

BioAIRad

Biodiversity monitoring of the airspace with radars — a project overview

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BioAIRAd

The airspace — an invisible habitat used daily by billions of birds, bats and insects — needs its own biodiversity monitoring! Existing (weather) radars can provide it.

Radars — from small instruments to the continental weather network — are remote-sensing tools for an essential, long-overlooked habitat: the airspace.

- Classify insect, bird and bat groups in both small-scale and weather-radar signals
- Interpolate and predict activity across the three-dimensional airspace
- Build data, methods and tools that stay useful beyond the project's lifetime
- Detect, verify and track migrations, and bioscatterer type

From Radar Echo to Biodiversity Variables

Weather radar

1. Reflectivity,
2. Radial velocity, and spectrum width
3. Differential reflectivity, correlation coefficient, and differential phase
4. Azimuth, beam elevation angle, range

Small-scale radars

1. Reflectivity/ radar cross section
2. Azimuthal direction and velocity
3. Wing beat frequency and flapping patterns
4. Polarization
5. Altitude

Ecological information

- | | |
|---|--|
| <ol style="list-style-type: none">1. Bioscatterers group abundance and mass2. Shape (aspect ratio), uniformity of individual shapes in the group;3. Ground speed, group flight direction and heading4. Altitude, distance from the radar | <ol style="list-style-type: none">1. Individual size, shape and mass2. Individual flight direction and ground speed3. Taxa or (size) class4. Altitude5. Flux/ traffic rate |
|---|--|

Essential Biodiversity Variables

Species populations

Abundance
Biomass

Species traits

Phenology
Flight behaviour
Migration

Community composition

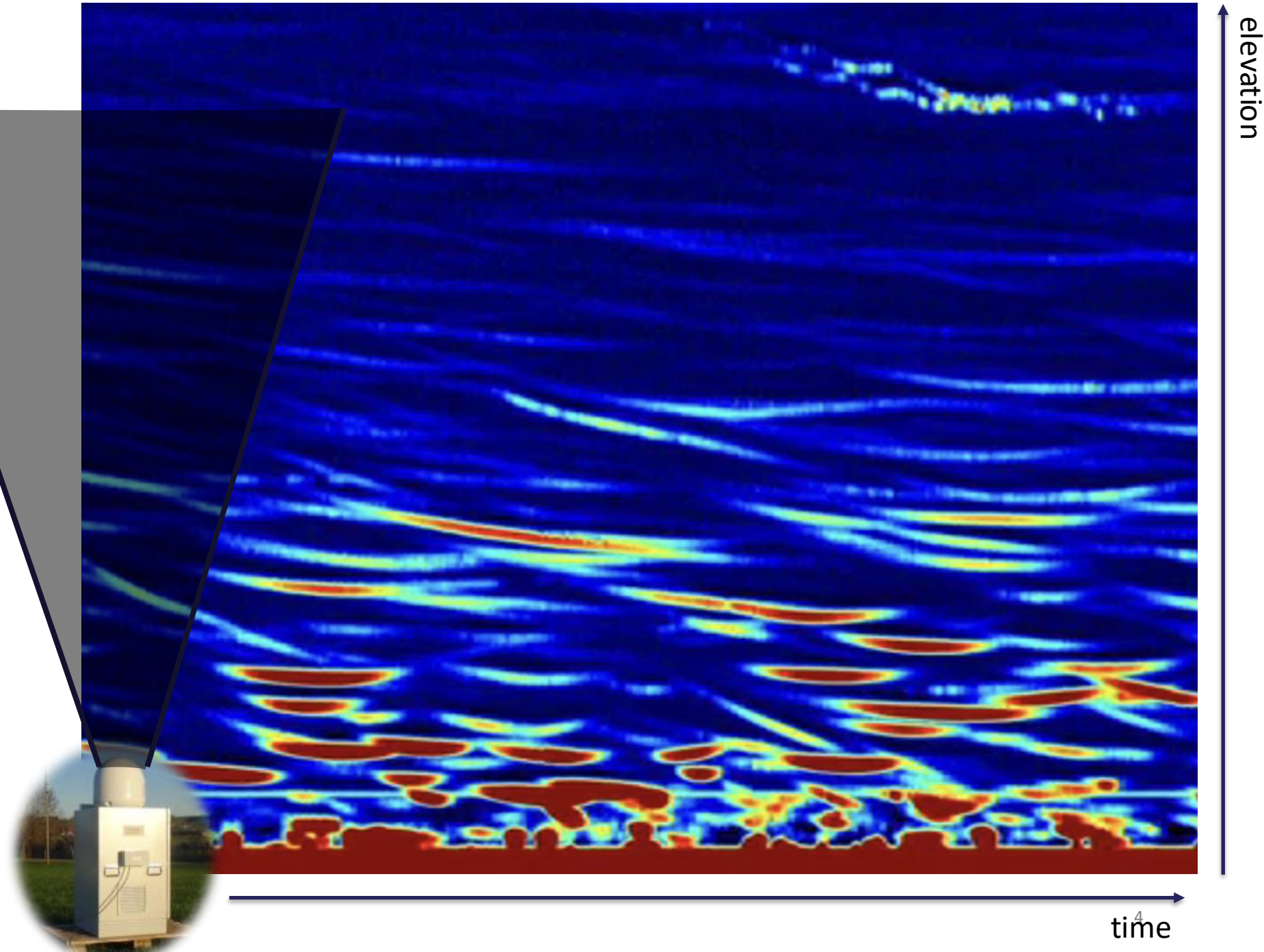
Taxonomic diversity
Species interactions

