Report 2026

REMOTE SENSING

Earth from Above: How Satellites, Drones and Sensors Reveal Our Planet's Environment, Climate and Landscapes

29 October 2026

Machera, Grevenmacher



COLLOQUIUM

REMOTE SENSING

Earth from Above: How Satellites, Drones and Sensors Reveal Our Planet's Environment, Climate and Landscapes

SAVE THE DATE **29.10** *2026*

Machera, Grevenmacher



Administration de la gestion de l'eau. Grand-Duché de Luxembourg

Administration de la nature et des forêts Grand-Duché de Luxembourg

LE GOUVERNEMENT DU GRAND-DUCHÉ DE LUXEMBOURG Ministère de l'Agriculture, de l'Alimentation et de la Viticulture

NATUR MUSÉE MUSÉE NATIONAL D'HISTOIRE NATURELLE LUXEMBOURG

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How can we observe changes in our landscapes that are invisible to the naked eye? How can satellites help us understand forests, monitor water quality, support agriculture, or even detect changes in the ground beneath our feet?

This event brings together researchers, experts, public institutions, and practitioners to explore how modern technologies are transforming the way we observe and understand our environment. From satellite-based radar and InSAR techniques to LiDAR, camera systems, and multi-parameter monitoring tools, participants will discover how data collected from above and increasingly from the ground, can provide valuable insights into the world around us.

The programme offers a fascinating journey through a wide range of applications in the Greater Region and Luxembourg: monitoring ground deformation, observing our planet through clouds and darkness, tracking harmful cyanobacteria in bathing waters, studying the complexity of forest ecosystems, supporting biodiversity, exploring renewable energy, and monitoring agricultural activities.

The event is designed to make these technologies and their scientific principles accessible to a broad audience, while also highlighting their practical relevance for society and environmental management.

Whether you are a scientist, professional, student, nature enthusiast, or simply curious about how technology can help us better understand our planet, this morning offers an opportunity to discover new perspectives, exchange ideas, and see how science is contributing to a more informed and sustainable future.

Program

8:30 **Registrations**

9:00 **Introduction**

9:10 **Satellite Synthetic Aperture Radar Interferometry (InSAR) for ground deformation monitoring in the Greater Region**
Dr Nicolas d'Oreye
National Museum of Natural History European Center for Geodynamics and Seismology

9:40 **Seeing Through Clouds and Darkness: SAR and InSAR for Earth Observation**
Dr Delphine Smittarello & Dr Quentin Glaude
European Center for Geodynamics and Seismology

10:10 **Applying a multi-parameter toolbox to track harmful cyanobacteria blooms in Luxembourgish bathing waters**
Dr Jean-Baptiste Burnet
Luxembourg Institute of Science and Technology

10:40 **Coffee break & possibility to visit stalls**

Utilisation de la technologie « lidar mobile » pour décrire la complexité de nos écosystèmes forestiers
Administraion de la nature et des forêts, Gestion des Ressources Forestières, Gembloux Agro-Bio Tech, Université de Liège

Sauvons bambi Luxembourg a.s.b.l.
Georges Fohl
Jacques Schroeder

Euro kite
Katharina Klein
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11:25 **La télédétection pour mieux connaître les forêts : où en est-on au Grand-Duché de Luxembourg ?**
Dr Philippe Lejeune
Administraion de la nature et des forêts, Gestion des Ressources Forestières, Gembloux Agro-Bio Tech, Université de Liège

11:55 **Windkraftanlagen, Kamerasysteme**
Guy Uhres
Head of Renewable Energies, Soler

12:25 **Monitoring agricultural activities with satellite data in the framework of the CAP**
Georges Thewes
Service d'Economie Rurale

12:55 **Closing remarks**
Claudine Felten
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13:05 **Lunch**

14:00 **Excursion: Krankheiten und Trockenheit im Weinbau: Esca Monitoring und Trockenstressanalysen mit drohnengestützten Sensoren**
Dr Miriam Machwitz
Luxembourg Institute of Science and Technology
Institut viti-vinicole

REMOTE SENSING

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29 October 2026
Machera - Grevenmacher

Registration & Information

Registration until Sunday, **25 October 2026**

€ 15 half-day without lunch

€ 40 half-day with lunch

€ 40 full day with lunch and an excursion
(Please make sure to wear sturdy shoes)

€ 10 half-day student discount without lunch

Location:
Machera - Centre culturel Grevenmacher
3, Place du Marché aux Bestiaux
L-6731 Grevenmacher

www.mobiliteit.lu



Administration de la gestion de l'eau
Grand-Duché de Luxembourg

Administration de la nature et des forêts
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LE GOUVERNEMENT DU GRAND-DUCHÉ DE LUXEMBOURG
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natur&ëmwelt a.s.b.l. 5, route de Luxembourg L-1899 Kockelscheuer
Tel: 29 04 04 - 1 / reservation@naturemwelt.lu / www.naturemweltasbl.lu



Nicolas d'Oreye is a senior scientist at the National Museum of Natural History (NMNH) and the European Center for Geodynamics and Seismology (ECGS) in Luxembourg.

He is an expert in instrumentation and ground deformation monitoring using terrestrial and spaceborne techniques, with more than 35 years of field experience in Latin America, Africa and Europe. In charge of the Walferdange Underground Laboratory for Geodynamics (WULG) since 1994, he set up in 2000 a major project to establish the Laboratory as an international reference station in gravimetry. In 2005 he initiated a research pole at the NMNH dedicated to satellite radar interferometry (InSAR) and started the systematic monitoring of several volcanoes in Africa. He developed the open-source AMSTer toolbox, dedicated to the fully automatic and unsupervised production of 1, 2 or 3D ground deformation time series. For about 20 years, in the frame of several projects co-led with the Royal Museum for Central Africa, he contributed to the study of the Nyiragongo and Nyamulagira volcanoes and the Kivu Rift in DR Congo. In addition to remote sensing studies, he designed and contributed to the maintenance and exploitation of a network of ~20 permanent telemetered geodetic GNSS stations, ~20 broadband seismic stations and 3 infrasound arrays in the Kivu basin from 2008 to 2021. Since 2025 he has been co-leading, with a French consortium, an international project aiming at studying slow-moving landslides in Central Nepal, in the Himalayas



Delphine Smittarello is a permanent researcher at the European Center for Geodynamics and Seismology (ECGS) in Walferdange, Luxembourg.

Her research focuses on characterizing volcanic deformation using multi-satellite Synthetic Aperture Radar (SAR) and InSAR combined with GNSS observations, with the goal of understanding the subsurface pressure sources driving volcanic activity. Her expertise spans remote sensing techniques for measuring surface deformation across active volcanic systems, including Piton de la Fournaise (Réunion), Karthala (Comoros), and Nyiragongo/Nyamulagira (Democratic Republic of Congo). By integrating SAR time series with geodetic data, she develops methodologies to isolate true deformation signals from atmospheric and environmental noise, enabling precise temporal monitoring of volcanic processes. A central aspect of her work is inverting deformation measurements to constrain the geometry and dynamics of magmatic and hydrothermal systems. Through forward and inverse modeling, she translates remote sensing observations into interpretable geophysical parameters—source depths, volumes of magma flux, and pressure variations—that illuminate how volcanoes function. This approach bridges the gap between satellite observations and physical understanding of subsurface volcanic processes. Delphine earned her PhD in 2019 from the COMUE Grenoble Alpes within ISTerre laboratory, where she built expertise in analysing and modeling dike induced deformation. Her research contributes to improved volcanic hazard assessment by providing tools and frameworks for sustained, systematic monitoring of active volcanic regions, advancing understanding of the mechanisms that drive eruptive behavior and ground deformation.



Quentin Glaude is a researcher at the European Center for Geodynamics and Seismology (ECGS) in Walferdange, Luxembourg, funded by the Luxembourg National Research Fund (FNR).

His work focuses on Synthetic Aperture Radar (SAR) and InSAR processing, with particular expertise in detecting and characterizing slow-moving landslides across the Himalayas, notably in Nepal. He develops and applies advanced processing pipelines, including the AMSTer toolbox, for multi-temporal deformation analysis, and works extensively with next-generation SAR missions such as NISAR, tackling challenges like ionospheric correction and large-scale data processing. His research combines classical InSAR techniques with advanced approaches for geospatial analysis, including deformation mapping and automated landslide detection. Quentin holds a PhD from the Centre Spatial de Liège (CSL, Belgium), where he worked on InSAR applications to Antarctic ice dynamics. He subsequently held a postdoctoral position at Laboratory of Climatology, Liège, where he studied Greenland surface mass balance, combining SAR-derived melt masks with the MAR regional climate model, and completed a research stay at Columbia University of NYC. He also brings hands-on High-Performance computing systems administration experience from the CÉCI consortium, Belgium.



Jean-Baptiste Burnet is Lead Scientist at the Luxembourg Institute of Science and Technology (LIST)

He conducts research at the interface of water sciences, environmental microbiology and monitoring technologies. After completing his PhD at CRP Gabriel Lippmann and Liège University, he pursued his career at Polytechnique Montréal in Canada before returning to LIST in 2020. His research focuses on the development and evaluation of multiparametric and automated approaches for monitoring microbial water quality, combining sensors, imaging, environmental data and microbiological methods. A current focus of his work is the detection and monitoring of cyanobacteria in lakes and reservoirs, and the combination of innovative monitoring technologies and citizen science to better support water management and decision-making. Jean-Baptiste coordinates and contributes to research projects involving research institutes, public authorities, water managers and technology providers. In Luxembourg, he works closely with the Water Management Agency (AGE) and water syndicates and operators. He is also active in several international scientific networks, including the International Water Association, the European Water Association, and the COST Action CYANOACTION, in which he represents Luxembourg. In 2023, he initiated the MicrobialSensors4Water Community of Practice dedicated to sharing knowledge and practical experience internationally among scientists, end-users, and sensor suppliers. His work aims to bridge scientific research, technological innovation and operational needs to support smarter, more resilient and sustainable water management.



L’équipe de l’axe Gestion des Ressources Forestières (GRF) de Gembloux Agro-Bio Tech (Université de Liège) développe des recherches dans le domaine de la foresterie, avec un intérêt particulier pour la caractérisation, le suivi et la gestion des écosystèmes forestiers.

Une partie importante de nos travaux porte sur le développement des inventaires forestiers nationaux et régionaux, ainsi que sur l’utilisation de la télédétection et des méthodes d’analyse spatiale pour produire et valoriser de l’information forestière à différentes échelles. Nos recherches associent données de terrain, données satellitaires, photographies aériennes, LiDAR et autres sources d’information géographique. Elles donnent notamment lieu au développement de produits cartographiques décrivant la composition et la structure des peuplements, mais également les conditions stationnelles, les aptitudes des essences, ainsi que différents facteurs de risque et indicateurs liés à l’évolution des forêts. En Wallonie, ces travaux ont notamment conduit au développement de nombreuses couches cartographiques accessibles via le portail Forestimator, qui rassemble et met à disposition des résultats issus de différents projets de recherche. L’équipe mène également des travaux de cartographie et de télédétection forestières au Grand-Duché de Luxembourg, où elle apporte un appui méthodologique à la réalisation de l’inventaire forestier national et à l’analyse des données récoltées dans ce cadre.



Georges Thewes

Ingénieur agronome de formation, Georges Thewes est Chef de Service « Area Monitoring System » (AMS) au sein de la Division des aides surfaciques et animales du Service d'économie rurale du Ministère de l'Agriculture, de l'Alimentation et de la Viticulture du Grand-Duché de Luxembourg. Le service « AMS » en charge du suivi des surfaces agricoles dans le cadre la mise en œuvre des différents régimes d'aide surfaciques dans le cadre la politique agricole commune de l'Union européenne.



Guy Uhres is Head of Renewable Energies at Soler S.A.



Sauvons Bambi Luxembourg a.s.b.l. is a non-profit organisation founded in Luxembourg in 2022 with the main goal of protecting young wild animals, particularly roe deer fawns, from being injured or killed during the mowing of agricultural fields.

The organisation works mainly during the spring and early summer, when fawns are born and often hide motionless in tall grass. This behaviour makes them difficult for farmers to see and puts them at serious risk from agricultural machinery. The association uses drones equipped with thermal cameras to locate animals in fields before mowing begins. Once a fawn is detected, trained volunteers carefully remove it from the danger zone and return it to its natural environment after the mowing has finished. This work is carried out in cooperation with farmers, volunteers, municipalities and other local stakeholders. The organisation's values are centred on animal welfare, respect for nature, environmental protection and community cooperation. It aims not only to prevent the suffering and death of wildlife, but also to support farmers by making the mowing process safer and less stressful. Another important objective is to protect the quality of animal feed and reduce the risk of livestock diseases caused by animal remains in harvested fields. Overall, Sauvons Bambi Luxembourg combines voluntary action, modern technology and cooperation with the agricultural community to find practical solutions for protecting wildlife.

Impressions 2026












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Sauvons
Bambi


FORMATIOUNEN,
DIE DECH
WEIDERBRENGEN.
LUXEMBOURG DRONE
CENTER
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Earth From Above
Machera, Grevenmacher, Luxembourg
October 29, 2026

Satellite Synthetic Aperture Radar Interferometry (InSAR) for ground deformation monitoring in the Greater Region

Nicolas d'Oreye[1,2], Delphine Smittarello[2], Quentin Glaude[2]

Benoit Smets[2,3], Sergey Samsonov[2,4], Dominique Derauw [2,5]

1 Musée national d'histoire naturelle
2 European Center for Geodynamics and Seismology
3 Now at Vrije Univ. Brussels
4 Now at Nat. Resources Canada
5 Now at Centre Spatial de Liège

On the menu Today

Outlines

- Synthetic Aperture Radar (SAR)
- SAR Interferometry (INSAR)
- Application to the Greater Region
- Conclusions

On the menu Today

Outlines

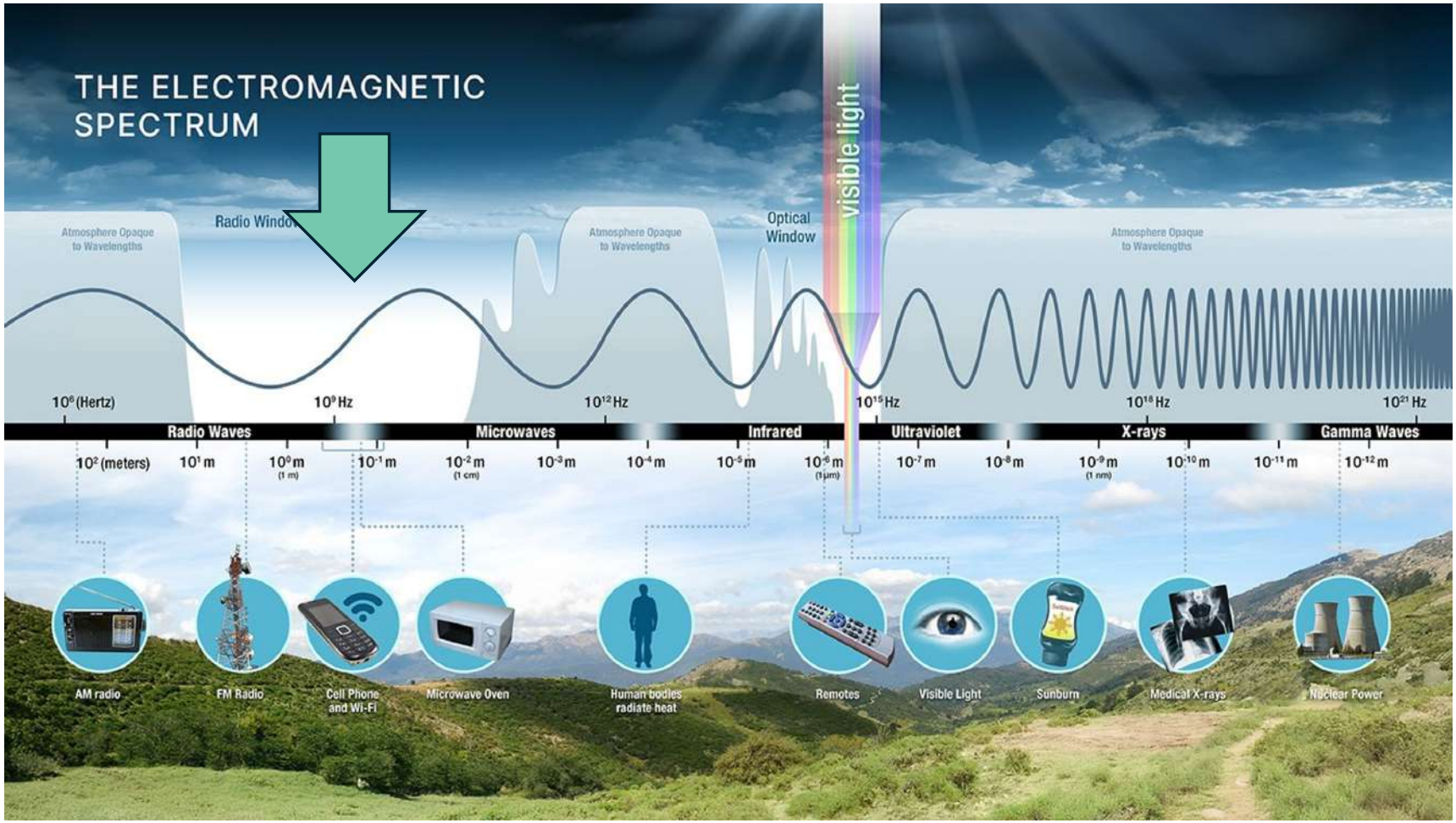
- Synthetic Aperture Radar (SAR)
- SAR Interferometry (INSAR)
- Application to the Greater Region
- Conclusions

What is Synthetic Aperture Radar (SAR) ?

Method

Radar

- Electromagnetic wave
- Not absorbed by atmosphere, all weather
- Satellite emits and receive => Night and day
- Subdivided in bands (like colours):
  - X: 2,4 – 3,8 cm
  - C: 3,8 – 7,5 cm
  - S: 7.5 – 15 cm
  - L: 15 – 30 cm
  - P: 30 - 100 cm



© nasa.gov

What is Synthetic Aperture Radar (SAR) ?

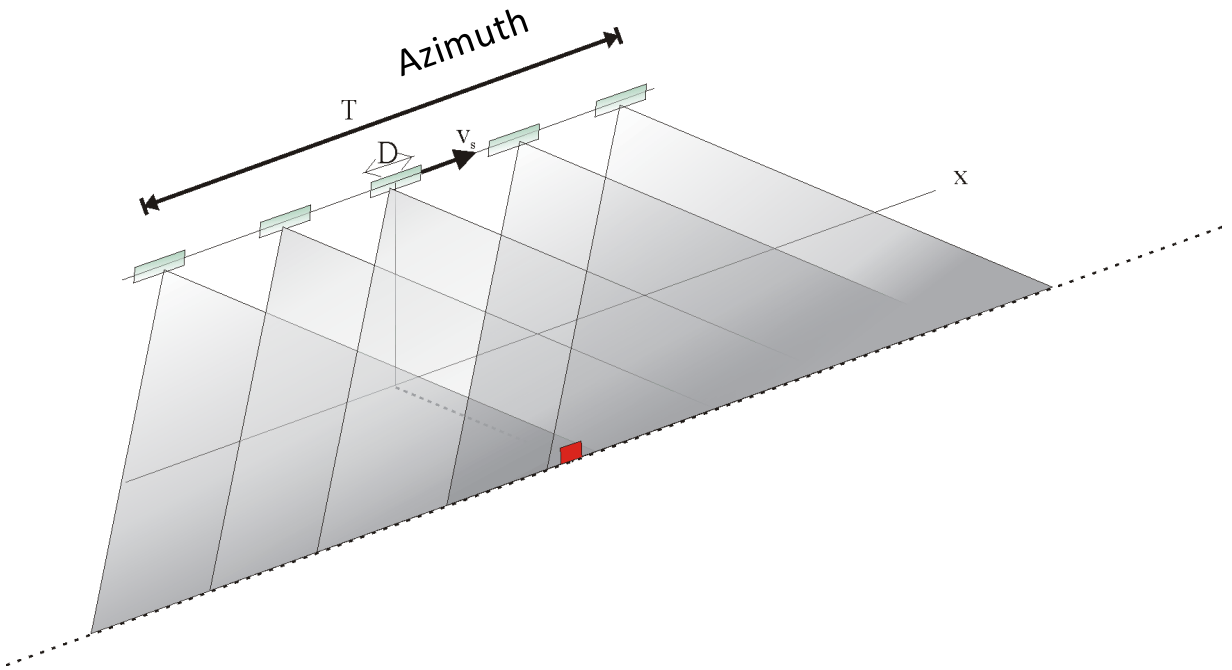
Method

Synthetic Aperture

- Resolution in azimuth (direction of satellite heading) depends on antenna length

  => use satellite displacement as if the antenna was longer

- Resolution in range (perpendicular to satellite displacement) depends on pulse duration



Size of the antenna needed for image with 20m resolution (pixel size):
Simple antenna: 2,2 km
Synthetic aperture: 10 m

What is Synthetic Aperture Radar (SAR) ?

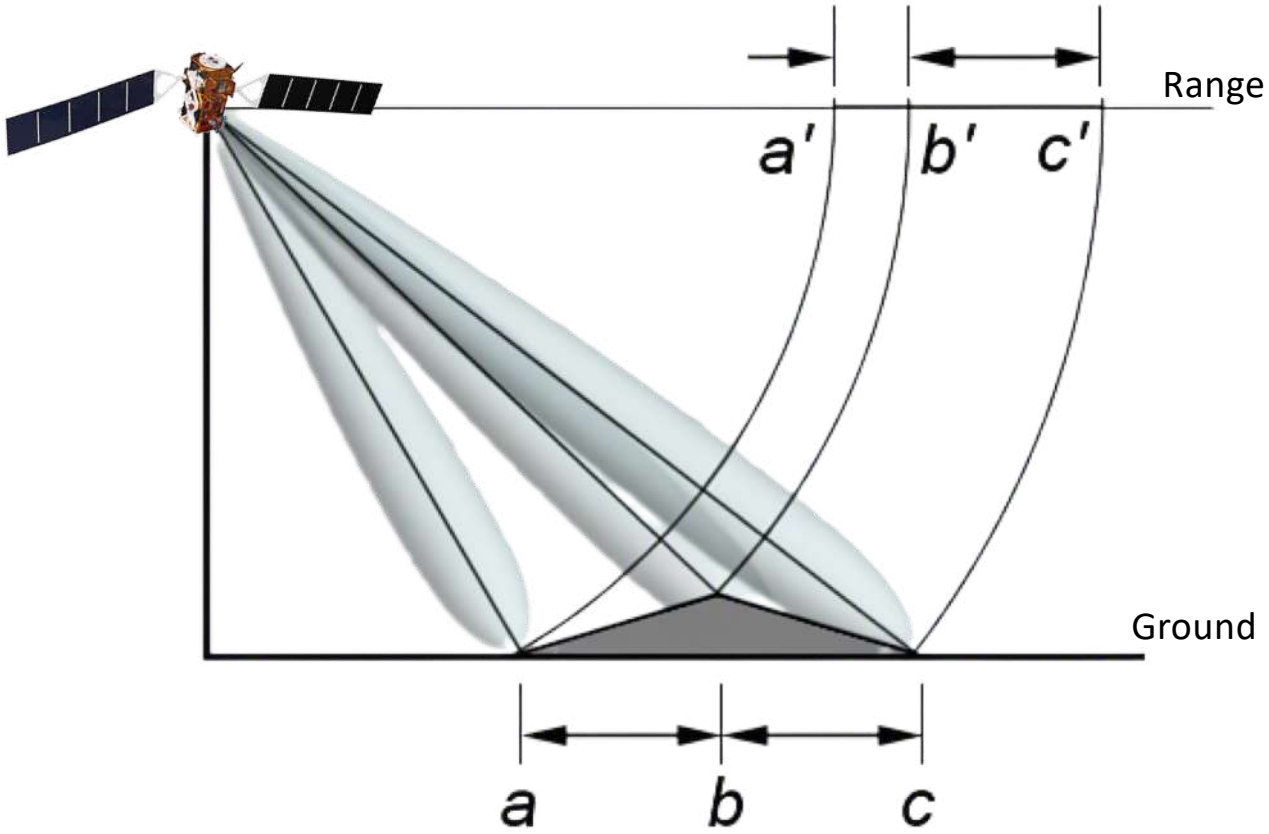
Method

SAR

- Satellite emits pulses
- antenna receives a portion of the energy backscattered by various objects
- Delay between transmission & reception of the impulsion

  => distance to the radar

  => position



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What is SAR ?

Method

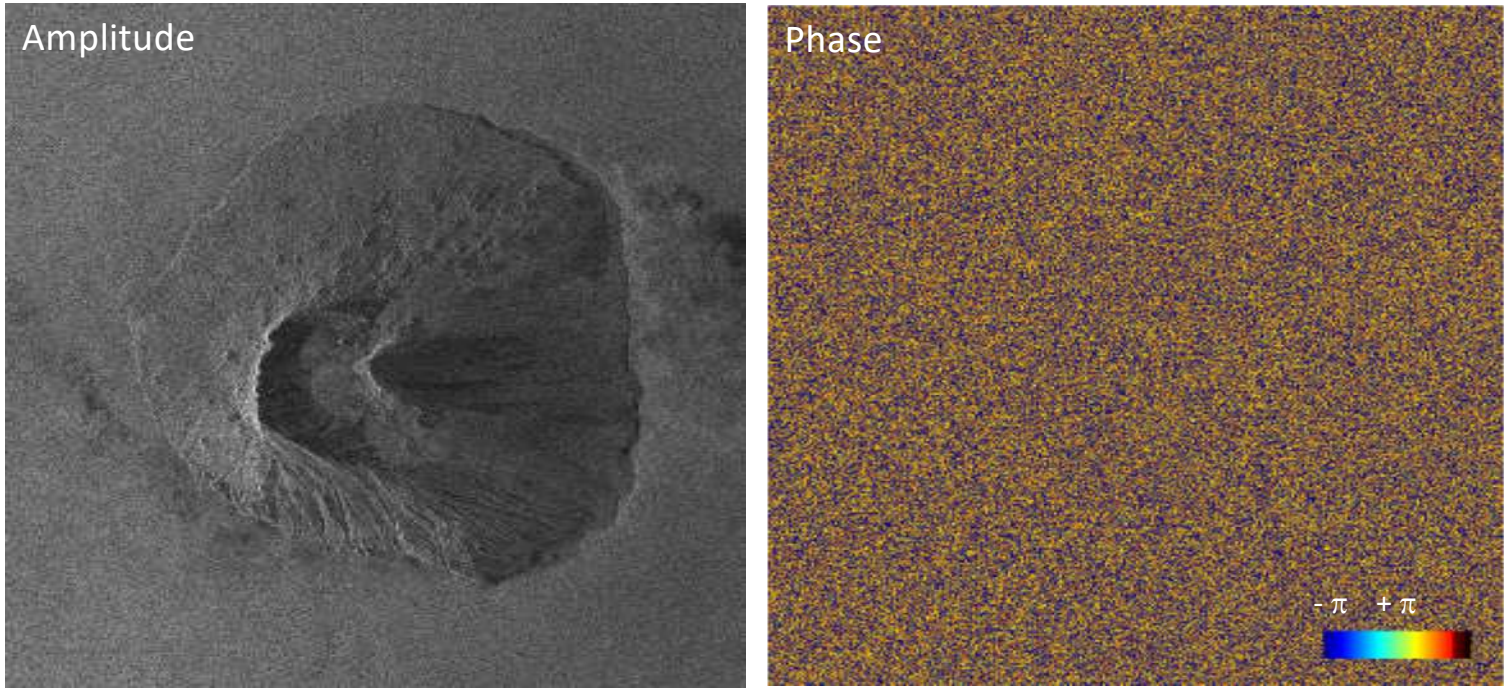
SAR image

- Amplitude
- Phase

Attention:
It looks like a black and white picture, but there are fundamental differences !

