

# Borkenkäfermonitoring mit Sentinel-2: Von der raschen Schaddetektion hin zur Risikoproggnose

**Copernicus Netzwerkbüro Wald - Online-Seminar, 15.11.2022**

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FNEWs-Team

(1) Joanneum Research, Austria; (2) Cloudflight Austria GmbH, Austria

**Janik Deutscher**

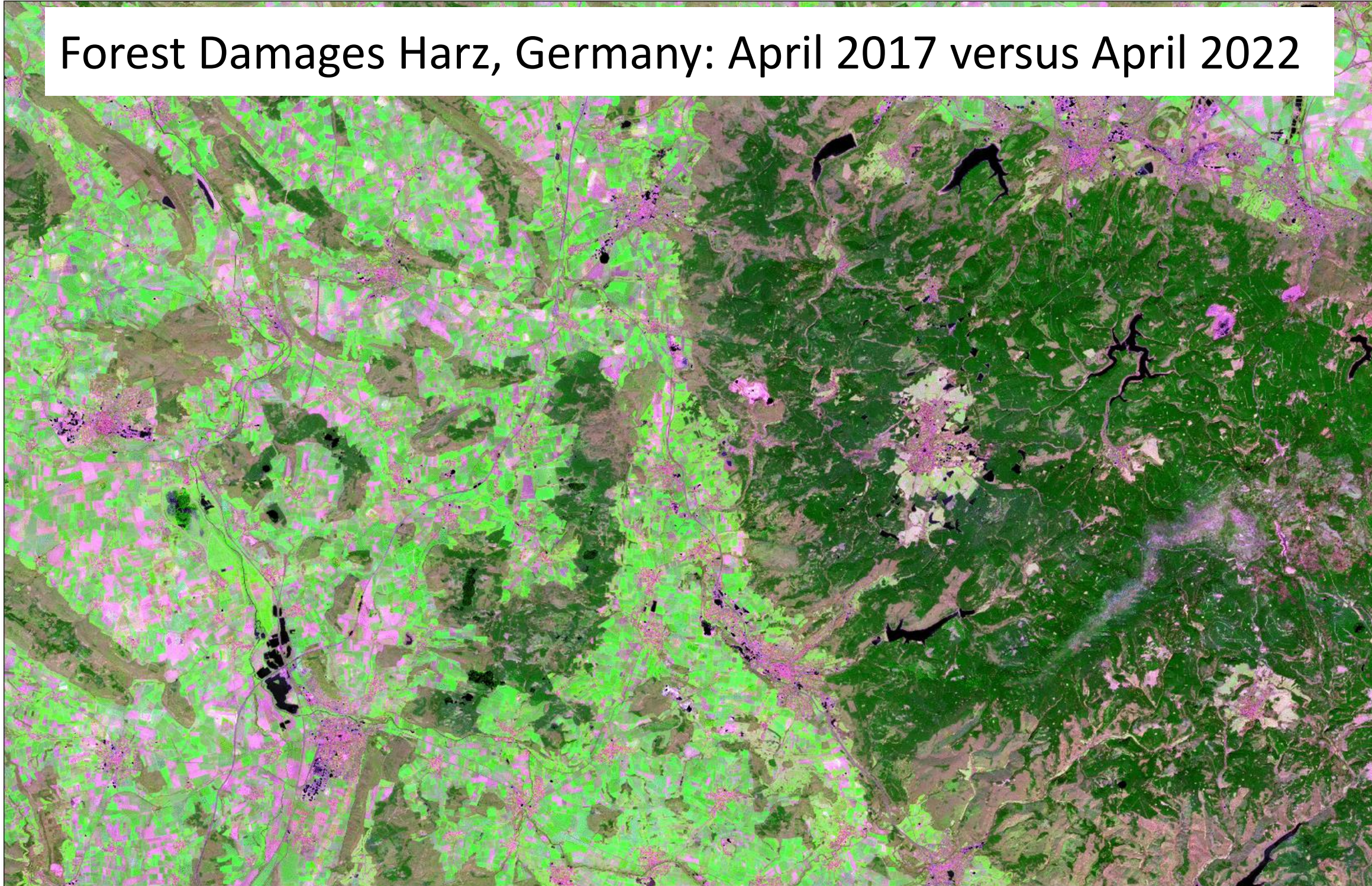
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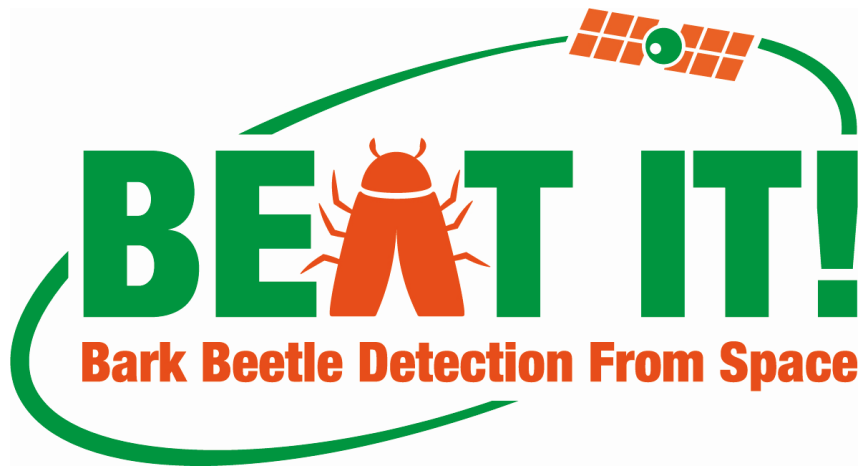


# Forest Damages Harz, Germany: April 2017 versus April 2022





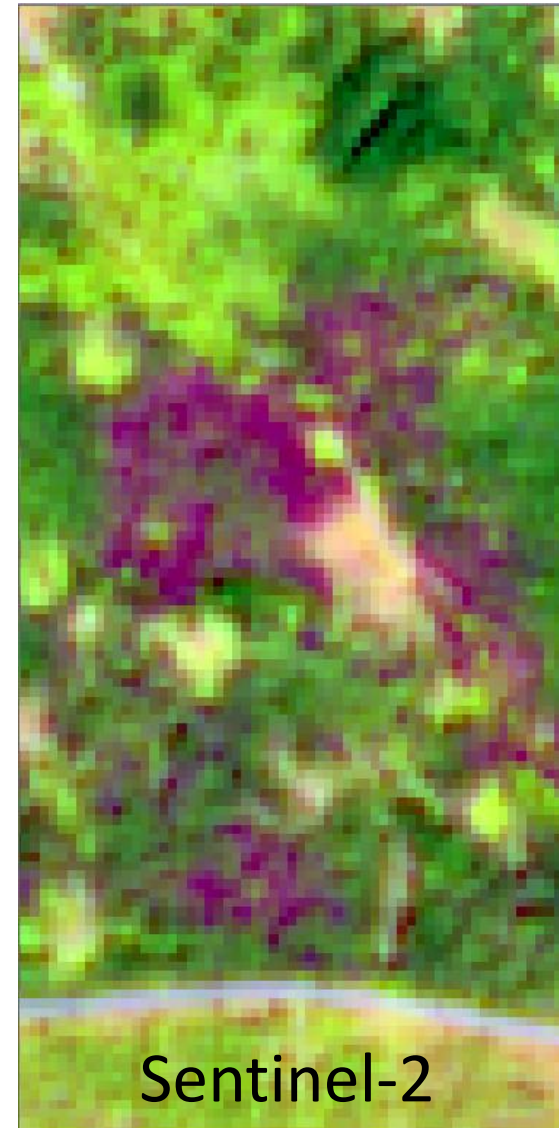
# Bark Beetle Monitoring



Project funded by ASAP 16, FFG



Project funded by FNR, BMEL



Sentinel-2



Luftbild



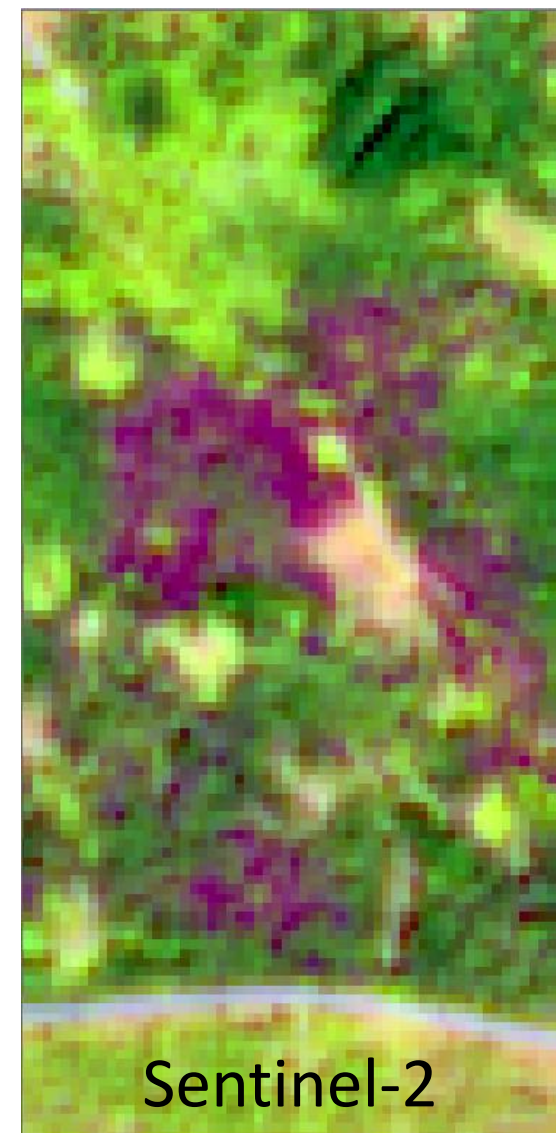
# Bark Beetle Monitoring



Project funded by ASAP 16, FFG



Project funded by FNR, BMEL



Sentinel-2



Luftbild

„Könnt ihr wirklich die Käfer aus dem All detektieren?“



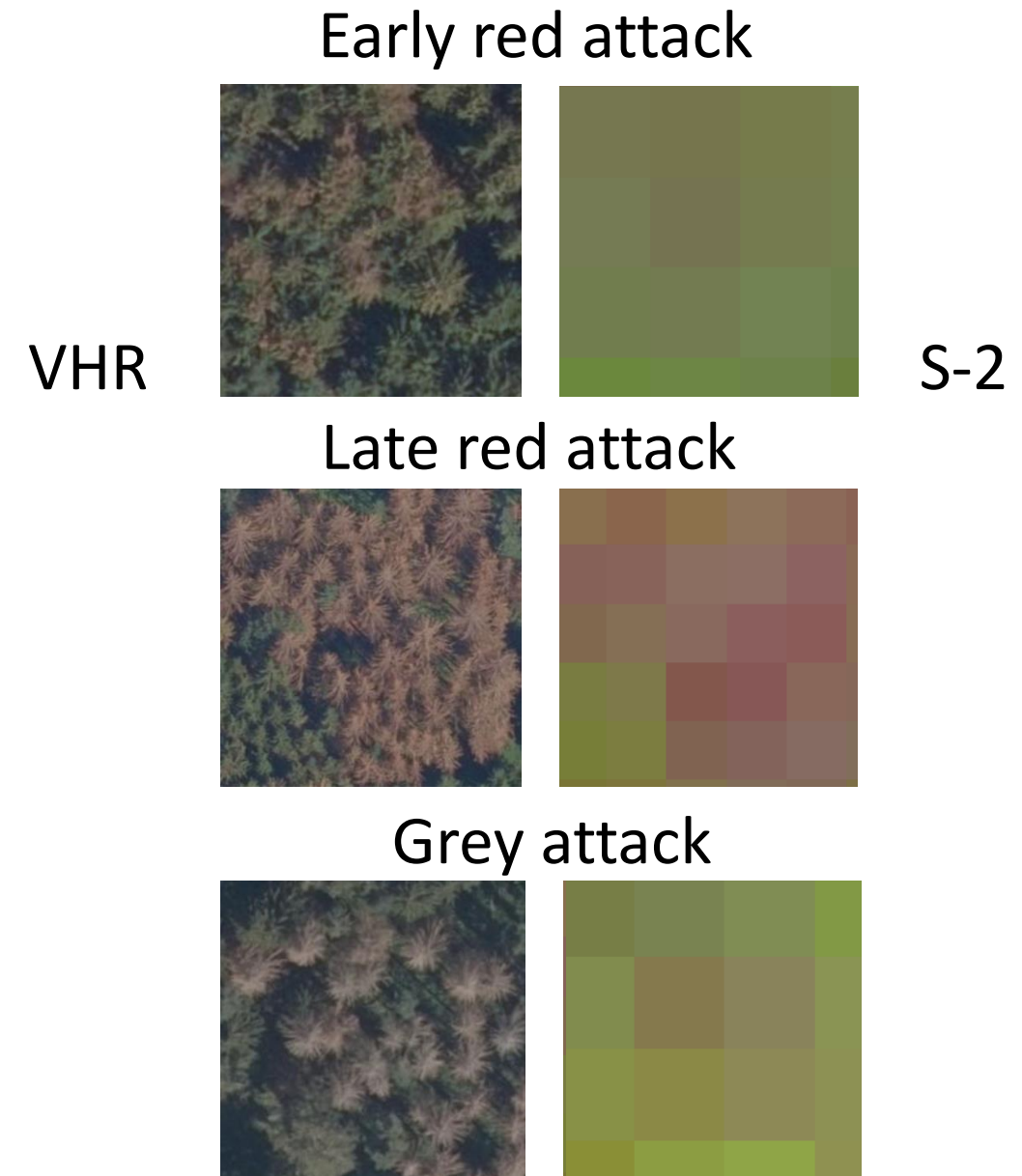
# ***Bark Beetle Monitoring***





# Bark Beetle Stages and EO Monitoring Aims

- **Green attack**
    - No visible needle color changes
    - Forester: beetles have not swarmed out yet
  - **Red attack**
    - Early red attack
      - Beginning/partial needle color change
    - Late red attack
  - **Grey attack**
    - Needles grey or dropped
    - Often an infestation from the previous season
- 
- **MMU:** 0.01ha or single Sentinel-2 pixel
  - **Season:** May to November

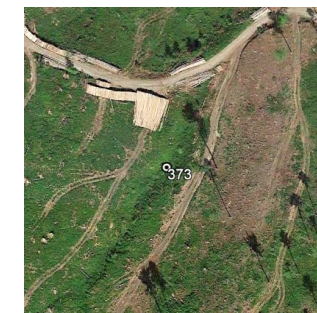
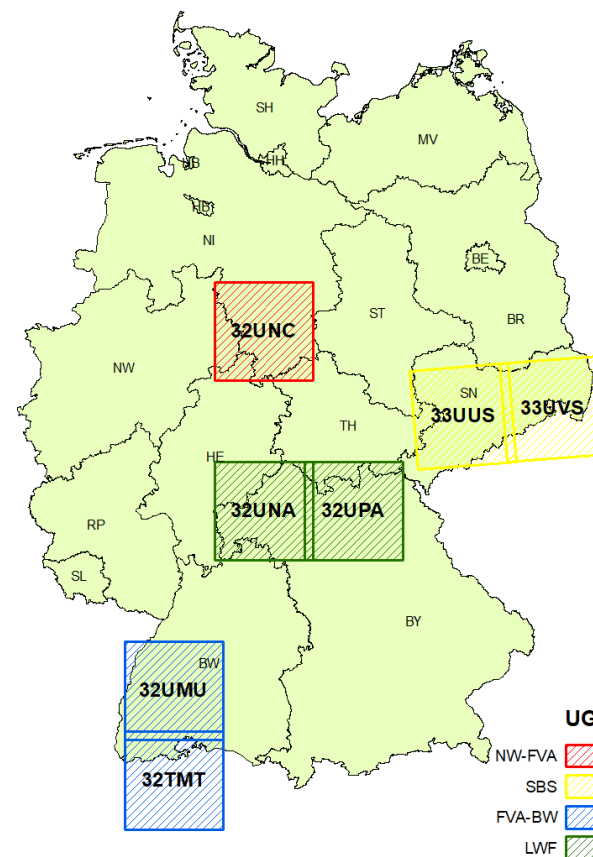




# Training Data Set



- Project partners of FNEWs collected reference data on German forest damages
- Covers 4 „Bundesländer“ = federal states
- Years 2018-2021
- ~15.000 forest damage polygons
- Different forest disturbance types
  - Bark beetle infestation
  - Storm damage
  - Gypsy moth
  - Drought stress
  - Clear cuts
  - Unknown disturbance





# Training Data Set

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  - Different forest disturbance types
    - Bark beetle infestation
    - Storm damage
    - Gypsy moth
    - Drought stress
    - Clear cuts
    - Unknown disturbance
- Problems:
    - Bark beetle polygons are derived from aerial imagery
    - Spatial extent only known at one point in time
    - No information on start time of the infestation
    - No information on sanitary cuts
    - No information on temporal development of infestation



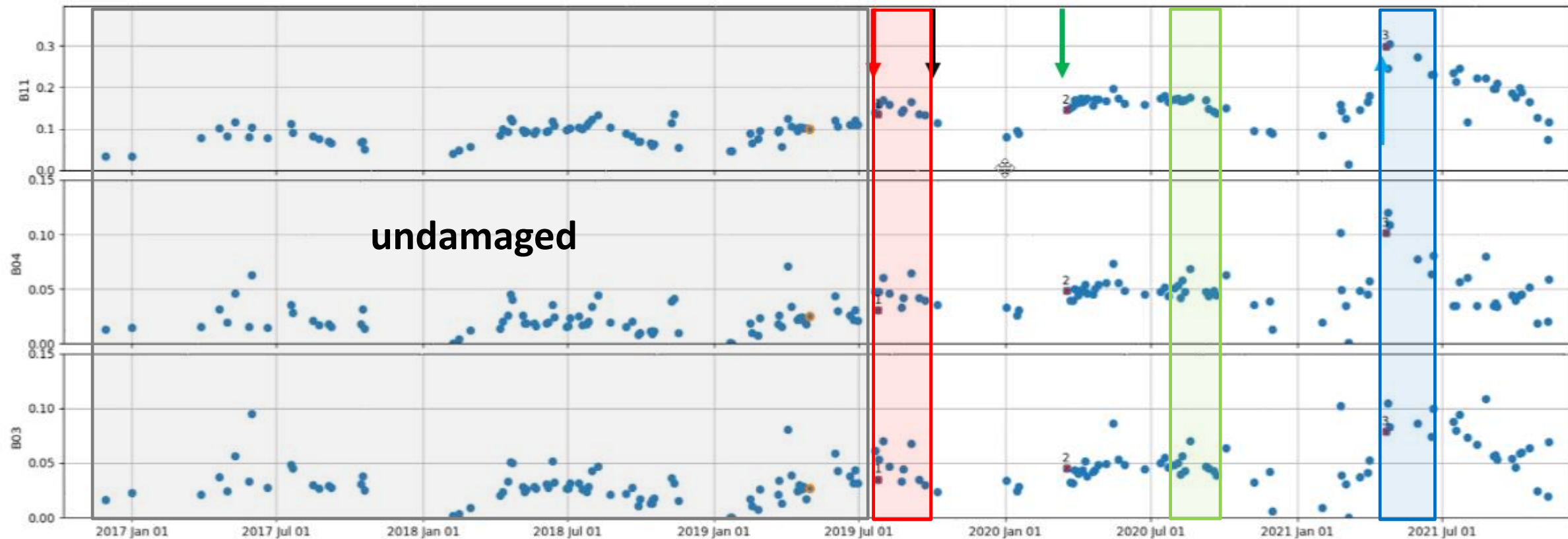
# Training Data Set

- Spectral training database for forest disturbances
- >640.000 spectral values

grey attack: 1 year later

early red attack: +60 days

Recent clear cut: +60 days





# ***EO Bark Beetle Monitoring Workflow***

- Bark Beetle Monitoring workflow builds on two components:

