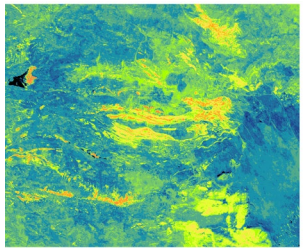
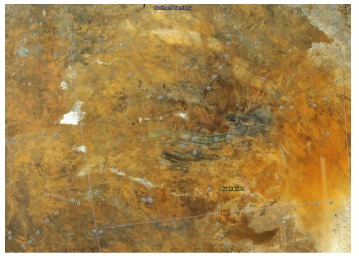
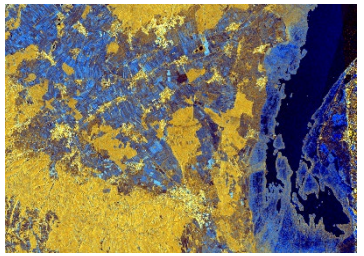

Practical Exercise

Interpretation of SAR Parameters

Microwave Remote Sensing – UE 120.030

Bernhard Bauer-Marschallinger & Claudio Navacchi

20 Oct 2022

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Exercise objective

- Explore and analyse Synthetic Aperture Radar (SAR) parameters
- Try to explain features in SAR-data or -parameters with ancillary datasets
  - qualitatively or/and quantitatively
- Suggest possible applications of the SAR multi-temporal parameters for geophysical retrievals
  (i.e. extent of a lake, monitoring of geomorphologic features, etc.)
- Use software: QGIS, Python, Google Earth & Co
- Compile report on your findings
- Present your results to the students & professors

Practical Exercise modus

- Form groups of 2-3
  - (via TISS)
- Define your application
  - Formulate a hypothesis
- Play with data and carry out the analysis
- Write the report
- Give a presentention of your work to all

Overview for today

- Physical Background
- SAR Data
- Task Description
- Reference Data
- Exercise Roadmap
- JupyterLab
- (QGIS)

Background

Microwave interactions with the earth surface

Theory → Script Chapter 5 & 6

Main factors influencing on radar backscatter

A) Dielectric properties

- mainly introduced by different soil moisture conditions, connected with the propagation of the EM wave through media

Solid Media	ε_r
Diamond	16,5
Ice (-20°C)	16
Glimmer	4,5 – 8,0
Rubber	2,5 – 3,5
Paraffin	2,0 – 2,3
Porcelain	5,5 – 6,0
Quart glass	3,7

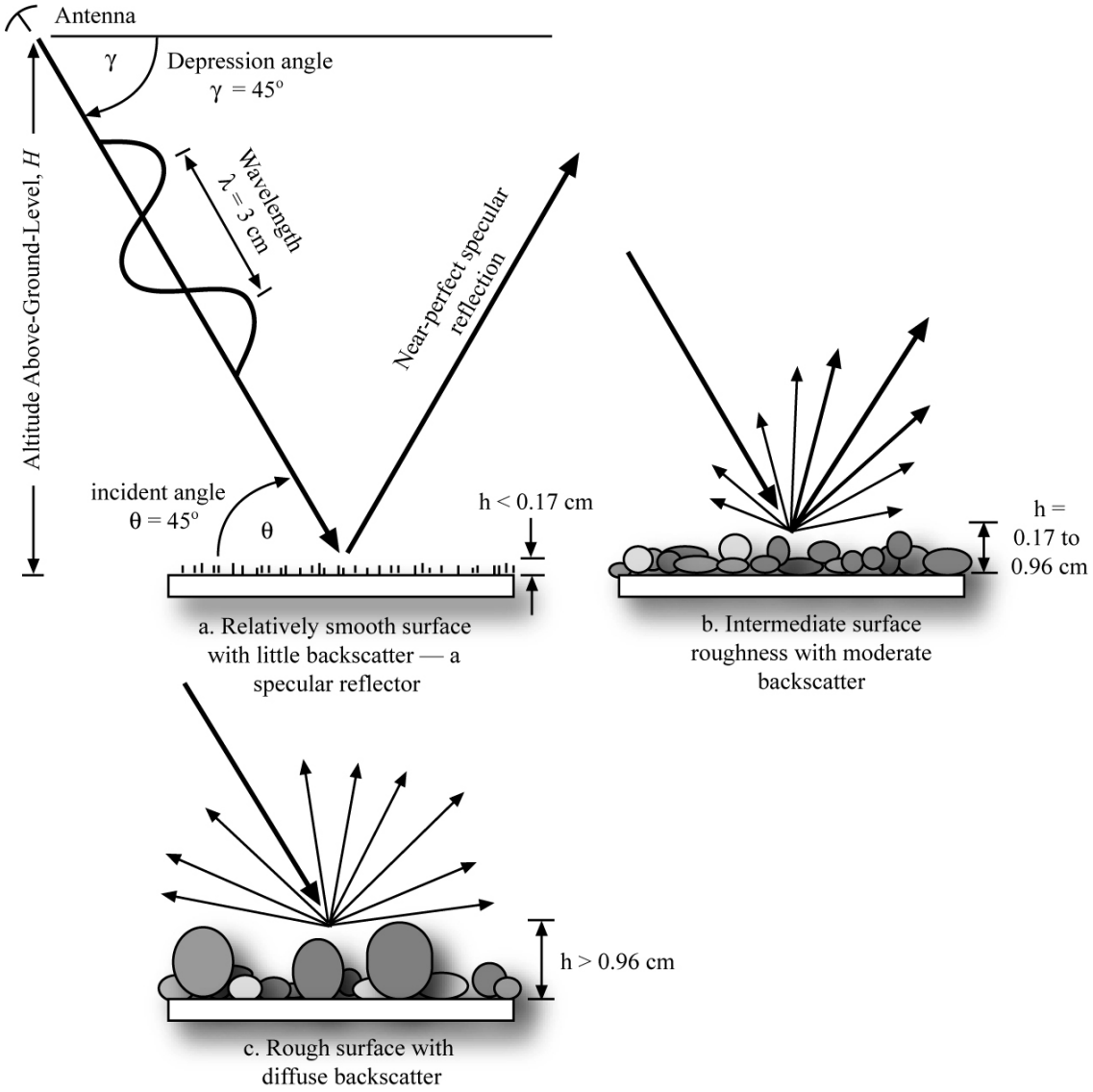
Liquids	ε_r
Ethyl	26
Benzol	2,3
Hydrocyanic acid HCN	95
Methylene	32
Paraffin-oil	2,1
Water	
at 0°C	88
at 18°C	81,1
at 40°C	73,4

Table 2-1: Static dielectric constant for solids and liquids (adapted from Hänsel and Neumann, 1993).

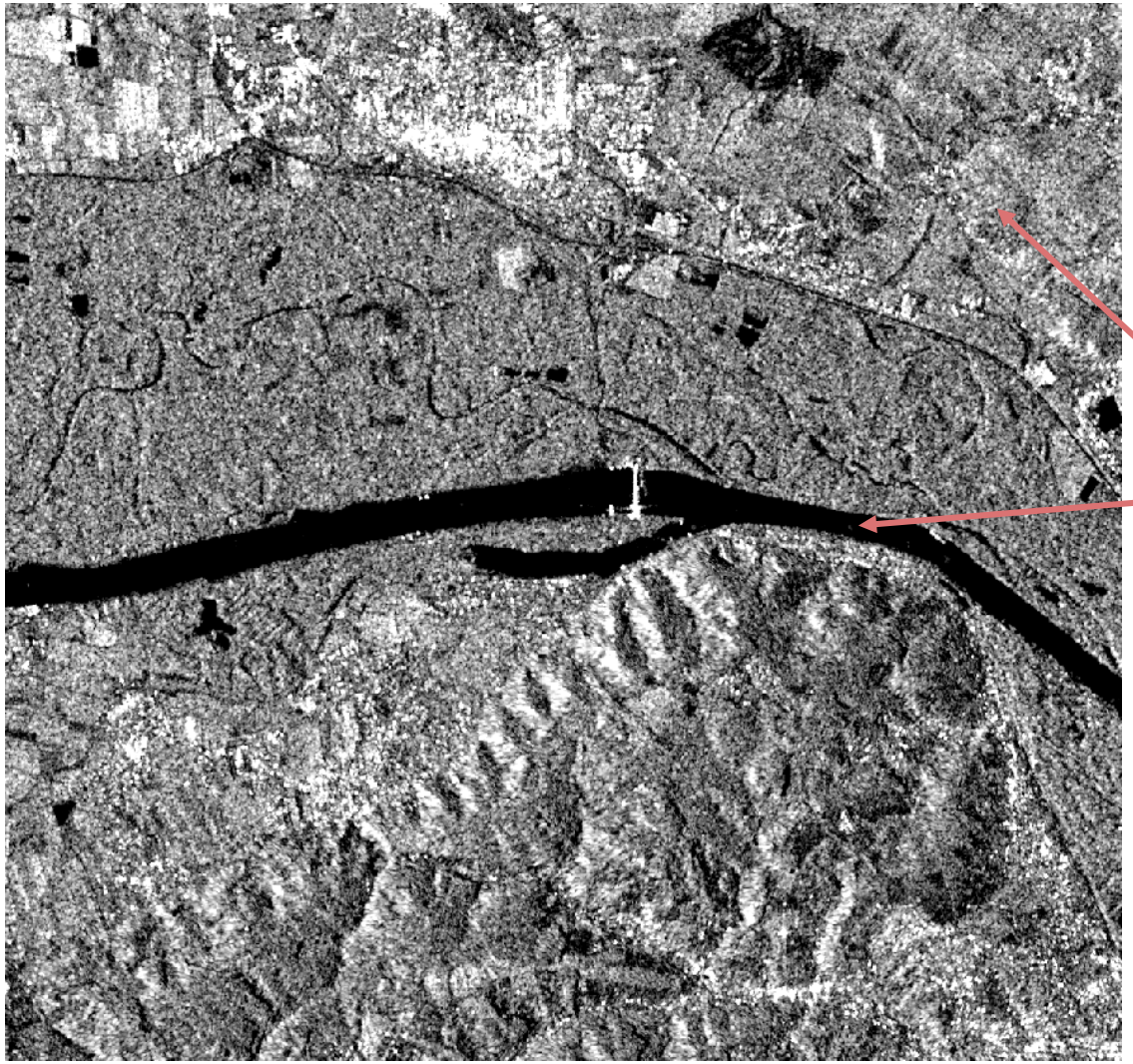
B) Geometric properties

- introduced by different surface conditions (i.e. soil roughness, vegetation structure)

Surface scattering



Surface scattering

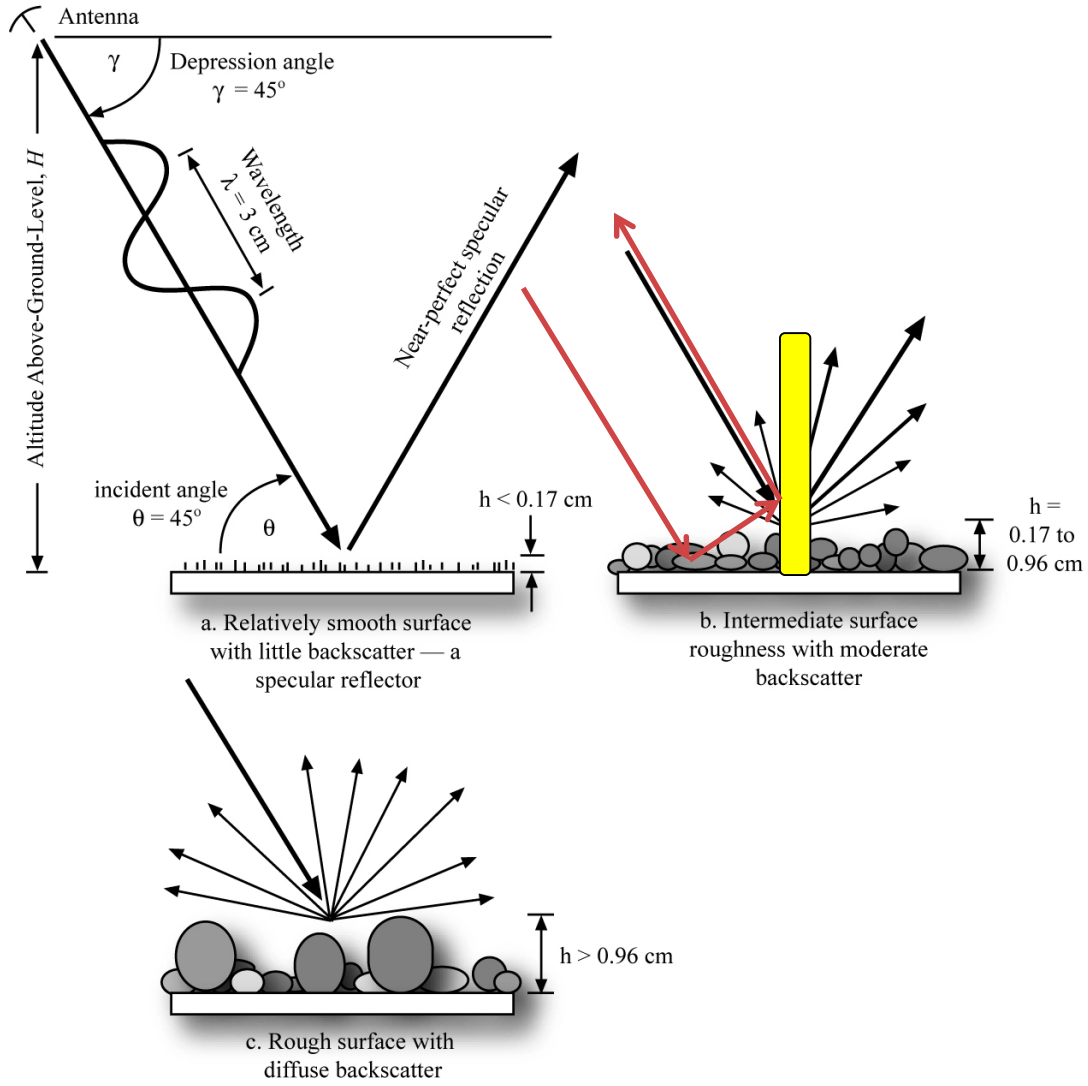


- Donaukraftwerk Greifenstein,
- Sigma0 backscatter Sentinel-1 10m in VV polarisation

rough surface

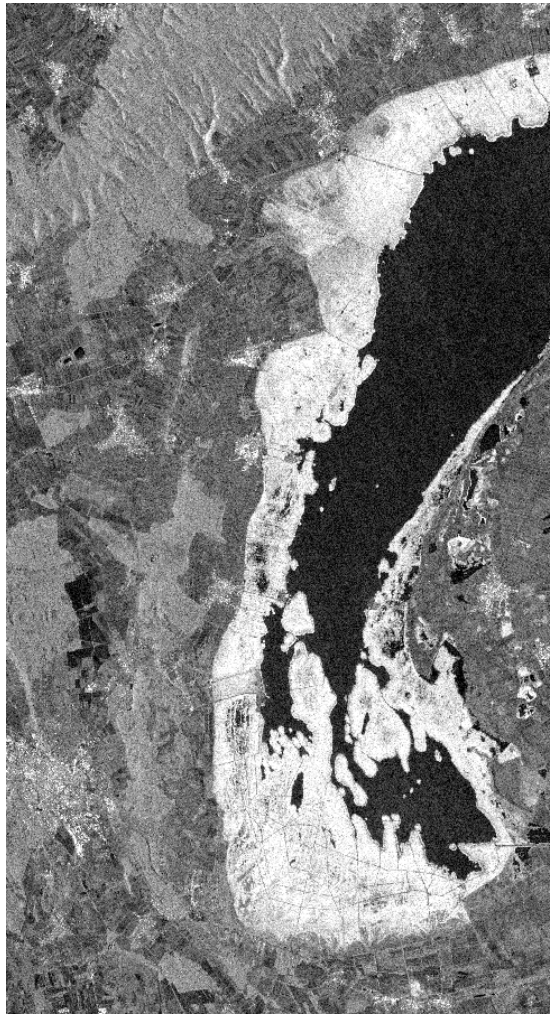
smooth surface

Double Bounce effects



Double Bounce effects

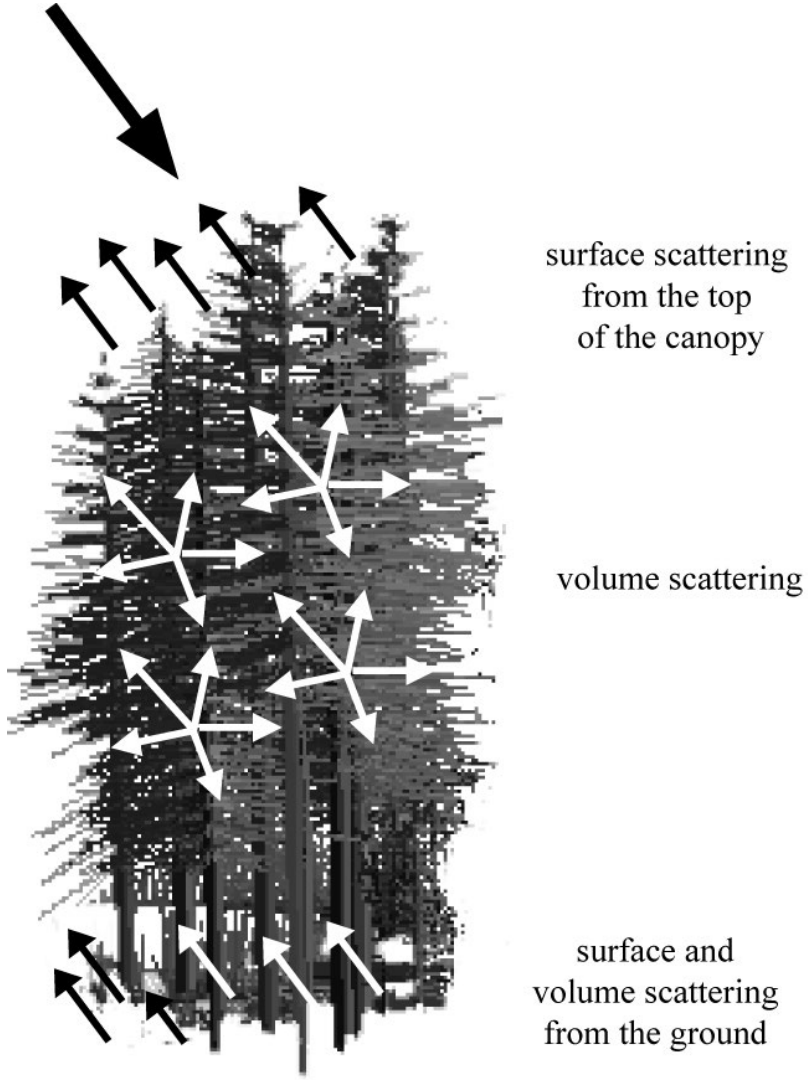
- Partially flooded Okavango delta, ASAR GM 1km HH