Amount of signal backscattered to the satellite

Number of wave cycles (modulo 2 Pi)



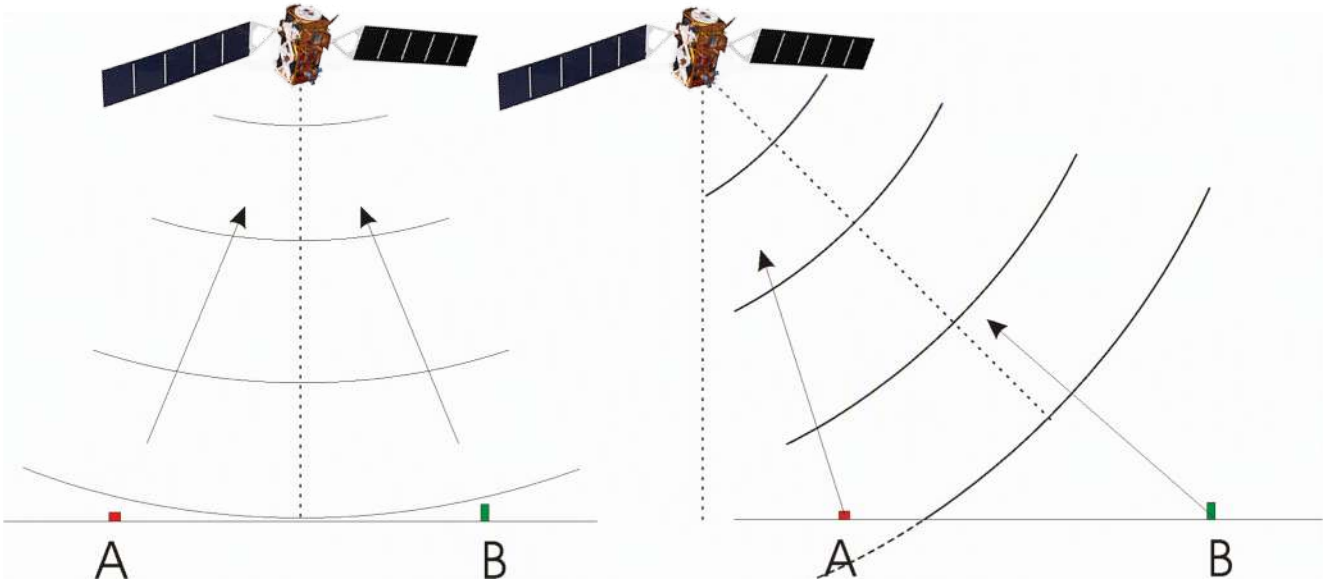
(Fogo volcano, Cap Vert; ENVISAT)

What is Synthetic Aperture Radar (SAR) ?

Method

SAR

- Need oblique view



Distance Radar to A = Distance Radar to B

Hence A and B are the same point on the image

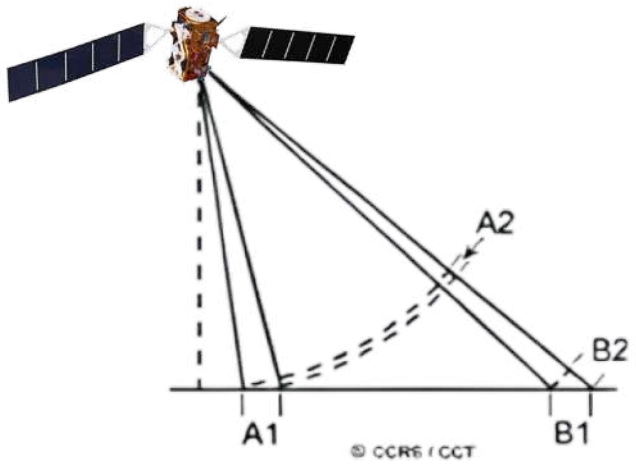
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What is Synthetic Aperture Radar (SAR) ?

Method

SAR

- Need oblique view
  => Distortions



Flat topography

Image in time range (or Line of Sight)



Image in ground-range

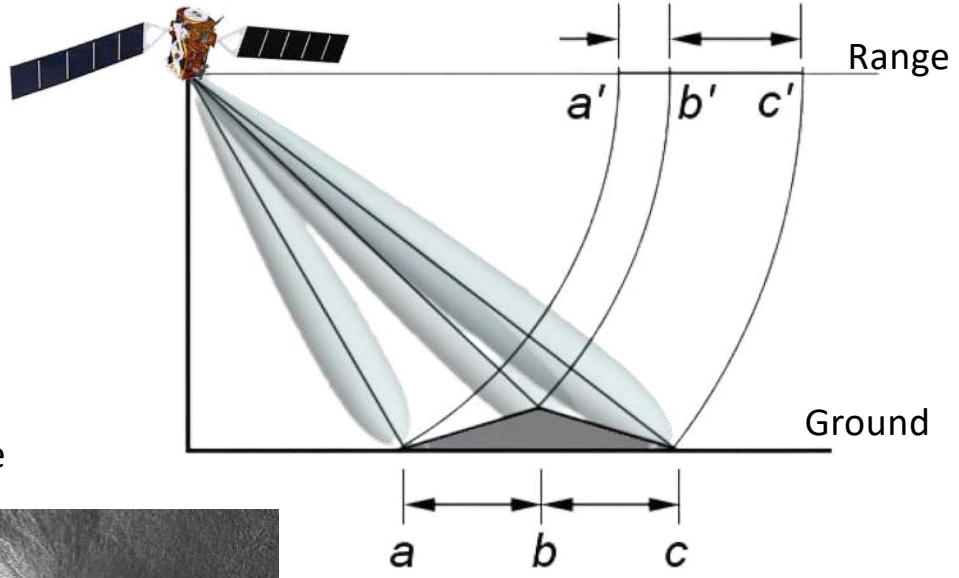


What is Synthetic Aperture Radar (SAR) ?

Method

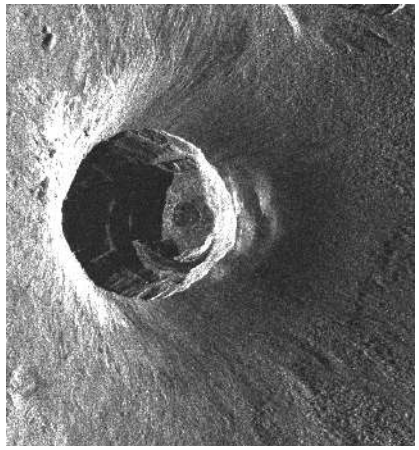
SAR

- Need oblique view
  => Distortions
- Shortening

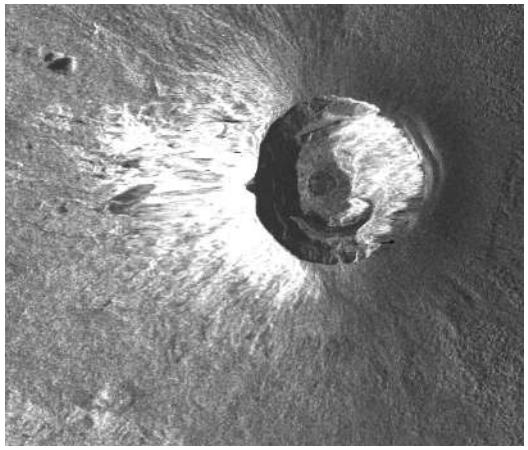


Steep topography

Time range



Ground range



Nyiragongo volcano, DR Congo (Radarsat2)

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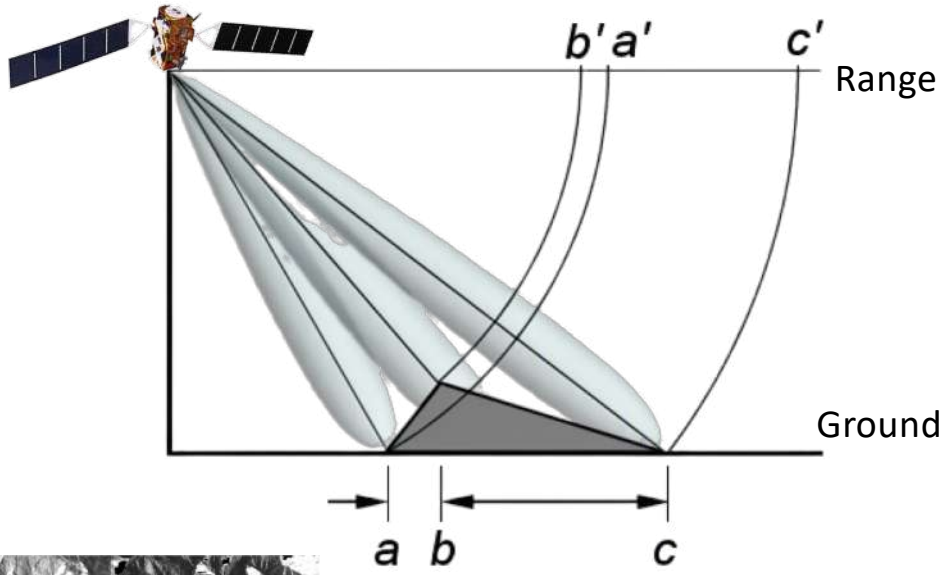
What is Synthetic Aperture Radar (SAR) ?

Method

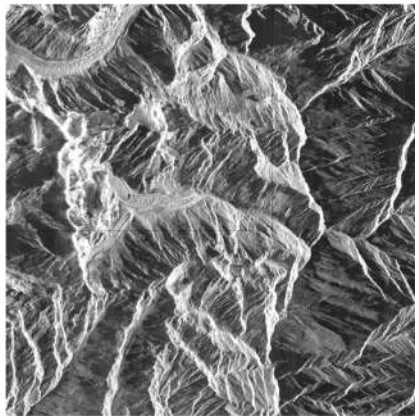
SAR

- Need oblique view
  => Distortions
- Shortening
- Layover

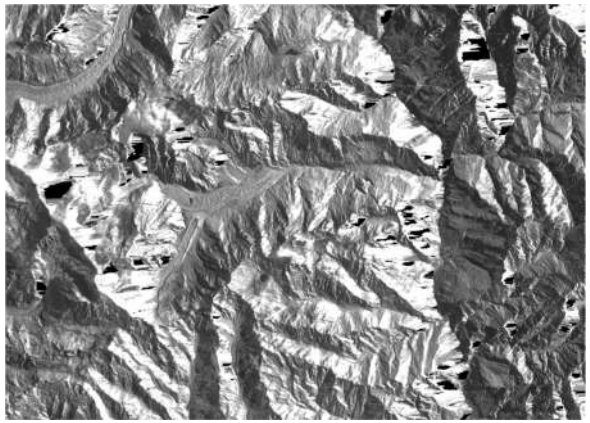
Very steep topography



Time range



Ground range



Himalaya, Nepal (NISAR)

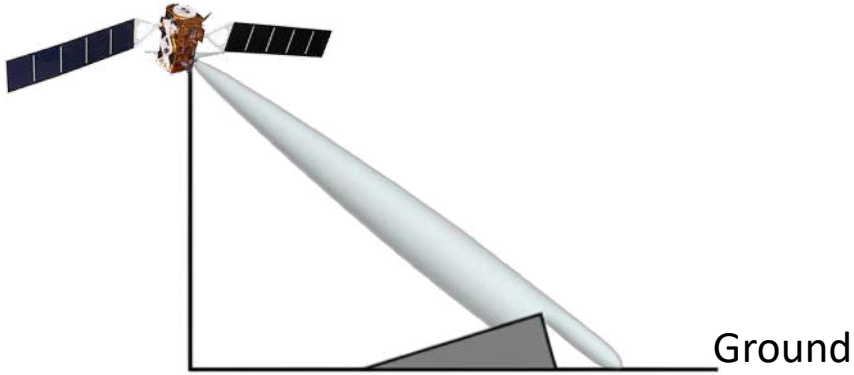
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What is Synthetic Aperture Radar (SAR) ?

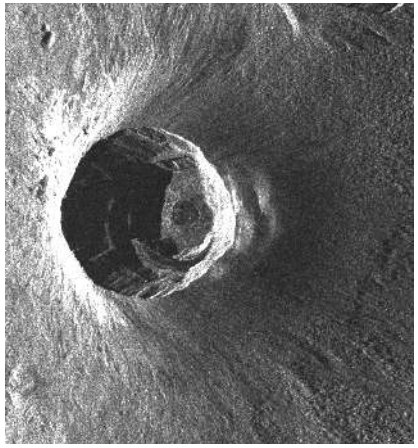
Method

SAR

- Need oblique view
  => Distortions
- Shortening
- Layover
- Shadowing



Time range



Ground range



Nyiragongo volcano, DR Congo (Radarsat2)

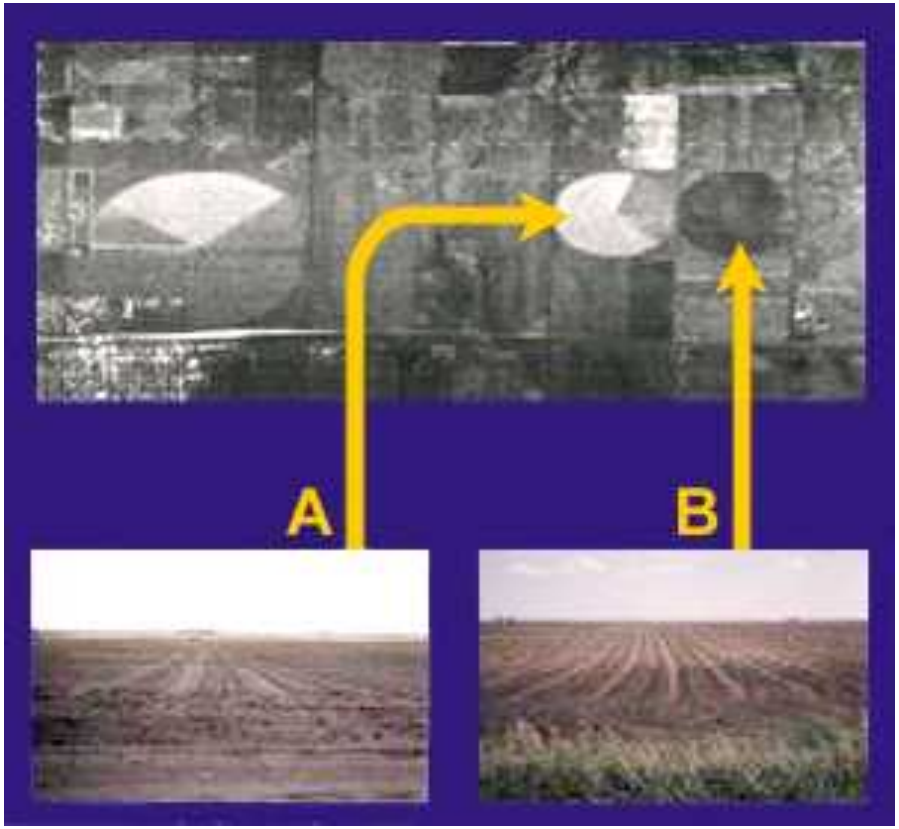
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What is Synthetic Aperture Radar (SAR) ?

Method

SAR

- Need oblique view
  =>
  Distortions
- Shortening
- Layover
- Shadowing
- Speckel: noise from interactions between scatterers inside a pixel
- Dielectric properties (e.g. Soil moisture)



Field A: irrigated

Field B: not irrigated

(Usage e.g. in glaciology)

What is Synthetic Aperture Radar (SAR) ?

Method

SAR

- Need oblique view
  =>
  Distortions
- Shortening
- Layover
- Shadowing
- Speckel: noise from interactions between scatterers inside a pixel
- Dielectric properties (e.g. Soil moisture)
- Penetration depth in dry material…



(Selma Sand Sheet - Sahara Desert NW Sudan; Penetration up to + 3m)

Nov. 1981, SIR-A L band.

Penetration depth in soil (or vegetation) depends on wavelength

On the menu Today

Outlines

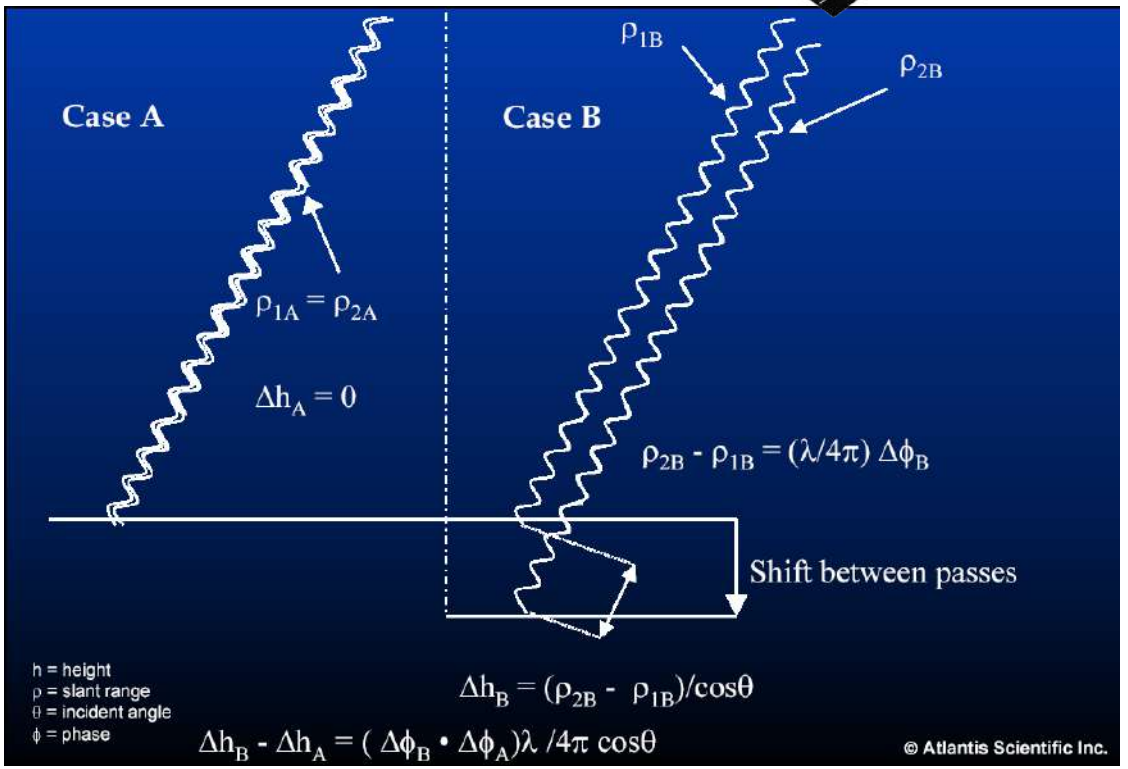
- Synthetic Aperture Radar (SAR)
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What is SAR interferometry InSAR ?

Method

InSAR

- 2 images of same regions



If distance Ground-Satellite remains the same:
=> same number of wave cycles

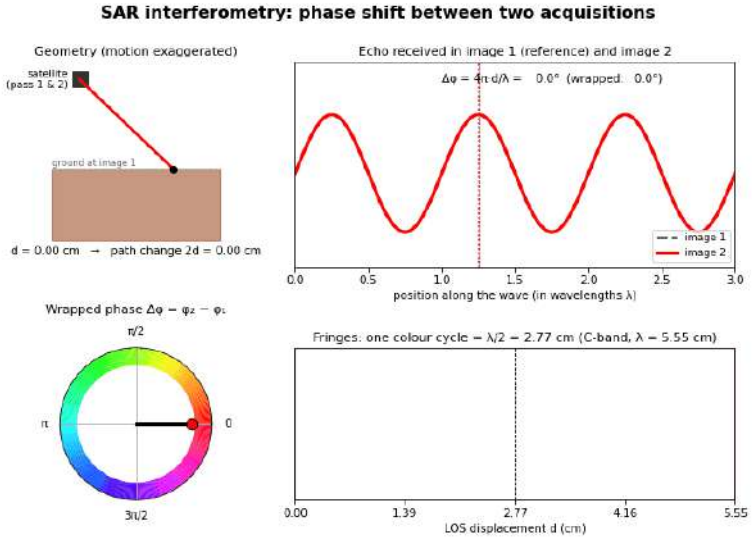
If distance Ground-Satellite increase (or decrease),
=> more wave cycles (or less)

What is SAR interferometry InSAR ?

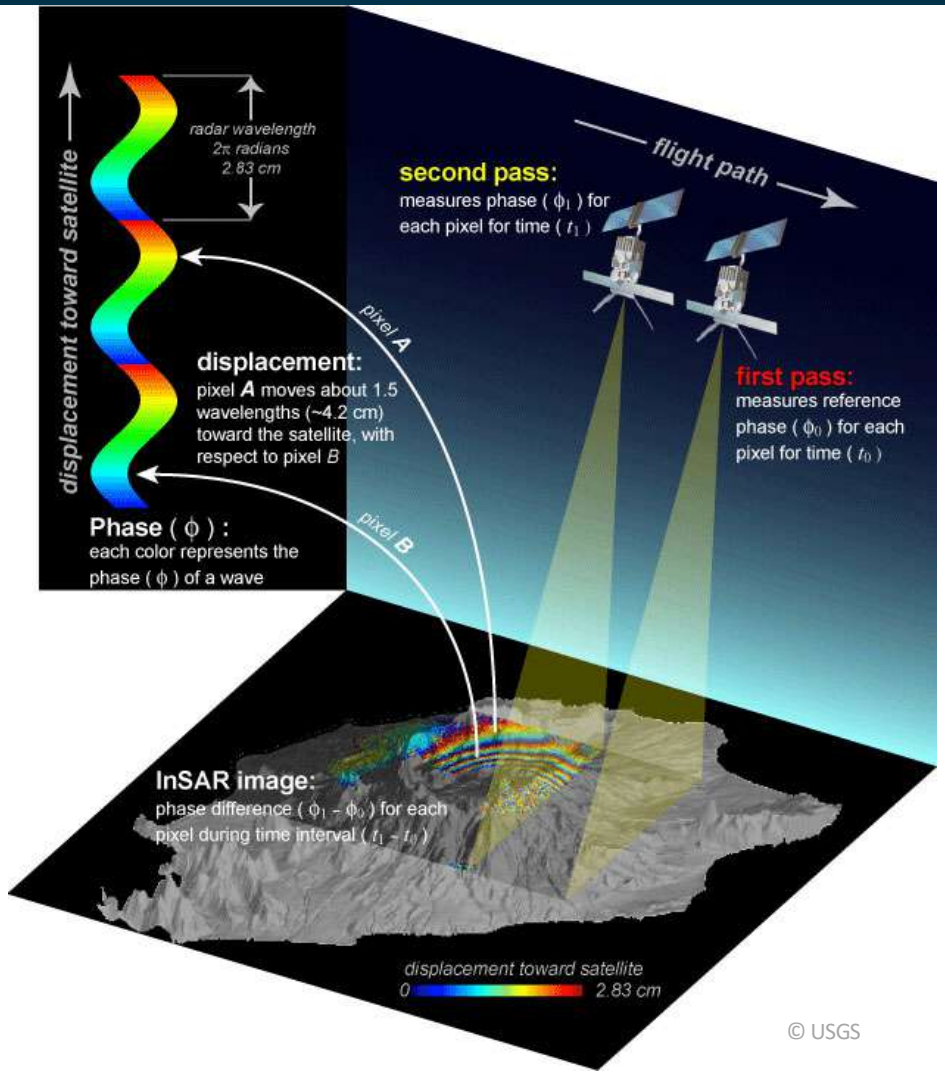
Method

InSAR

- 2 images of same regions
- Compare at each pixel the phase shift, then color code it for visualisation (= interferogram)



One colour cycle means the ground moved toward or away from the satellite by the half of the wavelength (e.g. 3 cm for C-band)



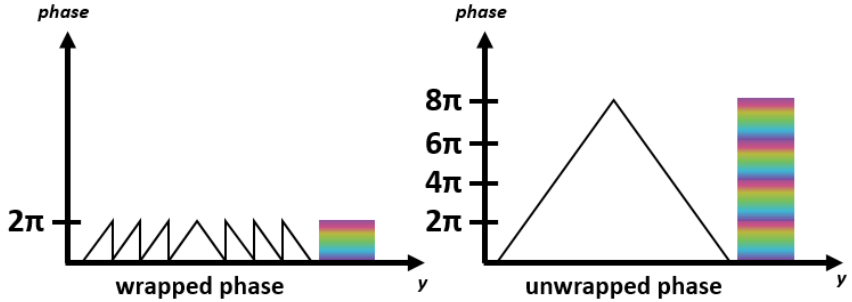
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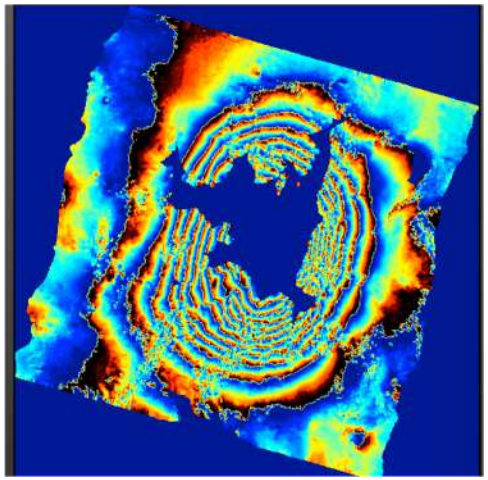
What is SAR interferometry InSAR ?

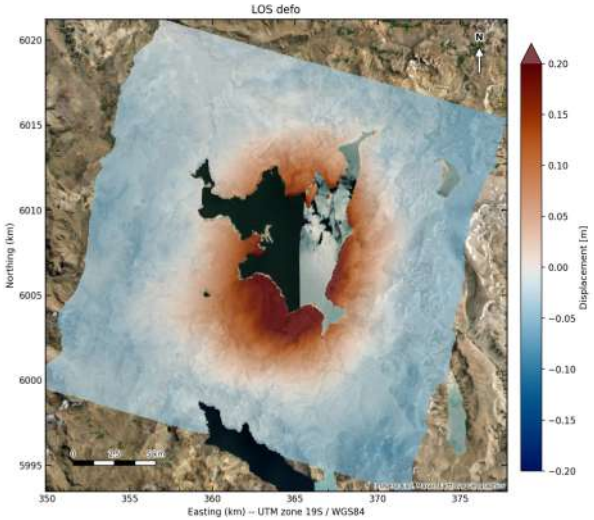
Method

InSAR

- 2 images of same regions
- Compare at each pixel the phase shift, then color code it for visualisation
- Unwrap the phase and convert into displacement







Example of deformation mapped : Laguna del Maule, Chile

What is SAR interferometry InSAR ?

Method

Limitations:

- **Temporal coherence**



Land cover changes, vegetation growth, movements of tree leaves…

Signal is not backscattered the same way

“Coherence loss” or “Decorrelation”

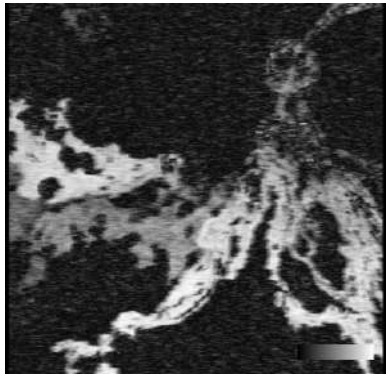
What is SAR interferometry InSAR ?

