geo engine

Explore and Combine Spatio-Temporal Data

Dr. Johannes Drönner

Philipps Universität Marburg

geo engine

Background

- Database Research Group @ University of Marburg, Germany

- research
  - spatio-temporal data processing
  - geo processing systems
  - deep-learning on satellite time-series

- Visualization, Analysis, and Transformation system
  - web-based
  - explorative
  - used @ GFBio, GEO BON, Eumetsat

What we are working on

- spatio-temporal data processing platform / engine
  - cloud-based (hosted / on-premise)
  - explorative analytics
  - sustainable

- transfer research → start up
- grant from German Ministry of Economics and Technology (EXIST)

⇒ geo engine

Data Scientists

Exploration & Analysis

Decision Makers

Apps & Reports

Customers

Co-Workers

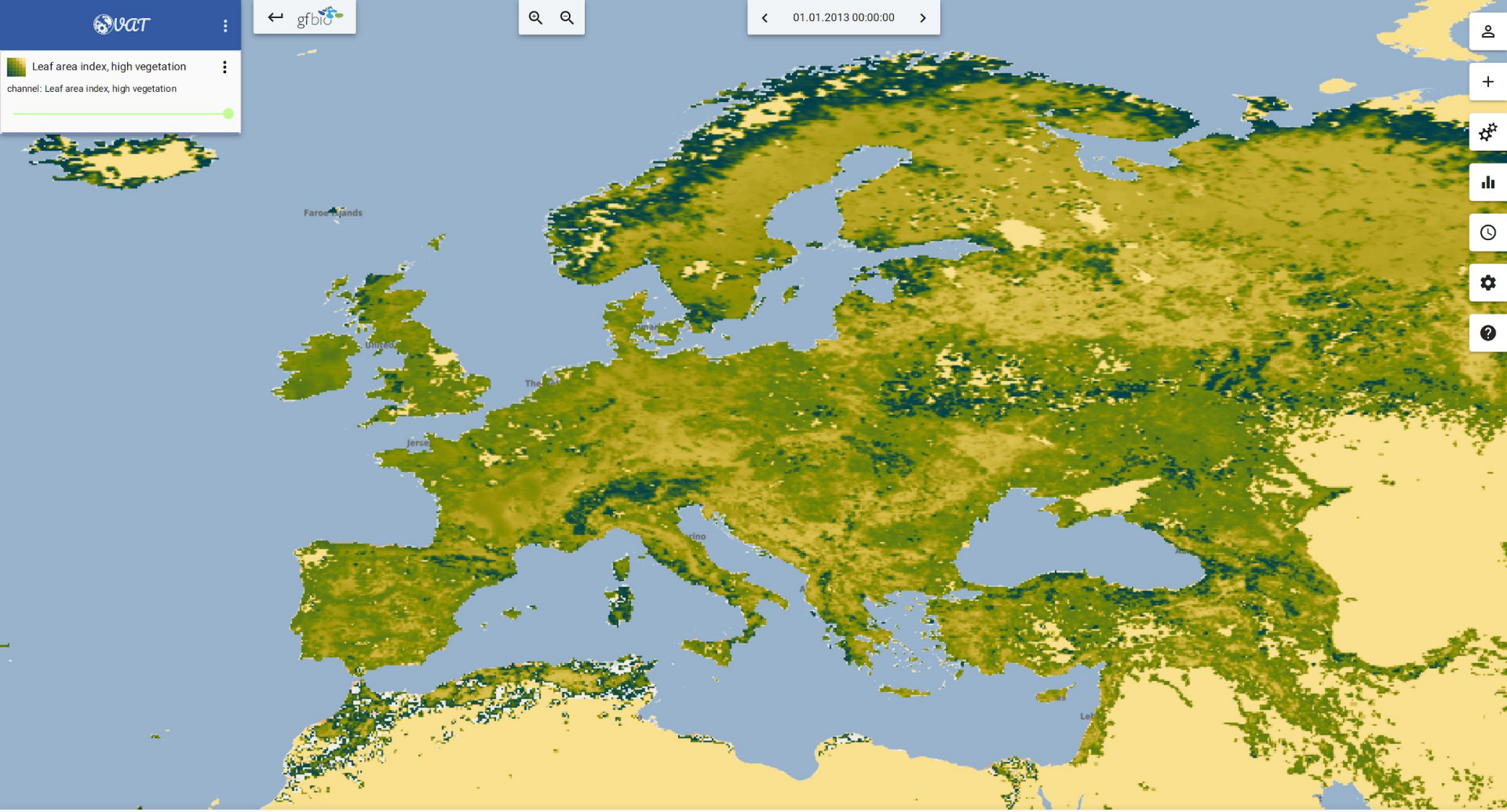
geo engine

Data Lakes

Copernicus
Europe's eyes on Earth

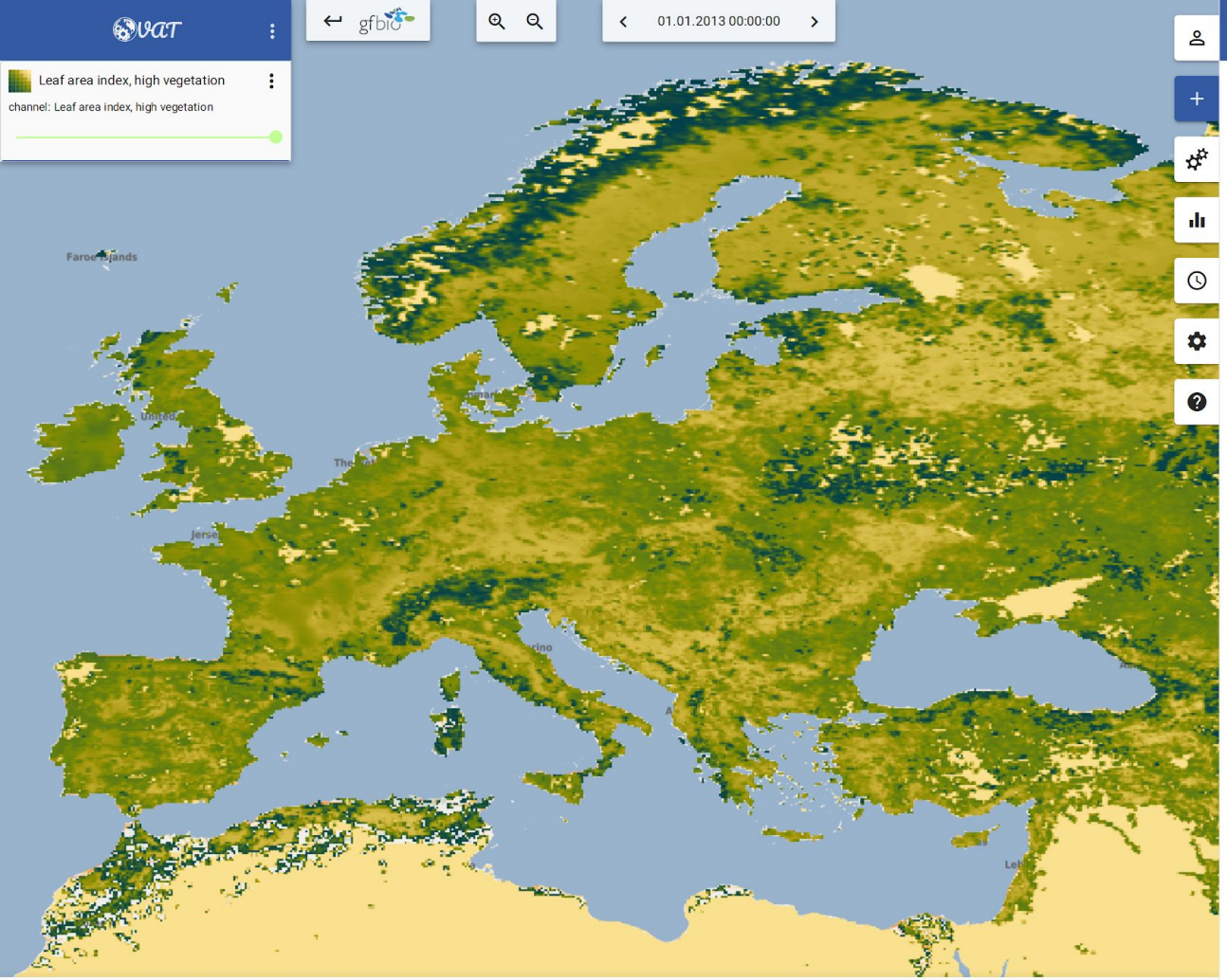
TensorFlow

Example with ERA5 Land Data



Data Table

Citations


vat
gfbio
01.01.2013 00:00:00
Leaf area index, high vegetation
channel: Leaf area index, high vegetation
Faroe Islands
United
Jersey
Add Data
Help
Data Repository
Generic data repository
ABCD Archives
Lookup GFBio ABCD archive
GFBio Search Baskets
Log in to display your GFBio search results
Draw Features
Draw features on the map
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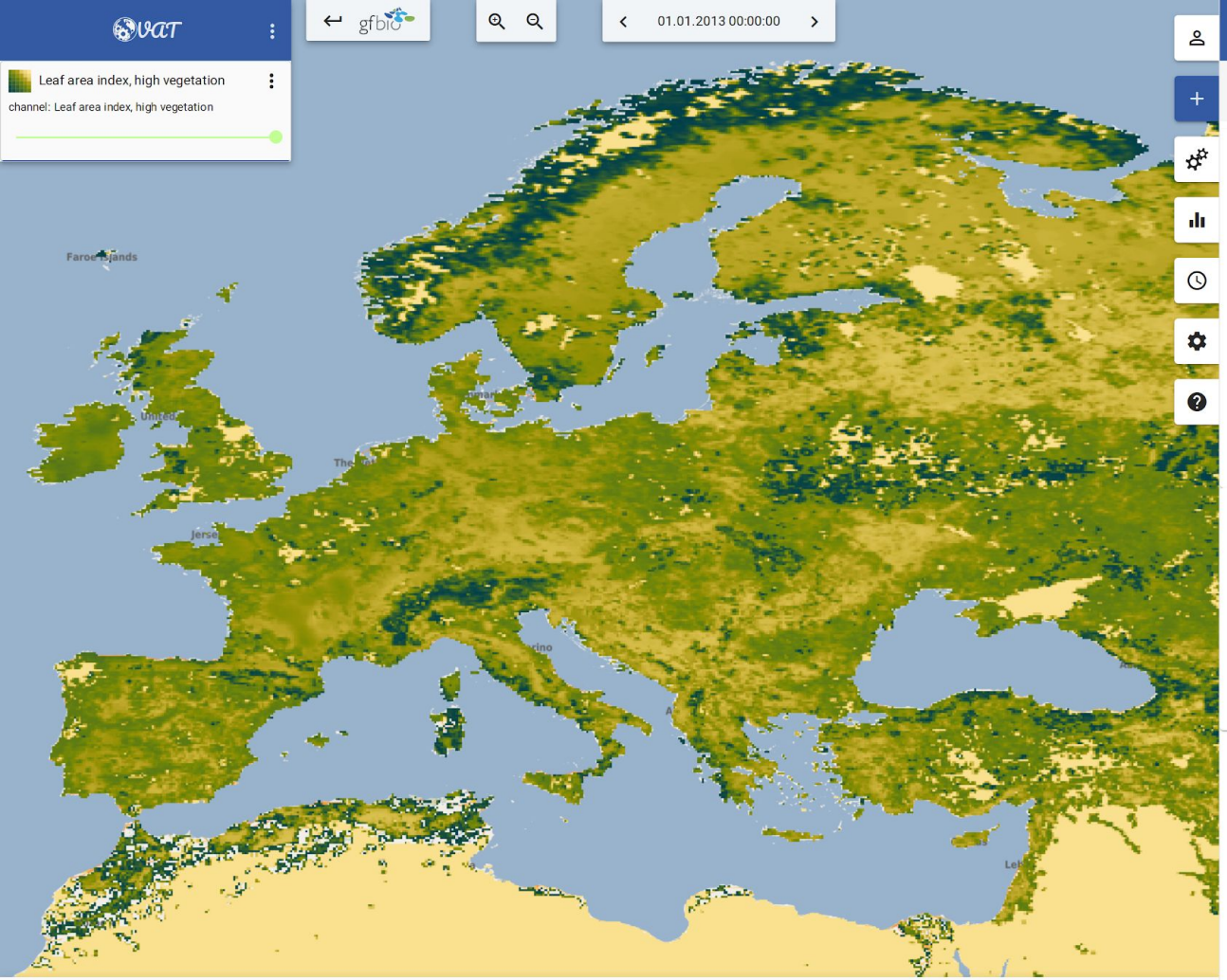
Log in to use custom vector data from, e.g., CSV files
Species Occurrences
Query data from GBIF
Country Selection
Select country borders
Data Table
Citations



Data Table

Citations

Data Repository

ERA5

ECMWF ERA5

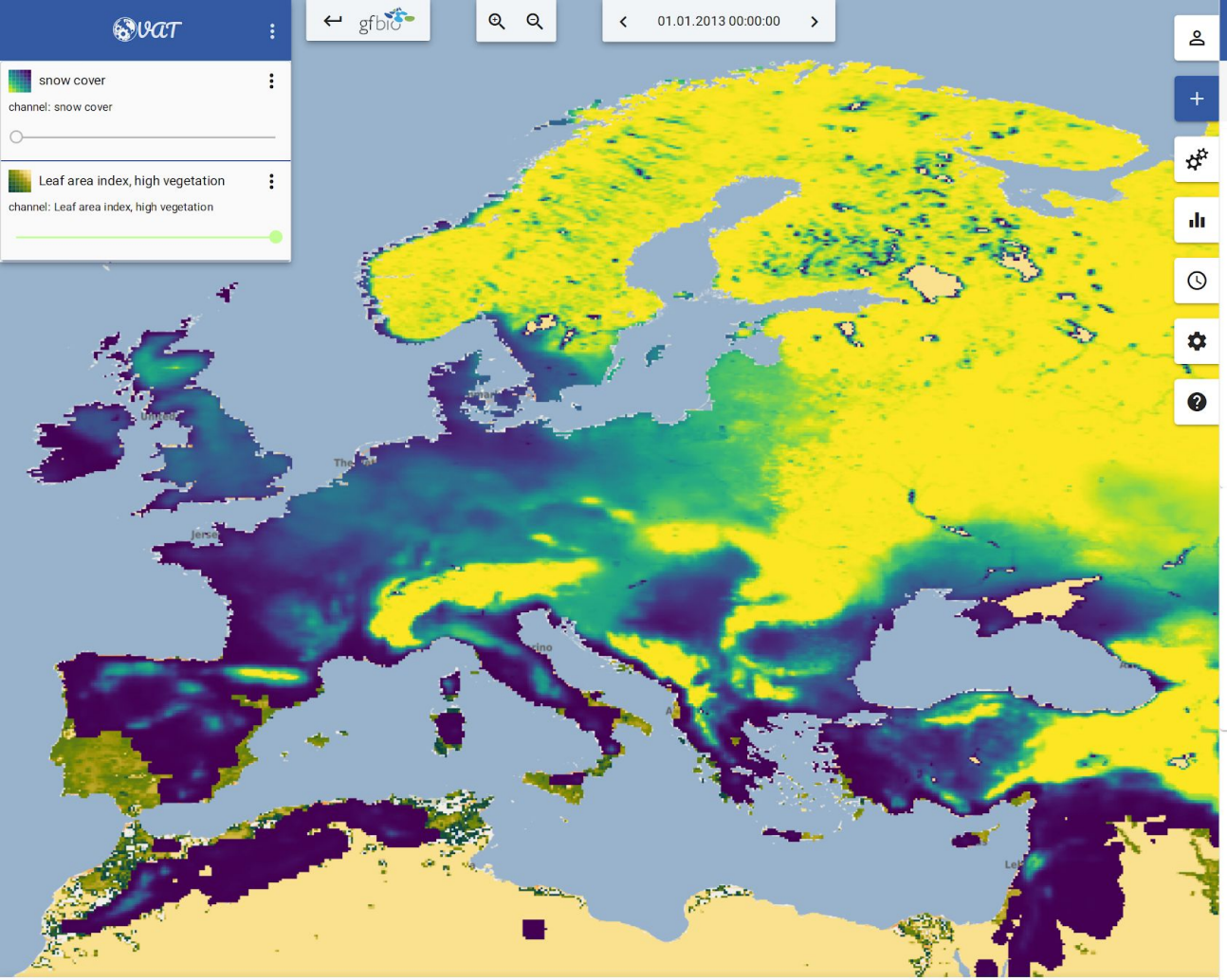
ECMWF ERA5

Channel	Measurement
snow cover	coverage (percent (%))
2m temperature	2 metre temperature (K)
Leaf area index, low vegetation	lai_lv (m**2 m**-2)
Leaf area index, high vegetation	lai_hv (m**2 m**-2)

ECMWF ERA5 Snow Cover

ECMWF ERA5

Channel	Measurement
snow cover	coverage (percent (%))



Data Table

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ERA5

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Channel	Measurement
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ECMWF ERA5 Snow Cover

ECMWF ERA5

Channel	Measurement
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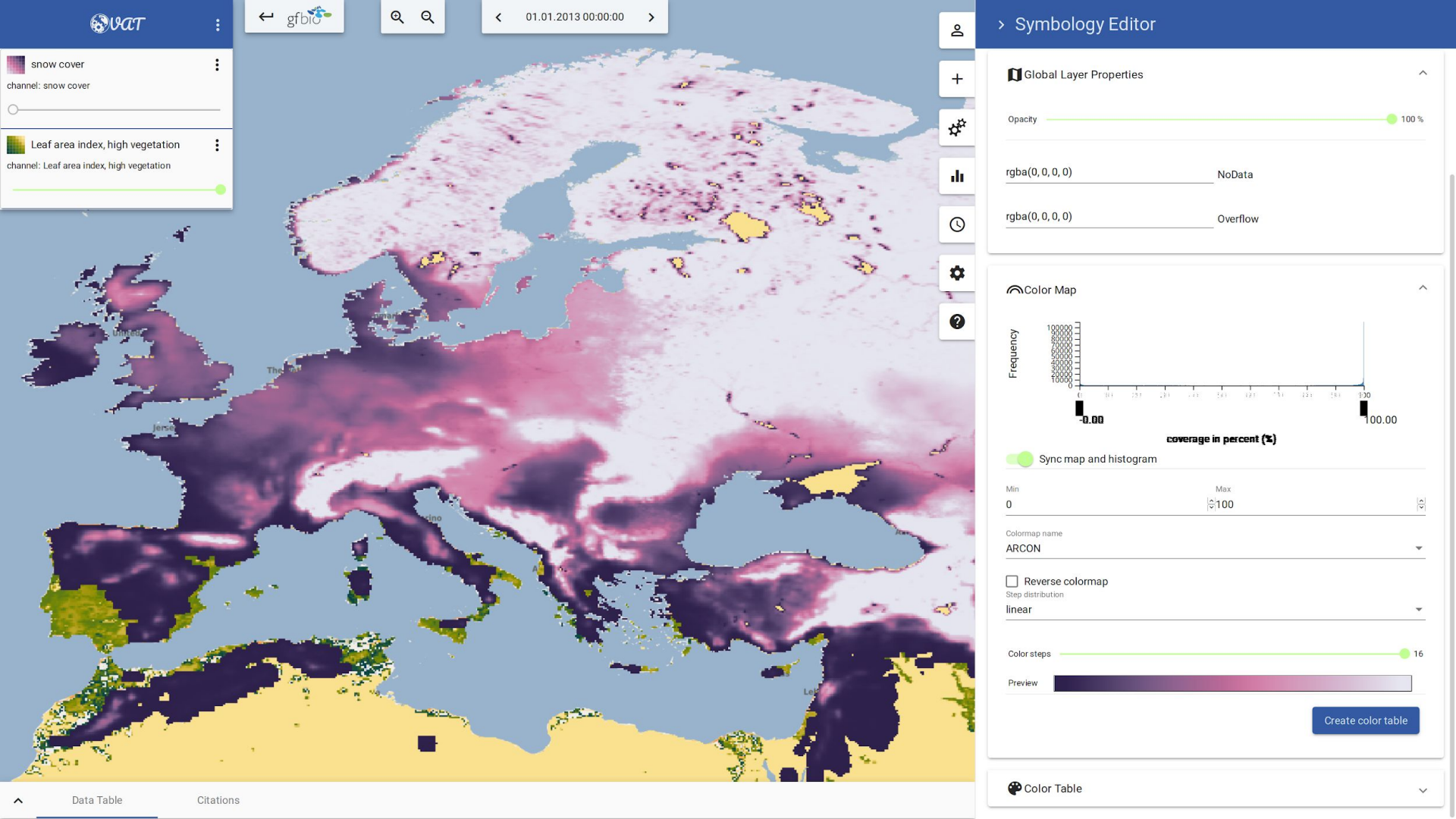
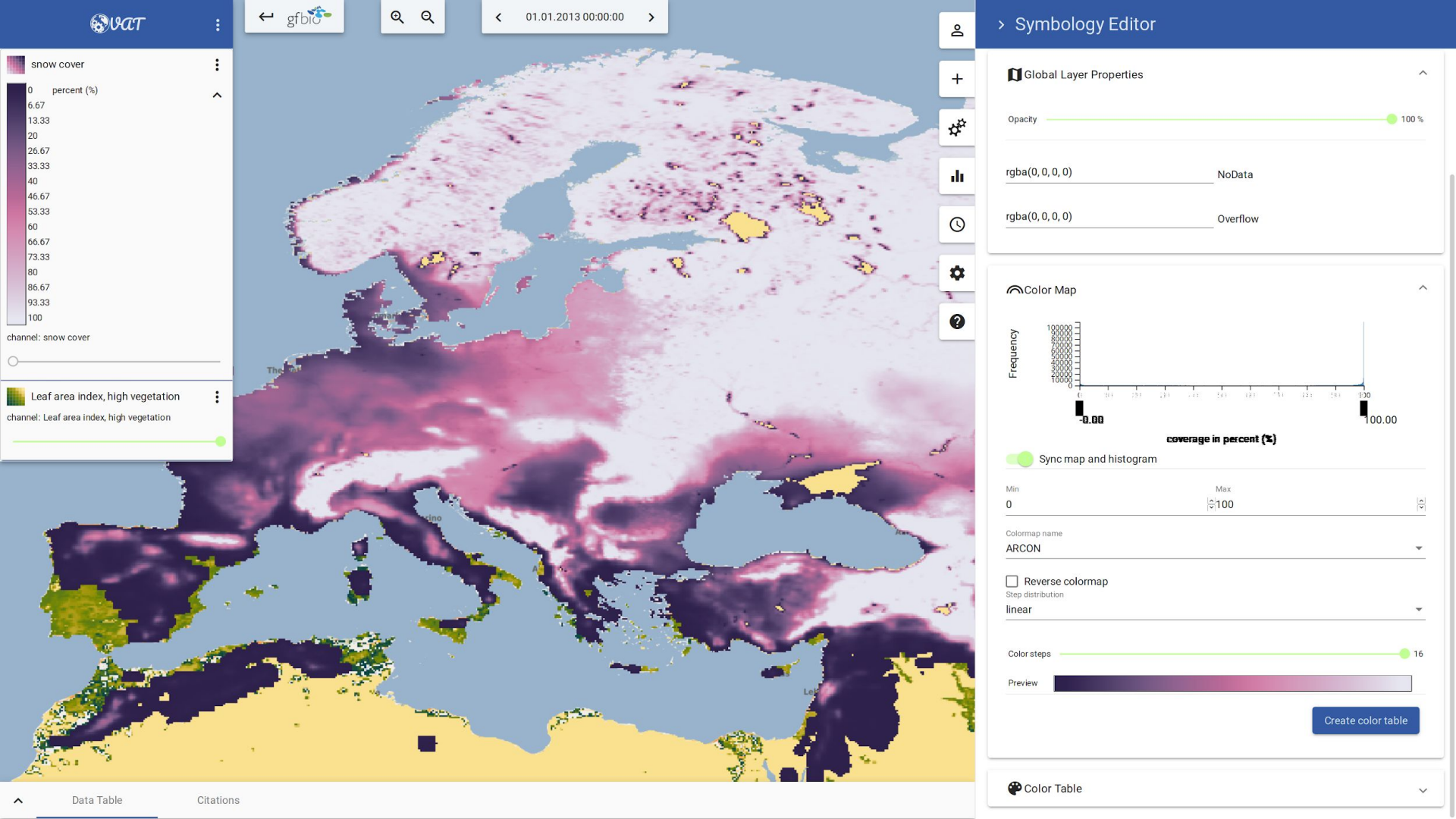

vat
gfbio
01.01.2013 00:00:00
snow cover
channel: snow cover
Leaf area index, high vegetation
channel: Leaf area index, high vegetation
Symbology Editor
Global Layer Properties
Opacity
100 %
rgba(0, 0, 0, 0)
NoData
rgba(0, 0, 0, 0)
Overflow
Color Map
Frequency
-0.00
100.00
coverage in percent (%)
Sync map and histogram
Min
0
Max
100
Colormap name
ARCON
Reverse colormap
Step distribution
linear
Color steps
16
Preview
Create color table
Color Table
Data Table
Citations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gfbio
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snow cover
0 percent (%)
6.67
13.33
20
26.67
33.33
40
46.67
53.33
60
66.67
73.33
80
86.67
93.33
100
channel: snow cover
Leaf area index, high vegetation
channel: Leaf area index, high vegetation
Data Table
Citations
Symbology Editor
Global Layer Properties
Opacity
100 %
rgba(0, 0, 0, 0)
NoData
rgba(0, 0, 0, 0)
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Color Map
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-0.00
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coverage in percent (%)
Sync map and histogram
Min
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Colormap name
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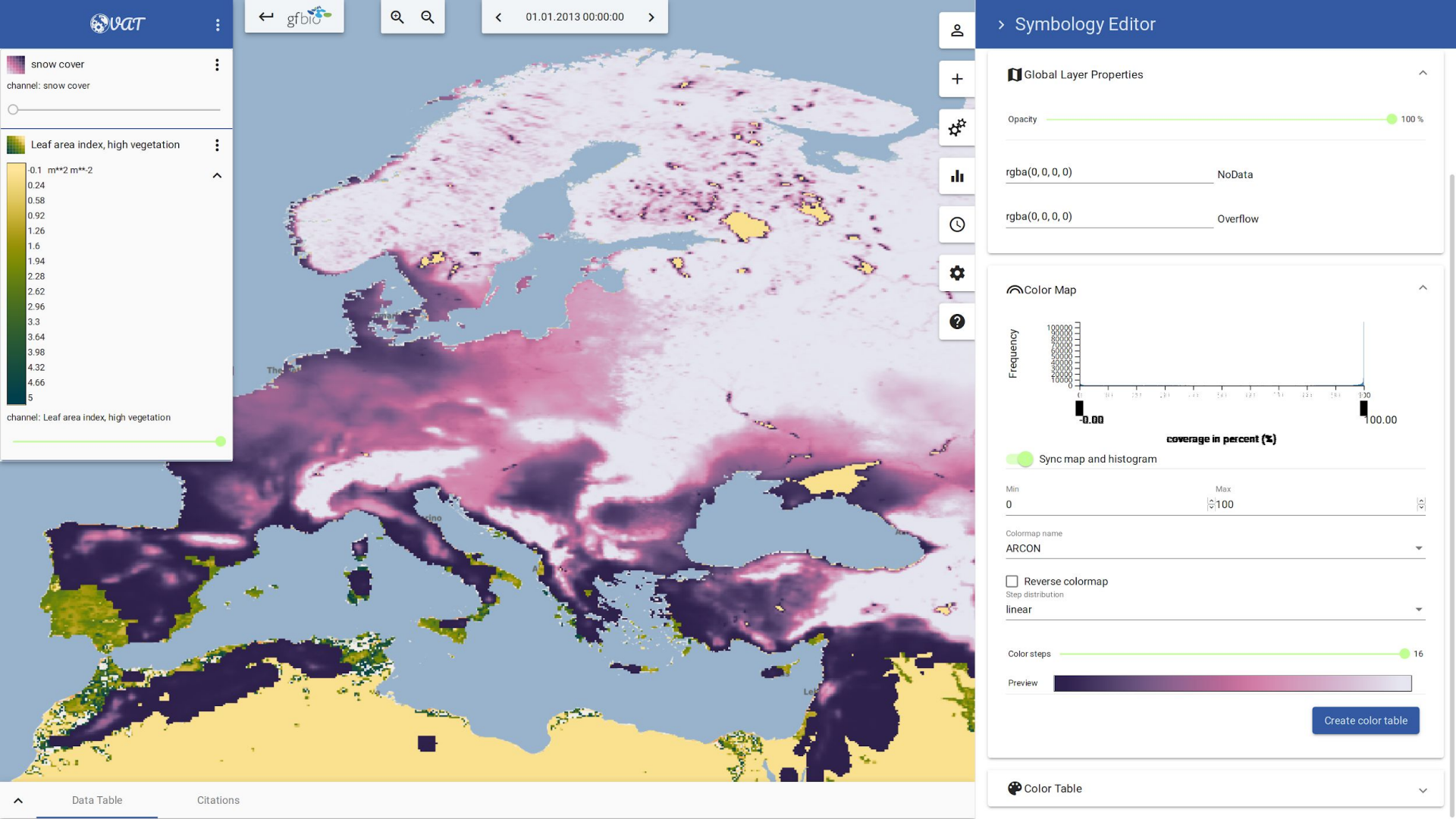
Create color table
Color Table