Ecosystem function

Secondary production
Nutrient retention and turnover

Portable weather radars

- High spatial and temporal resolution
- Airports
- Fixed view angle (upwards)
- Intensity (+ time of return)



Expert feature set

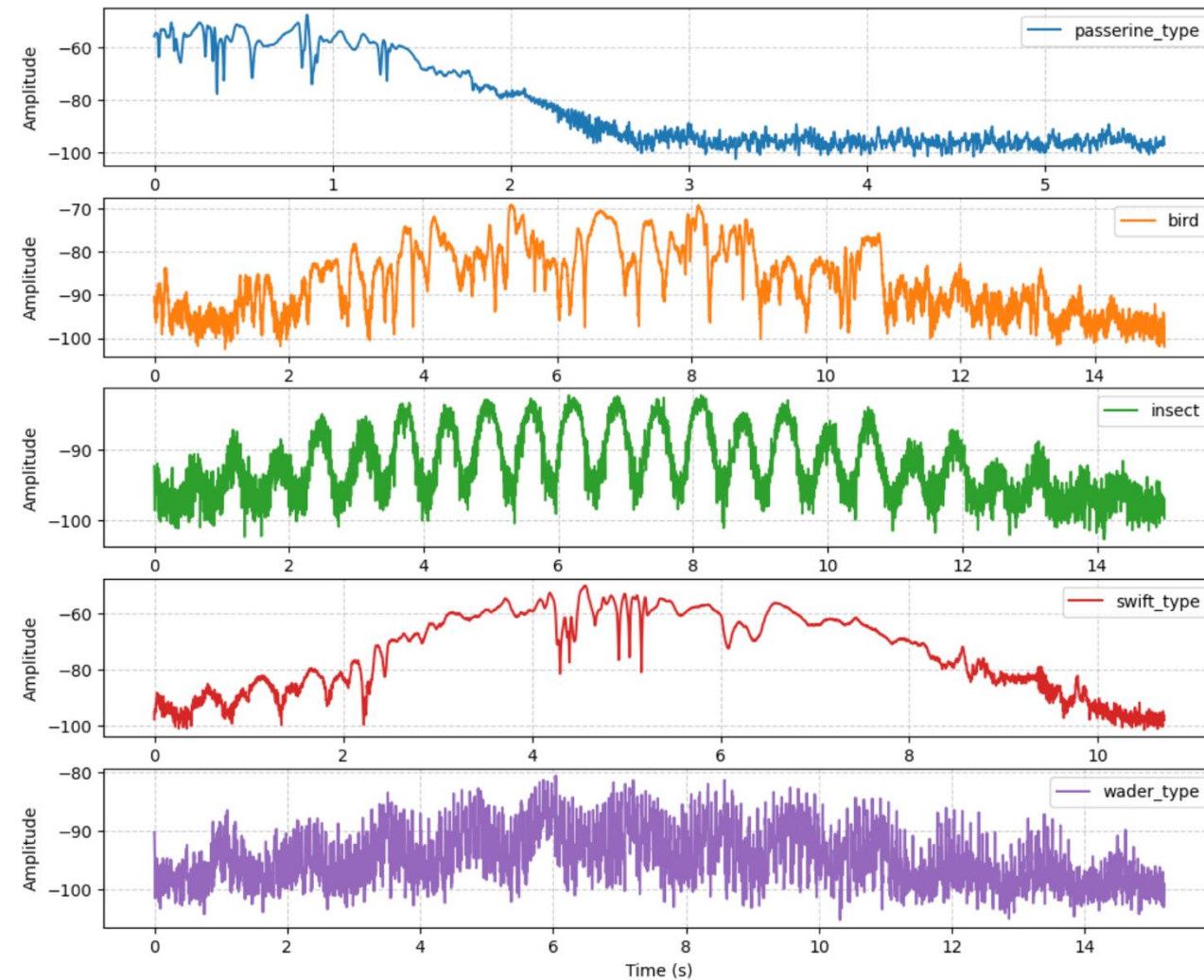
1. Fourier domain statistics (frequency)
2. Autocorrelation features (periodicity)
3. Signal properties (Intensity, direction)
4. Wing flap patterns (kinematics)

