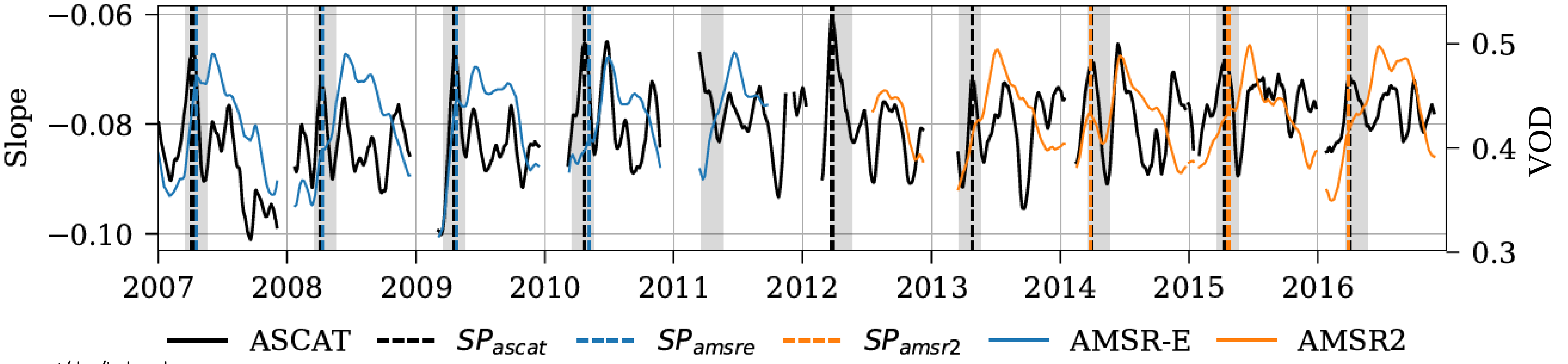
ASCAT GPI: 2421559

12% DBF



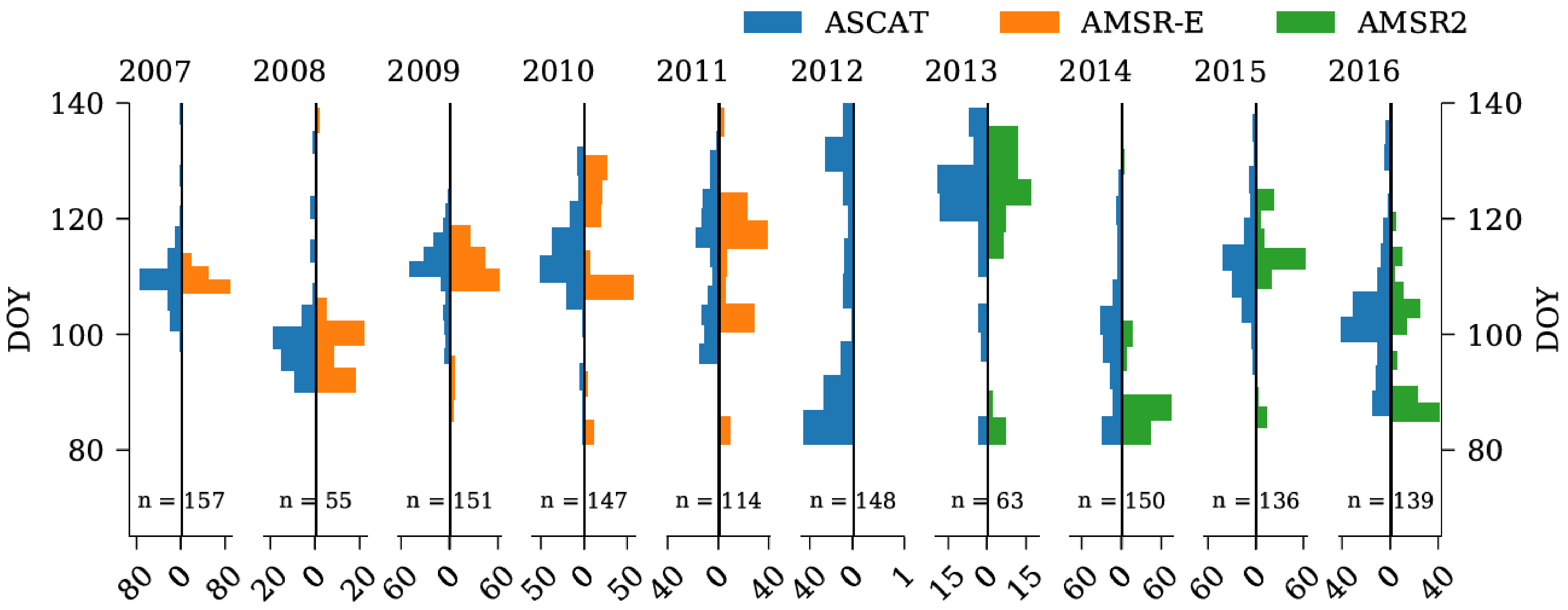
ASCAT GPI: 2425873

74% DBF



Grid Point Locator:
https://www.geo.tuwien.ac.at/dgg/index.php

Histograms: Comparison to C-Band radiometers



- Very good agreement between spring peaks found in ASCAT, AMSR-E (median absolute difference MAD 6 days) and AMSR2 (MAD 9 days)
- Unfortunately no data in 2012 – very interesting year due to bi-modal distribution of ASCAT spring peak dates

Validation metrics

- Metrics calculated between the occurrence of spring peaks in ASCAT, AMSR-E and AMSR2, years 2007-2016.
- Study area: „moderate flatlands“ in Austria
- Only grid cells with the given DBF fraction have been included. *n* is the sample size. Root mean squared deviation (RMSD), median absolute difference (MAD), average absolute difference (AAD) and bias are given in days. Significant Pearson (r_p) and Spearman (r_s) correlation coefficients ($p < 0.05$) are shown in black.

		DBF fr.	n	r_s	r_p	RMSD	MAD	AAD	Bias
AMSR-E	ASCAT	>0%	1352	0.18	0.14	15.2	6.0	10.4	-2.2
		>10%	391	0.33	0.23	13.2	6.0	9.2	1.5
		>20%	190	0.47	0.33	12.5	5.0	8.6	2.9
		>30%	85	0.78	0.70	9.6	5.0	7.0	4.3
		>40%	35	0.80	0.80	9.4	5.0	7.4	6.3
		>50%	17	0.83	0.84	9.1	6.0	7.7	7.7
	PEP725	>0%	269	-0.06	-0.02	16.4	11.0	13.3	-0.4
		>10%	64	0.00	-0.03	15.7	13.0	13.8	-5.7
