

COURSE OVERVIEW

GEOSPATIAL REPRESENTATION LEARNING

Course Structure and Format

Winter Semester 2026/27

Mobile Robotics, Geodesy and
Geoinformation & Geodetic Engineering

PRESS – OR SPACE. →

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Course Learning Outcomes

After completing the course, you will be able to:

1. Explain the principles of geospatial representation learning, how geospatial embeddings are created, and their potential and limitations for different applications.
2. Compare geospatial data sources and create and curate datasets from satellite imagery, time series, GIS layers, and other environmental and socio-economic data.
3. Implement Python-based machine-learning workflows using both fixed representations of existing geospatial data and representations learned through modern deep-learning methods.
4. Evaluate and compare models and representations for environmental and socio-ecological applications, considering predictive performance, generalization, and suitability for the task.
5. Critically assess and discuss research papers on geospatial representation learning, foundation models, and Earth embeddings, examining their methods, evidence, and limitations.
6. Design and conduct a research-oriented geospatial analysis project in a student group, and communicate its methods, results, and limitations through scientific writing and oral presentations.

Three Phases:

Phase 1: Lectures & Labs



Build conceptual and technical foundations through lectures and hands-on exercises.

Examination: final written exam on the course content.

Phase 2: Paper Analysis



Analyze and review recent research papers in student groups.

Examination: pass/fail paper presentation with questions.

Phase 3: Group Projects



Develop code and conduct a research-oriented geospatial analysis project in groups.

Examination: written project report.

Bloom's cognitive levels across the course

Remember

Understand

Apply

Analyze

Evaluate

Create

Timeline at a Glance

Fridays: Lectures 10:00–12:00 in HS VIII (Meckenheimer Allee 172)*

Labs 13:00–15:00 in Seminarraum 2.003 (Nußallee 1)

* Lecture 2 on October 30 is in HS IX (same floor).

Course week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Event date	Oct 16	Oct 23	Oct 30	Nov 6	Nov 13	Nov 20	Nov 27	Dec 4	Dec 11	Dec 18	Christmas + Jan 8	Jan 15	Jan 22	Jan 29	Feb 5
Phase 1: Lectures	Intro	L1	L2*	L3	L4	No class	L5	L6							
Phase 1: Labs		Lab 1	Lab 2	Lab 3	Lab 4										
Phase 2: Papers							P1	P2	P3	P4					
Phase 3: Projects															Group Projects

Presence and Examination Events

Paper Presentations pass/fail
Nov 27, Dec 4, 11 & 18, 2026

Phase 1 Written exam
February 5th, 2027

Phase 3 report deadline
Date: TBD

Phase 1: Lectures and Labs

Lectures

10:00–12:00 (s.t.)

HS VIII (Meckenheimer Allee 172)

Lecture 2 on October 30: HS IX (same floor).

Presentation slides introduce the core concepts, terminology, and research context.

They provide the shared conceptual foundation for the hands-on work.

Labs

13:00–15:00

Seminarraum 2.003 (Nußallee 1)

Interactive activities reinforce the lecture through self-directed, collaborative, and hands-on learning:

- Explore representations using PCA and t-SNE
- Collect, clean, and combine geodata
- Train and evaluate machine-learning models
- Investigate model architectures and explain them through peer teaching

Phase 1: Overview - Lectures & Labs

Lecture 1

Representations

What is a representation?

Lecture 2

Geospatial Data

What is geodata?

Lecture 3

Machine Learning on Data Representations

Learning on fixed representations

Lecture 4

Deep Representation Learning I

Learning the representation itself

Lecture 5

Deep Representation Learning II

Learning beyond memorization

Lecture 6

Geospatial Embeddings

Giving location a meaning

Lab 1

Visualizing high-dimensional representations

Lab 2

Geodata Scavenger Hunt

Lab 3

Machine Learning on Geospatial Data.

Lab 4

Practical: Supervised Deep Learning

Phase 2: Paper Analysis



Paper Analysis slides

Open the session deck



PowerPoint presentation template

Coming soon

Format

Each topical session introduces a new research area and assigns papers to the student groups.

1. **Read (between classes):** Study the assigned paper with your group.
2. **Analyze (between classes):** Identify the problem, method, evidence, limitations, and impact, and prepare your presentation.
3. **Present (in class):** Present your analysis, answer questions, and discuss the paper with the class.