vat
gfbio
01.01.2013 00:00:00
snow cover
channel: snow cover
Leaf area index, high vegetation
-0.1 m**2 m**-2
0.24
0.58
0.92
1.26
1.6
1.94
2.28
2.62
2.96
3.3
3.64
3.98
4.32
4.66
5
channel: Leaf area index, high vegetation
Symbology Editor
Global Layer Properties
Opacity
100 %
rgba(0, 0, 0, 0)
NoData
rgba(0, 0, 0, 0)
Overflow
Color Map
Frequency
-0.00
100.00
coverage in percent (%)
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Step distribution
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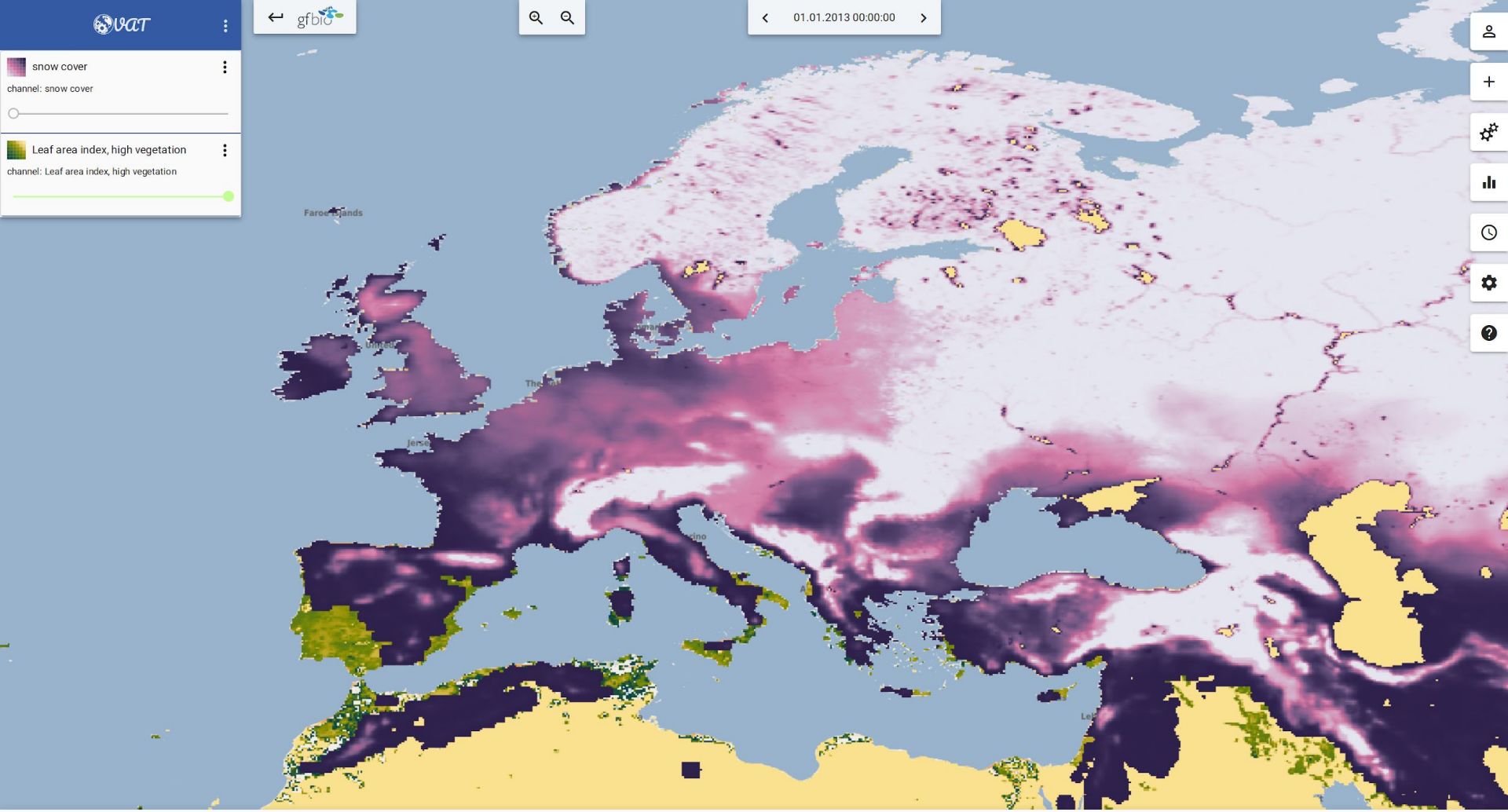
Create color table
Color Table
Data Table
Citations



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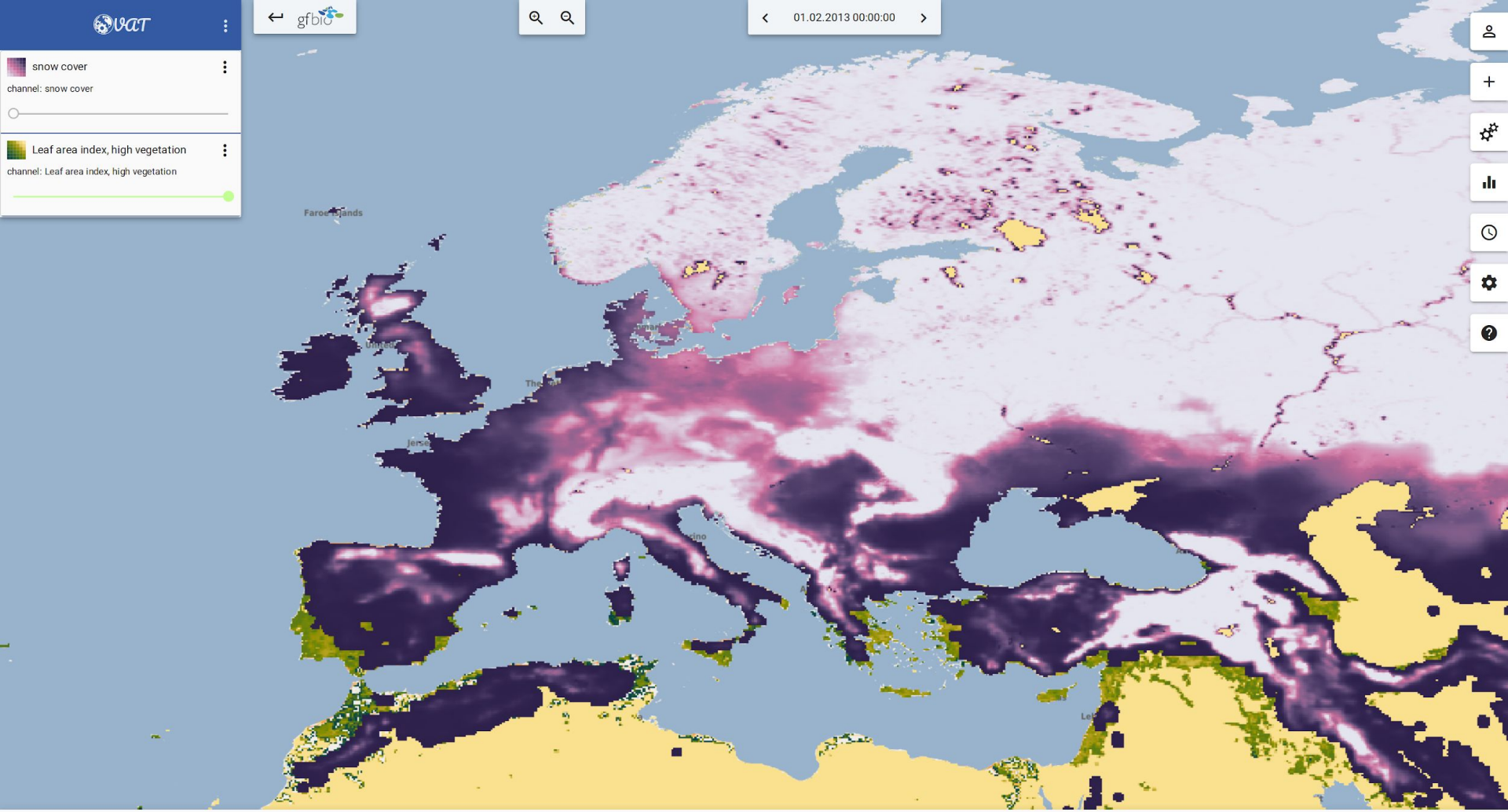

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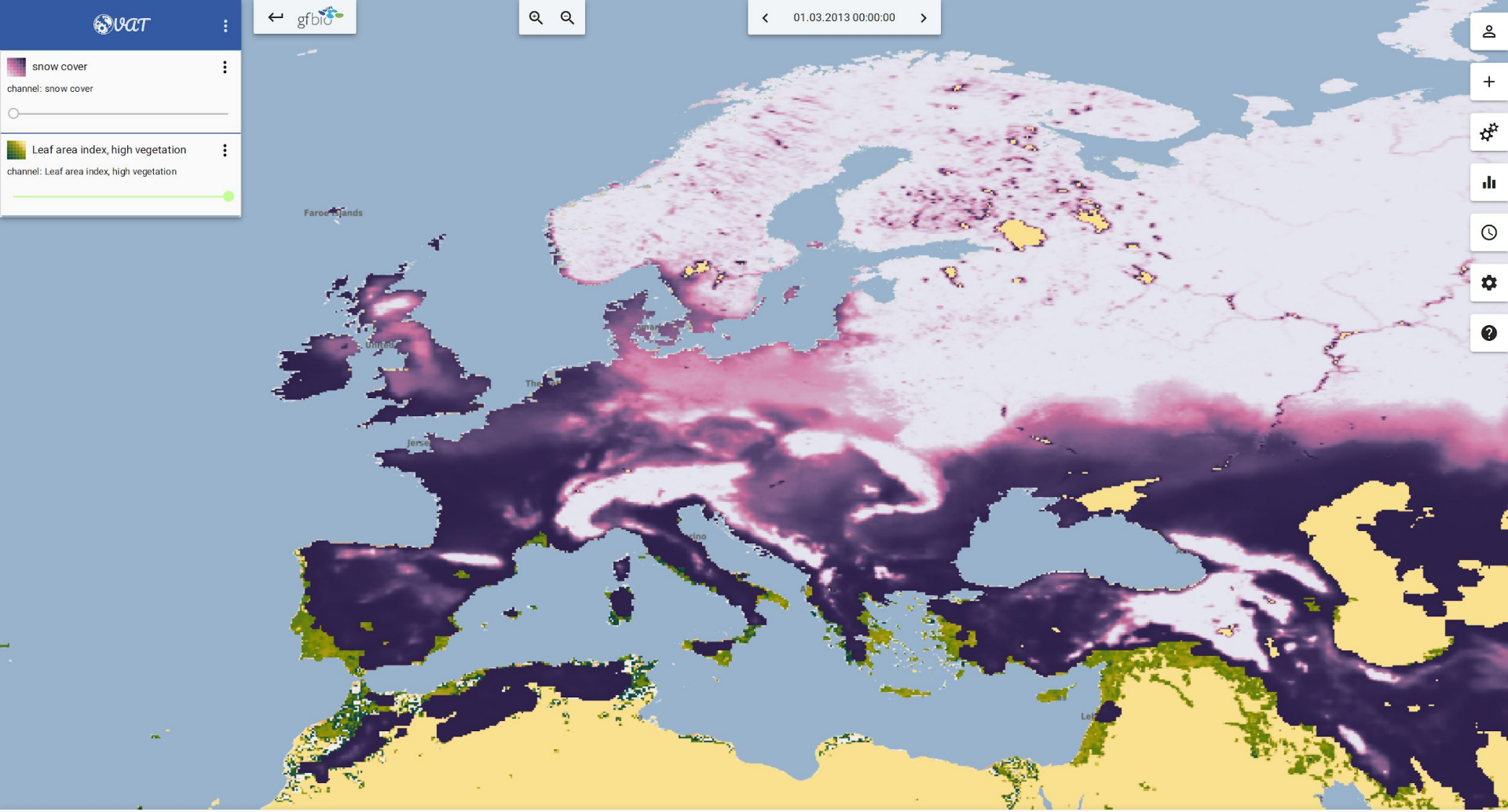

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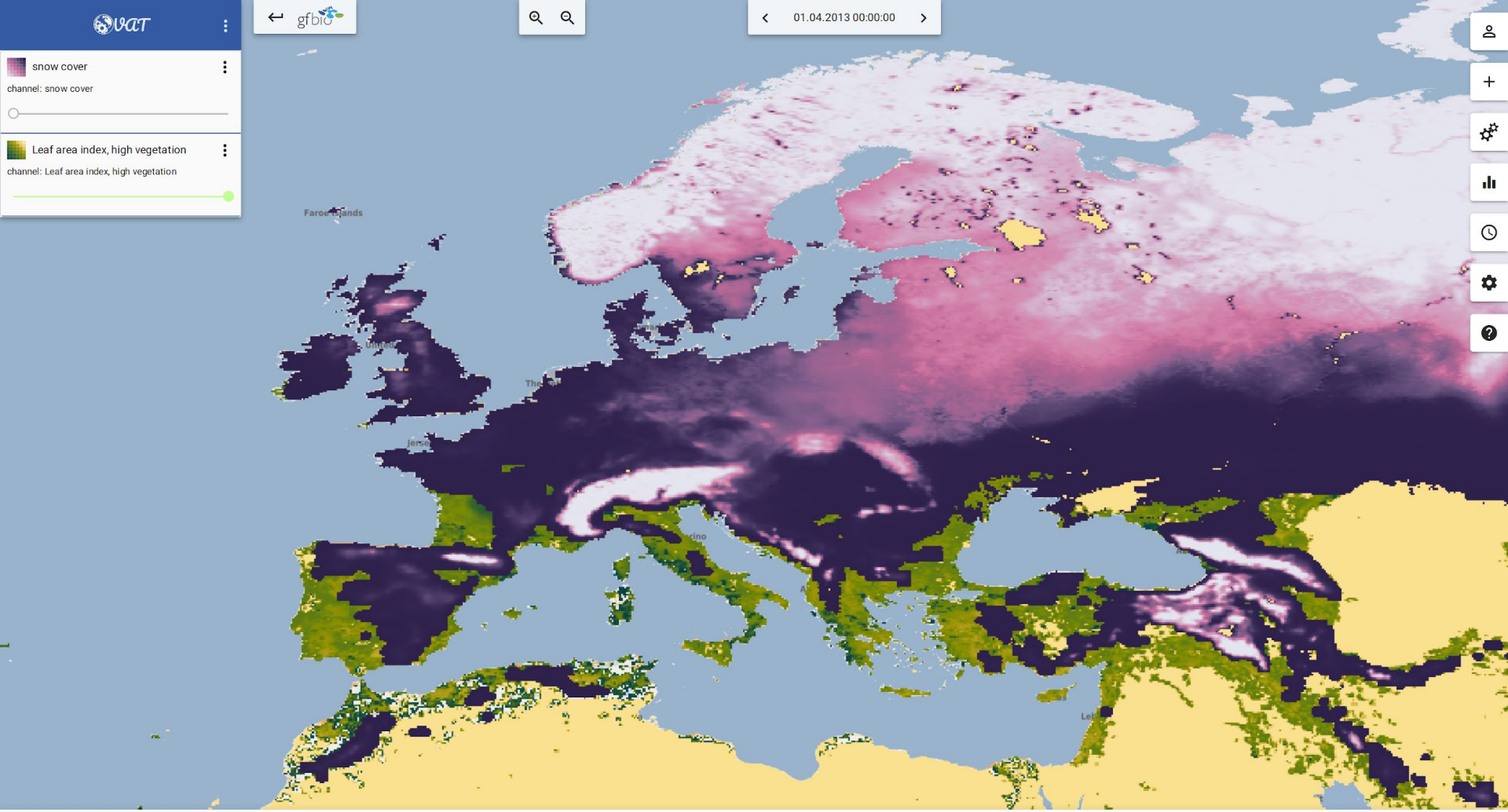

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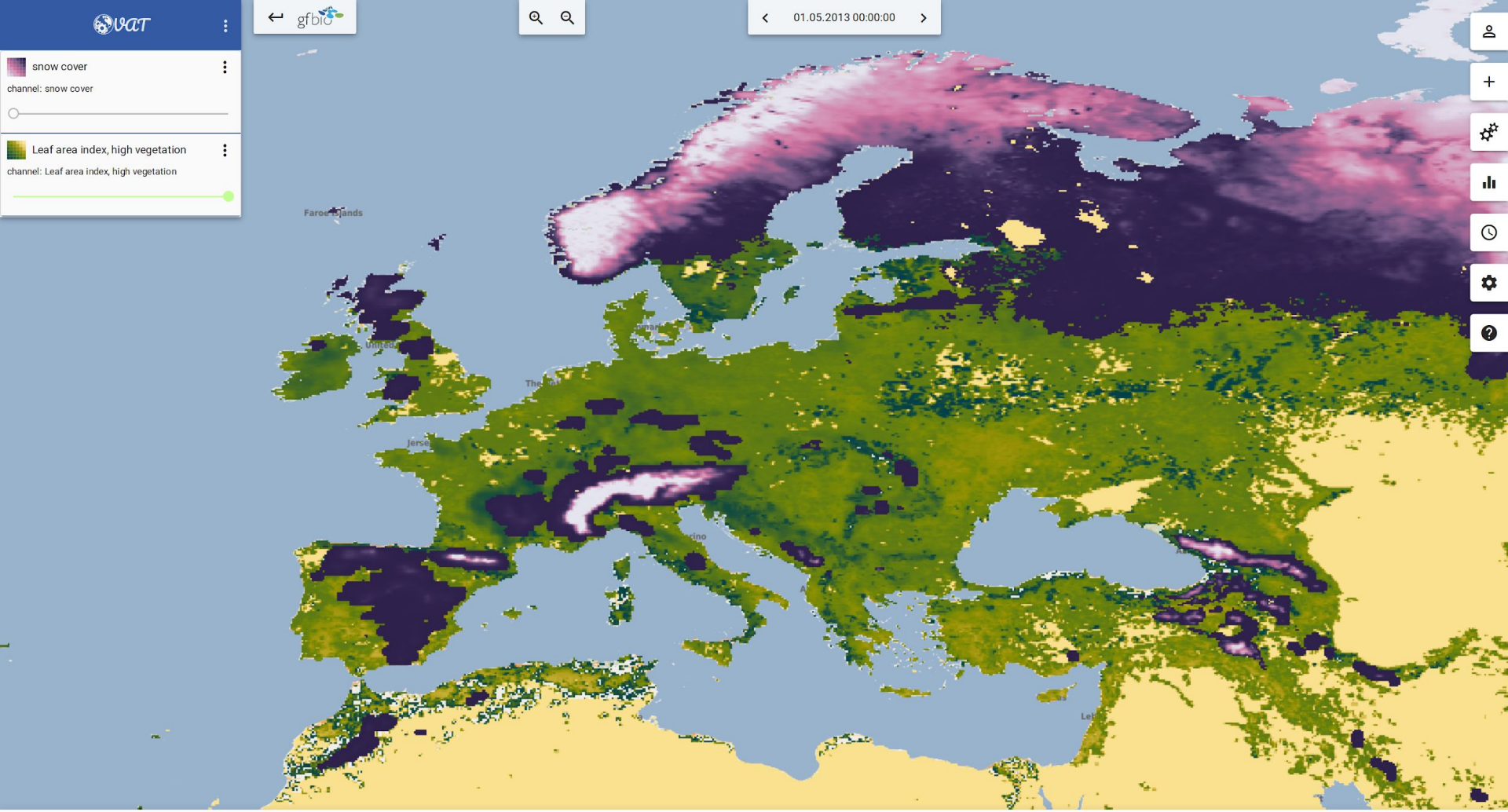

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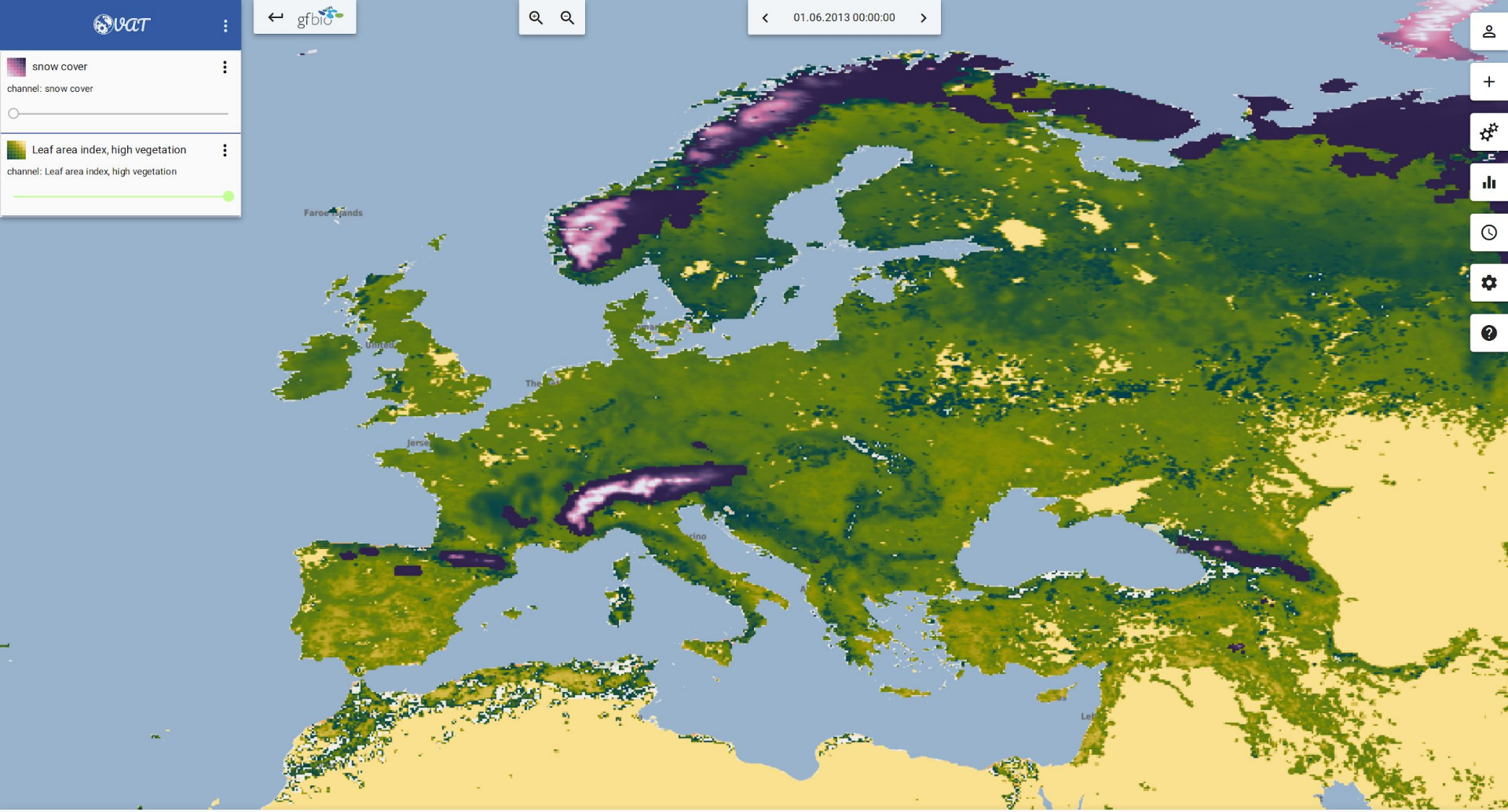

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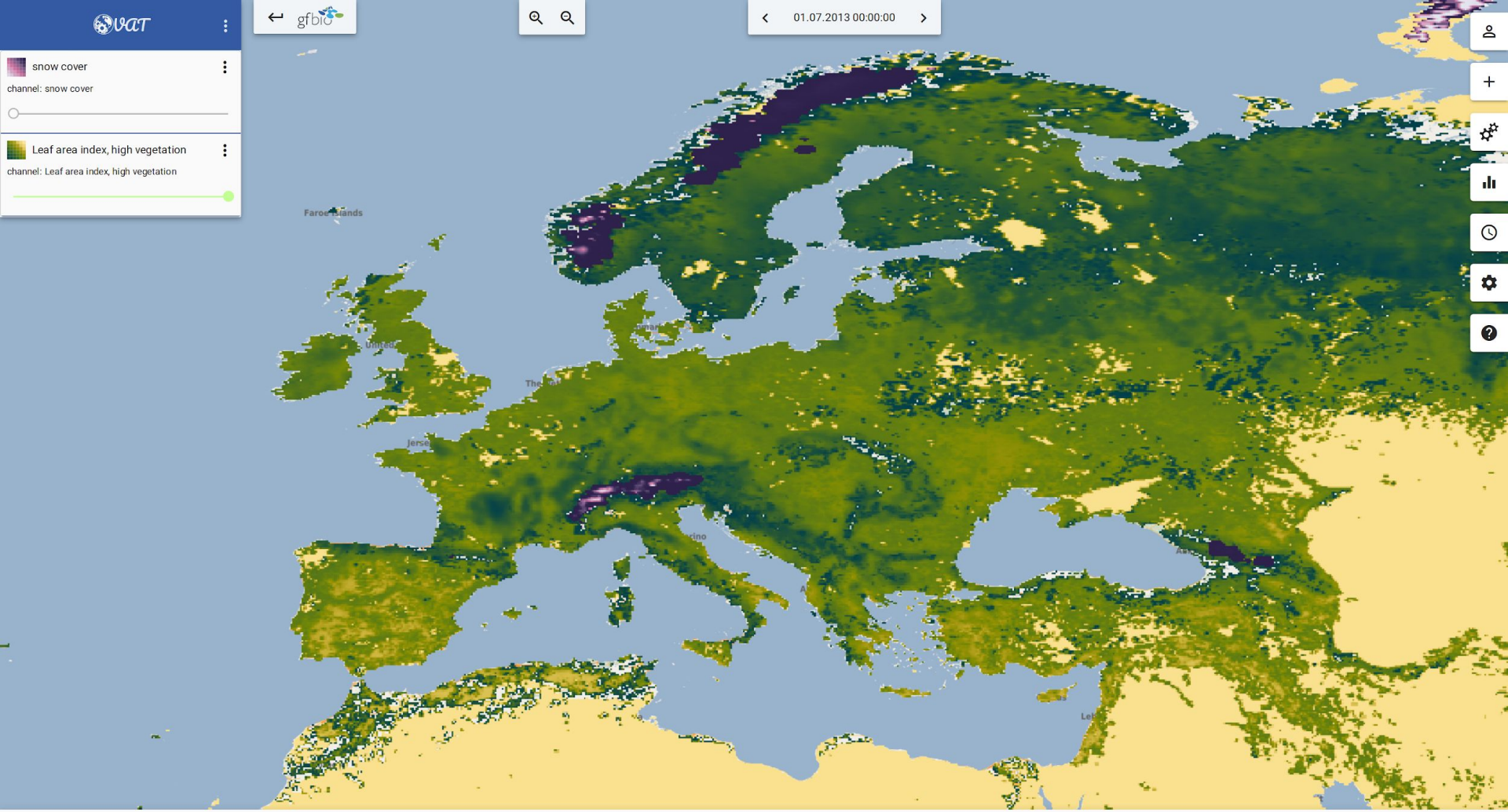
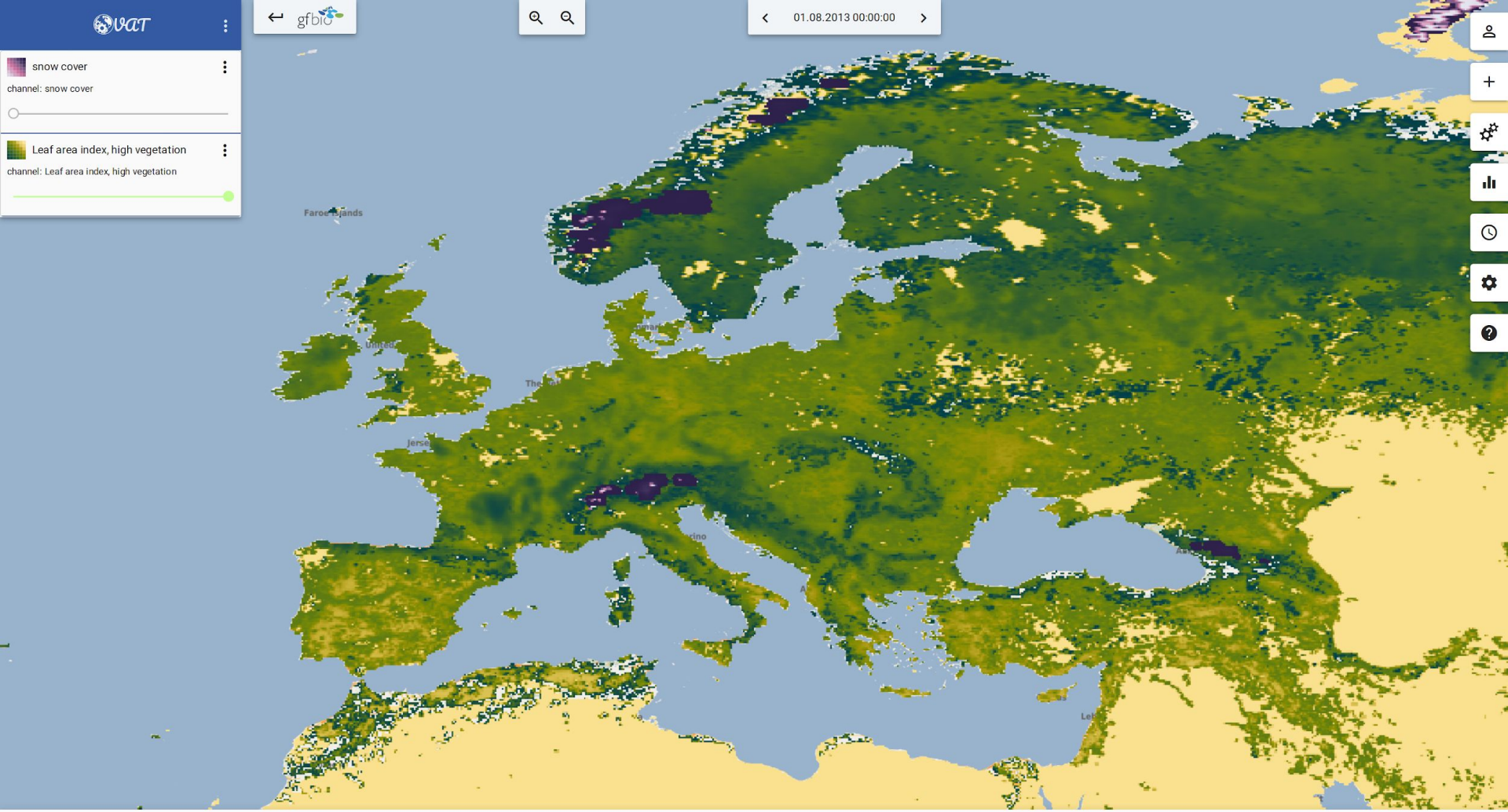