- NRT Forest Change Detection

- Disturbance Type Classification
  - Output: **Probability Map (0-100%) for Early Red Attack Infestation**



# EO Bark Beetle Monitoring Workflow

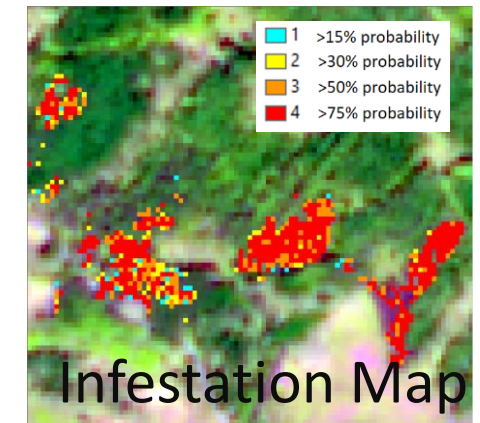
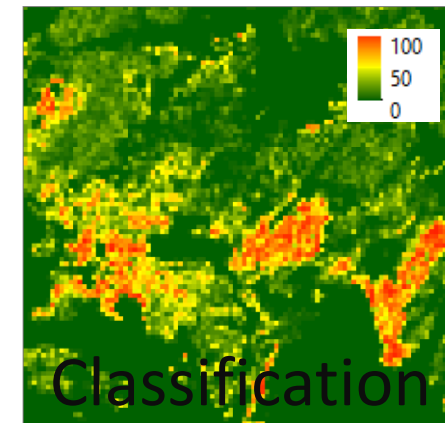
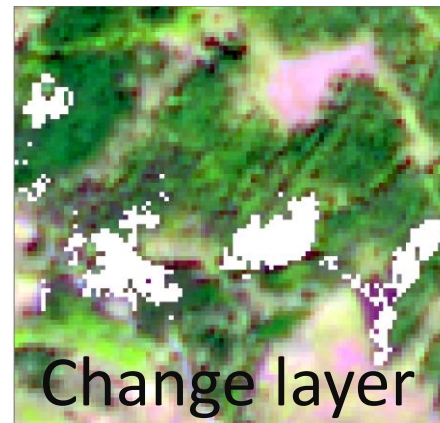
- Monitoring workflow builds on two components:

- NRT Forest Change Detection

- Disturbance Type Classification

- Output: **Probability Map (0-100%) for Early Red Attack Infestation**

- combine both products by a set of rules:
- for a pixel to be included in the bark beetle map:
  - NRT CD must signal a change
  - AND classification must have a probability > 30%
- Infestation map is updated every two weeks over the bark beetle season



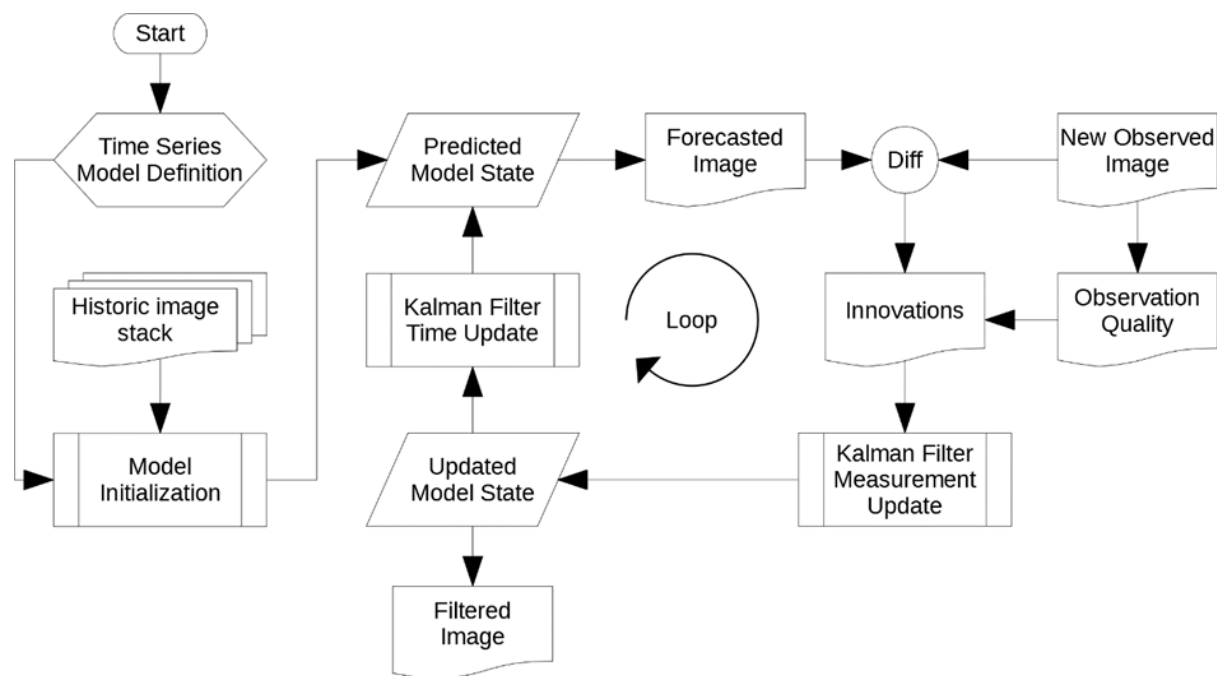
1	>15% probability
2	>30% probability
3	>50% probability
4	>75% probability



# EO Bark Beetle Monitoring Workflow

- Monitoring workflow builds on two components

- NRT Forest Change Detection



- Pixel-based modelling
- Dynamic** state space model
- Builds on **Kalman filter**
- Change Detection based on CUSUM of Innovations

Puhm et al, 2020: DOI: [10.3390/rs12193135](https://doi.org/10.3390/rs12193135)

Open Access Article

**A Near Real-Time Method for Forest Change Detection Based on a Structural Time Series Model and the Kalman Filter**

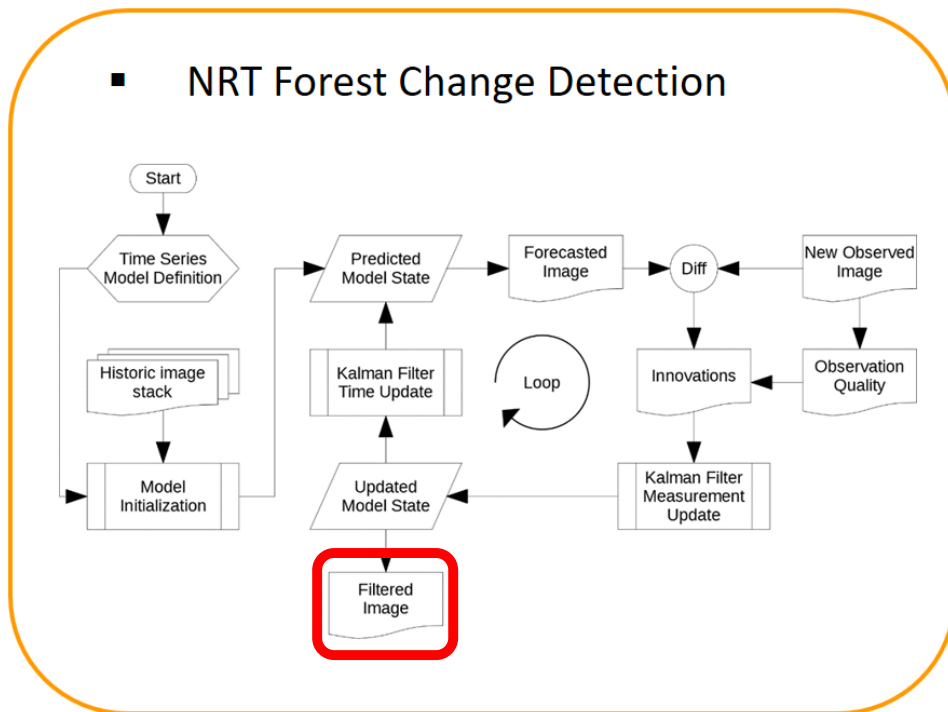
by [Martin Puhm](#), [Janik Deutscher](#), [Manuela Hirschmugl](#), [Andreas Wimmer](#), [Ursula Schmitt](#) and [Mathias Schardt](#)



# ***EO Bark Beetle Monitoring Workflow***

■ Advantage of dynamic time series model

Filtered model image time series during the bark beetle seasons 2018-2021. Model images for 1st day of the month.

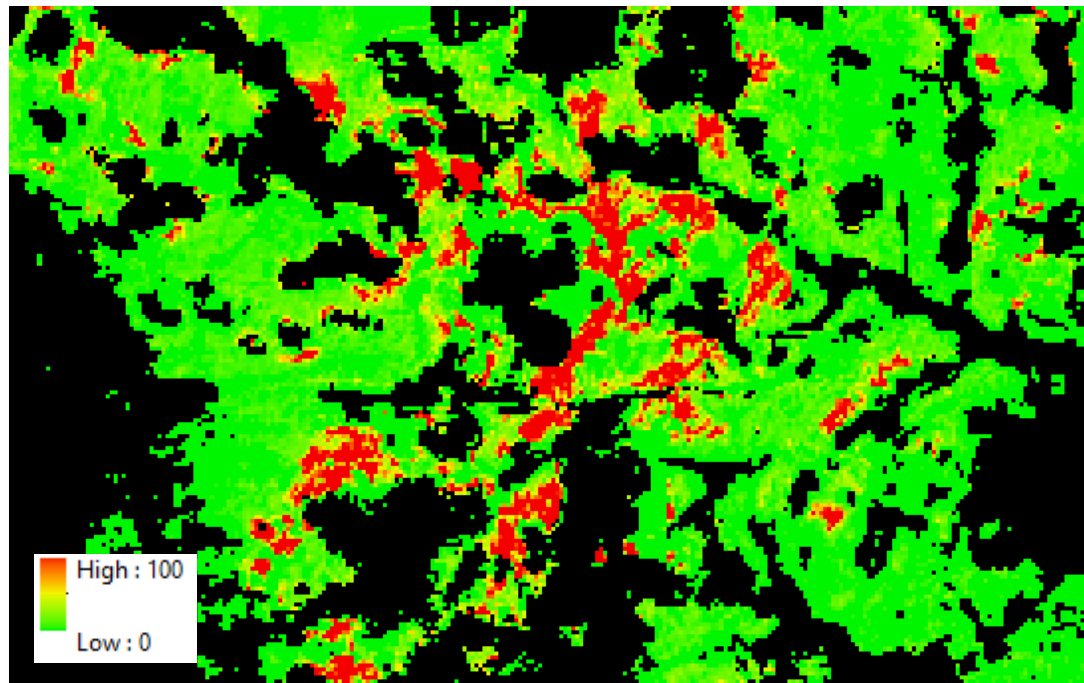




# *EO Bark Beetle Monitoring Workflow*

## ■ Monitoring workflow builds on a two components

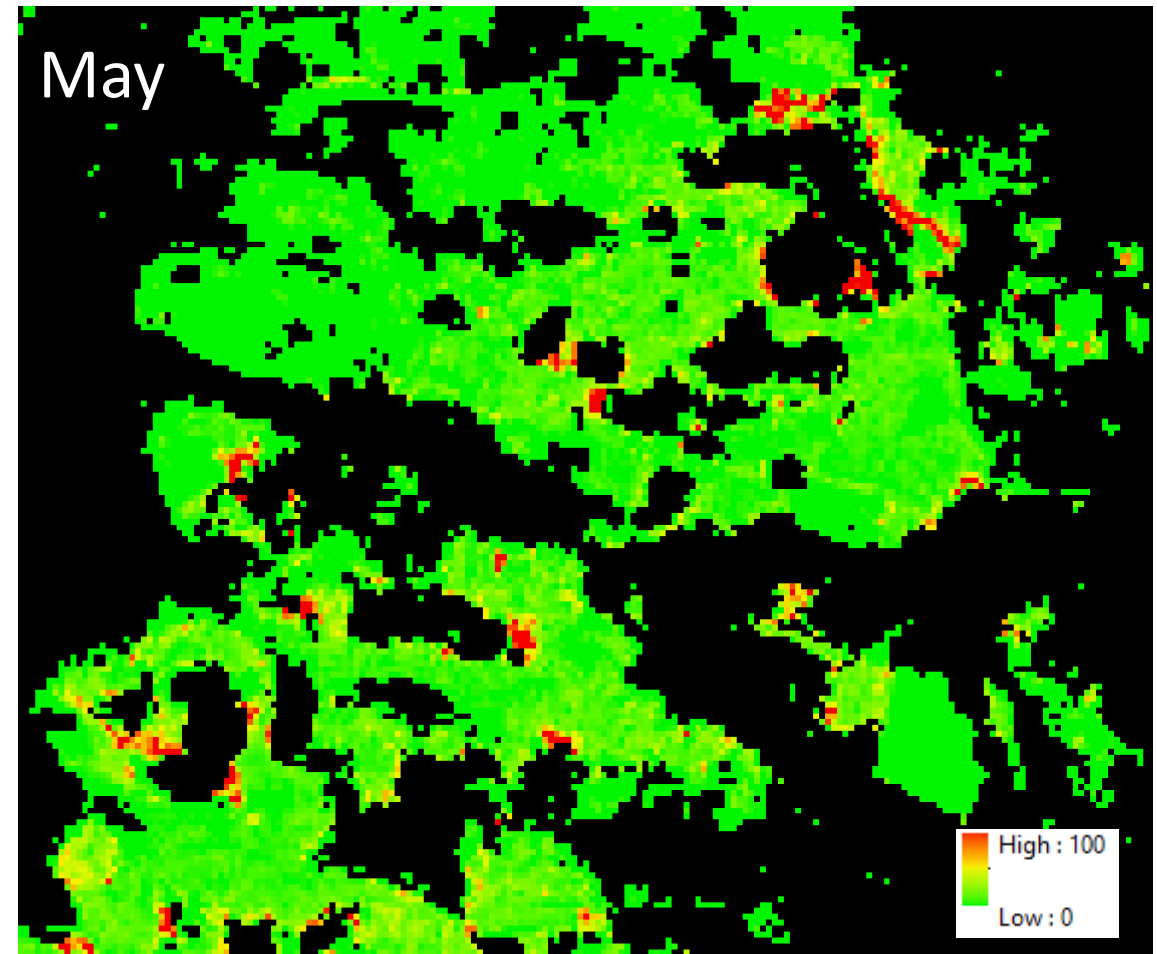
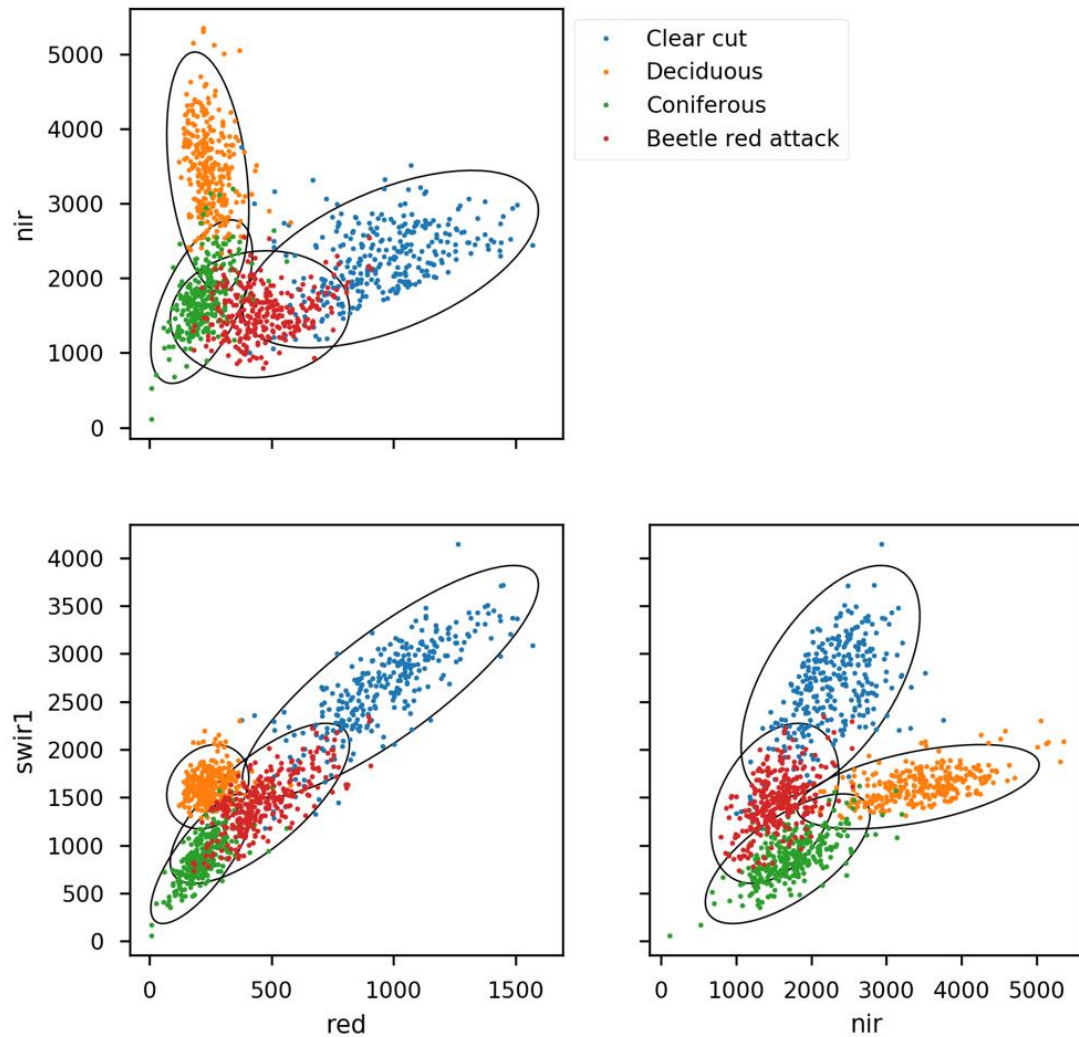
- Classification of early red attack stage bark beetle probability



- Robust Gaussian Mixture Classifier
- Assumption: disturbance types form (separate) clusters in spectral domain
- Cluster described by center point and covariance matrix (3 bands: ellipsoid)
- We calculate the Mahalanobis distances to cluster centre(s)
- Output: **Early Red Attack bark beetle probability map**