Four Topics

Session	Topic
1	Implicit Neural Representations and Approximation
2	Location Encoders
3	Self-Supervised Representation Learning
4	Geospatial Embeddings

Phase 3: Group Project

Core project idea

Students investigate geospatial questions by **conducting a research study** or **developing GeoAI agents**.

Example themes:

- Deforestation monitoring
- Marine litter monitoring
- Urban expansion
- Agricultural change
- Flood or drought impacts
- Biodiversity and habitat suitability
- Land-cover and land-use change
- Climate-risk indicators
- Infrastructure and mobility patterns
- Human-environment interactions

Examination Method: Short Research Paper



Application Paper

An in-depth study of a specific environmental or socio-economic phenomenon using geospatial AI models and representations.



Method Paper

A methodology paper describing how the group developed an AI agent to dynamically study a specific environmental or socio-economic phenomenon.

Live Understanding Pulse

Throughout this course, I will show this widget to touch base on your level of understanding. It synchronizes across all devices, including in-class and virtual participants.

Try it out - click on the line:

I am completely lost

I fully understand

Click on the line to vote.

This gives me feedback during class and also tracks the general understandability of the slides, so I can improve them in future iterations.

Why this course?

The Earth faces global challenges



Urbanization



Deforestation

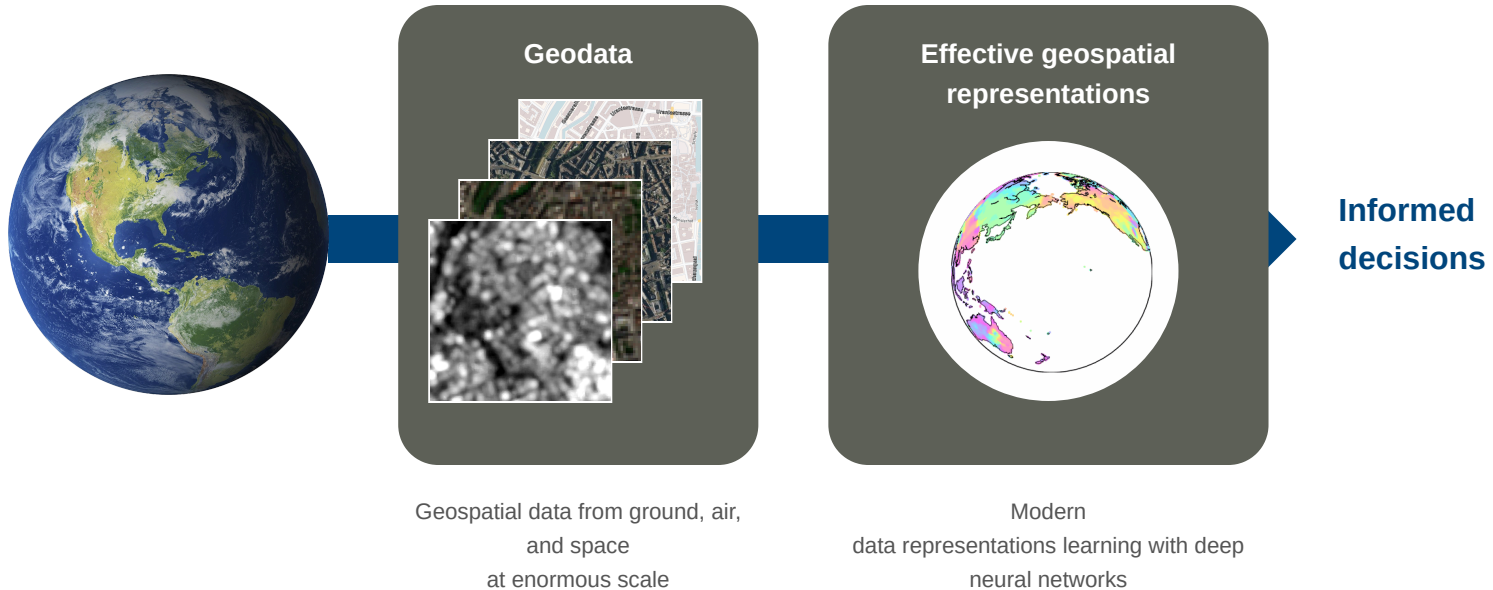
We need to analyze geodata at large scale
to inform policies on biodiversity, food security, human health, and livelihoods.