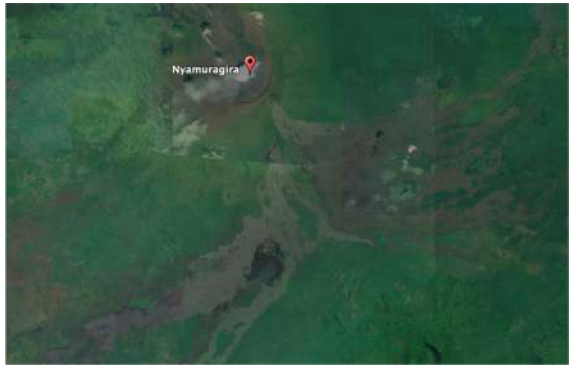
Method

Limitations:

- **Temporal coherence**

0 (black) < Coherence < 1 (white)





Lava flows at Nyamulagira volcano (DR Congo)



Land cover changes, vegetation growth, movements of tree leaves…

Signal is not backscattered the same way

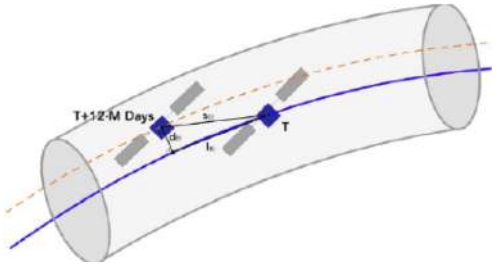
“Coherence loss” or “Decorrelation”

What is SAR interferometry InSAR ?

Method

Limitations:

- Temporal coherence
- Spatial coherence





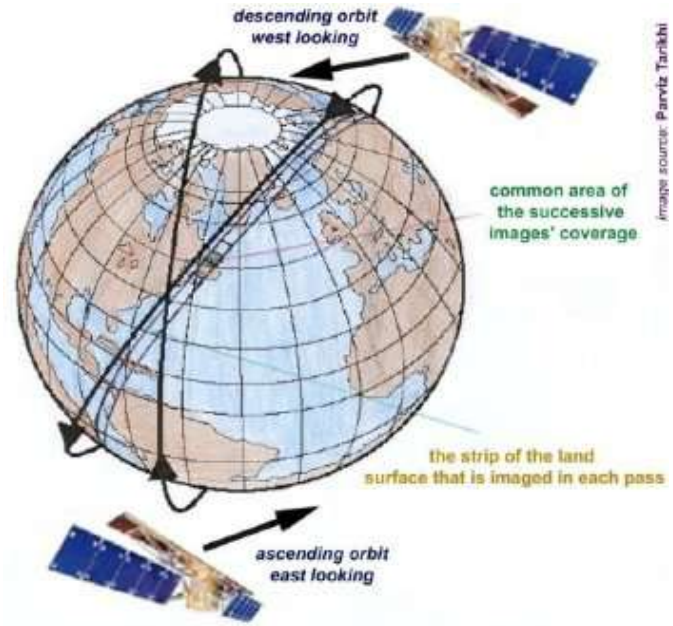
If a coherent object is illuminated from very a different angle, it does not backscatter the wave the same way

What is SAR interferometry InSAR ?

Method

Limitations:

- Temporal coherence
- Spatial coherence
- Not sensitive to North South displacments



What is SAR interferometry InSAR ?

Method

Limitations:

- Temporal coherence
- Spatial coherence
- Not sensitive to North South displacments

But also:

- Atmospheric artefacts
- Ionospheric atrefacts
- Aliasing when displacement is too fast
- DEM errors …

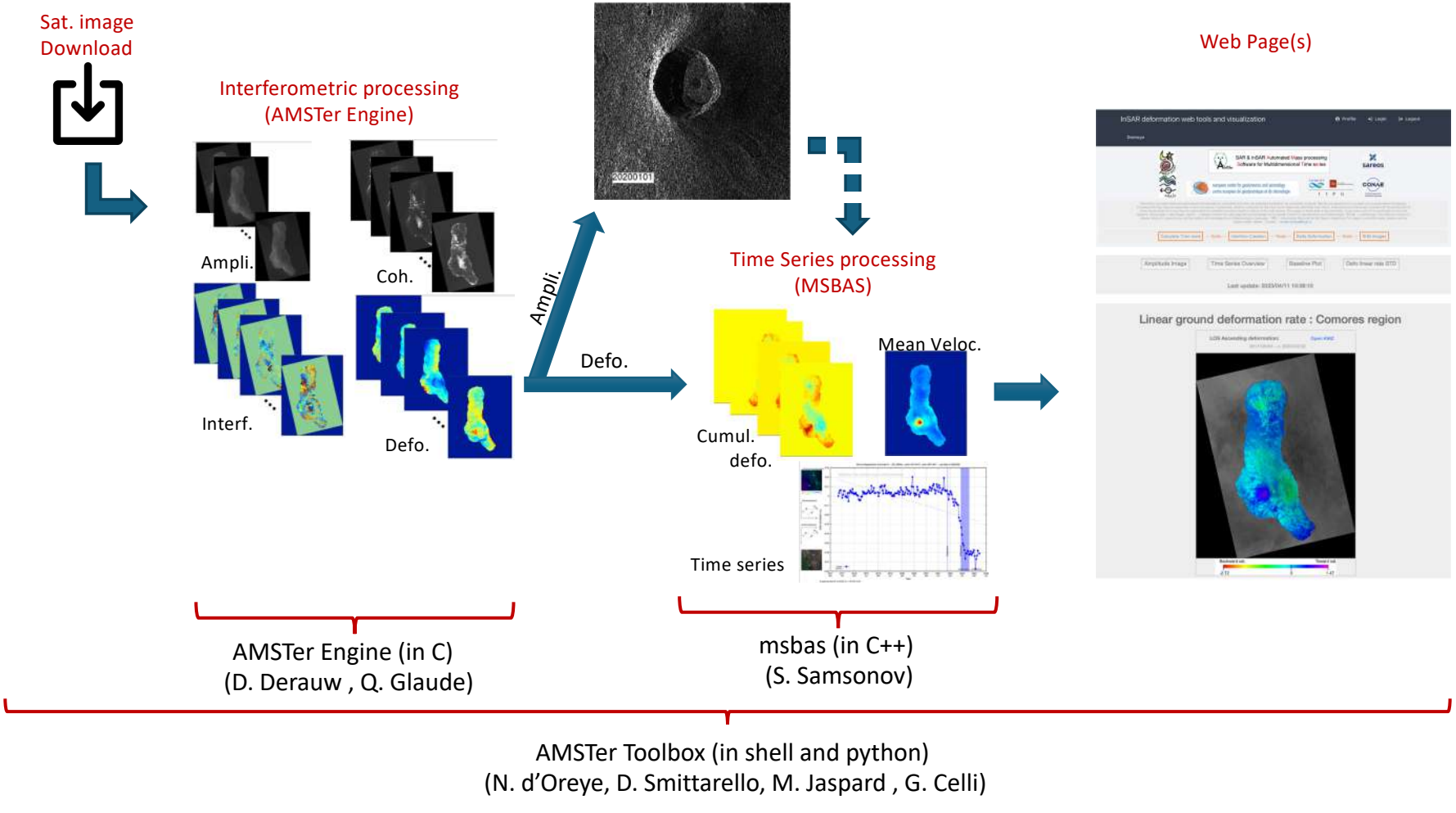
A way to mitigate some of the limitations:

Compute time series of InSAR, e.g. using AMSTer toolbox

NATUR MUSÉE ECGS European Center for Geodynamics and Seismology AMSTer

What is AMSter ?

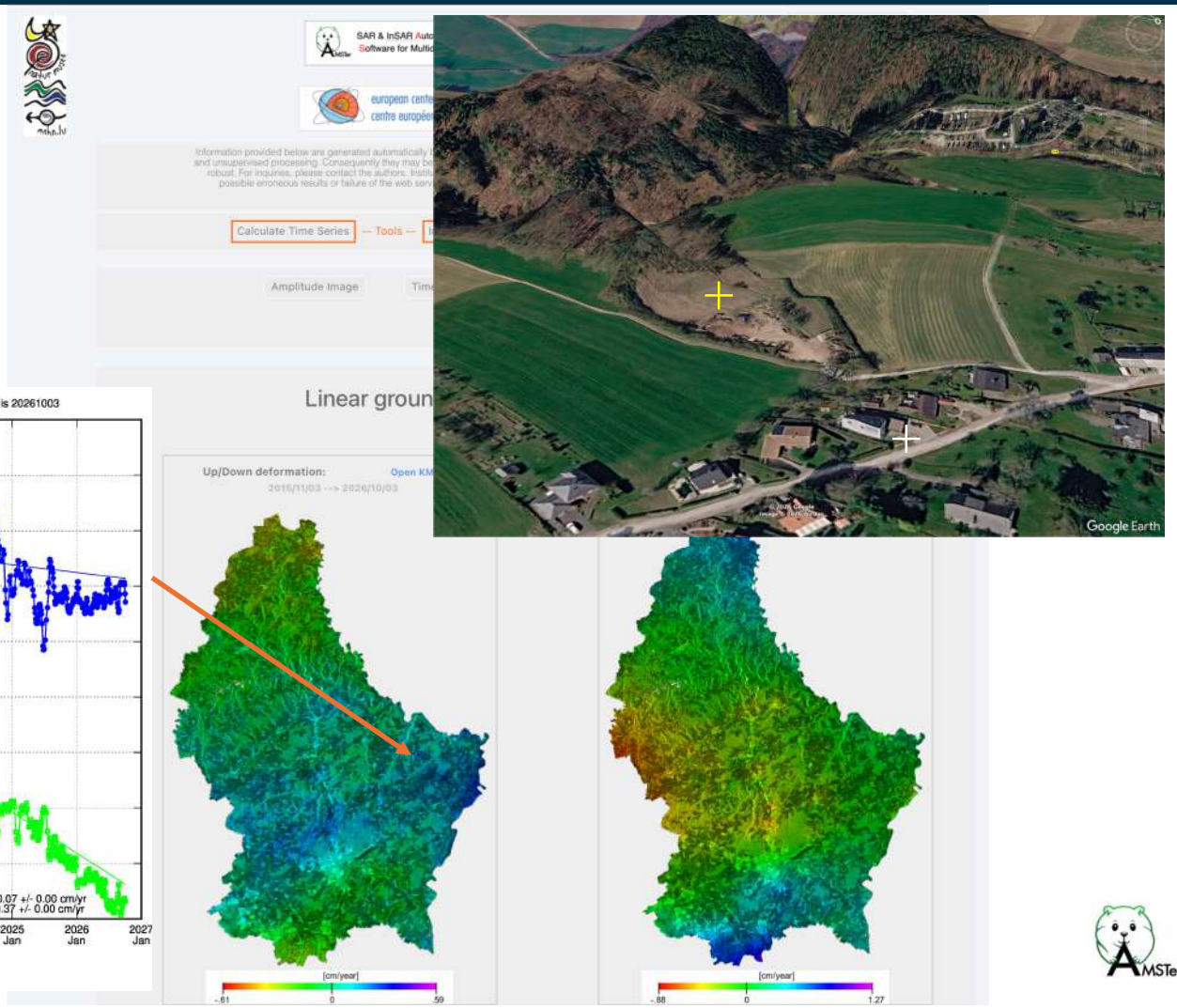
Tools



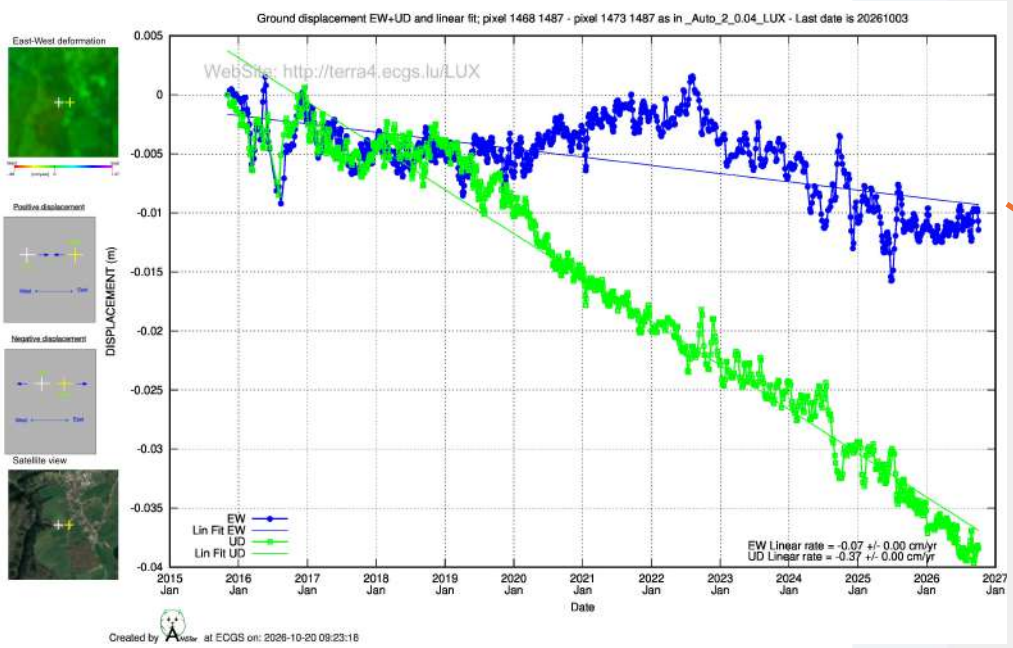
What is AMSter ?

Tools

Example for Luxembourg territory:



Consdorf



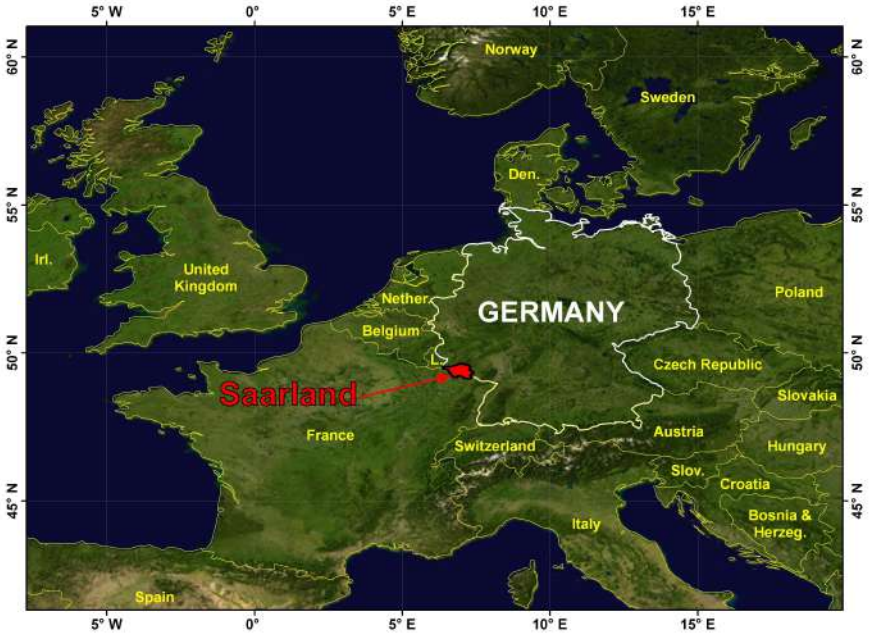
On the menu Today

Outlines

- Synthetic Aperture Radar (SAR)
- SAR Interferometry (INSAR)
- Application to the Greater Region
- Conclusions

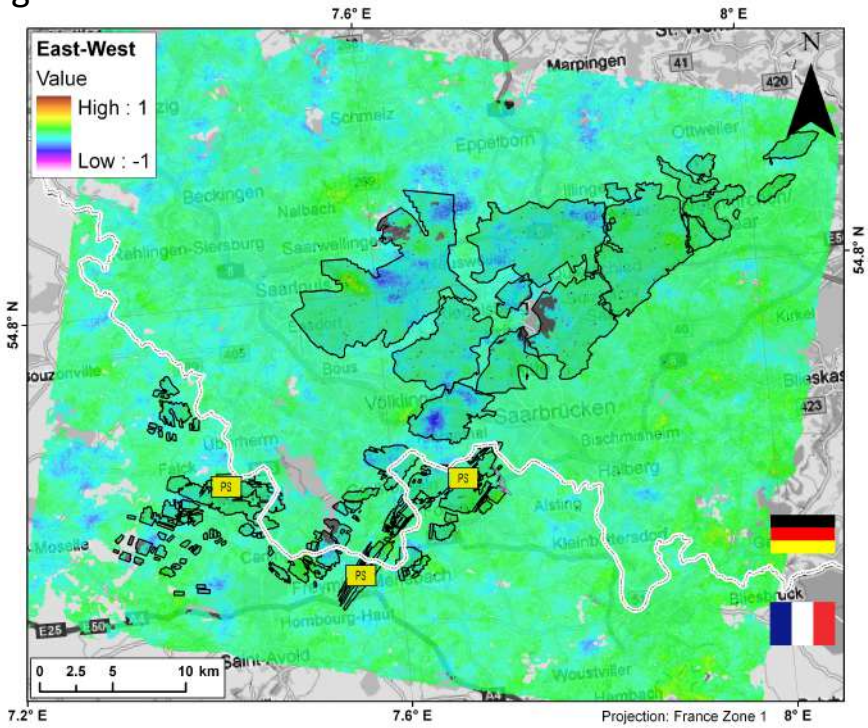
Mining subsidences in the Greater Region

Application



- Many sites with various levels of galleries (few m up to >1000m)
- Interconnected with galleries and pits

- Coal mining activity since 18th Century
- Still active in Saarland (Germany)
- Progressive closure in France (> 2004):
  => flooding of galleries
  => water pumping



Mining subsidences in the Greater Region

Application

Data availability

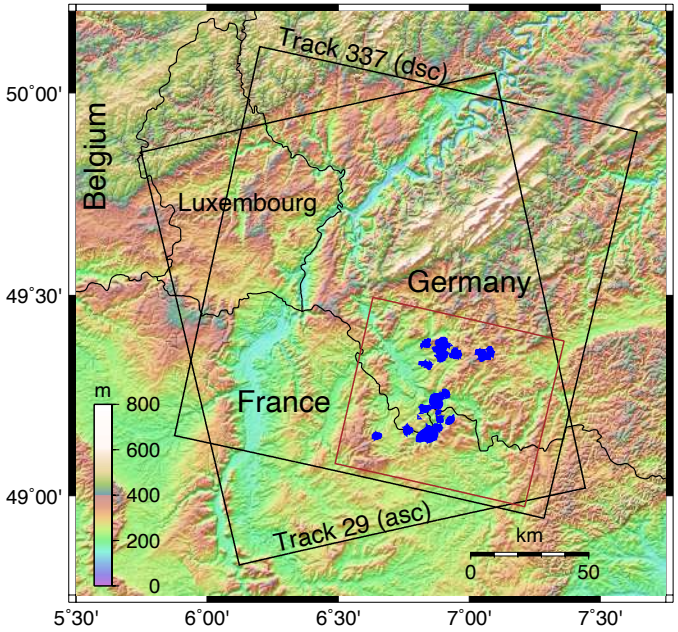
Satellites :

- ERS(1& 2) + ENVISAT (1995-2009)
  - 58 Ascending and 113 Descending SAR images
  - 510 interferograms (B_{perp} < 400m ; B_t < 1000 days)

Ground based:

- Intensive levelling by French geol. Survey:
  - 1700 benchmarks located along roads and paths.
  - Surveys annually
  - Vertical displacements : uncertainty better than 2cm

- Water level measured in nearby pits.
  - However, we do not know the link between pumping stations and galleries
  - No quantitative study

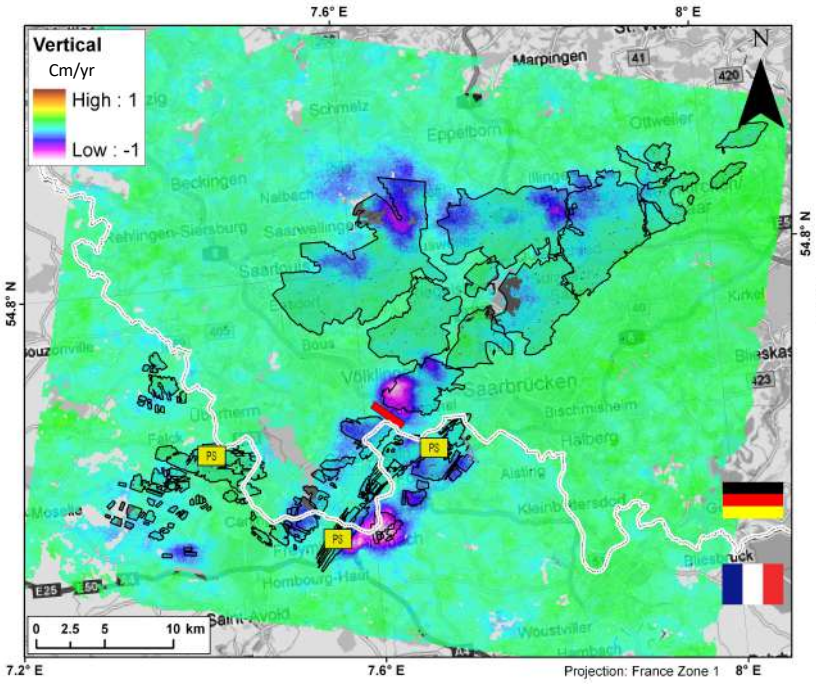


Mining subsidences in the Greater Region

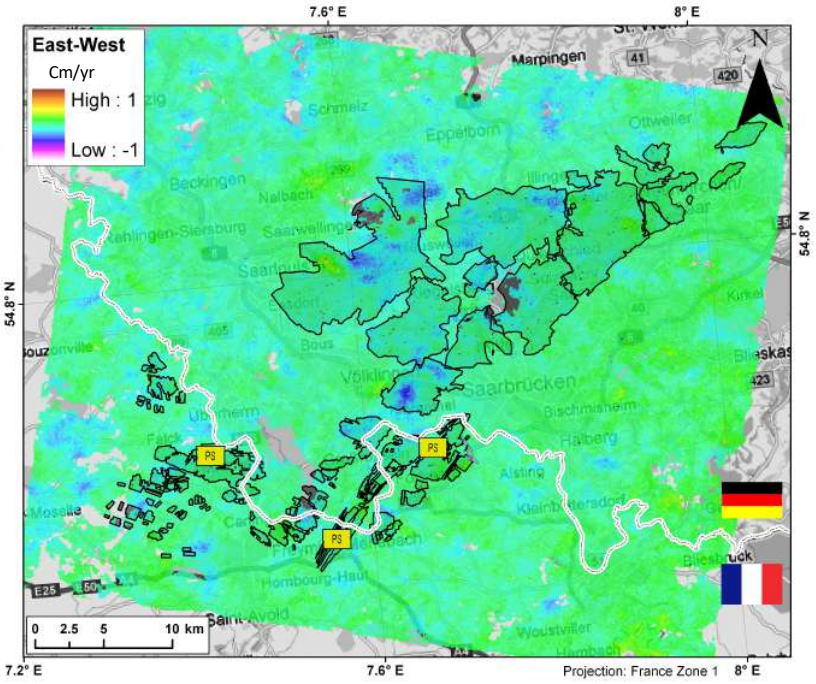
Application

Ground deformation measured by MSBAS

Deformations take place above mining sites.



Up-Down (cm/yr)



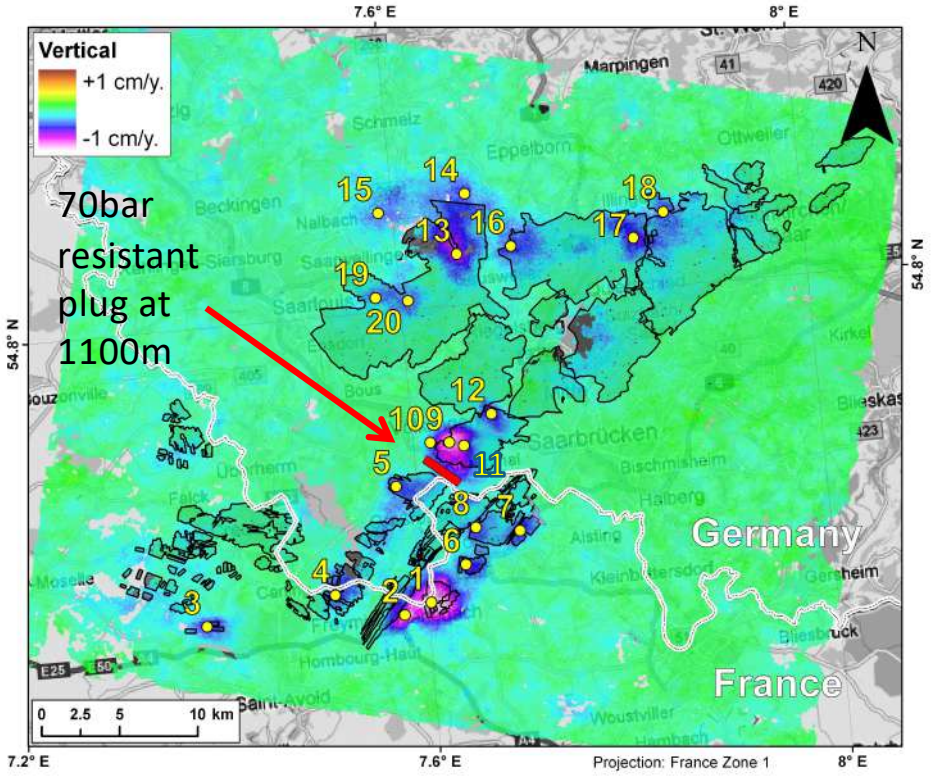
East-West (cm/yr)

Mining subsidences in the Greater Region

Application

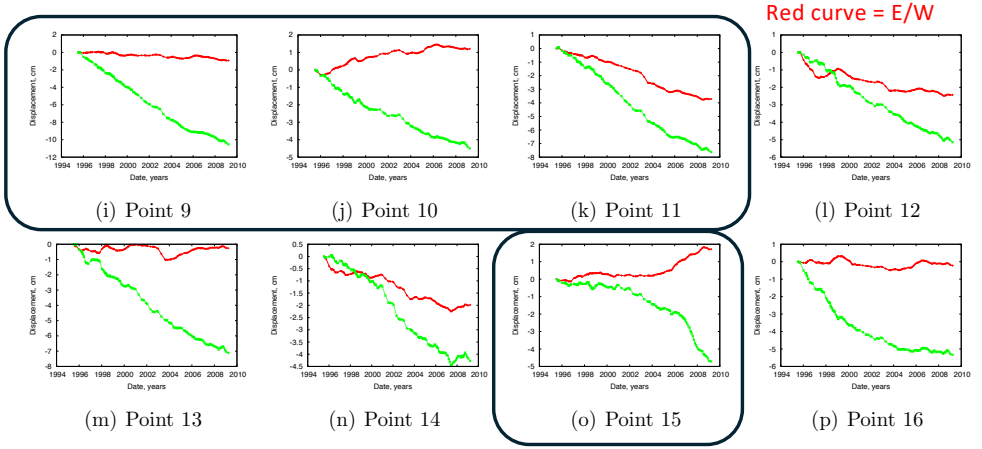
Ground deformation measured by MSBAS

No reversal in Germany (but point 5), All reversal in France.