→ 167 handmade features

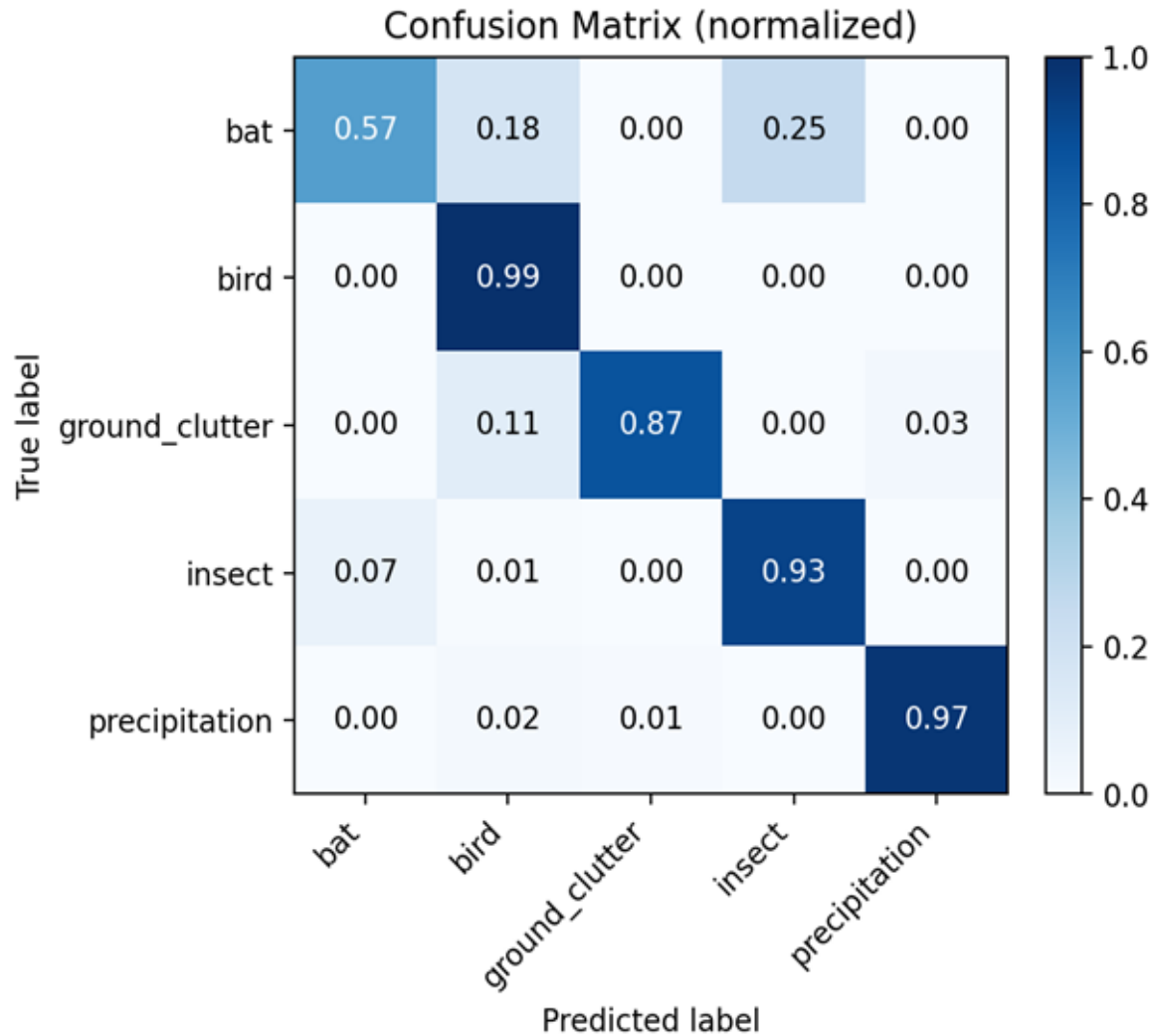
Trained NN from raw data

1. Signals cut at 9-10s snippets
2. One neural net for time series, one for the FT spectrogram (1D and 2D)
3. Models jointly learned and learned features concatenated in a 128+64D layer
4. Trained to optimize classification