- Reed at Neusiedlersee, 2015-05-02, Sentinel-1 CSAR 20m VV

Volume scattering

- Example of volume scatterer:
  - Very dry soil
  - Dry snow packs
  - Vegetation



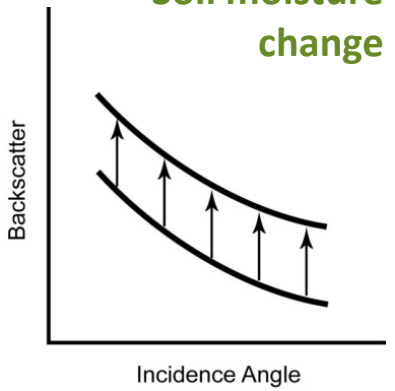
Vegetation influence – Incidence Angle (PLIA) slope

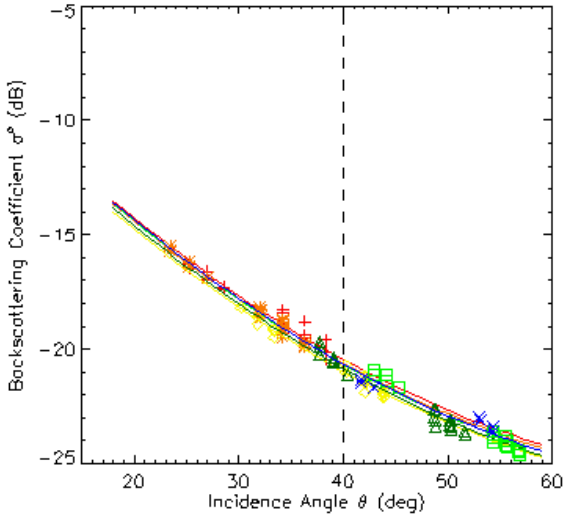
Steppe
Mongolia - Choybalsan (115E 48N)
pot. Biomass: 300 g/m²

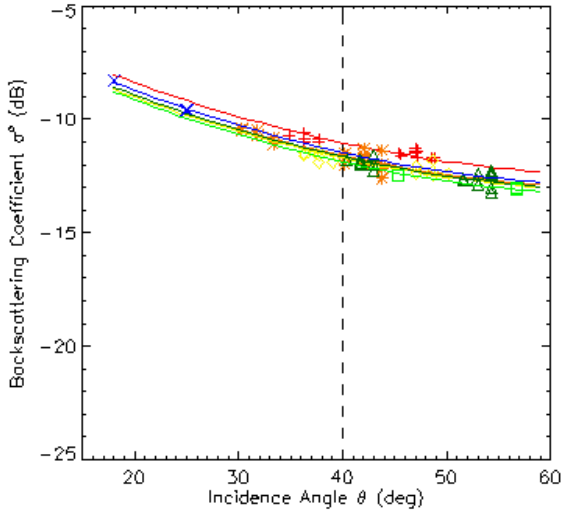
Temperate Zone
Russia - Roslav (33E 54N)
pot. Biomass: 900 g/m2

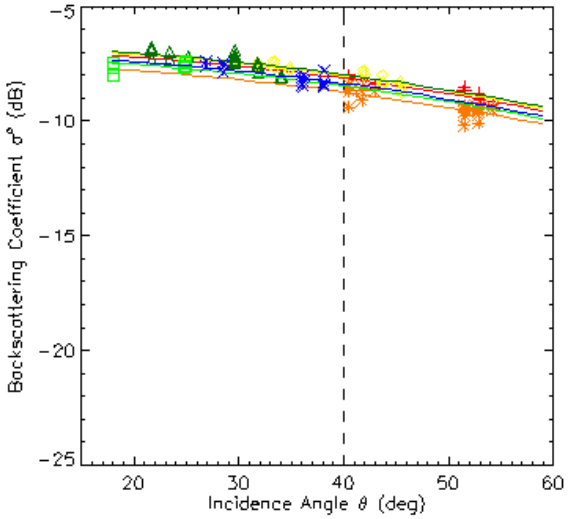
Tropical Forest
CAR - Berberati (16E 4N)
pot. Biomass: 1920 g/m2

Soil moisture change

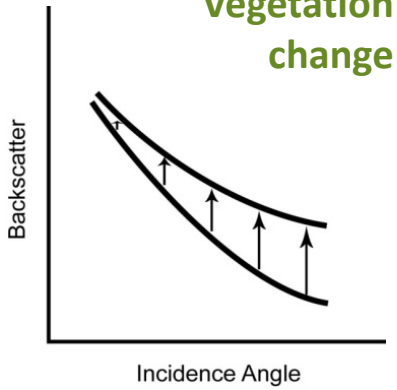






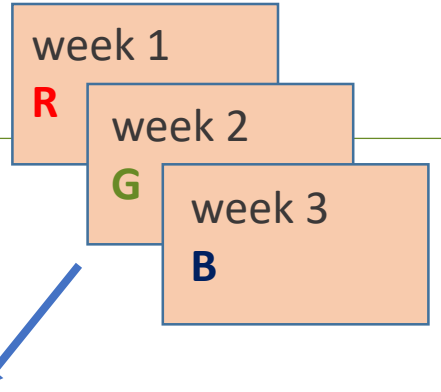


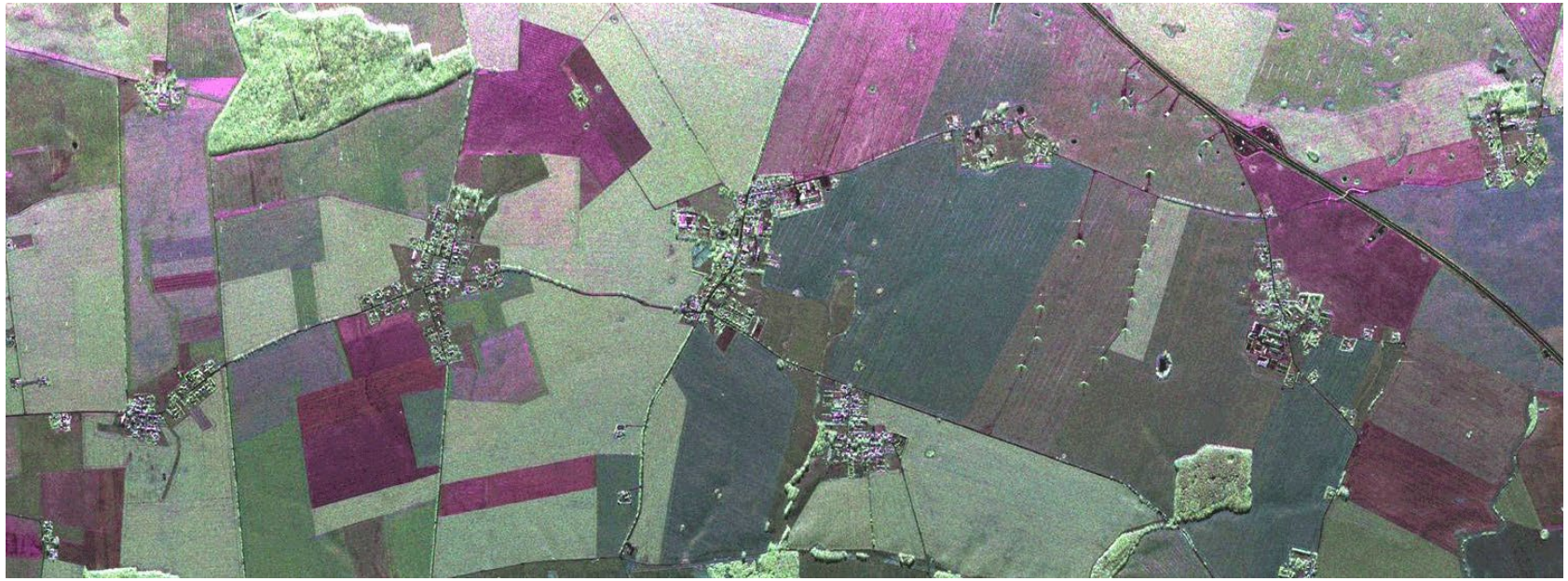
Vegetation change



Change in vegetation

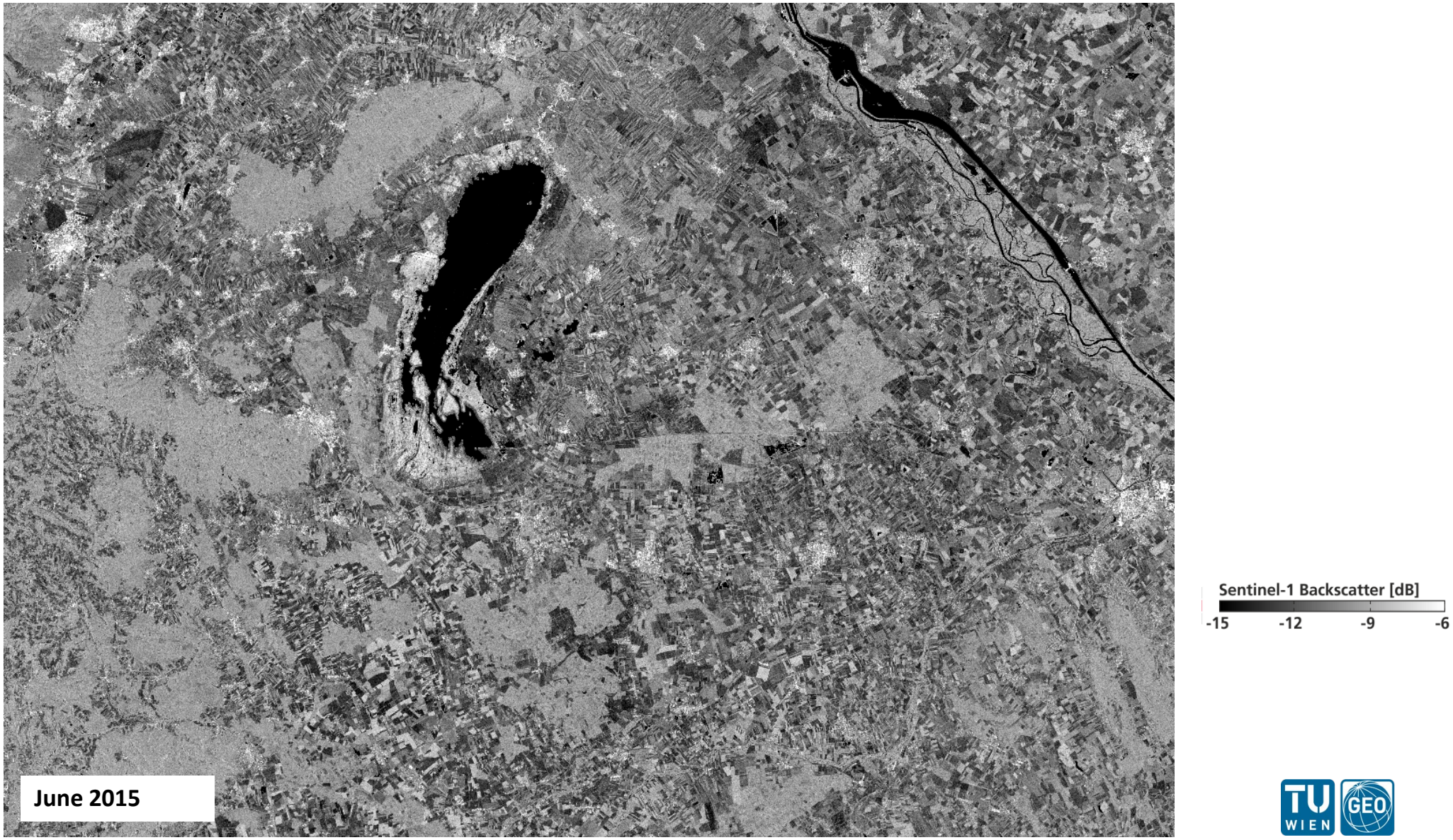
- C-band composed by dual pol SAR sensor



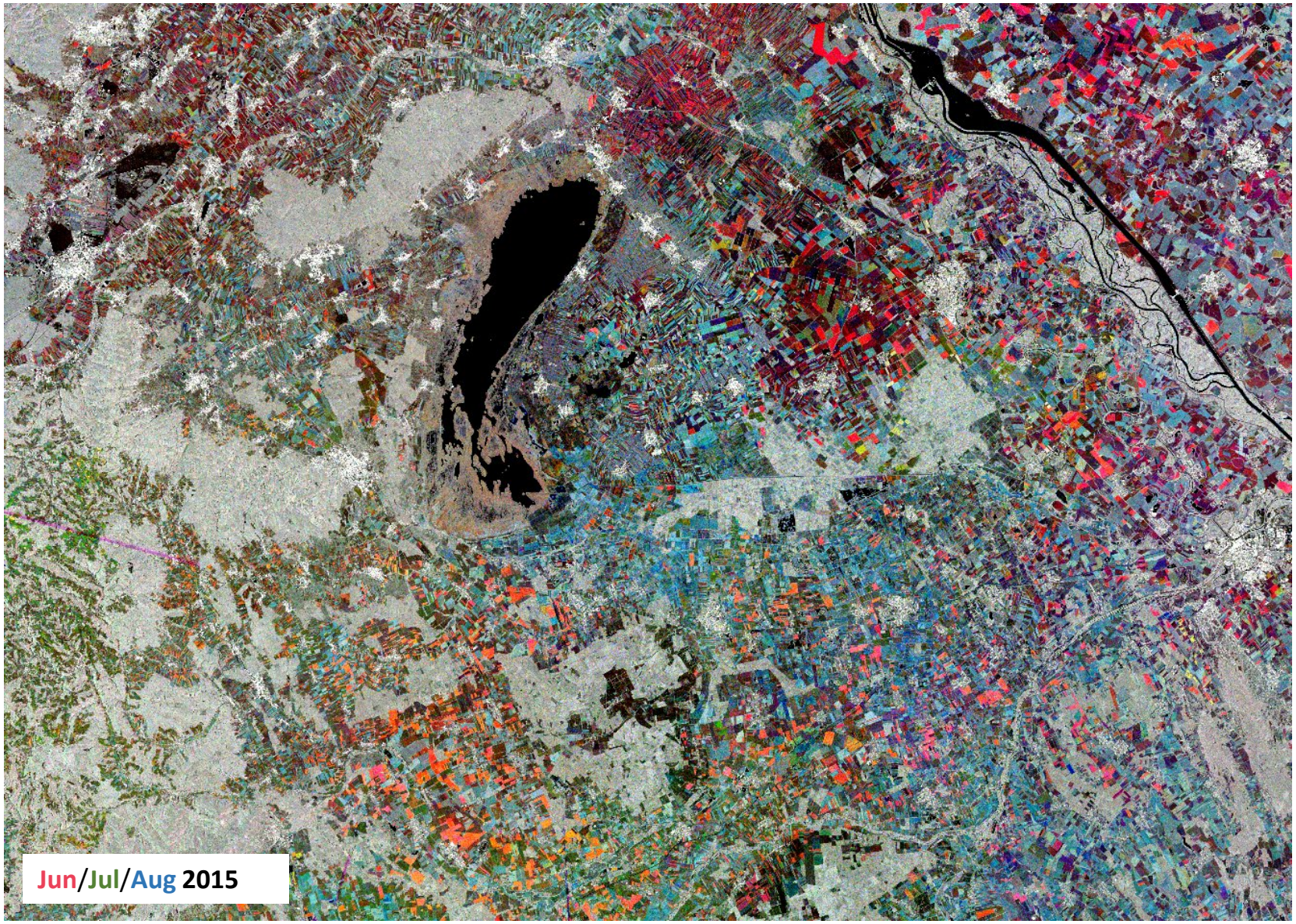


Colour composite of three SAR images taken over the AGRISAR test site
Within a period of 2½ weeks at the beginning of the growing season.
(the different colors reflect the crop type and change in crop condition during this short time period).

