Semantic Earth Observation Data Cube of AVHRR and Sentinel-3 SLSTR Data for Exploratory EO Analysis

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We can see changes, interpret and understand them, but we cannot operationally query EO imagery archives for them.

e.g. Google Earth Timelapse

We can see changes, interpret and understand them, but we cannot operationally query EO imagery archives for them.

Cloud: Bring the user to the data, rather than data to the user.

Big EO archives aren't the most user friendly, even for experts.

How does our relationship to satellite-based big EO archives and analysis change if an archive is semantically enabled?

Context

sen2cube.at

PARIS LODRON UNIVERSITÄT SALZBURG

- Earth Observation Analytics research group
  - Department of Geoinformatics Z_GIS
- Sentinel-2 semantic Earth Observation data cube(s)
- Web-based GUI + semantic querying language + jupyter notebooks
  - Top-of-Atmosphere reflectance + derived information / interpretation
  - Drag-and-drop blockly interface for access and analysis
- Programming-free, (exploratory) EO imagery analysis
- Towards increasingly explainable big EO data analysis
  - repeatable and sharable semantic models
- multiple sensors, imagery interpretations and information layers

AVHRR Archive: Remote Sensing Research Group University of Bern

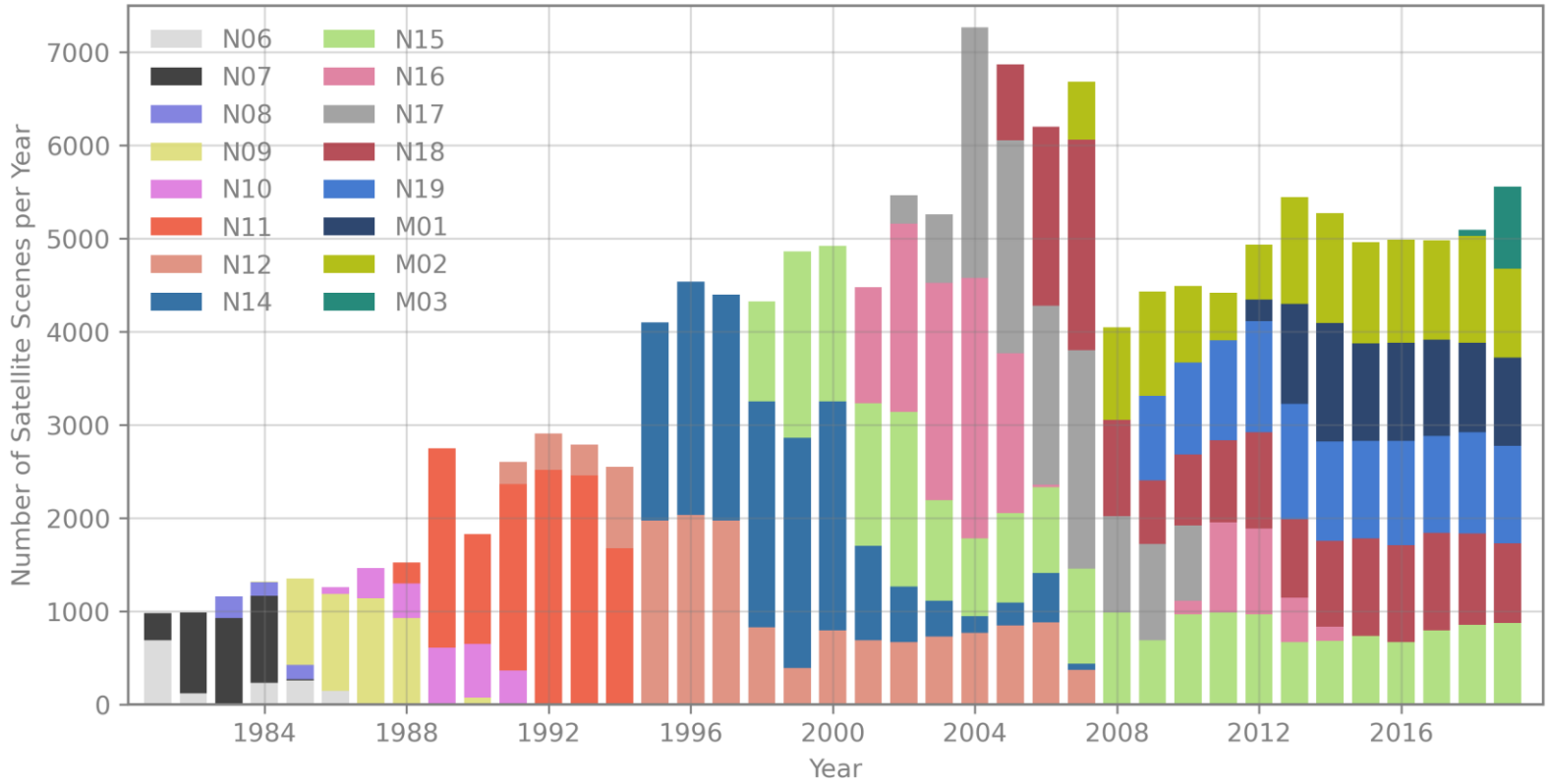
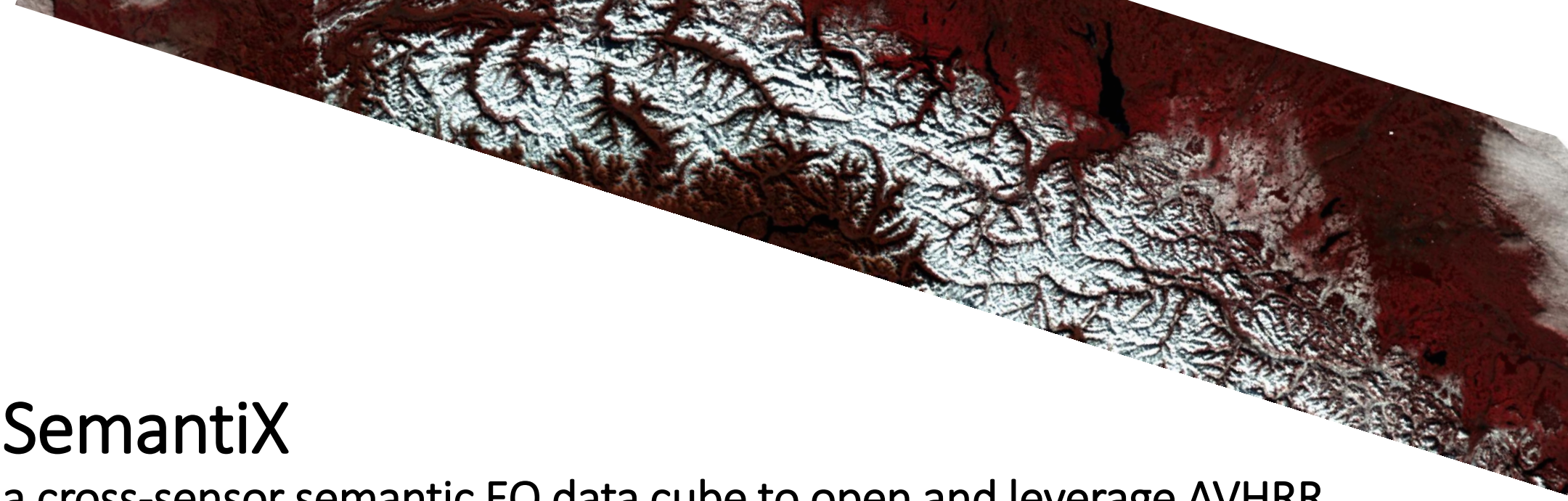


Figure: Number of AVHRR scenes per year color-coded by satellite platform (Weber & Neuhaus, 2020)