VAT
snow cover
channel: snow cover
Leaf area index, high vegetation
channel: Leaf area index, high vegetation
gfbio
01.07.2013 00:00:00
Faroe Islands
Data Table
Citations


vat
snow cover
channel: snow cover
Leaf area index, high vegetation
channel: Leaf area index, high vegetation
gfbio
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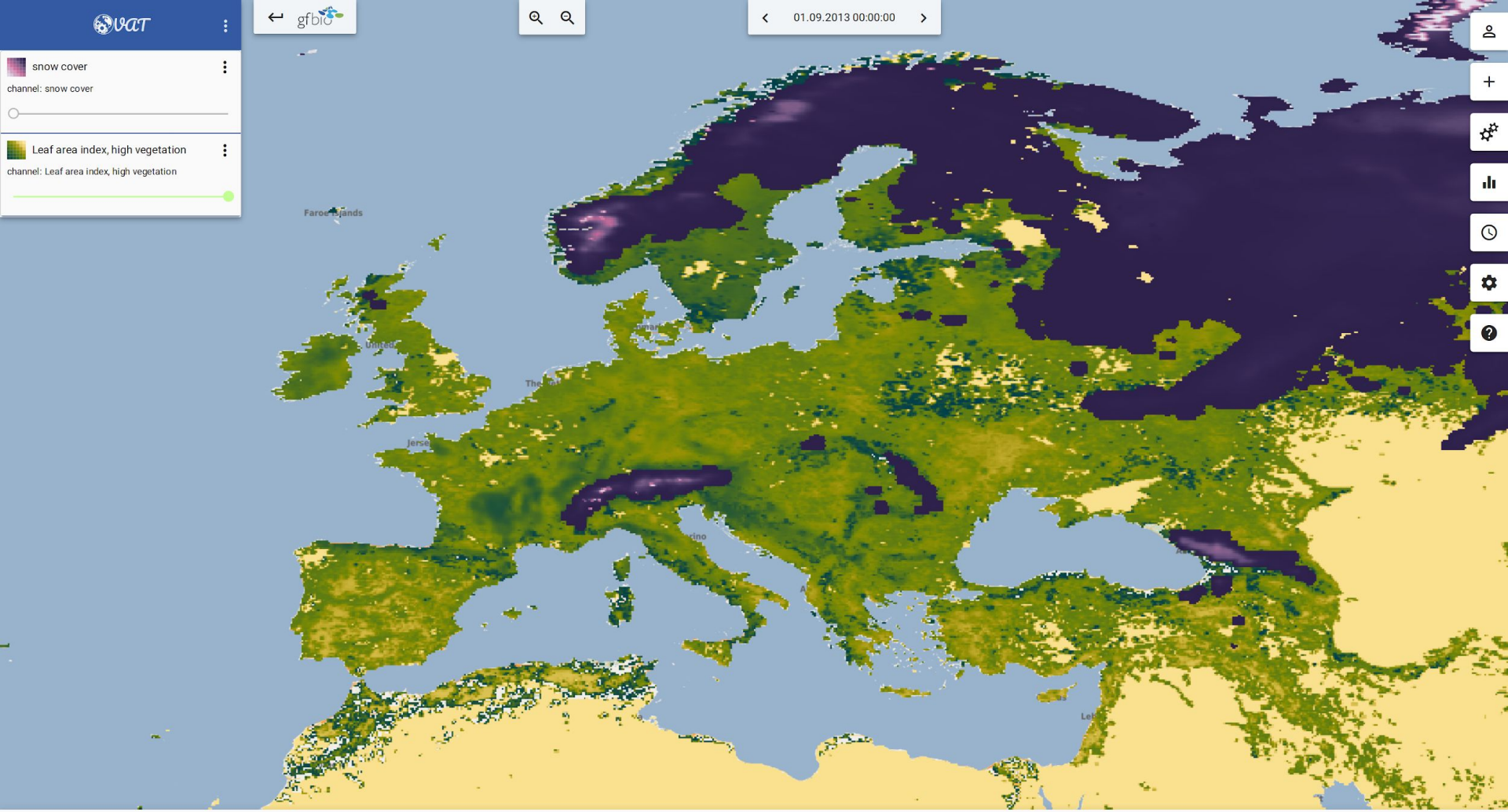
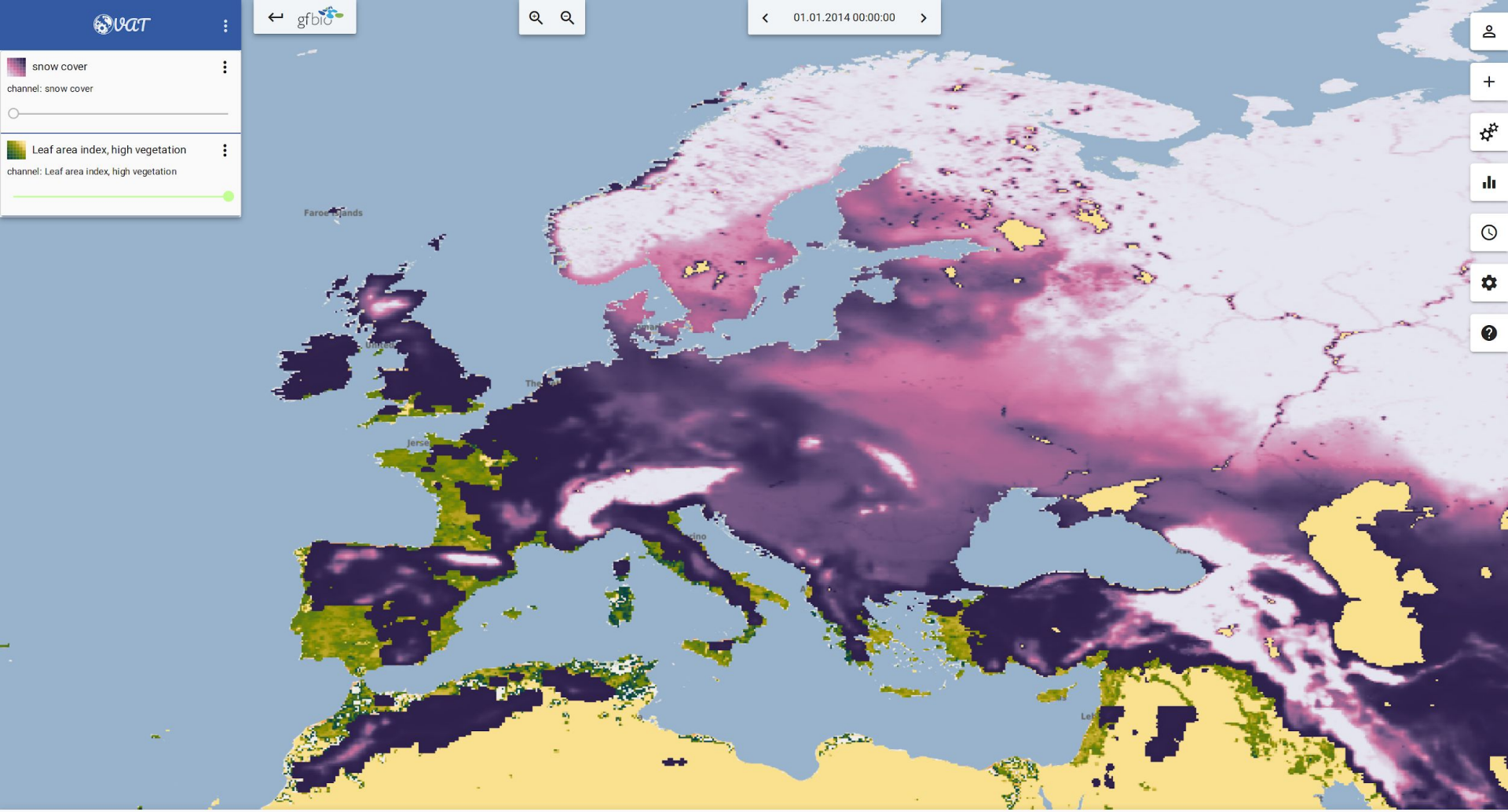
Faroe Islands
Data Table
Citations



Data Table

Citations



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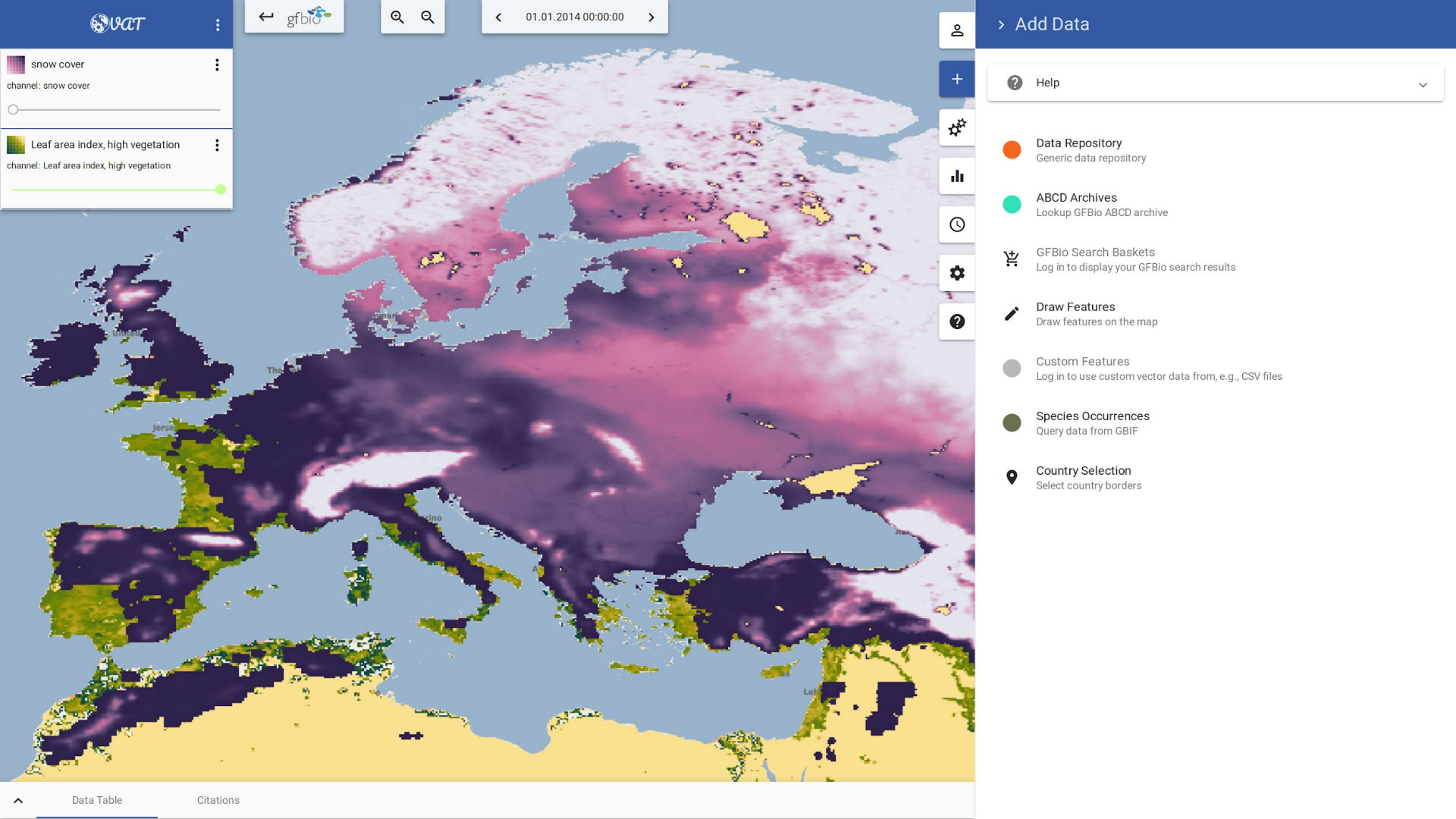
vat
gfbio
01.01.2014 00:00:00
snow cover
channel: snow cover
Leaf area index, high vegetation
channel: Leaf area index, high vegetation
Add Data
Help
Data Repository
Generic data repository
ABCD Archives
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Custom Features
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Country Selection
Select country borders
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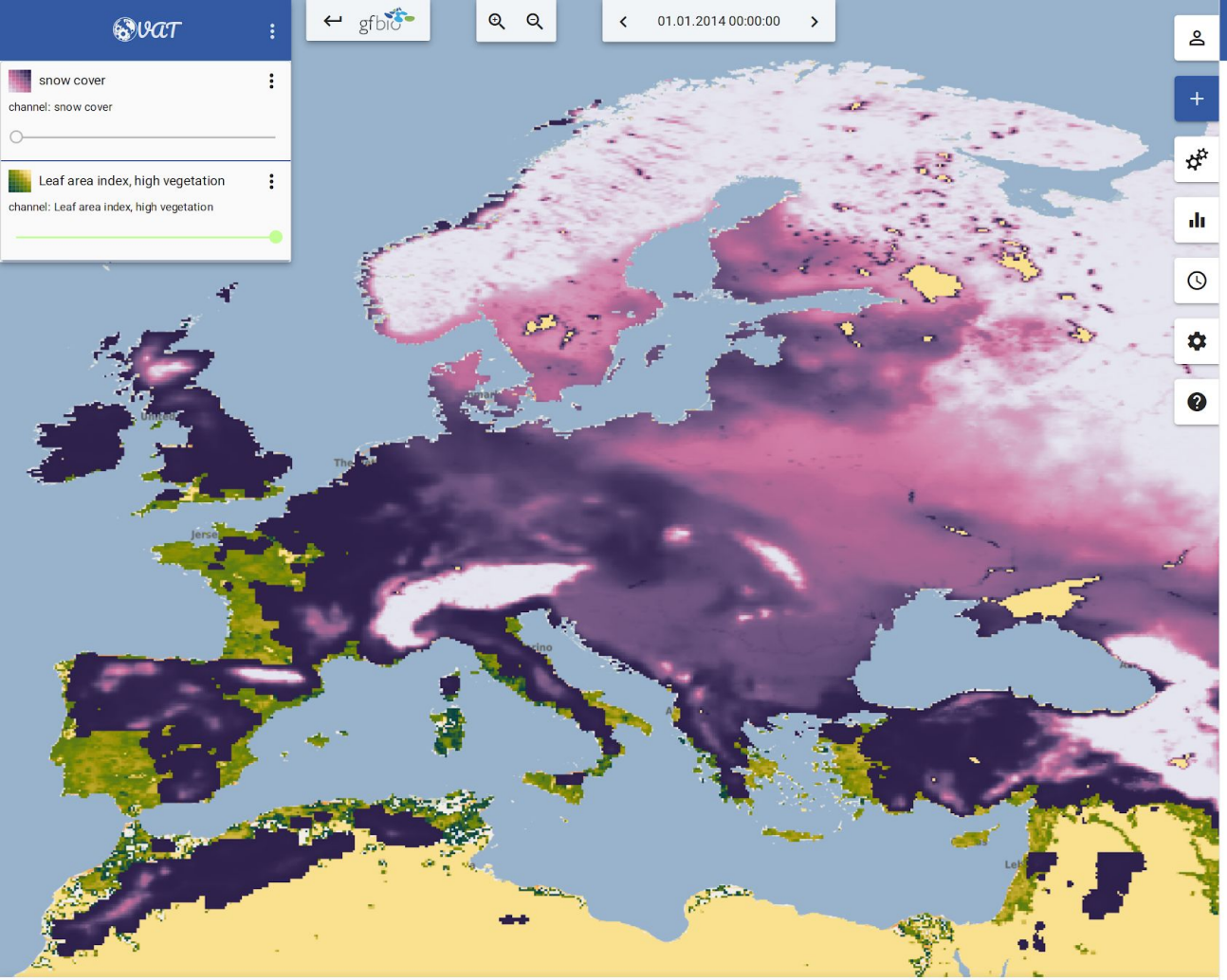
Citations



Data Table

Citations

GBIF Occurences Loader

1. Search Species

Lookup a Scientific Name

Search Level

Species

Scientific Name

Lynx lynx

Lookup

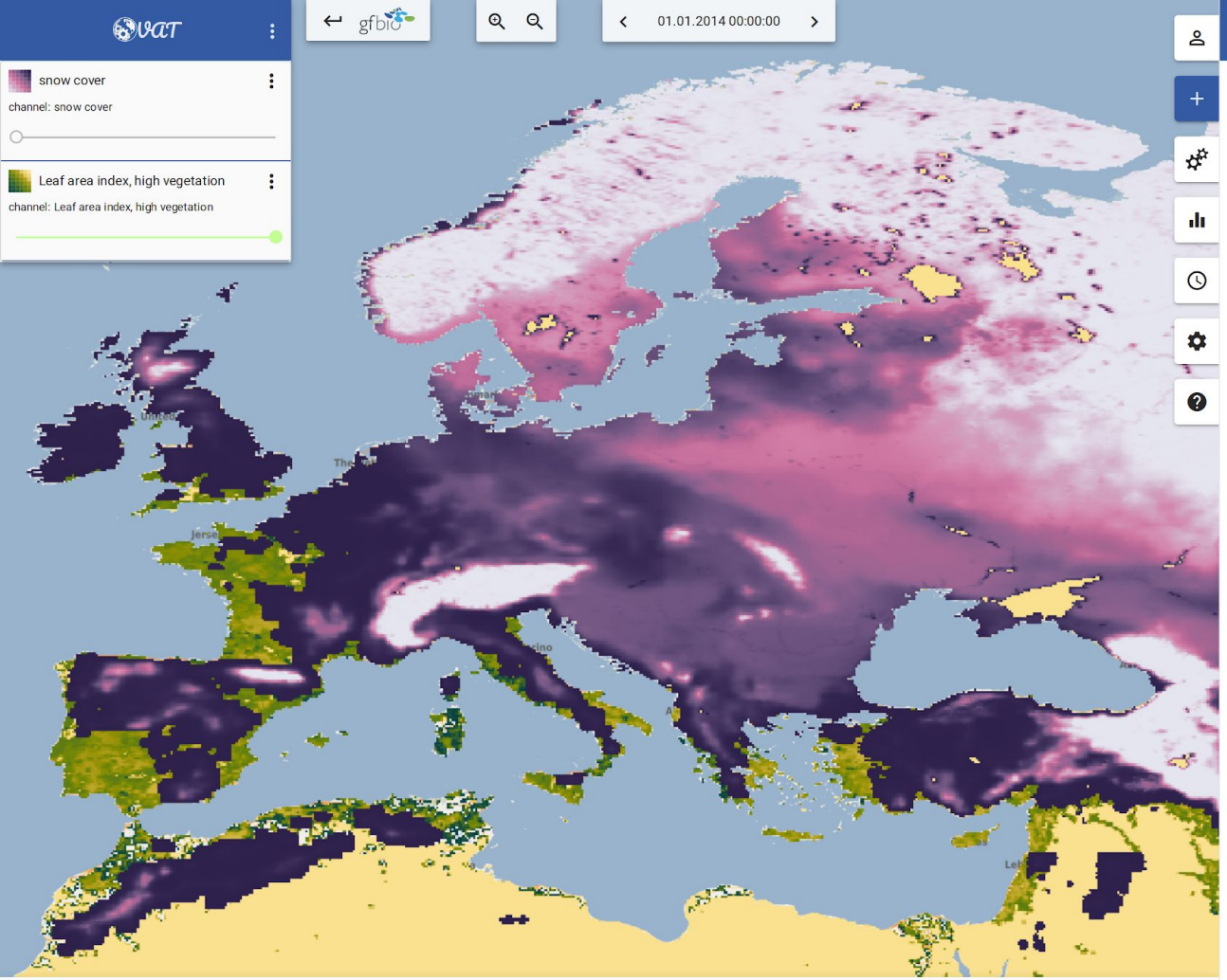
Output Name

Specify the name of the operator result

Output Layer Name

Lynx lynx

Bernard Landgraf (User:Baerni), CC BY-SA 3.0, via Wikimedia Commons



GBIF Occurences Loader

1. Search Species

Lookup a Scientific Name

Search Level

Species

Scientific Name

Lynx lynx

Reset

2. Select Resources

Select different source results

- [x] GBIF (22208)

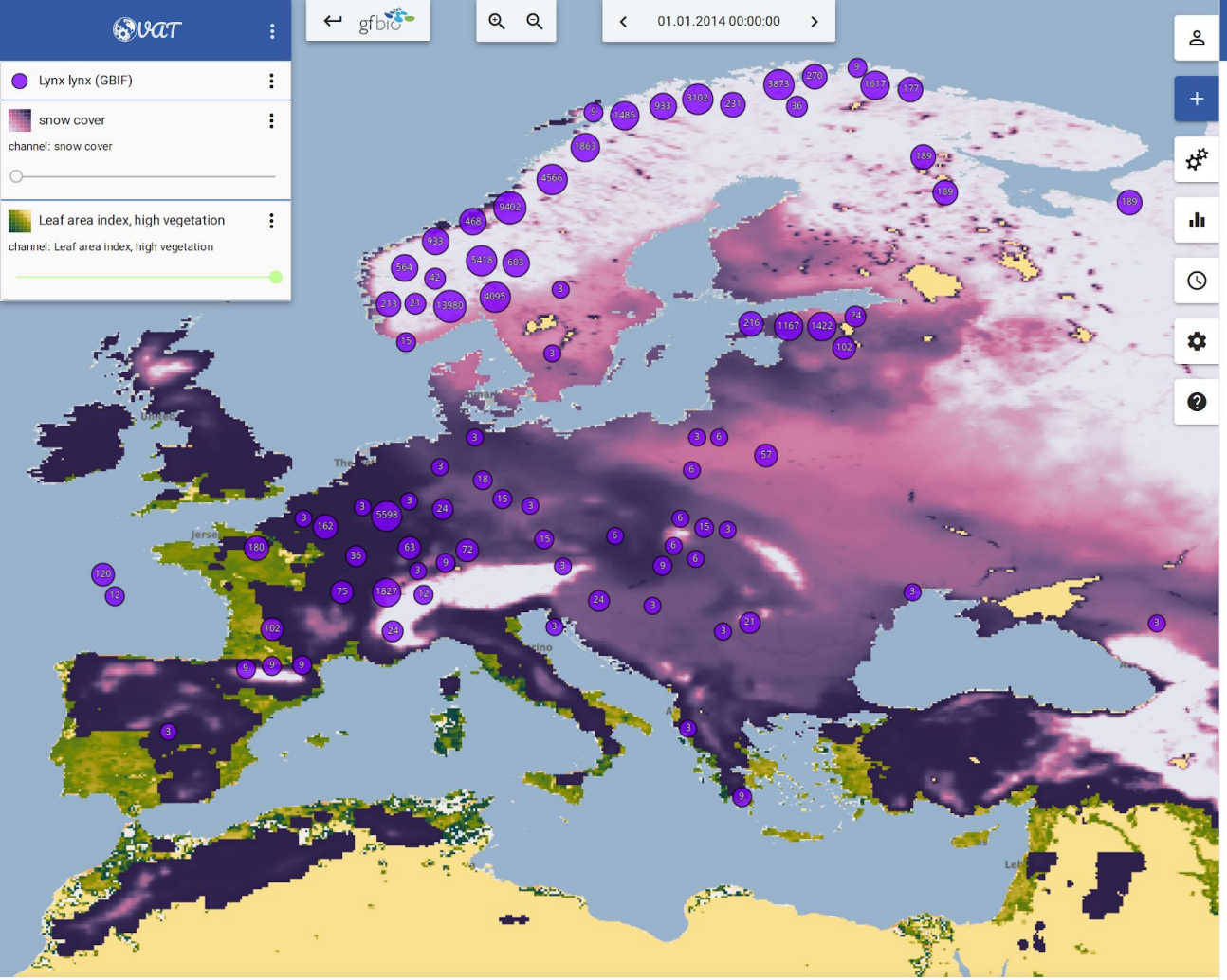
Output Name

Specify the name of the operator result

Output Layer Name

Lynx lynx

Add



GBIF Occurences Loader

1. Search Species

Lookup a Scientific Name

Search Level

Species

Scientific Name

Lynx lynx

Reset

2. Select Resources

Select different source results

- [x] GBIF (22208)