S1-SAR VV monthly composite



S1-SAR VH multitemporal false-color composite



Backscatter behavior

- Low backscatter
  - smooth surface
  - calm water, roads
  - very dry terrain, sand

- Moderate backscatter (-20 to -10 dB for VV)
  - medium level of vegetation
  - agriculture crops
  - moderately rough surface

- High backscatter (-10 to 0 dB for VV)
  - rough surface
  - dense vegetation, rainforest

- Very high backscatter (corner reflection)
  - urban areas
  - terrain with slopes towards radar
  - very rough surface
  - radar looking very steep

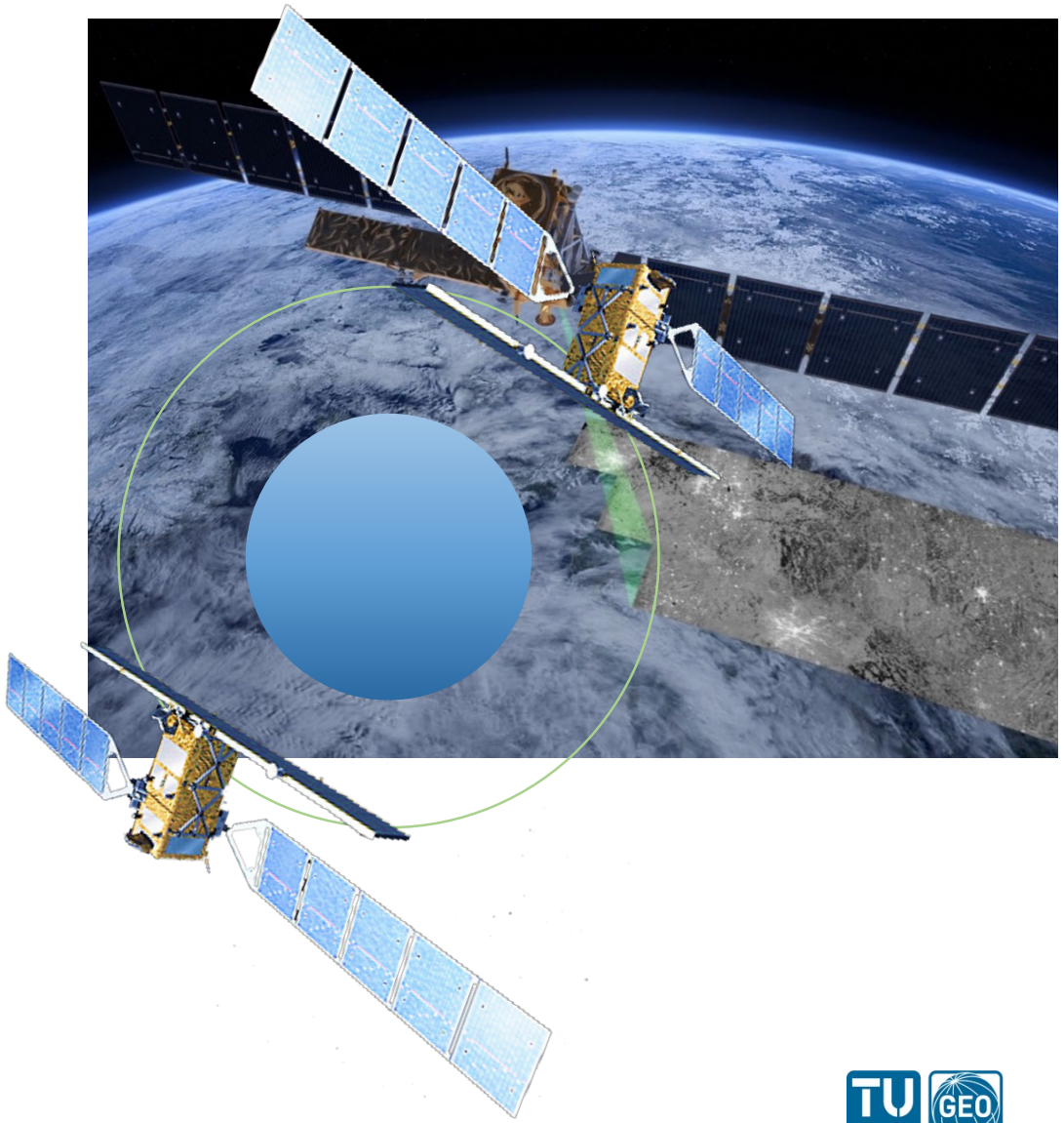
Courtesy: DLR, A. Moreira

SAR Data for Exercise

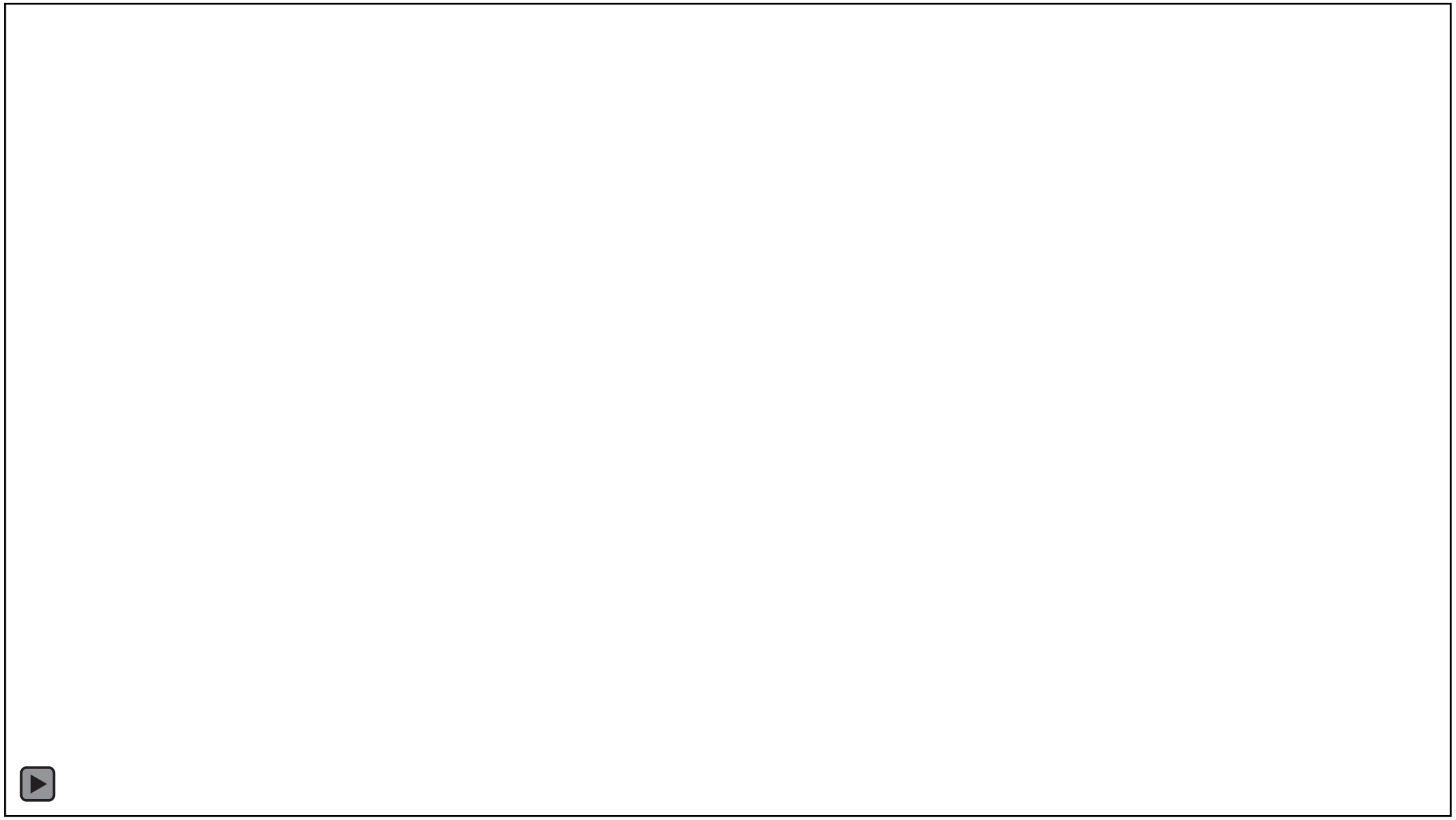
The data to work with

Sentinel-1 SAR mission

- Sentinel-1A & Sentinel-1B satellites carry CSAR sensor
  - in this exercise: Interferometric Wide Swath Mode (IW)
- C-band 5.405 GHz ~ 5cm
- 20m resolution (10m grid spacing)
  - + thereof resampled datasets in 500m spacing
- VV + VH : dual polarization!
- Equi7Grid
  - tiled GeoTIFFs and in [meter]
- Data from one single orbit → identical viewing geometry
  - minimum 12 days revisit time (Europe 1.5 – 4 days)
- Sentinel-1 backscatter datacube
  - here: since Jan 2015 (500m) and Jan 2017 (10m) until Dec 2021

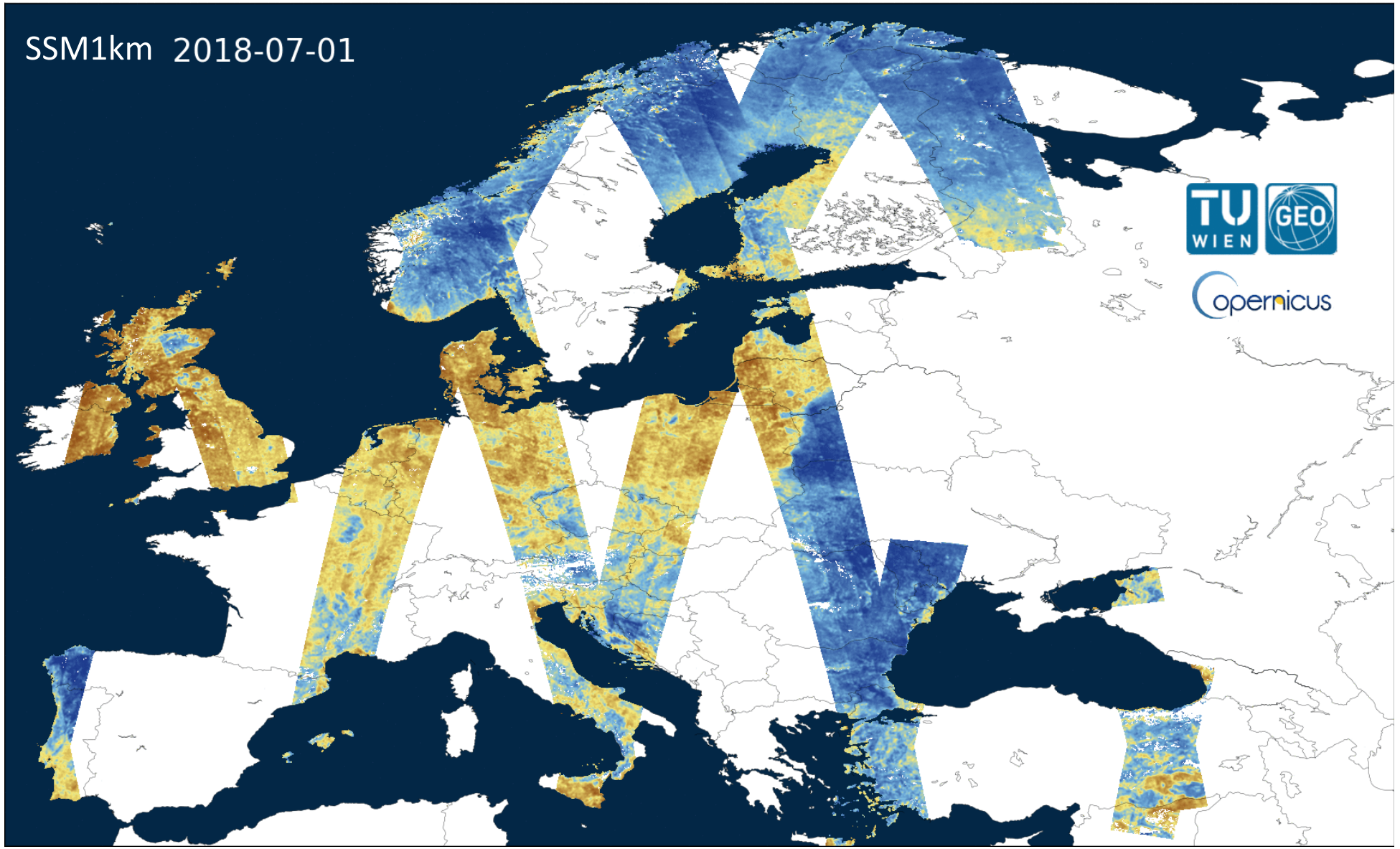


Sentinel-1: 2 satellites in orbit

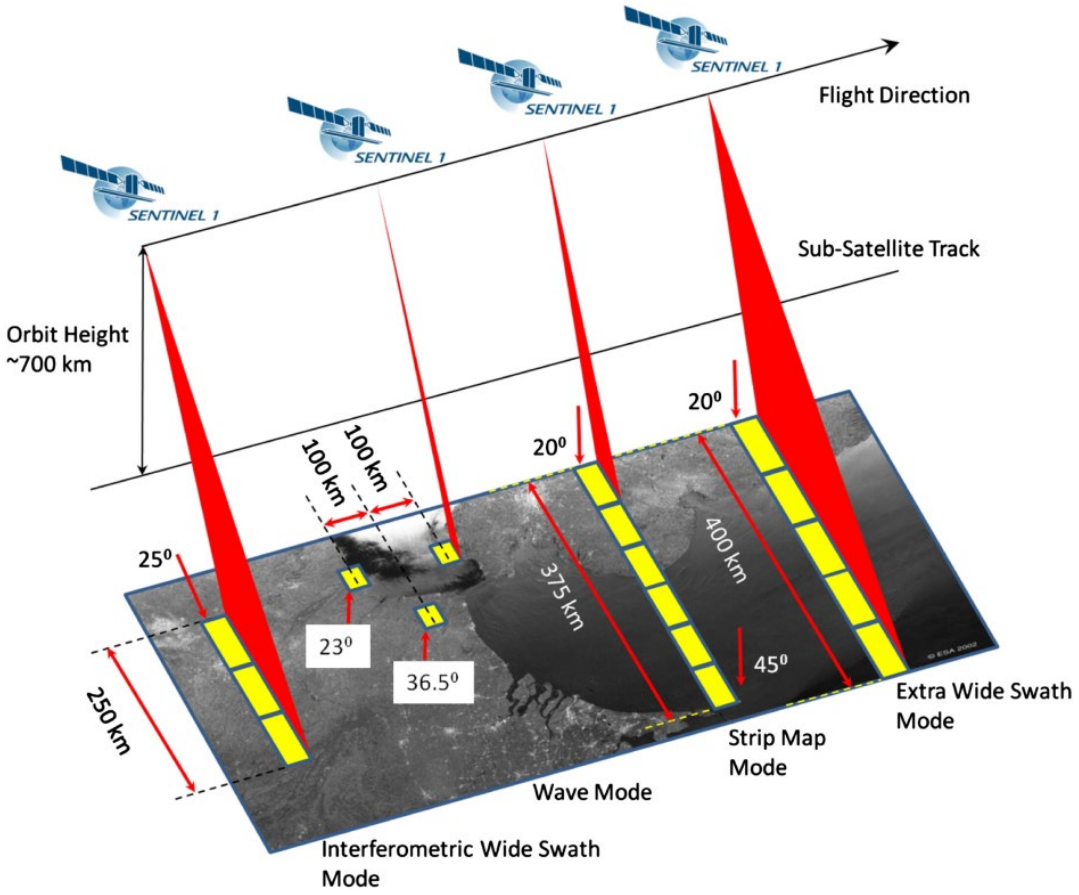


the satellites are bound to a strict orbit revisit scheme:
within 12 days, they move along 175 differenent „relative orbits“

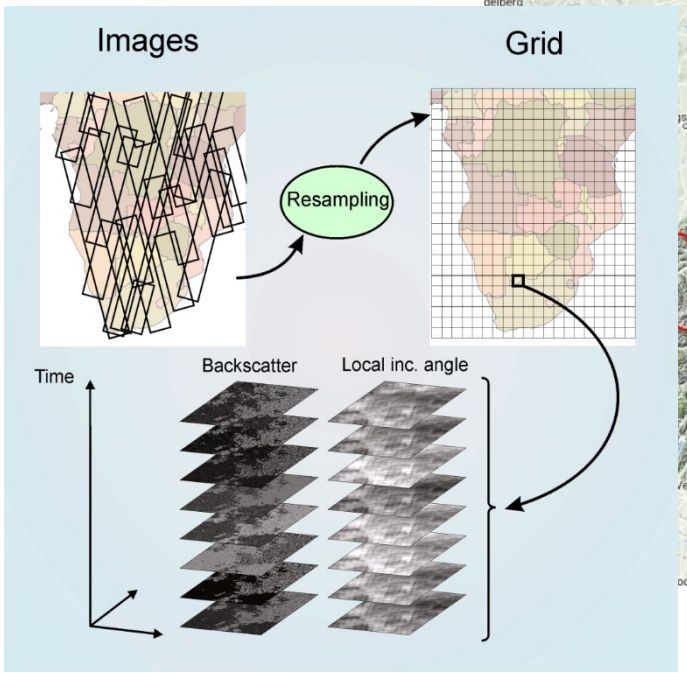
Soil Moisture from Sentinel-1 – daily coverage