Observing the Earth at unprecedented scales



Image: European Space Agency · Archive figures reproduced from the source talk.

We need effective representations of heterogeneous geodata



Pollution monitoring



Cuttings Beach, Durban, South Africa
Image: Lisa Guastella



Giel Hagenbeek · Wageningen University & Research

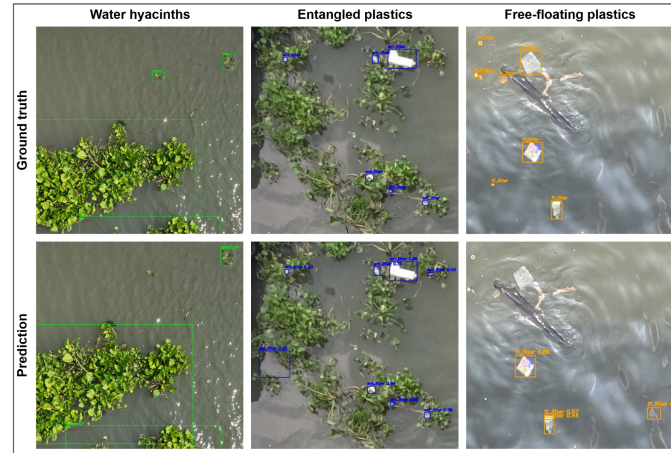
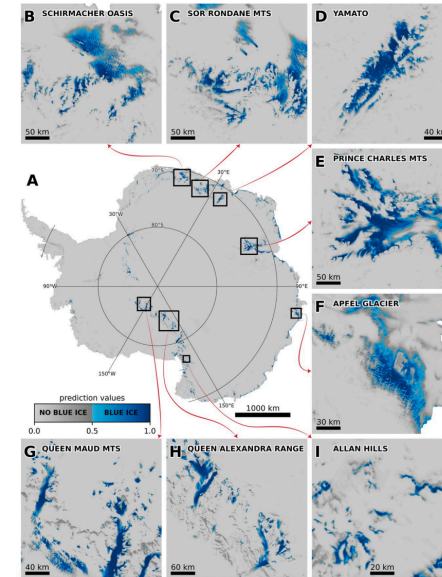
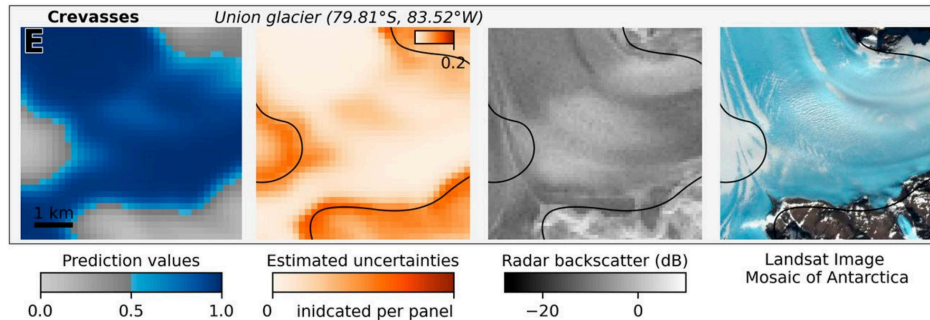


Figure 3: Examples of predicted bounding boxes compared to hand-annotated (ground truth) bounding boxes.

Finding meteorites in Antarctic blue ice



Veronica Tollenaar
Vrije Universiteit Brussel



Tollenaar, V., Zekollari, H., Pattyn, F., Rußwurm, M., Kellenberger, B., Lhermitte, S., Izeboud, M., & Tuia, D. (2024). Where the White Continent Is Blue: Deep Learning Locates Bare Ice in Antarctica. *Geophysical Research Letters*, 51(3), e2023GL106285. [doi:10.1029/2023GL106285](https://doi.org/10.1029/2023GL106285)