Output Name

Specify the name of the operator result

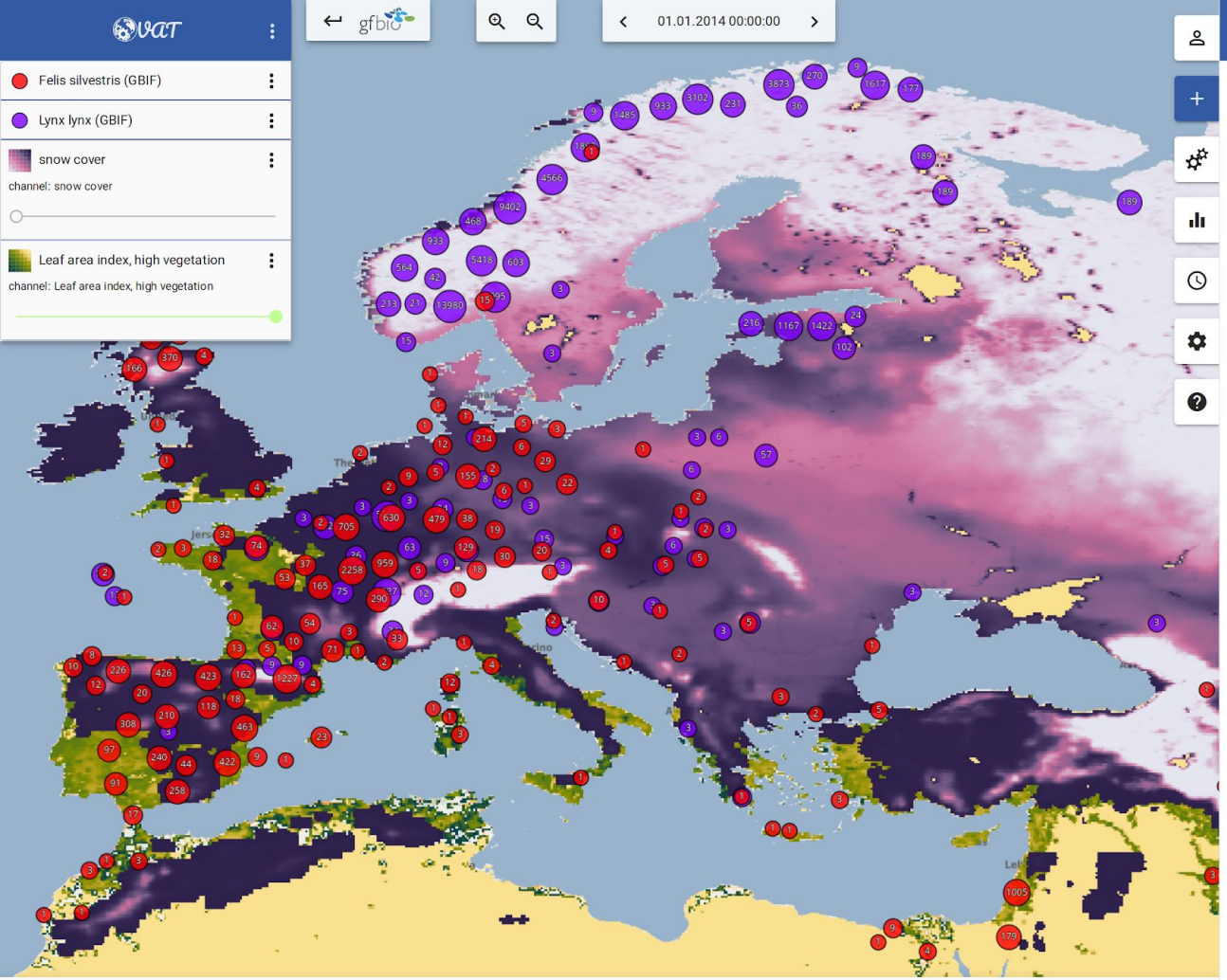
Output Layer Name

Lynx lynx

Add

Data Table

Citations



GBIF Occurences Loader

1. Search Species

Lookup a Scientific Name

Search Level

Species

Scientific Name

Felis silvestris

Reset

2. Select Resources

Select different source results

GBIF (14033)

Output Name

Specify the name of the operator result

Output Layer Name

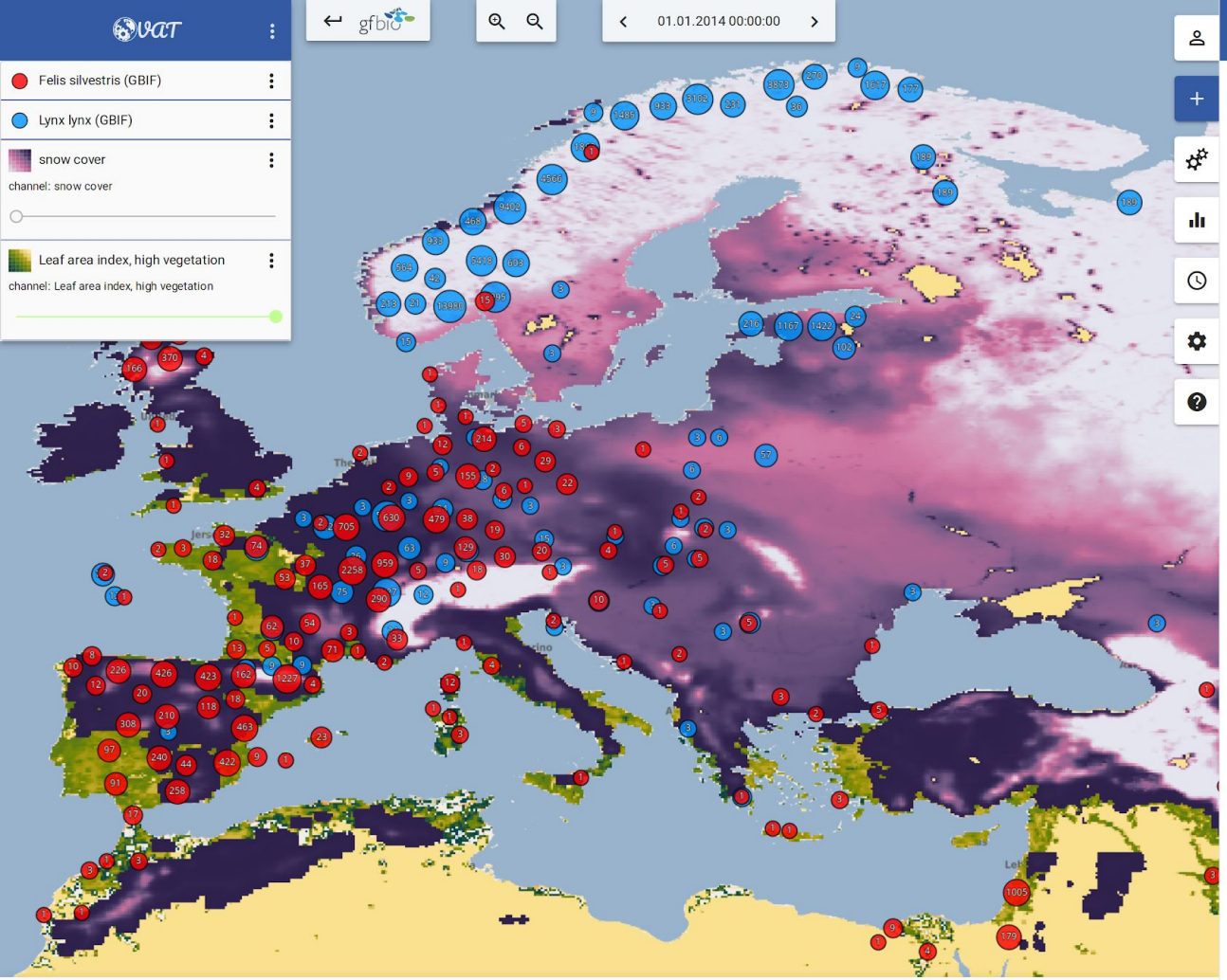
Felis silvestris

Add

Aconcagua, CC BY-SA 3.0, via Wikimedia Commons

Data Table

Citations



Add Data

Help

Data Repository
Generic data repository

ABCD Archives
Lookup GFBio ABCD archive

GFBio Search Baskets
Log in to display your GFBio search results

Draw Features
Draw features on the map

Custom Features
Log in to use custom vector data from, e.g., CSV files

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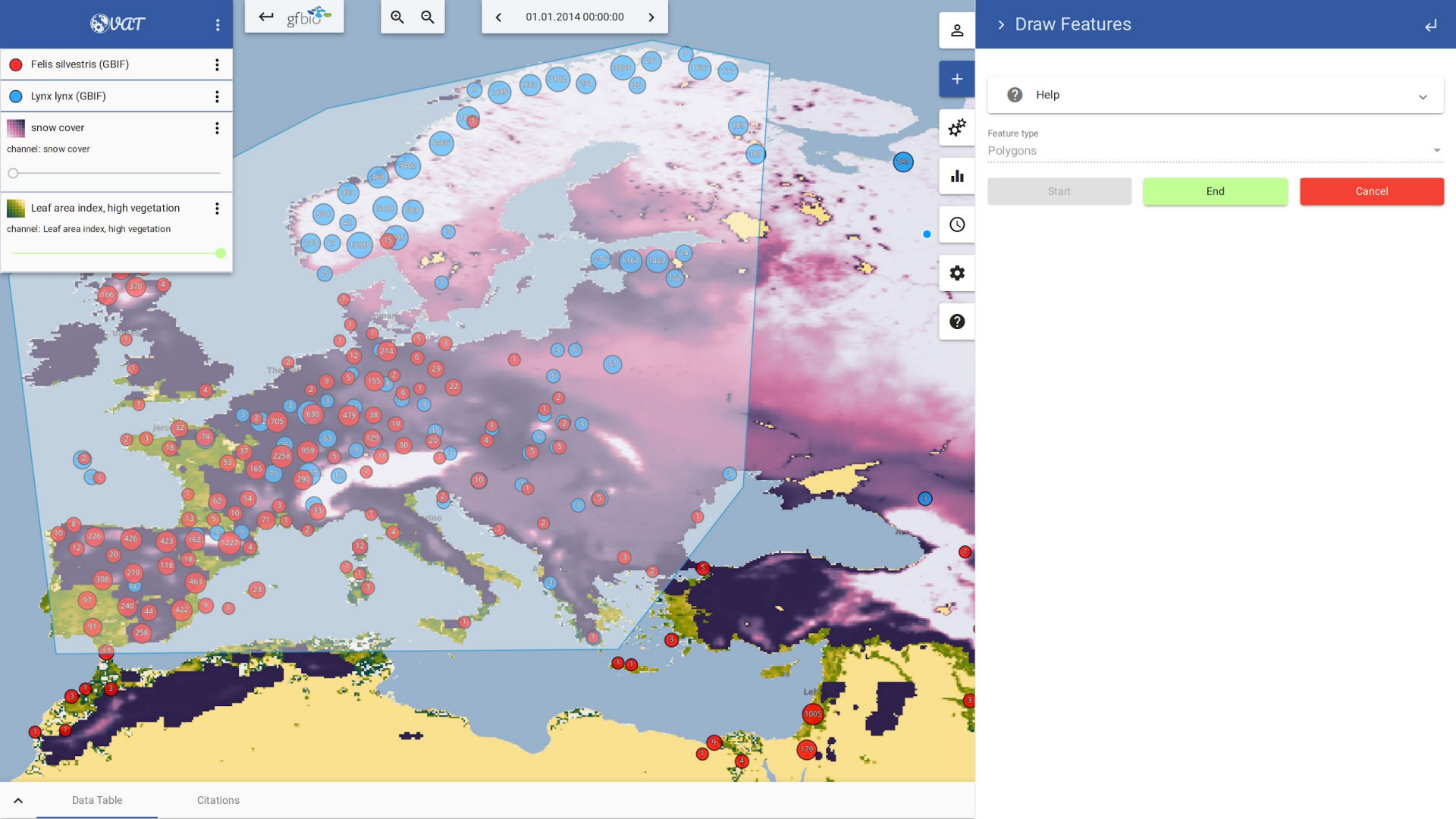
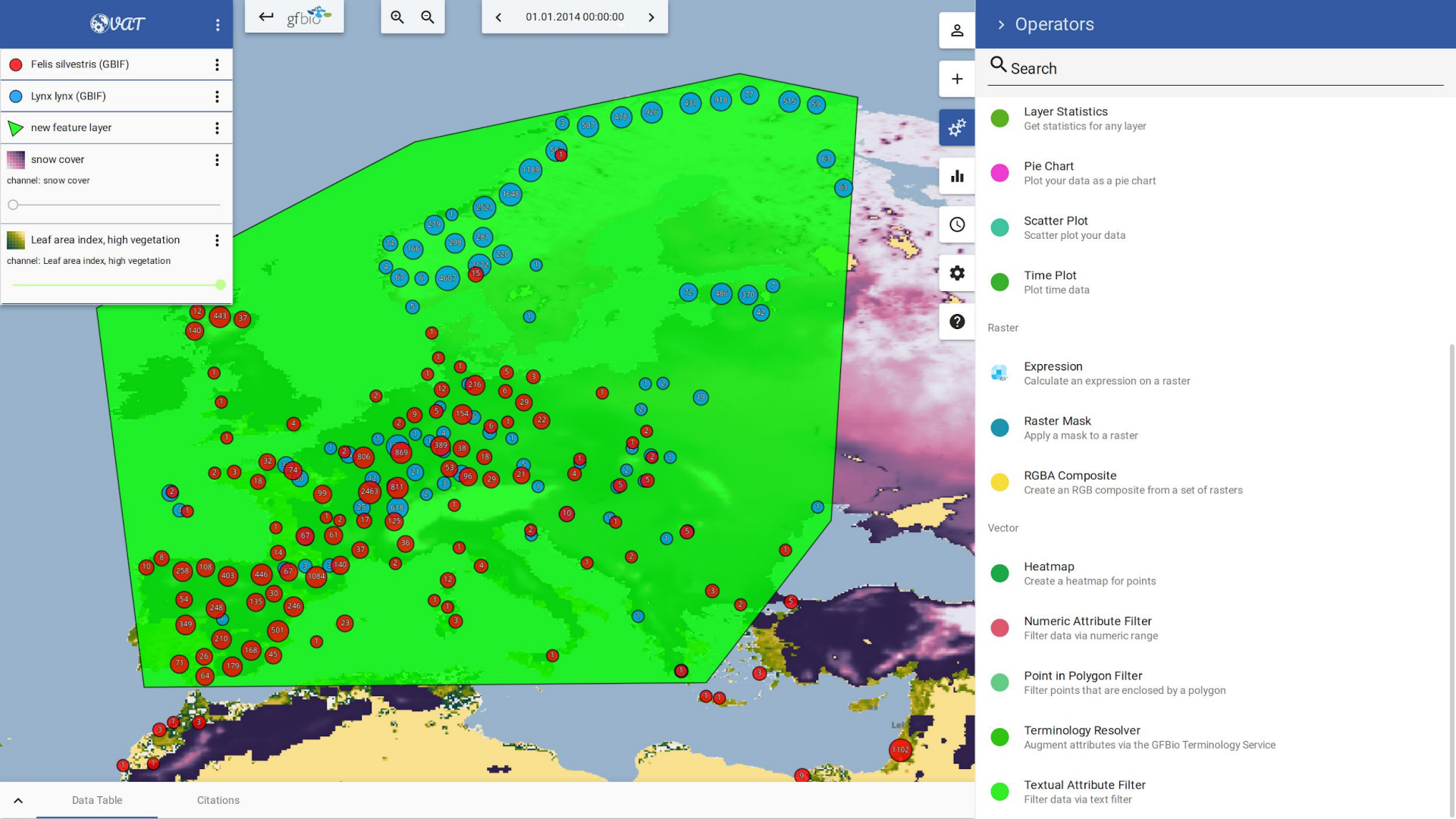
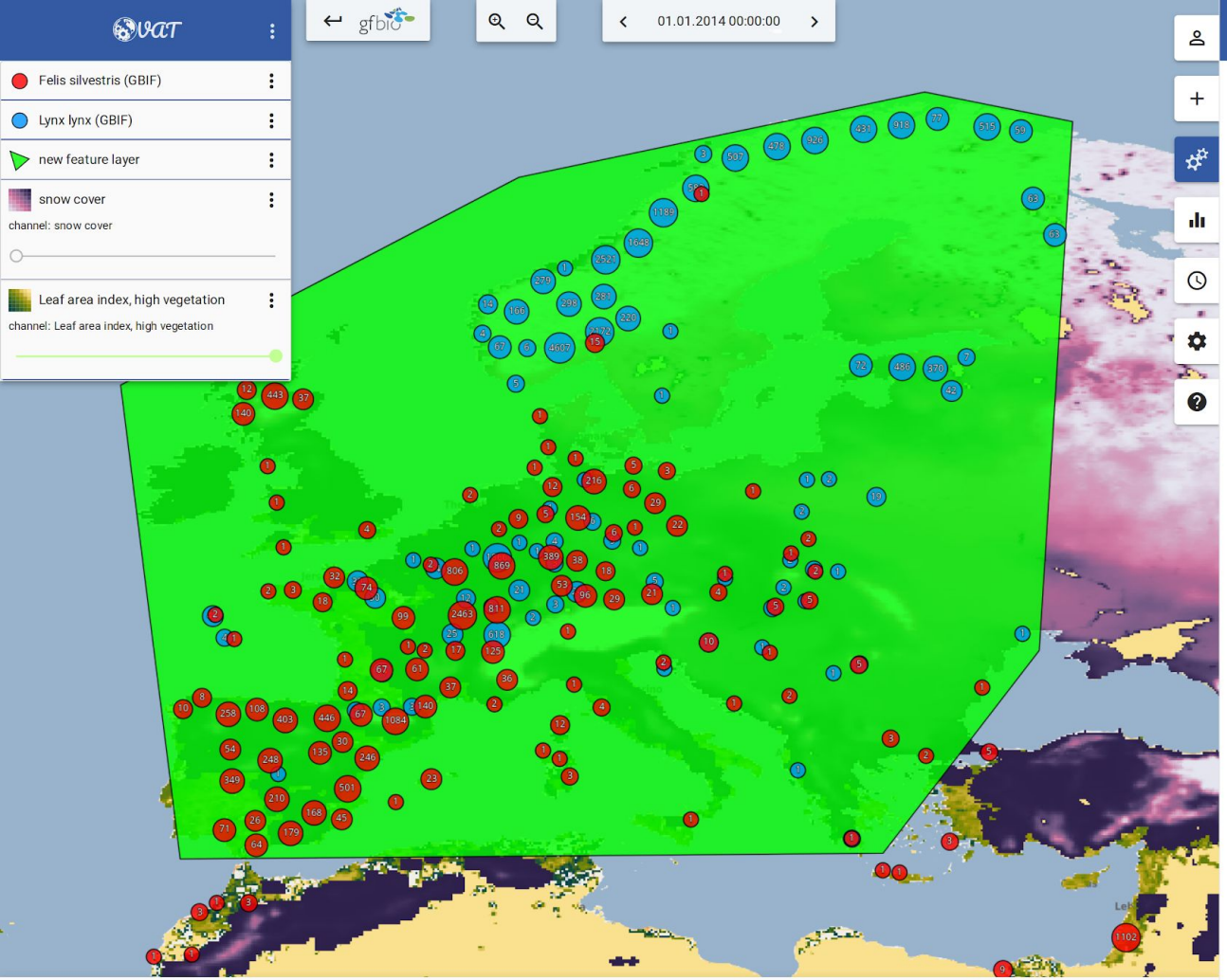
Query data from GBIF

Country Selection
Select country borders

Data Table | Citations


VAT
gfbio
01.01.2014 00:00:00
Felis silvestris (GBIF)
Lynx lynx (GBIF)
snow cover
channel: snow cover
Leaf area index, high vegetation
channel: Leaf area index, high vegetation
Draw Features
Help
Feature type
Polygons
Start
End
Cancel
Data Table
Citations


vat
gfbio
01.01.2014 00:00:00
Felis silvestris (GBIF)
Lynx lynx (GBIF)
new feature layer
snow cover
channel: snow cover
Leaf area index, high vegetation
channel: Leaf area index, high vegetation
Operators
Search
Layer Statistics
Get statistics for any layer
Pie Chart
Plot your data as a pie chart
Scatter Plot
Scatter plot your data
Time Plot
Plot time data
Raster
Expression
Calculate an expression on a raster
Raster Mask
Apply a mask to a raster
RGBA Composite
Create an RGB composite from a set of rasters
Vector
Heatmap
Create a heatmap for points
Numeric Attribute Filter
Filter data via numeric range
Point in Polygon Filter
Filter points that are enclosed by a polygon
Terminology Resolver
Augment attributes via the GFBio Terminology Service
Textual Attribute Filter
Filter data via text filter
Data Table
Citations



Point in Polygon Filter

Point
Select Input Point

Input
Felis silvestris (GBIF)

Polygon
Select Input Polygon

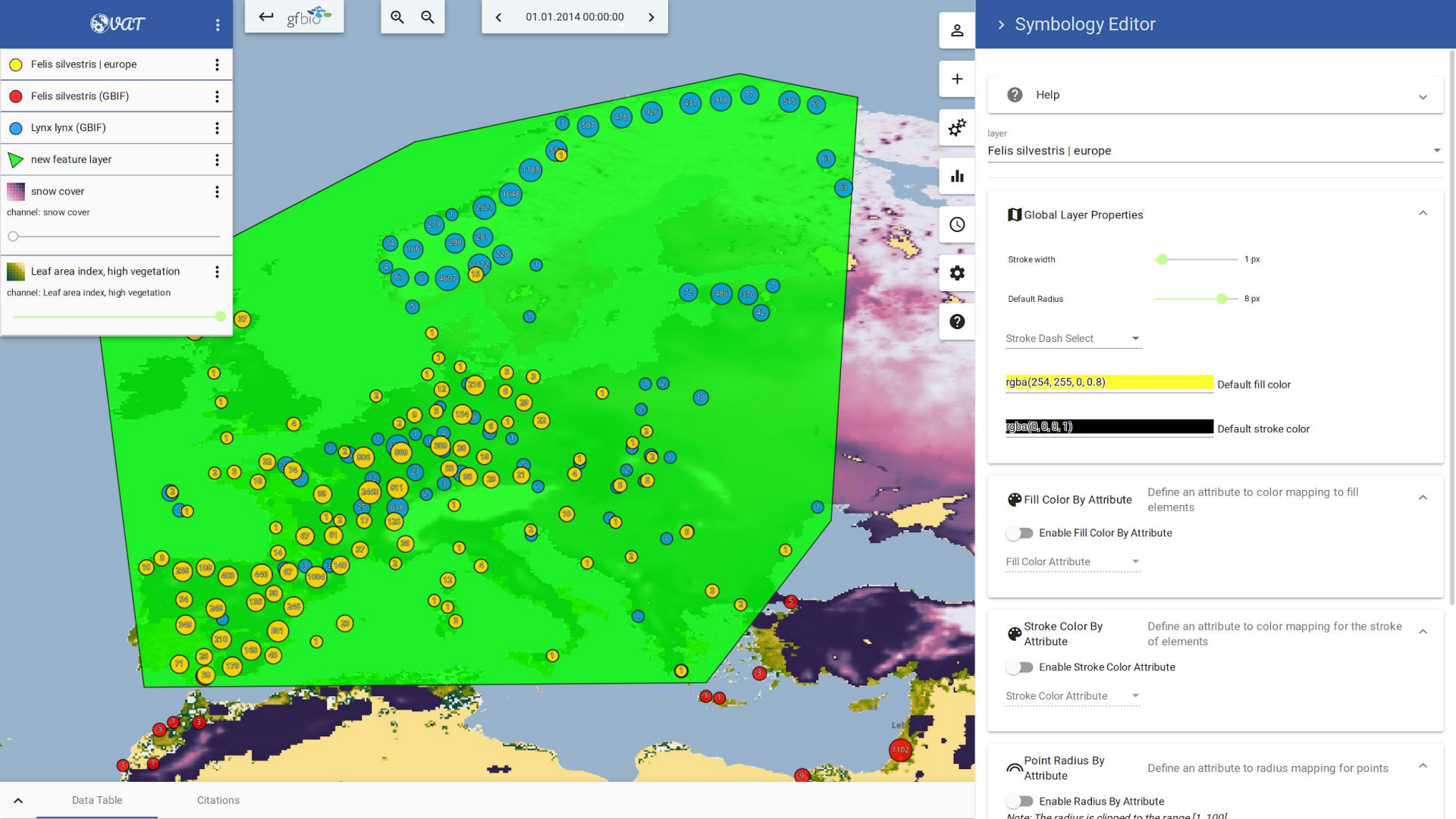
Input
new feature layer

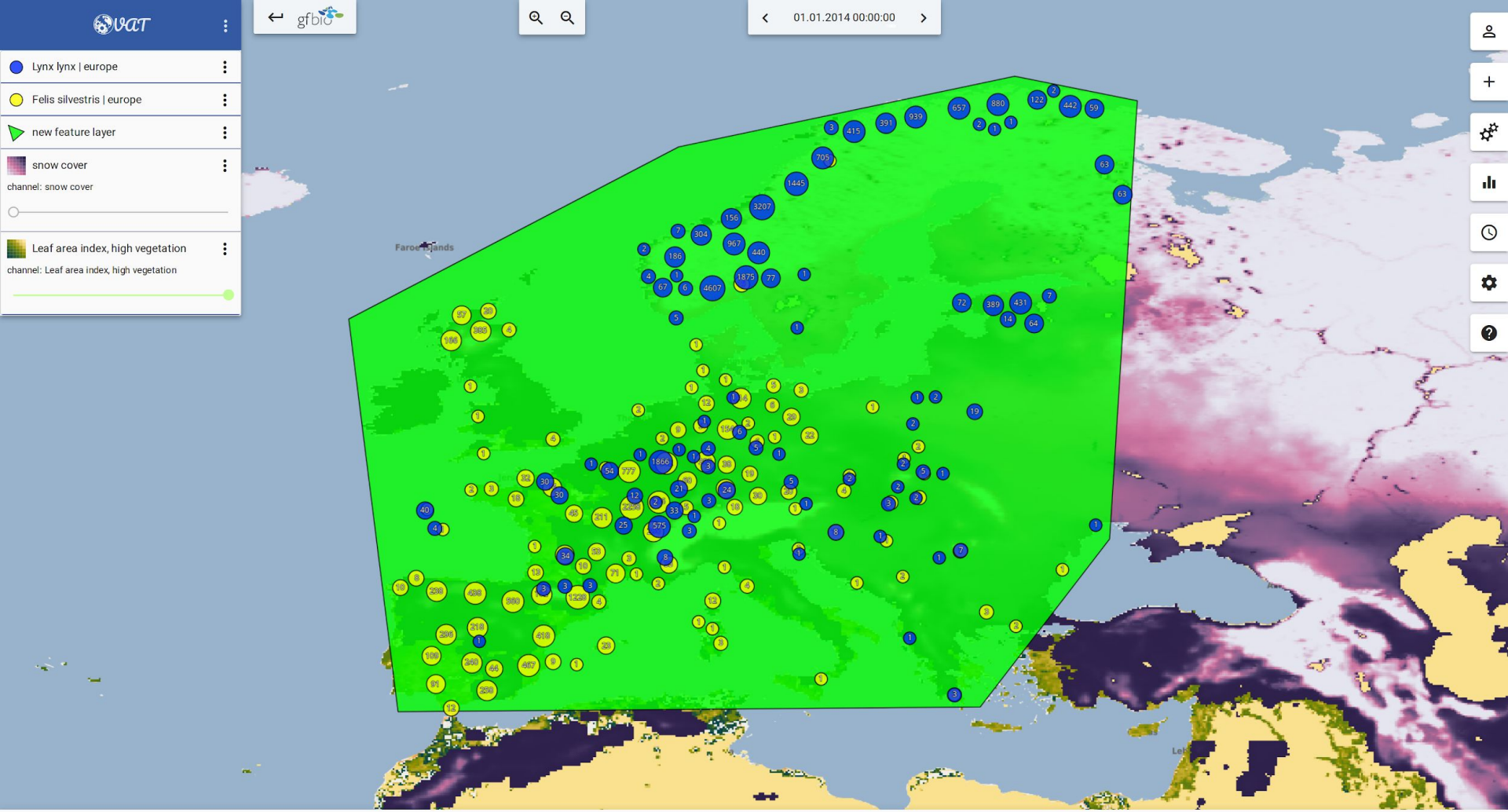
Output Name
Specify the name of the operator result

Output Layer Name
Felis silvestris | europe

Apply

Data Table Citations


vat
gfbio
01.01.2014 00:00:00
Felis silvestris | europe
Felis silvestris (GBIF)
Lynx lynx (GBIF)
new feature layer
snow cover
channel: snow cover
Leaf area index, high vegetation
channel: Leaf area index, high vegetation
Symbology Editor
Help
layer
Felis silvestris | europe
Global Layer Properties
Stroke width
1 px
Default Radius
8 px
Stroke Dash Select
rgba(254, 255, 0, 0.8)
Default fill color
rgba(0,0,0,1)
Default stroke color
Fill Color By Attribute
Define an attribute to color mapping to fill elements
Enable Fill Color By Attribute
Fill Color Attribute
Stroke Color By Attribute
Define an attribute to color mapping for the stroke of elements
Enable Stroke Color Attribute
Stroke Color Attribute
Point Radius By Attribute
Define an attribute to radius mapping for points
Enable Radius By Attribute
Data Table
Citations