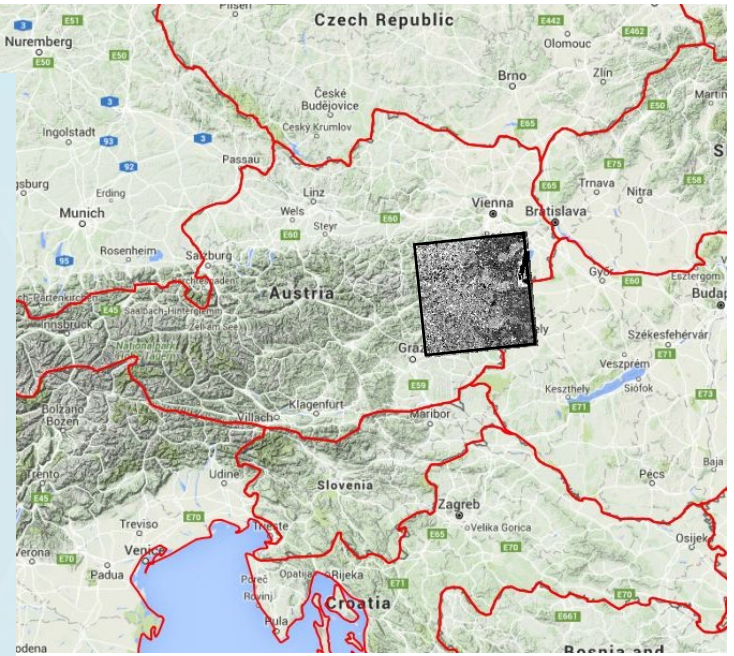


Production of SAR data – 1: image data



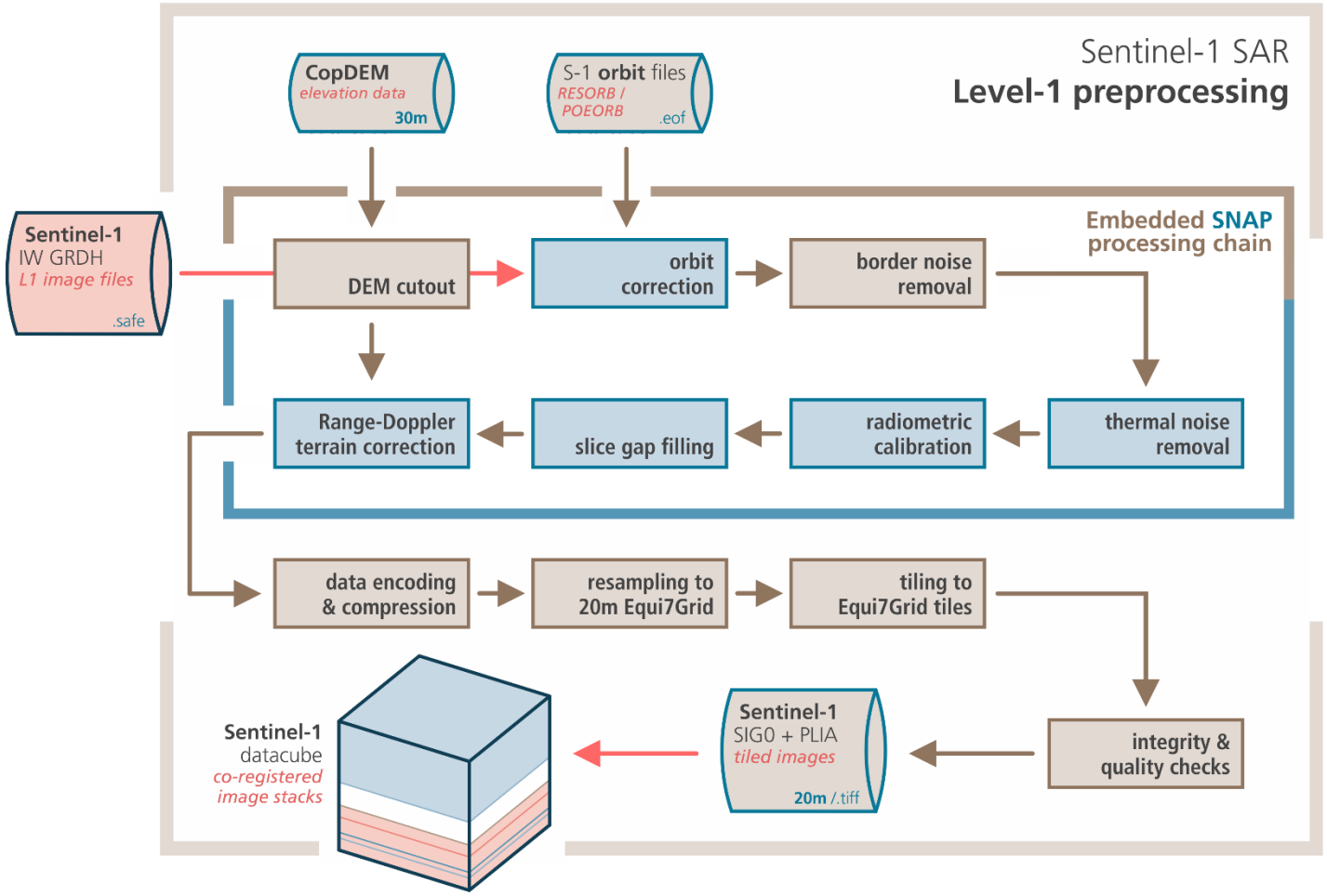
- Huge daily data volume (TB/day)
- Supercomputing!
- Parallellization!
- Swath images -> gridded & tiled images





Production of SAR data – 2: „preprocessing“

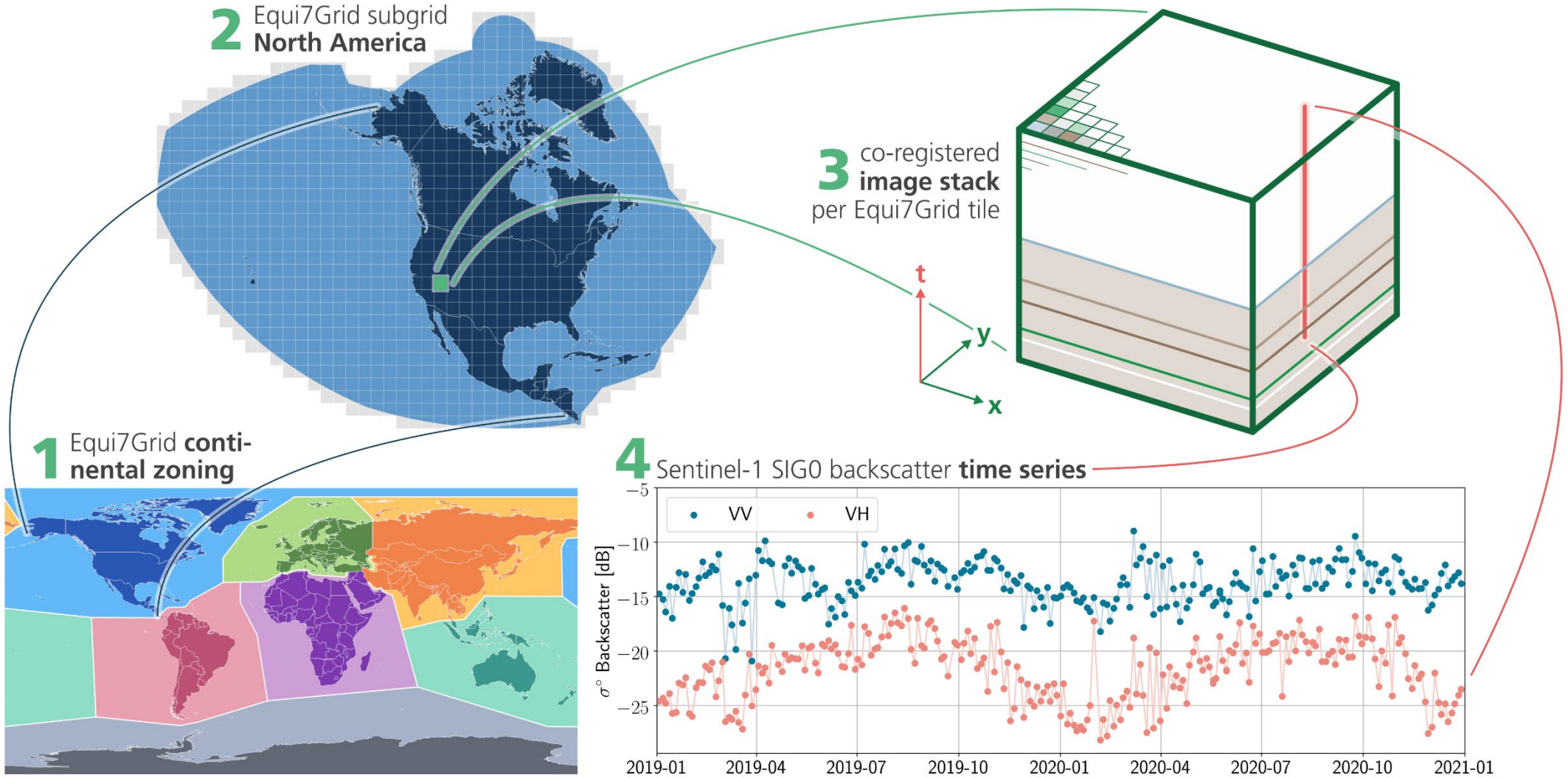
- **SGRT** software package at GEO (Java & Python)
  - SAR Geophysical Retrieval Toolbox
- preprocessing steps
  - geocoding
    - involving topography and viewing geometry correction
  - resampling & gridding
  - tiling & documentation
  - masking
- product & parameter retrieval
  - parameter retrieval
    - statistics from time series
  - e.g. scaling to soil moisture
    - dB-backscatter to relative SM



TUW's Sentinel-1 preprocessing workflow in 2021

Production of SAR data – 3: georeferencing

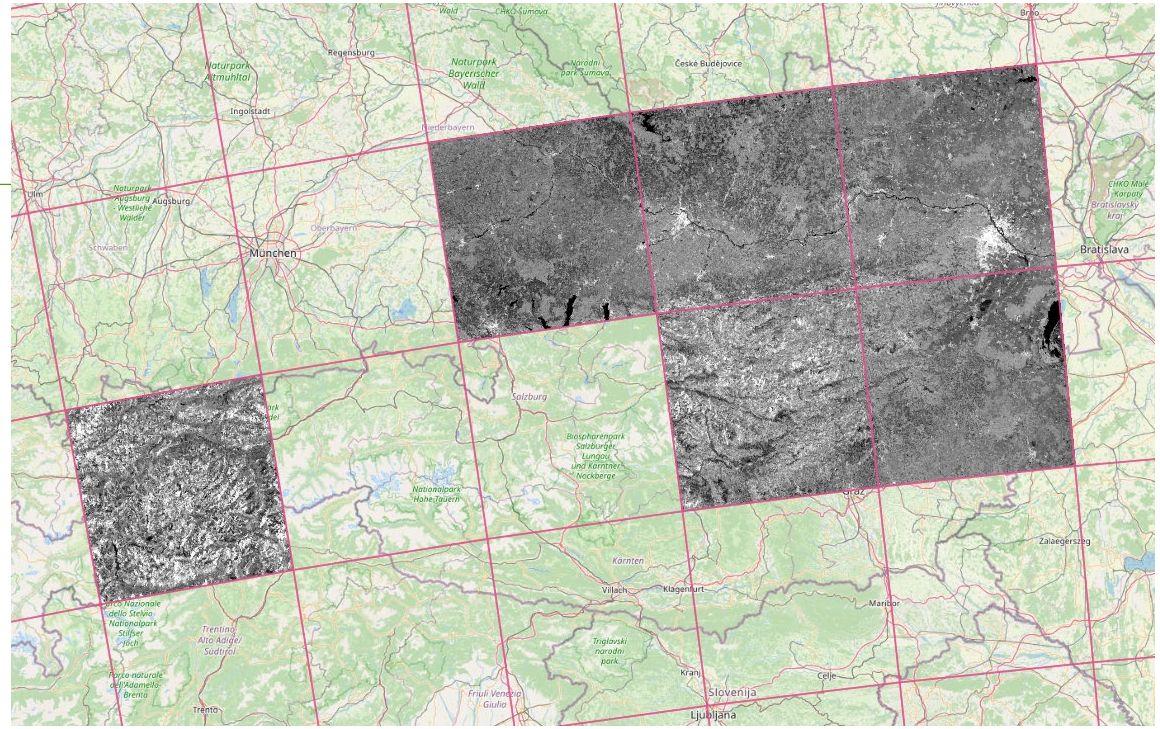
Sentinel-1 ARD datacube: Concept of **Equi7Grid data structure** & **time series access** | Example for T3-tile over the USA



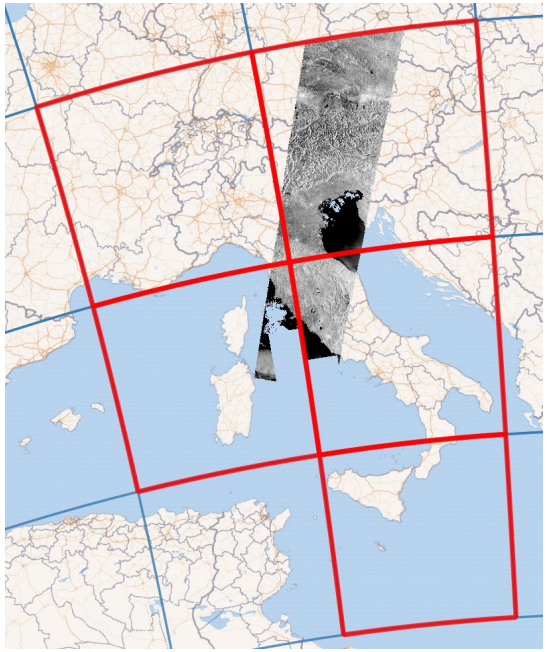
TUW's Sentinel-1 datacube structure

UE radar datasets

- Sentinel-1 IW GRDH
  - already pre-processed by GEO
  - GeoTIFF format
  - two resolutions…



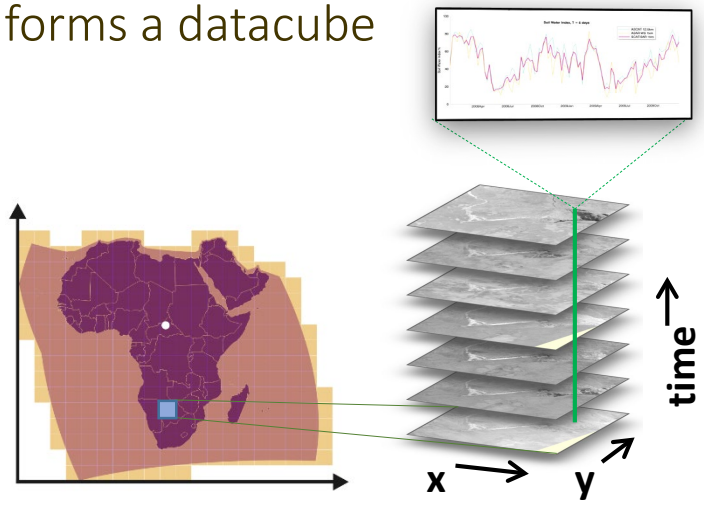
- 10m pixel spacing
  - 6 boxes in Austria
  - 2017/01 – 2021/12
  - Sigma0 VV & VH images
  - Sigma0 parameters + mplia images
    - (only for 2016/17)
  - Sigma0 monthly means
    - (just 2 boxes)
  - large data volume
    - with quick-look images



- 500m pixel spacing
  - 5 boxes ~ Italy & neighbours
  - 2015/01 – 2021/12
  - Sigma0 VV images
  - Sigma0 parameters + mplia images
    - (only for 2015/18)
  - small data volume

S-1 Backscatter (Sigma0) time series

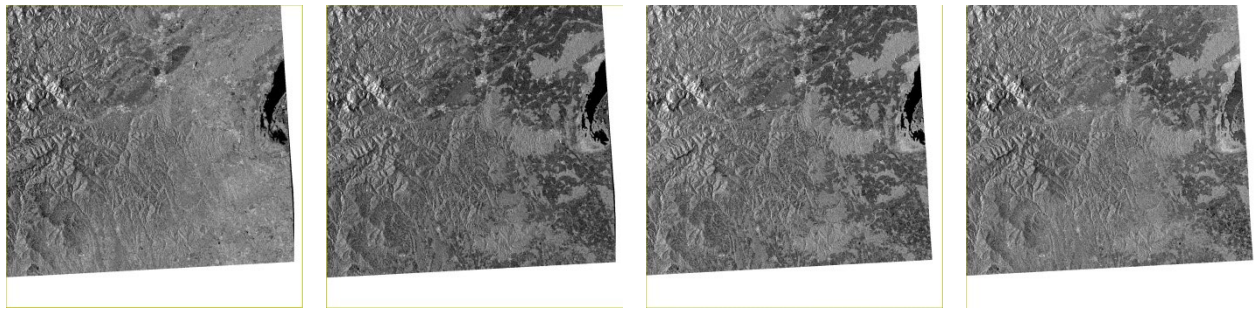
- Stack of gridded & tiled images
  - forms a datacube

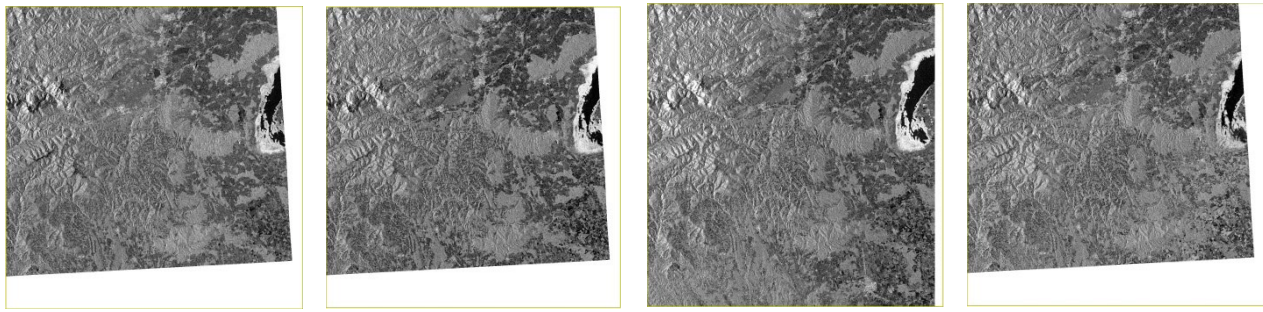


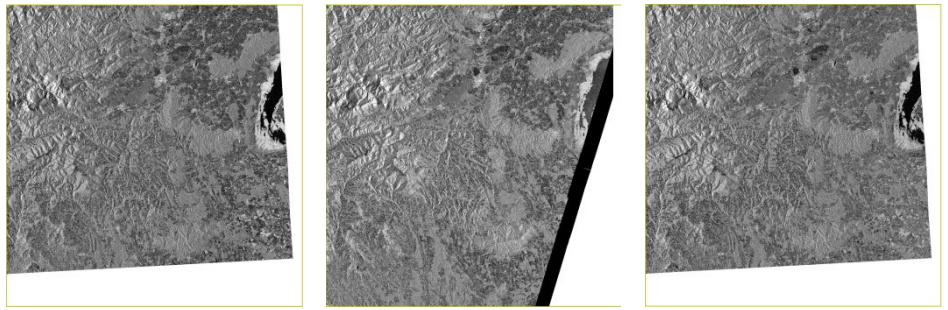
Sensing Date
Variable
Sensor Mode
Grid ID
Tile ID