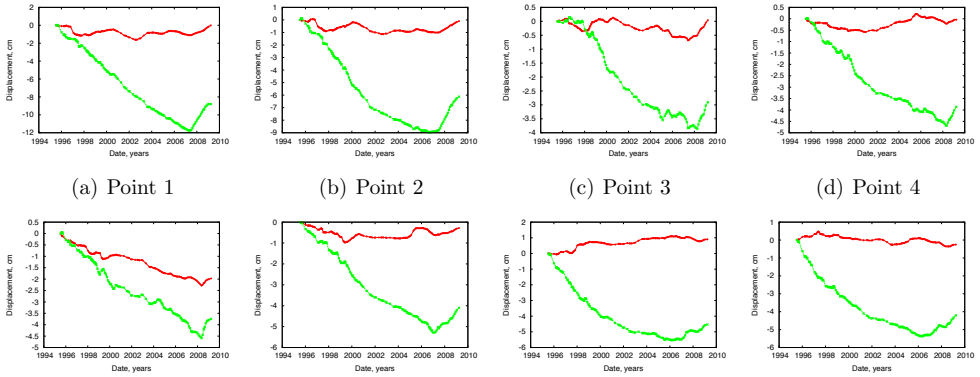
Up-Down (cm/yr)

Green curve = vertical
Red curve = E/W



(i) Point 9 (j) Point 10 (k) Point 11 (l) Point 12

(m) Point 13 (n) Point 14 (o) Point 15 (p) Point 16



(a) Point 1 (b) Point 2 (c) Point 3 (d) Point 4

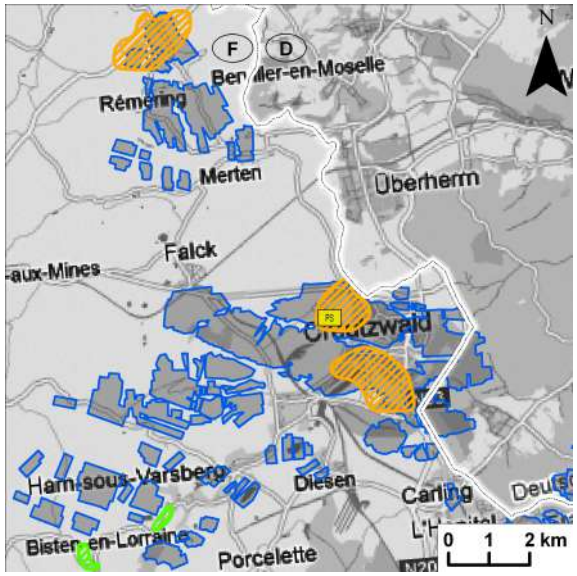
(e) Point 5 (f) Point 6 (g) Point 7 (h) Point 8

Mining subsidences in the Greater Region

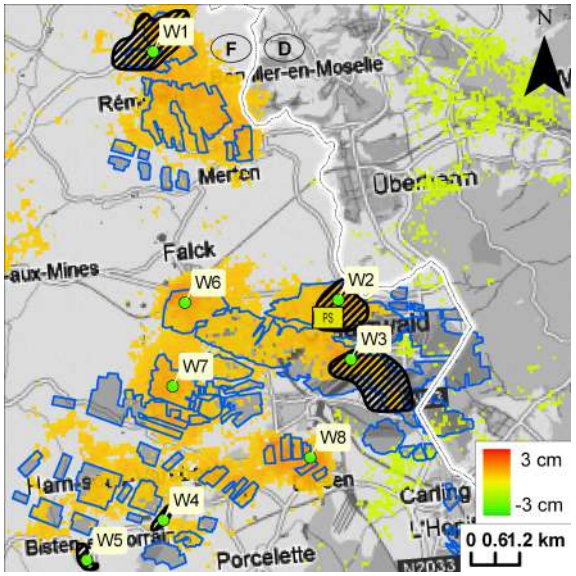
Application

Ground deformation : MSBAS vs levelling

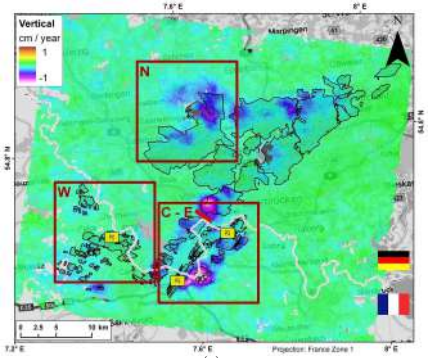
Western sector.



Levelling: Nov.2006-Nov.2008



MSBAS: Nov.2006-Nov.2008



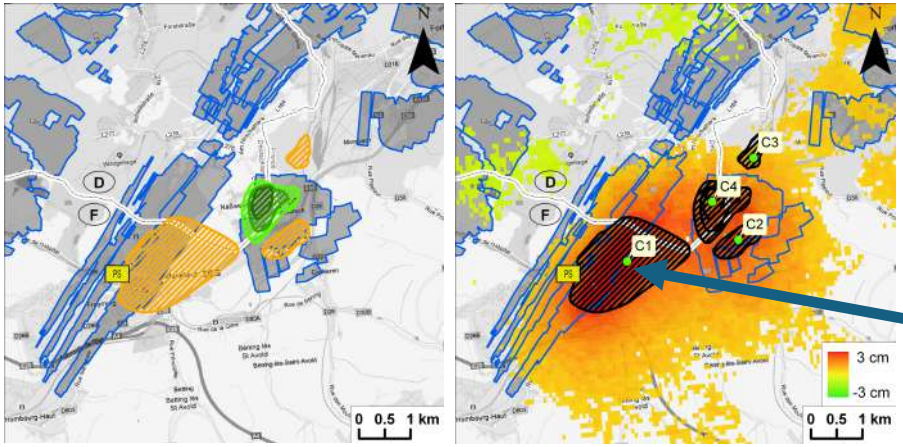
- Good agreement for swell: W1-3
- More revealed by InSAR: W6-8

Mining subsidences in the Greater Region

Application

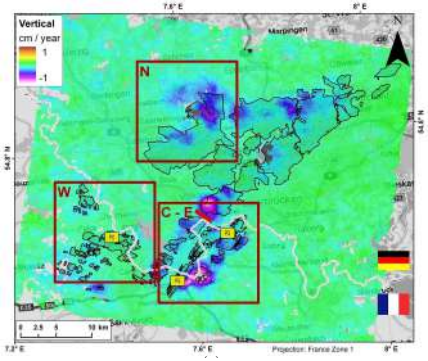
Ground deformation : MSBAS vs levelling

Central sector.



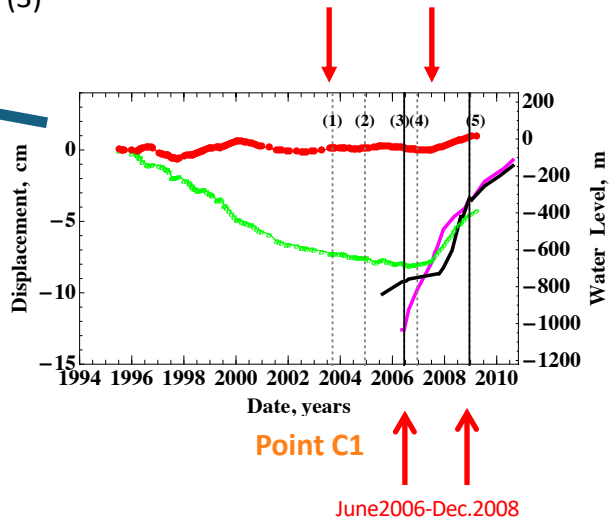
Levelling: June2006-Dec.2008

MSBAS: June2006-Dec.2008



- Good agreement for swell. (C1-3)
- Apparent disagreement for C4 ?
- More revealed by InSAR

- Do not stop after end of exploitation (1)
- Consistent with water level (purple and black curves)
- Stabilize after onset of flooding (3)

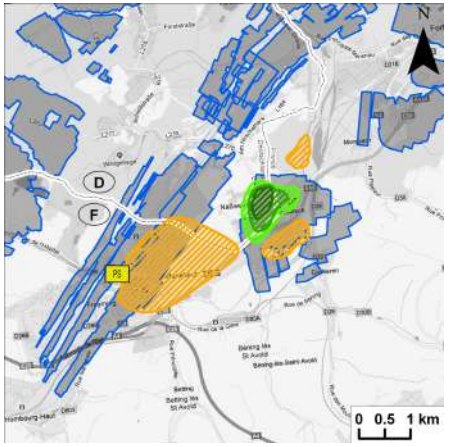


Mining subsidences in the Greater Region

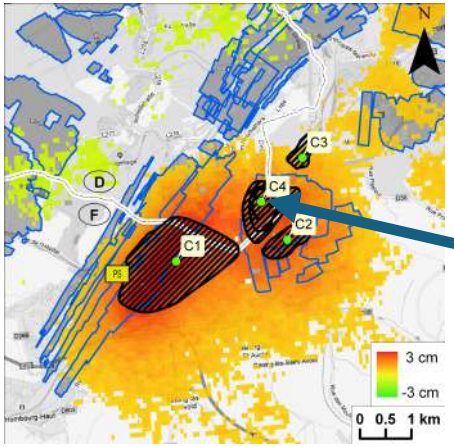
Application

Ground deformation : MSBAS vs levelling

Central sector.

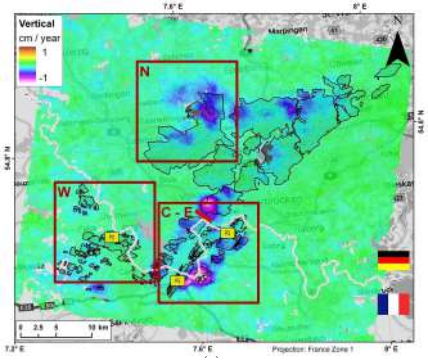


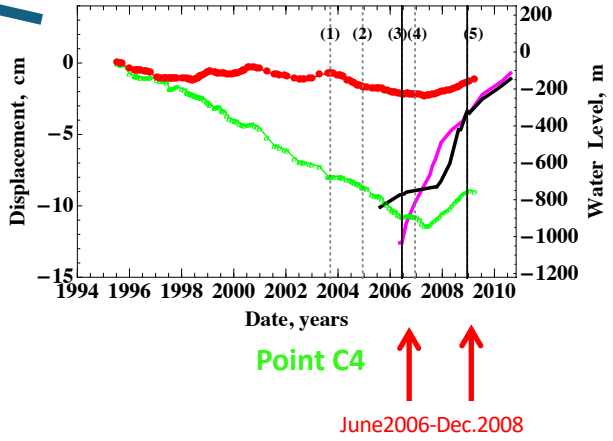
Levelling: June2006-Dec.2008

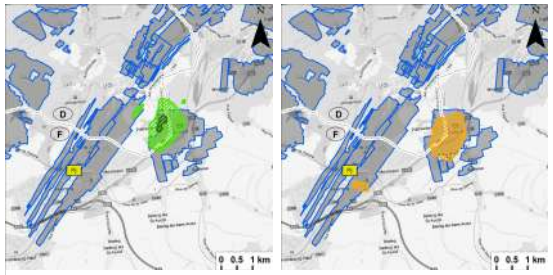


MSBAS: June2006-Dec.2008

- Disagreement at C4 (10cm !) ?
- Consistent with water level
- Why discrepancy ?







Levelling: Sep06-Sep07 ; Sept07-Sep08

- Smoothing (ML)
- InSAR limitation ?
- Levelling uncertainty / dates of campaigns ?

On the menu Today

Outlines

- Synthetic Aperture Radar (SAR)
- SAR Interferometry (INSAR)
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Conclusions

- **Powerful method** for measuring ground deformations. Each pixel acts as a sensor
- **High resolution** (sub cm level)
- **Limitations** : vegetation, atmosphere, ionosphere, type of movements, resolutions…
- **Complementary** to other geodetic methods
  (eg GNSS, which is continuous in time but not in space)
- **Easy** (Do not need fieldwork, "Only" needs computers resources - a lot !)
- **Historical reconstruction:** May get back in time thanks to archives

- Mnhn and ECGS have a large experience and developed a unique tool: the **AMSTer Toolbox**

- Several other applications at Mnhn and ECGS in volcanology, geodesy, hydrology, glaciology…: see next presentation by Delphine and Quentin

NATUR MUSÉE

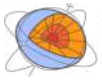
ECGS European Center for Geodynamics and Seismology

AMSTer

Thank you

ndo@ecgs.lu

NATUR MUSÉE



ECGS European Center for Geodynamics and Seismology



Earth From Above
Machera, Grevenmacher, Luxembourg
October 29, 2026

Seeing Through Clouds and Darkness
SAR and InSAR for Earth Observation

Delphine Smittarello[1], Quentin Glaude[1], Nicolas d'Oreye[1,2], Dominique Derauw[3]

1 European Center for Geodynamics and Seismology (ECGS), Luxembourg
2 Musée national d'histoire naturelle (Mnhn), Luxembourg
3 Centre Spatial de Liège (CSL), Belgium

Clouds and darkness hide the ground

Two obstacles for optical satellites

ECGS | CEGS



~2/3

of the Earth is covered by clouds at any time



1/2

of the planet is in the dark at any time

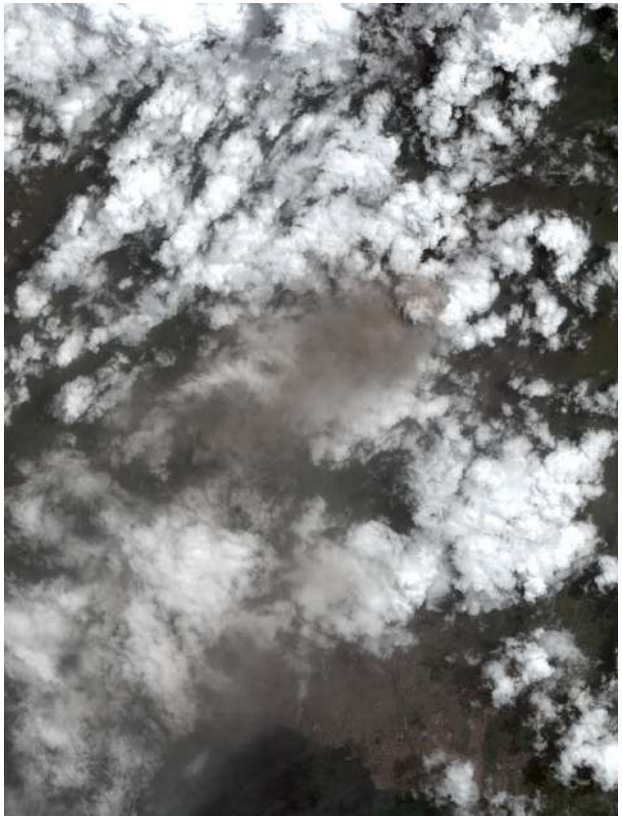
Radar brings its own light: **it sees through clouds, day and night**

Radar sees through, day and night

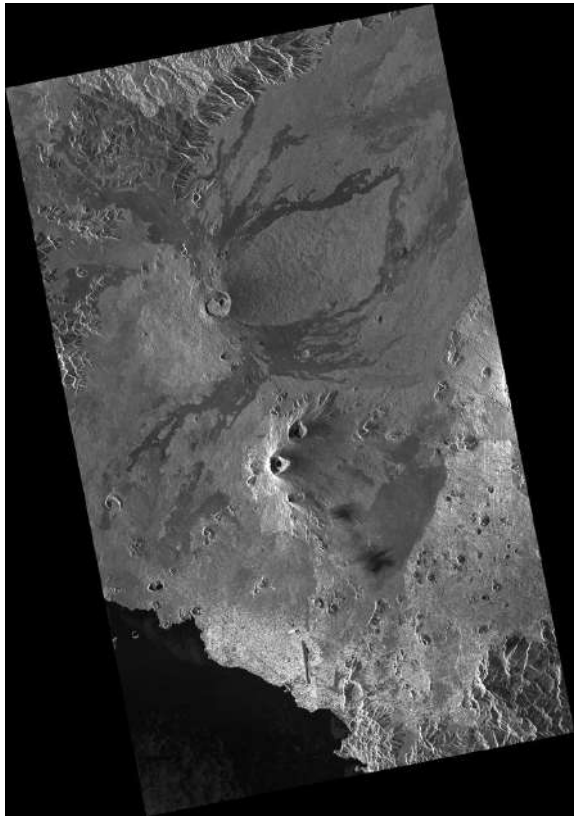
Nyiragongo, DR Congo · May 2021

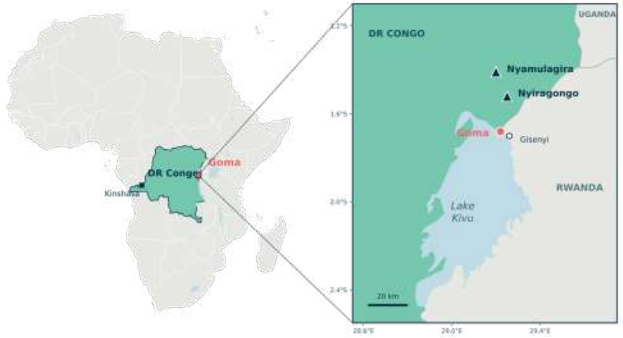
ECGS | CEGS

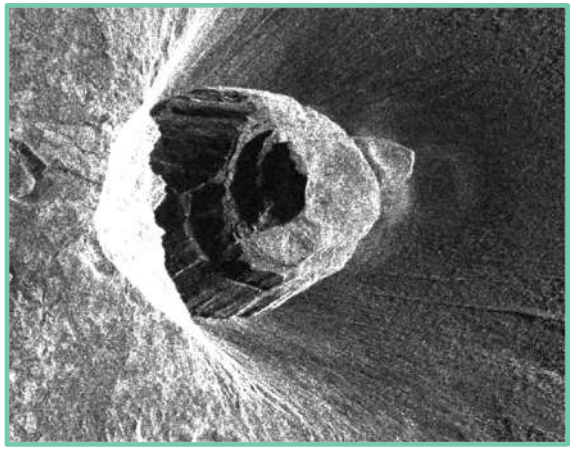
OPTICAL — Pléiades, 27 May



RADAR — TerraSAR-X, 24 May







Radar zoom on the summit crater

PART 1

Nyiragongo, DR Congo

An active volcano next to a city

~1 million

people live in the Goma urban area



Photo: N. d'Oreye (2013)

22 May 2021: an eruption without warning

Nyiragongo, next to the city of Goma



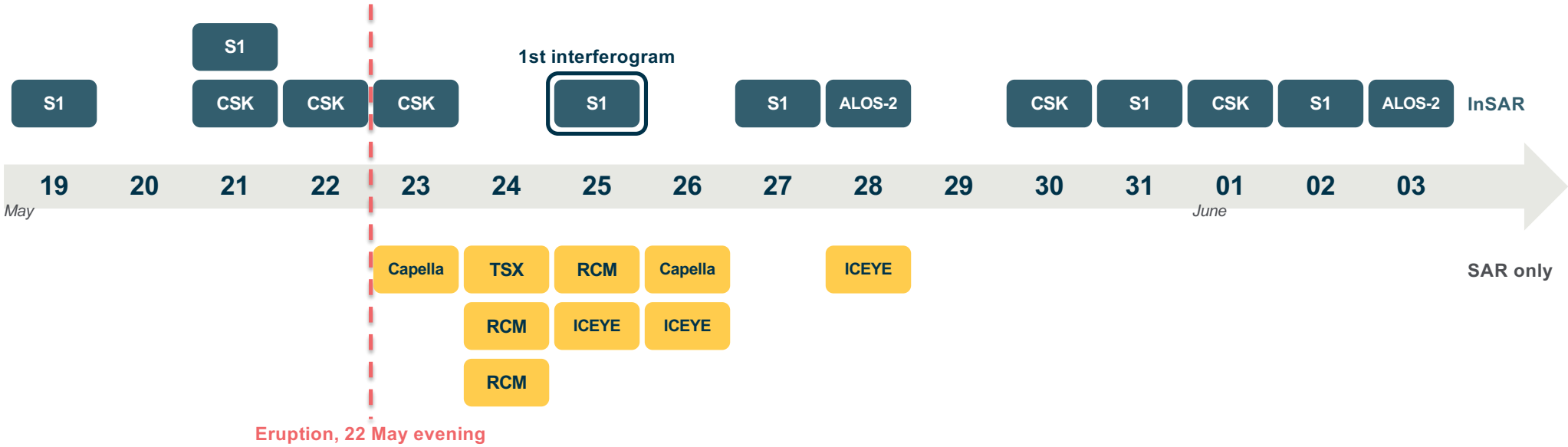
Lava flow through the northern districts of Goma

- **Evening of 22 May:** lava flows rush towards Goma
- **No warning:** ground, earthquakes and gas were quiet before
- **Next days:** hundreds of earthquakes beneath Goma and Lake Kivu

To better understand what's happening underground? Satellites can help!

Radar images, almost every day

SAR acquisitions over Nyiragongo · 19 May – 3 June 2021



InSAR

Sentinel-1, COSMO-SkyMed, ALOS-2
repeated orbits → interferometry: ground motion

SAR only

TerraSAR-X, RCM, ICEYE, Capella
radar images: crater shape, lava flows

22
radar images in 16 days

7
different satellites

3 days
to the first interferogram

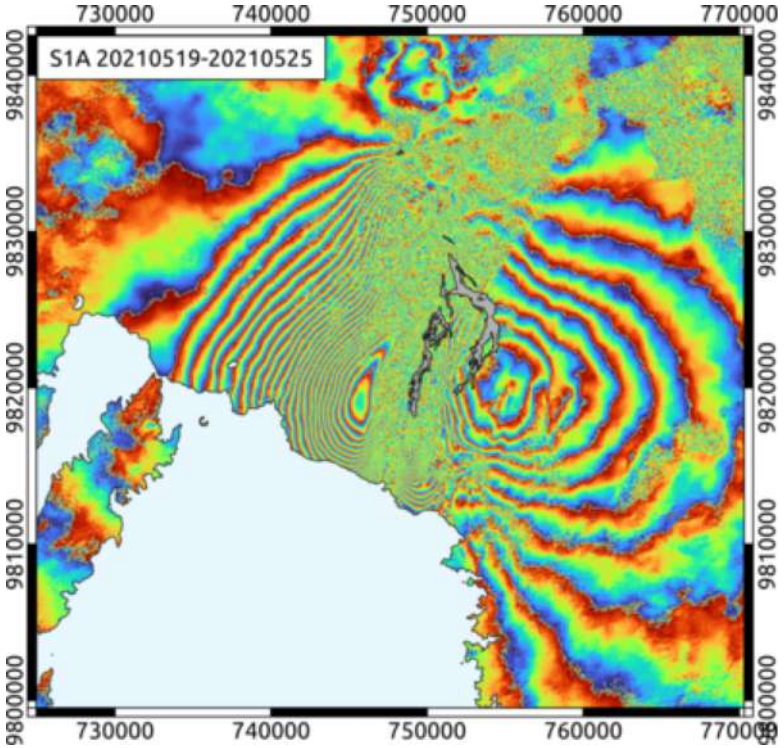
Images used to follow the crater collapse: Smittarello et al. (2023), Table S2

InSAR images the ground motion

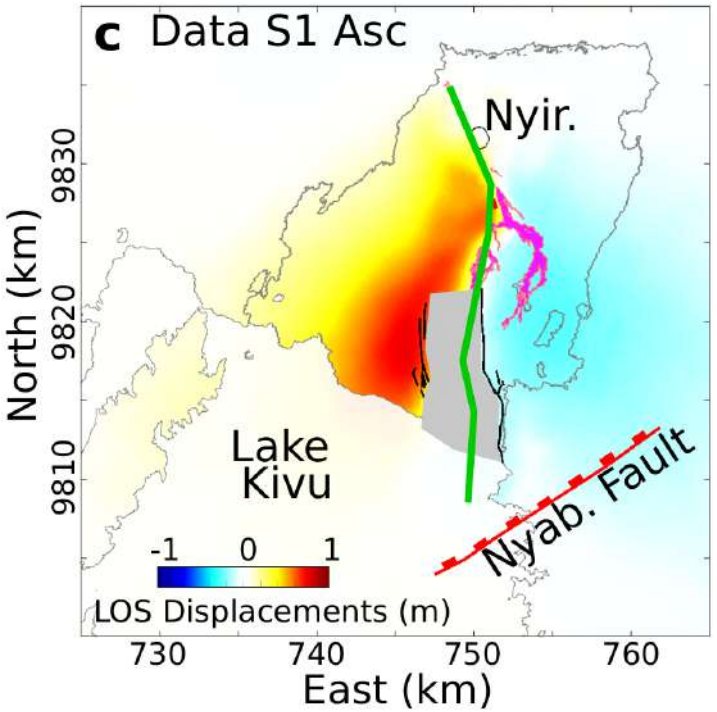
Sentinel-1 · first images after the eruption

ECGS | CEGS

RADAR FRINGES — 19 → 25 May



GROUND MOTION — up to ~1 m



2.8 cm

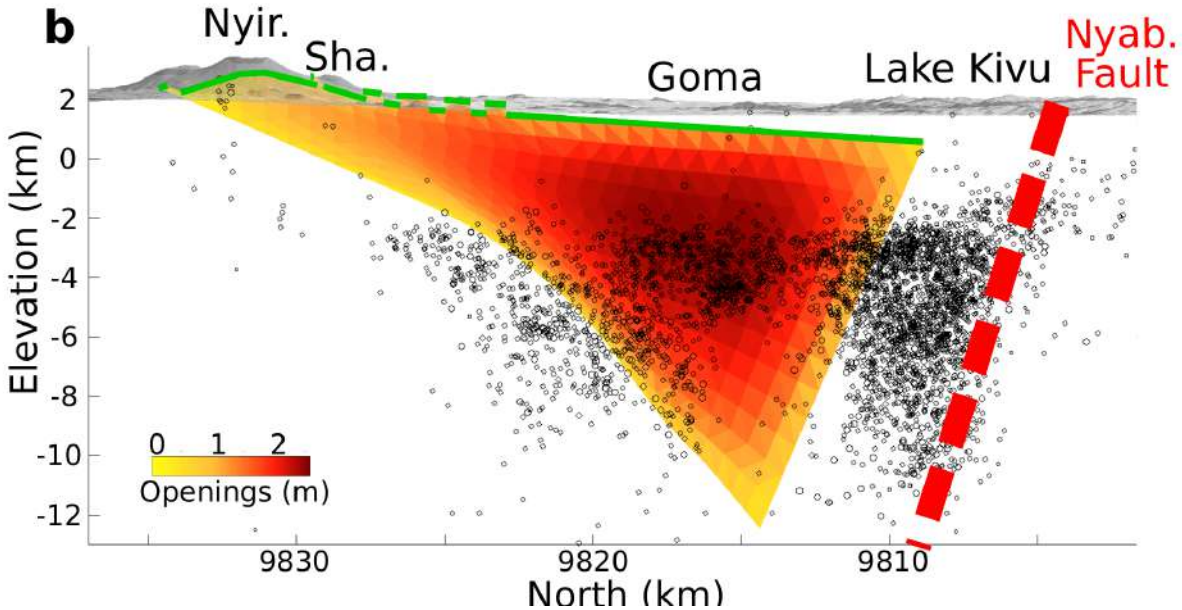
per colour cycle

- **Fringes** = contour lines of ground motion
- **Centred on Goma,** not on the volcano