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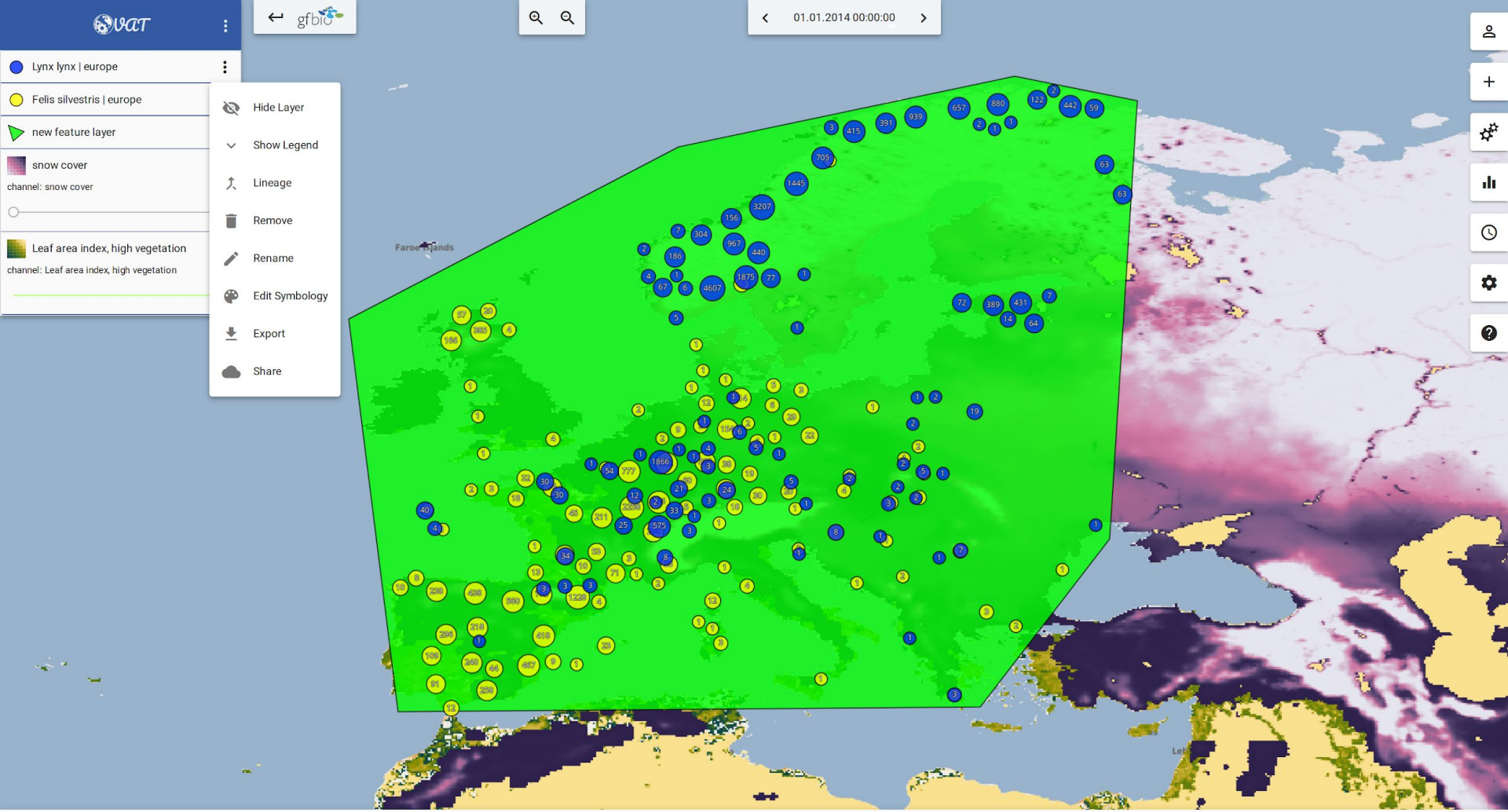

Data Table

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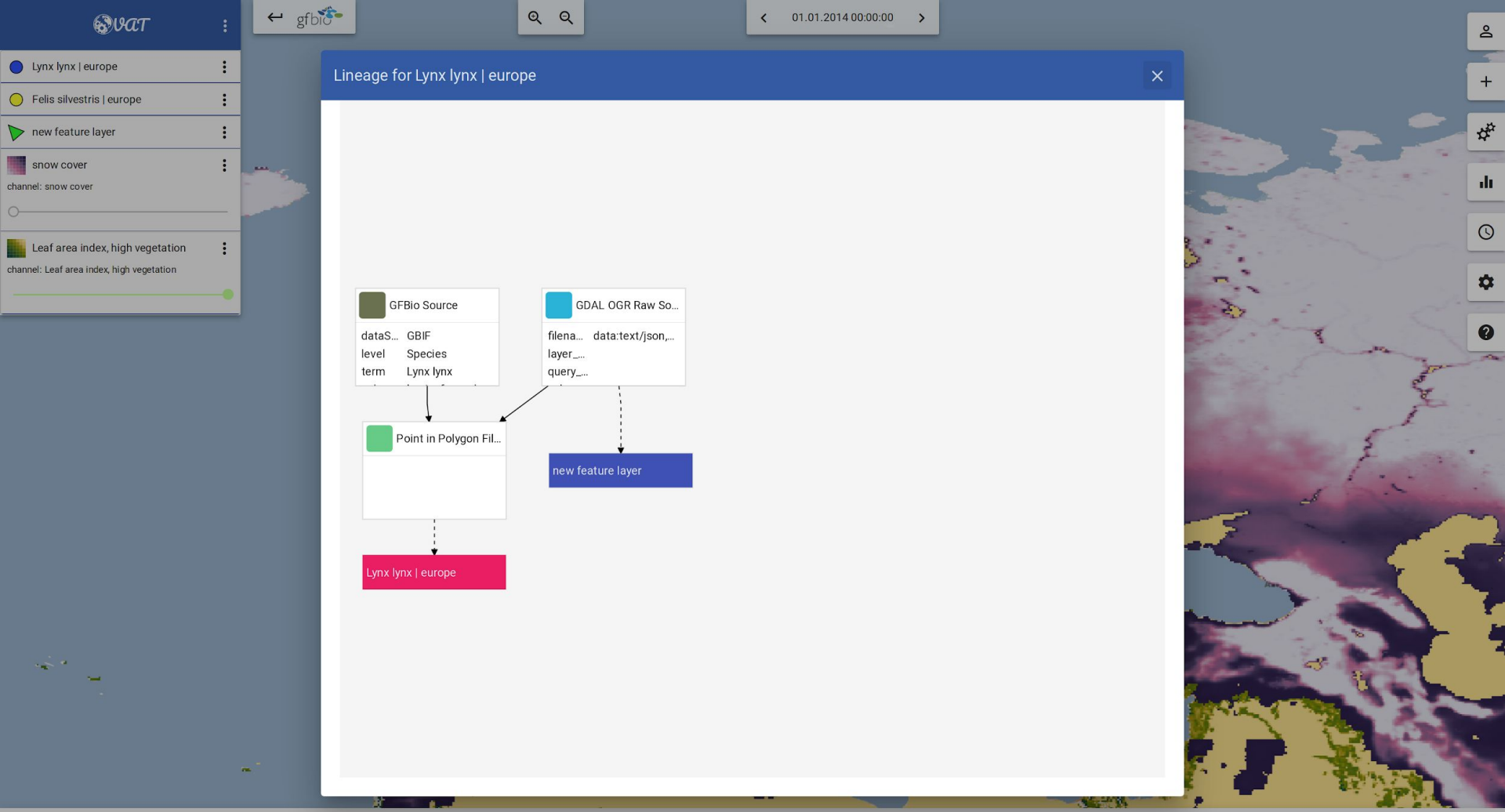
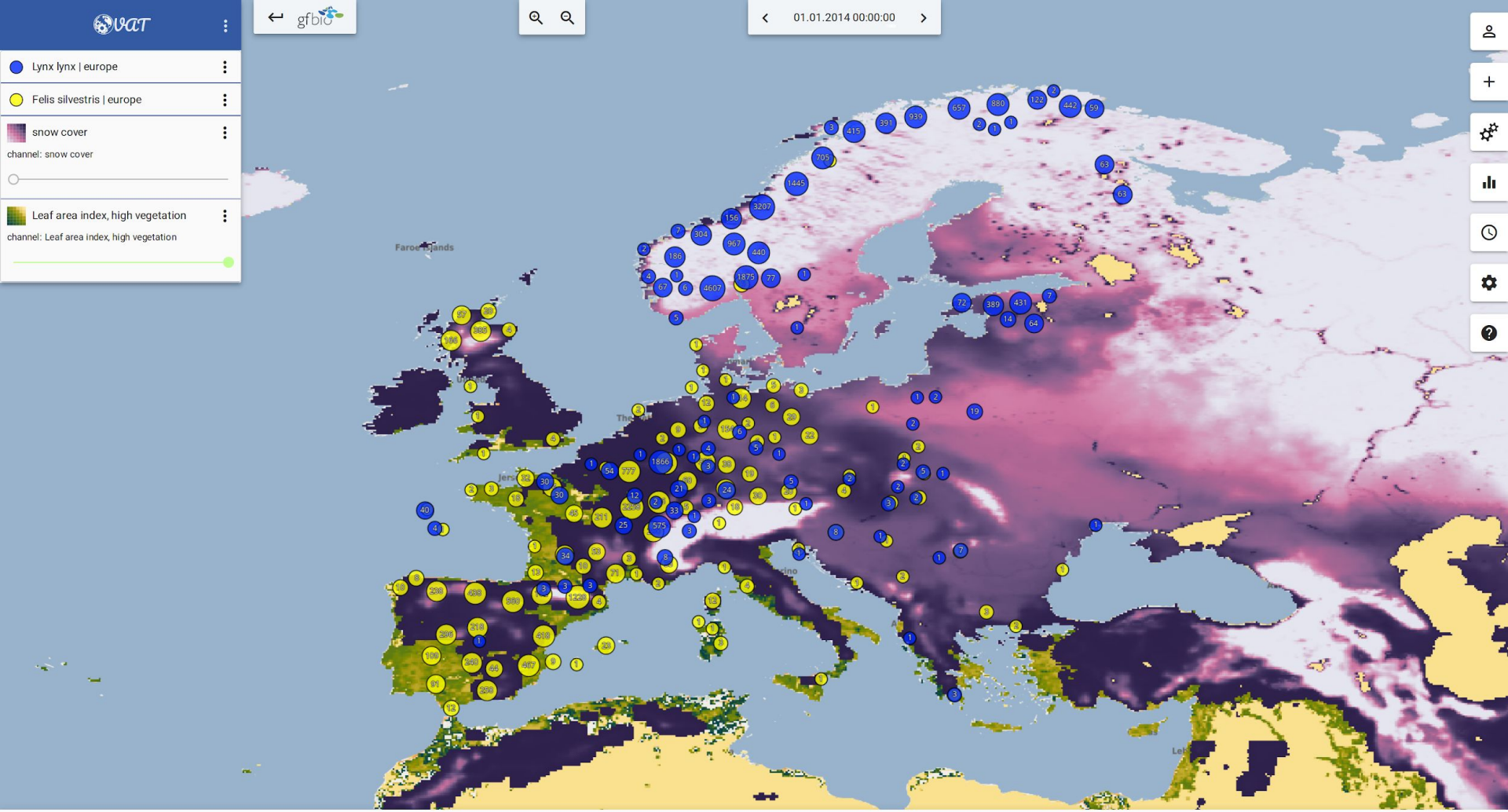
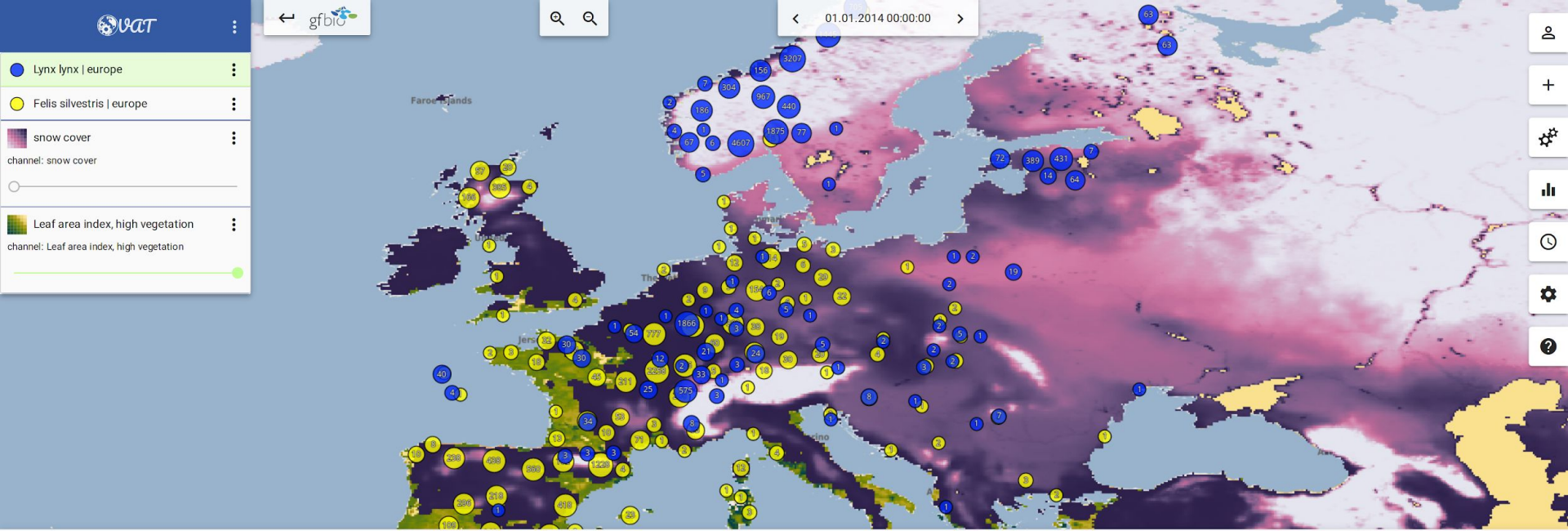

Lynx lynx | europe
Felis silvestris | europe
new feature layer
snow cover
channel: snow cover
Leaf area index, high vegetation
channel: Leaf area index, high vegetation
01.01.2014 00:00:00
Lineage for Lynx lynx | europe
GFBio Source
dataS... GBIF
level Species
term Lynx lynx
GDAL OGR Raw So...
filena... data:text/json,...
layer_...
query_...
Point in Polygon Fil...
new feature layer
Lynx lynx | europe
Data Table
Citations



Data Table

Citations



Data Table | Citations

basisofrecord	gbifid	scientificname
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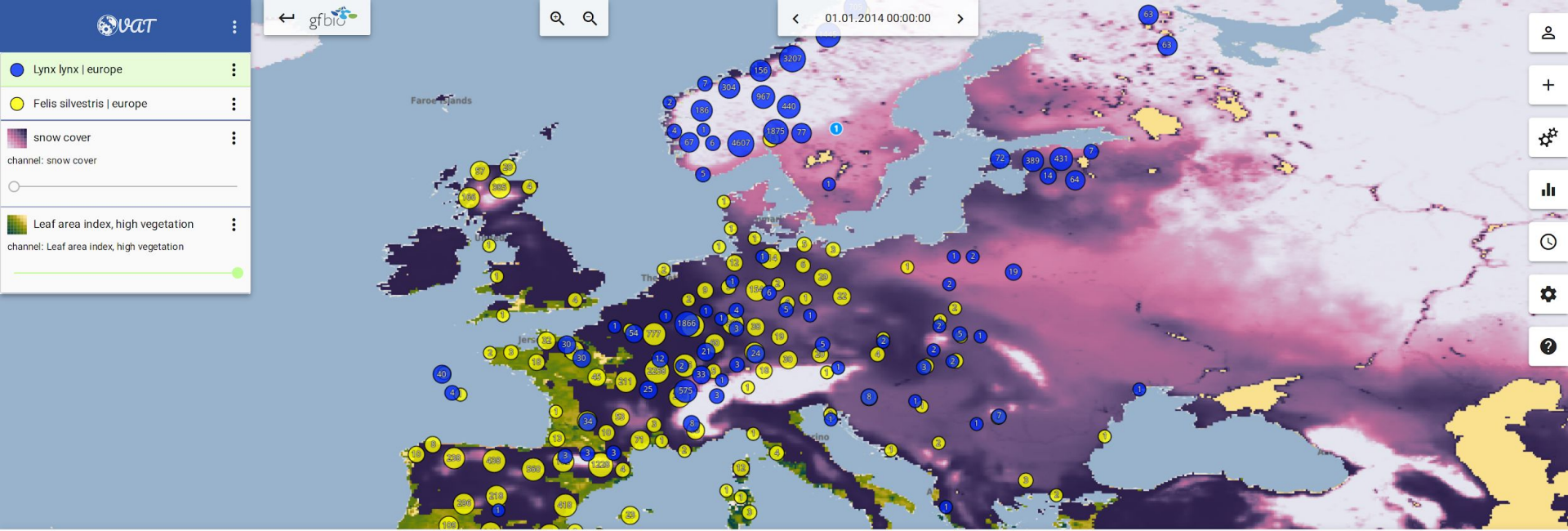
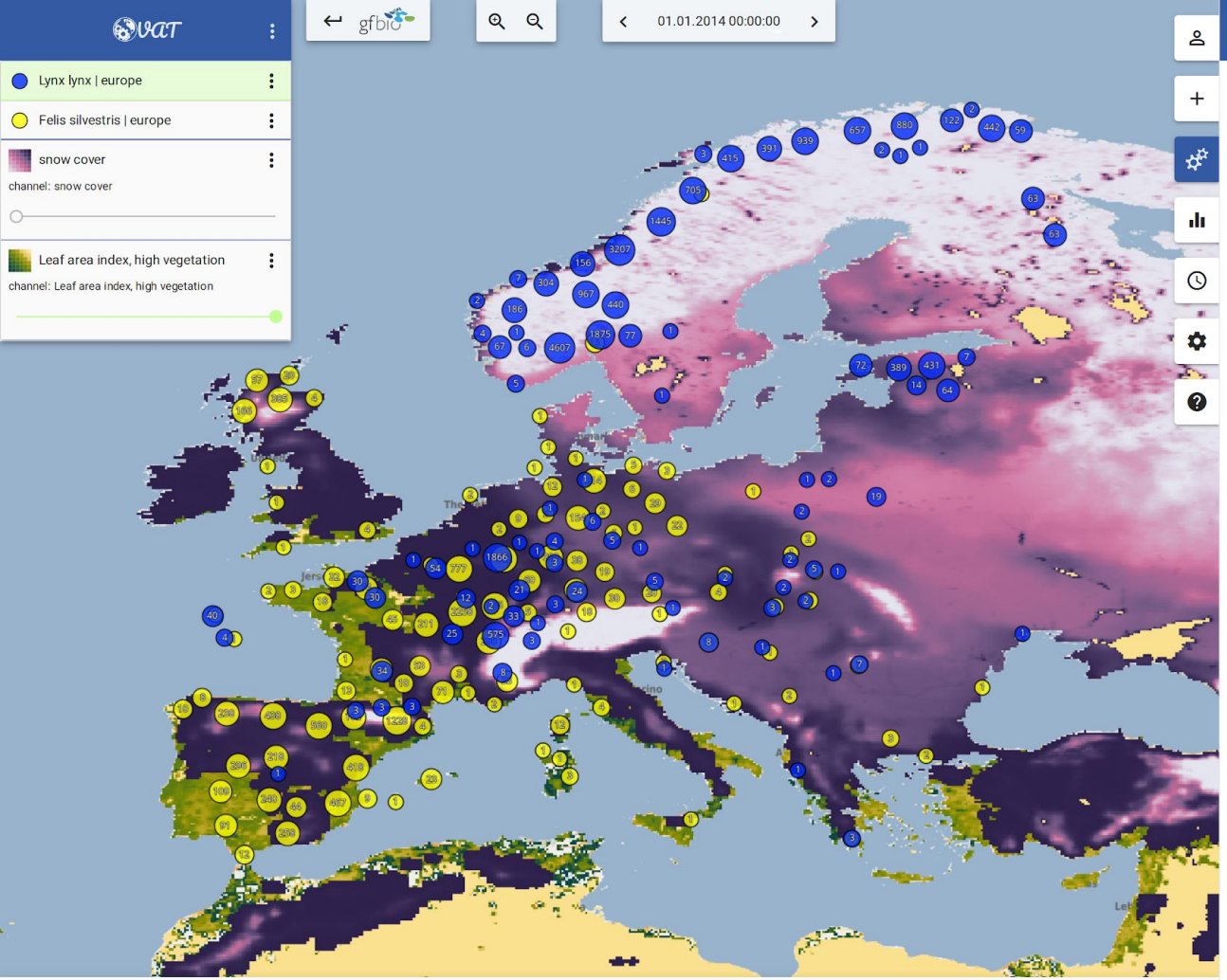
HUMAN_OBSERVATION	9.21708e+08	Lynx lynx (Linnaeus, 1758)
HUMAN_OBSERVATION	3.05095e+08 ± 3.64895e+07	Lynx lynx (Linnaeus, 1758)
FOSSIL_SPECIMEN	3.79681e+07	Lynx lynx (Linnaeus, 1758)
FOSSIL_SPECIMEN	1.46433e+08	Felis lynx Linnaeus, 1758
HUMAN_OBSERVATION	1.1056e+09 ± 4.66651e+08	Lynx lynx (Linnaeus, 1758)
HUMAN_OBSERVATION	6.84505e+08 ± 27.7128	Lynx lynx (Linnaeus, 1758)
UNKNOWN	1.00142e+09 ± 2223.02	Lynx lynx (Linnaeus, 1758)
HUMAN_OBSERVATION	3.21384e+08	Lynx lynx (Linnaeus, 1758)
HUMAN_OBSERVATION, PRESERVED_SPECIMEN	1.24858e+09 ± 30762.7	Lynx lynx (Linnaeus, 1758)



Data Table | Citations

basisofrecord	gbifid	scientificname
HUMAN_OBSERVATION, PRESERVED_SPECIMEN	1.25964e+09 ± 3.03229e+07	Lynx lynx (Linnaeus, 1758)
HUMAN_OBSERVATION	9.22265e+08	Lynx lynx (Linnaeus, 1758)
HUMAN_OBSERVATION, PRESERVED_SPECIMEN	1.25802e+09 ± 6.92179e+07	Lynx lynx (Linnaeus, 1758)
HUMAN_OBSERVATION	1.24859e+09 ± 5539.54	Lynx lynx (Linnaeus, 1758)
HUMAN_OBSERVATION, PRESERVED_SPECIMEN	1.25403e+09 ± 1.95963e+07	Lynx lynx (Linnaeus, 1758)
HUMAN_OBSERVATION, PRESERVED_SPECIMEN	1.24858e+09 ± 3.57526e+07	Lynx lynx (Linnaeus, 1758)
HUMAN_OBSERVATION	1.26541e+09 ± 32	Lynx lynx (Linnaeus, 1758)
HUMAN_OBSERVATION	1.24858e+09	Lynx lynx (Linnaeus, 1758)
HUMAN_OBSERVATION	1.24856e+09 ± 20041.5	Lynx lynx (Linnaeus, 1758)
HUMAN_OBSERVATION	1.24858e+09	Lynx lynx (Linnaeus, 1758)



Extract a Raster Value and Add it to the Vector L...