M20150705_050128--_SIG0-----_S1AIWGRDH1VVD_124_A0101_EU010M_E052N015T1.tif

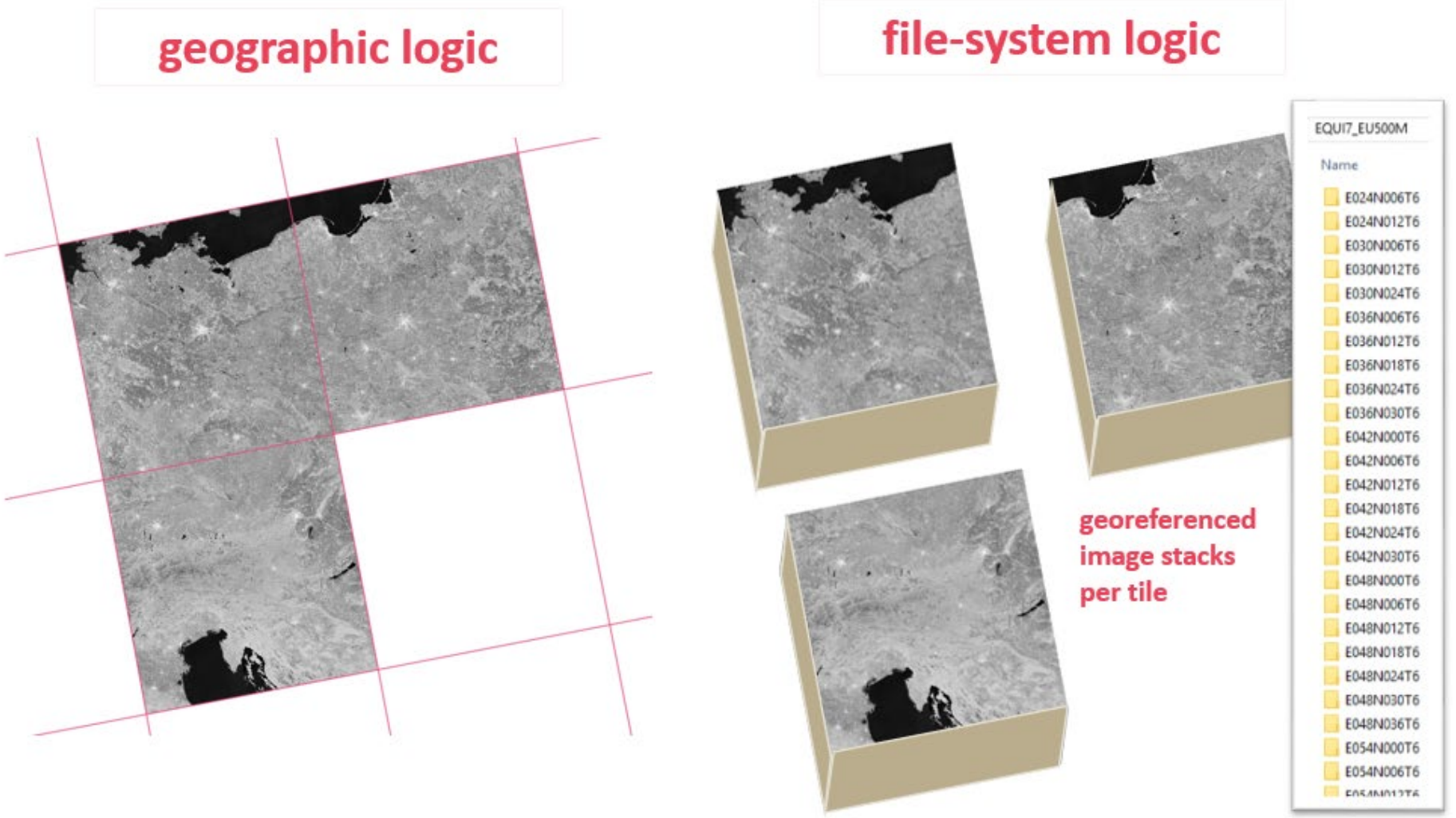
Sensing Time
Relative Orbit Nr.
Software version ID


2015-02-24 2015-03-08 2015-03-20 2015-04-01


2015-04-13 2015-04-25 2015-05-02 2015-05-19

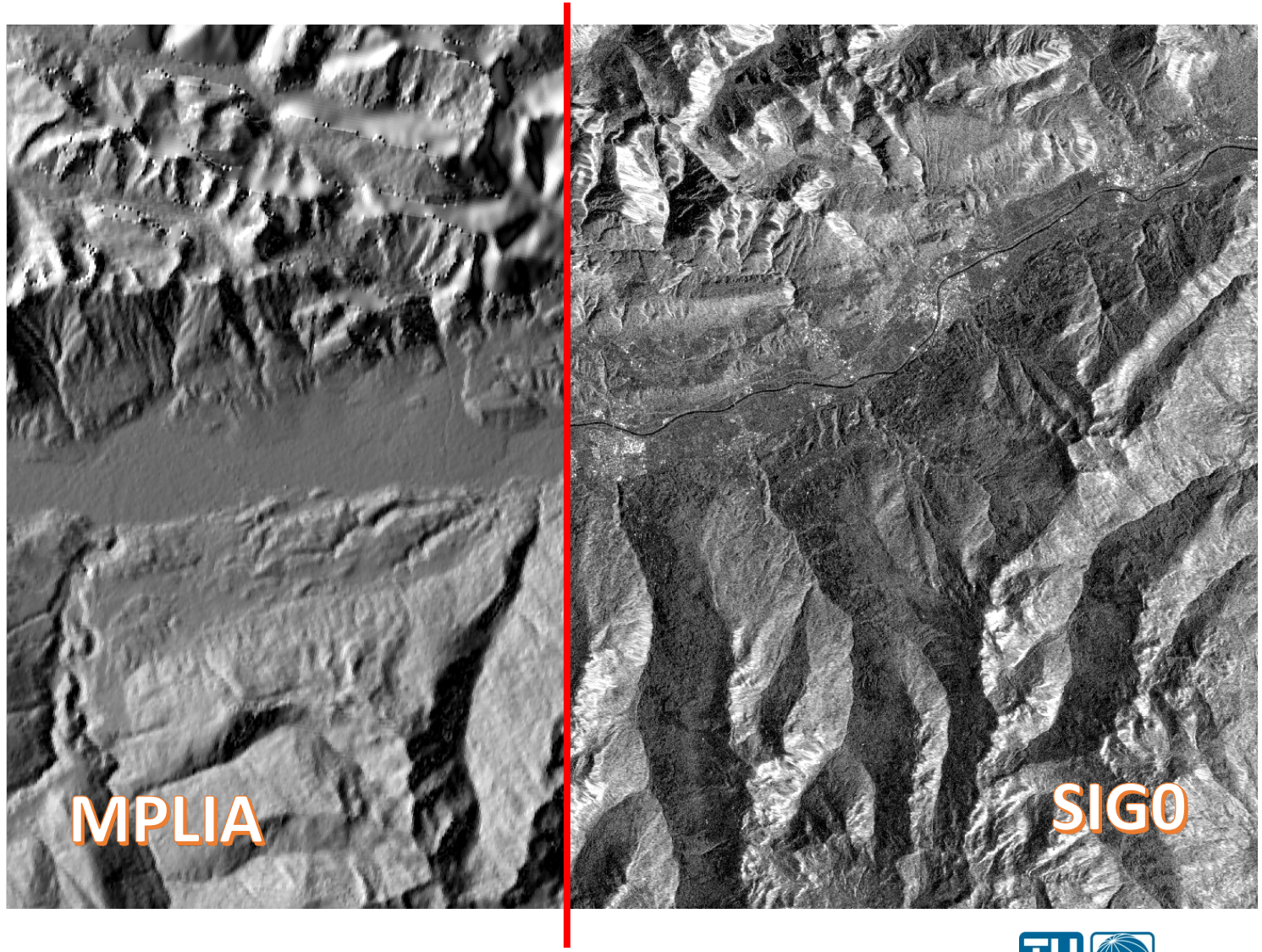

2015-05-31 2015-06-04 2015-06-12

Sentinel-1 datacube/tile structure



Sentinel-1 Sigma0 images

- Each 10m Sentinel-1 scene comprises 2 corresponding GeoTIFF images
  - 2x *Sigma0 Backscatter (SIG0): VV and VH polarisation*
- Corresponding *Mean Projected Local Incidence Angle (MPLIA):*
  - *describes radar viewing angle for each relative orbit*



Sentinel-1 Sigma0 parameters

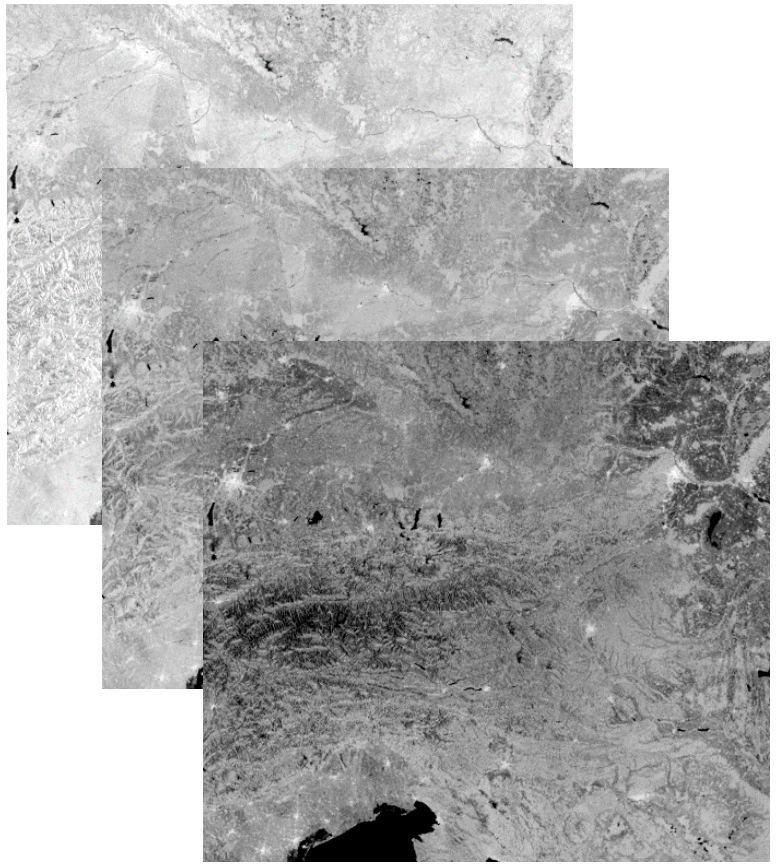
- Statistical analysis of image stacks
  - *mean, max, min, percentiles (10, 50, 90)*
    - *500m: + normalised to 40°*
  - *standard deviation, PLIA-slope*
  - *number of observations*

10m

- tmaxsig0
- tmenplia
- tmensig0
- tminsig0
- tnumsig0
- tp10sig0
- tp50sig0
- tp90sig0
- tsdvsig0

500m

- tmaxplia
- tmaxsig0
- tmenplia
- tmensig0
- tmensig40
- tminplia
- tminsig0
- tnorsig0
- tnumsig0
- tp05sig0
- tp05sig40
- tp10sig0
- tp10sig40
- tp25sig0
- tp25sig40
- tp75sig0
- tp75sig40
- tp90sig0
- tp90sig40
- tp95sig0
- tp95sig40
- tsdvsig0
- tsdvsig40
- tsmslope



Data for your exercise

- Some file characteristics:
  - *Backscatter units: dB*
  - ***Background values**: -9999 or NaN*
  - ***Scale factor** of normalised images:*
    100 (image value -1381 = -13.81 dB)
- Location: *~/shared/data/*
- Your working directory: *~/groups/group**X**/*

Task Description

What to be done in the Practial Part Exercise?

Task description

- Explore and analyse SAR empirical parameters & backscatter data
- Try to explain features in SAR parameters with other datasets qualitatively/quantitatively
  - Qualitative analysis of 1 or more features/phenomena using comparison with at least 2 other datasets
    - i.e. lake extent clearly distinguishable with SAR within one study area → mountains identified with DEM, lake borders from optical images)

  or

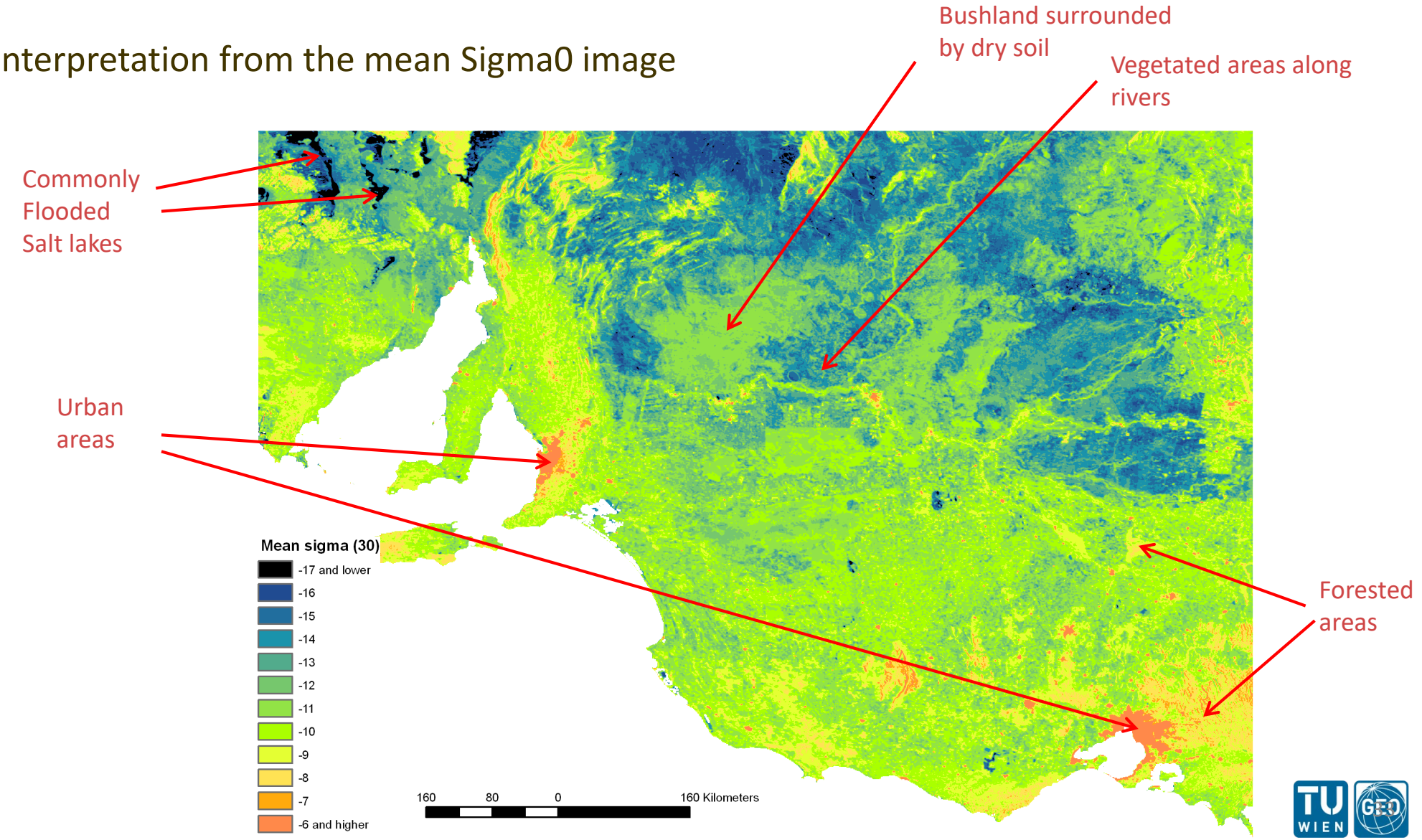
  - Quantitative analysis of 1 feature using at least 2 quantitative methods available in QGIS/python (i.e. spectral characteristics, classification, histogram analyses)
- Use the gained knowledge to suggest a geophysical application of the SAR parameter
- Compile a report on your findings

Recommendations for the experiment

1. Investigate the SAR parameters in QGIS/python/GoogleEarth
2. Set a hypothesis: (i.e. “SAR sensitivity layer can monitor maximum extent of reed around a lake”, “SAR can be used for landcover classification”)
3. Set a test and identify data needed: “Compare GIS vector of the reed belt delineated from Google Maps to the Sensitivity values, investigate the relationship.”
4. Discuss it with your advisor → latest 15.12.2022!
    1. E-mail for appointment
    2. 10-15 min meeting (online or presence?)
    3. Done
5. Carry out the experiment
6. Accept or reject the hypothesis
7. Write up and compile the report