# Bark Beetle Red Attack Probability Maps

## Gaussian Mixture Classification with bands Green / Red / NIR / SWIR1

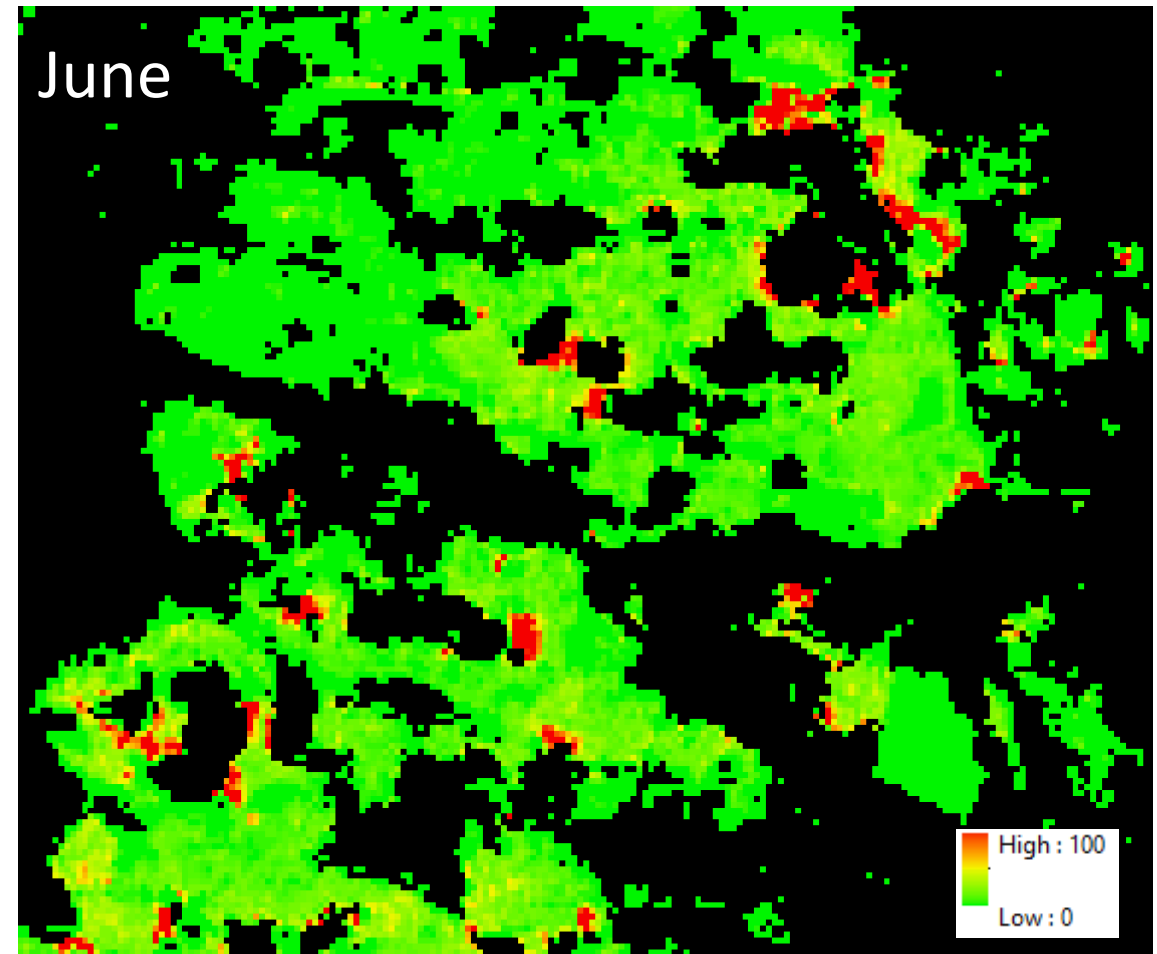
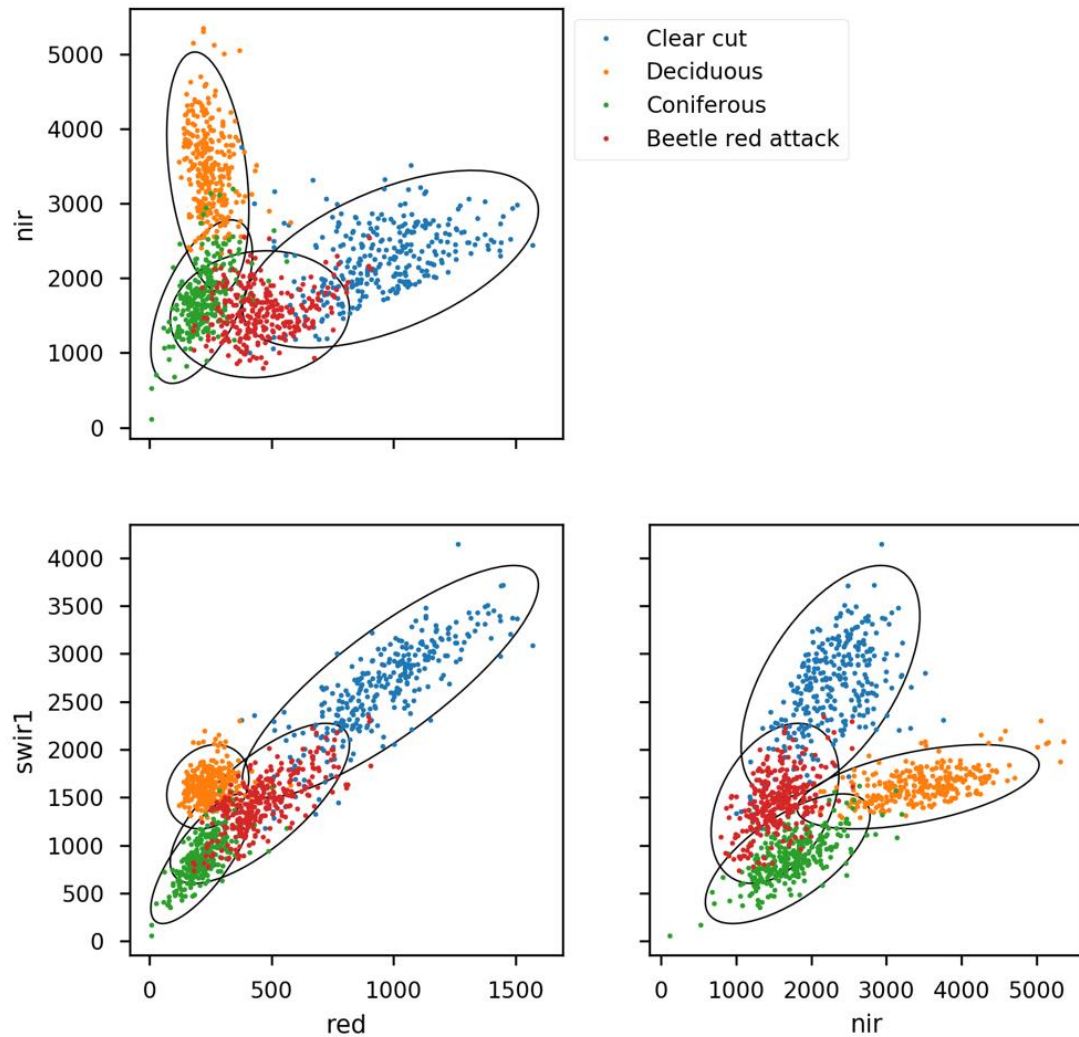


TÜP Allentsteig, Austria



# Bark Beetle Red Attack Probability Maps

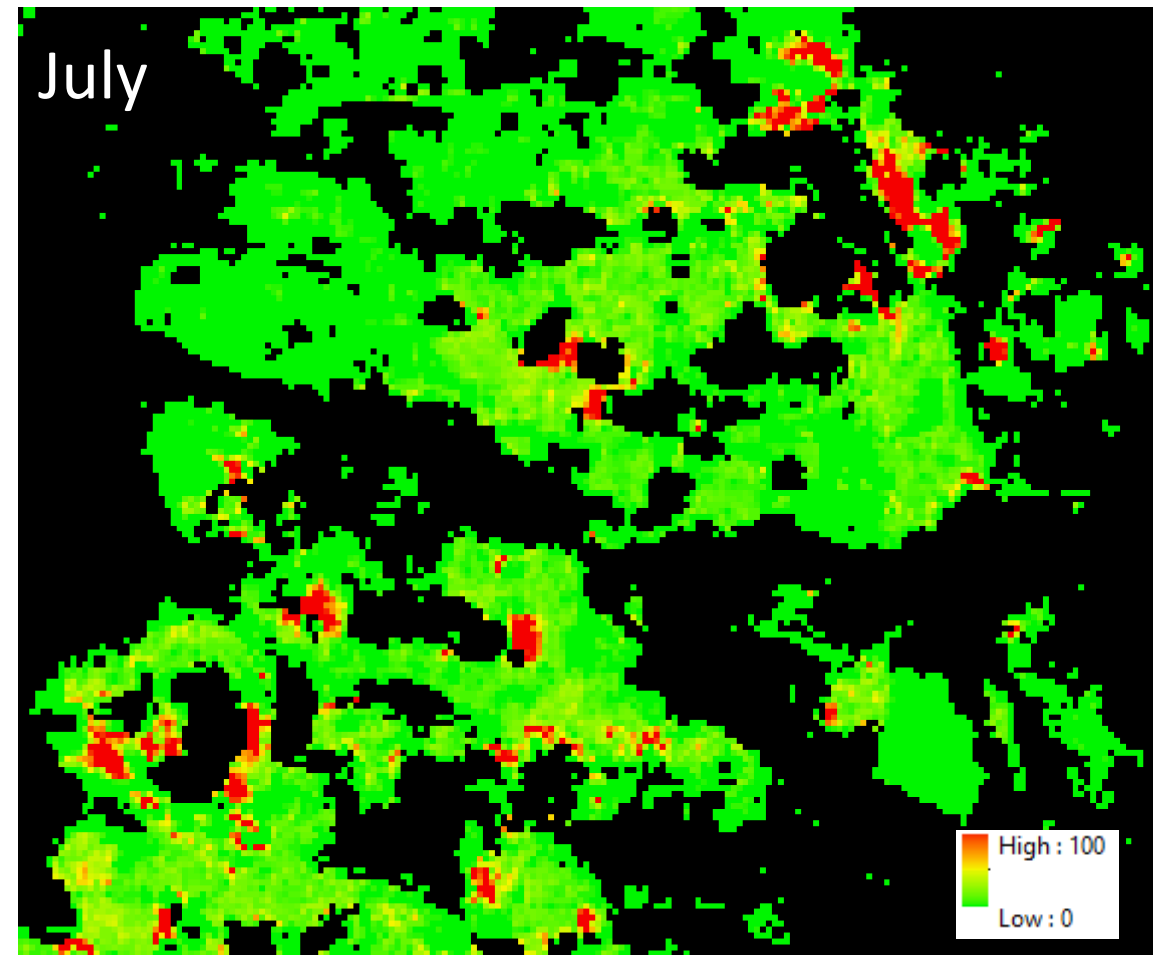
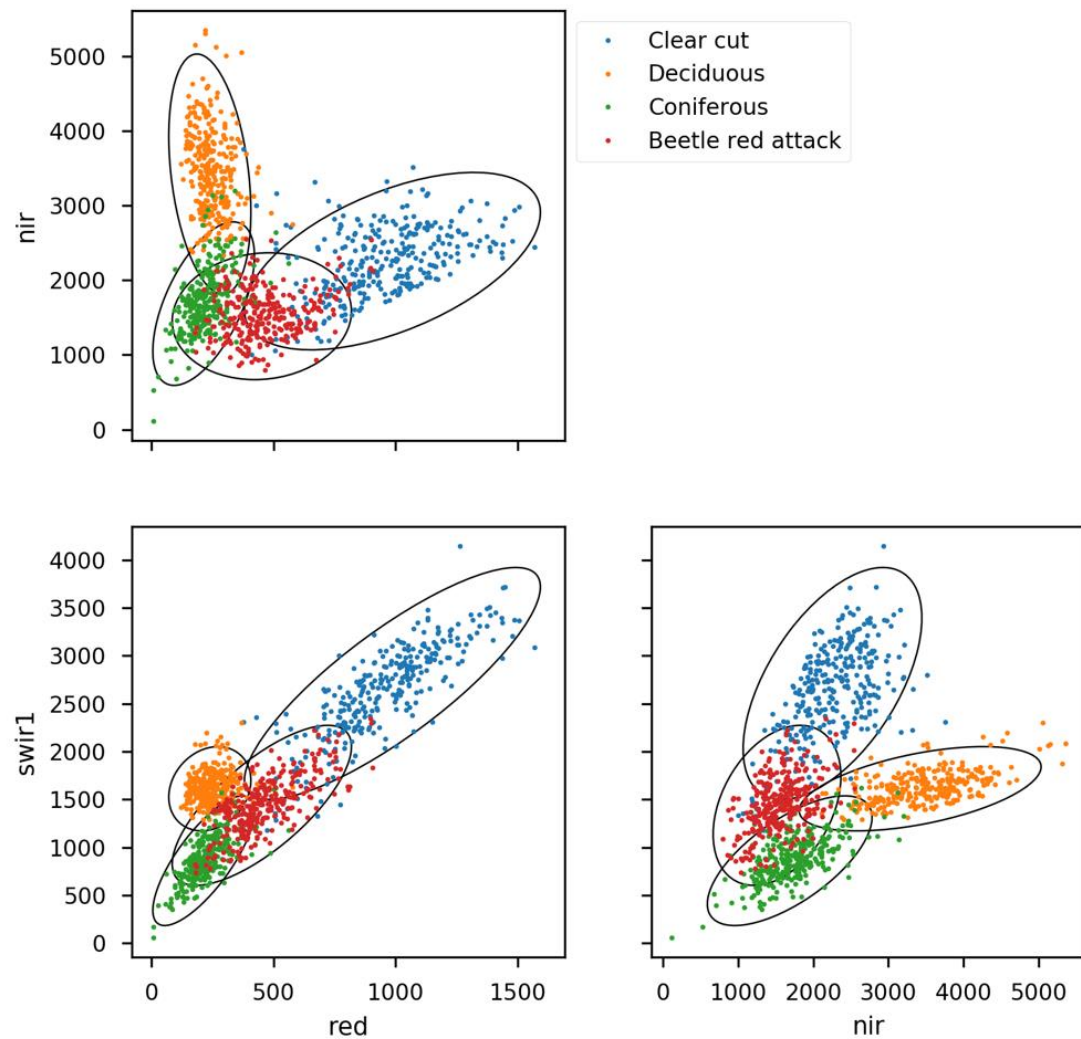
## ■ Gaussian Mixture Classification with bands Green / Red / NIR / SWIR



TÜP Allentsteig, Austria

# Bark Beetle Red Attack Probability Maps

## Gaussian Mixture Classification with bands Green / Red / NIR / SWIR

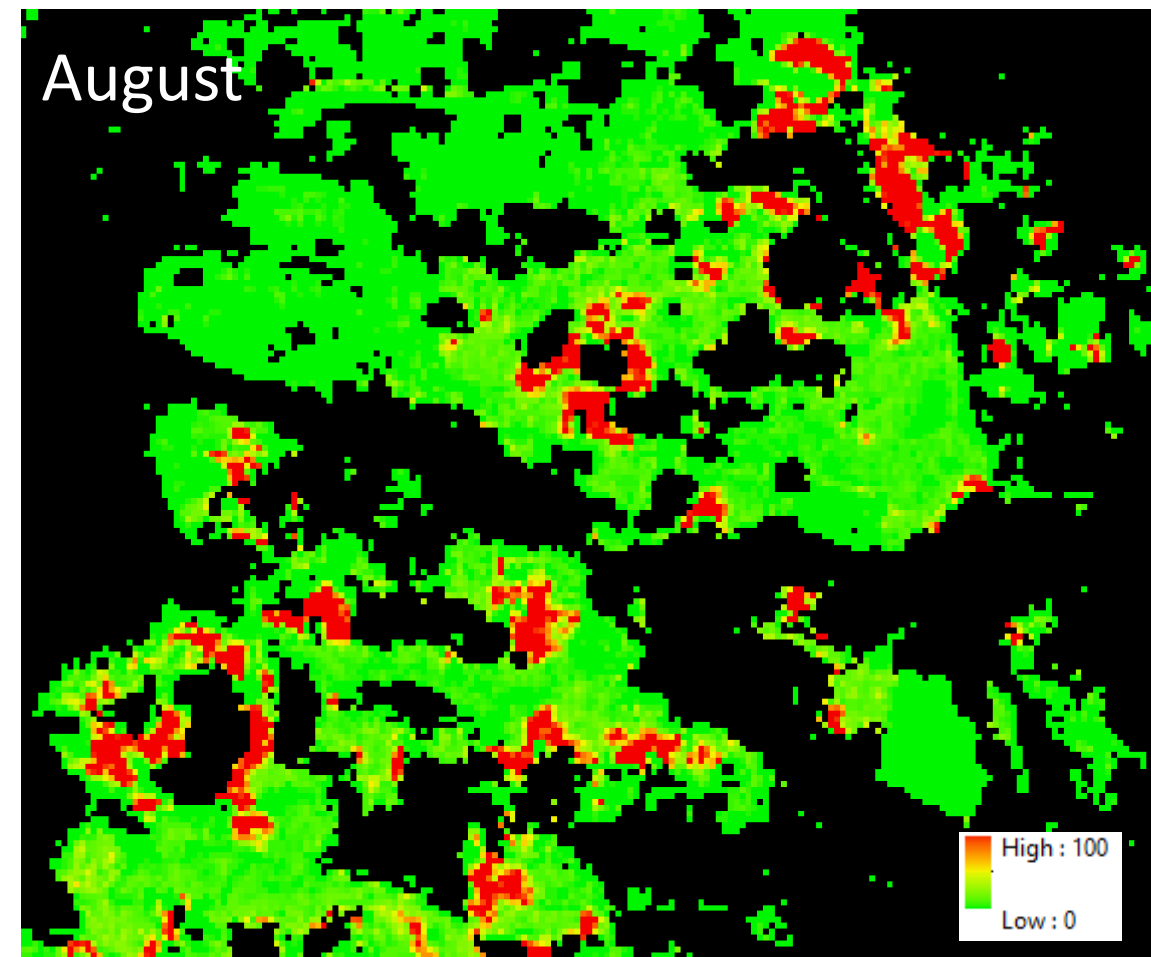
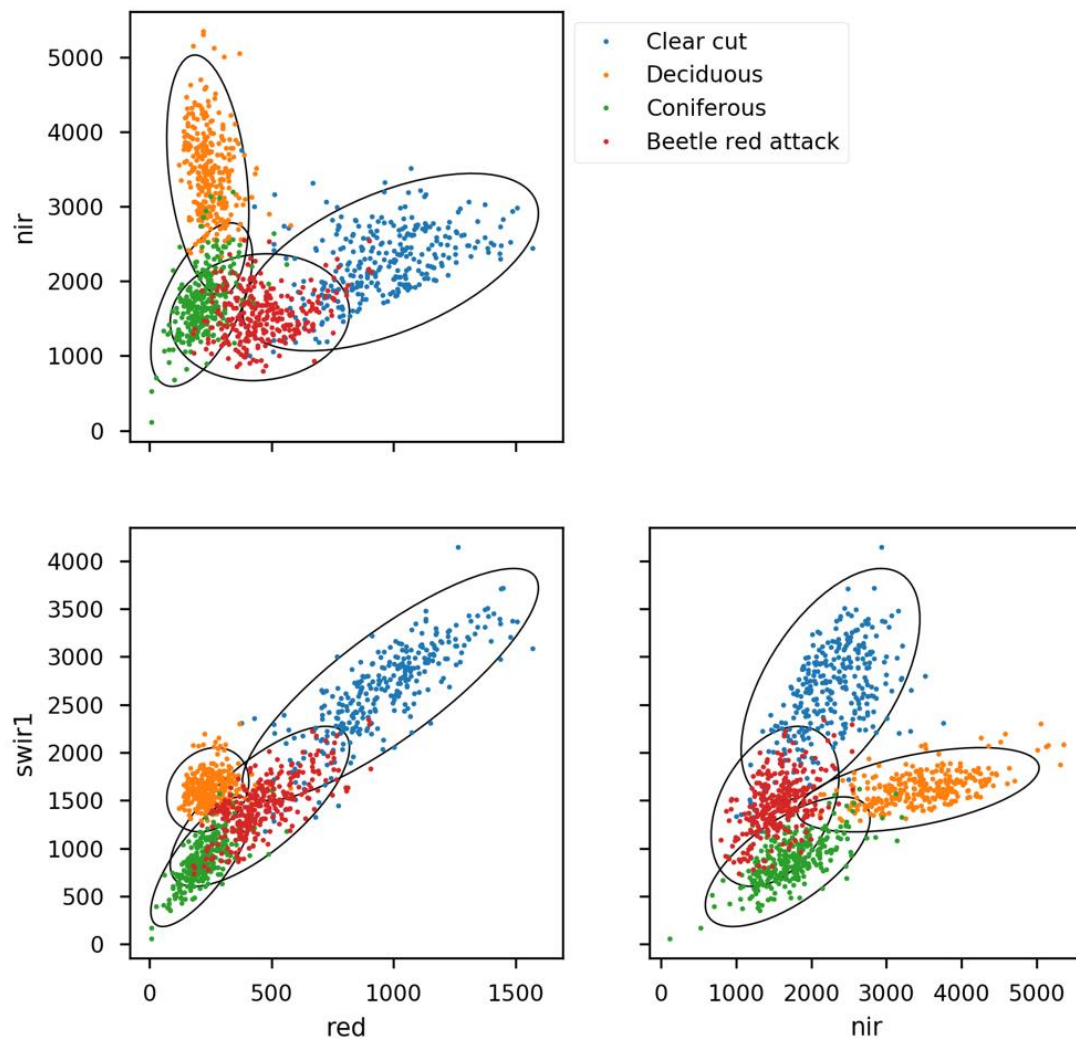