Point, Polygon

Select Input Point, Polygon

Input

Lynx lynx | europe

Raster

Select input Raster

Input A

snow cover

Input B

Leaf area index, high vegetation

Configuration

Specify the operator

Value Name for Raster A

snow cover

Value Name for Raster B

Leaf area index, high vegetation

Output Name

Specify the name of the operator result

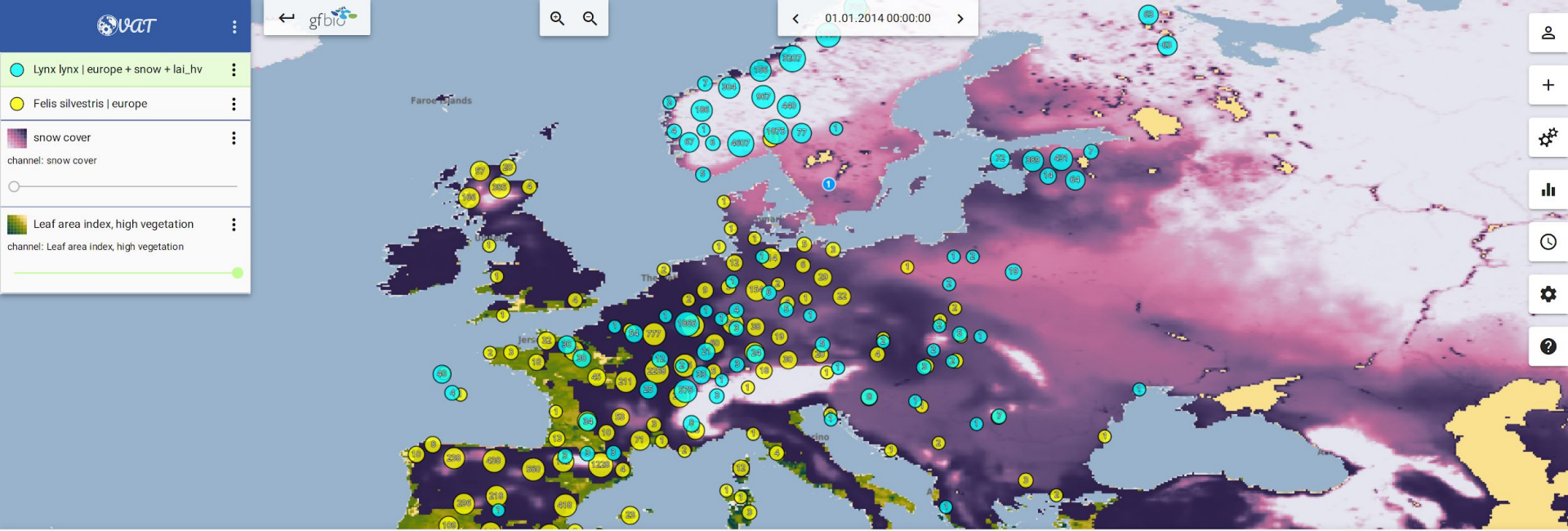
Output Layer Name

Lynx lynx | europe + snow + lai_hv

Create

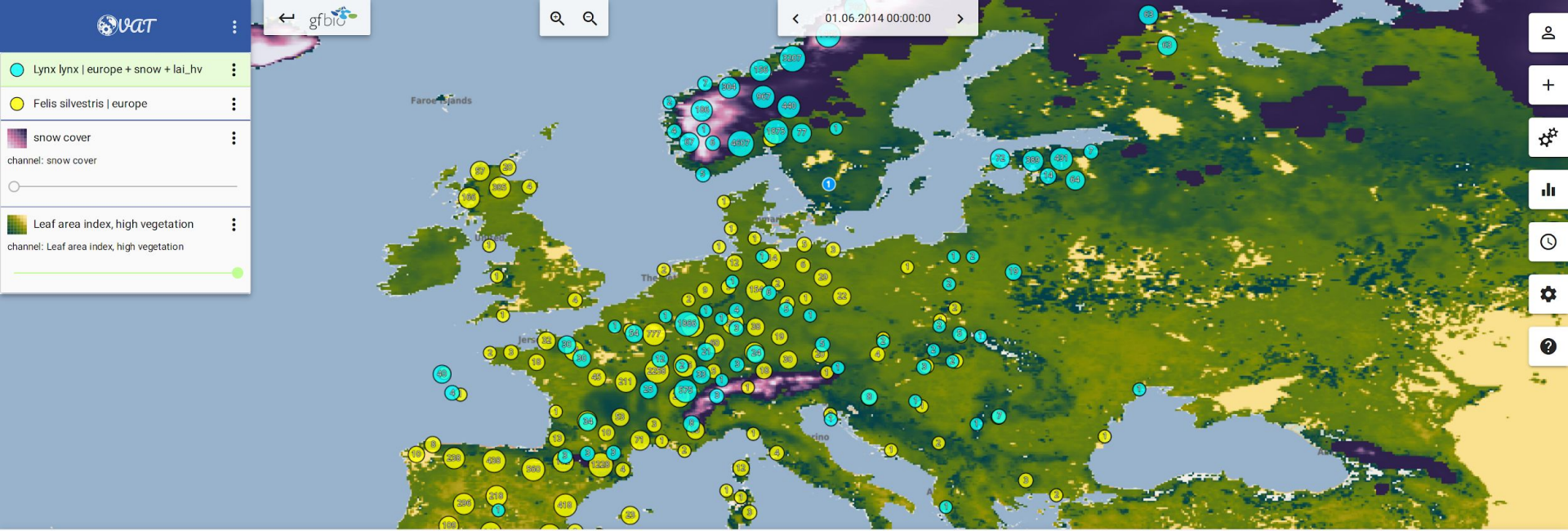
Data Table

Citations



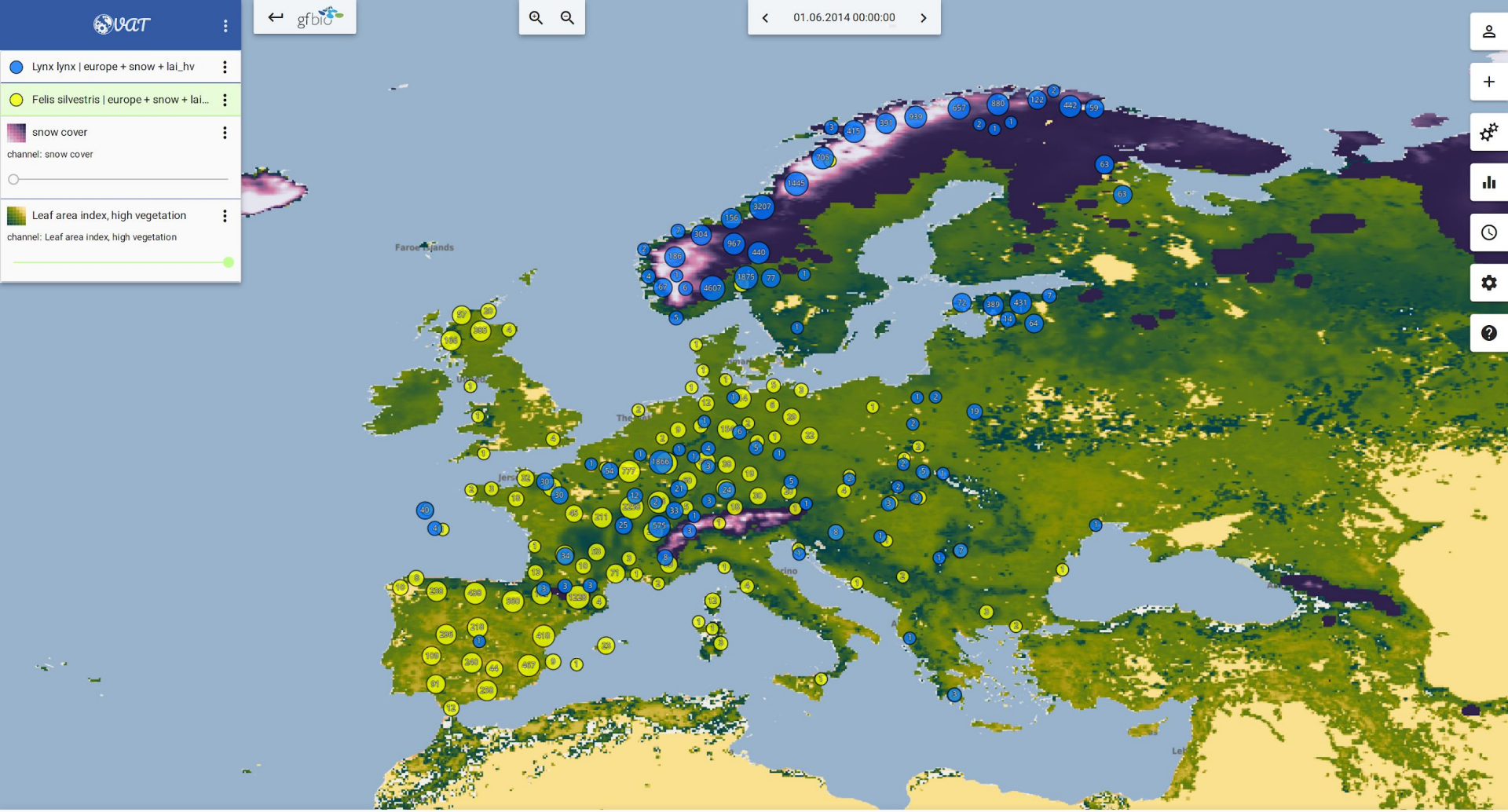
Data Table | Citations

Leaf area index, high vegetation [m**2 m**-2]	basisofrecord	gbifid	scientificname	snow cover [percent (%)]
1.71071	PRESERVED_SPECIMEN	8.00312e+07	Lynx lynx (Linnaeus, 1758)	55.3675
3.8007 ± 1.08023	HUMAN_OBSERVATION	7.23571e+08 ± 887.964	Lynx lynx (Linnaeus, 1758)	23.3873 ± 1.53098
1.53337 ± 0.118875	HUMAN_OBSERVATION, PRESERVED_SPECIMEN	1.25964e+09 ± 3.03229e+07	Lynx lynx (Linnaeus, 1758)	75.2045 ± 4.96682
1.30359	HUMAN_OBSERVATION	9.22265e+08	Lynx lynx (Linnaeus, 1758)	70.1662
	HUMAN_OBSERVATION, PRESERVED_SPECIMEN	1.25802e+09 ± 6.92179e+07	Lynx lynx (Linnaeus, 1758)	
4.0423 ± 0.177697	HUMAN_OBSERVATION	1.24859e+09 ± 5539.54	Lynx lynx (Linnaeus, 1758)	83.1042 ± 23.8943
	HUMAN_OBSERVATION, PRESERVED_SPECIMEN	1.25403e+09 ± 1.95963e+07	Lynx lynx (Linnaeus, 1758)	
	HUMAN_OBSERVATION, PRESERVED_SPECIMEN	1.24858e+09 ± 3.57526e+07	Lynx lynx (Linnaeus, 1758)	
2.22249	HUMAN_OBSERVATION	1.26541e+09 ± 32	Lynx lynx (Linnaeus, 1758)	93.2858



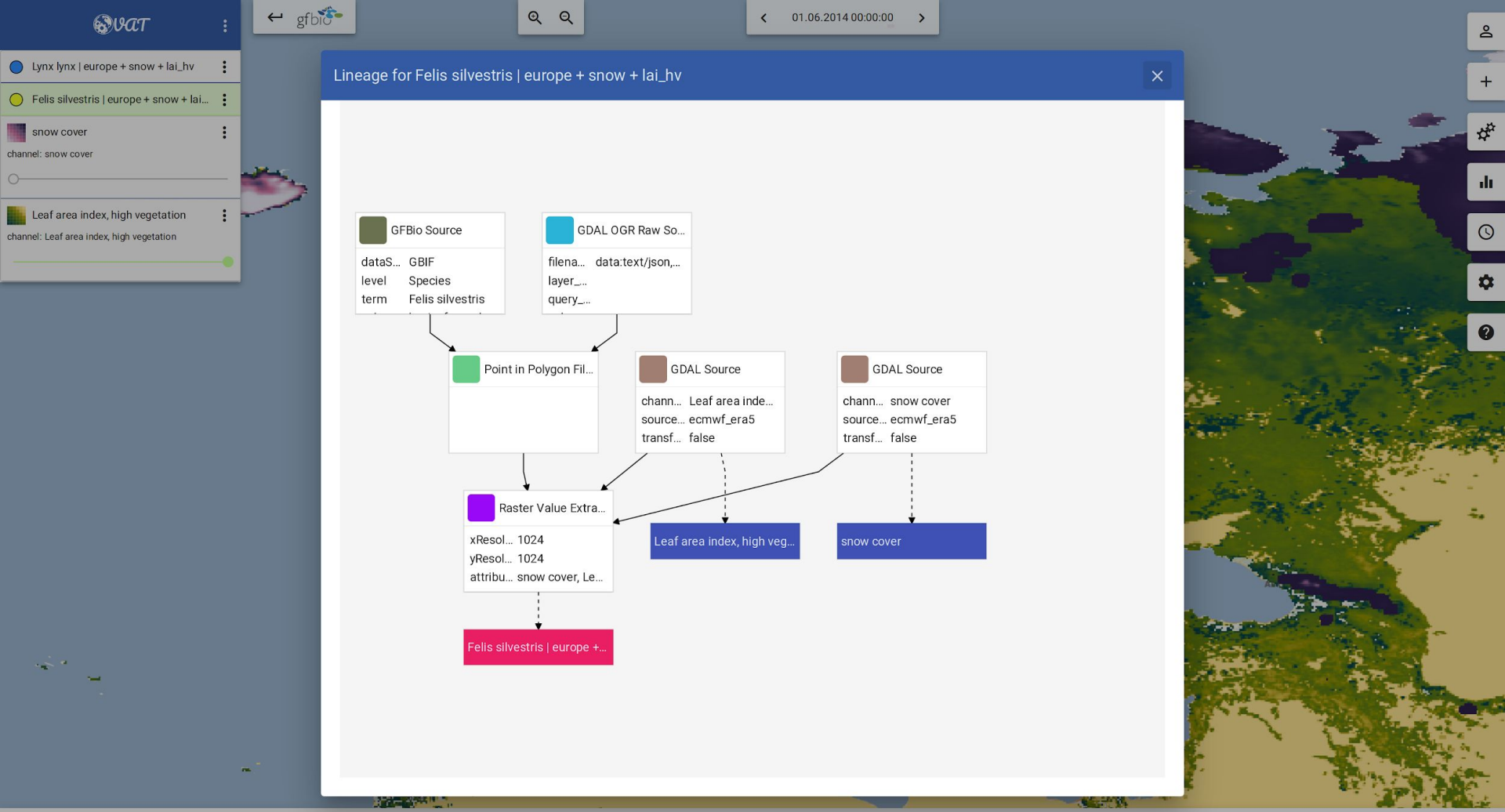
Data Table | Citations

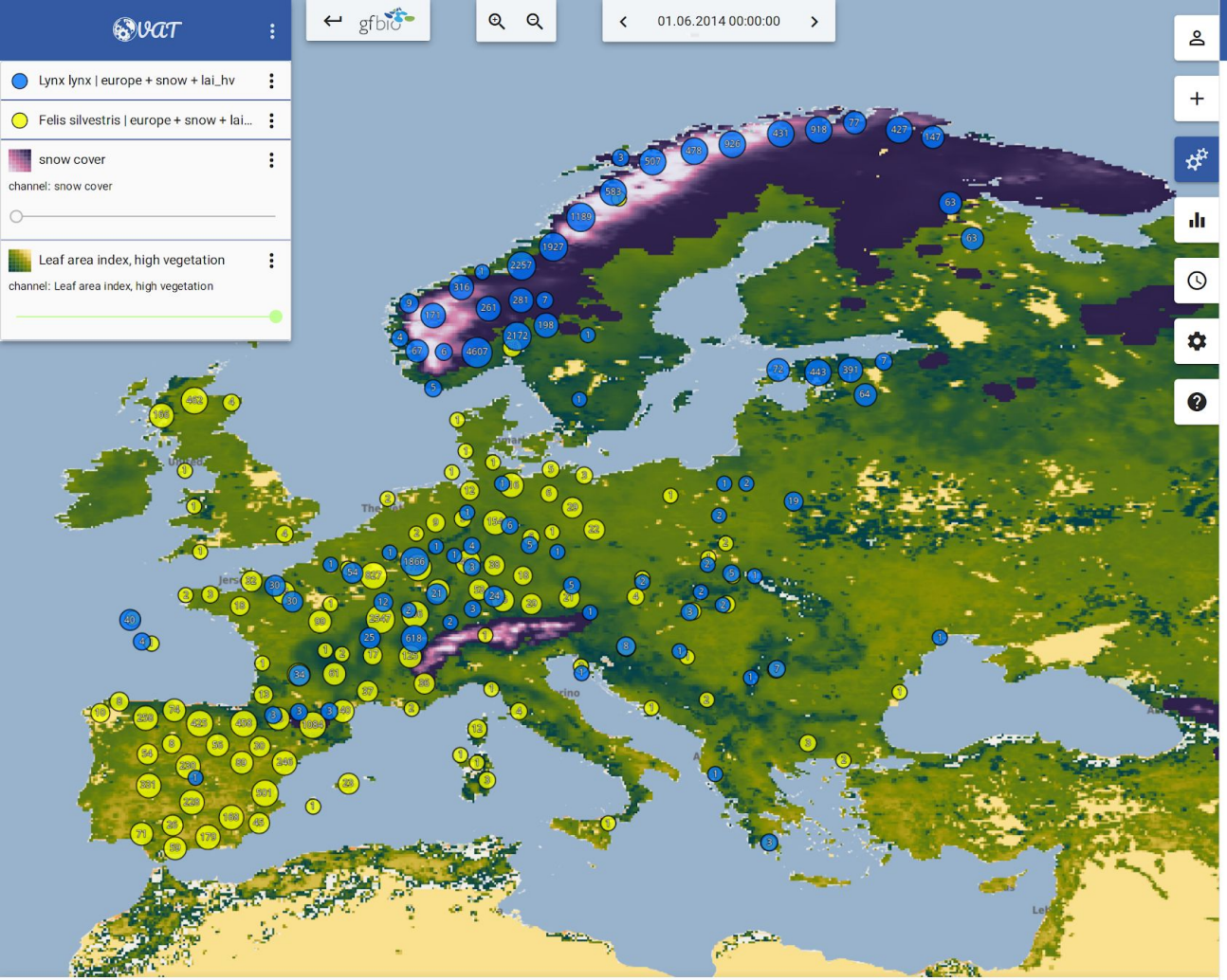
Leaf area index, high vegetation [m**2 m**-2]	basisofrecord	gbifid	scientificname	snow cover [percent (%)]
3.33511	PRESERVED_SPECIMEN	8.00312e+07	Lynx lynx (Linnaeus, 1758)	
3.92791 ± 1.06227	HUMAN_OBSERVATION	7.23571e+08 ± 887.964	Lynx lynx (Linnaeus, 1758)	
3.36791 ± 0.193956	HUMAN_OBSERVATION, PRESERVED_SPECIMEN	1.25964e+09 ± 3.03229e+07	Lynx lynx (Linnaeus, 1758)	
2.88528	HUMAN_OBSERVATION	9.22265e+08	Lynx lynx (Linnaeus, 1758)	
	HUMAN_OBSERVATION, PRESERVED_SPECIMEN	1.25802e+09 ± 6.92179e+07	Lynx lynx (Linnaeus, 1758)	
4.35103 ± 0.192414	HUMAN_OBSERVATION	1.24859e+09 ± 5539.54	Lynx lynx (Linnaeus, 1758)	5.1383 ± 3.57728
	HUMAN_OBSERVATION, PRESERVED_SPECIMEN	1.25403e+09 ± 1.95963e+07	Lynx lynx (Linnaeus, 1758)	
	HUMAN_OBSERVATION, PRESERVED_SPECIMEN	1.24858e+09 ± 3.57526e+07	Lynx lynx (Linnaeus, 1758)	
3.17262	HUMAN_OBSERVATION	1.26541e+09 ± 32	Lynx lynx (Linnaeus, 1758)	0.0563825



Data Table

Citations


Lynx lynx | europe + snow + lai_hv
Felis silvestris | europe + snow + lai...
snow cover
channel: snow cover
Leaf area index, high vegetation
channel: Leaf area index, high vegetation
01.06.2014 00:00:00
Lineage for Felis silvestris | europe + snow + lai_hv
GFBio Source
dataS... GBIF
level Species
term Felis silvestris
GDAL OGR Raw So...
filena... data:text/json,...
layer_...
query_...
Point in Polygon Fil...
GDAL Source
chann... Leaf area inde...
source... ecmwf_era5
transf... false
GDAL Source
chann... snow cover
source... ecmwf_era5
transf... false
Raster Value Extra...
xResol... 1024
yResol... 1024
attribu... snow cover, Le...
Leaf area index, high veg...
snow cover
Felis silvestris | europe +...
Data Table
Citations



Data Table

Citations

Histogram

Help

Raster, Point, Line, Polygon

Select Input Raster, Point, Line, Polygon

Input

Lynx lynx | europe + snow + lai_hv

Config

Specify the Histogram

Attribute

snow cover

Range Type

Custom

Min

1

Max

100

☐ Choose number of buckets automatically

Number of Buckets

20

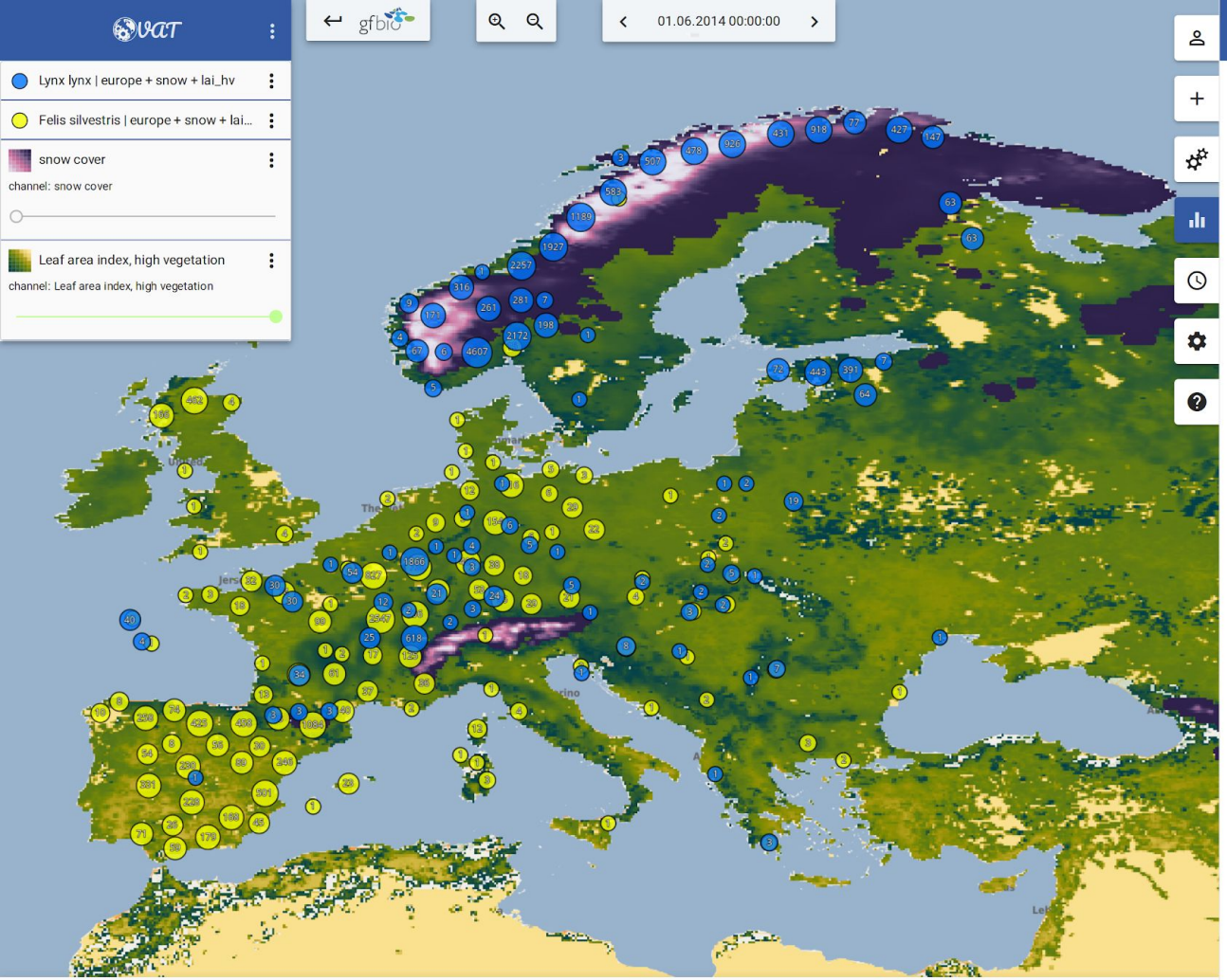
Output Name

Specify the name of the operator result

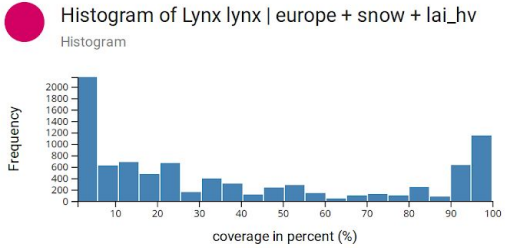
Output Layer Name

Histogram of Lynx lynx | europe + snow + lai_hv

Create

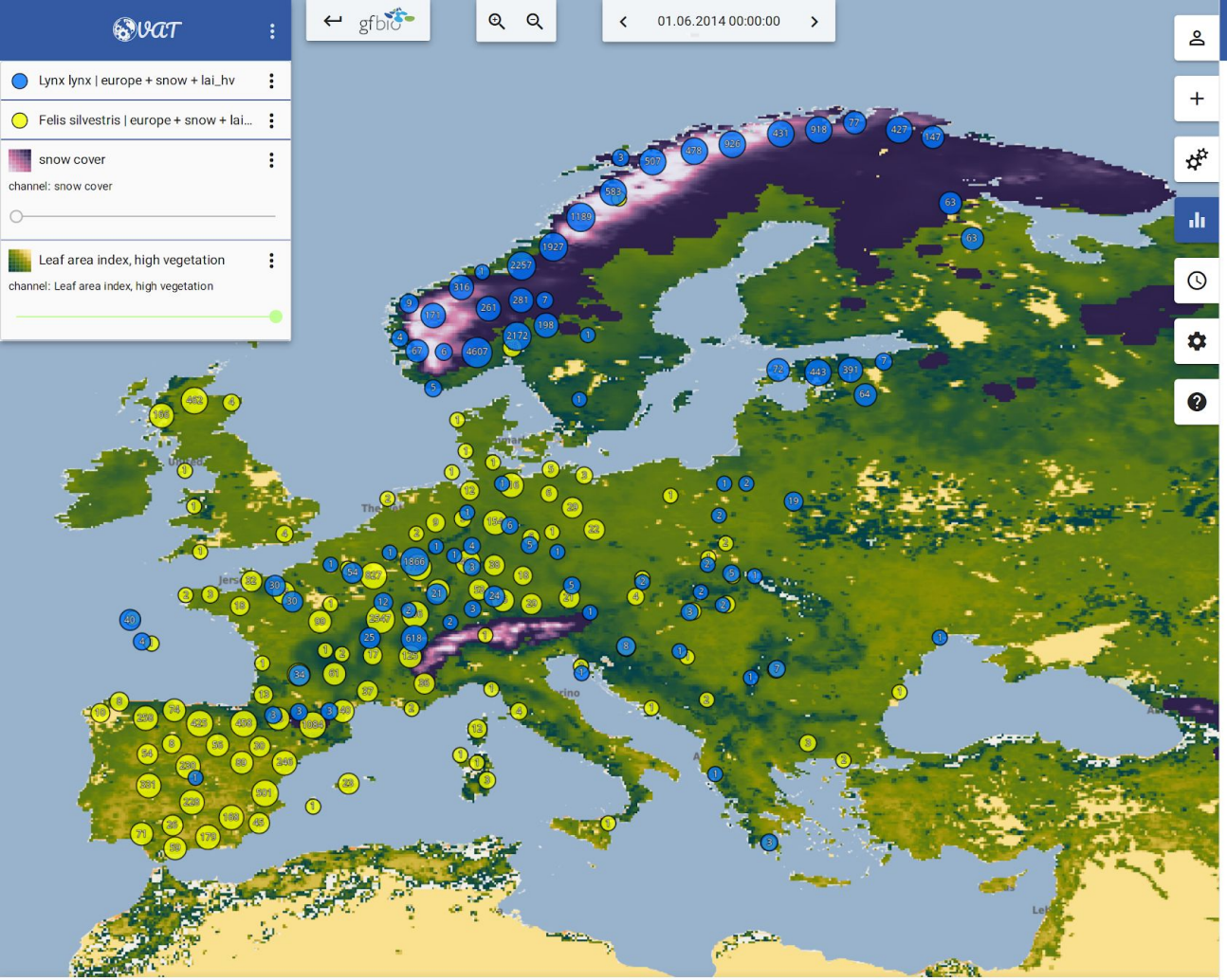


Plots



Data Table

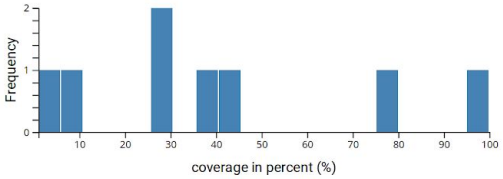
Citations



Plots

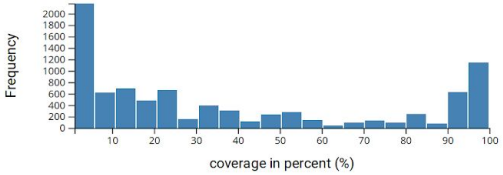
Histogram of Felis silvestris | europe + snow + lai_hv

Histogram



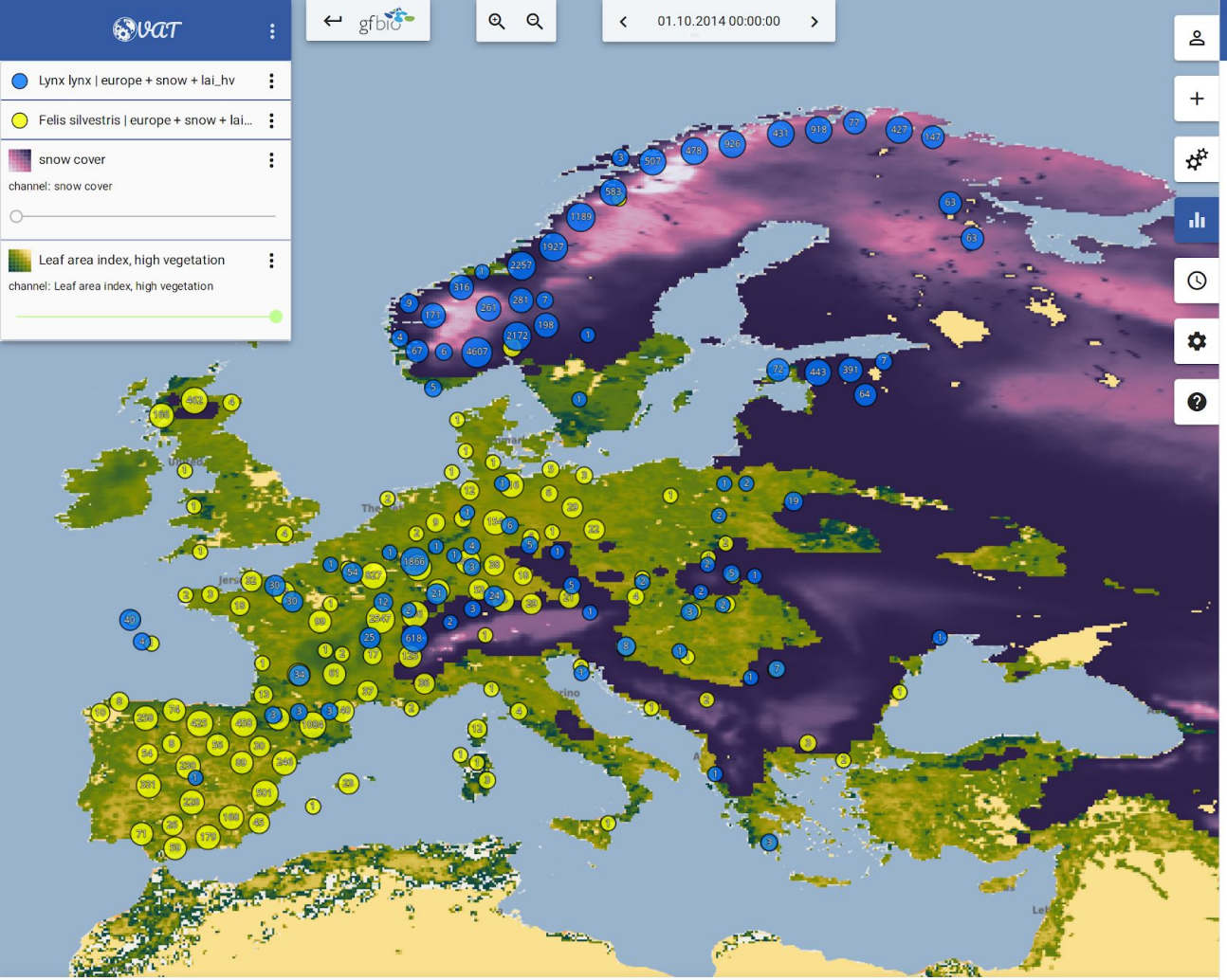
Histogram of Lynx lynx | europe + snow + lai_hv