Investigate parameters and set a hypothesis - 1

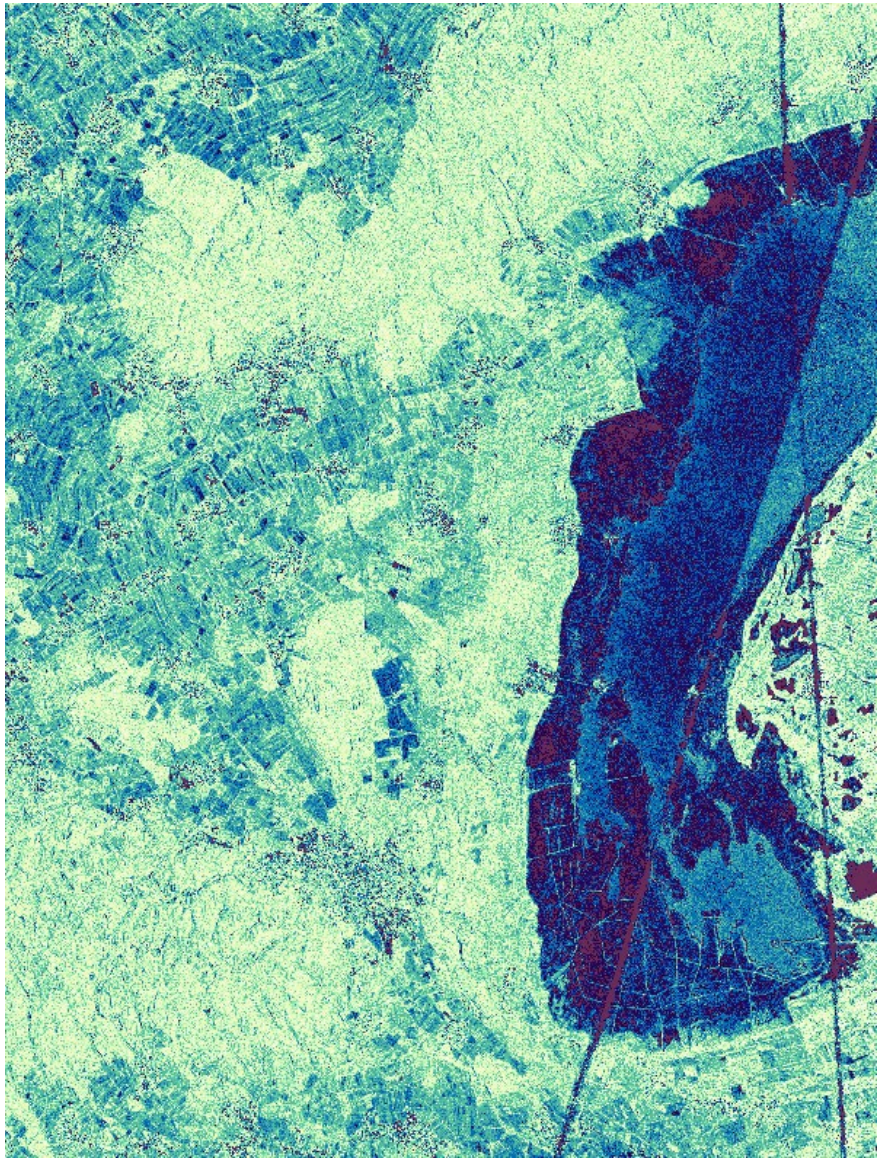
- Visual interpretation from the mean Sigma0 image



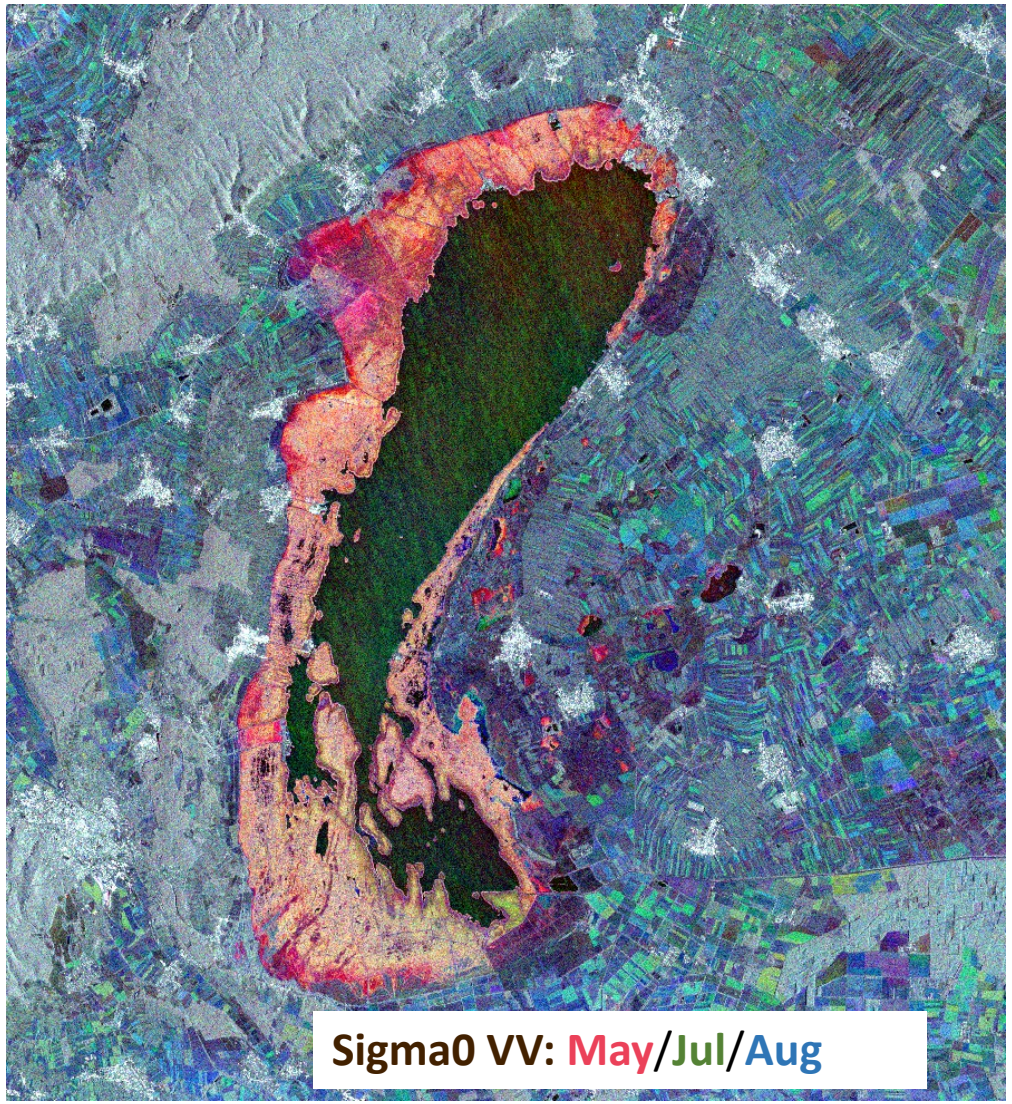
Investigate parameters and set a hypothesis - 2

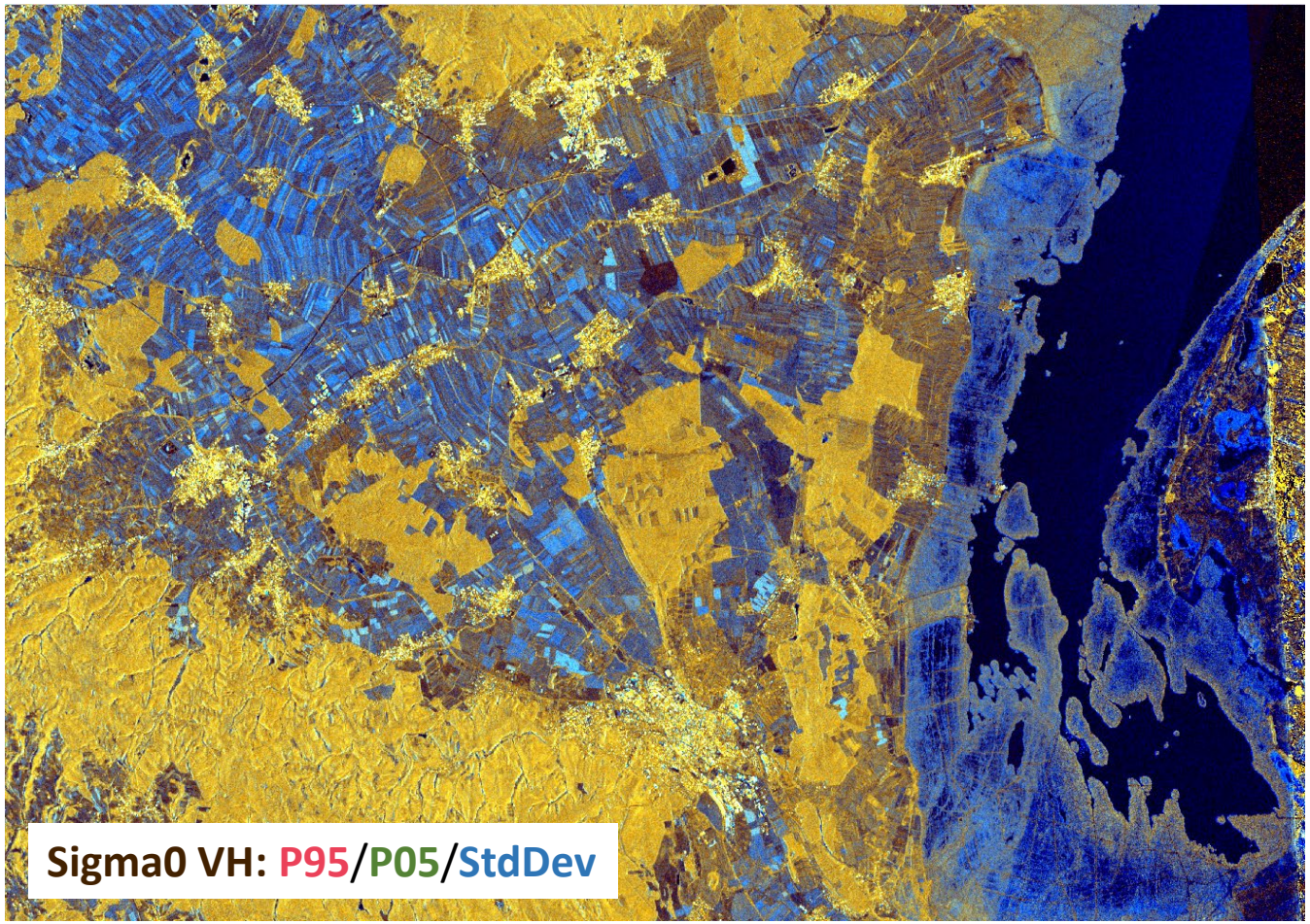
- The sensitivity is the range of backscatter values at one location
  - e.g. Δ(TMAXSIG0, TMINSIG0)
  - e.g. Δ(TP95SIG0, TP05SIG0)

- E.g.: One can demonstrate the maximum extent of the reed belt around *Neusiedler See.*
  - or even the development over time?



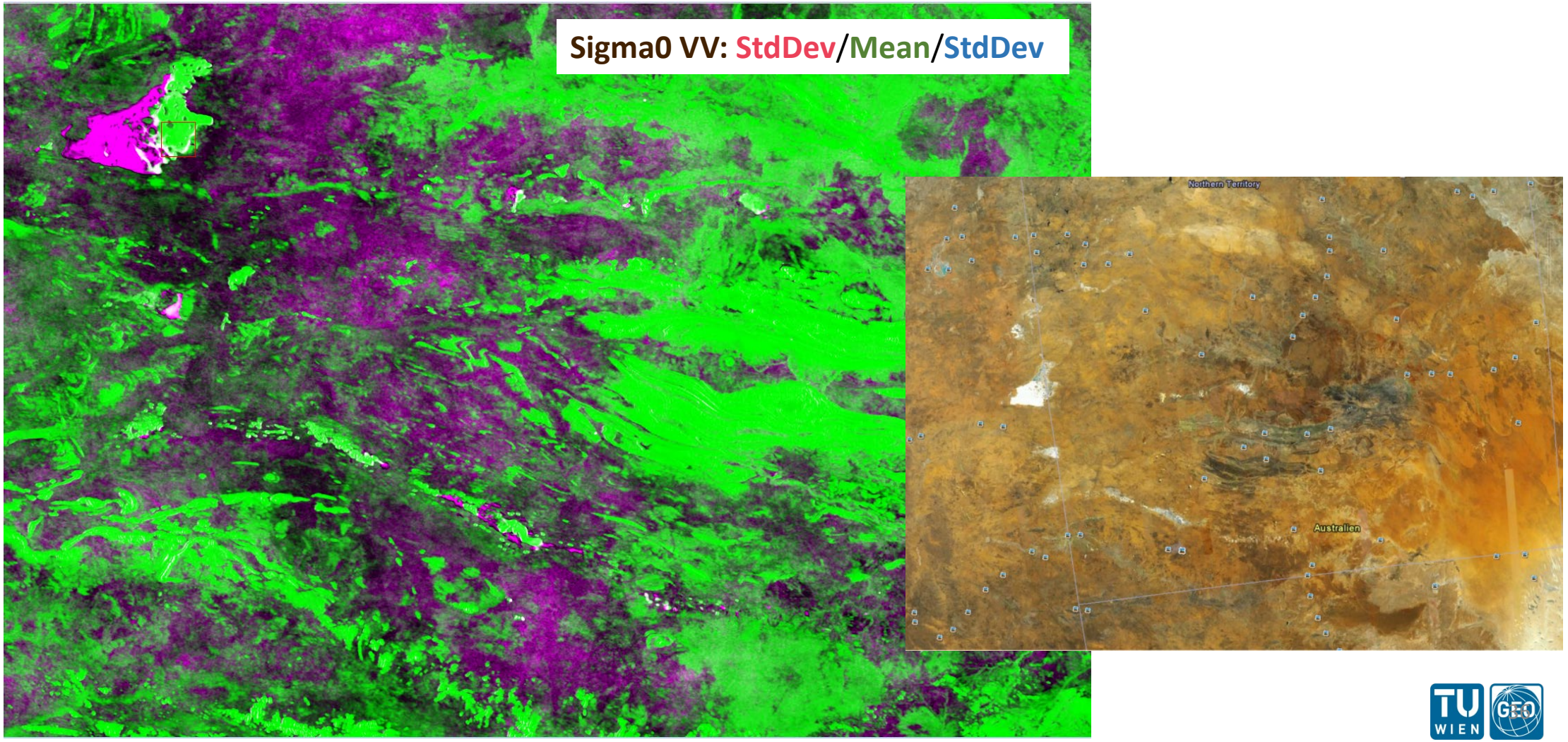
Perform analysis with combining multi-temporal parameters





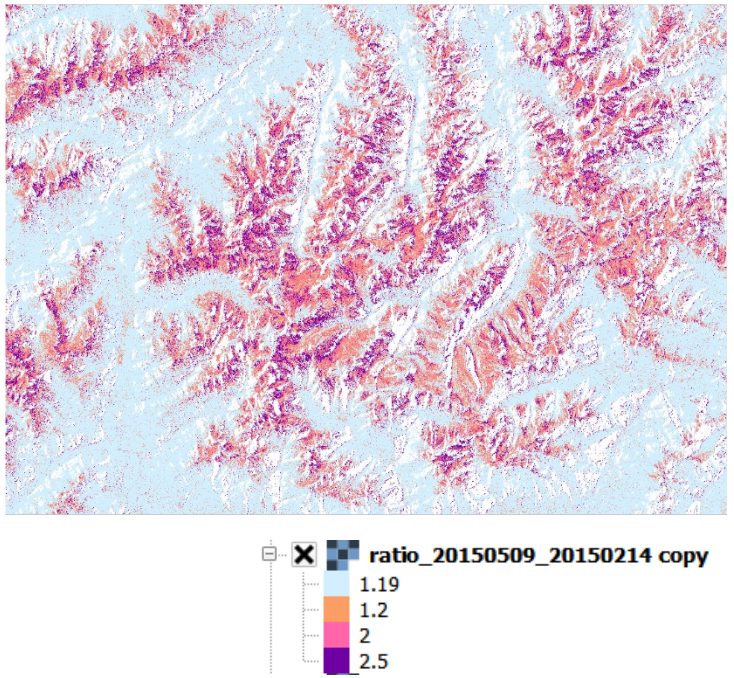
Perform analysis with combining the parameters

- RGB composite of two parameters



Perform analysis with combining multi-temporal observations

- e.g. detecting snow melt from ratio between images at dry/wet conditions



Report requirements - 1

Each group should deliver a report (8-12 pages) in English as PDF-file (no hardcopy needed). It must contain the following:

- Hypothesis [4 points]
  - Formulate in 1-2 sentences your idea (à la how can which SAR-data be used for what in which environment?)
- Dataset description [4 points]
  - Describe which data were used; with graphics covering your study area(s)
- Study area description [2 points]
  - Describe briefly your chosen study area(s)
- Methods [6 points]
  - Describe completely and concisely your experiment: the used methods & the sequence of data processing
- Results [6 points]
  - Describe in neutral language the most important results, document them with useful figures, tables, and maps.
- Discussion [8 points]
  - Discuss and comment your findings. Use description of different scattering techniques (diffuse, volume etc.) to describe the physics behind the relationships. [5 points]
  - Discuss in general potential global application of SAR data for your hypothesis. [3 points]
- Conclusion [5 points]
  - Summarise your study, results, gained insights and accept or reject your hypothesis.