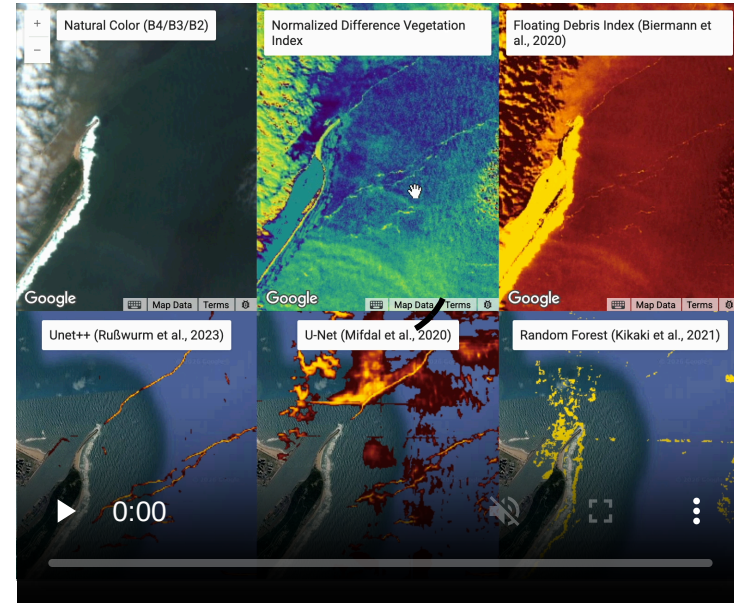
Detecting litter in open waters



Cuttings Beach, Durban · Image: Lisa Guastella



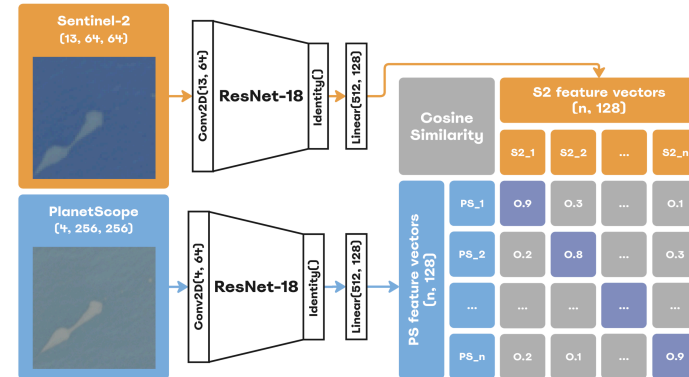
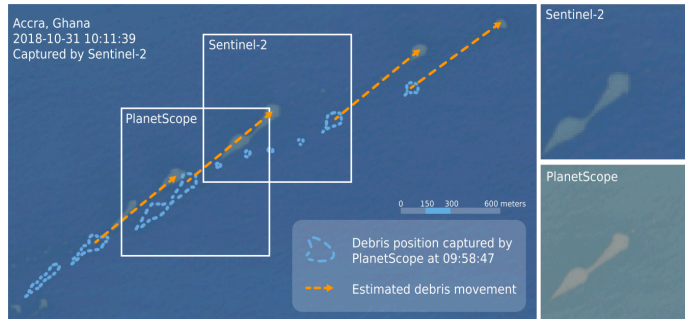
Sentinel-2 satellite