Histogram



Data Table

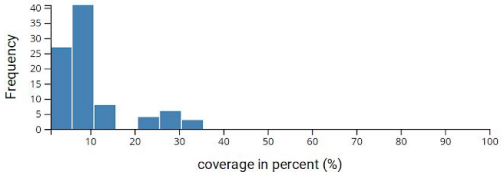
Citations



Plots

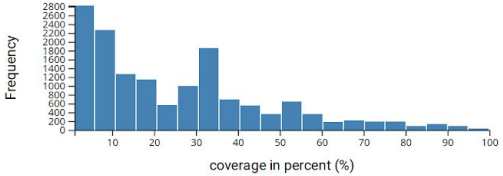
Histogram of Felis silvestris | europe + snow + lai_hv

Histogram



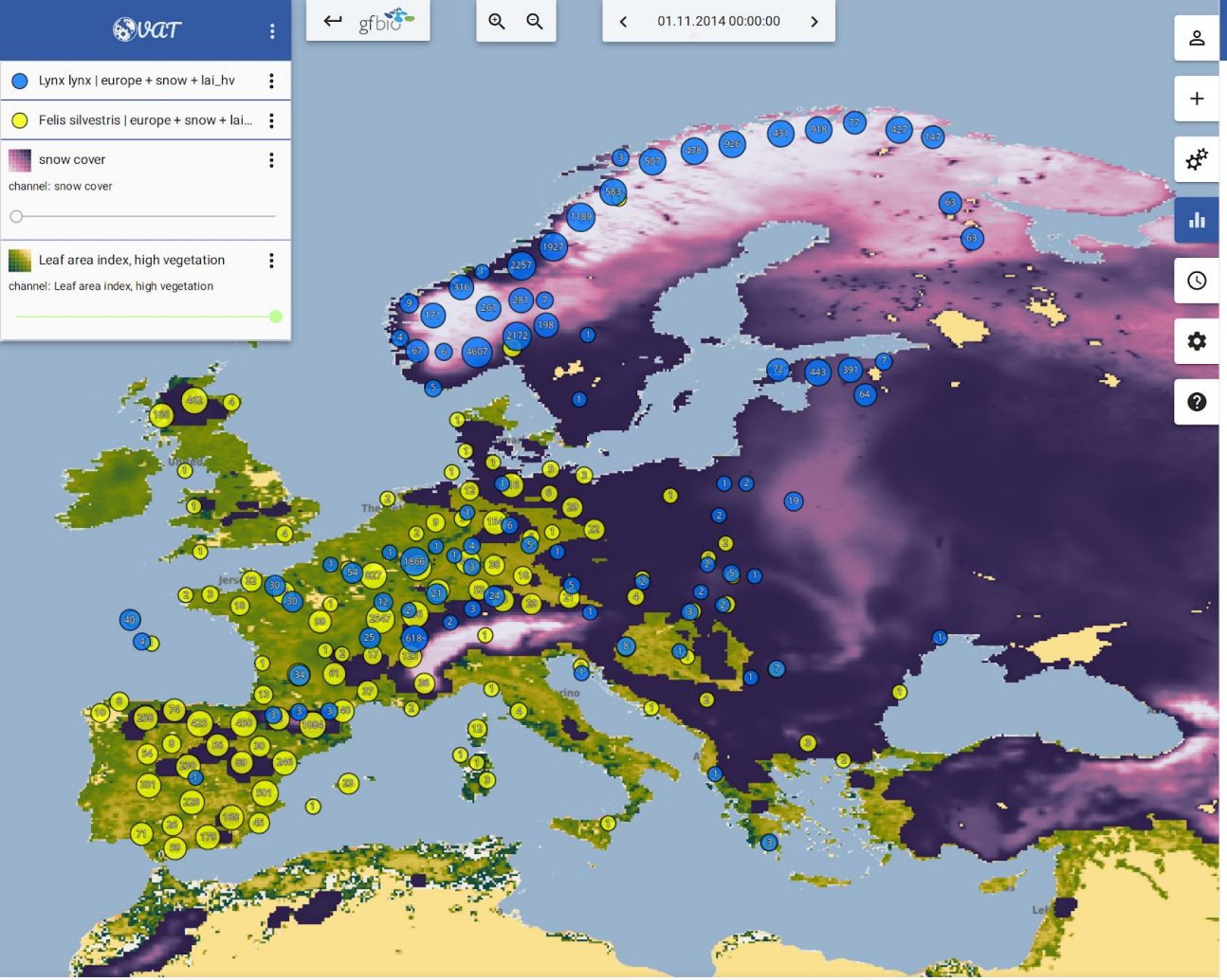
Histogram of Lynx lynx | europe + snow + lai_hv

Histogram



Data Table

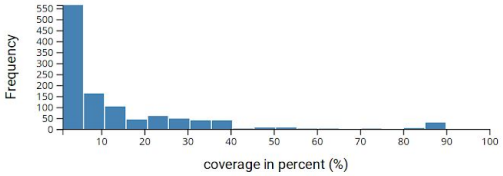
Citations



Plots

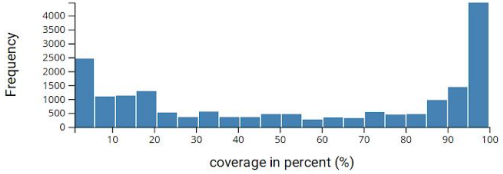
Histogram of Felis silvestris | europe + snow + lai_hv

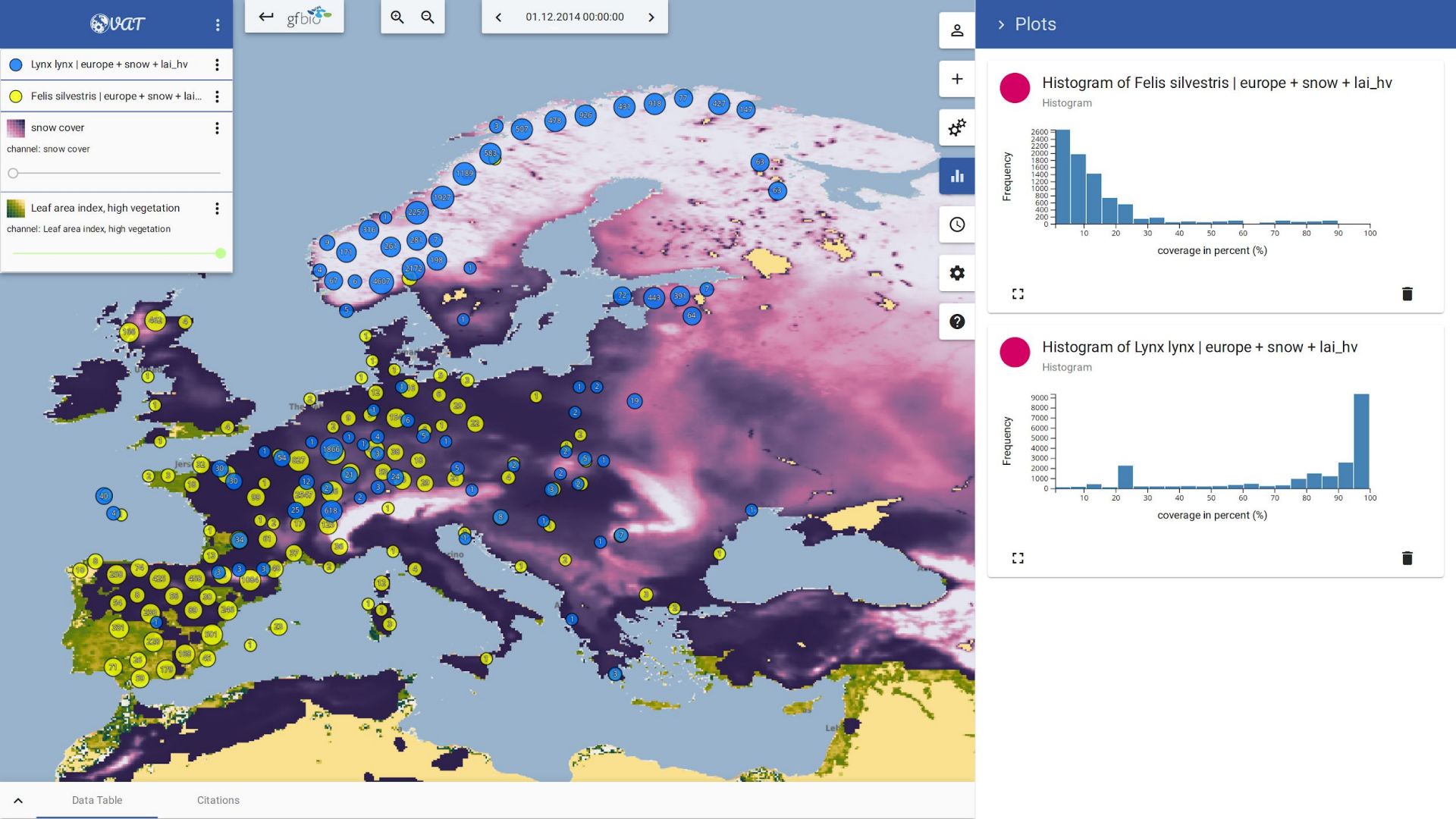
Histogram

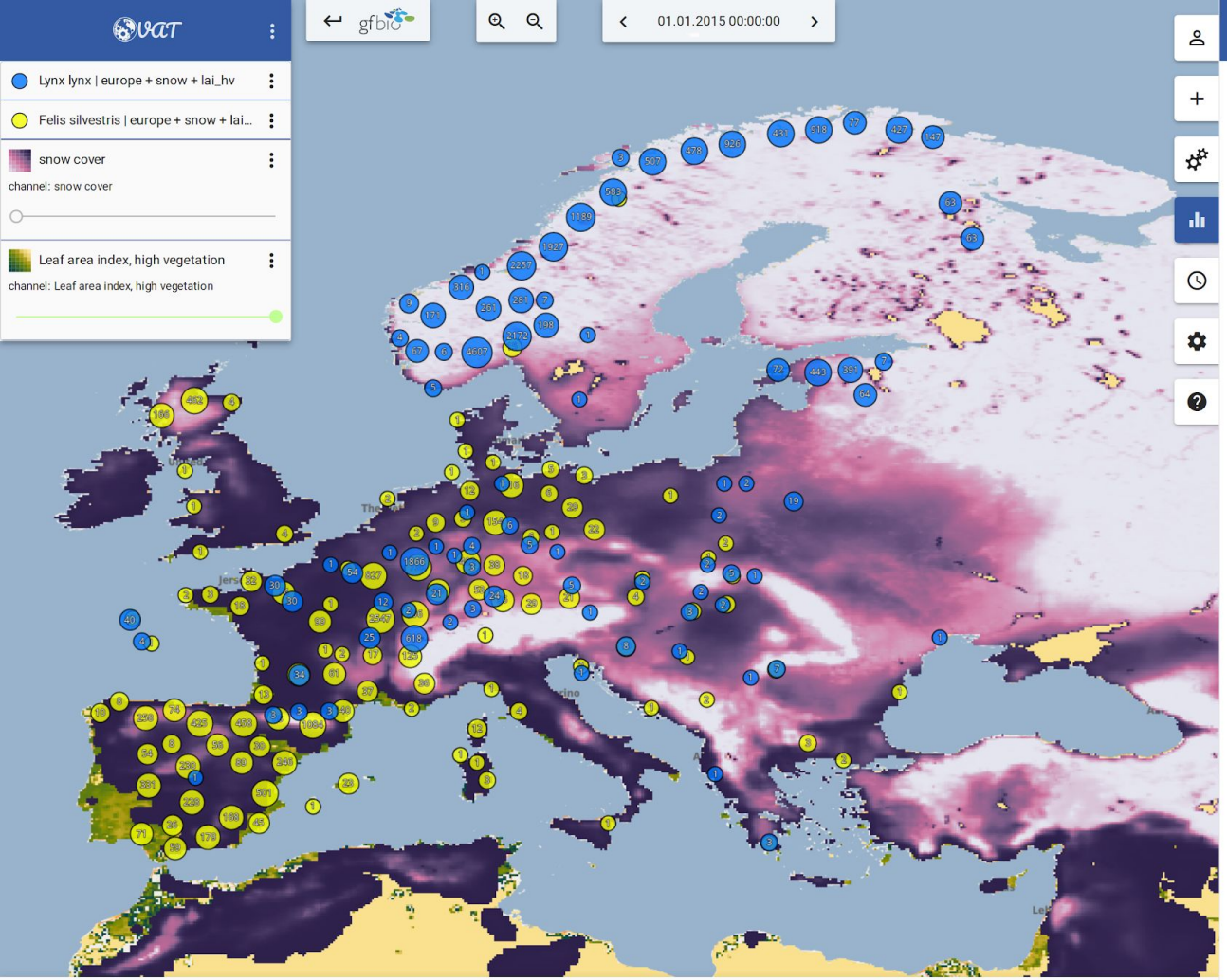


Histogram of Lynx lynx | europe + snow + lai_hv

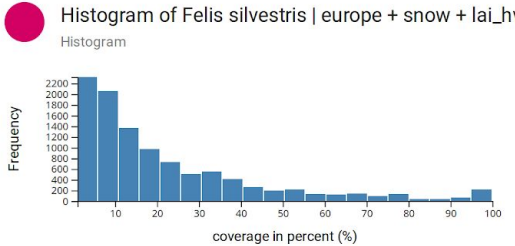
Histogram

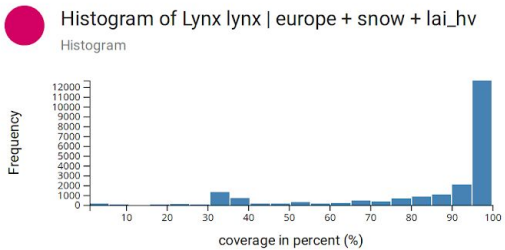



VAT
gfbio
01.12.2014 00:00:00
Lynx lynx | europe + snow + lai_hv
Felis silvestris | europe + snow + lai...
snow cover
channel: snow cover
Leaf area index, high vegetation
channel: Leaf area index, high vegetation
Plots
Histogram of Felis silvestris | europe + snow + lai_hv
Histogram
Frequency
coverage in percent (%)
Histogram of Lynx lynx | europe + snow + lai_hv
Histogram
Frequency
coverage in percent (%)
Data Table
Citations

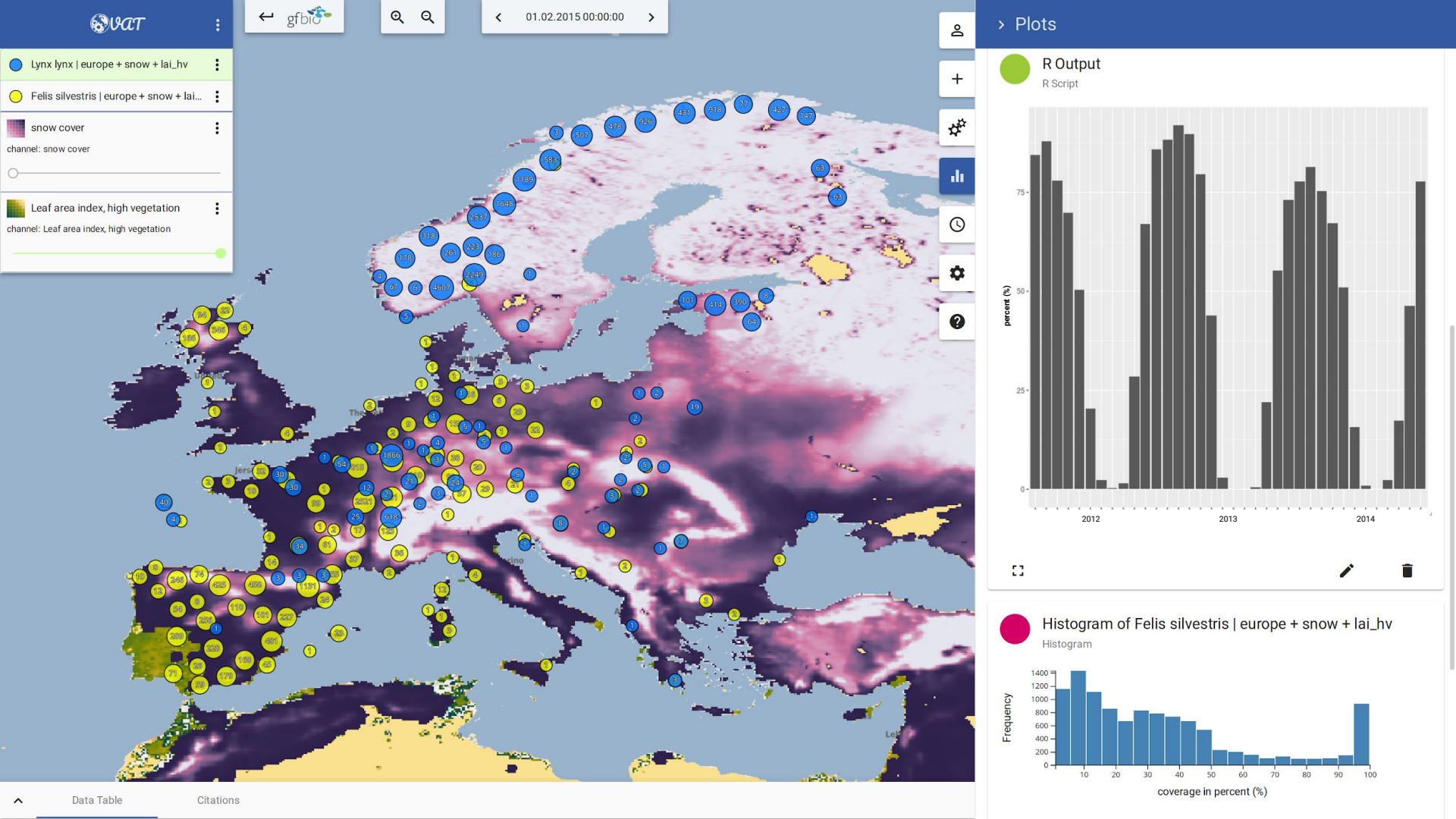


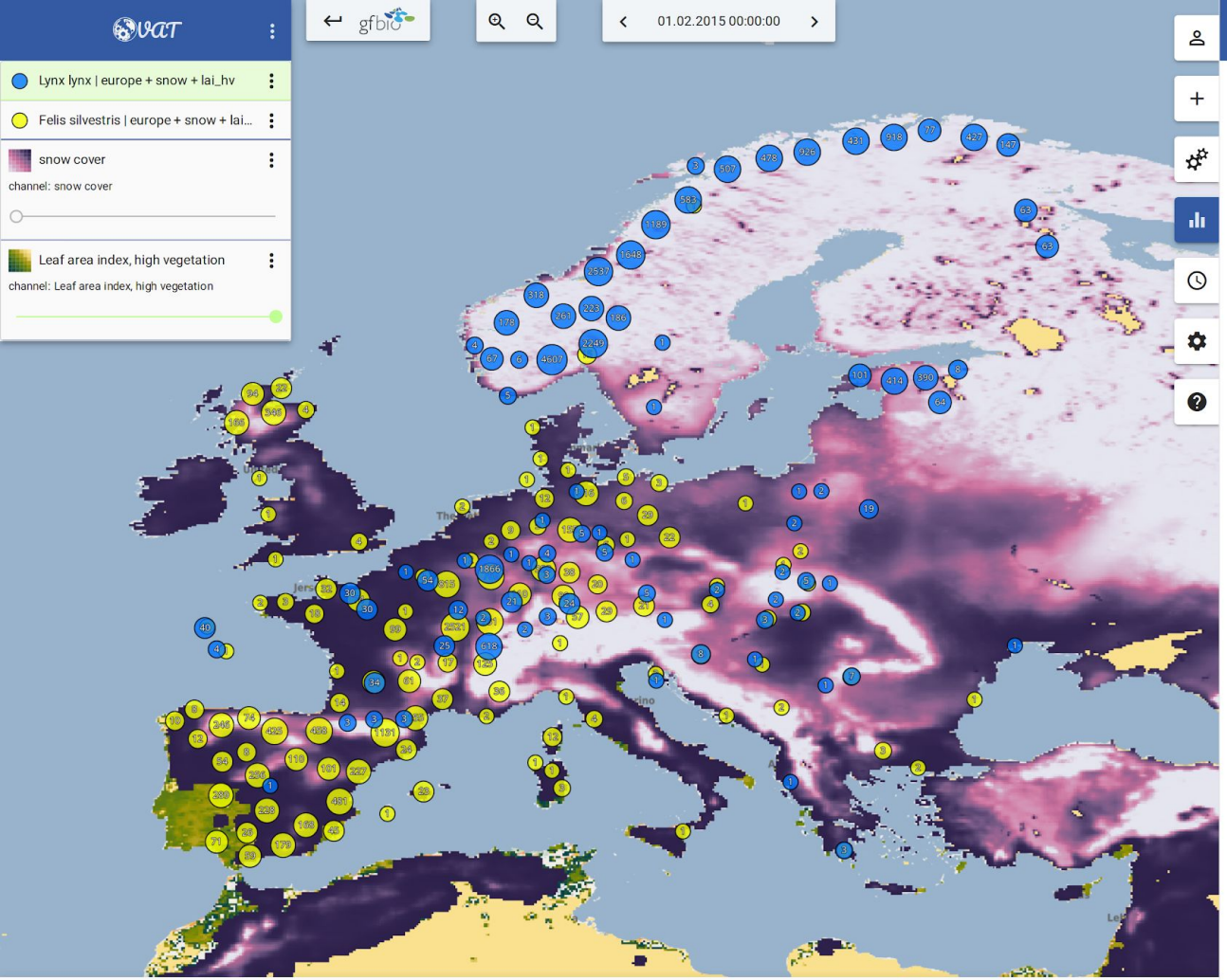
Plots





Data Table Citations

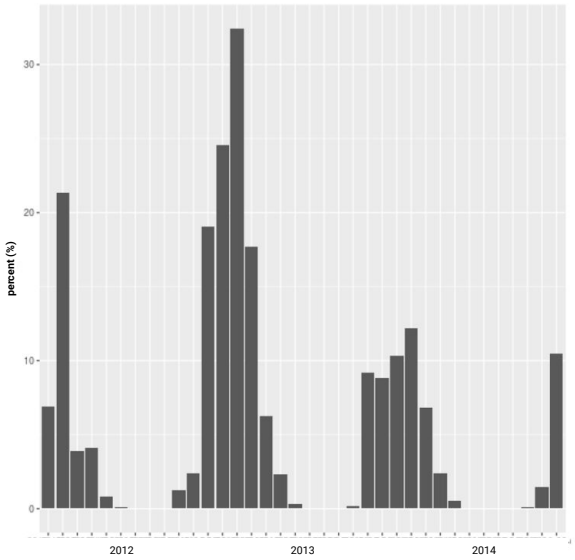

vat
gfbio
01.02.2015 00:00:00
Lynx lynx | europe + snow + lai_hv
Felis silvestris | europe + snow + lai...
snow cover
channel: snow cover
Leaf area index, high vegetation
channel: Leaf area index, high vegetation
Plots
R Output
R Script
percent (%)
0
25
50
75
2012
2013
2014
Histogram of Felis silvestris | europe + snow + lai_hv
Histogram
Frequency
0
200
400
600
800
1000
1200
1400
10
20
30
40
50
60
70
80
90
100
coverage in percent (%)
Data Table
Citations



Data Table

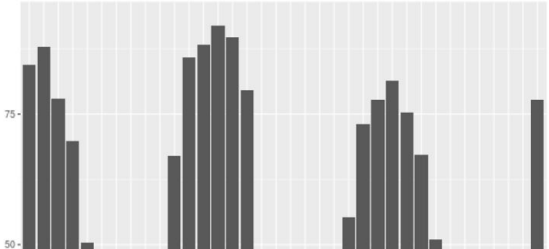
Citations

Plots



R Output

R Script



Tech-Stack

Frontend

- map view with **OpenLayers**
- Angular & Material Design
- interactive
  - workflow generation
  - plots
- pan and zoom
  - time
  - space

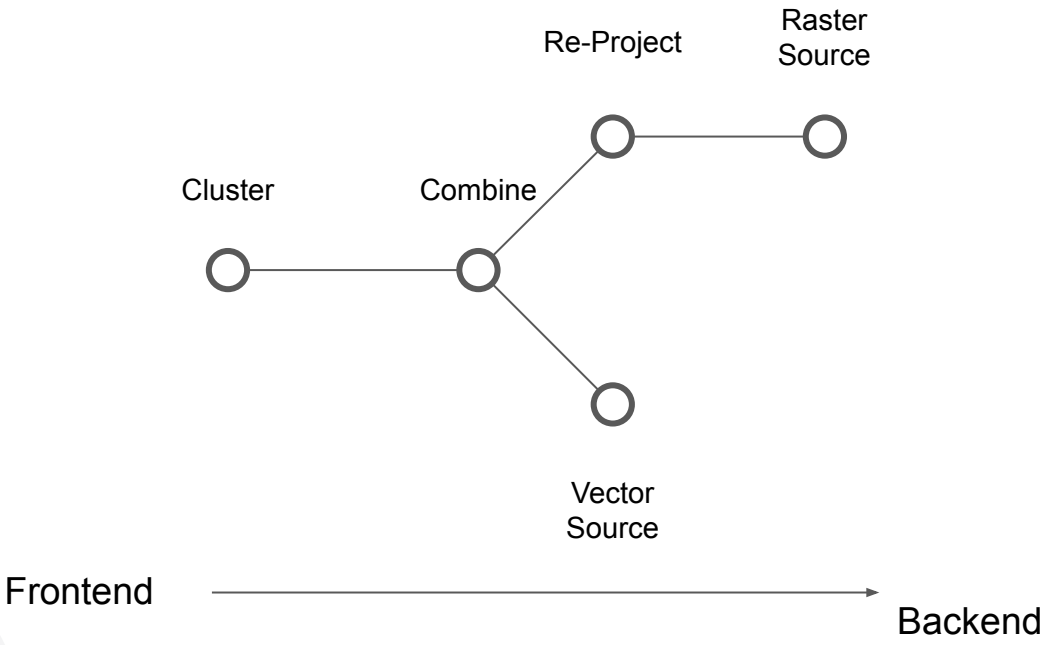
Backend

- everything is a time-series
- workflow-based processing
- written in **Rust**
- data access with **GDAL**
- user-functions with **Python**
- Apache Arrow for interoperability
- OpenCL integration