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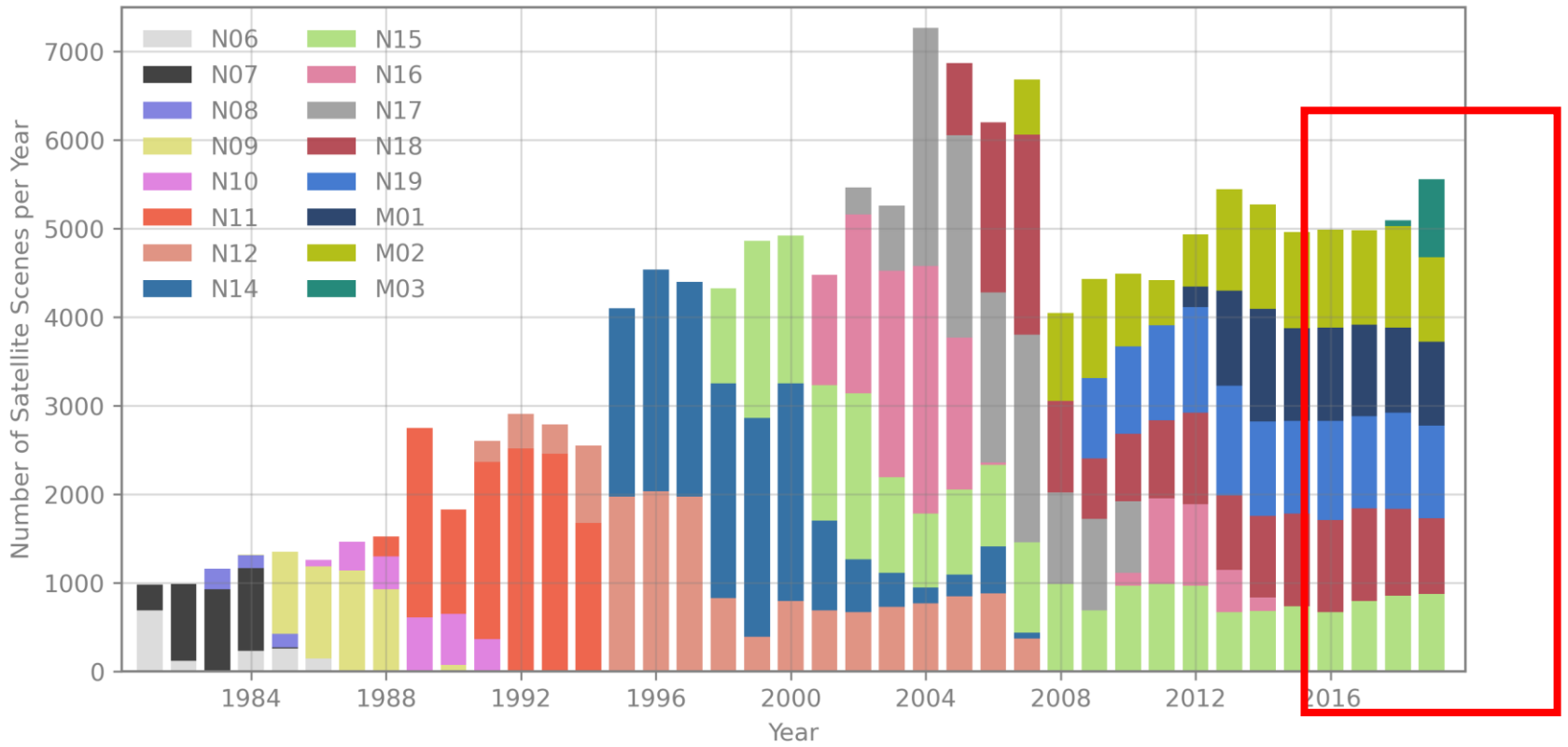
a cross-sensor semantic EO data cube to open and leverage AVHRR time-series and essential climate variables with scientists and the public

… retrieve, curate, facilitate

AVHRR Archive: Remote Sensing Research Group University of Bern



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opening EO data to the public

Relative spectral response between AVHRR and Sentinel-3 SLSTR

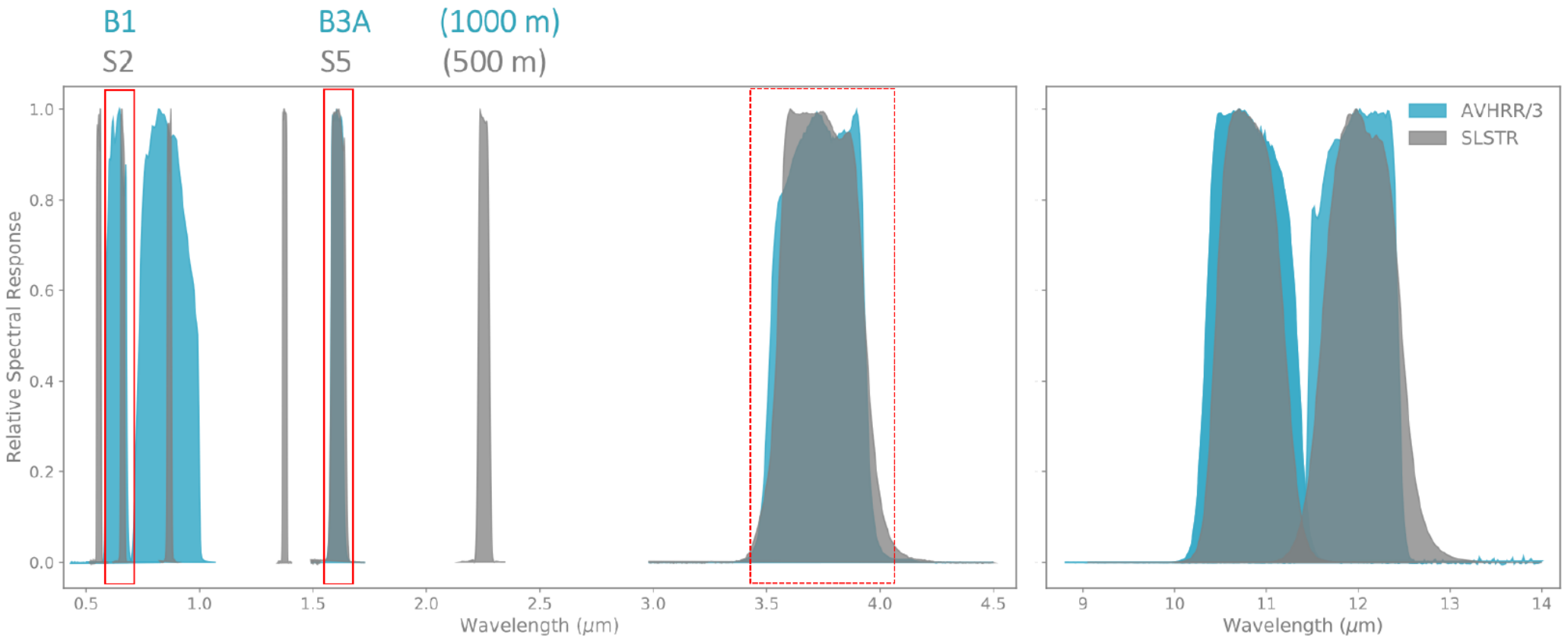
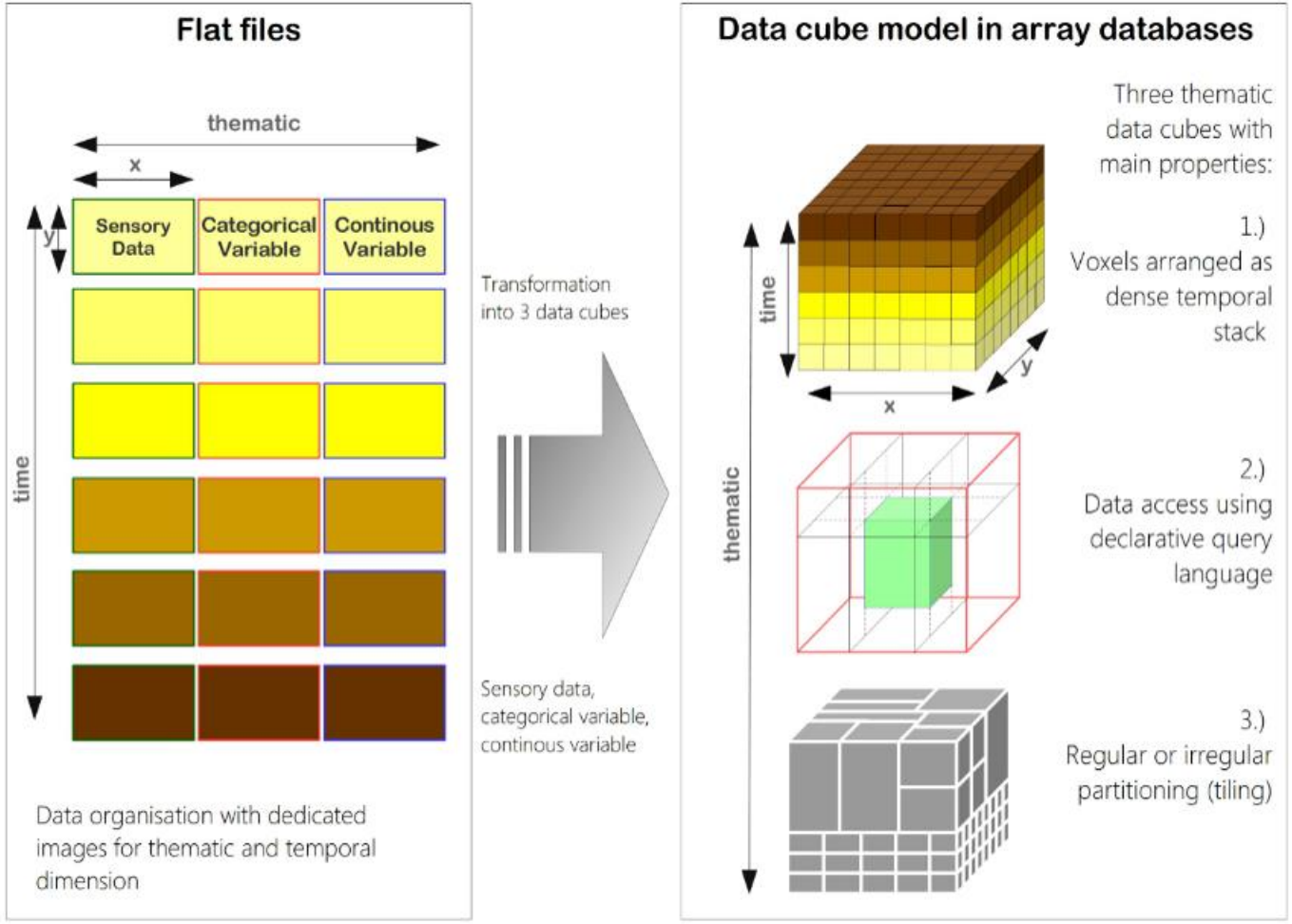