→ 192 learned feature space



Feature set suitable to automatically distinguish bio-scatterers



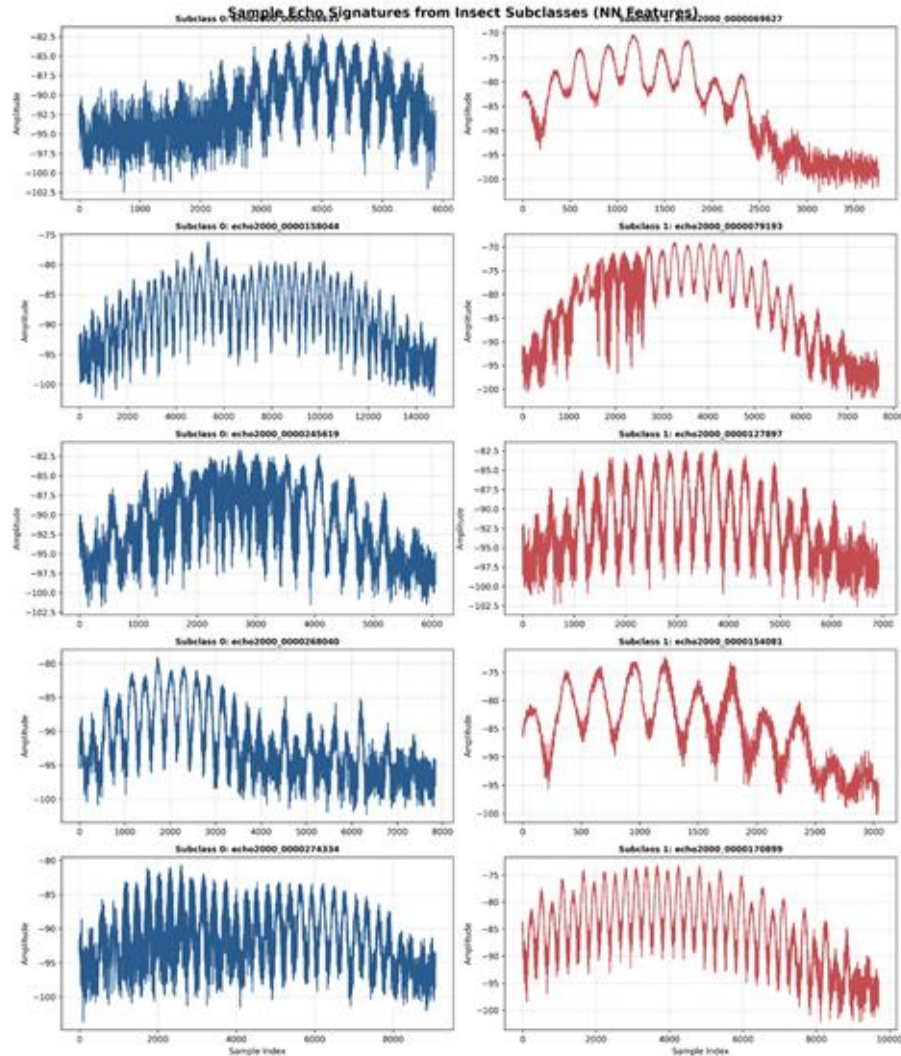
Models

- 1) Plain Random forest (fast, portable)
- 2) Neural network on raw signals

Most important features

- 1) size/shape features