Report requirements - 2

Bonus points (for additional work):

- Usage of suitable data other than provided [2 points]
- Integration of additional information about the features you chose to analyse [2 points]
  - on your study area, feature of interest, physical background
- Search for publications discussing the suggested application [2 points]
  - e.g. at http://www.scopus.com
  - or at http://www.sciencedirect.com
  - or https://scholar.google.at/
- Report examples:
  - See files *~/shared/mrs_ue/report_examples/*

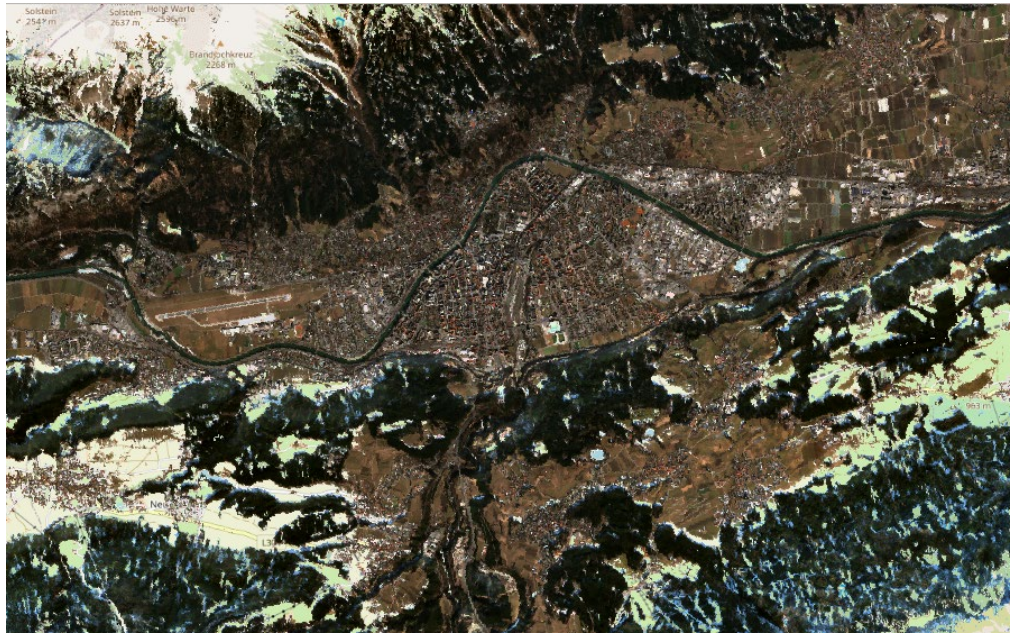
Reference Data

Data to compare with

~/shared/data/auxiliary_data/
~/shared/data/sentinel2/

Sentinel-2 multispectral data

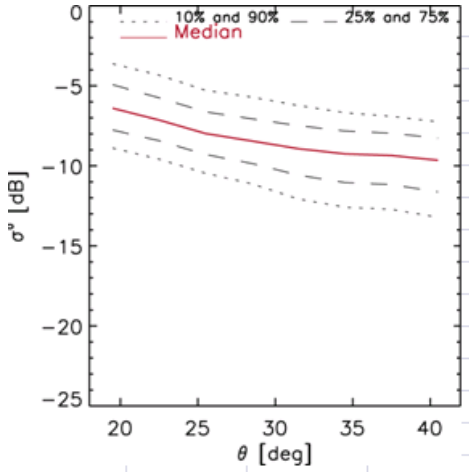
- Sentinel-2 data pre-processed by BOKU
  - At 10m pixel spacing
  - Same 6 Equi7Grid tiles
  - Same time span
- Multiple data layers:
  - Band 2 – Band 8
  - Band 11 – Band 12
  - Cloudmasks
  - True Colour Images (TCI) available as quick-looks



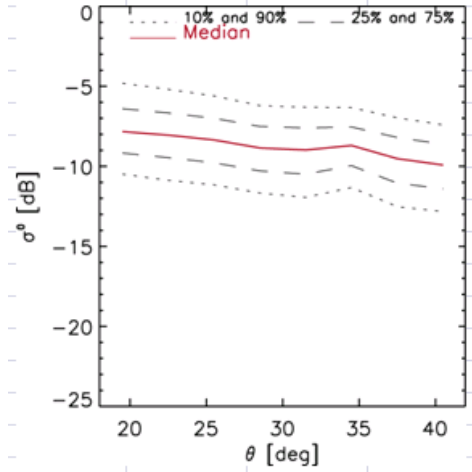
Sentinel-2 True Colour Image (TCI) covering Innsbruck

Global Signature Database

- Provides average backscatter values over 7 selected land cover types
- Derived from Envisat ASAR WS (2004 - 2012, 150m resolution)



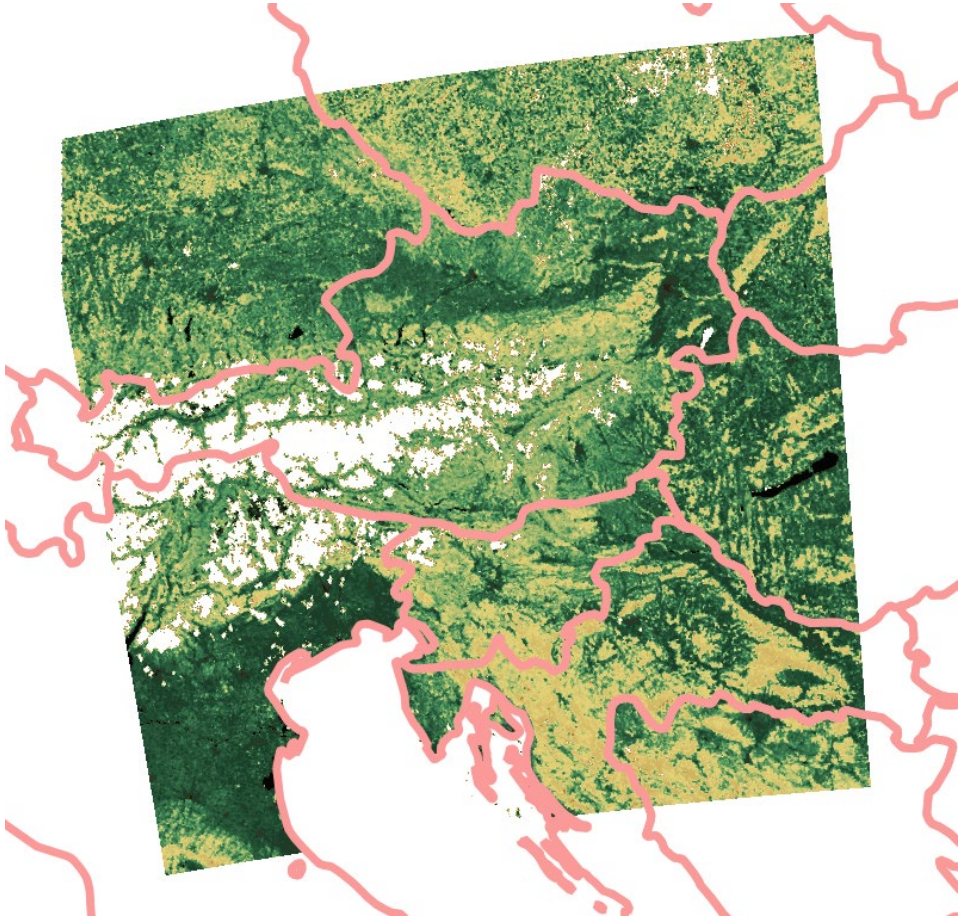
HH - Agriculture and Grassland	POL HH	LR - lat 42,5	UL - lon -92,5	UL - lat 43,5	LR - lon -91,5			
Local Incidence Angle	**18-21**	**21-24**	**24-27**	**27-30**	**30-33**	**33-36**	**36-39**	**39-42**
Number of measurements (in thousands)	15613,40	14347,90	12299,50	14700,00	20423,60	24095,80	22810,10	16039,40
Mean	-6,32	-7,04	-7,90	-8,40	-8,91	-9,29	-9,44	-9,86
Median	-6,40	-7,14	-7,98	-8,45	-8,93	-9,25	-9,35	-9,65
Stdev	2,04	2,05	2,04	2,17	2,31	2,29	2,25	2,31
Percentile (10%)	-8,89	-9,58	-10,46	-11,12	-12,07	-12,58	-12,72	-13,21
Percentile (25%)	-7,76	-8,43	-9,29	-9,85	-10,58	-11,04	-11,17	-11,62
Percentile (75%)	-4,93	-5,75	-6,63	-7,06	-7,49	-7,82	-7,96	-8,27
Percentile (90%)	-3,62	-4,33	-5,28	-5,71	-6,23	-6,68	-6,91	-7,24



VV - Agriculture and Grassland	POL VV	LR - lat 52,5	UL - lon 8,6	UL - lat 53,5	LR - lon 9,6			
Local Incidence Angle	**18-21**	**21-24**	**24-27**	**27-30**	**30-33**	**33-36**	**36-39**	**39-42**
Number of measurements (in thousands)	16260,10	21615,60	21727,30	20244,40	10833,10	3499,56	13092,70	21782,40
Mean	-7,61	-7,89	-8,19	-8,64	-8,83	-8,43	-9,37	-9,60
Median	-7,83	-8,05	-8,35	-8,85	-8,98	-8,70	-9,52	-9,92
Stdev	3,26	3,56	3,49	3,42	3,88	4,45	3,89	3,26
Percentile (10%)	-10,49	-10,87	-11,16	-11,67	-11,94	-11,32	-12,52	-12,83
Percentile (25%)	-9,17	-9,46	-9,78	-10,29	-10,49	-9,96	-11,05	-11,41
Percentile (75%)	-6,40	-6,67	-7,00	-7,51	-7,60	-7,54	-8,20	-8,62
Percentile (90%)	-4,81	-5,19	-5,60	-6,21	-6,31	-6,33	-6,97	-7,41

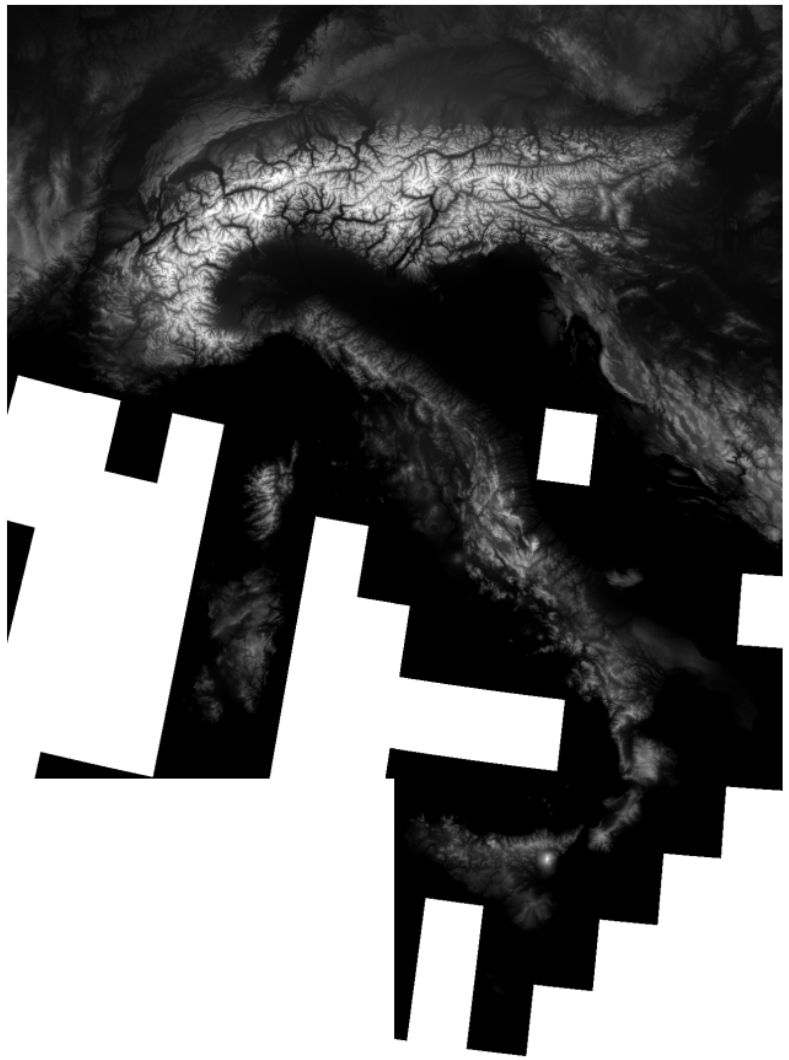
Normalized difference vegetation index (NDVI)

- „Copernicus NDVI“
  - https://land.copernicus.eu/global/products/ndvi
- describes vegetation density & health
  - from optical sensors
    - here: ESA‘s PROBA-V
  - relates reflectivity of plants in bands for Infrared an Red
  - dimensionless quantity
    - ranges from -1 to 1
- 500m spatial sampling
  - 1km resolution
- Jan 2016 – Sep 2019
- over Italian tiles



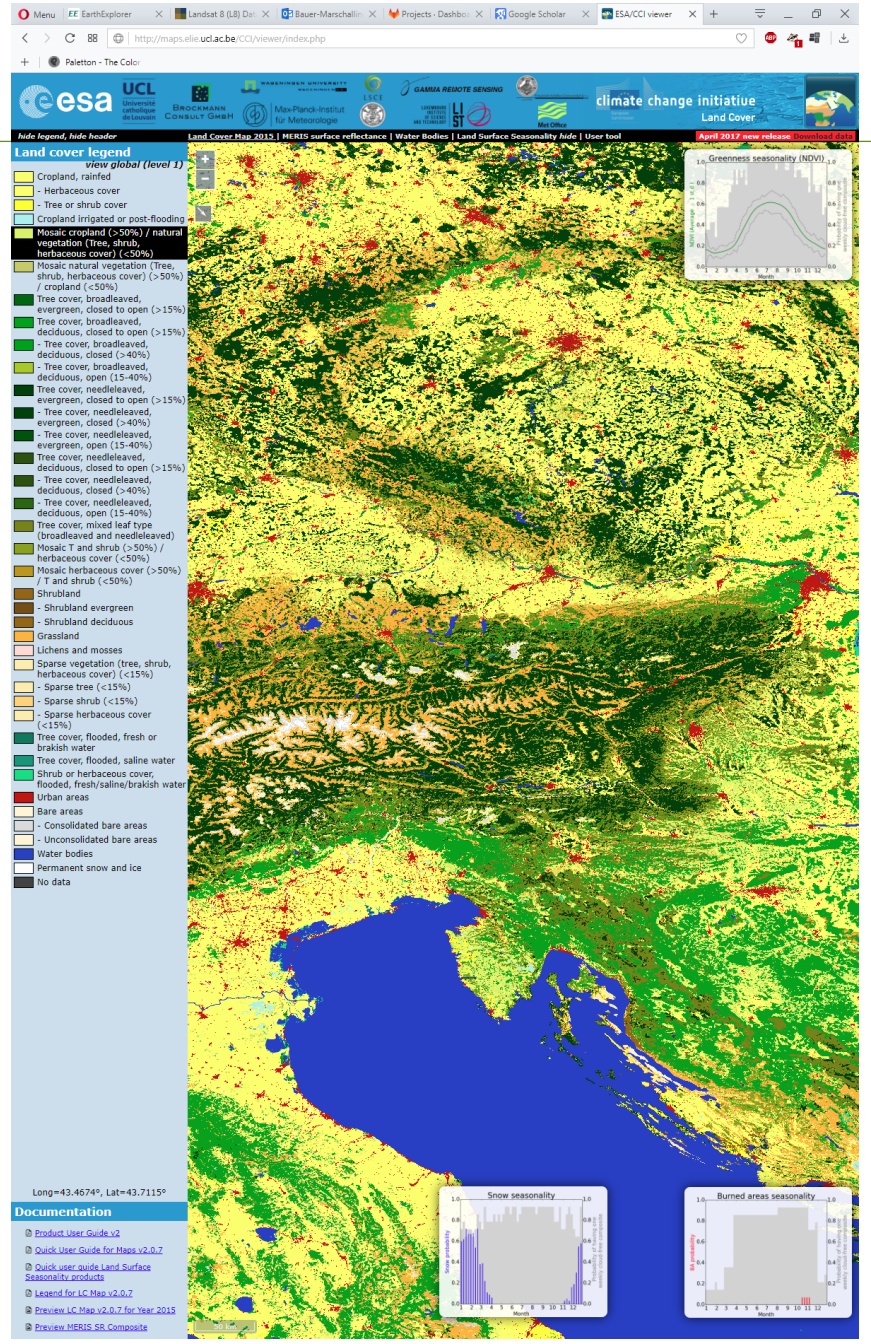
Topography

- SRTM VFP
  - 10m (oversampled) and 75m spatial sampling
  - from http://www.viewfinderpanoramas.org/dem3.html