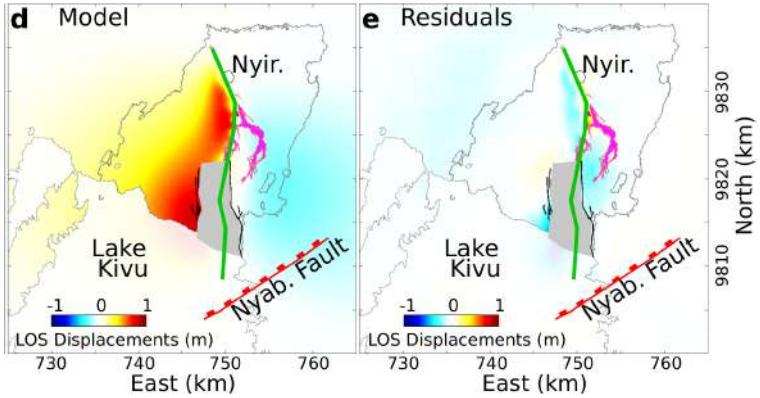
The ground opened **beneath the city**

Modelling finds the source: a sheet of magma

From surface motion to what happens underground



Modelled magma sheet (dyke) beneath Goma, north–south section



Model reproduces the data (residuals small)

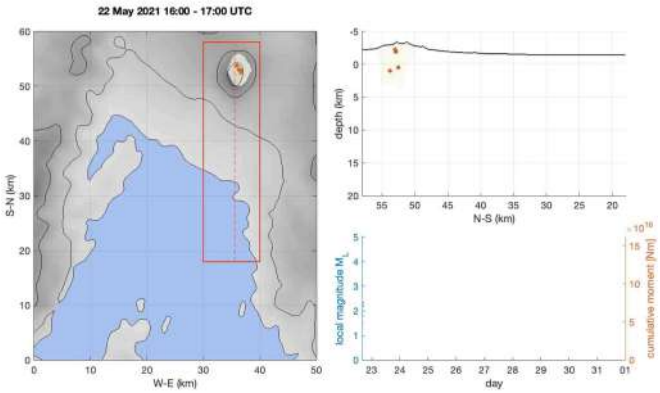
- **A crack filled with magma,** up to ~2 m wide
- **From the volcano** to beneath Lake Kivu, a few km deep

Satellites told crisis managers **where the magma was**

Smittarello et al. (2022), Nature

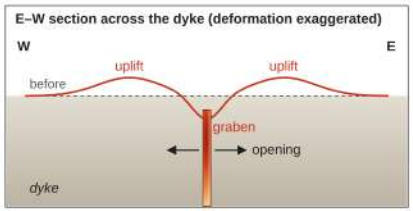
Earthquakes and GNSS confirm the model

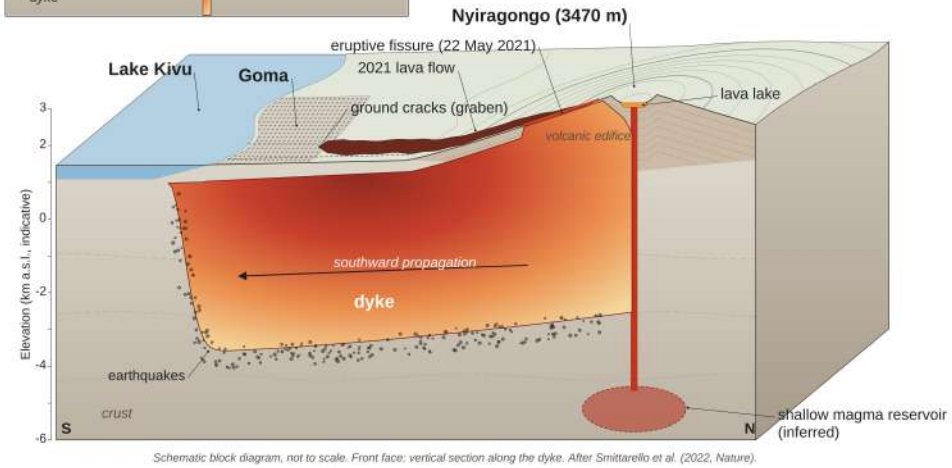
The magma moved south, step by step

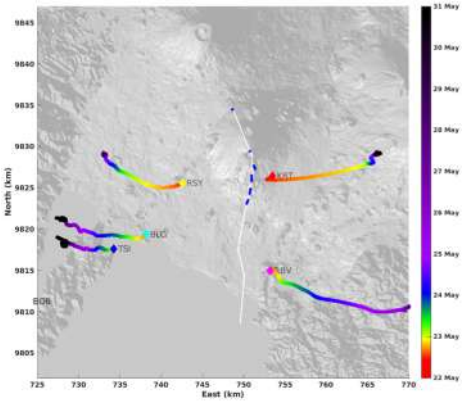


Earthquakes, 22 May – 1 June 2021 (animation)

- **Earthquakes** migrate south, day after day





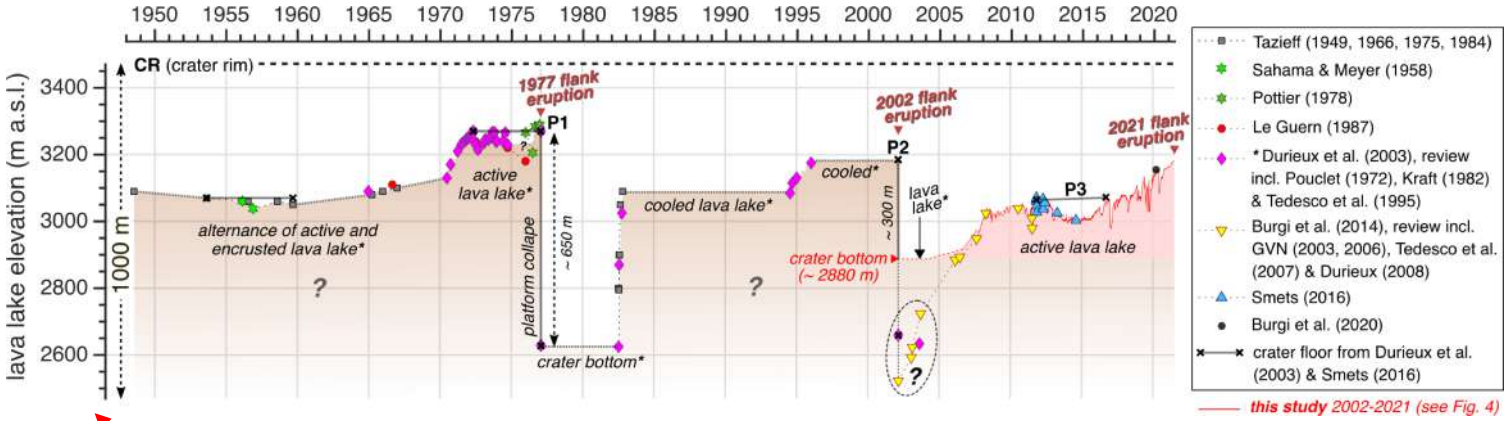


GNSS stations moving apart over time (colours = days)

- **GNSS:** the ground opens progressively southwards

Watching the lava lake over years

Long term: radar shadows measure the lava lake level



Barrière et al. (2022), JGR

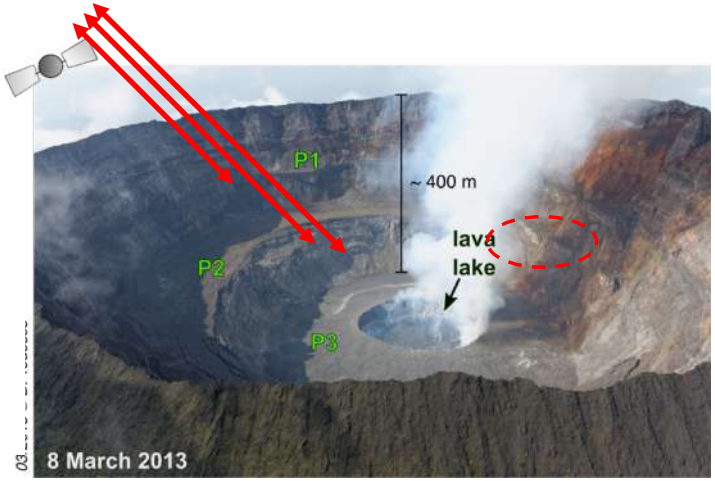


Photo: D. Tedesco

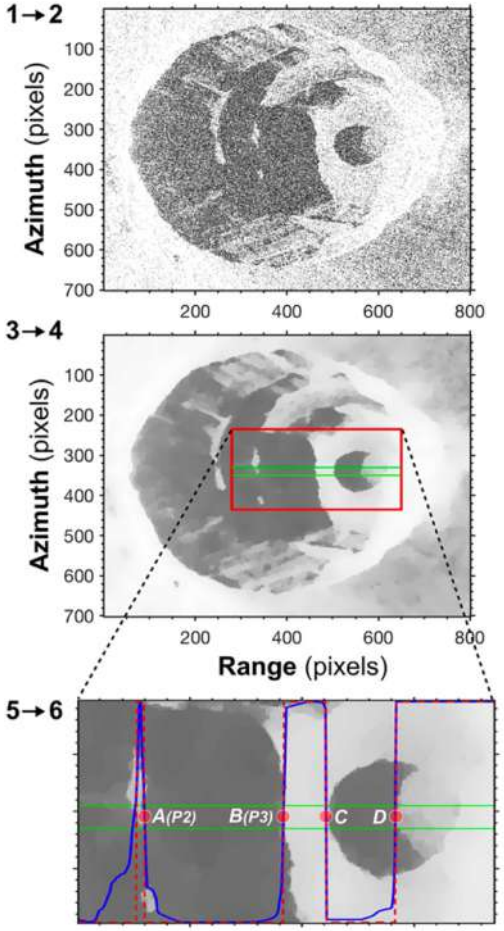
95

field estimates since 1948

~15 yr

of radar data (red curve)

Radar looks sideways: the crater walls cast shadows. Their length gives the depth of the lava lake.



When the crater collapsed, only radar could see

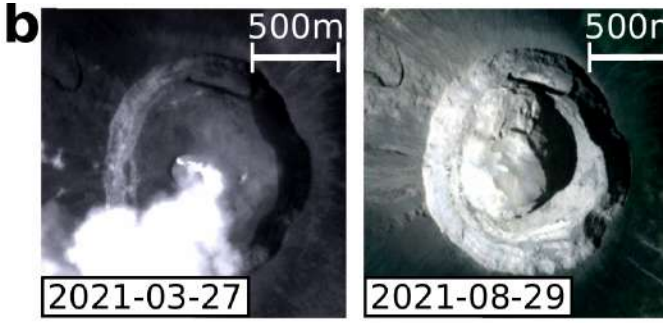
Short term: 1 June 2021, same day, two satellites

ECGS | CEGS

OPTICAL — Sentinel-2

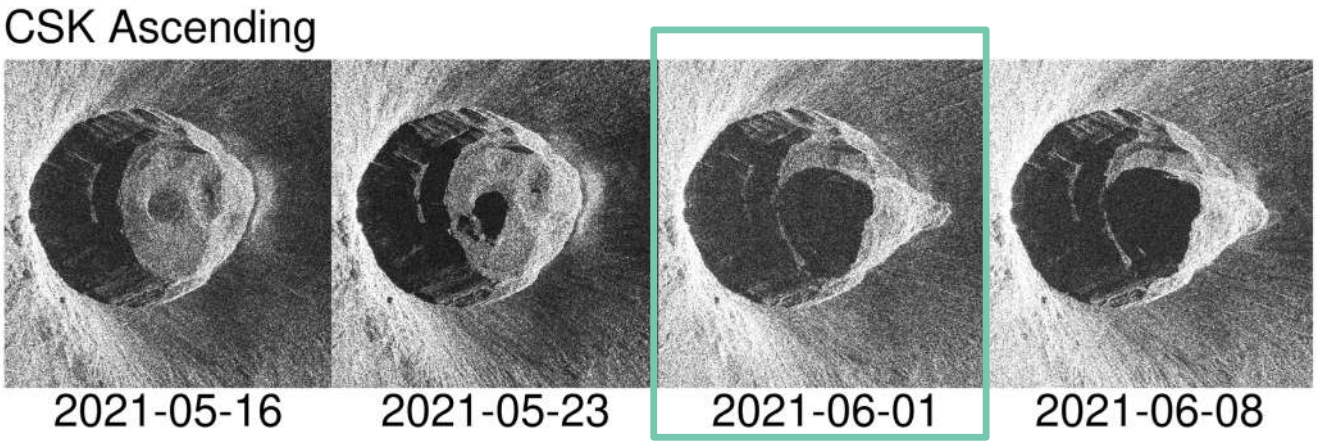


1 June 2021
08:06 UTC
The crater is hidden by clouds and haze



Before the eruption, and first clear view: end of August

RADAR — COSMO-SkyMed amplitude

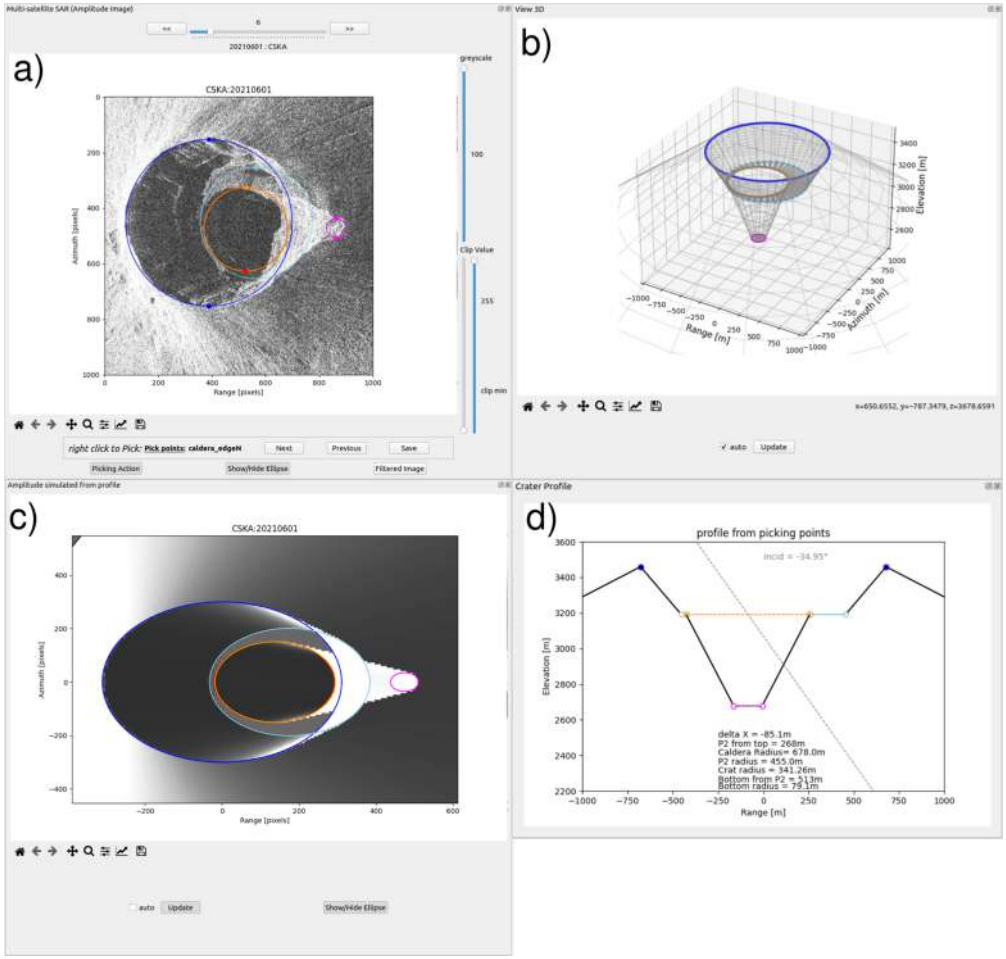


same day as Sentinel-2

- **The lava lake drains** and the crater floor collapses
- **Radar: an image every few days** during the crisis — optical: first clear view months later
- **Too deep for shadow measurements:** other radar effects (layover) reveal the crater shape

Reading the crater shape from radar geometry

Bright slopes (layover) and dark shadows outline the pit



1 **Trace the crater rims**

bright walls facing the radar, dark shadows

2 **Build a 3D crater model**

a cone-shaped pit

3 **Compare with the radar image**

→ depth, radius and volume

The shape of the new pit, measured without going there

PART 2

Bukavu earthquake, 2008

South of Lake Kivu: a small earthquake, a big impact

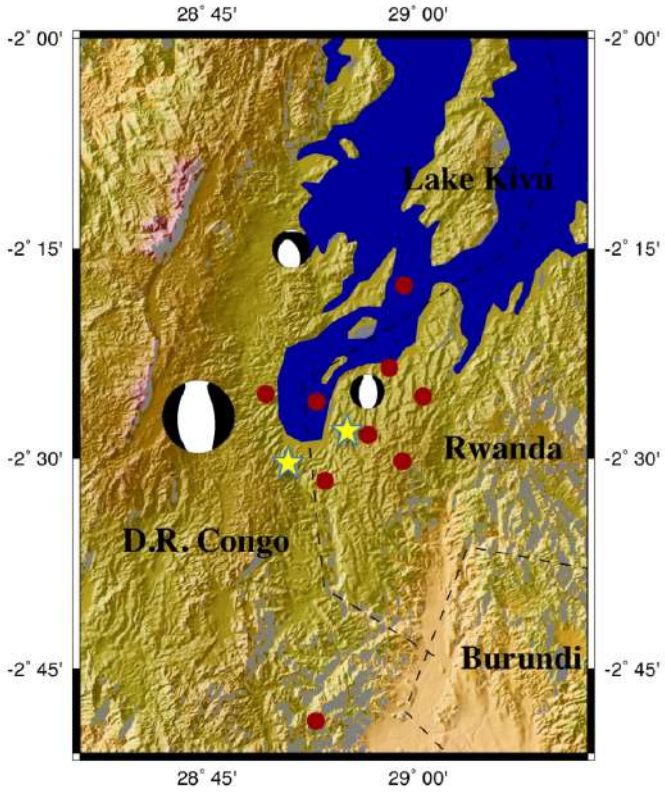


Mw 5.9

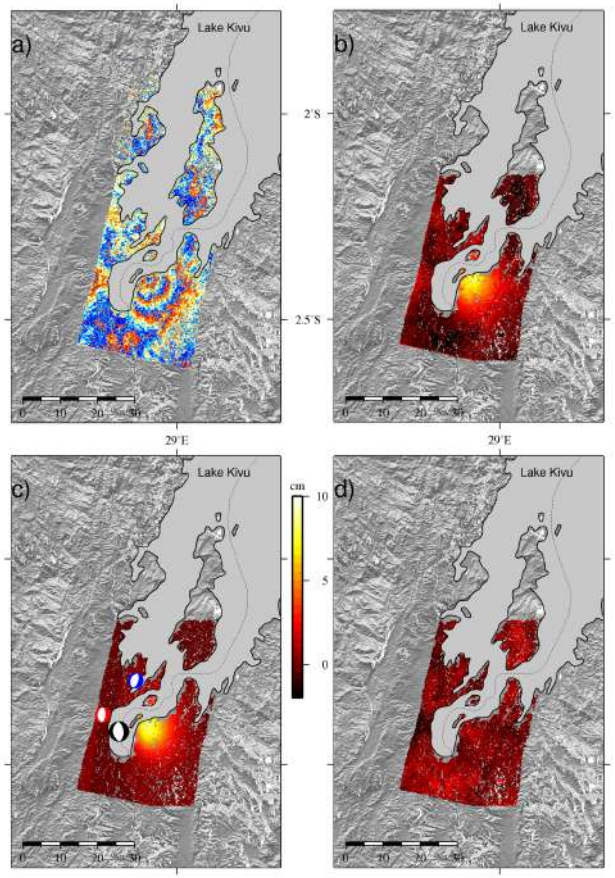
at least 43 deaths, more than 5,000 houses destroyed

Locating the earthquake from space

Bukavu–Cyangugu earthquake, 3 February 2008, Mw 5.9



Catalogue locations and aftershocks (dots)



InSAR data (a), model (b–d)

- **No dense local network:** international catalogues place the shock far from the real signal
- **InSAR pinpoints** the deformation and the fault
- **A tectonic earthquake,** not a magma intrusion

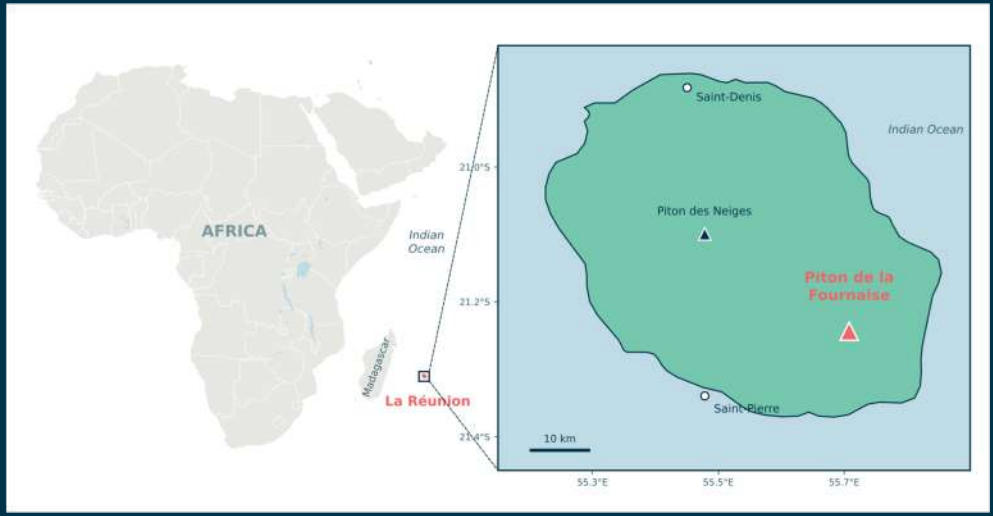
Where instruments are missing, **satellites fill the gap**

d'Oreye et al. (2011), Geophys. J. Int.

PART 3

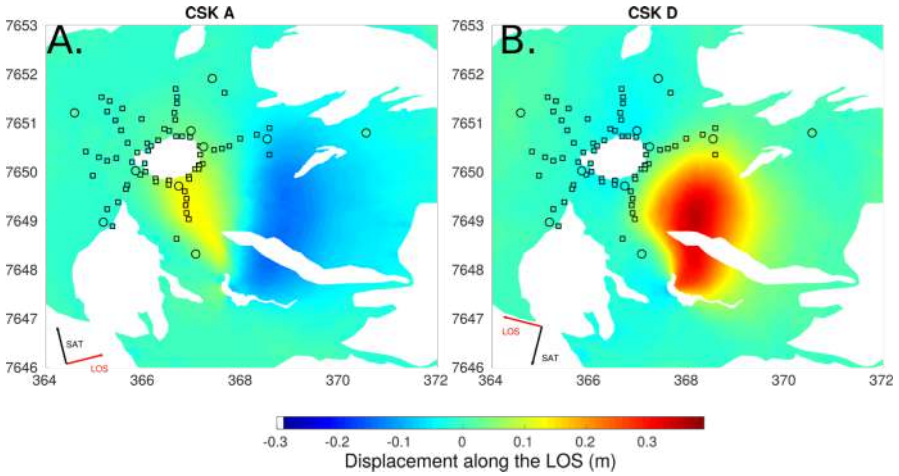
Piton de la Fournaise

La Réunion: one of the best-monitored volcanoes

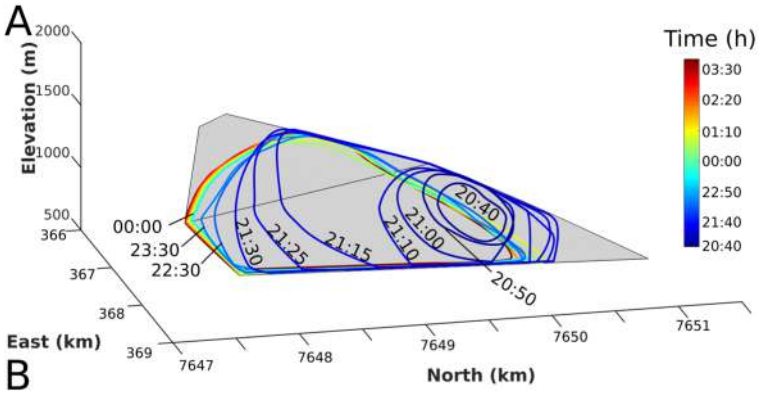


GNSS: continuous in time — InSAR: continuous in space

Piton de la Fournaise · May 2016 magma intrusion



InSAR: the full map of ground motion



GNSS + InSAR: the intrusion hour by hour

GNSS

dozens of points, measured continuously

InSAR

millions of points, every few days

Together: **where and when the magma moved**

A unique dataset: from quasi-2D to true 3D

ALOS-2 · 22 viewing directions over Piton de la Fournaise

ECGS | CEGS

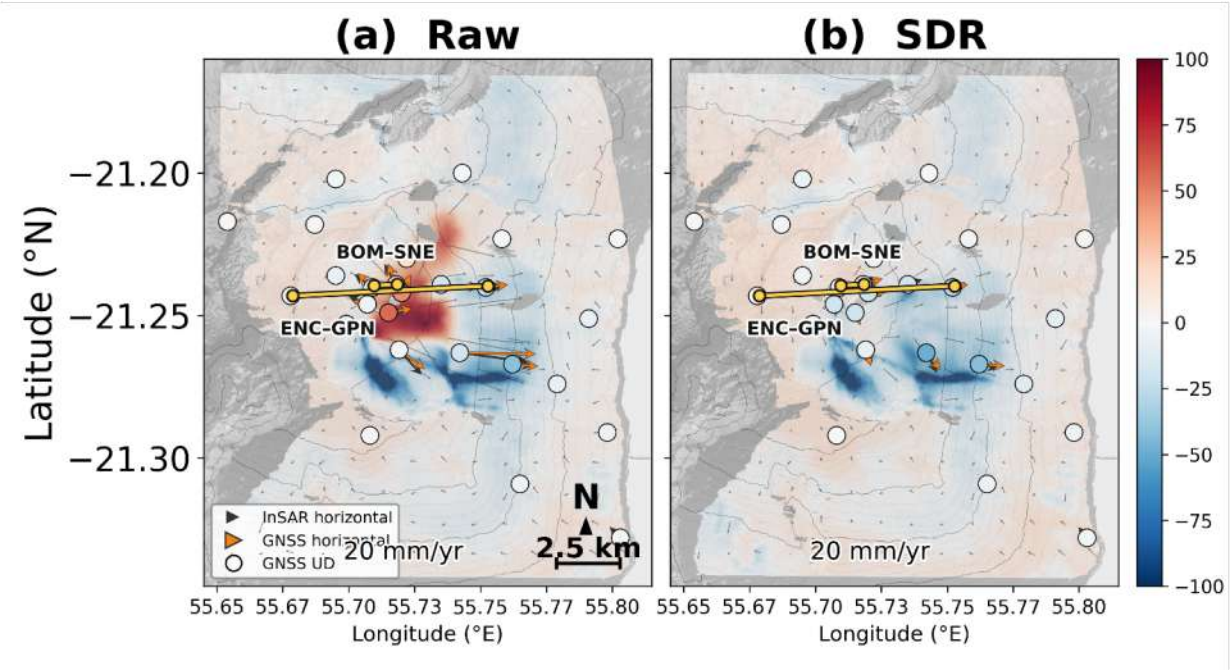
22
viewing directions

>1,600
radar images

3D
east · north · up

4.5 yr
2021 – 2025

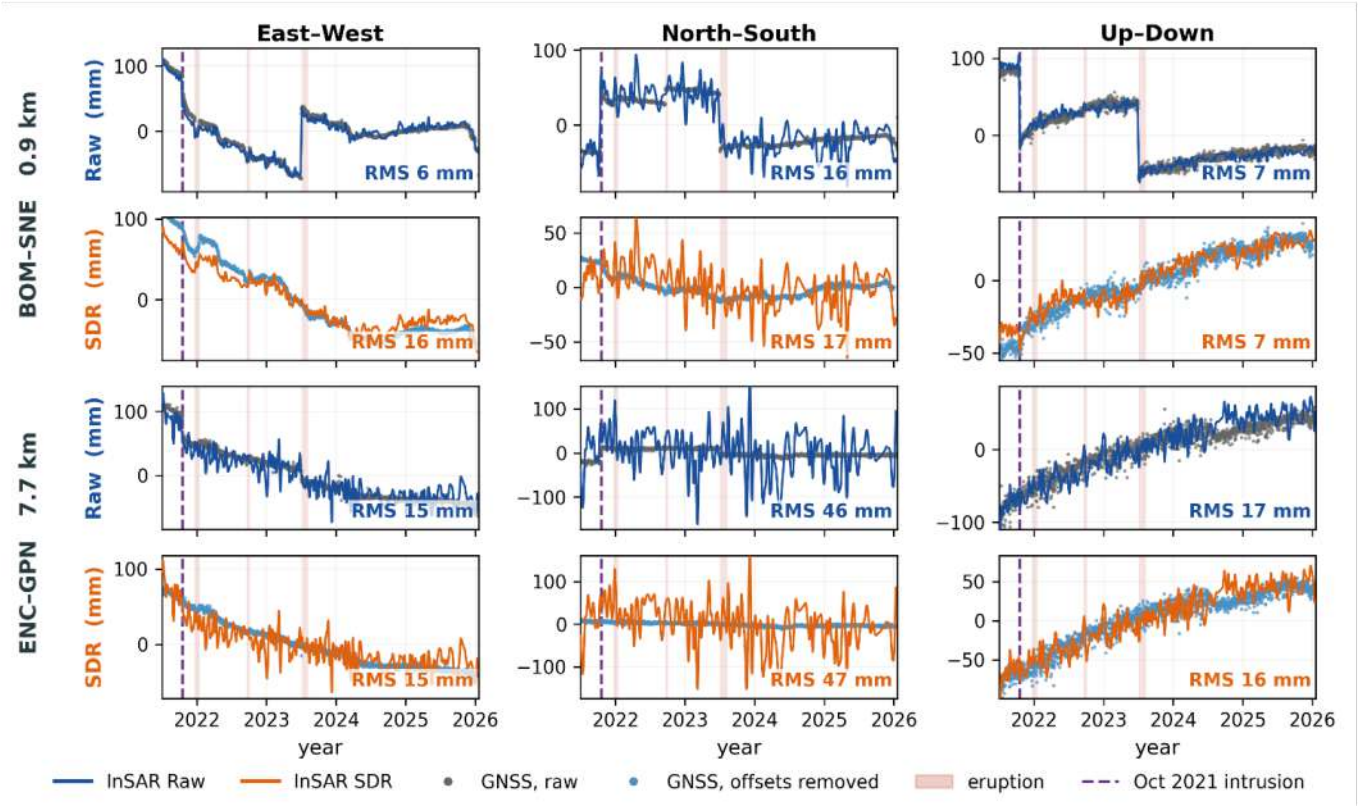
- **Usually:** 2 viewing directions → east–west and vertical only (quasi-2D)
- **Here:** 22 directions → north–south too: true 3D