- 2) spectrum
- 3) autocorrelation

Can we refine the model by clustering subclasses?



Two main clusters of insects

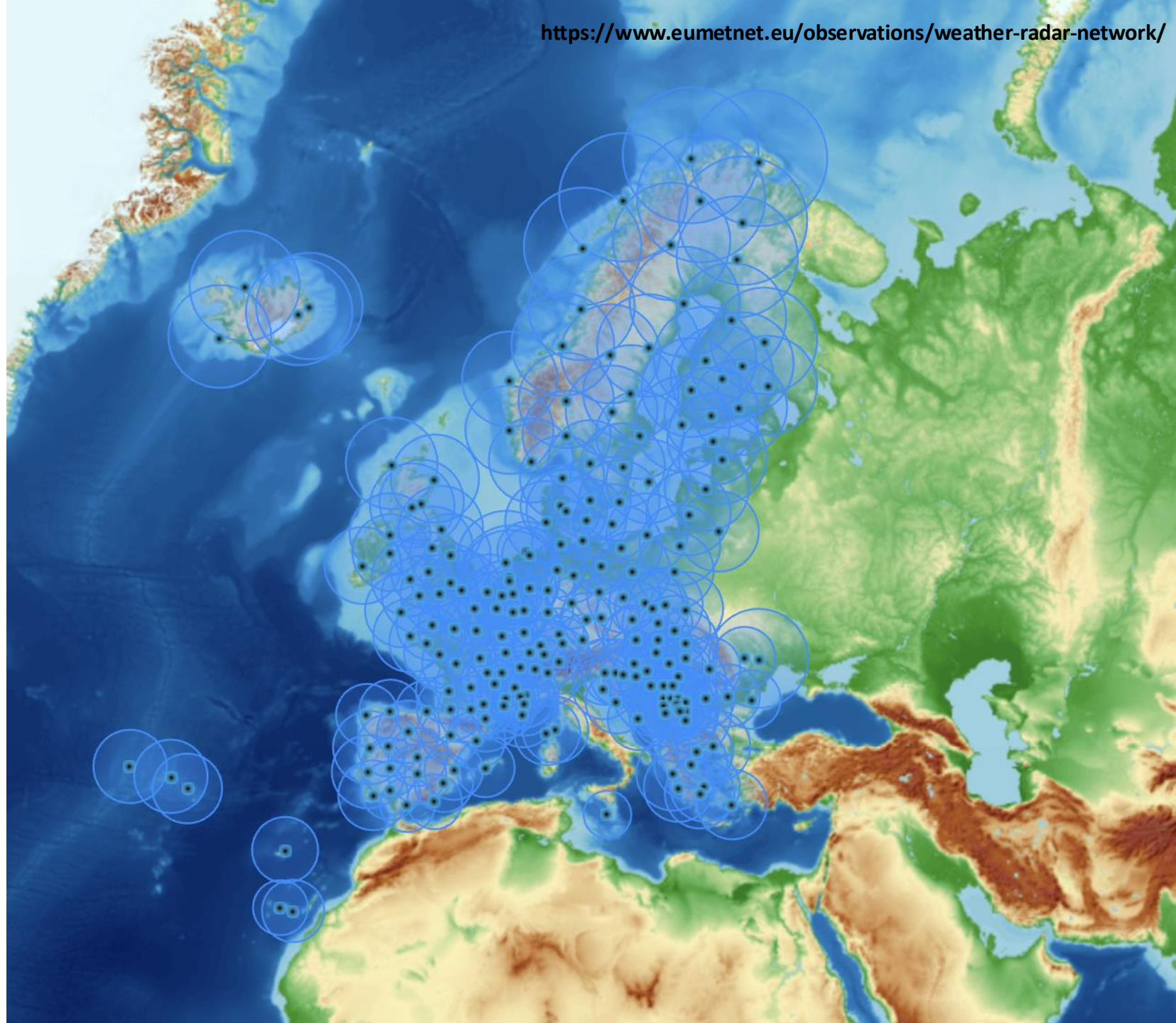
- strong vs weak flappers
- size relation on flapping frequency
- based on learned features → discriminative