TÜP Allentsteig, Austria



# Bark Beetle Red Attack Probability Maps

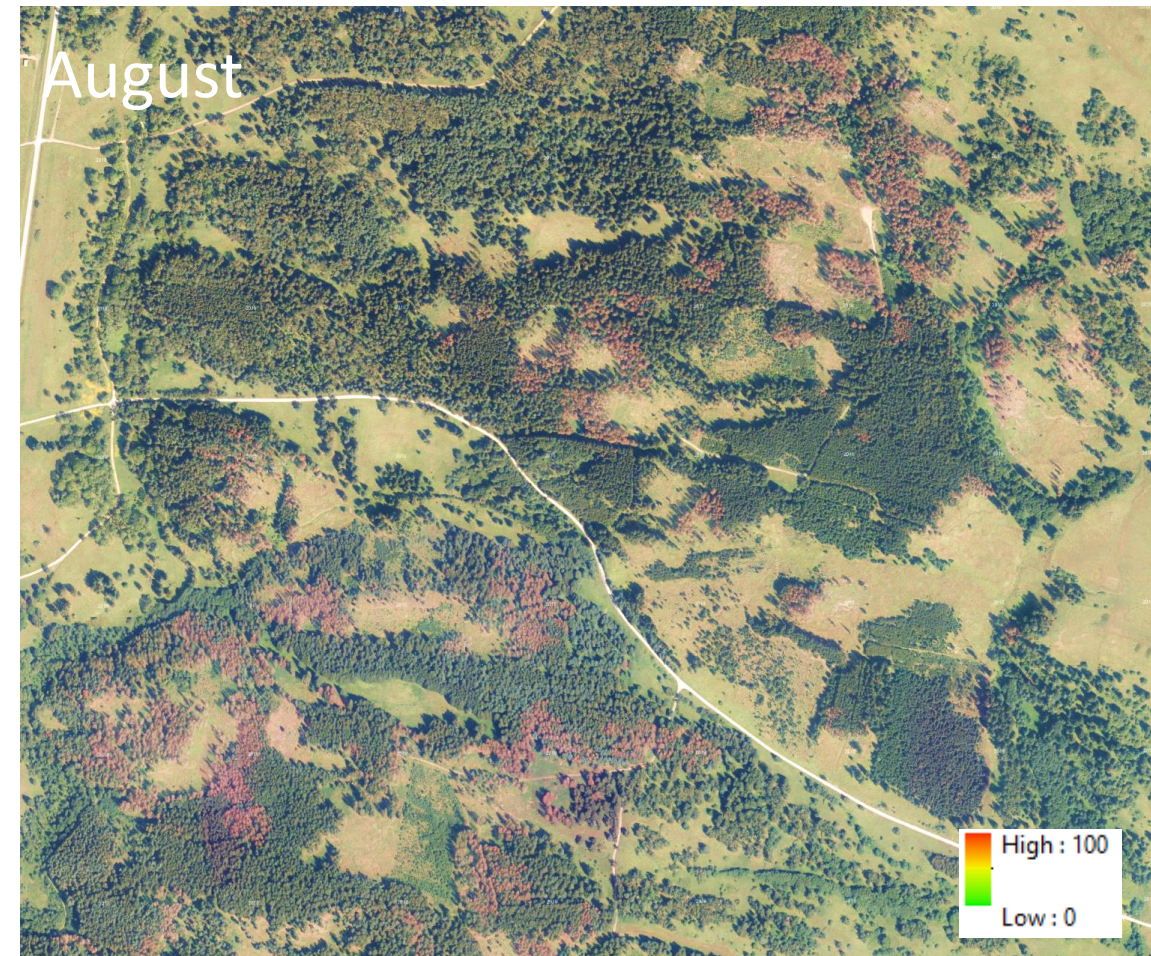
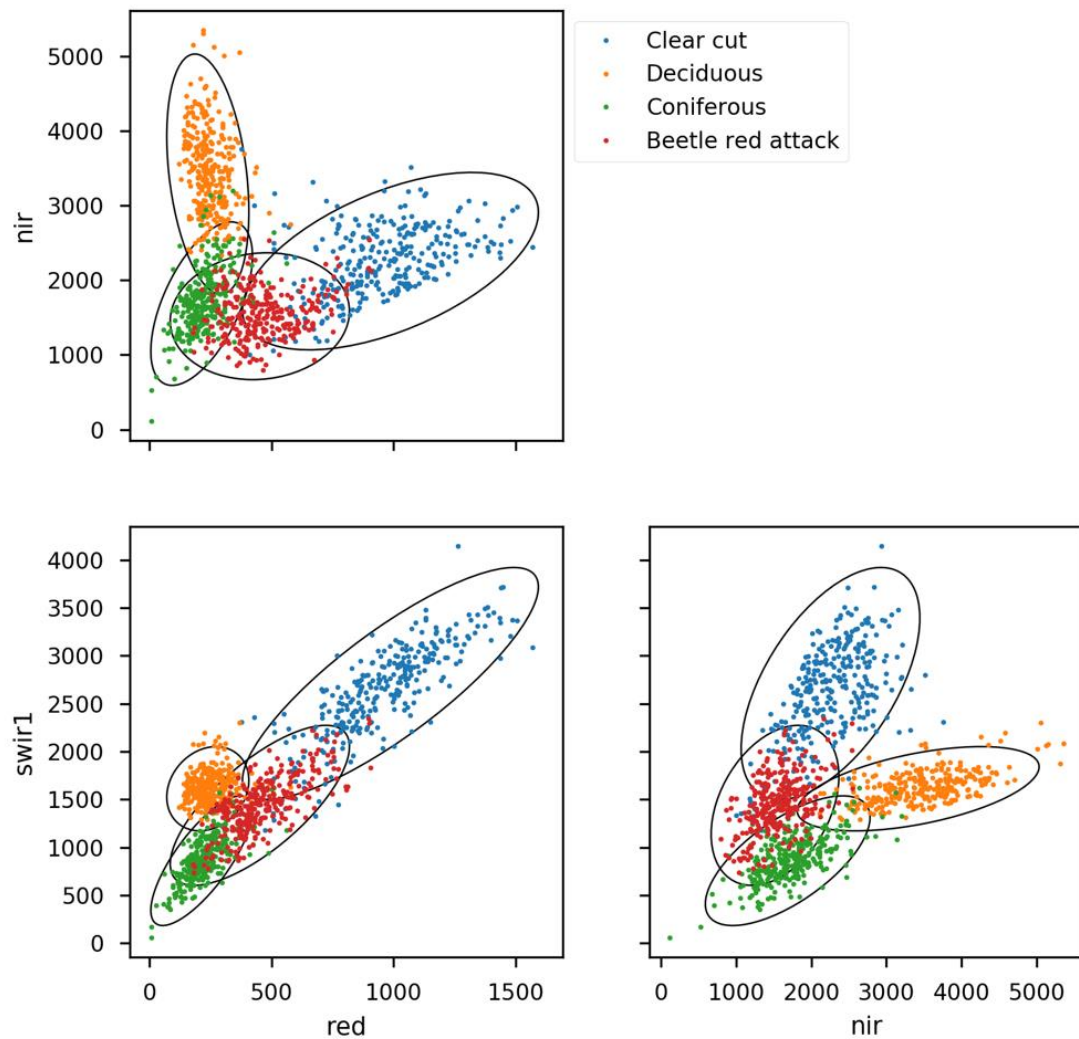
## ■ Gaussian Mixture Classification with bands Green / Red / NIR / SWIR



TÜP Allentsteig, Austria

# Bark Beetle Red Attack Probability Maps

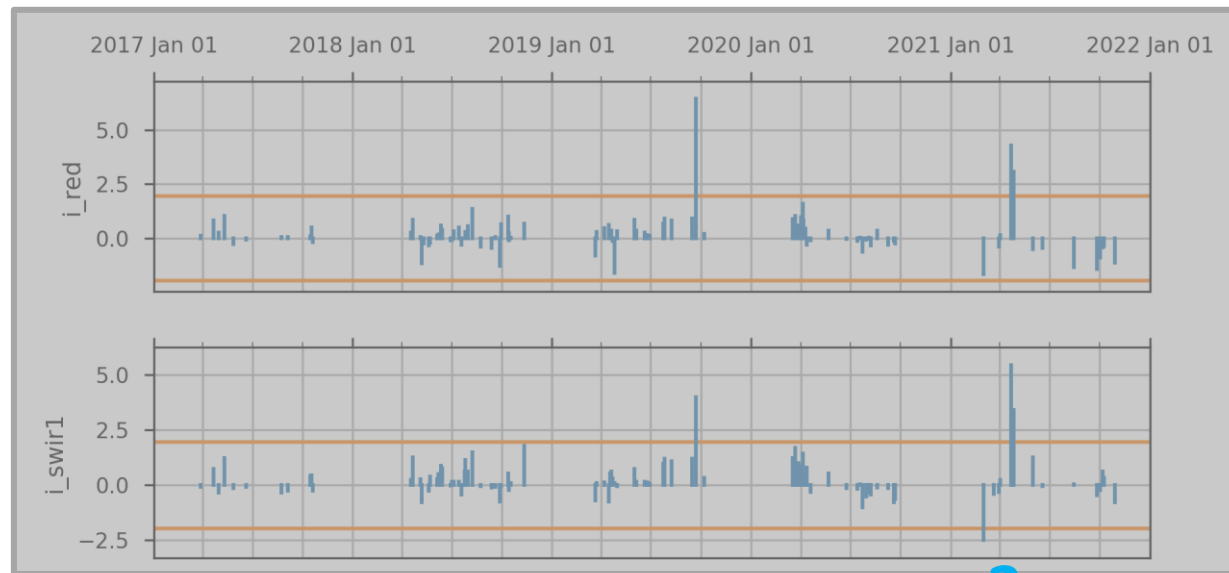
■ Gaussian Mixture Classification with bands Green / Red / NIR / SWIR



TÜP Allentsteig, Austria

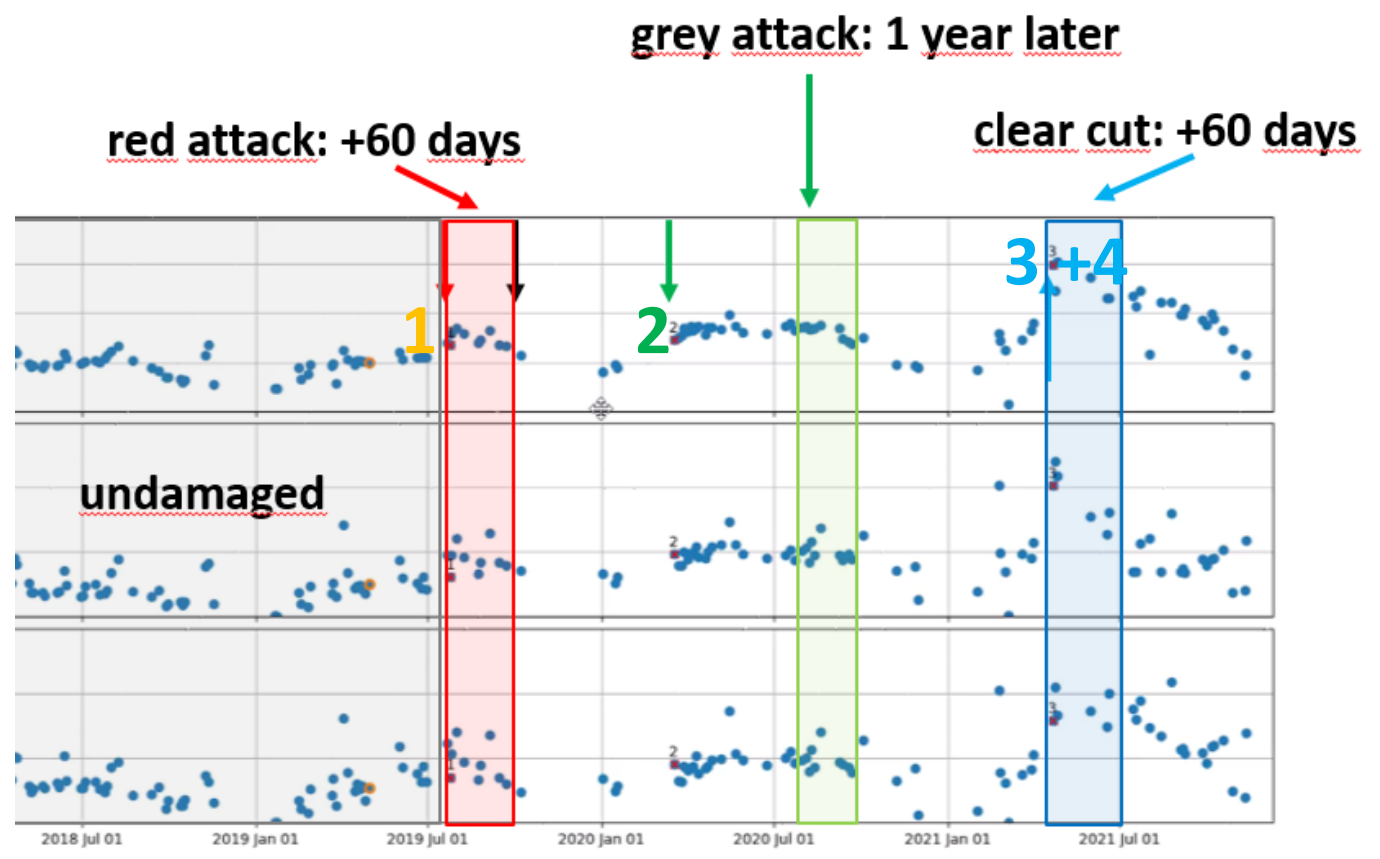
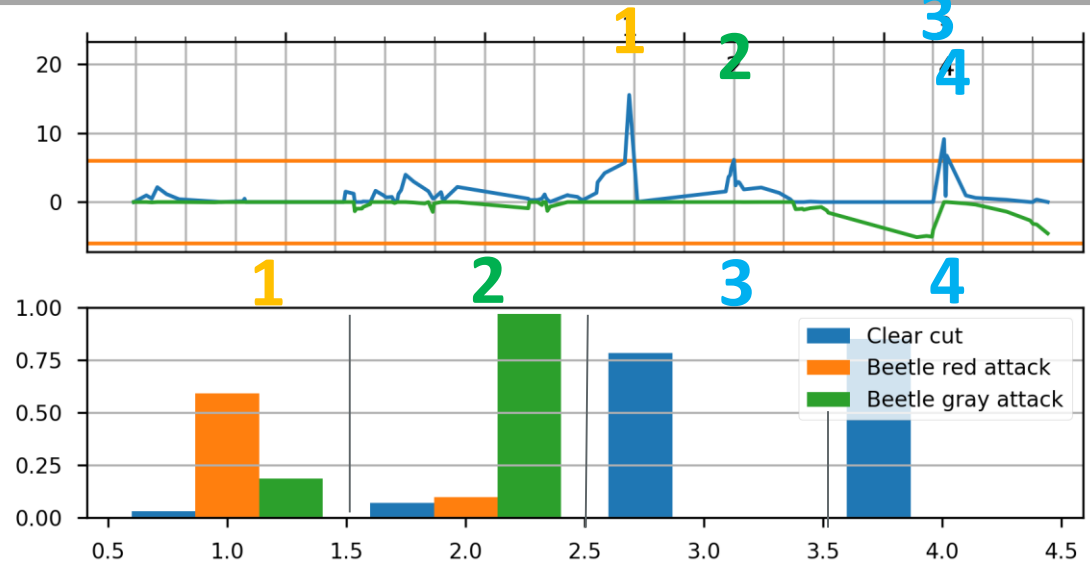