Ground velocity 2021–2026: colour = up/down (mm/yr), arrows = horizontal. (a) raw, (b) eruptions removed

Years of motion, eruption after eruption

ALOS-2 3D time series · 2021–2026



East, North and Up motion at two sites — InSAR vs. GNSS

Between eruptions

slow, continuous motion

During intrusions

sudden jumps of centimetres

Both together

the long-term life of the volcano

Mapping new lava flows

Radar coherence: where the ground has changed



Piton de la Fournaise: coherence between two radar images spanning an eruption

Bright

ground unchanged

Dark

new lava flow

Lava flows mapped through clouds, **as soon as the next radar image arrives**

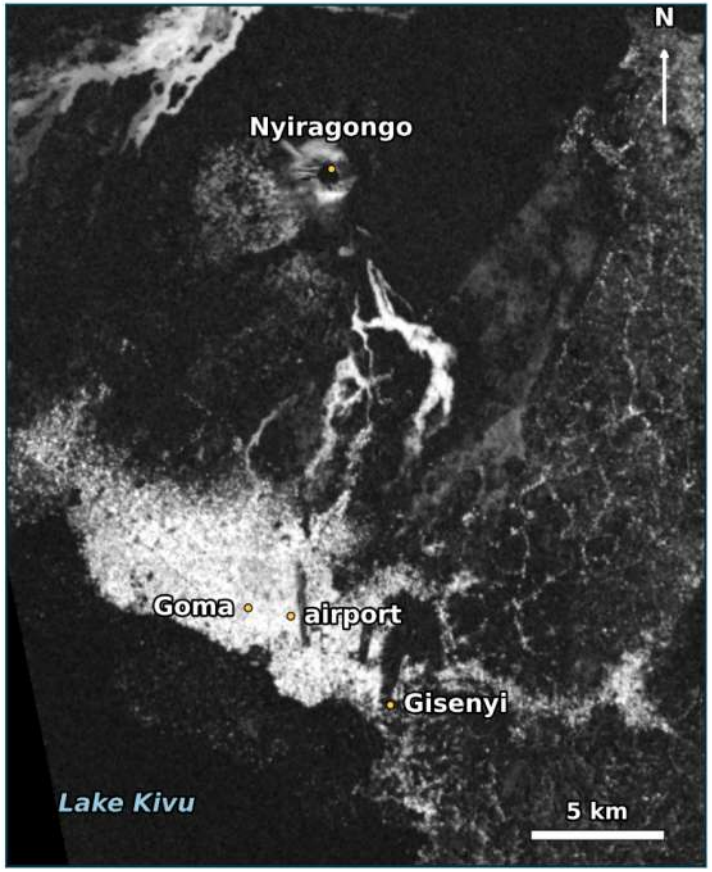
Coherence: how similar the radar echo is between two dates

Useful to map changes

Lava flows of May 2021 seen by radar coherence

Nyiragongo · COSMO-SkyMed coherence, April – June 2021

ECGS | CEGS



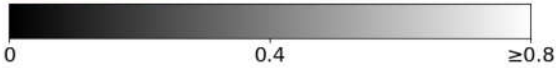
Radar coherence (COSMO-SkyMed)

01 Jun → 09 Jun 2021

Lava flows cooled: new flows appear bright



Coherence



dark = ground changed (new lava, vegetation)
bright = stable surface

CSK © ASI — processing ECGS

QUENTIN GLAUDE

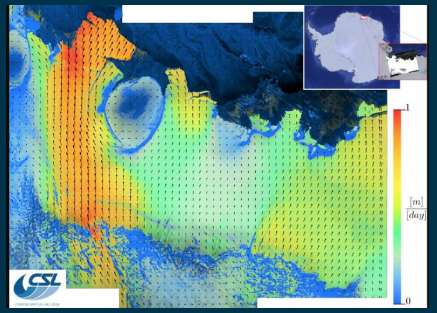
PART II :
Beyond volcanoes…

Fires, floods, ice sheets and landslides seen by radar

quentin.glaude@ecgs.lu









PART 4

Forest and bush fires

Radar coherence outlines the burnt area



Photo: © Sébastien Georis, RTBF

2026 Fire - Belgium

The August 2026 wildfire, seen from the ground





Photo: © Sébastien Georis, RTBF

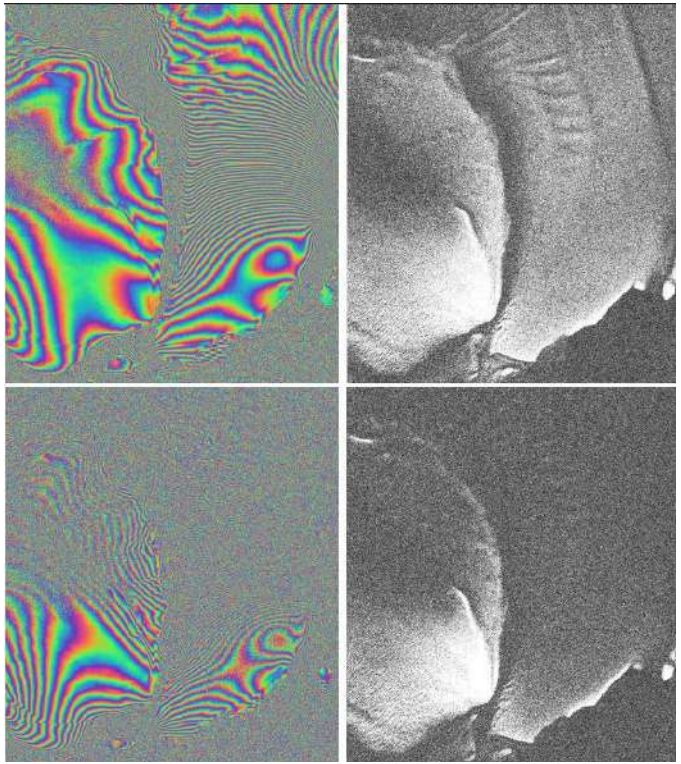
Interferometric coherence

How similar the radar echo is between two dates

ECGS | CEGS

- **Phase stability** between two images, measured in a small window (e.g. 5×5 pixels)
- **Close to 1:** the two images correlate well, with clear fringes
- **Close to 0:** decorrelation, e.g. large ground displacement or changed soil properties between the two dates
- **Used as** a quality indicator for displacement, or as a metric for change detection

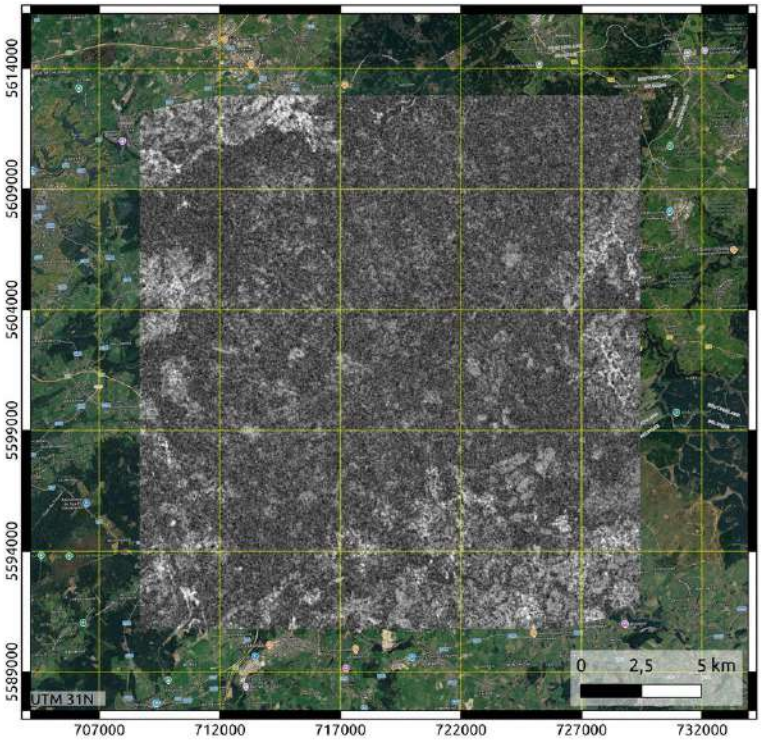
$$\gamma = \frac{|\sum_W M.S^*|}{\sqrt{\sum_W |M|^2 * \sum_W |S|^2}}, \in [0,1]$$



Effect of increasing the time between two acquisitions

2026 Fire - Belgium

Radar coherence before, during and after the fire



- **Before (8 and 14 August):** the normal coherence for this area and season
- **During (10 and 16 August):** the fire changes the surface, so coherence drops over the burnt area
- **After (22 and 28 August):** coherence recovers strongly over the burnt area, which sharpens its outline

Coherence change **outlines the burnt area**

PART 5

Flood events

Open water turns dark in radar images



July 2021 Flooding - Liège

The July 2021 floods, seen from the ground





Flood detection from SAR image

Water reflects the radar signal away from the satellite

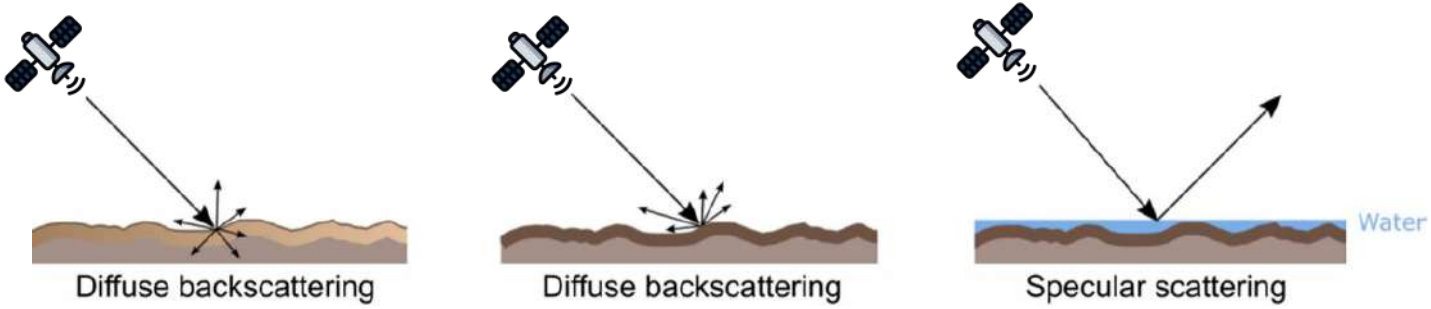
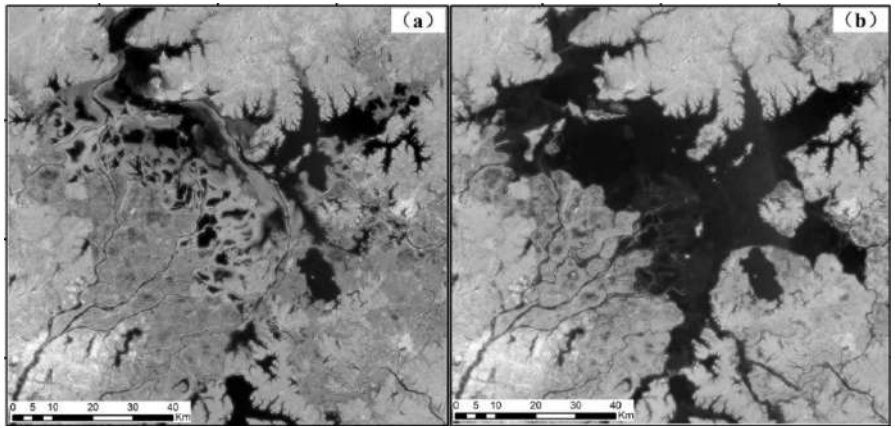


Figure: Marco Ottinger (2020)



SAR images before (a) and after (b) the Poyang Lake (China) flood

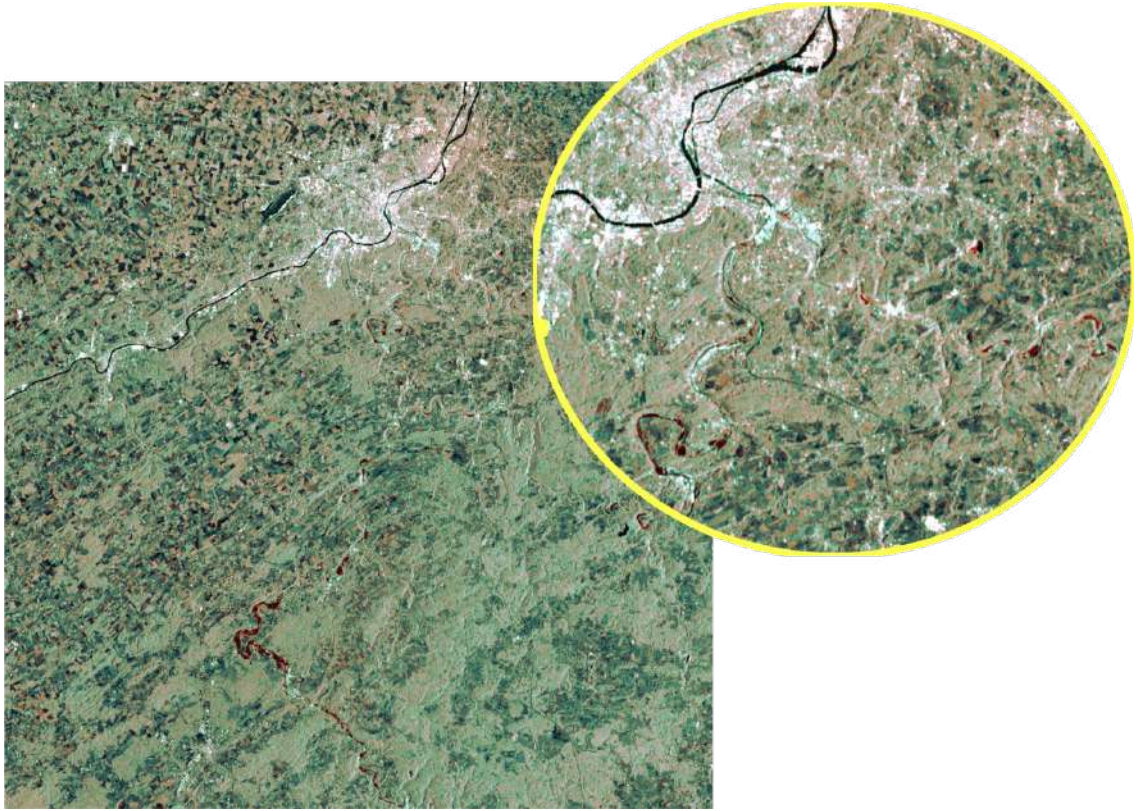
- **Water acts as a mirror** for the radar signal
- The signal bounces away and **does not come back** to the sensor
- Flooded pixels **appear black**

July 2021 Flooding - Liège

Sentinel-1 before/after amplitude composite

ECGS | CEGS

- Sentinel-1 radar images acquired before and after the July 2021 floods
- **RGB composite:** red = pre-flood amplitude; green and blue = post-flood amplitude
- **Unchanged surfaces:** green-grey tones; **urban areas:** white
- **Permanent water (Meuse):** black, dark at both dates
- **Flooded areas:** red, bright before the flood and dark after it



2021 Flooding - Luxembourg

The 2021 floods, seen from the ground





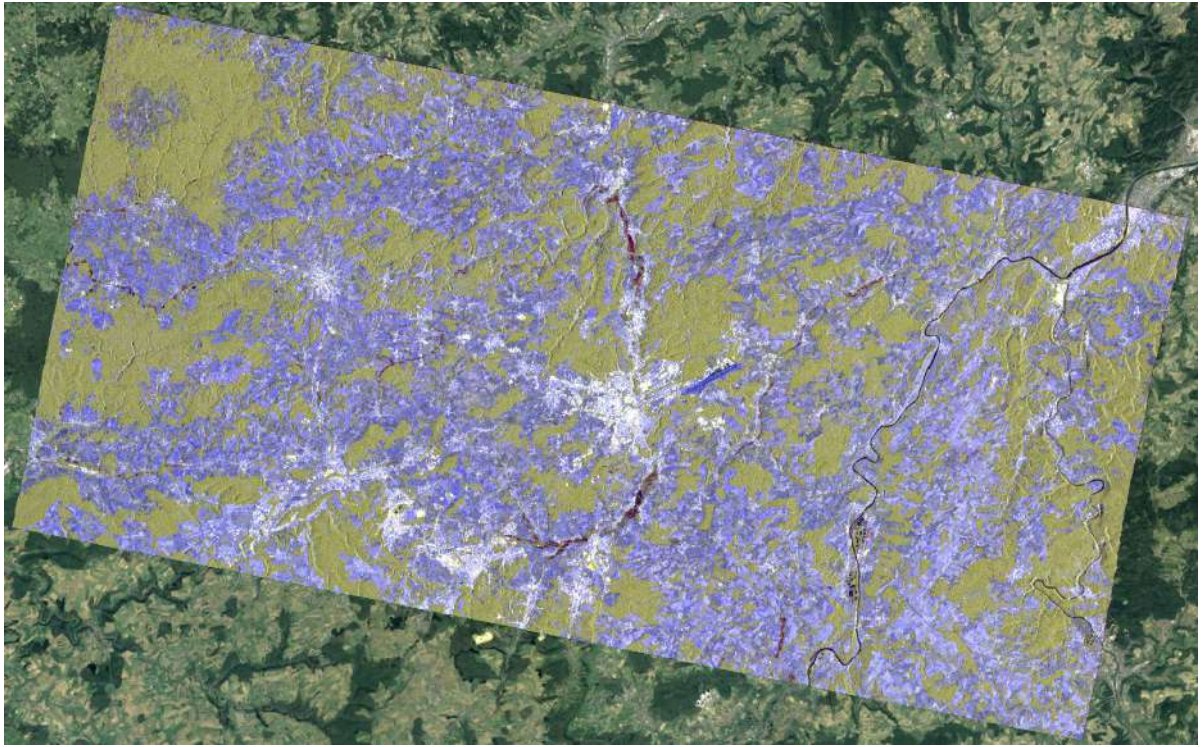
Photos: mersch.lu

2021 Flooding - Luxembourg

Combining amplitude and InSAR coherence

ECGS | CEGS

- **RGB composite:** red = pre-flood amplitude, green = post-flood amplitude, blue = coherence of the pre/post pair
- **Yellowish:** forests (strong backscatter, low coherence)
- **Blue/lavender:** agricultural fields (stable in winter, high coherence)
- **White:** urban areas (strong and coherent)
- **Black:** permanent water (Moselle)
- **Red:** flooded areas (strong backscatter before, weak after, coherence lost)



2018 Flooding - Paris

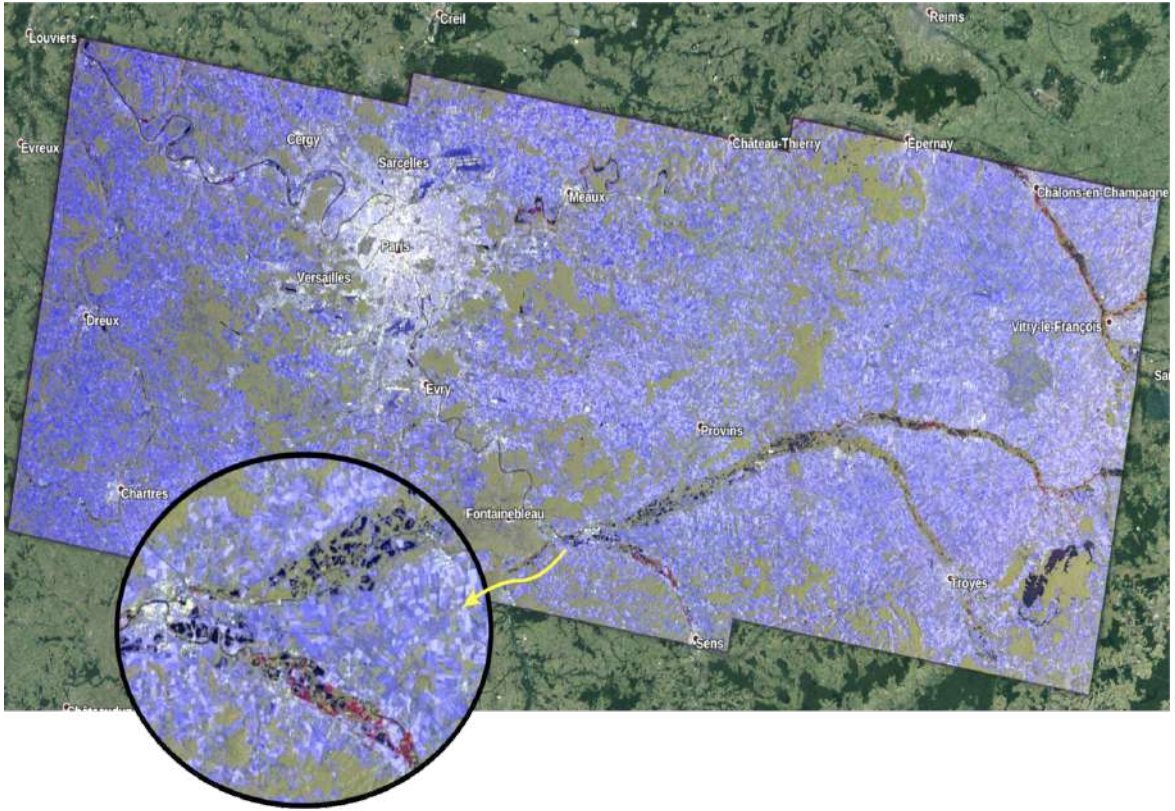
The 2018 Seine flood, seen from the ground



2018 Flooding - Paris

Combining amplitude and InSAR coherence

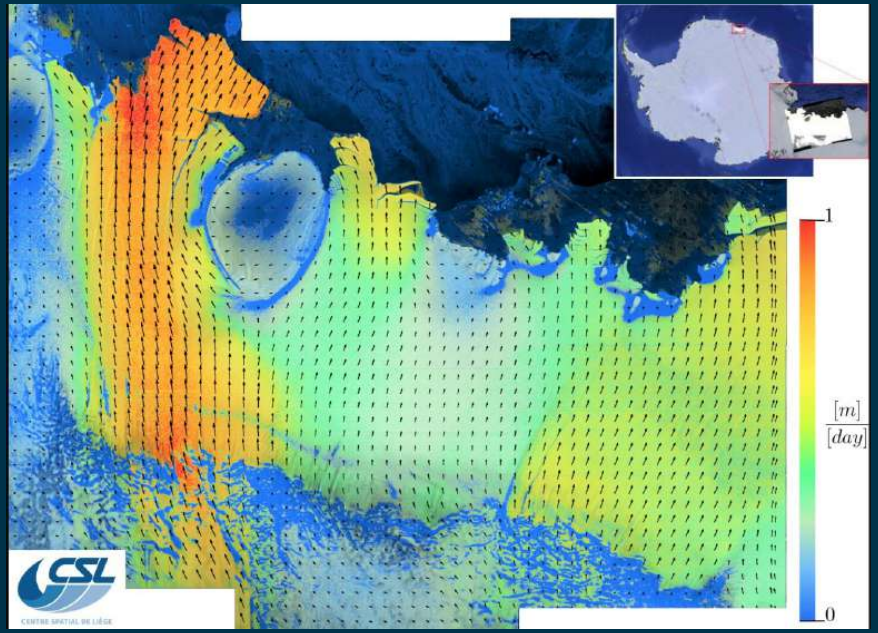
- **Same composite as Luxembourg:** red = pre-flood amplitude, green = post-flood amplitude, blue = coherence
- **Red:** flooded floodplains of the Seine and Marne
- **Zoom (La Bassée):** black patches are permanent gravel-pit lakes; red is newly flooded land
- **Dark area east of Troyes:** the Seine reservoirs (Lac d'Orient area), which store water during floods
- **White:** Paris and its suburbs, with strong, stable urban backscatter