Tracking litter patches across sensors



Gabrielė Tijūnaitytė · Wageningen, Bonn

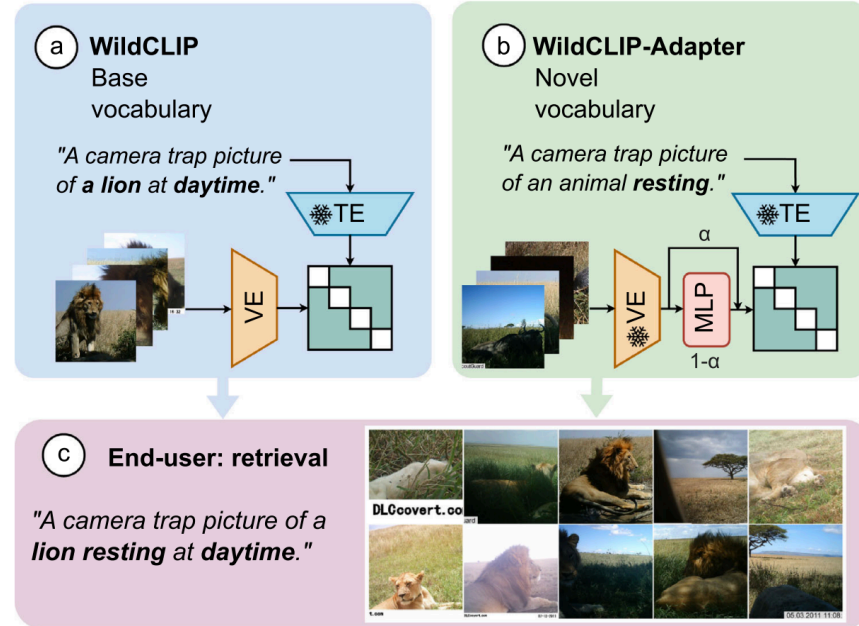


Text-based image retrieval on camera traps

Trained on the Snapshot Serengeti camera-trap dataset (Swanson et al., 2015) with more than **seven million images**.



Valentin Gabeff · EPFL

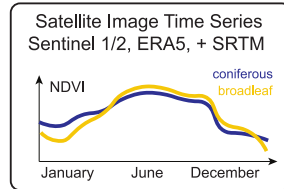


Tree species classification

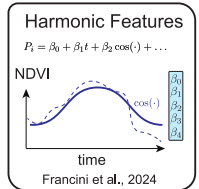
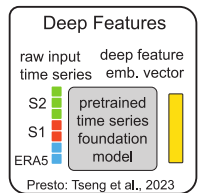


Takayuki Ishikawa · WUR MSc student

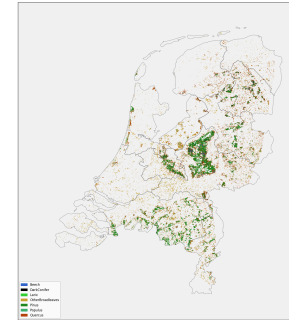
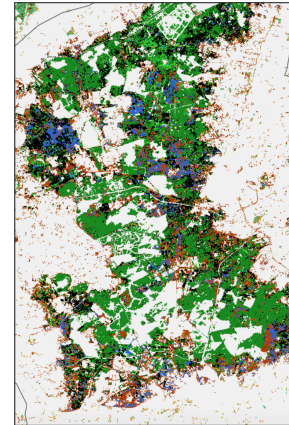
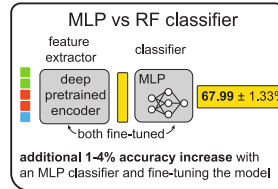
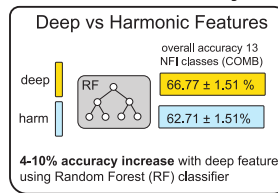
Tree Species Classification



Feature Extraction



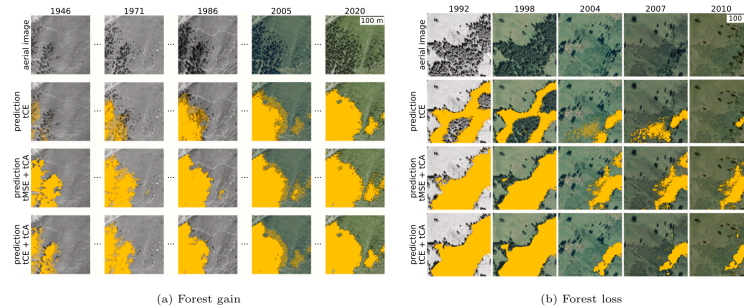
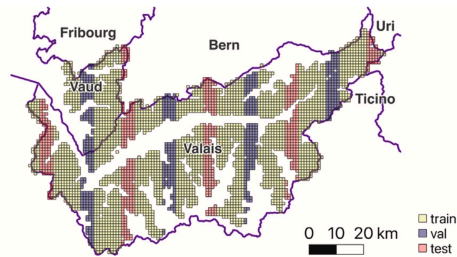
Results & Takeaways



Forest change in the Swiss Alps

Historic aerial photos (1946–2020) reveal forest gains at high altitudes as the tree line advances upwards with a warming climate.

Data: 2,660 tiles of 1 km × 1 km, with 12–20 time steps.



See you next Friday for Lecture 1!

Representations: What is a representation?

We will explore how images, words, and places can be represented as data—and how choosing or learning a representation shapes what a model can understand.

- From visual features to word embeddings
- Representing places with coordinates, maps, and geospatial embeddings
- Why useful representations depend on the task

10:00–12:00 (s.t.) · HS VIII

Meckenheimer Allee 172