Figure: relative spectral response between AVHRR and S3 (H. Weber, 2020). Data sources: star.nesdis.noaa, sentinels.copernicus.eu

EO Data Cube

- Data access …
  - independent of file naming, location and structure
  - using coordinates in space and time!
  - e.g. OpenDataCube



Tiede, Dirk; Baraldi, Andrea; Sudmanns, Martin; Belgiu, Mariana; Lang, Stefan (2017): Architecture and prototypical implementation of a semantic querying system for big Earth observation image bases. In European journal of remote sensing 50 (1), pp. 452–463. DOI: 10.1080/22797254.2017.1357432.

Semantic EO data cube

"[…] a data cube, where for each observation at least one nominal (i.e. categorical) interpretation is available and can be queried in the same instance."

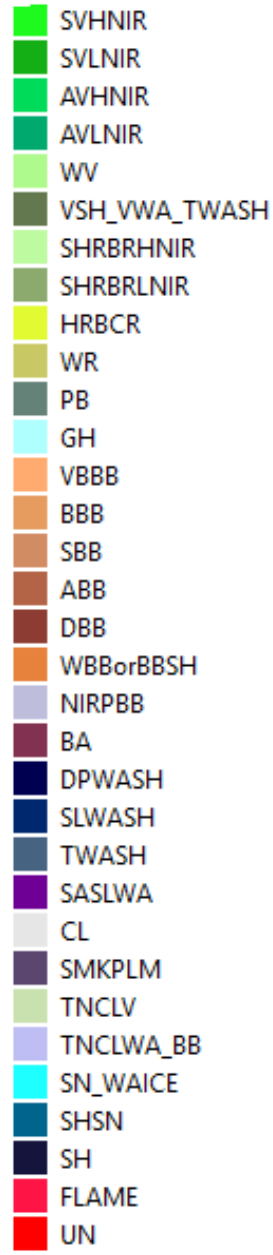
Augustin, H., Sudmanns, M., Tiede, D., Lang, S., & Baraldi, A. (2019). Semantic Earth Observation Data Cubes. *Data*, *4*(3), 102. https://doi.org/10.3390/data4030102

SIAM: multi-spectral colour naming

- fully automated, physical-model-based decision tree
- parameter-free, no samples needed
- near real-time (ca. 3 min. per AVHRR scene)
- scalable and parallelisable
- multi-sensor support (at least TOA calibrated)
- ➔ Expert system – good old-fashioned AI

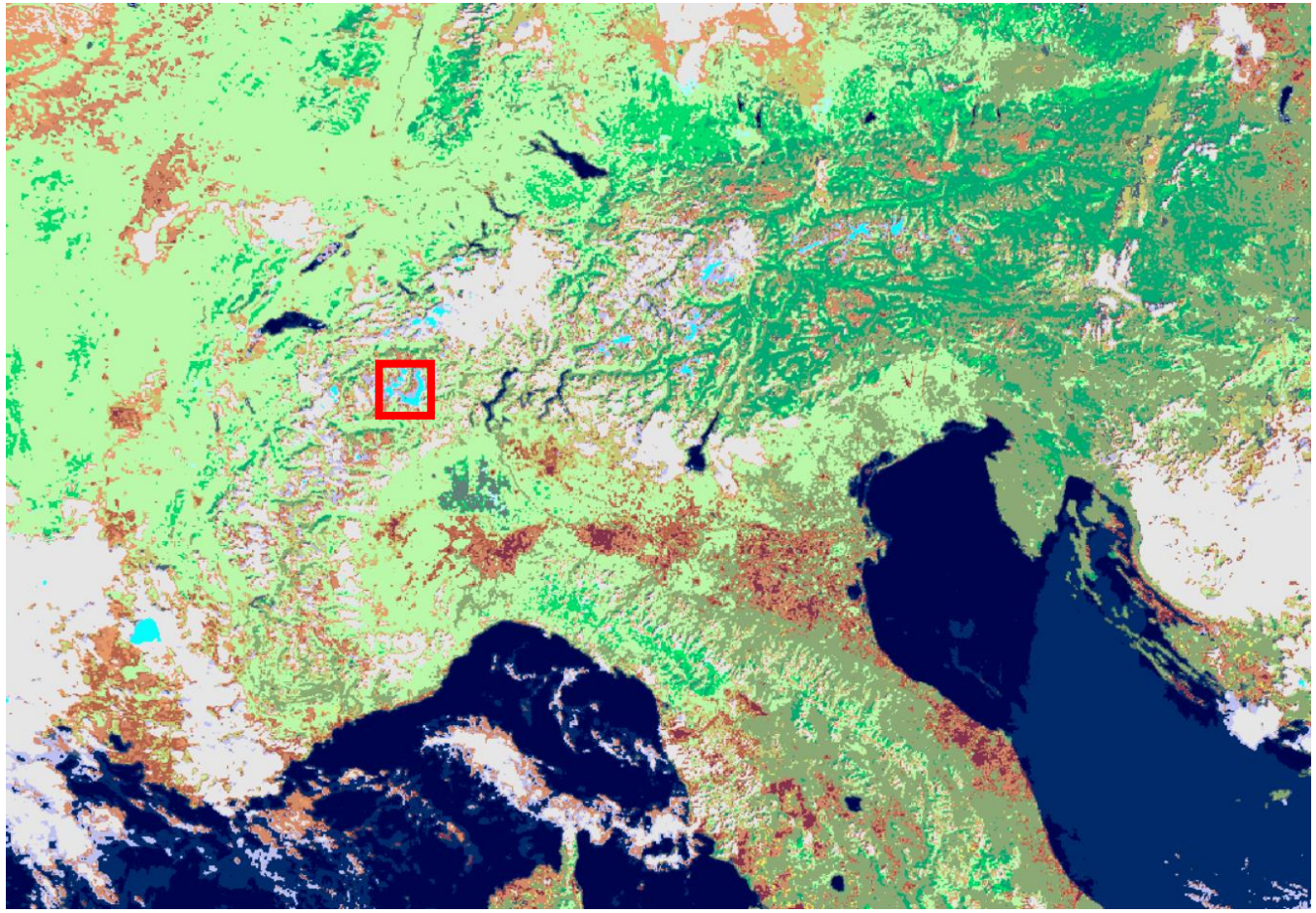
- stable spectral categories with semantic association(s)