From small scale to weather radars

Weather radar from EU weather services (OPERA)

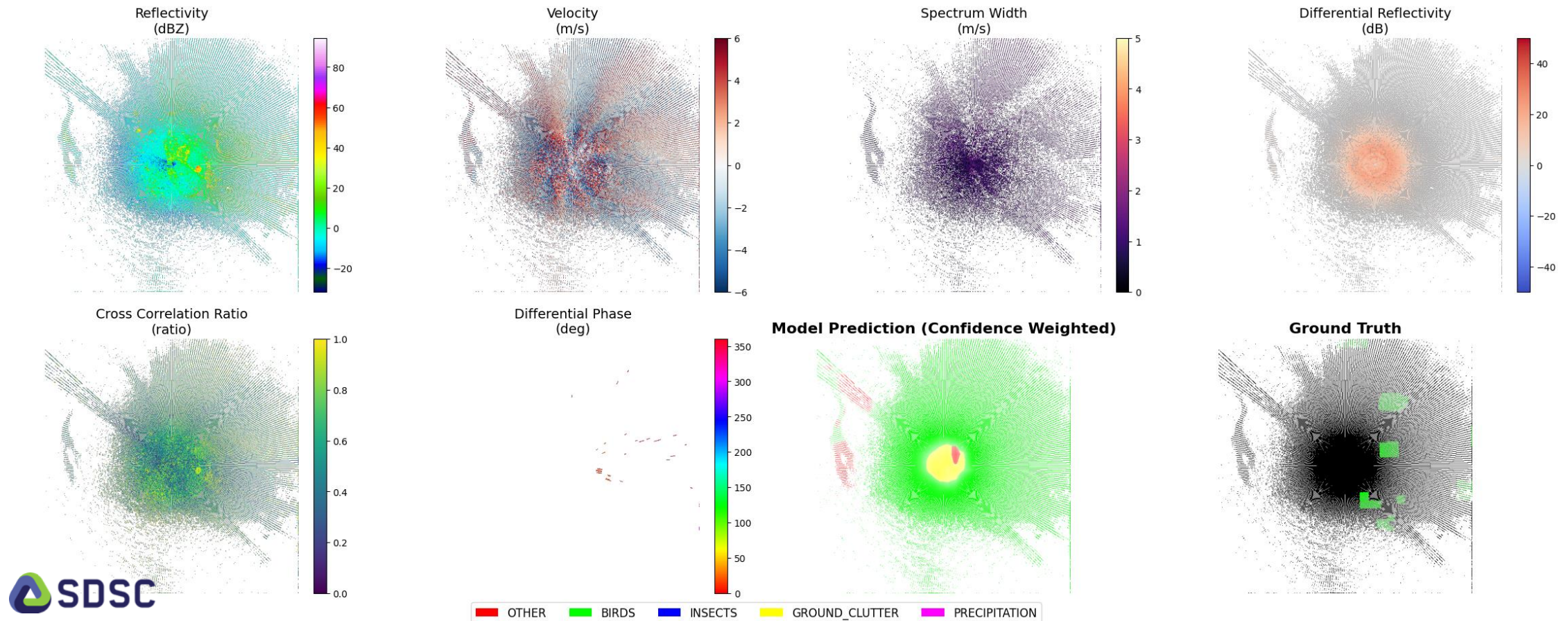
- Dense network covering all EU territory
- Interoperable but subtle differences across instruments and sensors
- Detect, verify and track migrations, and bioscatterer type in space and time