PART 6

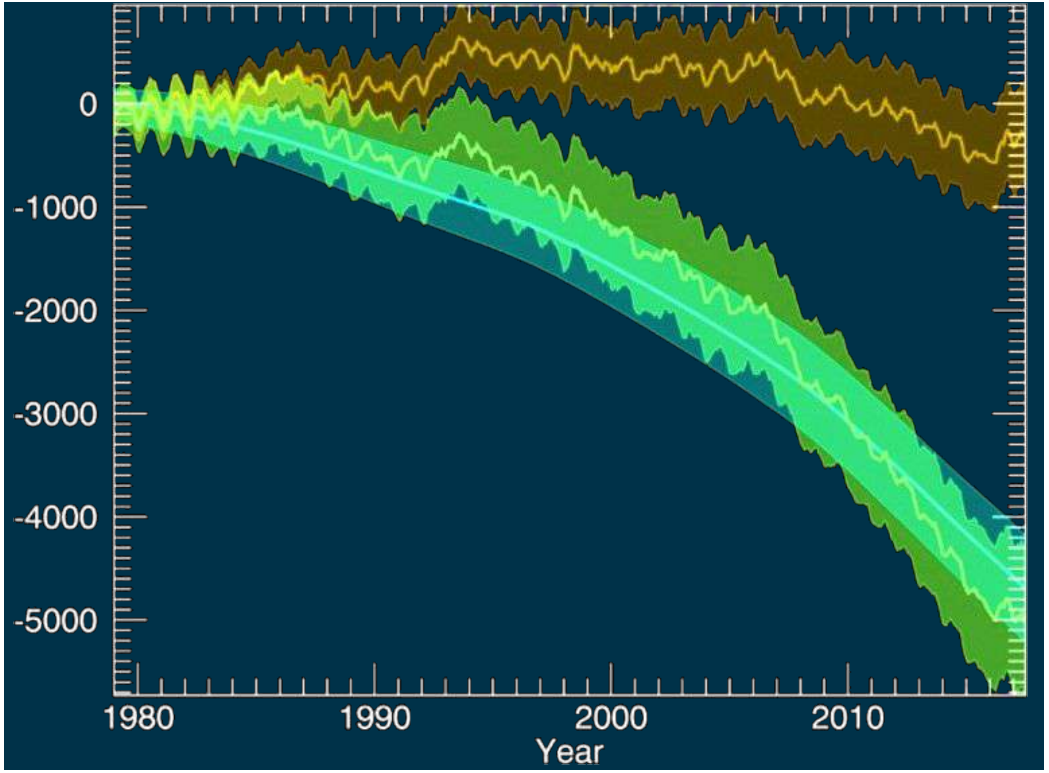
Antarctica

Ice-shelf flow, grounding lines and surface melt



Antarctic studies

Antarctic ice mass loss over four decades



Rignot et al. (2019), PNAS

- **1979-1990:** 40 Gt/yr
- **1989-2000:** 50 Gt/yr
- **1999-2009:** 166 Gt/yr
- **2009-2017:** 252 Gt/yr

×6

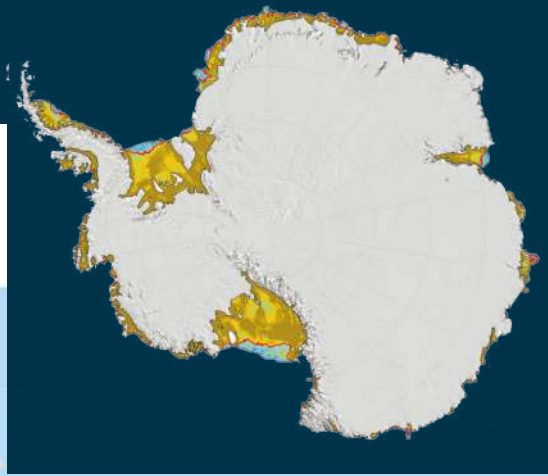
more ice lost per year than 40 years ago

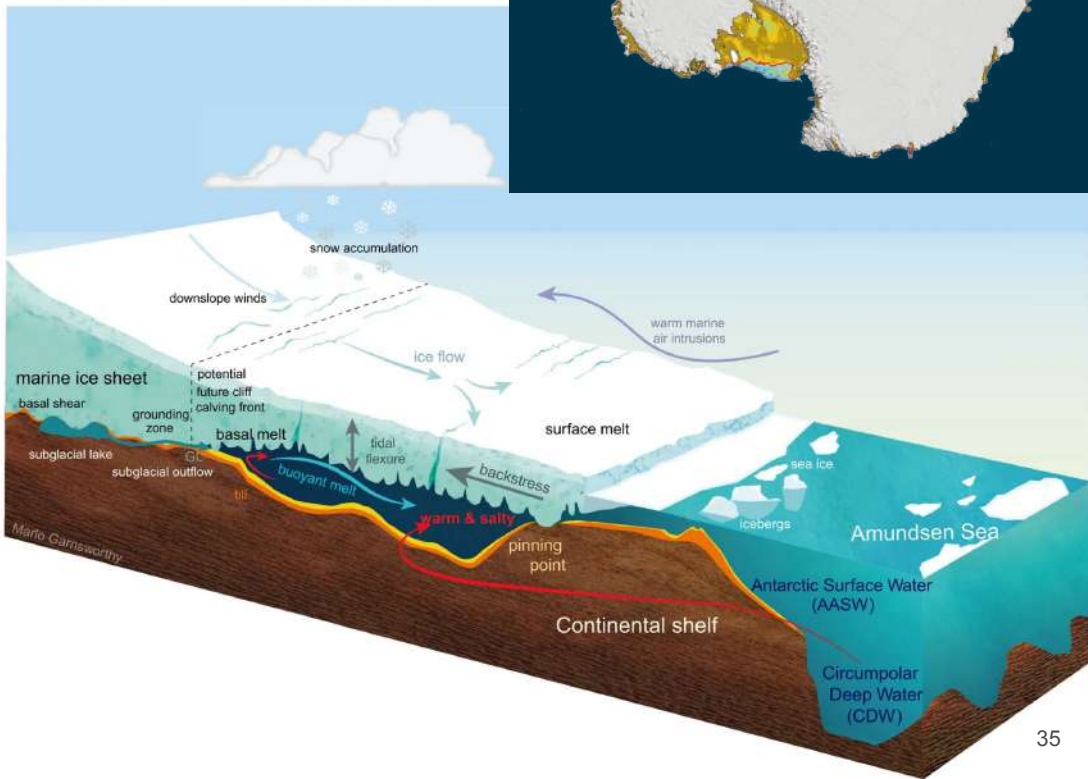
Antarctic studies

Ice shelves hold back the ice sheet: the Larsen-B collapse



Larsen-B ice shelf breaking up, 2002

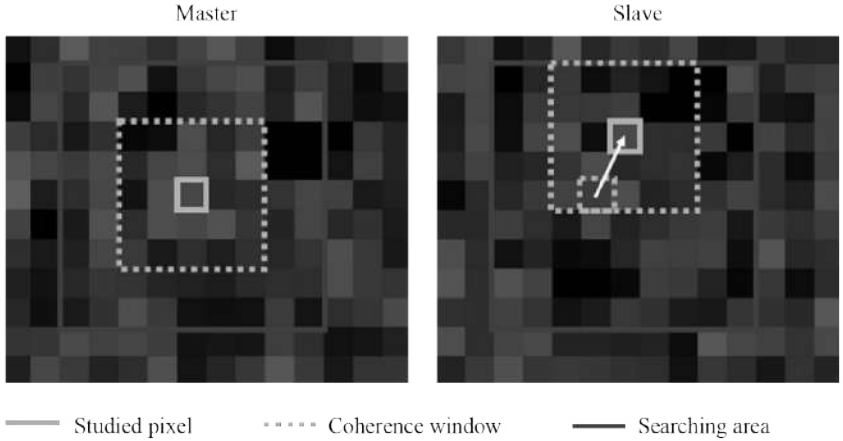




When Larsen-B broke up, **the glaciers behind it sped up**

Antarctic studies

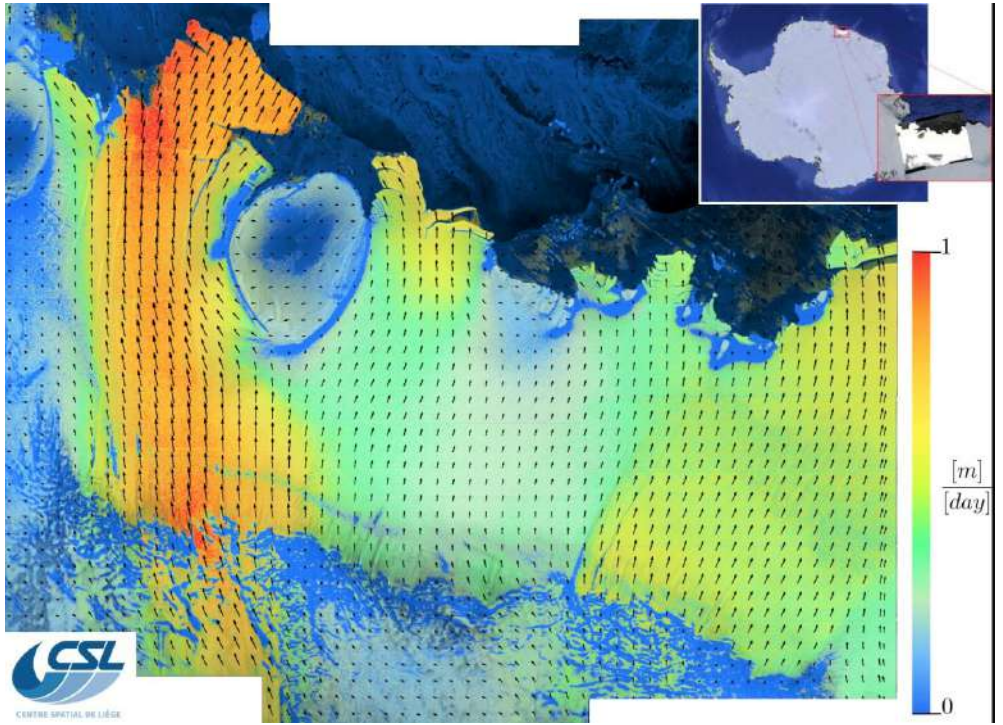
Ice-shelf flow from offset tracking



$$(i,j) = \underset{(i,j)}{\arg\max}\{\hat{\gamma}(s_1(x,y), s_2(x+i, y+j))\}$$

with

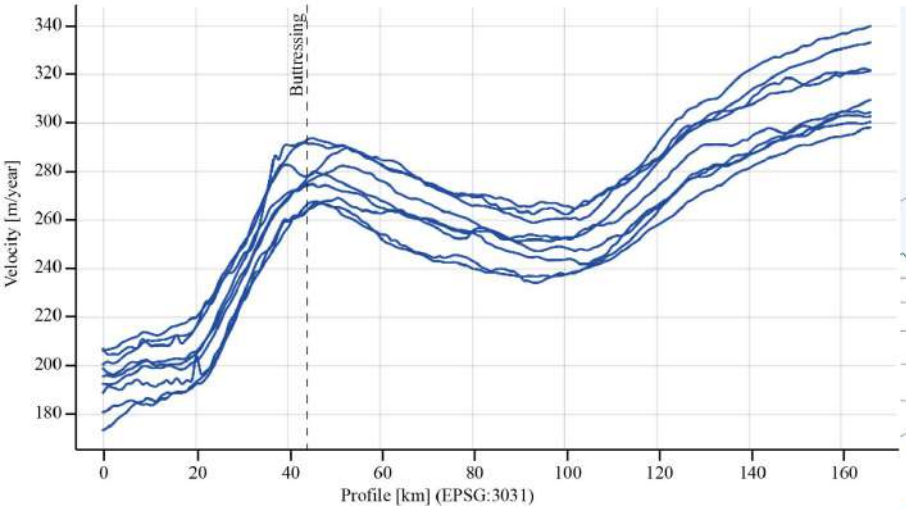
$$\hat{\gamma}(s_1(x,y), s_2(x,y)) = \frac{\left| \sum_{(x,y)\in n} s_1(x,y) \cdot s_2^*(x,y) \right|}{\sqrt{\sum_{(x,y)\in n} |s_1(x,y)|^2 \cdot \sum_{(x,y)\in n} |s_2(x,y)|^2}}$$



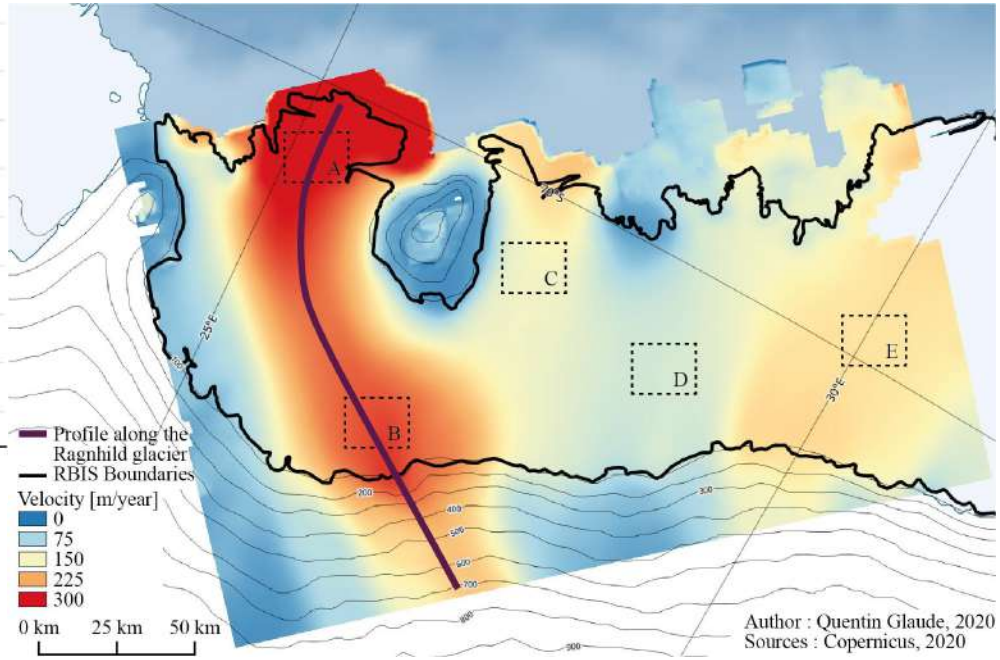
Average 4-year velocity field: up to about 300 m/yr on the western side, where many small ice rises regulate the flow

Antarctic studies

Ice-shelf flow from offset tracking



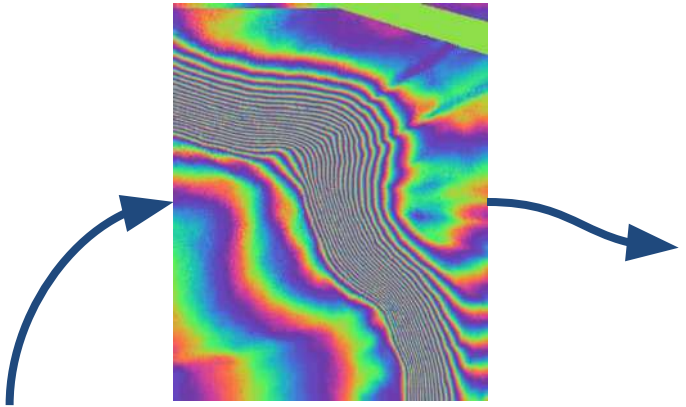
The sharp velocity drop along the profile shows **the ice shelf's buttressing effect**

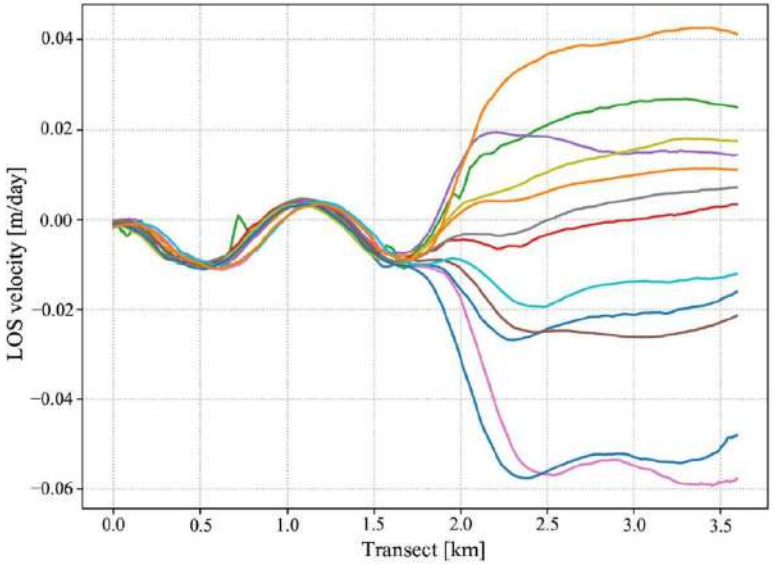


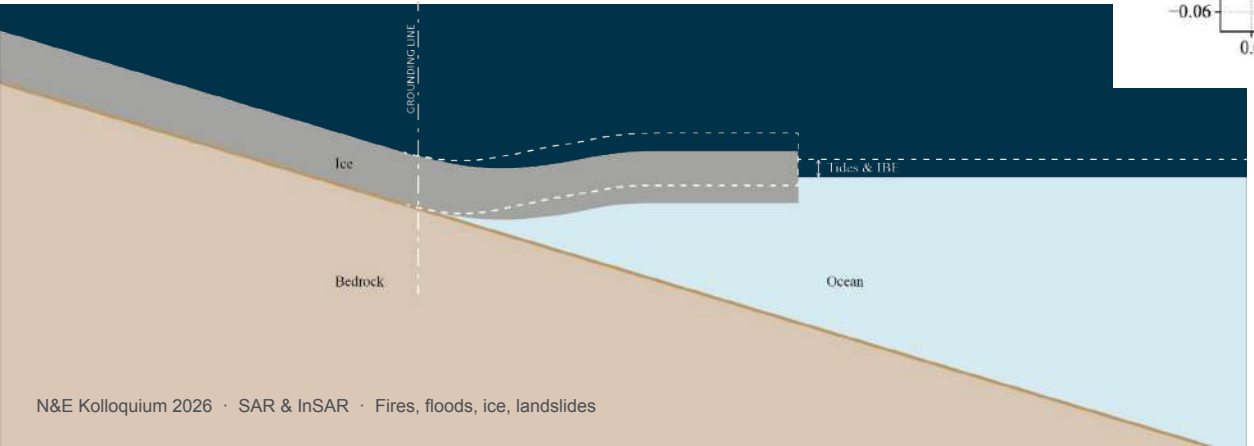
Velocity along the Ragnhild glacier profile (purple line on the map)

Antarctic studies

Grounding line location from double-differential SAR interferometry



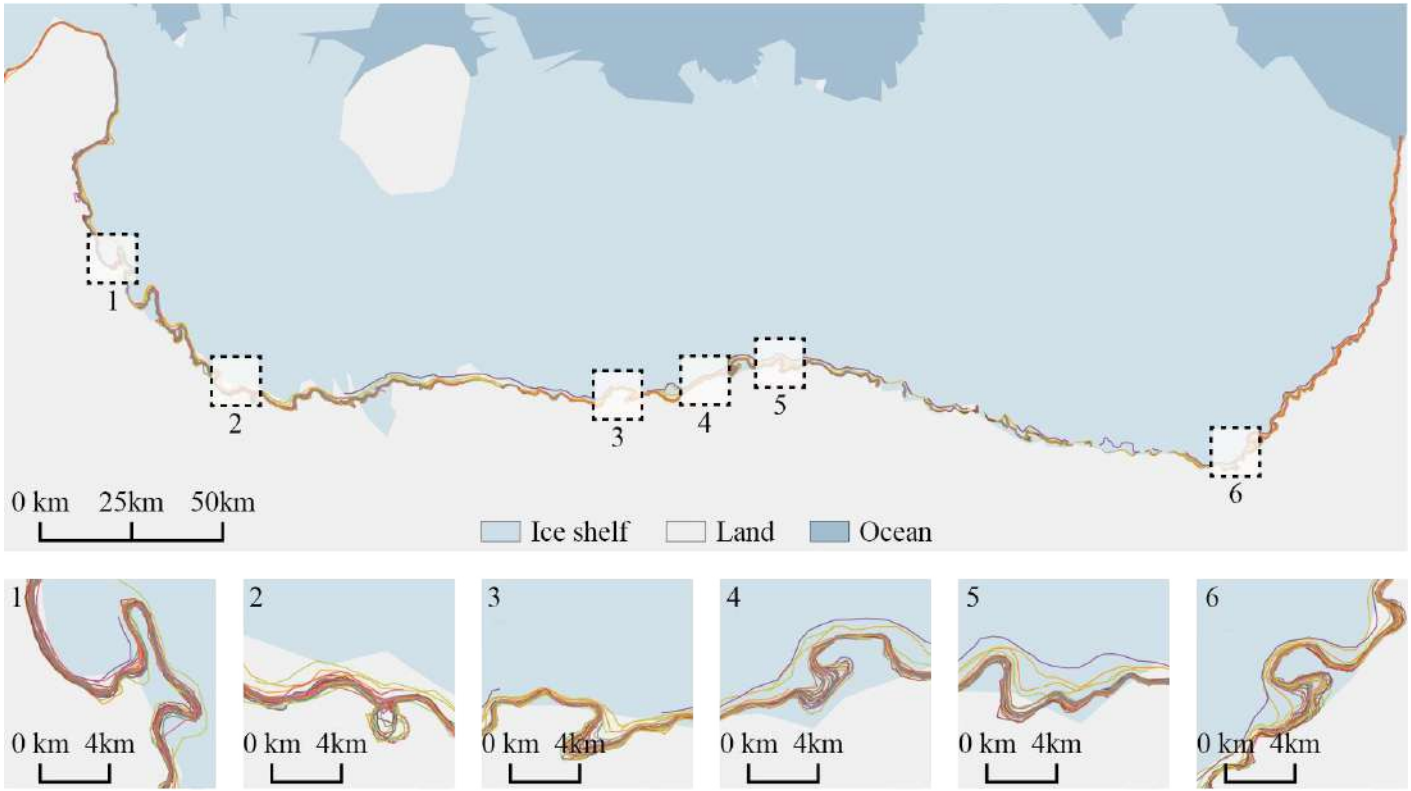




Tides lift the floating ice: **the grounding line is where this flexure stops**

Antarctic studies

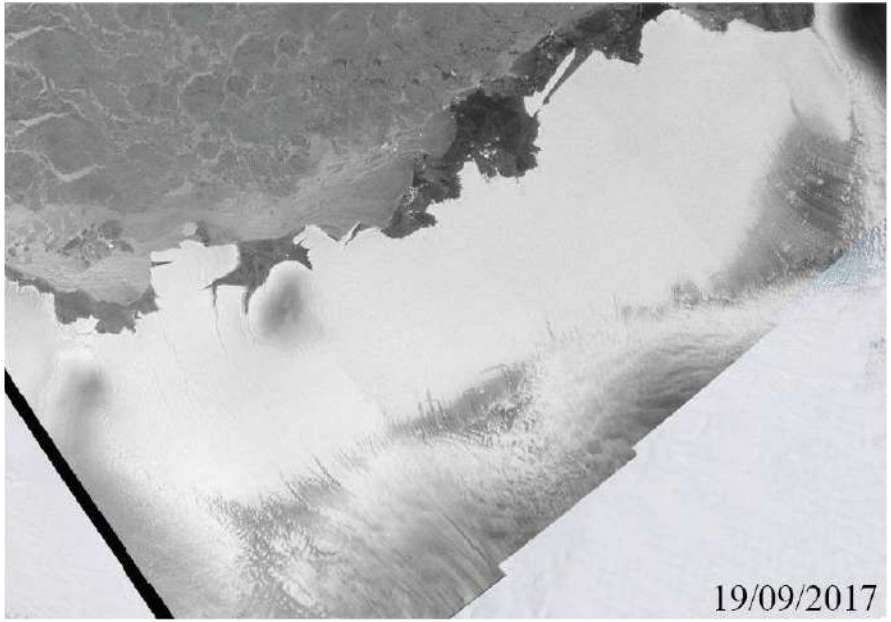
Grounding line location from double-differential SAR interferometry

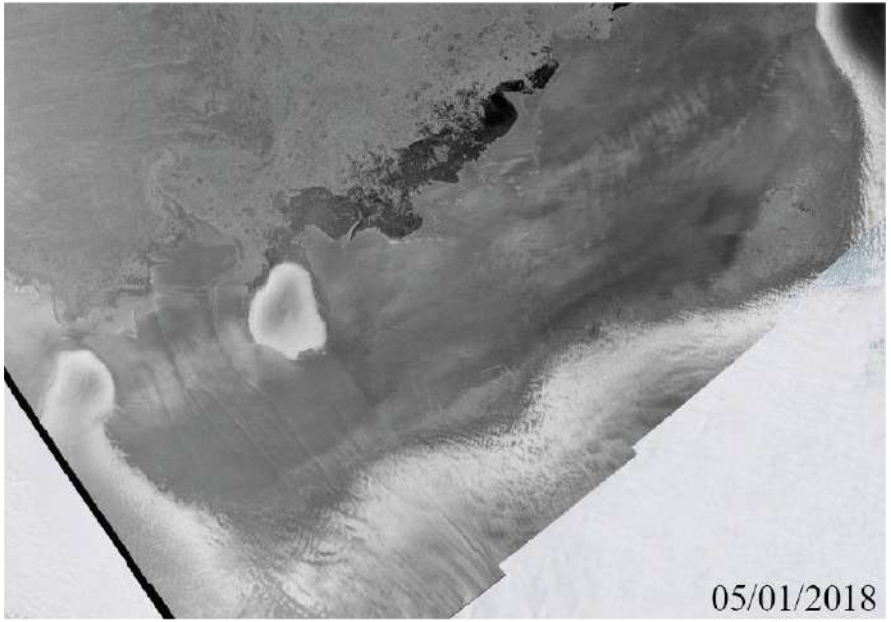


Each coloured line is the grounding line from one interferogram pair

Antarctic studies

Surface melt seen by SAR

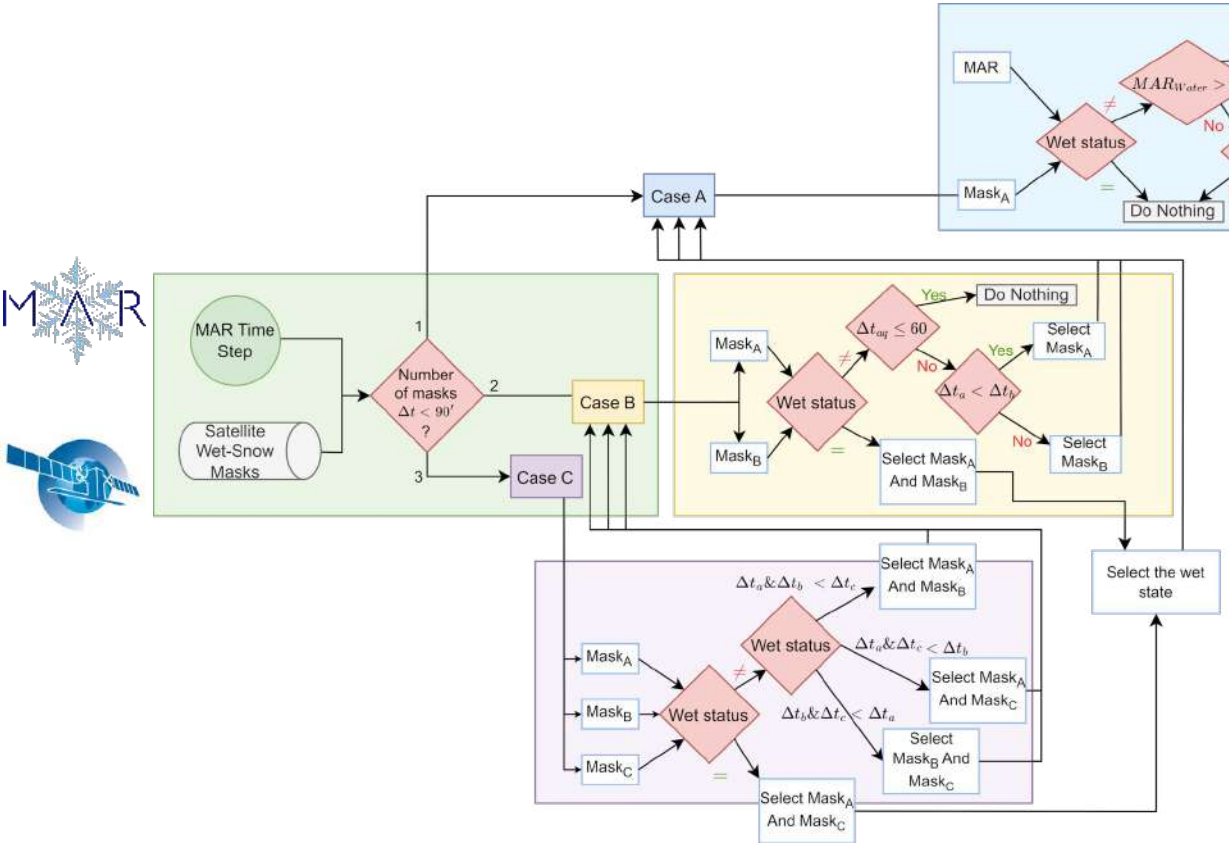


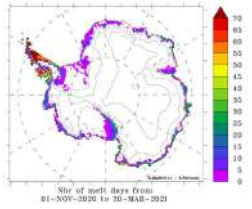


Wet snow absorbs the radar signal: **in summer (right), melting areas turn dark**