33 spectral categories



First look: 8 September 2014, METOP1

33 spectral categories



33 spectral categories

- SVHNIR
- SVLNIR
- AVHNIR
- AVLNIR
- WV
- VSH_VWA_TWASH
- SHRBRHNIR
- SHRBRLNIR
- HRBCR
- WR
- PB
- GH
- VBBB
- BBB
- SBB
- ABB
- DBB
- WBBorBBSH
- NIRPBB
- BA
- DPWASH
- SLWASH
- TWASH
- SASLWA
- CL
- SMKPLM
- TNCLV
- TNCLWA_BB
- SN_WAICE
- SHSN
- SH
- FLAME
- UN

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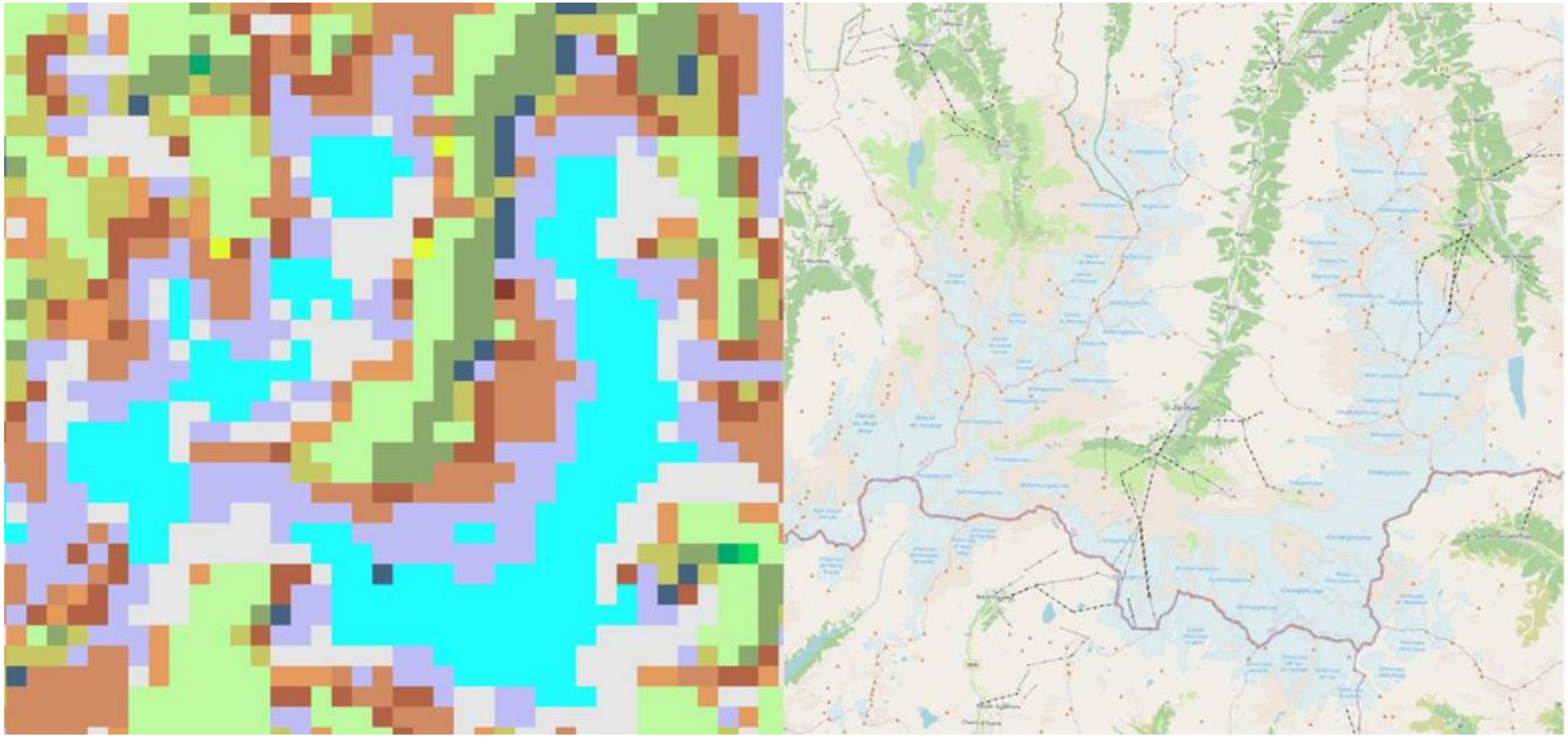
First look: 8 September 2014, METOP1