<https://www.eumetnet.eu/observations/weather-radar-network/>



Scarce labels: self-supervised learning

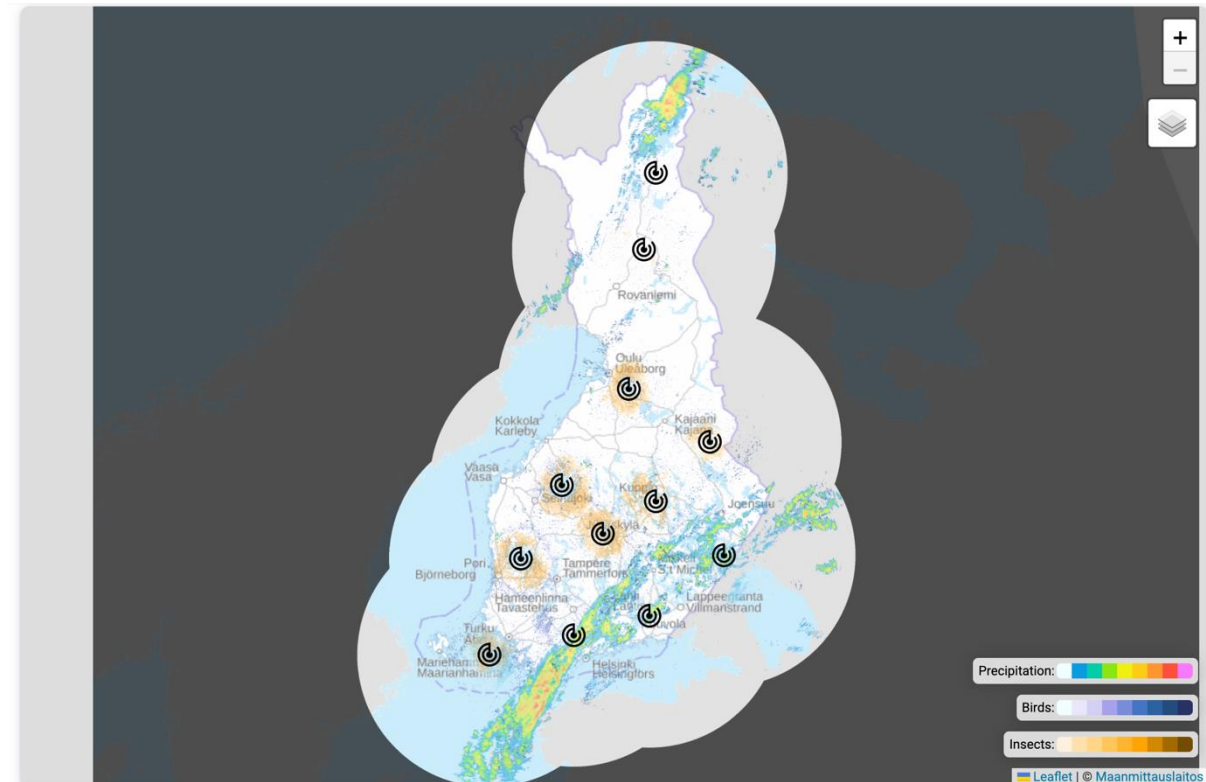
Models trained to discover label agnostic patterns in the data first, then refined to fit expert partial annotations



Stakeholder Engagement & Outlook

BioAIRad aims to turn radar biodiversity data into tools stakeholders can use — built to stay useful beyond the project itself.