		>20%	32	0.24	0.16	17.0	14.0	14.9	-10.3
		>30%	8	0.80	0.69	13.7	10.0	12.2	-12.2
		>40%	5	1.00	0.95	9.8	9.0	9.5	-9.5
		>50%	4	1.00	0.95	10.6	10.0	10.5	-10.5
AMSR2	ASCAT	>0%	1055	0.51	0.49	15.9	9.0	11.7	-5.5
		>10%	316	0.48	0.48	15.8	9.0	11.6	-2.6
		>20%	147	0.39	0.43	15.4	9.0	11.3	-2.7
		>30%	65	0.33	0.30	15.1	10.0	11.0	-2.8
		>40%	27	0.77	0.80	8.6	4.0	6.7	-1.8
		>50%	12	0.70	0.92	6.3	5.0	5.6	-1.9
	PEP725	>0%	141	0.43	0.40	16.0	11.8	12.9	1.8
		>10%	49	0.56	0.62	14.1	12.3	11.7	1.9
		>20%	26	0.43	0.59	12.9	10.5	10.6	0.6
		>30%	6	0.61	0.42	12.8	11.5	11.4	-4.9
		>40%	2	1.00	1.00	13.8	10.6	10.6	8.9
		>50%	2	1.00	1.00	13.8	10.6	10.6	8.9

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Conclusions & Outlook

- ASCAT is sensitive to the water increase and subsequent leaf-out in deciduous broadleaf trees, which manifests itself as a shallow backscatter incidence angle dependency
- Similar peaks observed in passive AMSR-E and AMSR2 vegetation optical depth
- Challenges: coarse-scale sensors always observe signals from mixed land cover types → disentangling of land cover effects is not straightforward
- Outlook:
  - Extension of the study area
  - Analysis of Sentinel-1 backscatter and cross ratio time series
  - Comparison with larger phenological reference database (leaf out, if available also tree water content)