OpenStreetMap data

33 spectral categories

- SVHNIR
- SVLNIR
- AVHNIR
- AVLNIR
- WV
- VSH_VWA_TWASH
- SHRBRHNIR
- SHRBRLNIR
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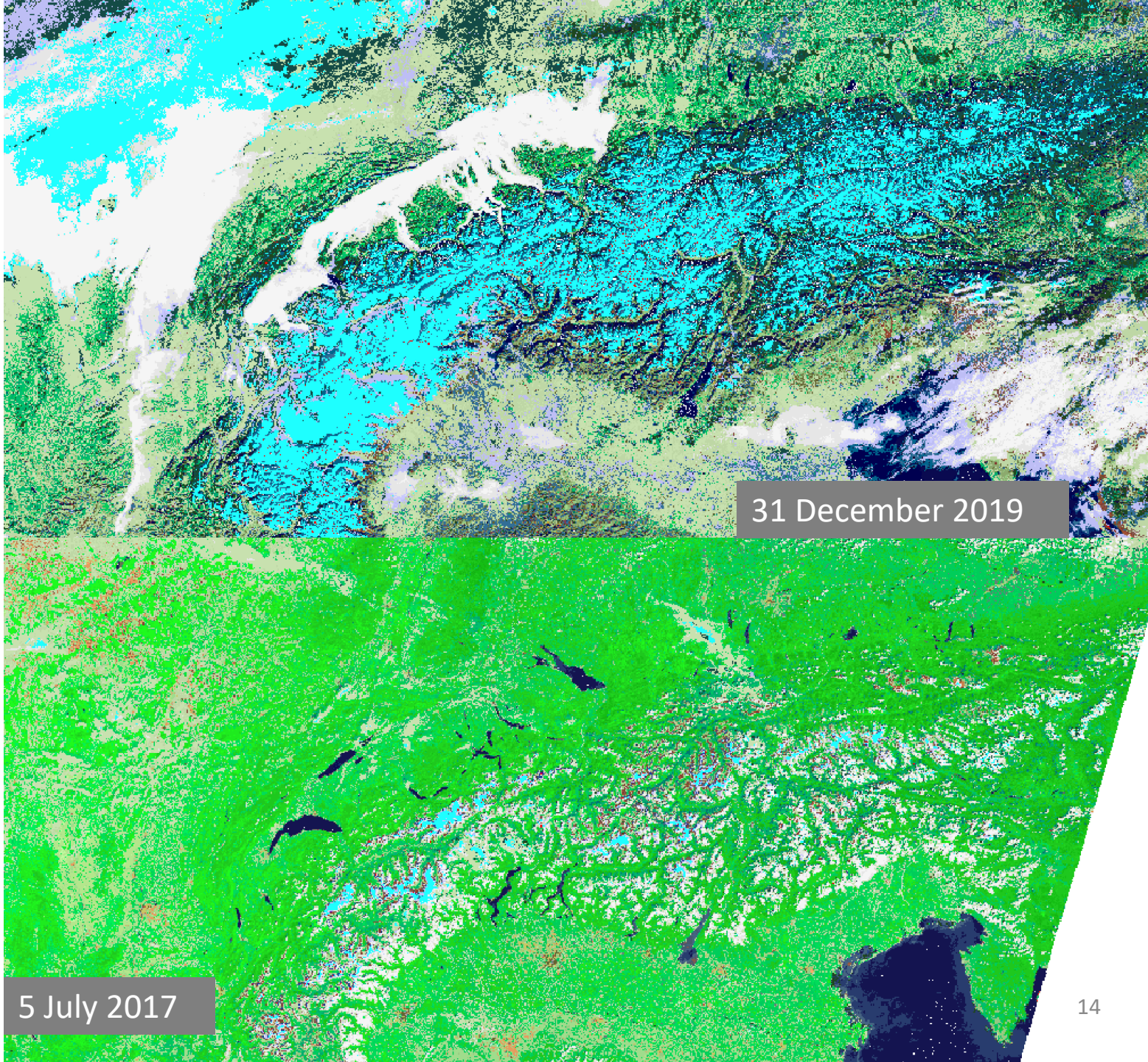
- TWASH
- SASLWA
- CL
- SMKPLM
- TNCLV
- TNCLWA_BB
- SN_WAICE
- SHSN
- SH
- FLAME
- UN

Sentinel-3 SLSTR

- all available data covering most of Switzerland
  - processed to L1C and to better match AVHRR data (Dr. H. Weber, Uni Bern, 2022)



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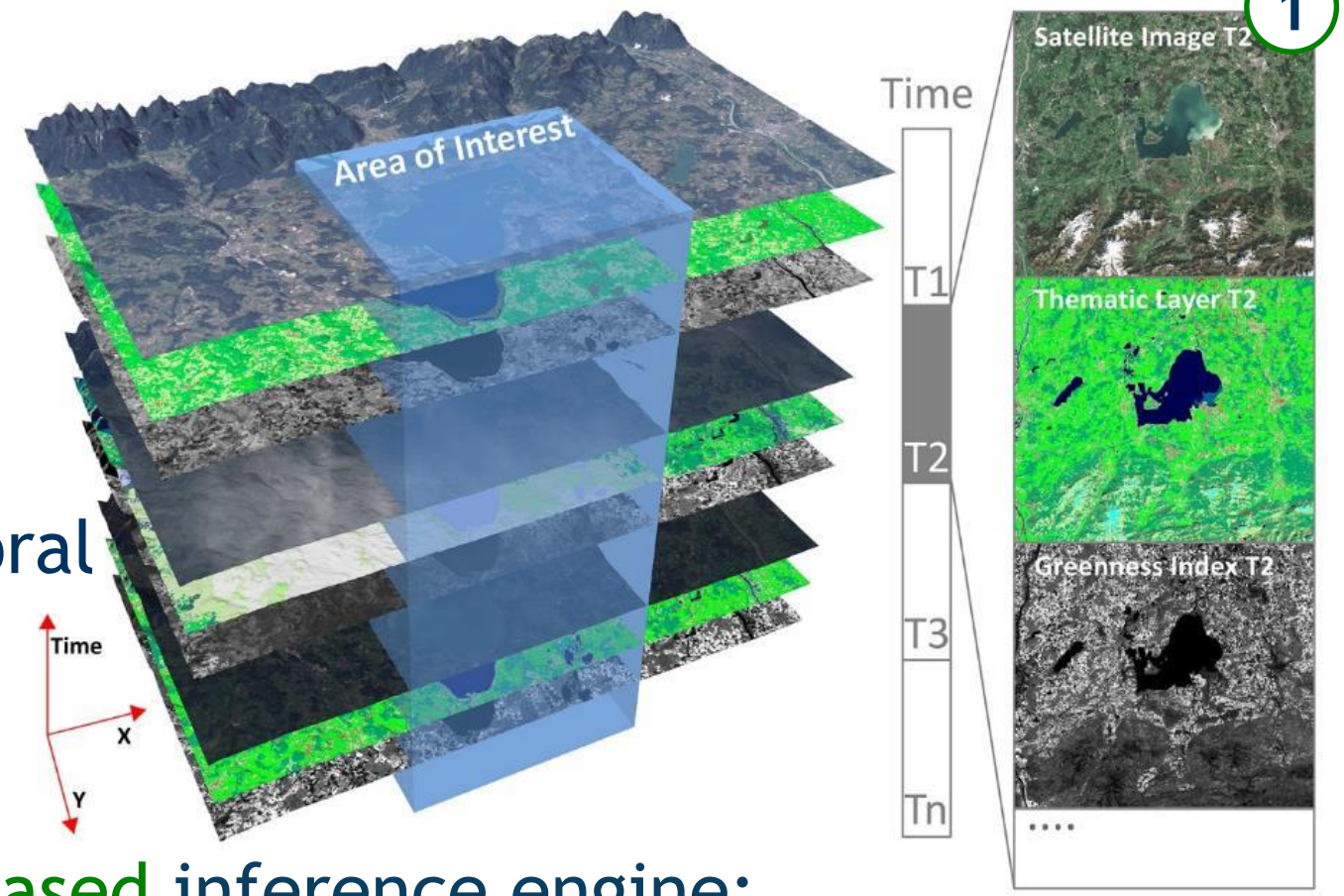
Semantic EO data cube



1

Imagery: reflectance and geometry AVHRR and S3-SLSTR (5+yrs)

Automated semantic enrichment: SIAM (5+yrs)

EO-derived ECVs: NDVI, FSC, LSWT (40+ years)

\+ additional (open) information (e.g. DEM, CLC)

2

Data cube technology: spatio-temporal coordinates

3

Web-based inference engine: user-defined AOI + query

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Tiede, Dirk; Baraldi, Andrea; Sudmanns, Martin; Belgiu, Mariana; Lang, Stefan (2017): Architecture and prototypical implementation of a semantic querying system for big Earth observation image bases. In European journal of remote sensing 50 (1), pp. 452–463. DOI: 10.1080/22797254.2017.1357432.