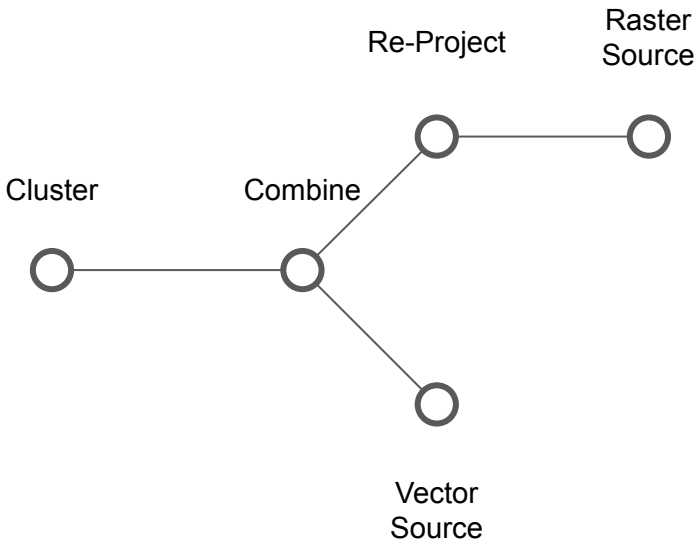
How queries work

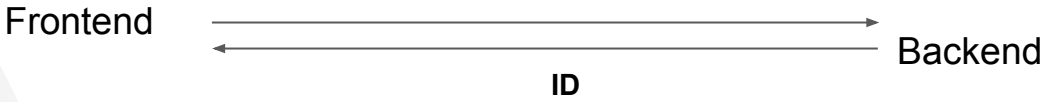
in two steps

1. Register workflow



1. Register workflow





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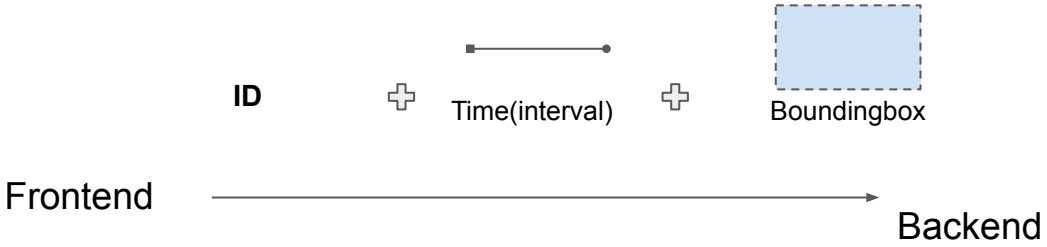
2. Query data

with ID via WMS / WFS → Raster / Vector data

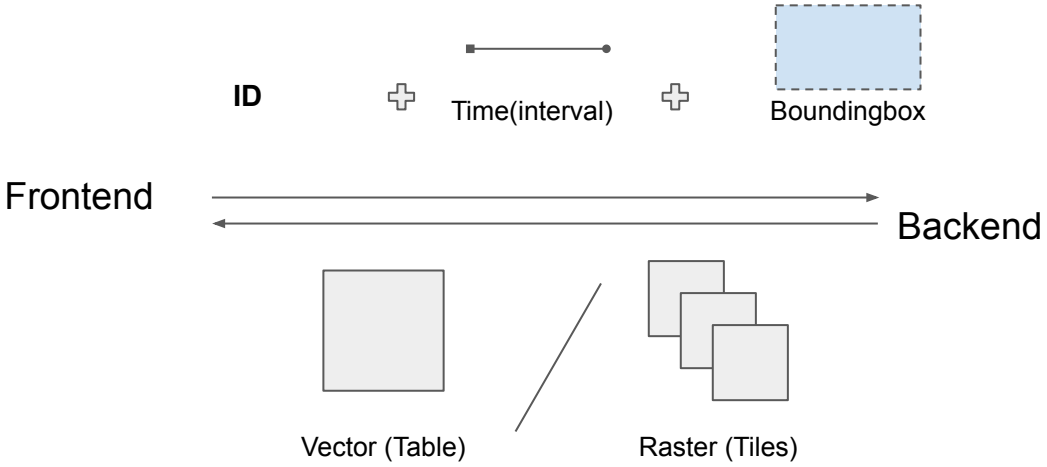
2. Query data

with ID via WMS / WFS → Raster / Vector data



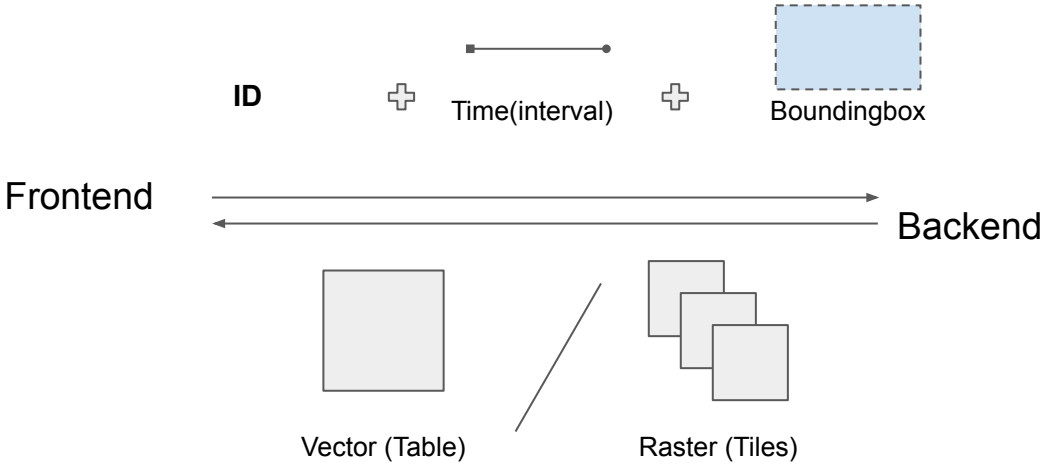
2. Query data

with ID via WMS / WFS → Raster / Vector data



2. Query data

with ID via WMS / WFS → Raster / Vector data



What is next?

- More operators

- Python operator for user functions
- APIs for Jupyter integration

- ML integration
  - Train: feed stream into ML frameworks (e.g. Tensorflow)
  - Apply: use model as operator

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Explore and Combine Spatio-Temporal Data

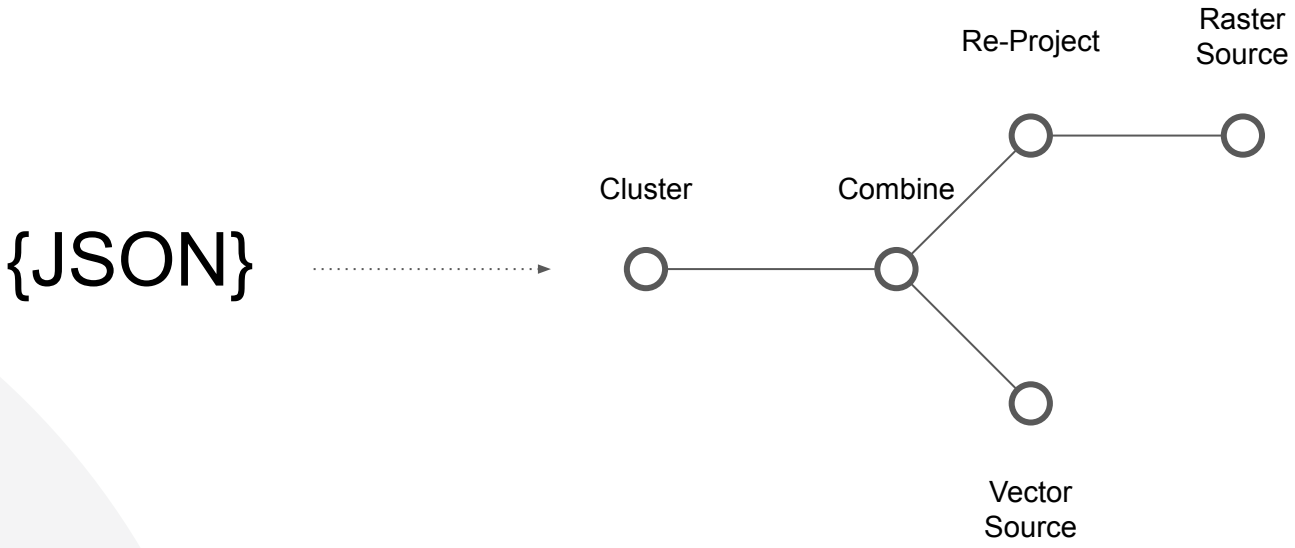
geo engine

Backup

How the backend works 🧙‍♀️

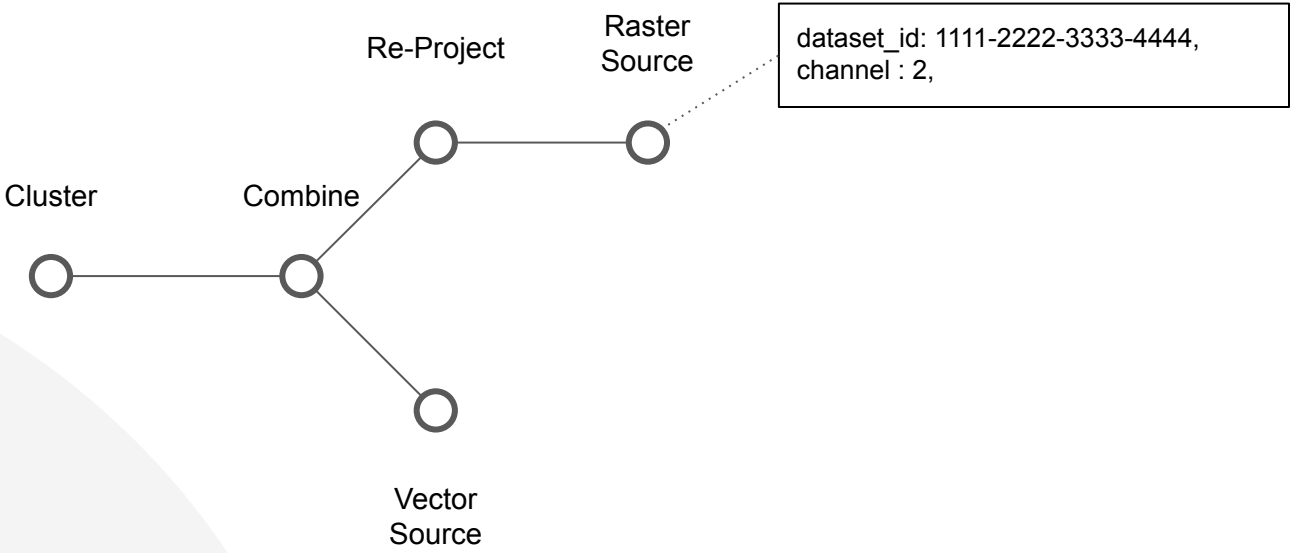
1. Deserialize workflow

into an operator graph



1. Deserialize workflow

and parse operator parameters



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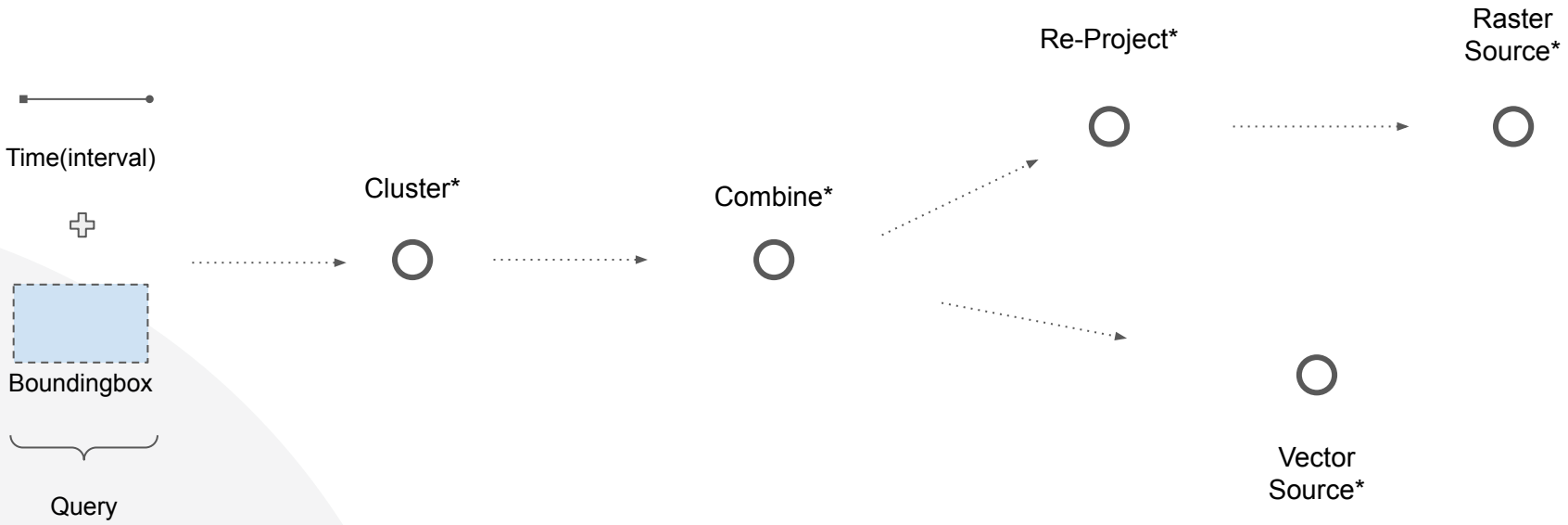
2. Query the graph

by forwarding the query to sources



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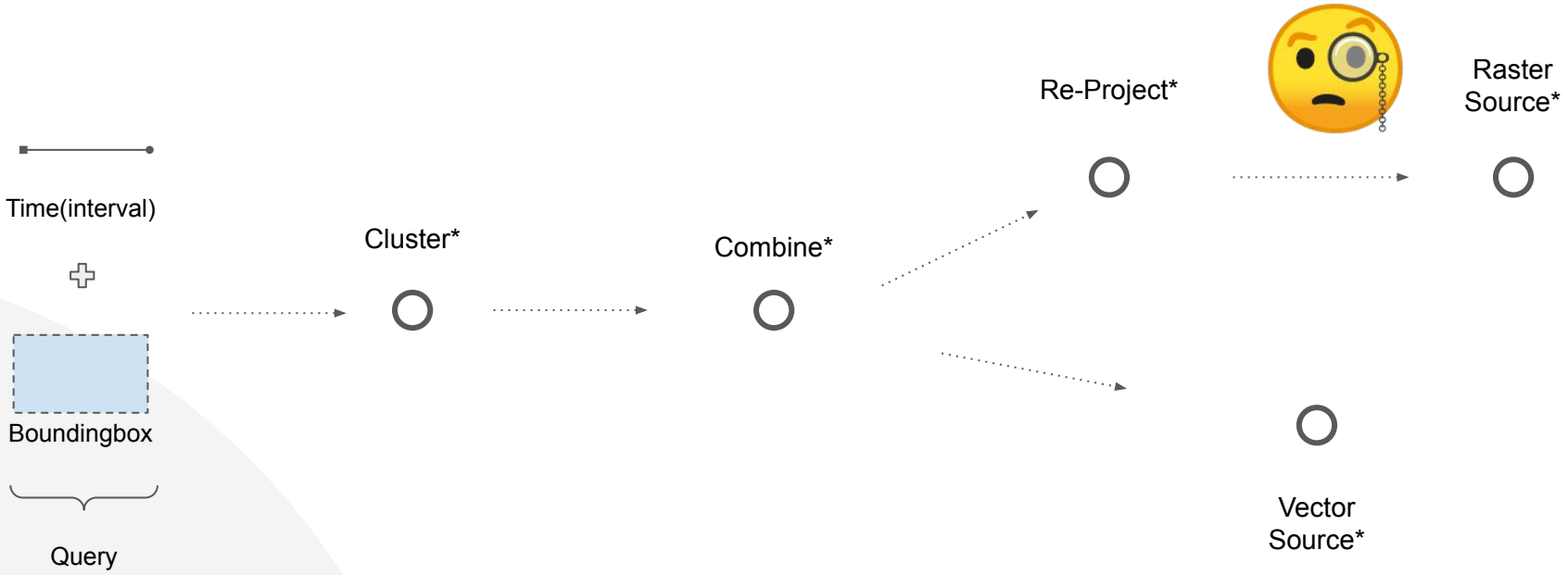
2. Query the graph



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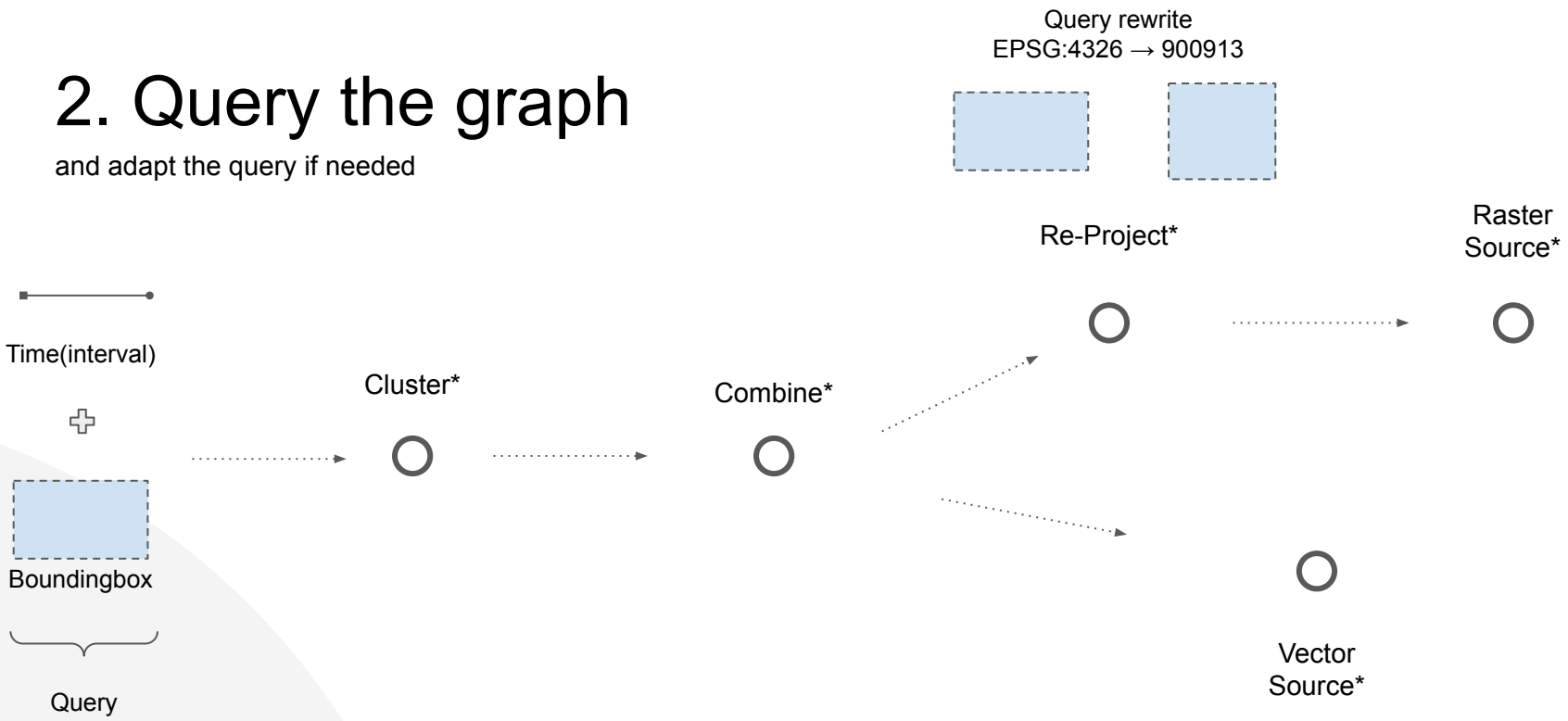
2. Query the graph

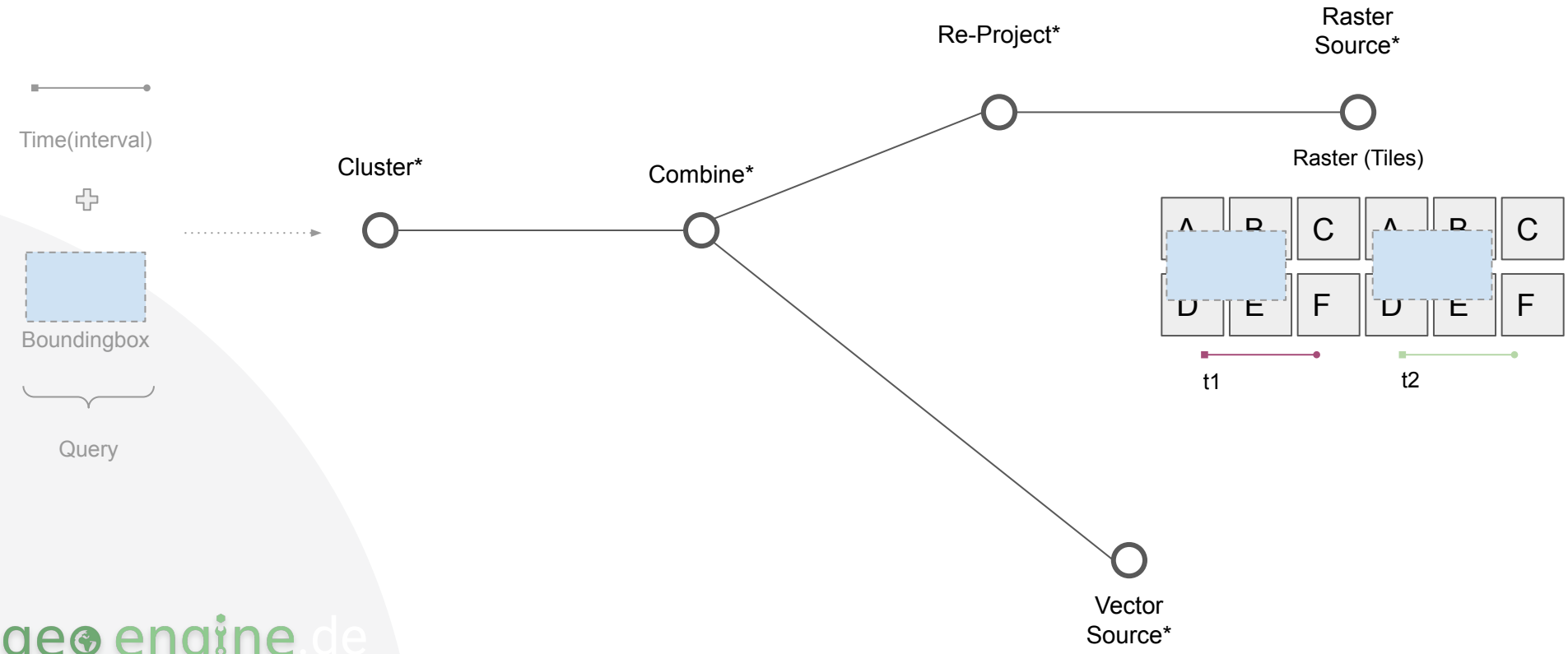
and adapt the query if needed



geo engine.de

3. Data streams

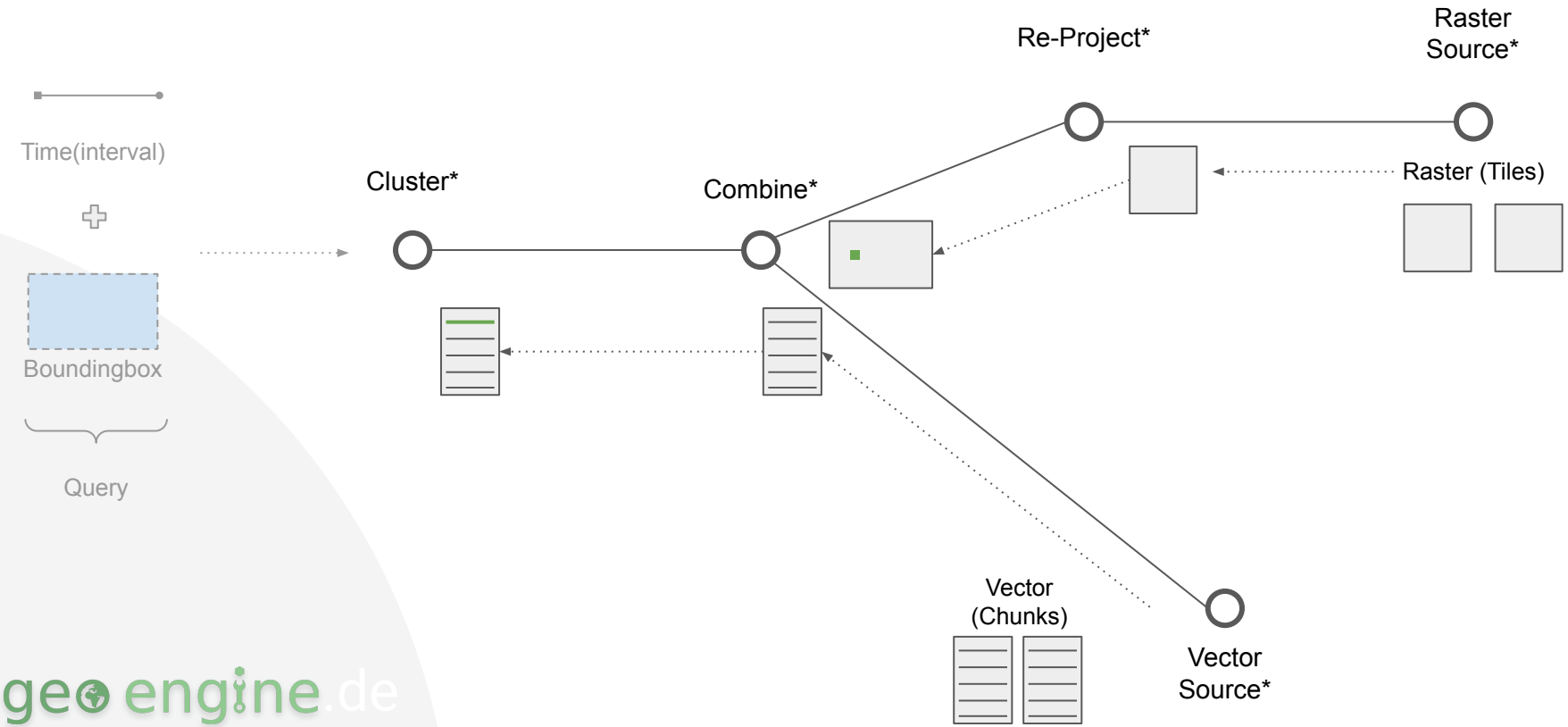
produce data matching the query



geo engine.de

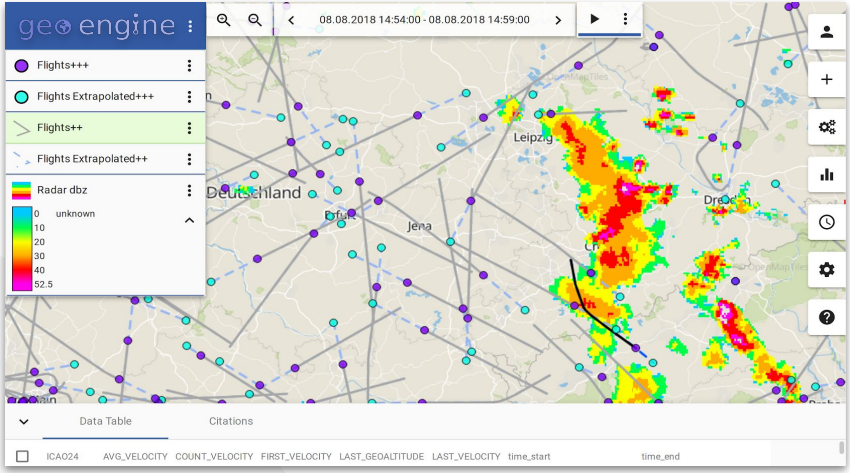
4. Apply operators

to each raster tile / vector chunk

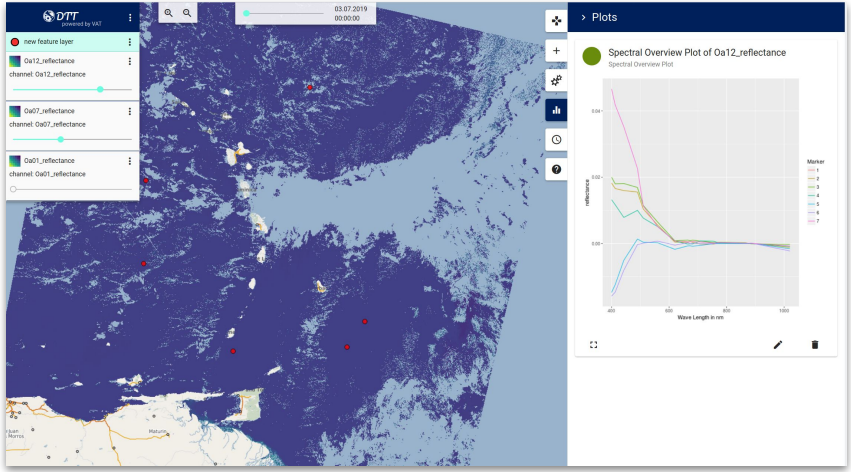


geo engine.de

Other examples



Combination of flight-tracks and weather radar (OpenSky Workshop)



Digital Teaching Tool for Copernicus-Data (Eumetsat)

Cloud strategy

- Current: Deploy next to the data
  - Data portal @ GEO BON, GFBio, NFDI4Biodiversity
  - Training tool @ Eumetsat
- Next: Hosted Service
  - one service for many users
  - projects & data in one place → share data and functions
  - no maintenance for users
- Additionally: Parallel processing
  - split data processing along spatial and temporal axis