# Combining NRT Change Detection and Classification



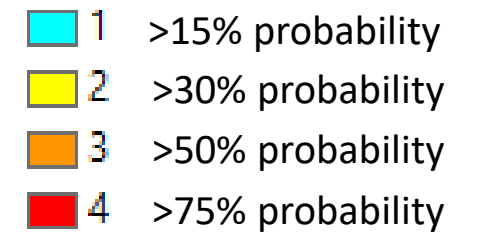
CUSUM  
combined

Class  
probability

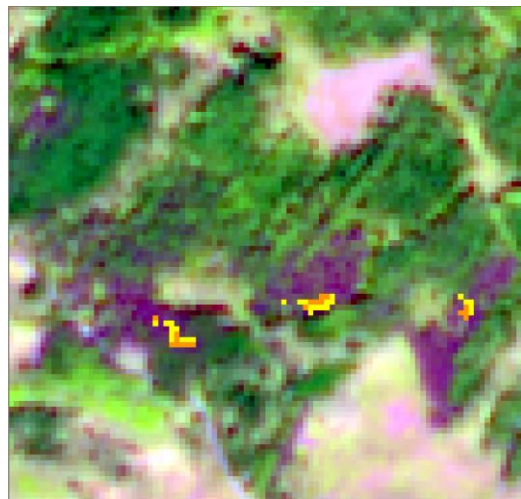


# Combining NRT Change Detection and Classification

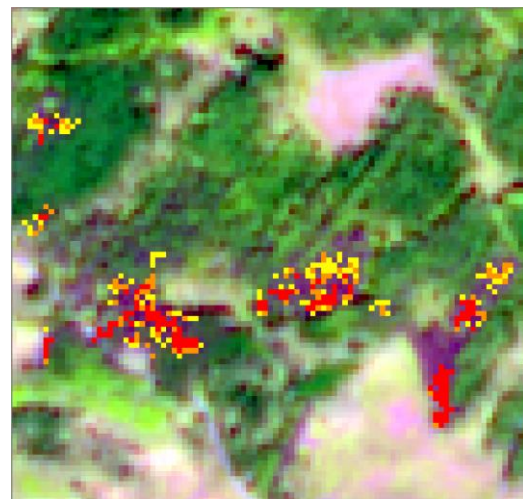
- Current implementation of NRT bark beetle detection in Austria:
  - We calculate new forest changes and new classification probabilities on a 14-day basis



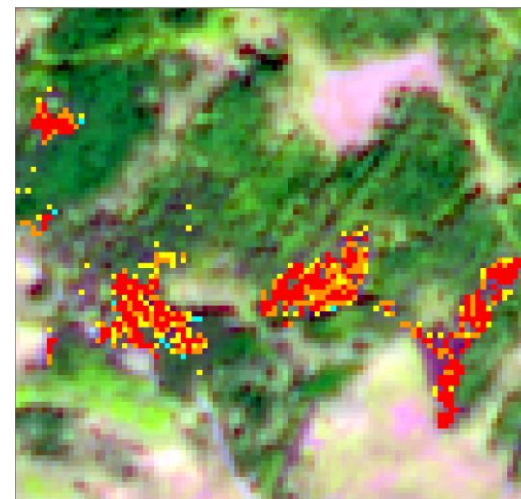
Background image: always Sentinel-2, August 29



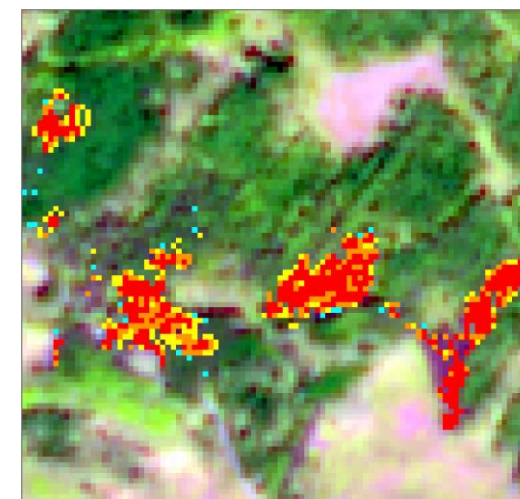
July 10th



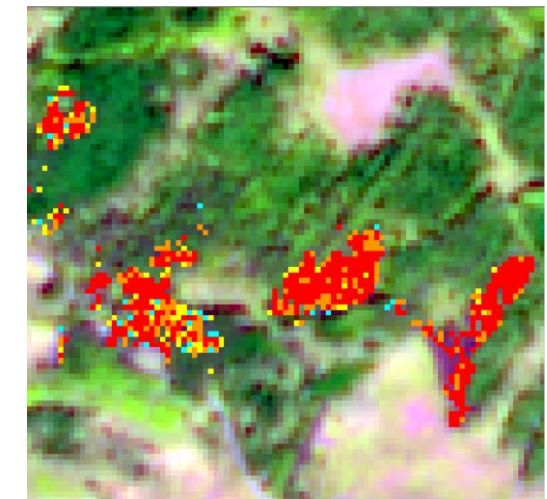
July 24th



August 7th



August 21st



September 4th



# Combining NRT Change Detection and Classification

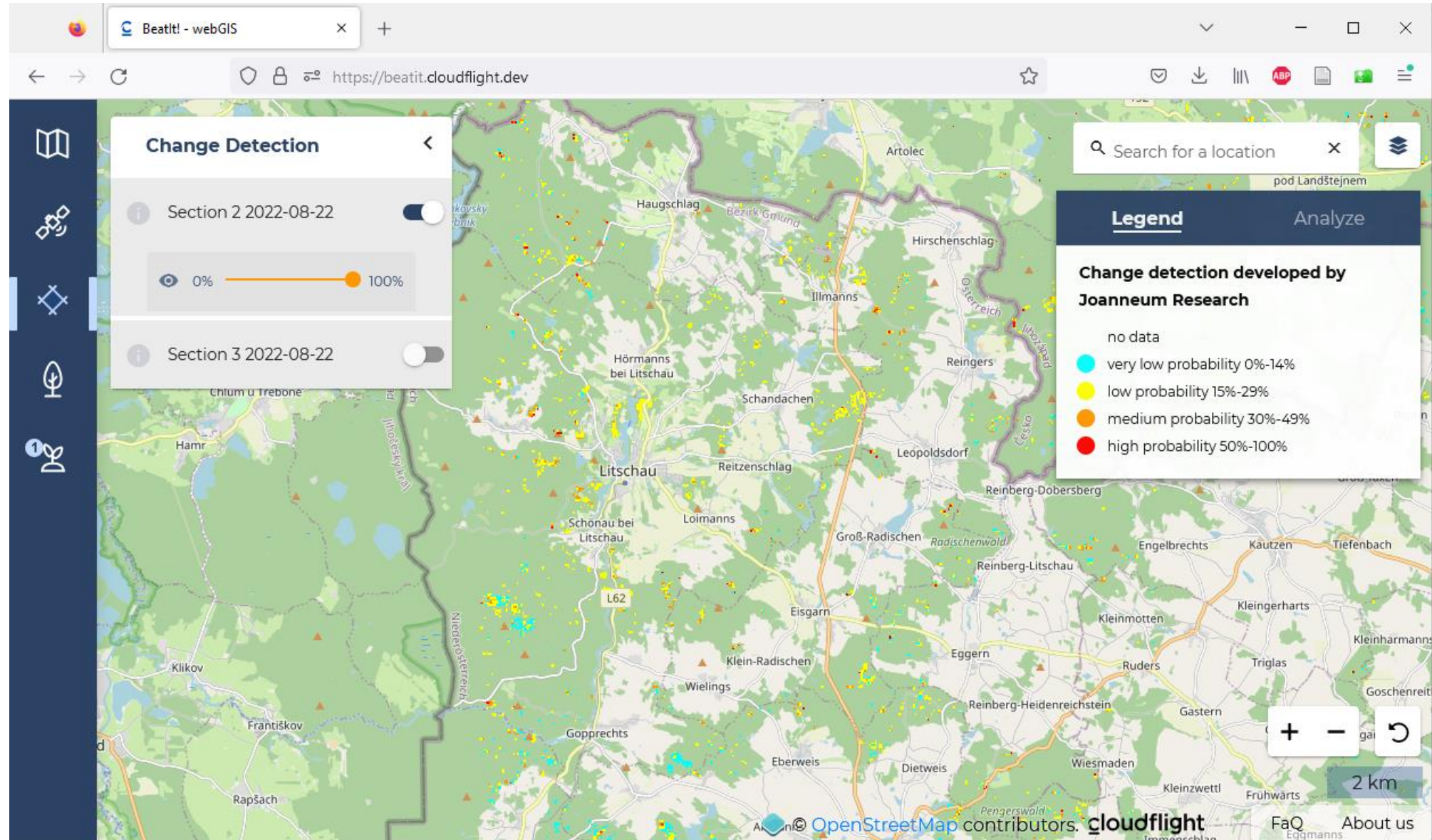
- Maximum bark beetle infestation risk over the entire bark beetle season



Background image:  
Sentinel-2



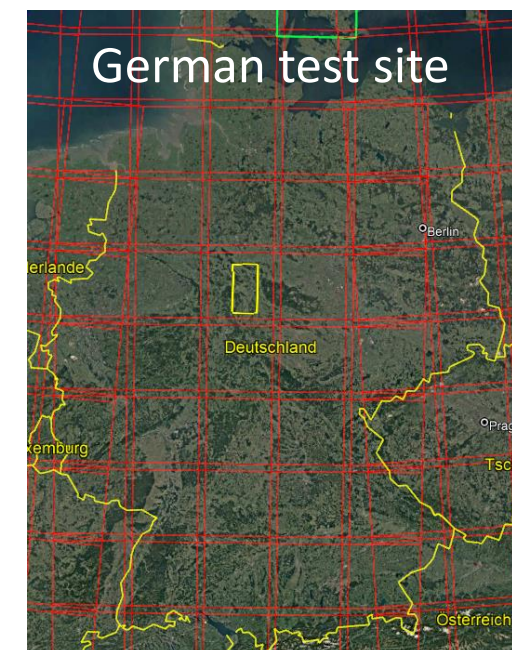
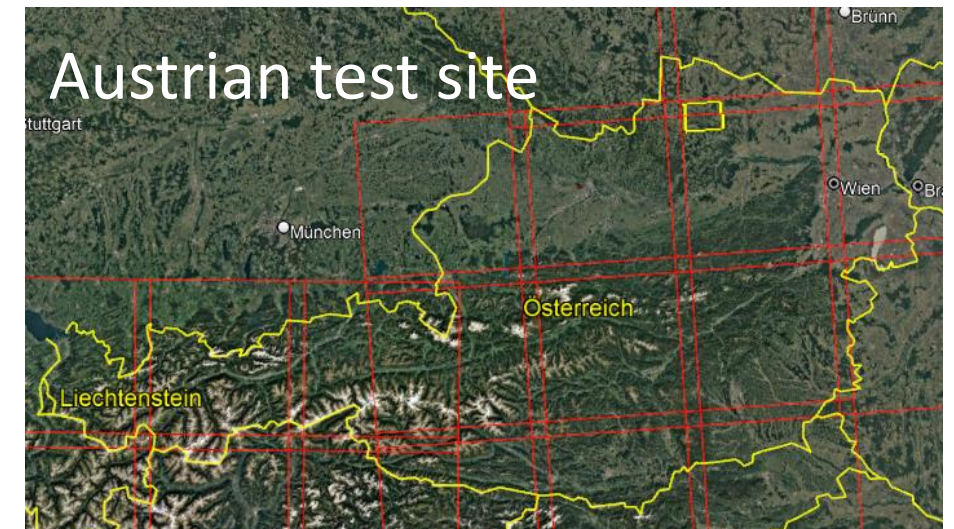
# Bark Beetle Monitoring Service Prototype





# Validation

- Workflow tested in **Niederösterreich & Niedersachsen**
- Training data only from Germany
- In Austria: validation with aerial imagery (16.08.2018)
  - Map status is 21.08.2018
- Validation on **single pixel level** / 0.01ha MMU
- Validation is based on a stratified random sampling approach (following Olofsson et al. 2014)

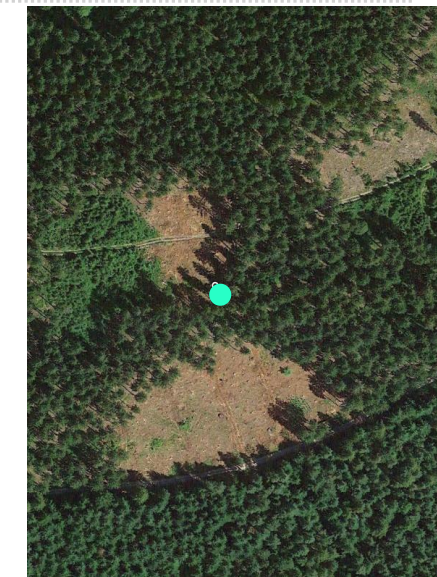


# Validation

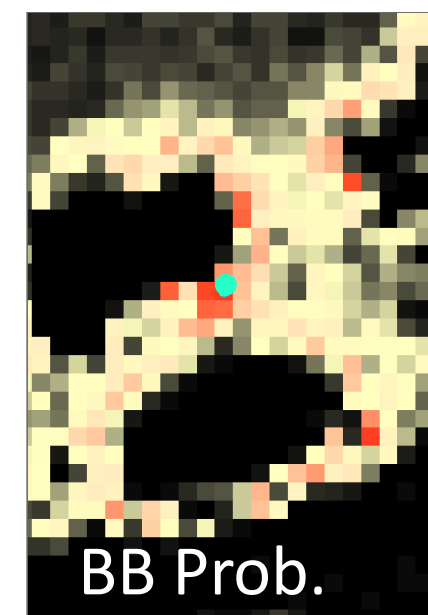
- Results for the Austrian test site (weighted by area)
  - Mapped damage area: 156.62ha
  - Estimated damage area: 165.19ha; +/- 15.4ha

	F1 Score	User Acc.	Producer Acc.
Red Attack infestation	0.930	0.954	0.907
Undamaged forest	0.997	0.996	0.998

- Validation results ongoing for Niedersachsen, Germany, test site (point based)
  - User Accuracy for the „early red attack“ class: **80.40%**
  - Accuracy significantly lower!
    - **Reasons:** managed forest with many sanitary cuts and clear cuts. Classification errors mostly at the edge of recent clear cuts.