Spatial Extent: COSMO-1E by MeteoSwiss

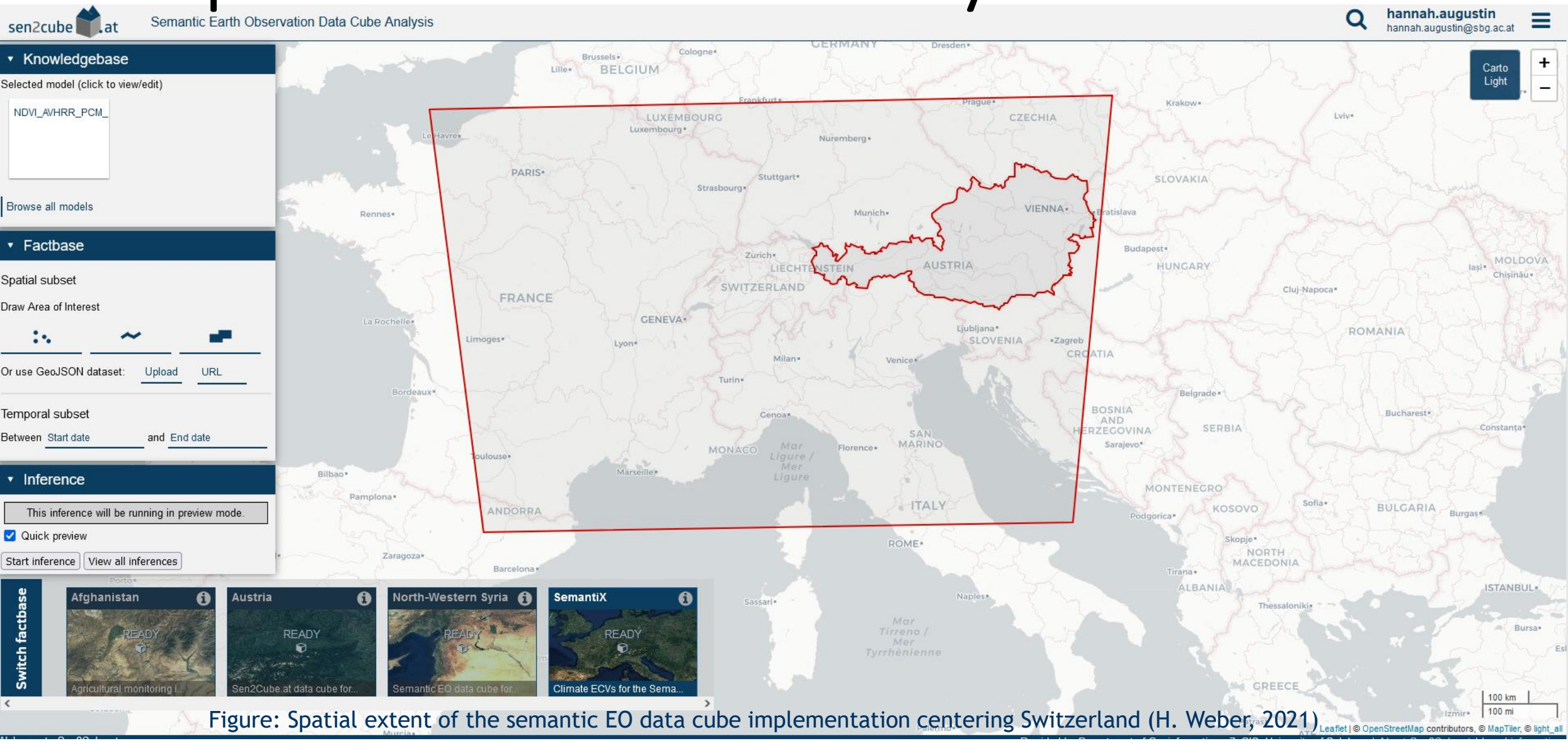
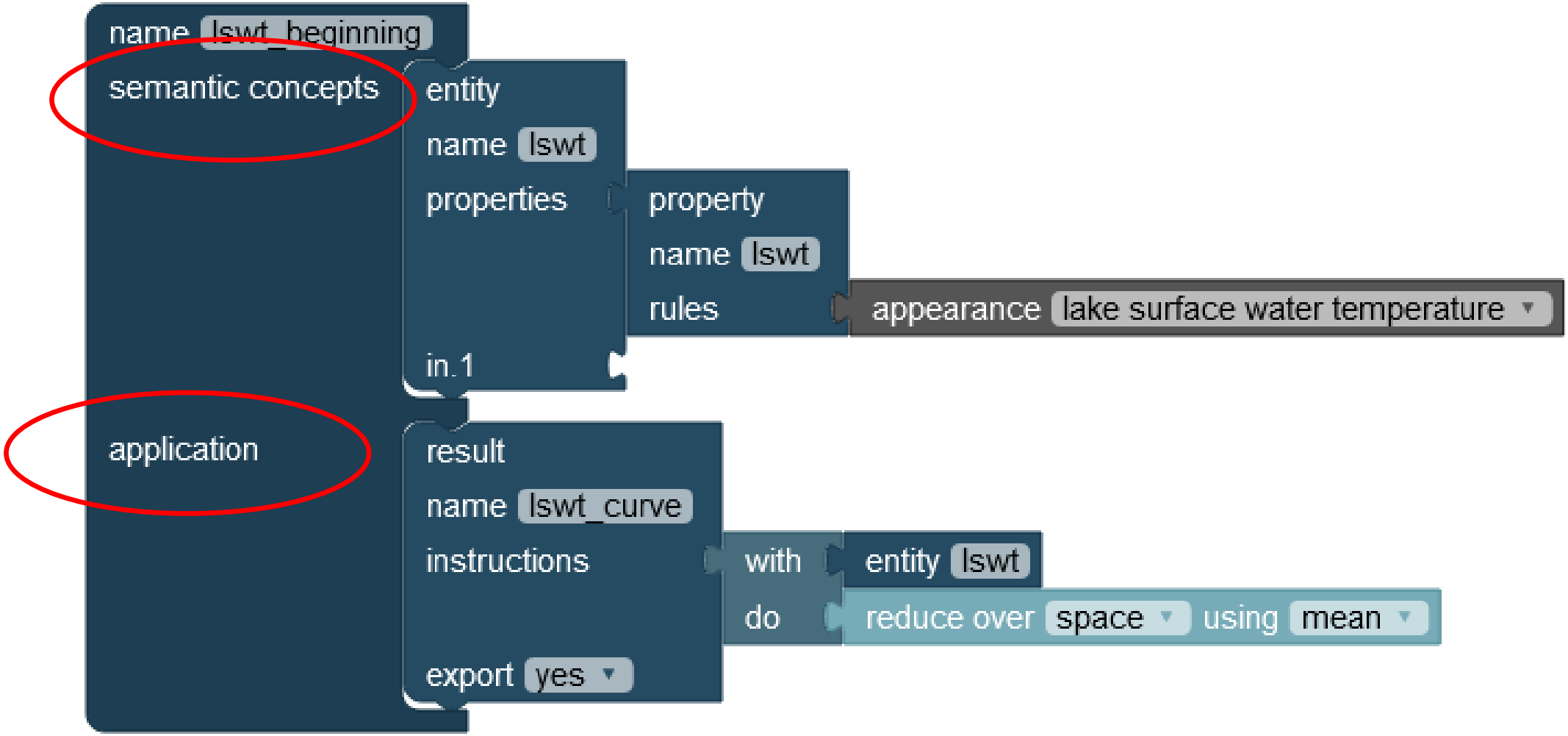


Figure: Spatial extent of the semantic EO data cube implementation centering Switzerland (H. Weber, 2021)

Sudmanns, M., Augustin, H., van der Meer, L., Baraldi, A., & Tiede, D. (2021). The Austrian Semantic EO Data Cube Infrastructure. *Remote Sensing*, *13*(23), 4807. https://doi.org/10.3390/rs13234807



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App integration

- citizen science mobile app
- location-based queries
- long-term trends based on the AVHRR ECVs

SPOTTERON

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What does this have to do with land ice and snow?