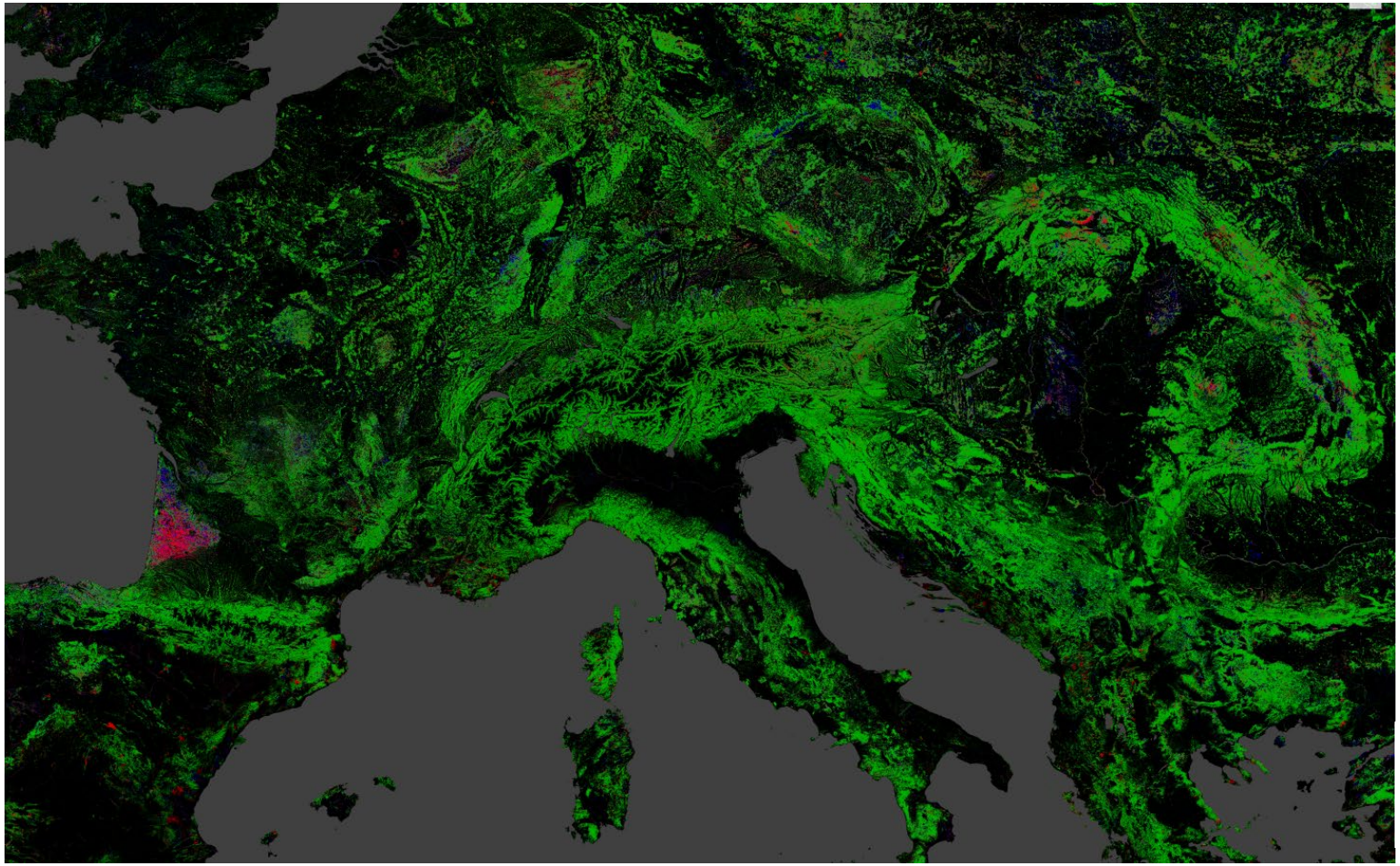
Land cover

- Corine Land Cover 2018
  - available over Europe
  - https://land.copernicus.eu/pan-european/corine-land-cover
- CCI Land Cover 2015
  - global
  - http://maps.elie.ucl.ac.be/CCI/viewer/index.php



Global forest cover

- Forest cover & change – Uni Maryland, 2013
  - http://earthenginepartners.appspot.com/science-2013-global-forest



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DEPARTMENT OF GEOGRAPHICAL SCIENCES

WIEN GEO

Reference Data

Some more ideas

Optical imagery

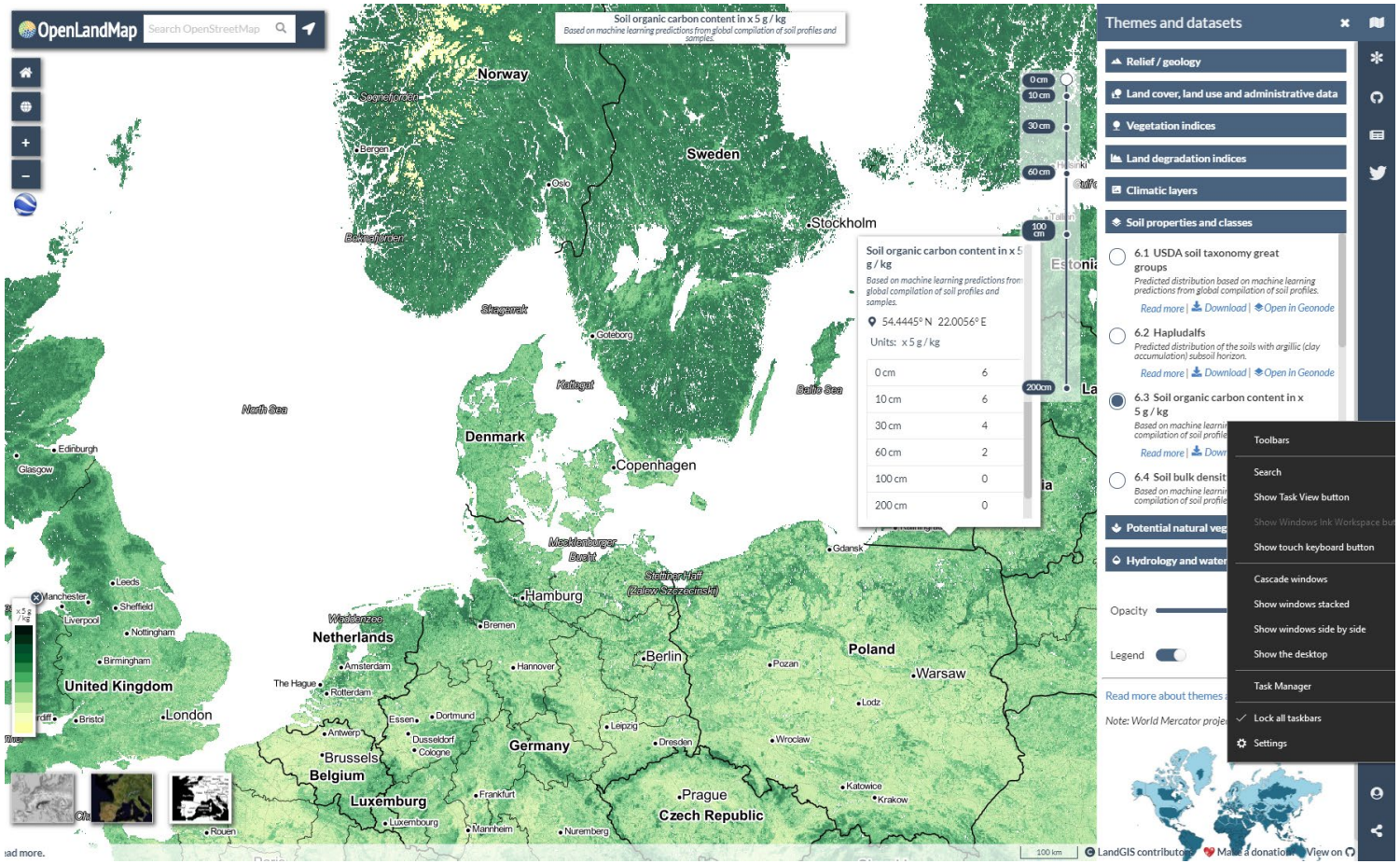
- Google Earth optical imagery

e.g. with QGIS OpenLayers plugin

OpenLandMap

- global database on soils and more (2019)

  https://openlandmap.org/



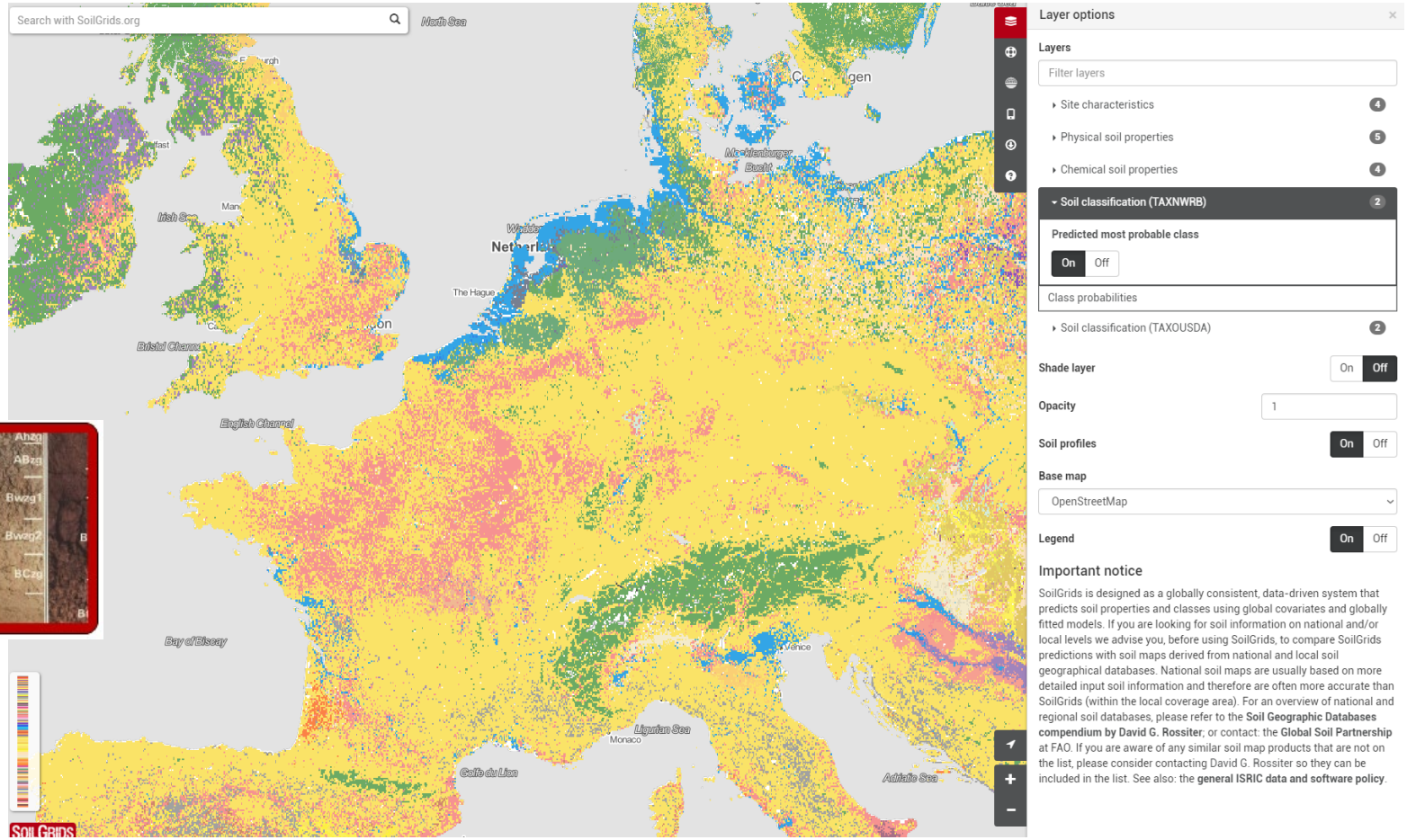
OpenGeoHUB
Connect · Create · Share · Repeat

TU WIEN GEO

ISRIC soil grids

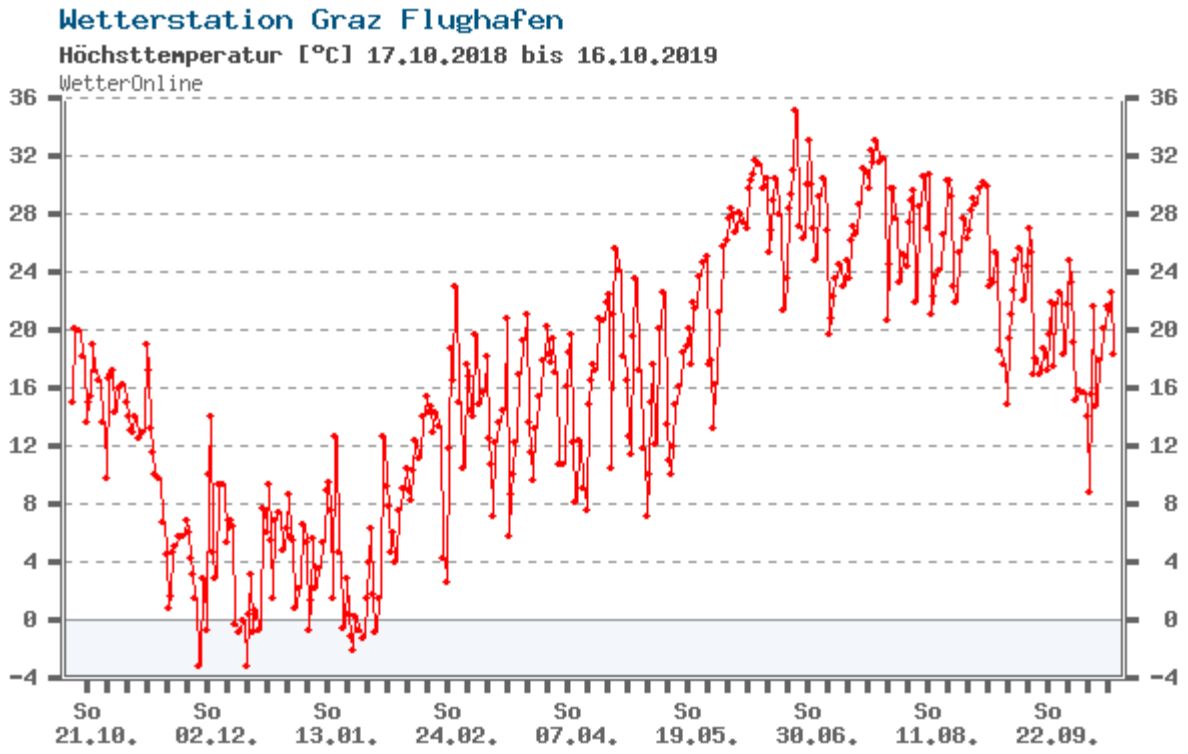
- global database on soils (2017)

  https://soilgrids.org/



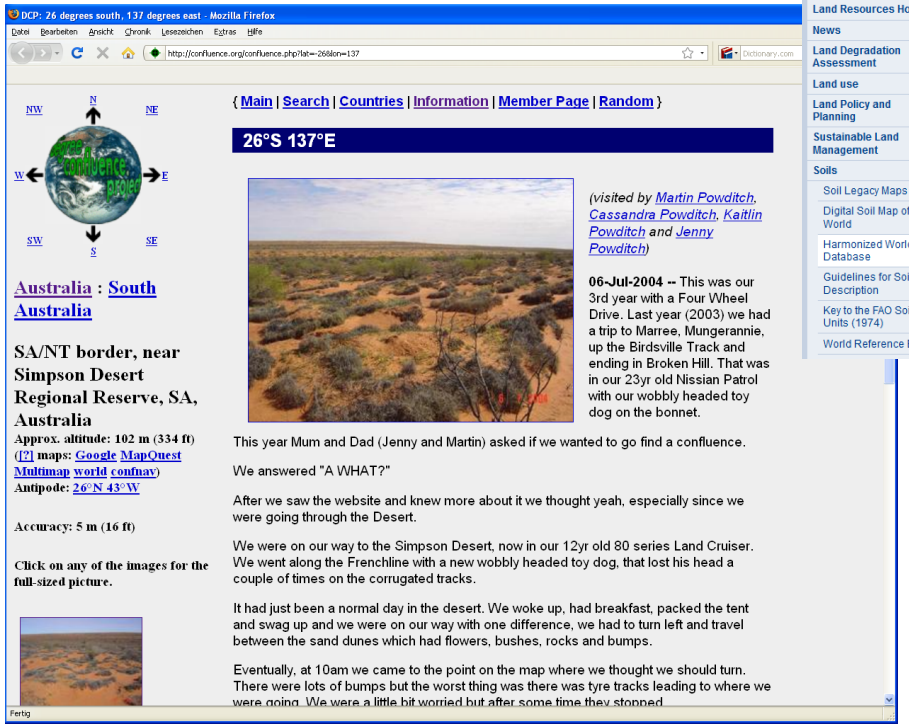
Precipitation & weather

- Public and commercial providers:
  - e.g. meteo-history for Graz: https://www.wetteronline.de/wetterdaten/graz



Other sources

- Harmonised World Soil Database (FAO):
  - http://www.fao.org/nr/land/soils/harmonized-world-soil-database/en/
- Degree Confluence Project:
  - http://confluence.org/
- One Geology (web map service):
  - http://onegeology.org/portal/home.html
- Others?



Summary

Summary

- **The aim is to explain features in SAR data**
  - Sigma0 images, and/or multi-temporal parameters
  - analyse qualitatively and/or quantitatively against ancillary datasets
- This slides can be found in TUWEL
- Compile a report with a description of your work and findings
- Advisors: Bernhard Bauer-Marschallinger & Claudio Navacchi
  - bbm@geo.tuwien.ac.at | claudio.navacchi@geo.tuwien.ac.at | TUWEL Forum!
- Submission of report only to bbm@geo.tuwien.ac.at
- Prepare results already with final presentation in mind ☺

Further Roadmap

Summary & dates for the Practical Exercise

Final presentation - Practical Exercise

- Each group presents their study at the end of the semester
- The (moderated) presentation will be held in a scientic conference-like setting and should take 10-12 minutes (sharp!) and is to be held in English. The presentation is followed by 3-5 min discussions, between the audience, students, and the presenters.
- You can decide whether one or all persons of your group present. In any case, all group members should be ready answering questions after the presentation.
  - The activity and responsiveness of the individual persons contributes to the individual scores.
  - A single presenter would be honoured with extra scores.
  - Each group member must contribute to the discussion.
- The presentation should cover:
  - Introduction (hypothesis, study aim etc.)
  - Short description of the dataset
  - Methodology: steps of experiment, data manipulation processing
  - Results (screenshots of the output images and workflows during the process)
  - Discussion & conclusion

Roadmap Practical Exercise

- Thu Oct 20: Introduction Practical Exercise
- Thu Dec 15: Deadline hypothesis
  - Before that, each group must visit supervisor and report idea on hypothesis
  - E-mail notification for date/zoom
- Thu Jan 12, 12:00: Deadline report Practical Exercise
  - handing-in earlier is more than welcome!
- Thu Jan 19: Feedback on report returned to students
  - *comments on experiment, results, report → consider for final presentation*
  - *no second (revised) hand-in required!*
- Thu Jan 26: Final presentations