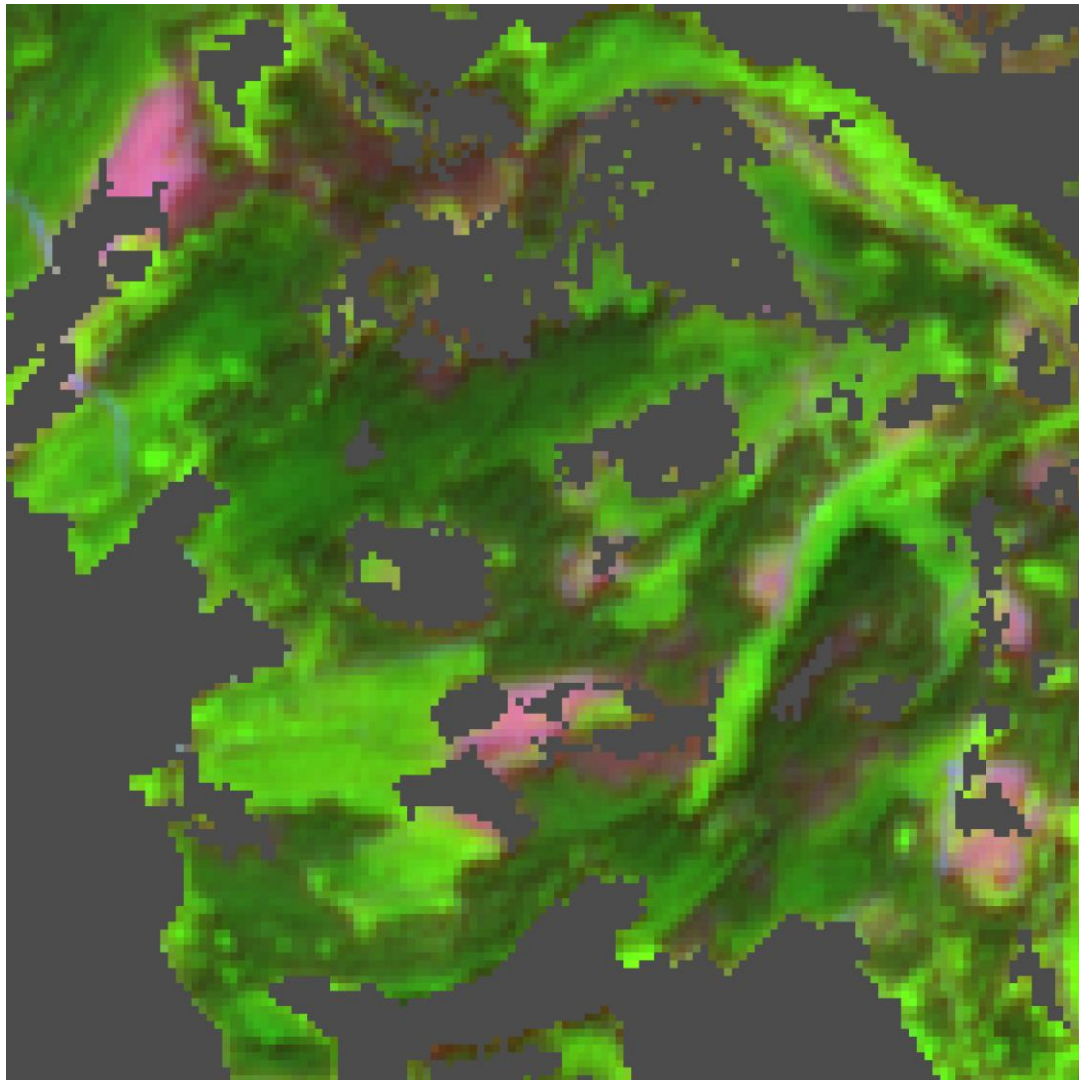


Error example from Germany

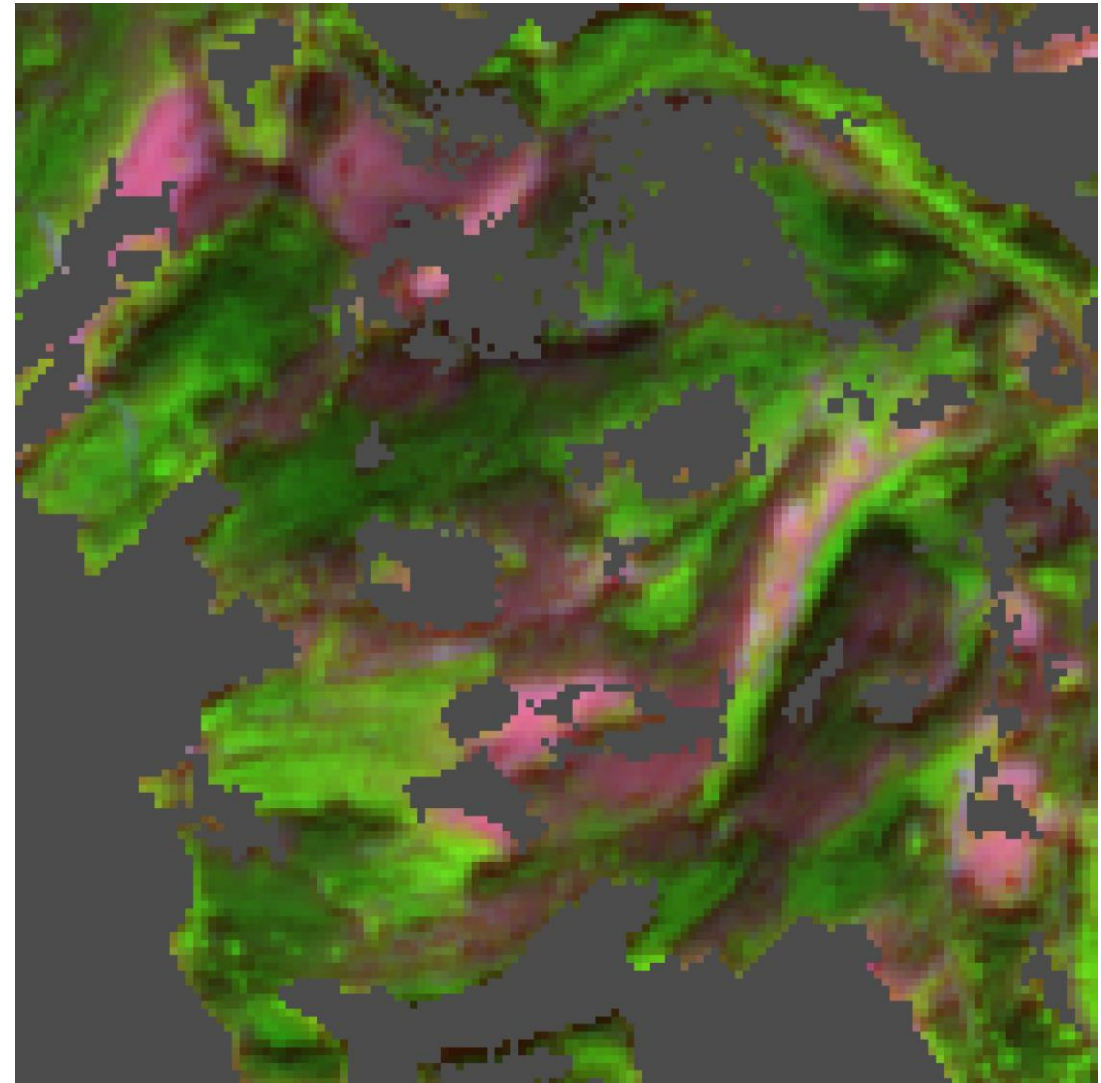




# *Other Product Examples from Germany 2022*

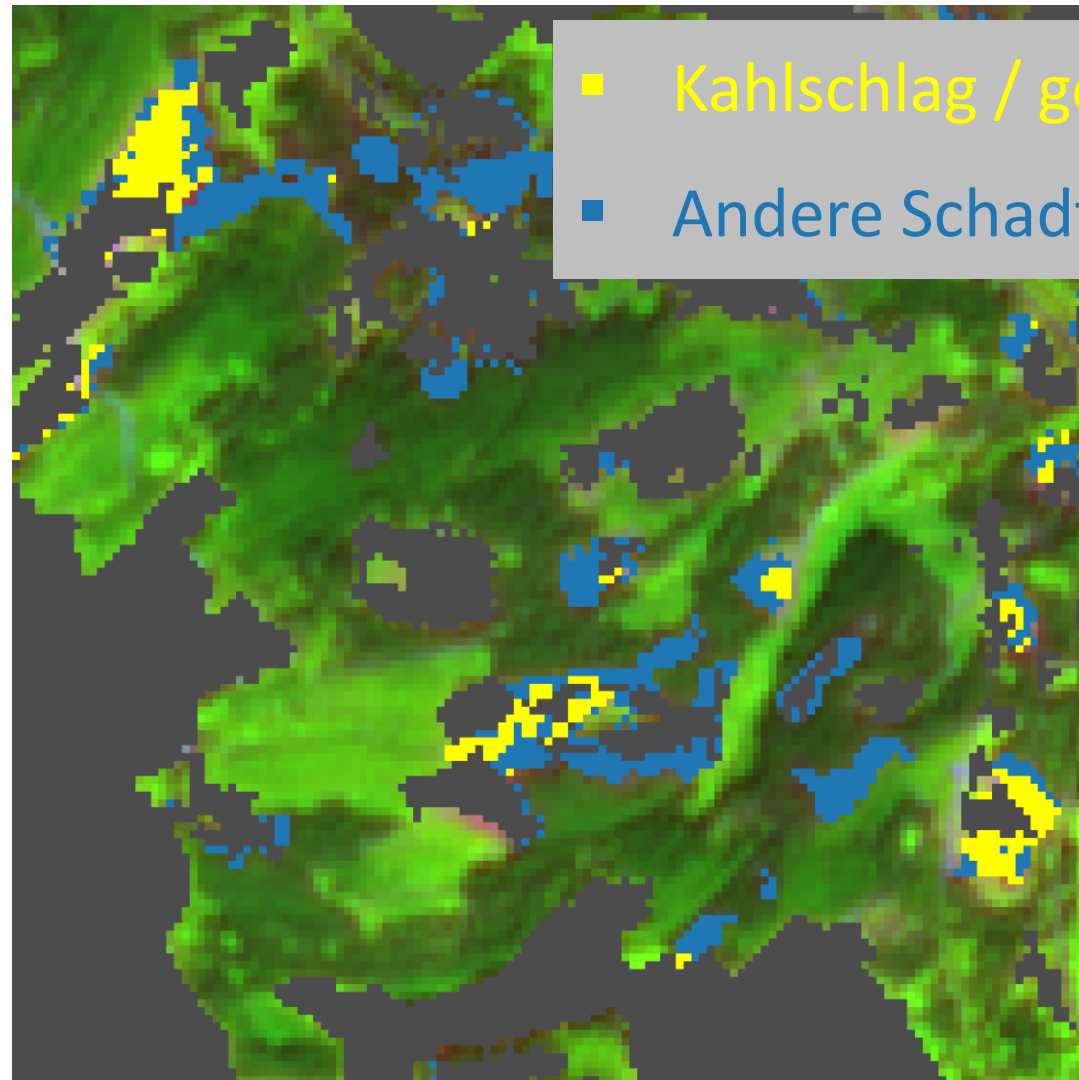


Sentinel-2 15.06.2022

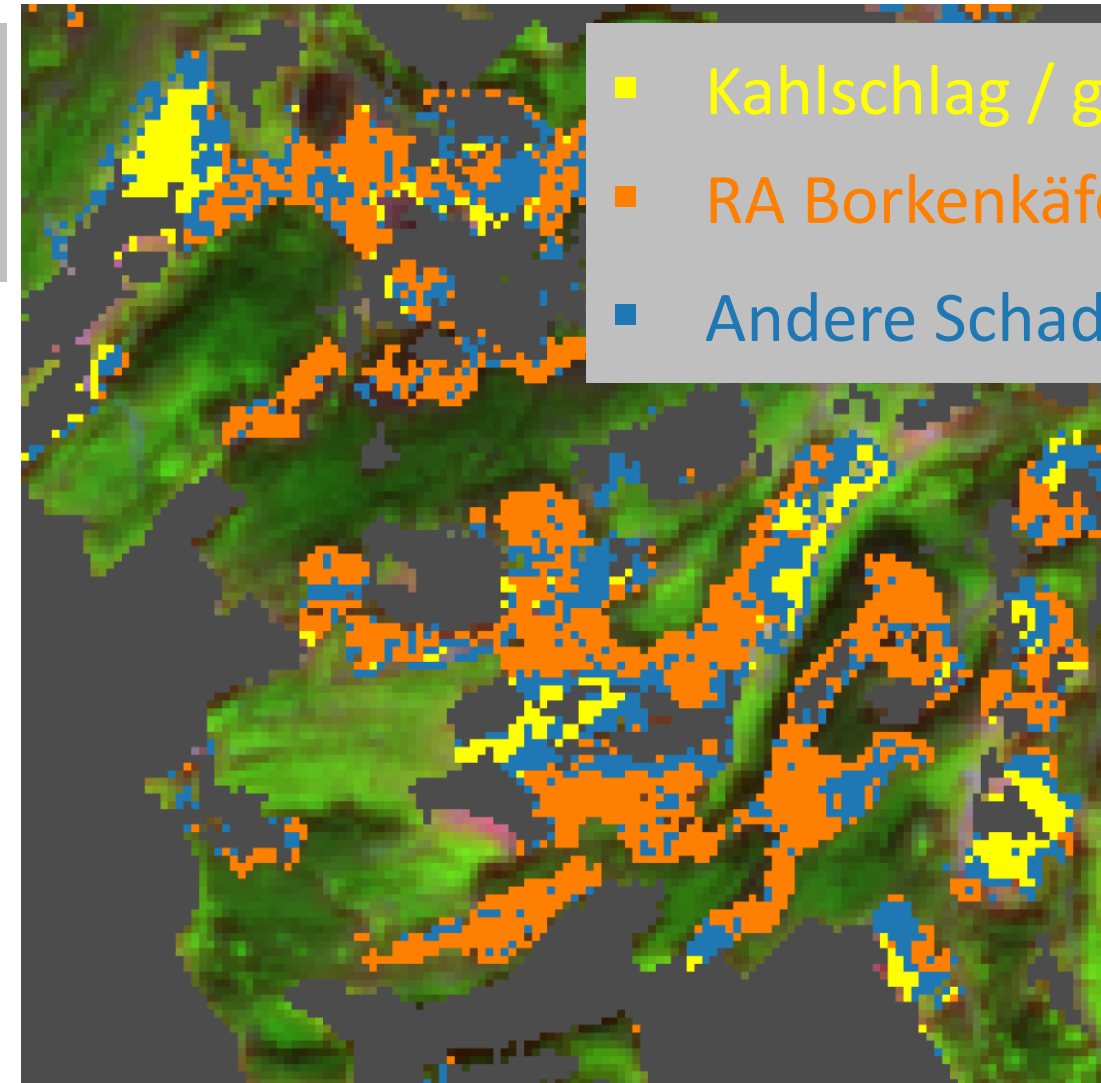


Sentinel-2 03.09.2022

## Other Product Examples from Germany 2022



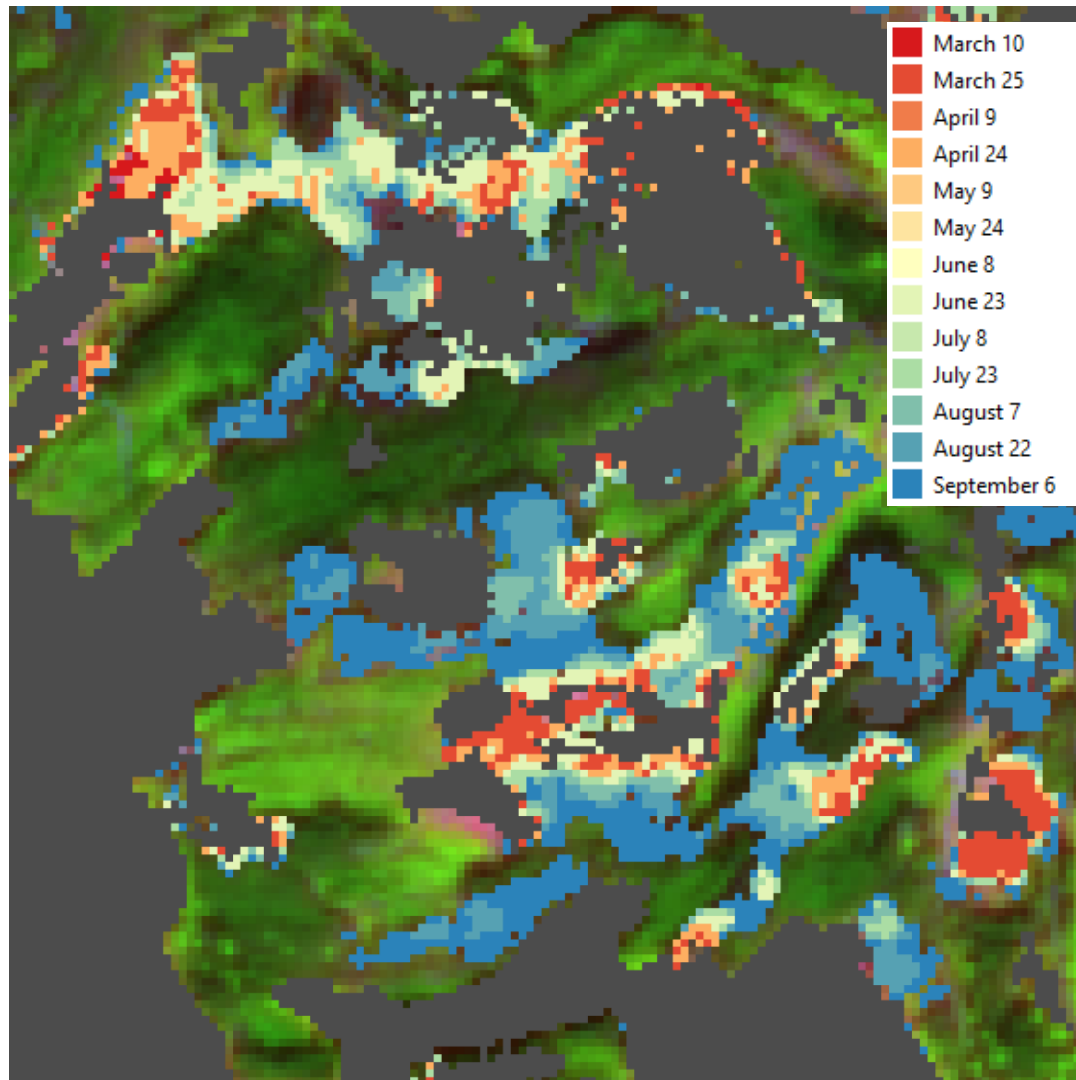
15.06.2022 – Änderungen aus Vorjahr



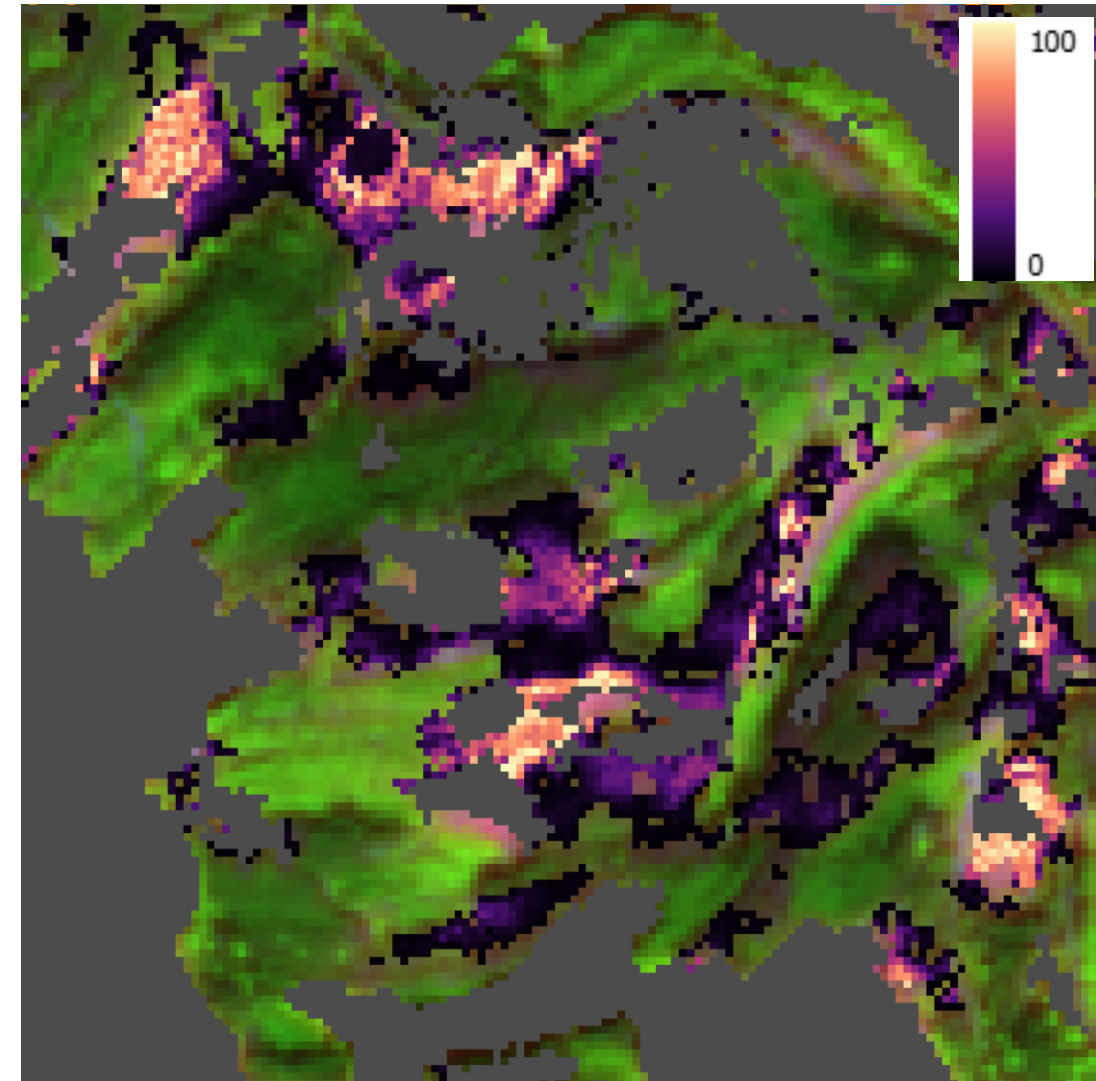
03.09.2022 – aktuelle Käferschäden



# Other Product Examples from Germany 2022



03.09.2022 – Zeitstempel der Änderung

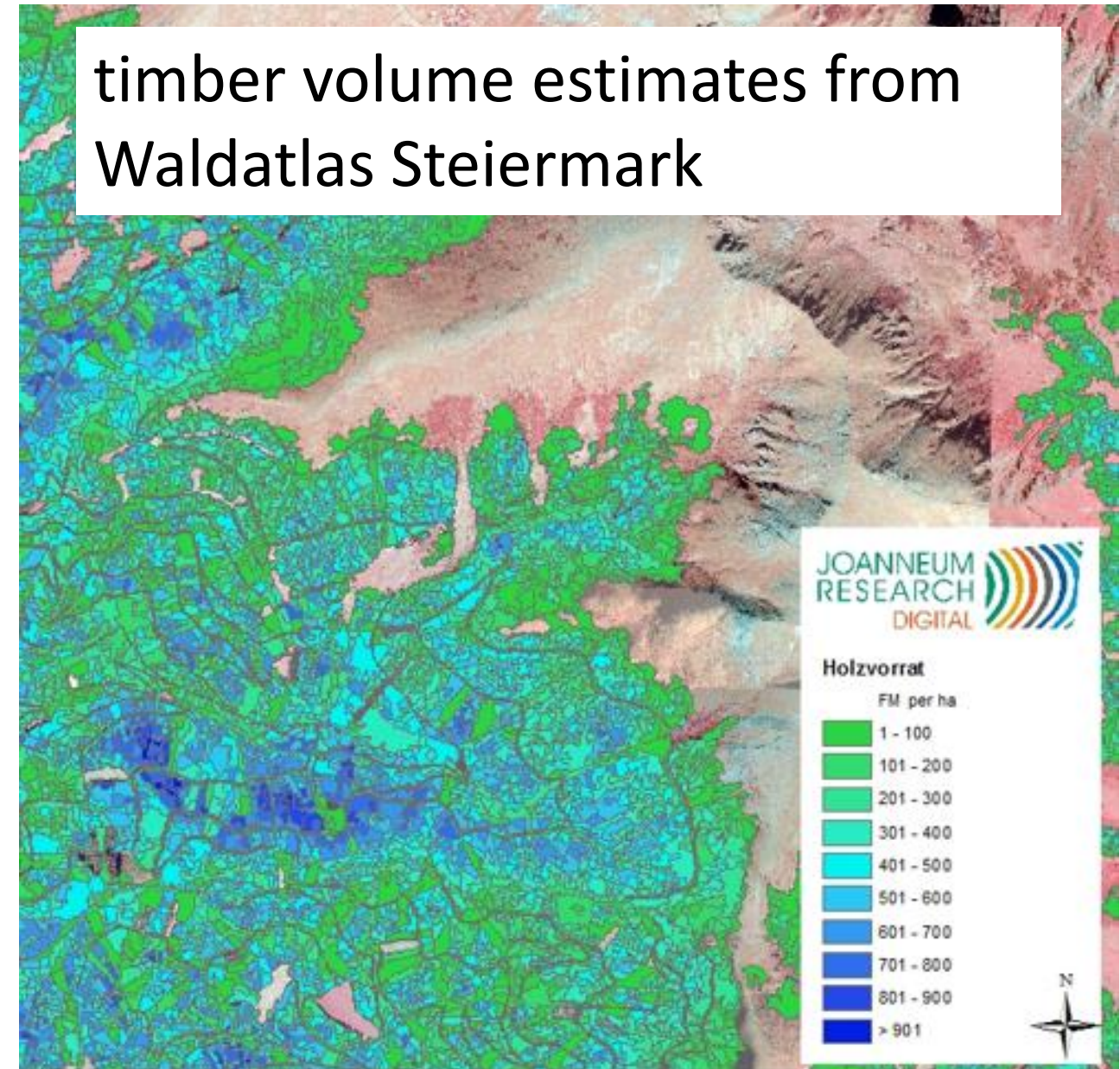
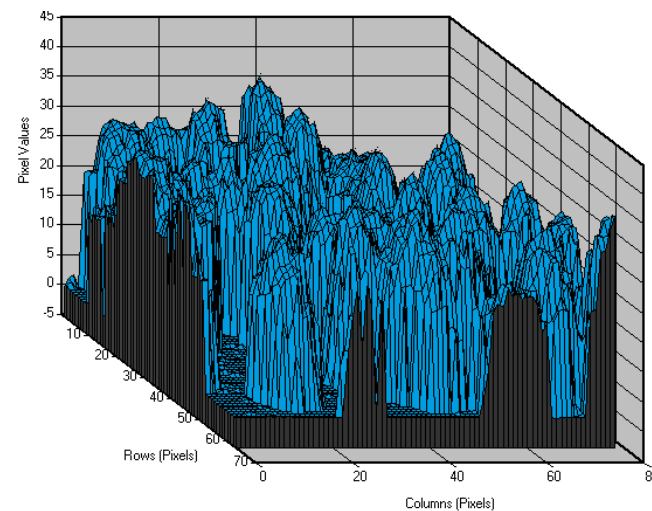
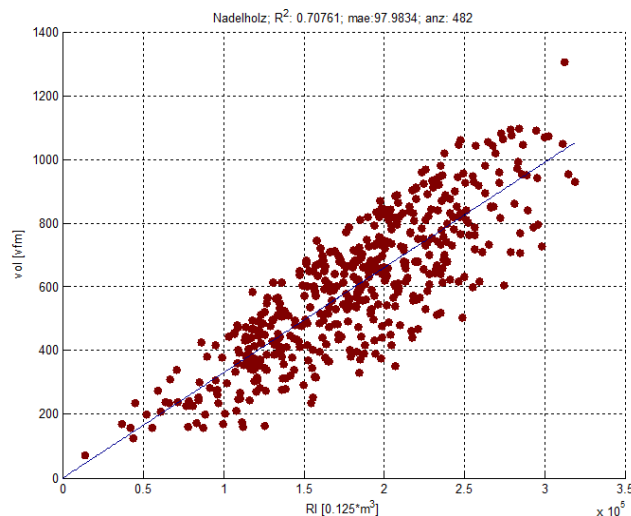


03.09.2022 – Wahrscheinlichkeit für Räumung

# An automated estimation of the affected timber volume and wood biomass for damage polygons

## Biomass estimates from ALS data:

- Open ALS data is available for all of Austria!!!
- These data sets can be used to estimate biomass on a polygon/forest stand level using our in-house regression models (see below)

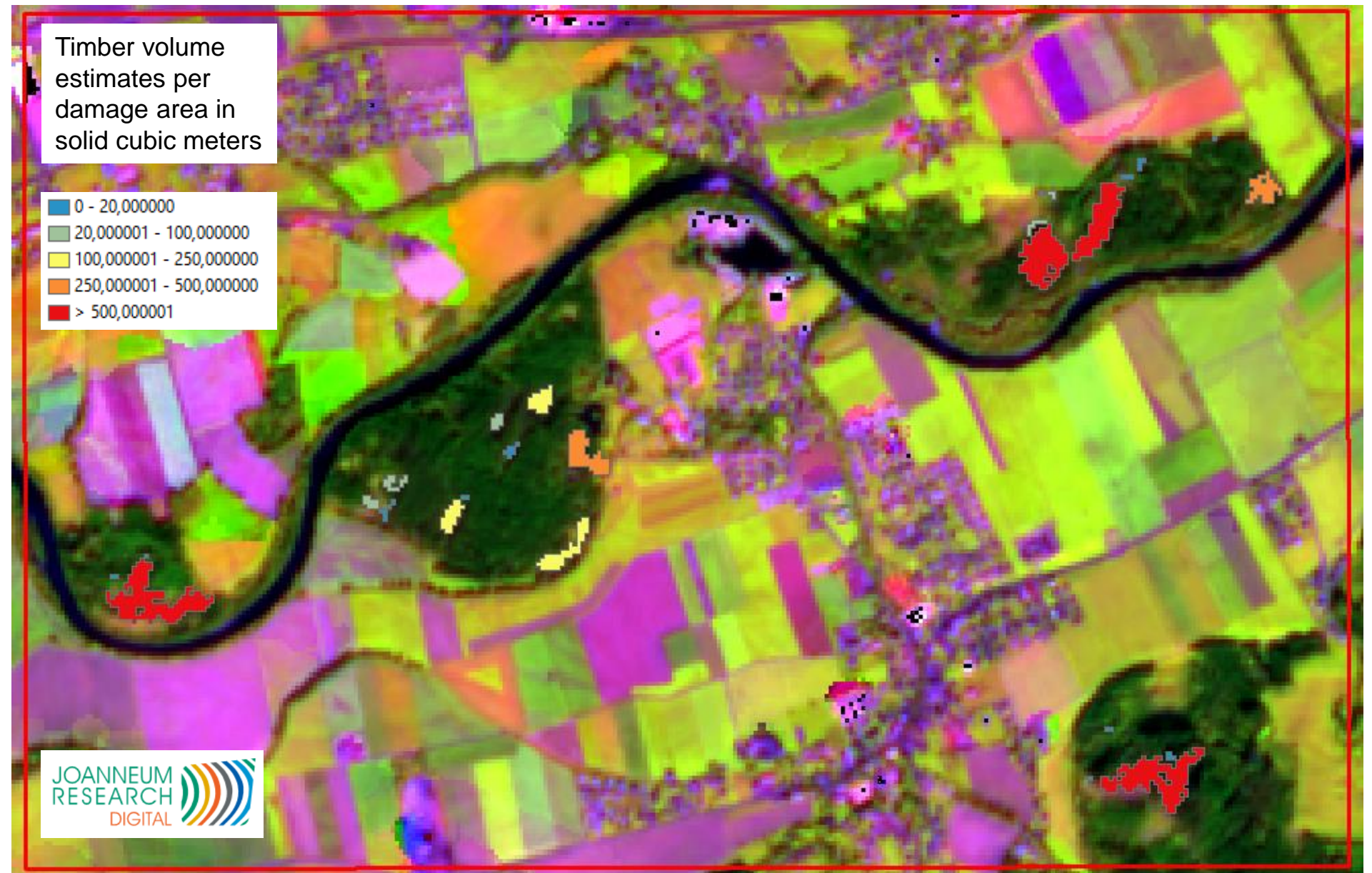




# *An automated estimation of the affected timber volume and wood biomass for damage polygons*

Example of biomass estimates from ALS data per damage polygon

storm event of 18.08.2022, Styria



# An automated estimation of the affected timber volume and wood biomass for damage polygons

## Other forest parameters from ALS data:

- We can also detect single trees and estimate the **number of trees/stems within the damage polygon**. This is important information for **timber harvesting logistics!**
- Other forest parameters that can be derived include:
  - Mean height of trees (MH)**
  - Top height of trees (top 10%) (OH)**