While currently geographically focused on the Alps …

… the approach is generic, applicable anywhere there is optical EO data.

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2010-2019

Custom AOI

Details for inference #6248

Results

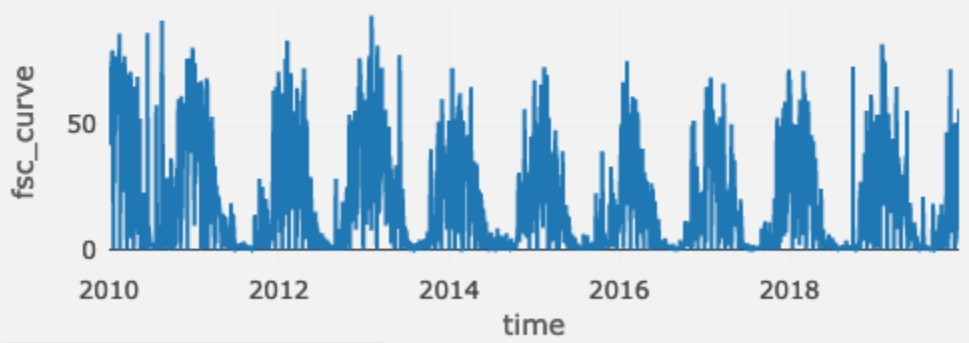
Average fractional snow cover over time

Legend

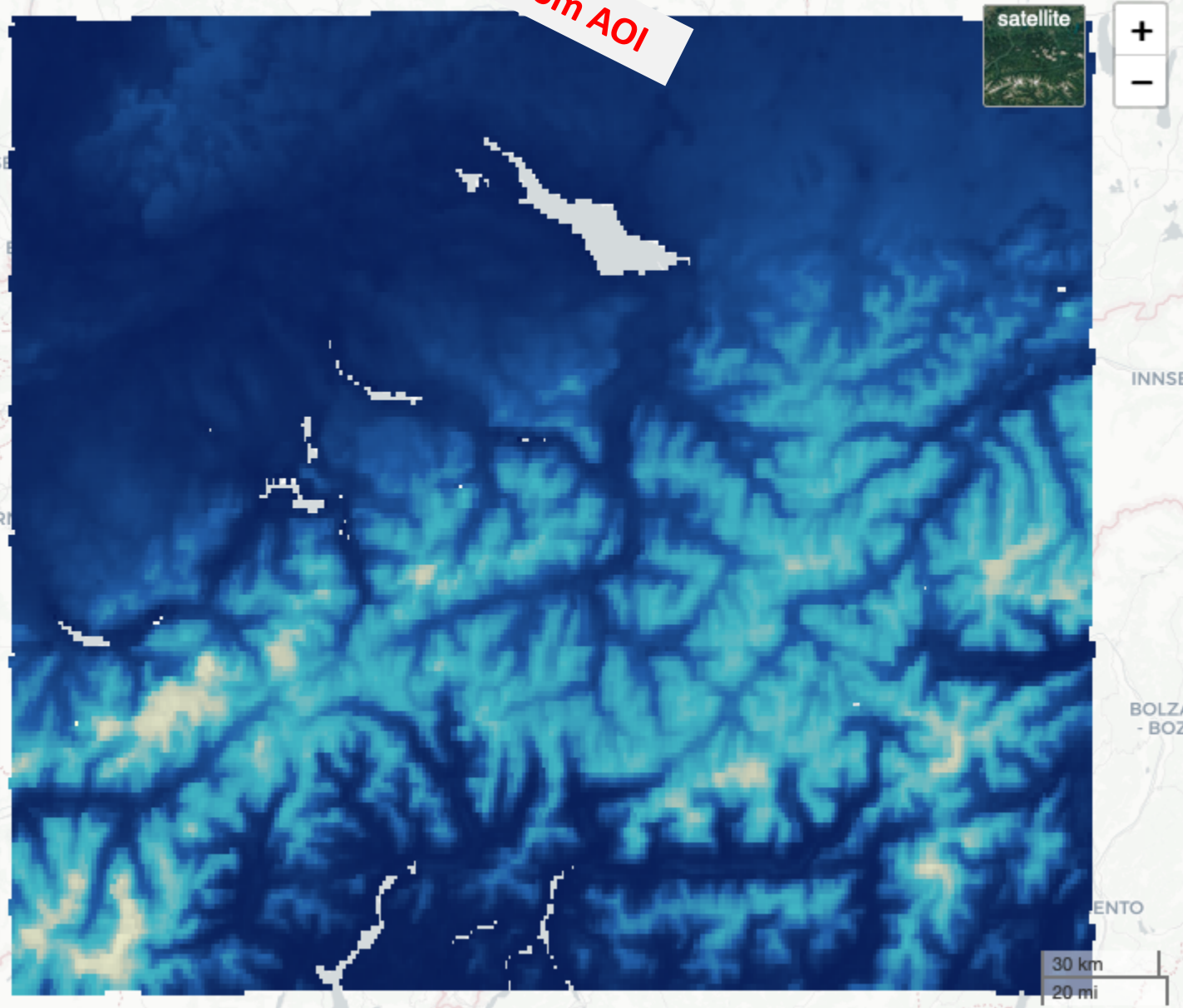
0 — 100

Download GeoTIFF (610.9 KB) | Copy OGC WMS Link

Average fractional snow cover over AOI



Download data (CSV) (107.1 KB)



2004

Custom AOI

Details for inference #6208

Results

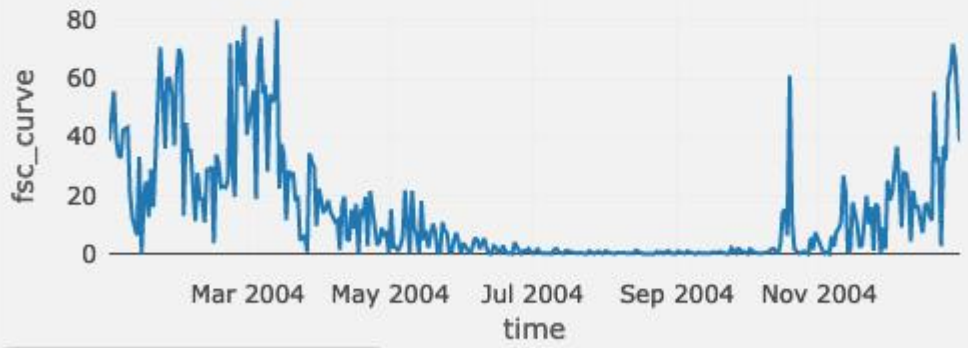
Average fractional snow cover over time

Legend

0 — 98

Download GeoTIFF (2.6 MB) | Copy OGC WMS Link

Average fractional snow cover over AOI



Download data (CSV) (13.4 KB)