- Monitor migration at continental level
- Verify with local, high-res information from portable radars
- Integrate expert feedback
- Dashboard for classifications and data access as embedded in a larger EU project
- Key biodiversity indicators available for the wider community



Thank you

Michele Volpi, SDSC — on behalf of the BioAIRad team

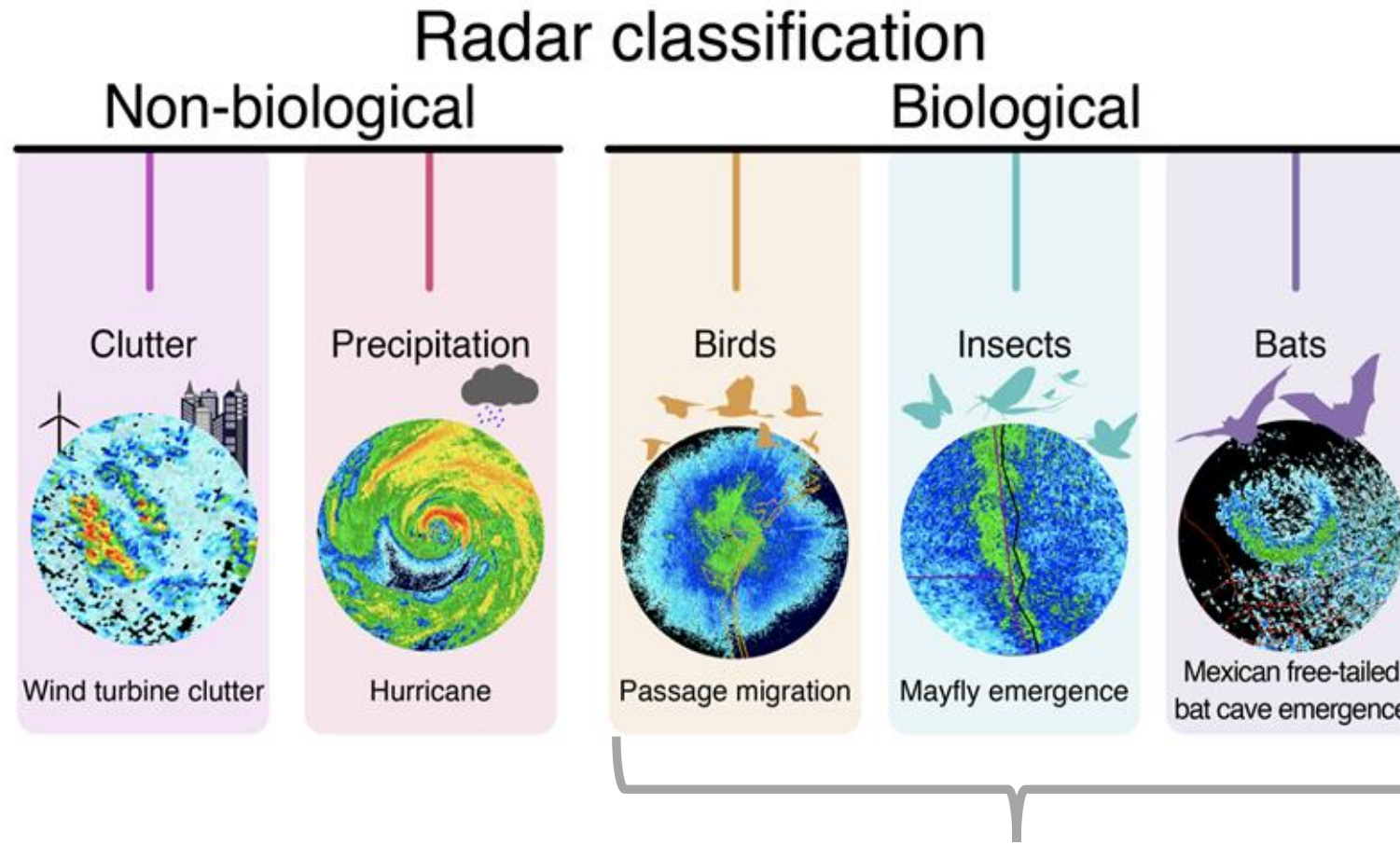
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From small scale to weather radars

Existing workflows (i.e. cluttermasks)

Existing algorithms remove weather (i.e. mistnet²)



Roost detection using computer vision¹

The current challenge