  - Age class**
  - Vertical structure**
- Joanneum Research workflows can derive this information **for any input polygon**.

**number of trees in the polygon**

Table					
AOI1_forestparameter					
OH STD	DG	TC AO	TC HA	RI AO	
-99999	44	2	200	441,75	
0,273692	89	30	750	3507	
-99999	72	6	200	4080,5	
-99999	96	7	700	2107,25	
0,193529	92	17	566,666667	5175,25	
0,616936	87	201	502,5	68720,75	
0,743264	83	26	325	14484,25	

AOI2_forestparameterv1							
FID	Shape	id	OH	TC AO	MH	VOL AO	VOL HA
0	Polygon	1	26	6	15,86793	0,281792	28,17921
1	Polygon	2	32	25	23,430034	35,082375	438,529682
2	Polygon	3	33	14	25,227177	14,396945	359,923616
3	Polygon	4	33	56	30,09379	83,736763	558,245088
4	Polygon	5	30	24	25,125315	14,688839	367,220967



# ***NRT Monitoring -> KI-basierte Risikoproggnose***

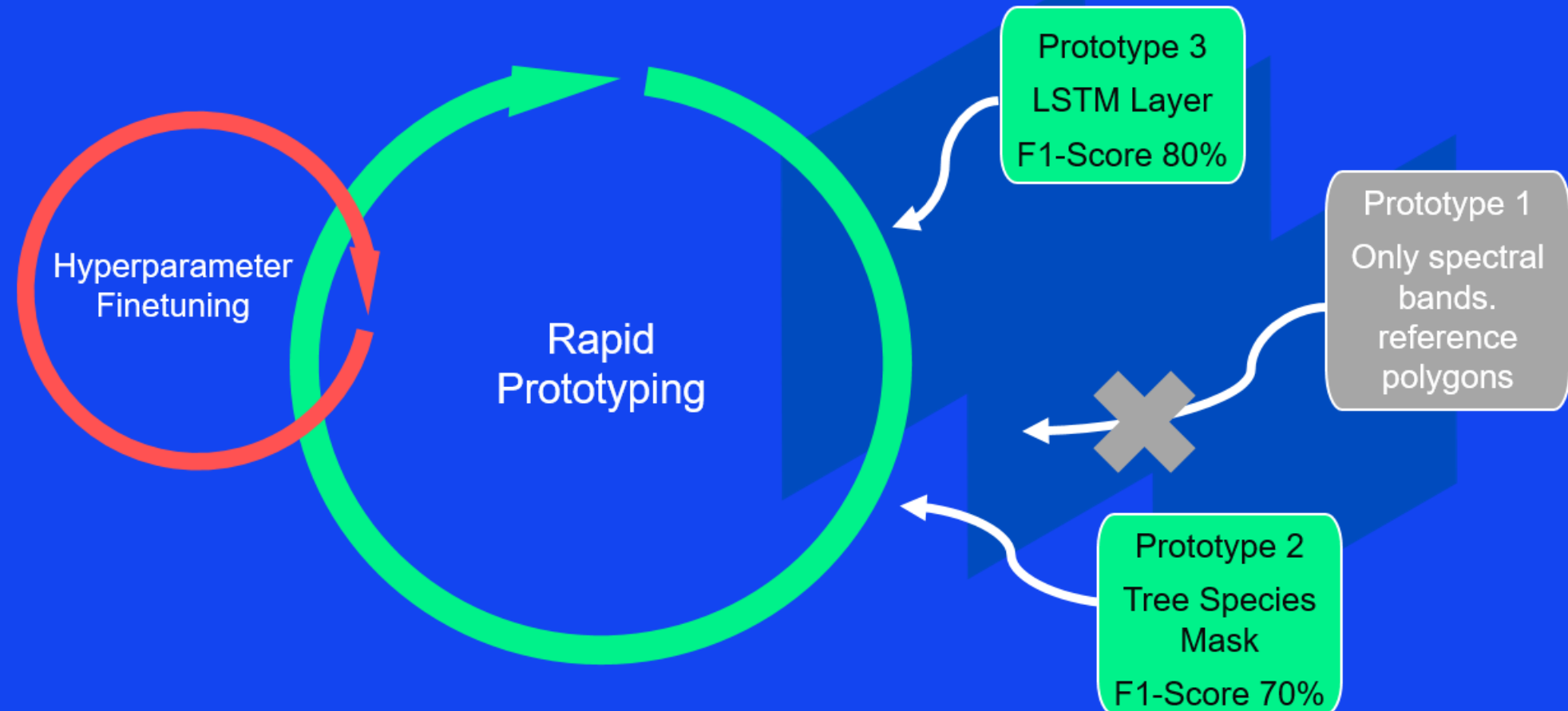
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- NRT-System im Schnitt 2-3 Wochen zeitlich verzögert
  - Aktualisierung des Zeitreihenmodells braucht etwas Zeit
  - Abhängig von der Datensituation und -qualität (Wolken!)
- Oft sind Borkenkäfer bereits in benachbarte Bestände ausgeschwärmt
  - Zu spät, um Käfer-Population noch einzudämmen?
- Keine Detektion von befallenen Einzelbäumen mit Sentinel-2 möglich
  - Nur Baumgruppen ab ca. 10 Bäumen erkennbar
  - Einzelne Bäume im Mischbestand nicht detektierbar
- Idee: Zusätzlich zum NRT-Monitoring **mittels KI- und Einbindung von Klimadaten Risikoprososen für Borkenkäferbefall erstellen**, um die Arbeit im Wald auf Risikostandorte zu fokussieren

# AI Based Bark Beetle (Risk) Prediction

## Model Evolution using Rapid Prototyping

Continuous improvement

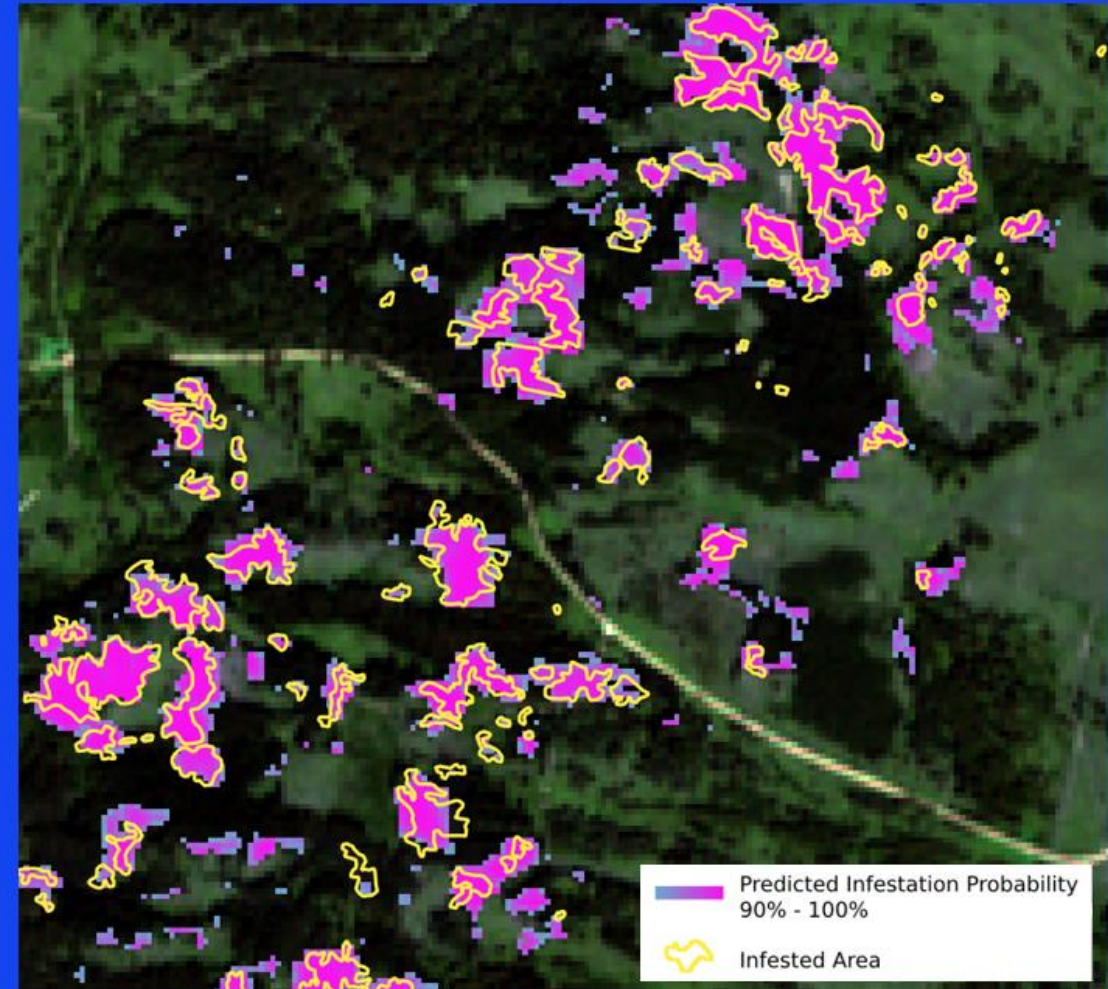
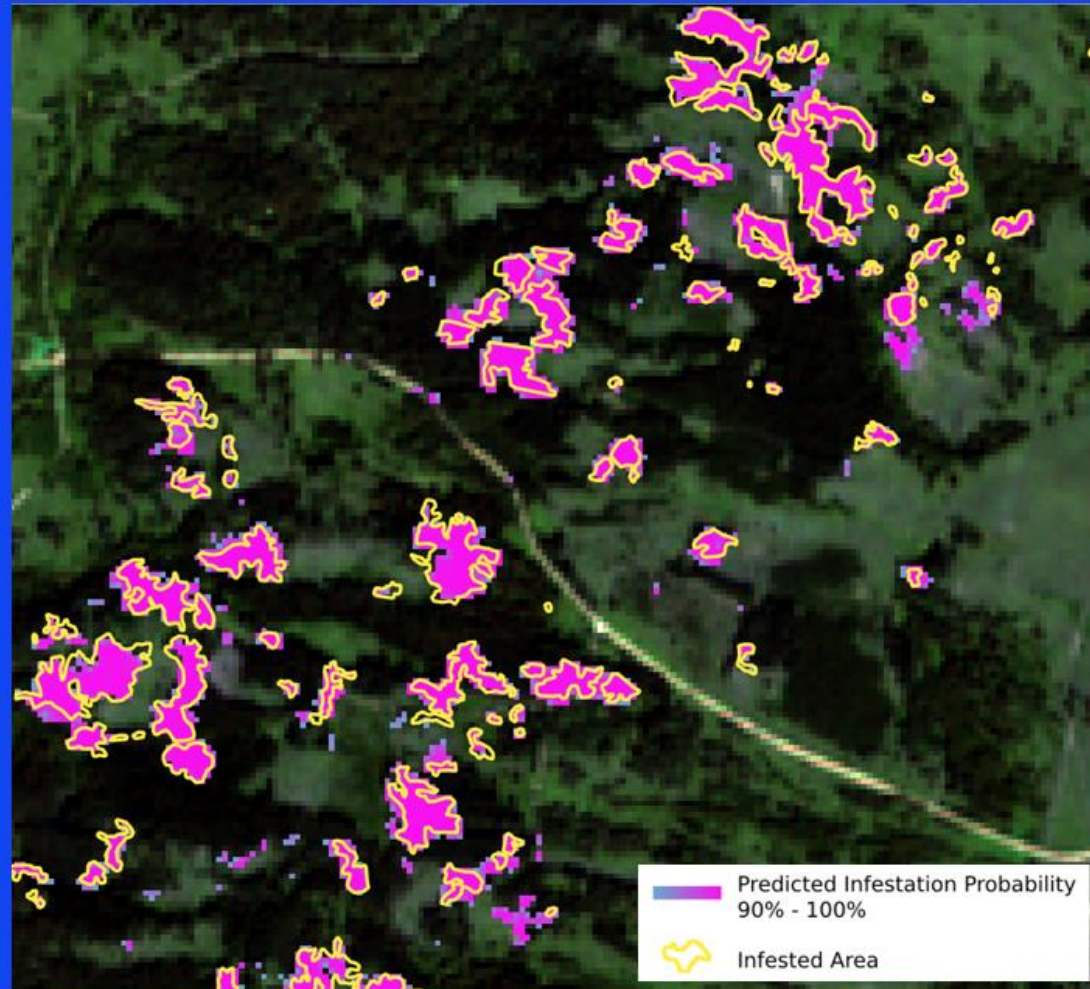