satellite

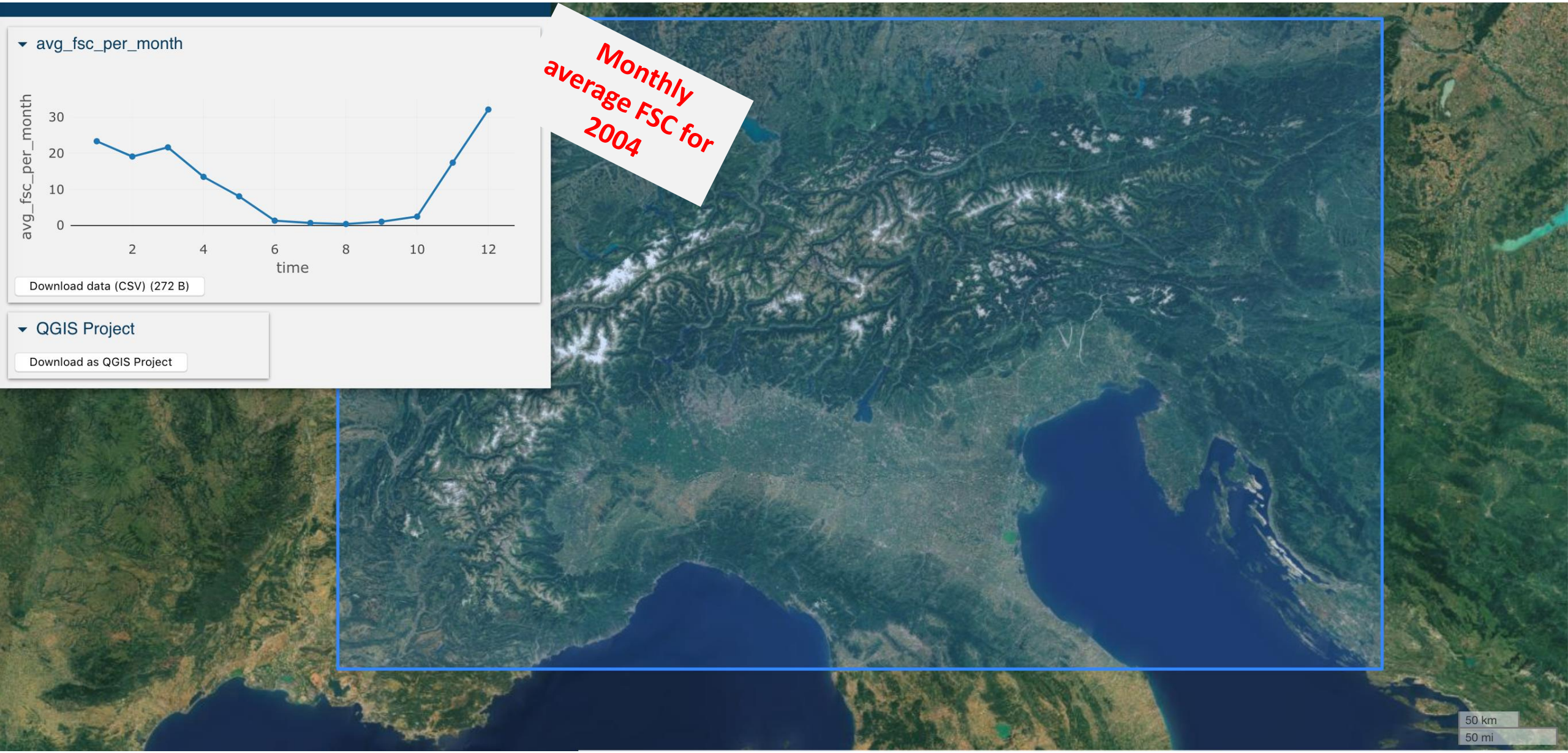
Strasbourg

Triest

Nimes

50 km
50 mi

Leaflet | © OpenStreetMap contributors, © MapTiler, © light_all



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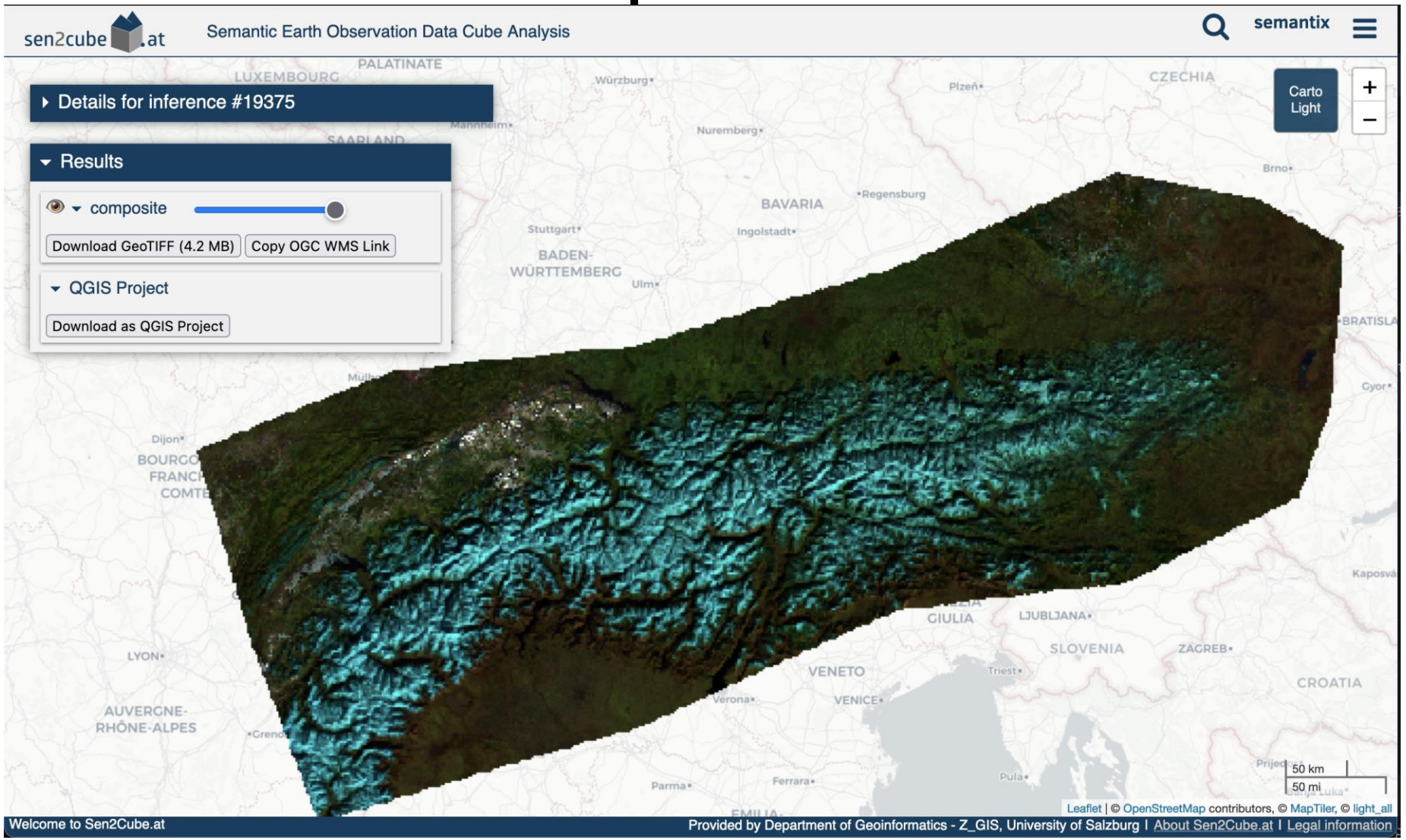
on-the-fly user-defined composites

- TOA reflectance for both sensors in combined access
- e.g. cloud-free 22-31.12.2019 (10 days, median TOA)



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More concretely:

- selection of cloud-free scenes beyond existing scene-wide metadata
  - search for suitable (optical) imagery
- physical-model-based enrichment can inform common indices
  - threshold setting – add semantically enabled pixel selection before calculating an index
  - categorical variability may be informative enough rather than identity
- ability to integrate other information, interpretations, uncertainty
  - … but also other products

Take-Aways

- Potential facilitator for EO-data access, exploration and analysis
  - convergence-of-evidence approaches
- semantic focus and semantic querying language offer different possibilities
  - e.g. stratification or pixel selection based on interpretations or user-defined entities
- multiple sensors, image-derived interpretations and other data or information
- towards a lower barrier of entry to multiple optical EO sensors
  - accessing data
  - conducting and sharing analysis towards transferable and repeatable queries/analysis
- We need more open solutions in the big EO data domain

Contact: hannah.augustin@plus.ac.at PhD Researcher, EO Analytics, Z_GIS, PLUS

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