# AI Based Bark Beetle (Risk) Prediction

## Detection and Prediction Results

cloudflight



# AI Based Bark Beetle (Risk) Prediction

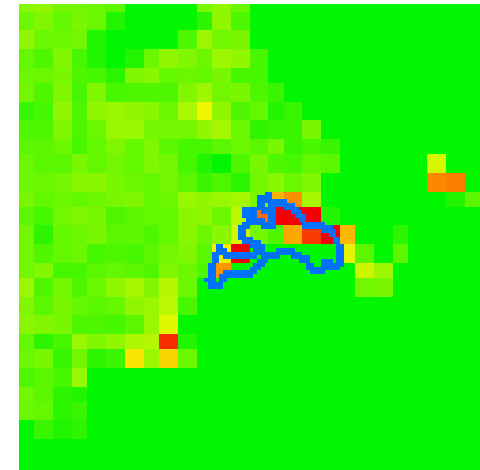
0-Tage Prognose



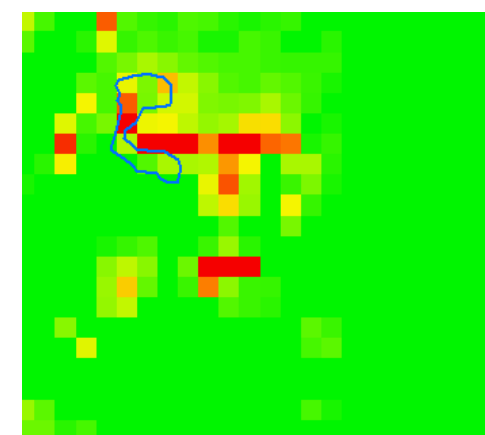
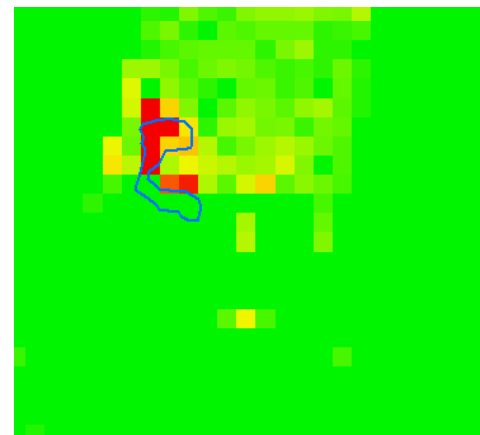
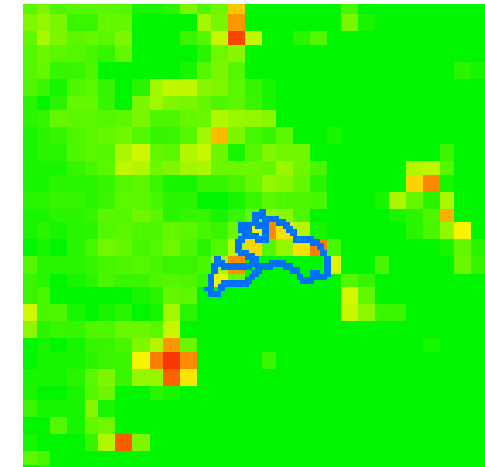
40-Tage Prognose



Schadklassifikation  
T+0



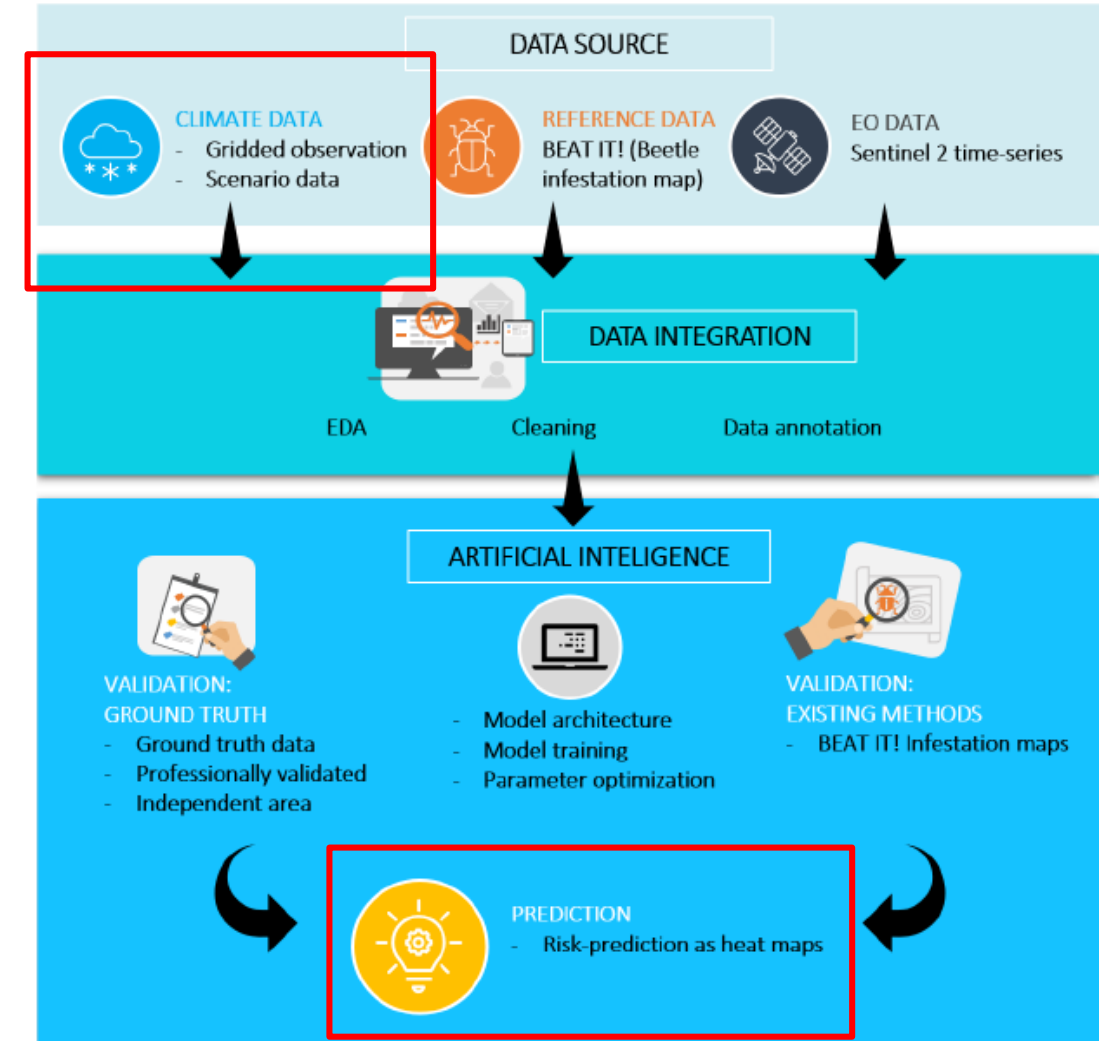
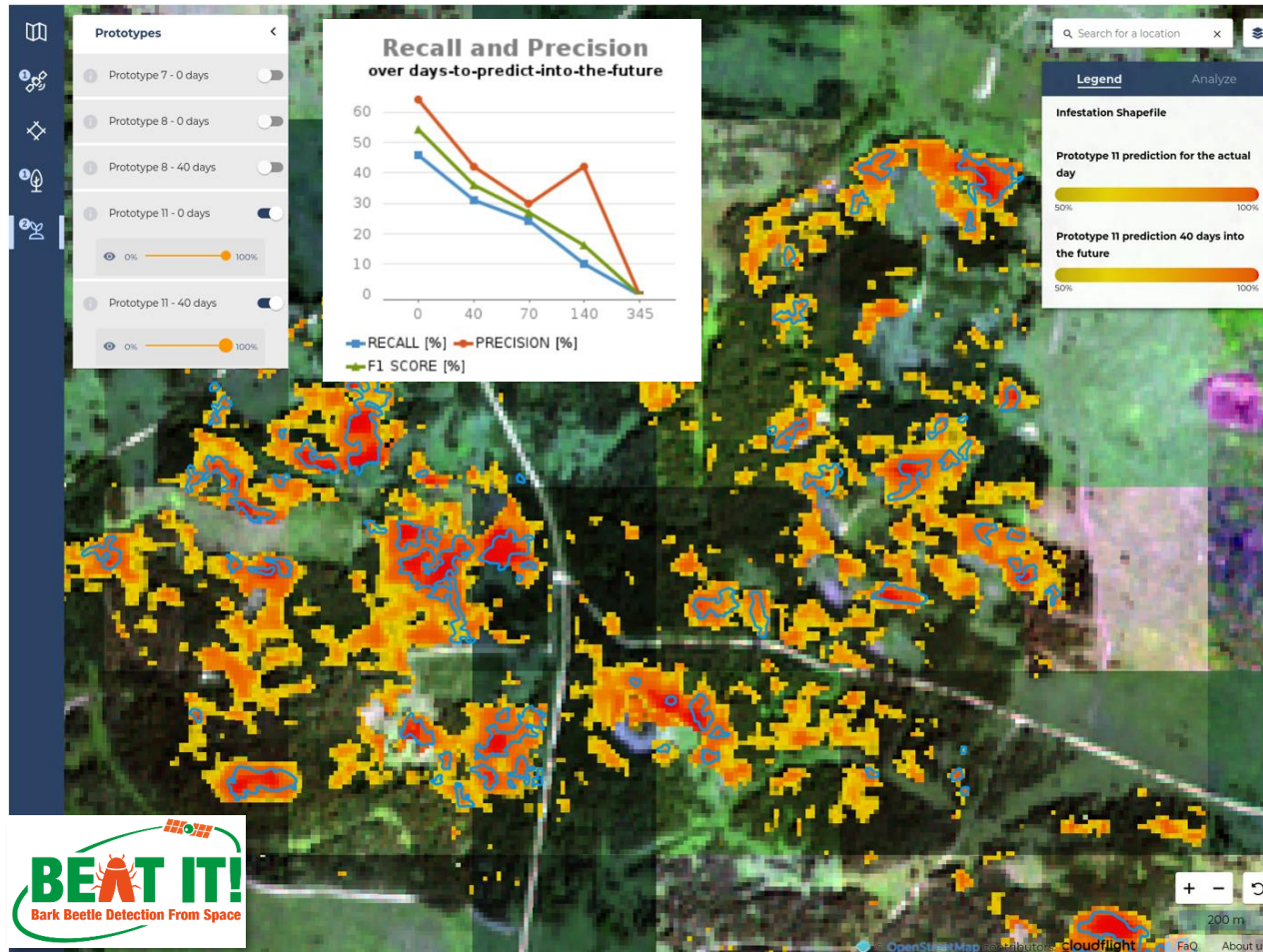
Schadklassifikation  
T+40





# AI Based Bark Beetle (Risk) Prediction

cloudflight

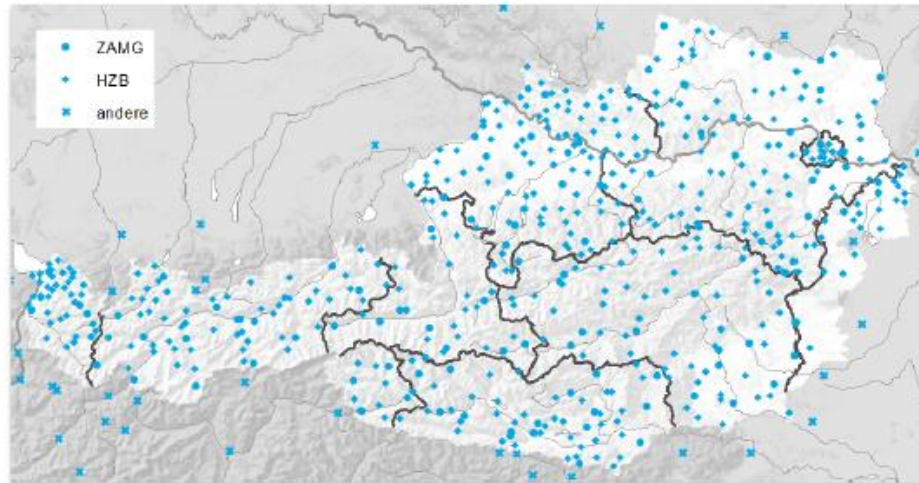


Long short-term memory network results for bark beetle prediction (0-40 days)

Project: AIDForHeRi, FFG ASAP 18

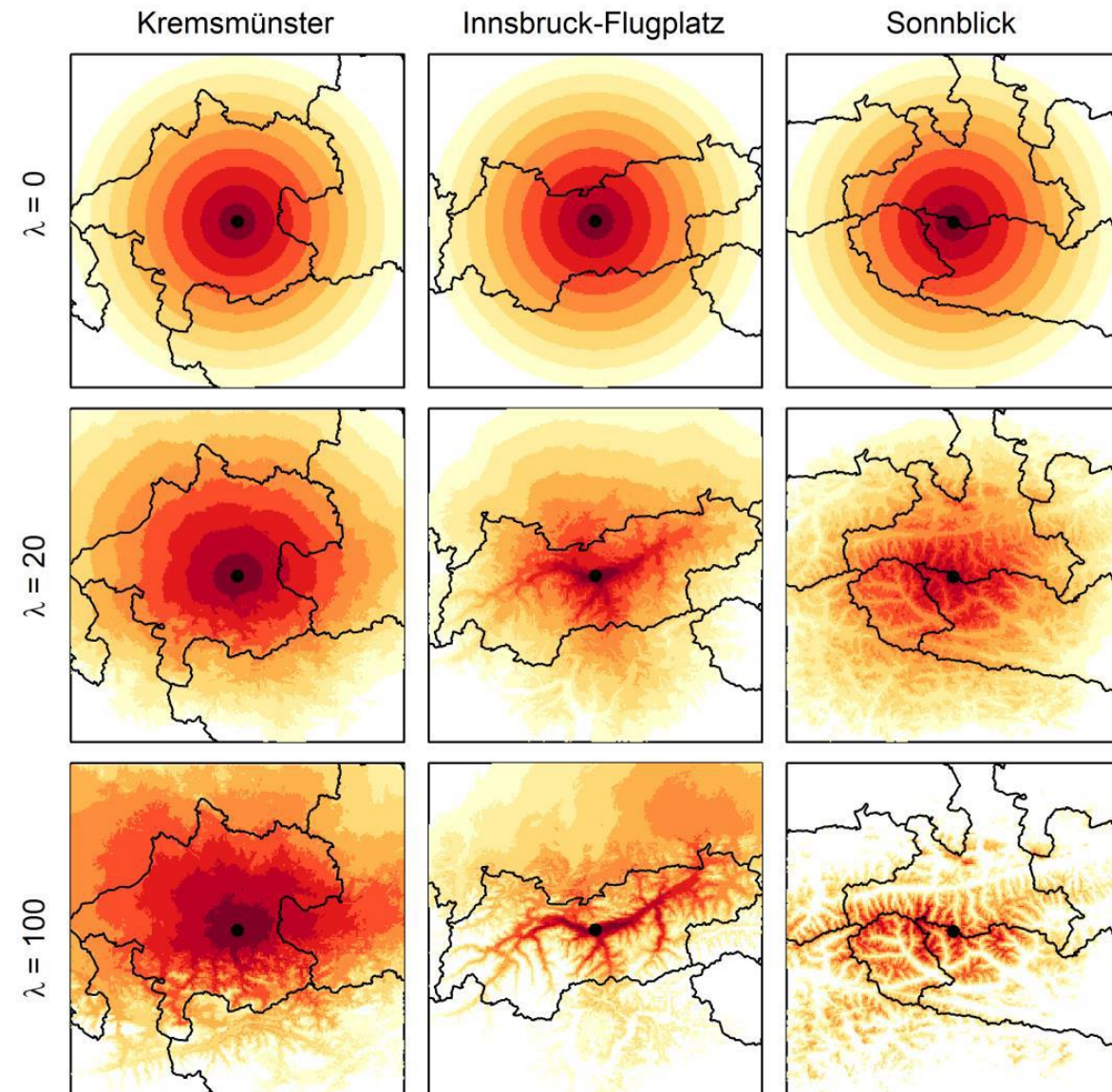


# AI Based Bark Beetle (Risk) Prediction



Klimastationen ZAMG in Österreich

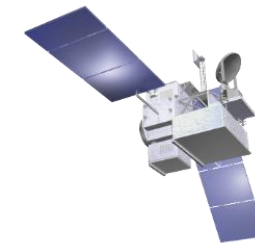
- Interpolation auf 1km x 1km Gitter:
    - Feinskalige Muster
    - Vom Stationsnetz nicht aufgelöst
  - Beispiel Temperatur:
    - Vertikale Temperaturprofil
    - Repräsentiert Makroklima: Föhn, Heat Island, ...
    - Einfluss einer Stationsmessung
- Temperatur / Niederschlag aus SPARTACUS  
 - Downscaling auf 100mx100m  
 - Waldklima oder Bestandesklima ???







**Danke für Ihr Interesse!**



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