Antarctic studies

Surface melting and data assimilation





Satellite wet-snow masks **guide the model** to reconstruct the liquid water content

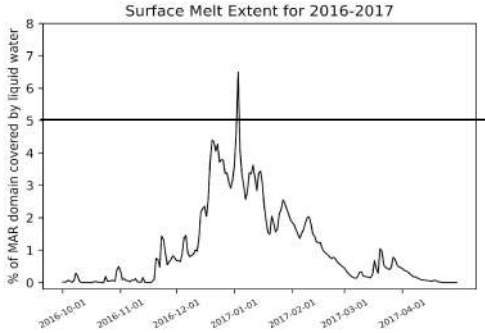
Figure: Dethinne (2023)

Antarctic studies

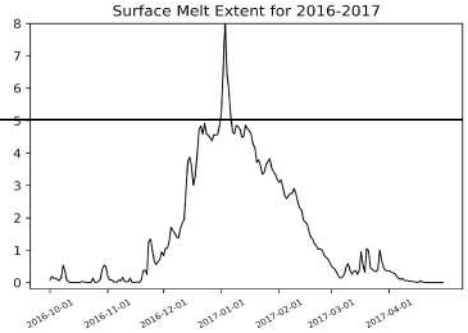
Surface melting and data assimilation

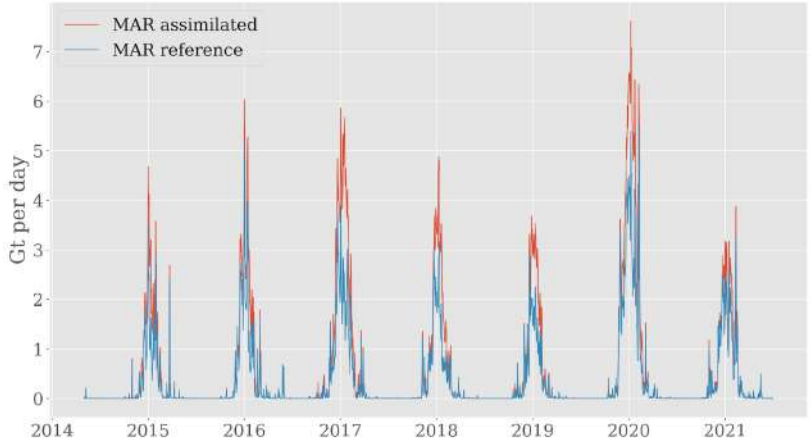
ECGS | CEGS

Reference

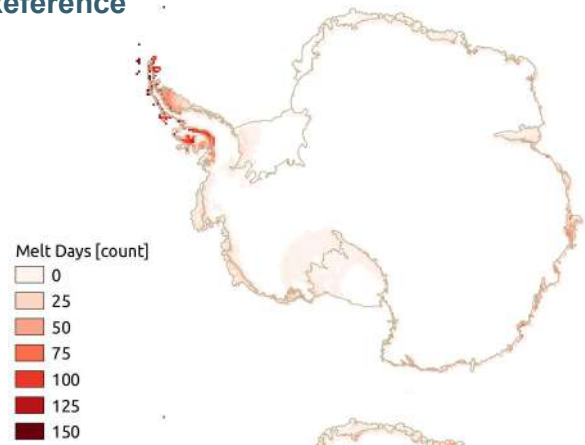


Assimilated

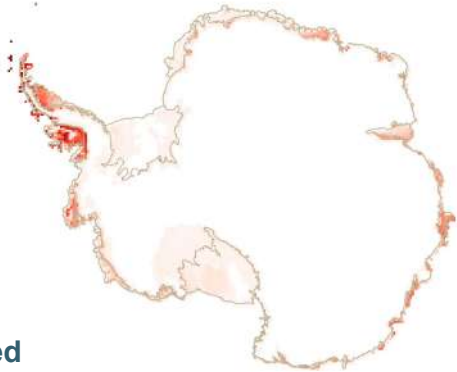




Reference



Assimilated



PART 7

Landslides

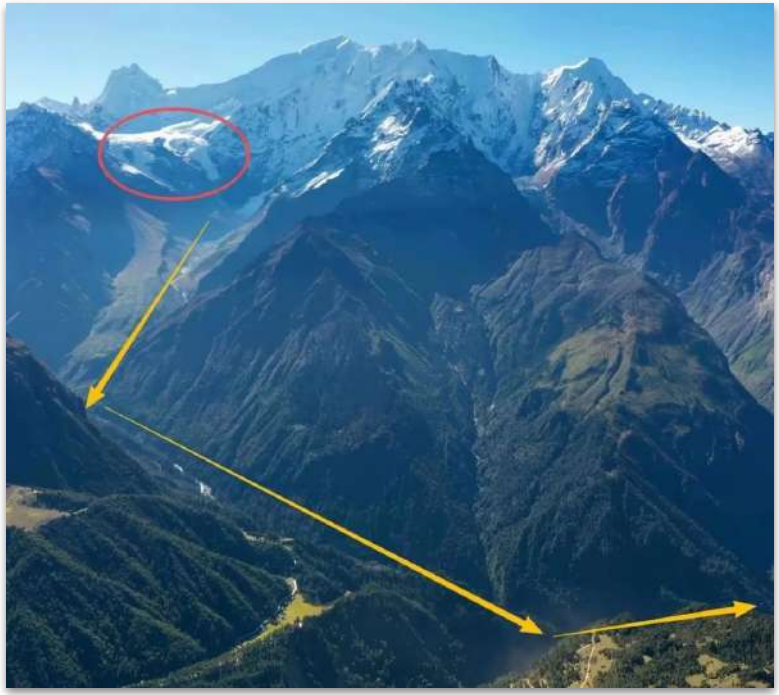
Slow-moving landslides in Central Nepal



Bolde village, Central Nepal

Nepal Slow Moving Landslides

Landslides in the Himalaya





Nepal Slow Moving Landslides

Landslides in the Himalaya



Joshimath, Uttarakhand, 2023: progressive damage to a town built on an old landslide body (Dalal, 2025)

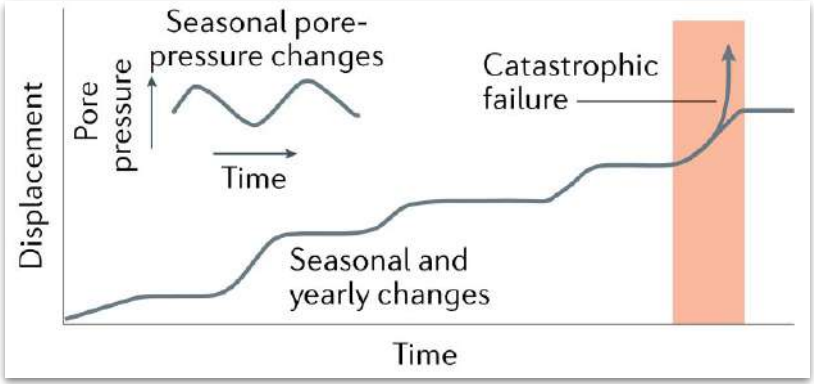


Nepal Slow Moving Landslides

What is a slow-moving landslide?

ECGS | CEGS

- **Persistent deformation** of a hillslope, from millimeters to meters per year, without complete failure
- **Episodic motion:** seasonal acceleration driven by pore-pressure changes during the monsoon, on top of a multi-year trend
- **Progressive damage** to roads, terraces and buildings; a fraction of these bodies accelerates to catastrophic failure



Lacroix et al. (2020)

Nepal Slow Moving Landslides

Central Nepal and the SLIDE project

ECGS | CEGS



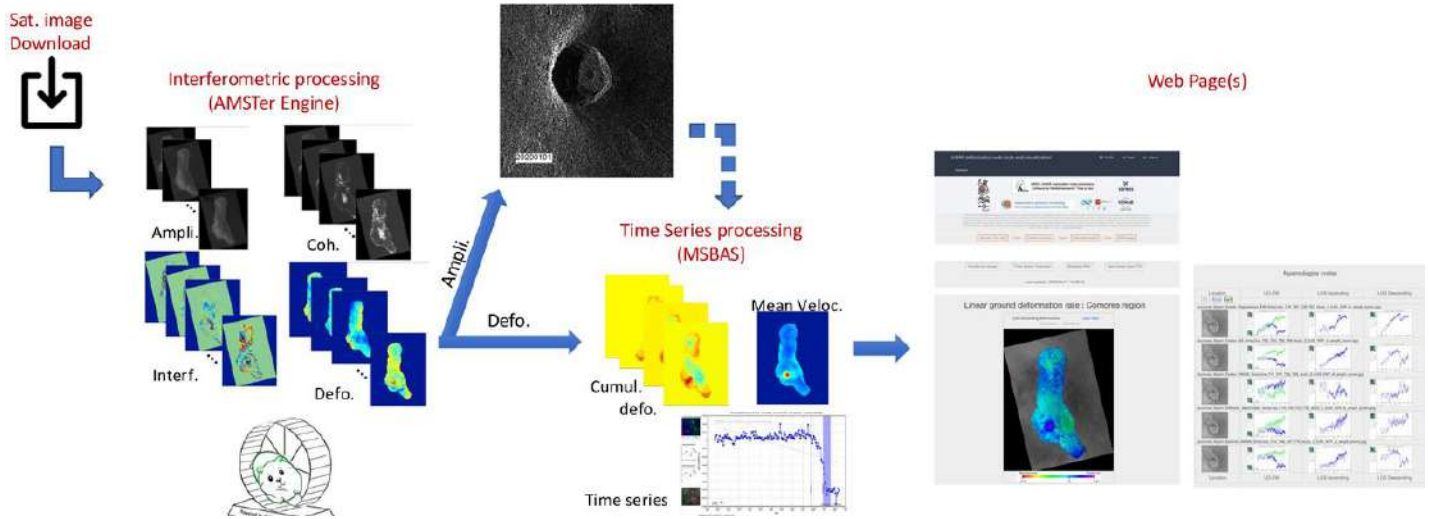
Bolde village

Funding	FNR Luxembourg + ANR France
Partners	ECGS, CSL/ULiège,
	CRPG Nancy, ISTerre Grenoble
Test site	Bolde-Tapgaon villages (station network)

My role in SLIDE: **finding a way to detect and catalog slow-moving landslides in Central Nepal**

Nepal Slow Moving Landslides

InSAR-based displacement from AMSTer and MSBAS



Multisensor
All 12+ SAR sensor families, ERS to NISAR and BIOMASS

AGPL v3
Open source, github.com/AMSTerUsers

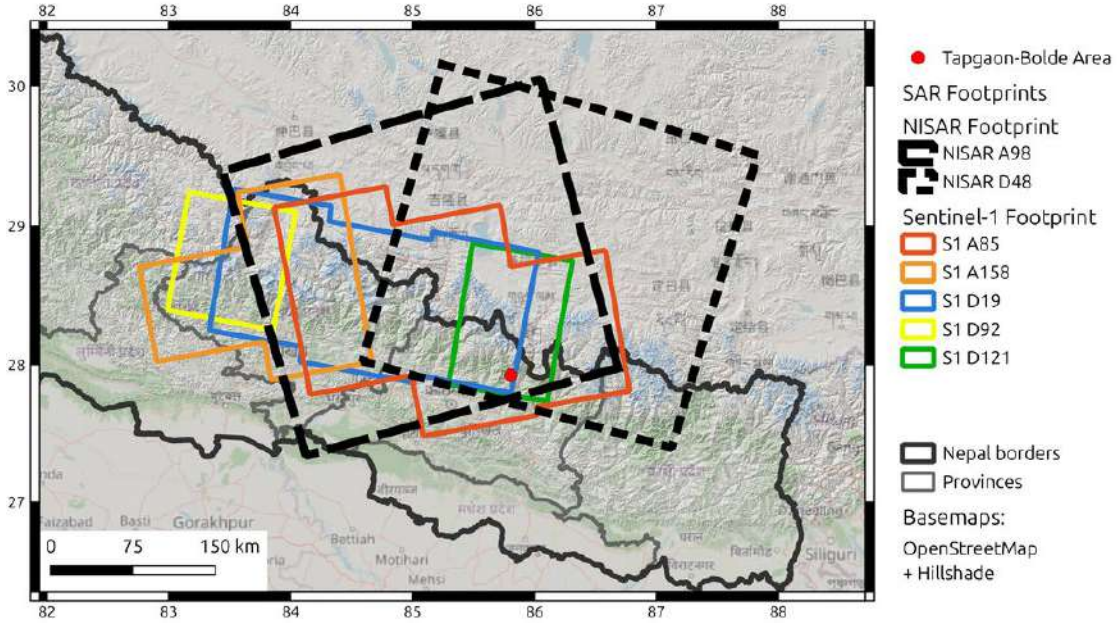
2D / 3D
MSBAS multi-geometry inversion

Automation
Cron-driven mass processing and publication

Derauw et al. 2020 · d'Oreye et al. 2021 · Samsonov & d'Oreye 2012 · d'Oreye et al., this issue. Products on terra4.ecgs.lu (restricted).

Nepal Slow Moving Landslides

Dataset over Central Nepal

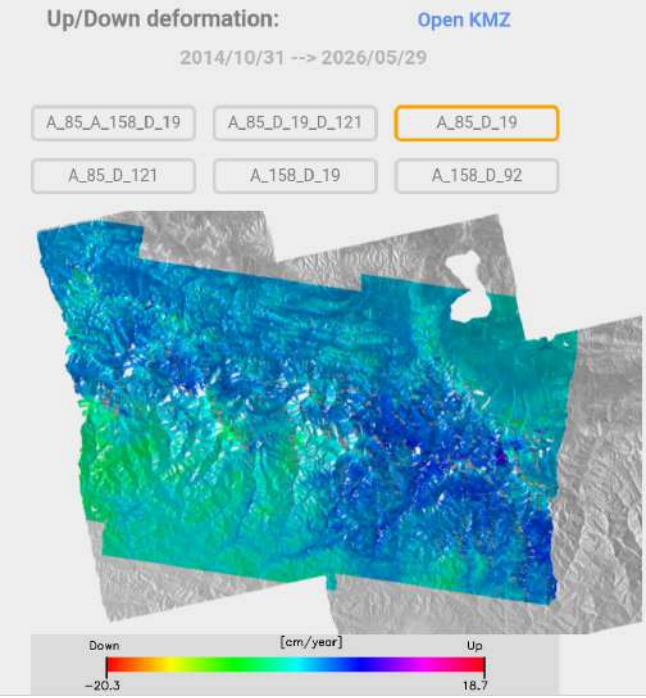


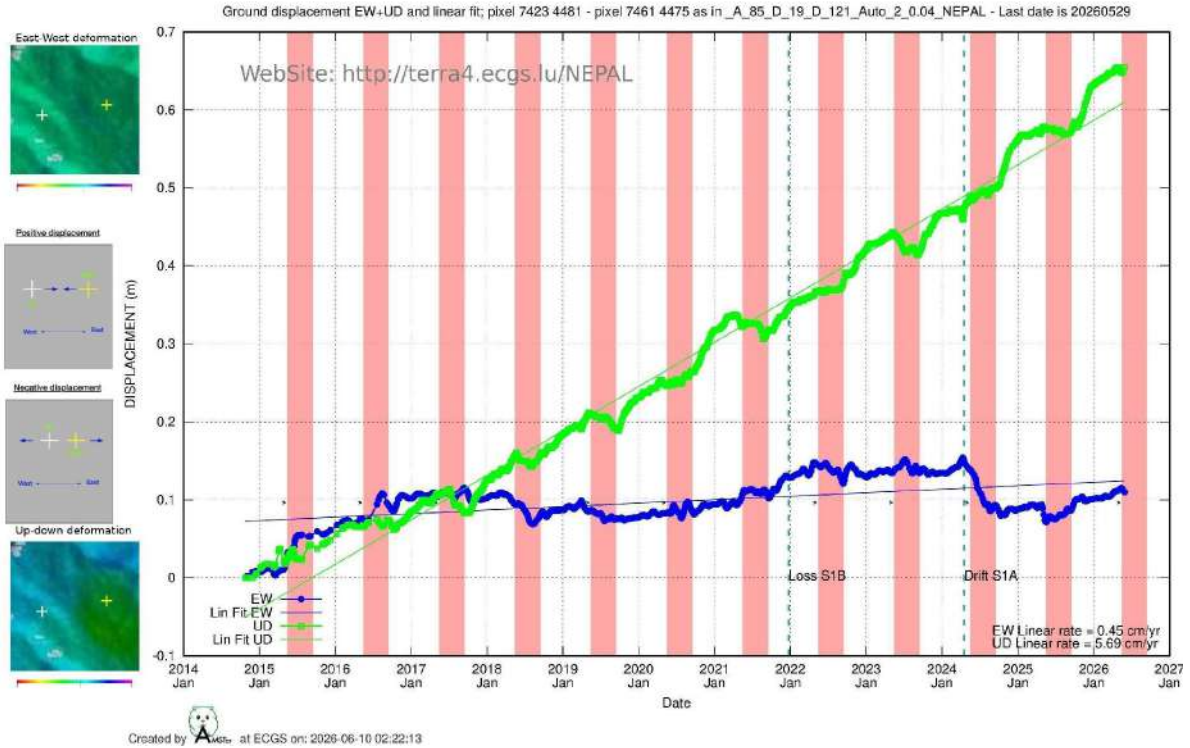
Sentinel-1	A85, A158, D19, D92, D121
	≈ 1 500 images, 2014–2026
	> 4 500 interferometric pairs
NISAR	A98, D48, since Nov 2025
ALOS-2/4	A157, D48 stripmap
Others	ERS, ENVISAT, TSX, PAZ

Two to three geometries over most of the area: **the condition for a 2D inversion**

Nepal Slow Moving Landslides

Bolde landslide, MSBAS time series 2014–2026





Geometry	A85 + D19 + D121
Components	EW and UD

Displacement of one pixel relative to a nearby one (both marked on the small maps); monsoon intervals in pink. Published continuously on terra4.ecgs.lu.

Nepal Slow Moving Landslides

Current inventory of landslides

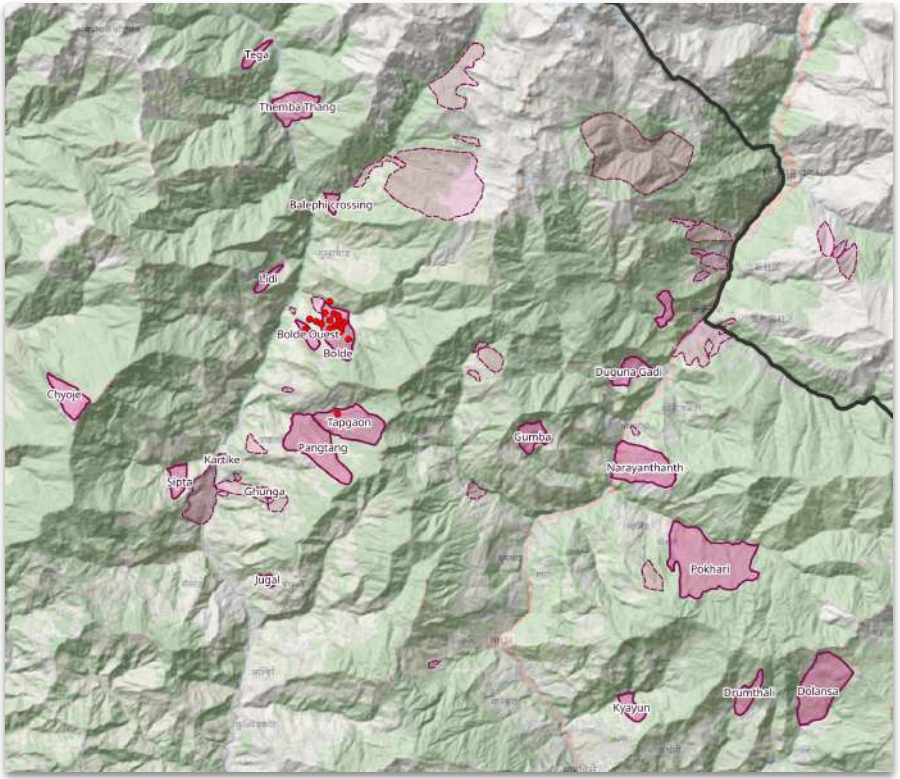
ECGS | CEGS

51
landslide bodies

58.4 km²
total area

0.49 km²
median area

1000-3800 m
altitude range



Manual inventory mapped by Leo Letellier (CRPG) from pixel offset tracking

Nepal Slow Moving Landslides

Monsoon: atmosphere and decorrelation

ECGS | CEGS

Atmospheric challenges

- Intense **monsoon** precipitation (June-September)
- Severe **tropospheric** water vapor variations
- Phase delays: several centimeters of apparent displacement

Decorrelation challenges

- Steep **topography** → geometric artifacts (shadowing)
- Dense **vegetation** → temporal decorrelation
- Rapid surface changes → coherence loss
- **Snow** cover variability

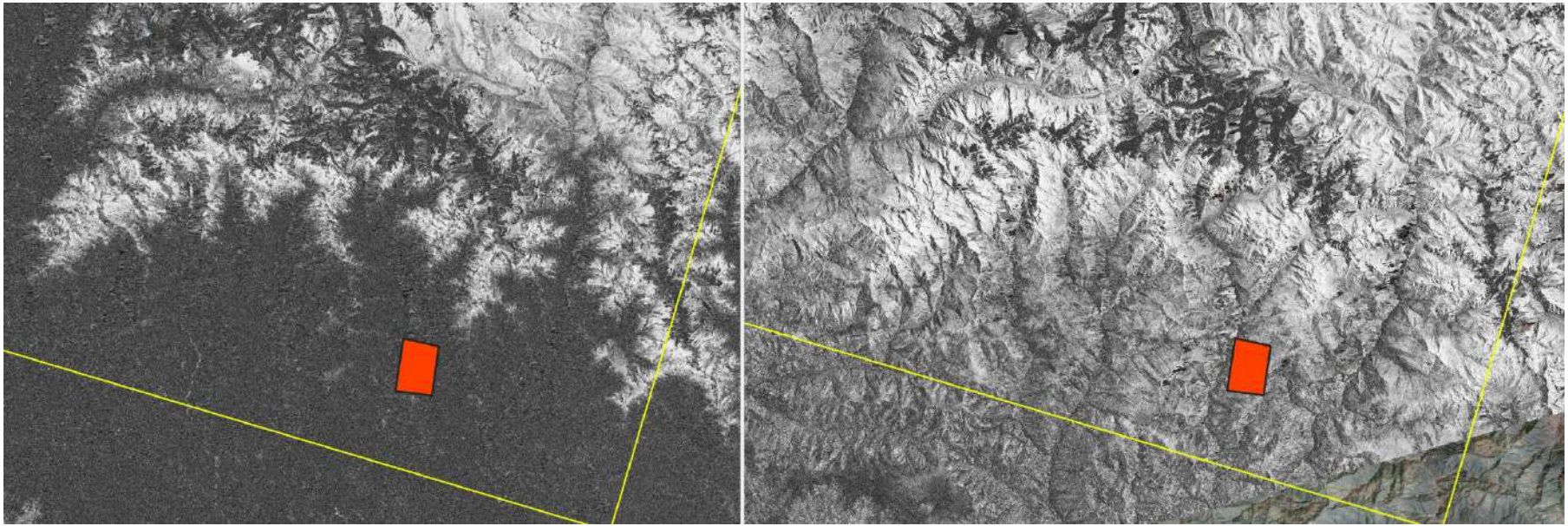


Nepal Slow Moving Landslides

Multifrequency synergies

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C-BAND · Sentinel-1 (5.6 cm) | **L-BAND · NISAR (24 cm)**

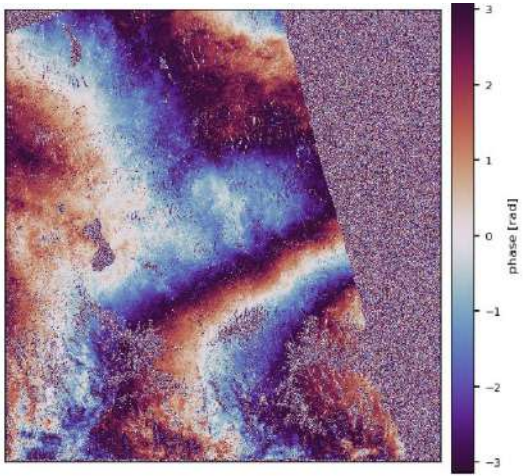


Coherence at C-band and L-band, summer 2026. Red box: Bolde.

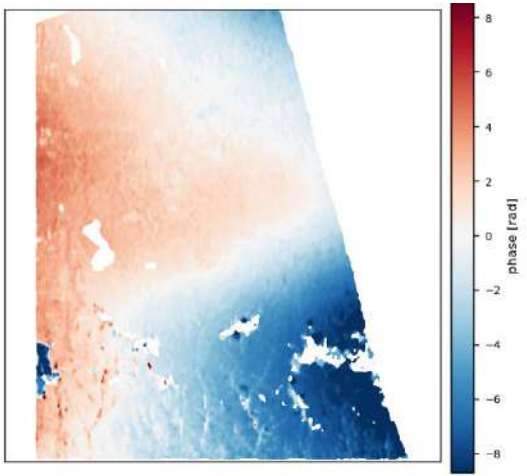
C-band coherence collapses over vegetated slopes during the monsoon, when the landslides move.
L-band keeps coherence over the same interval.

Nepal Slow Moving Landslides

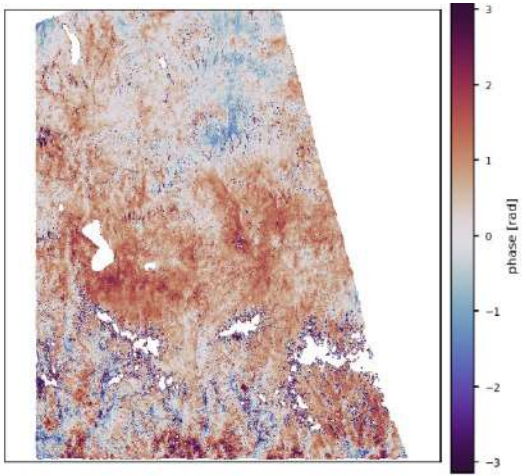
The ionosphere: a signal-processing challenge



Residual phase after deformation model (wrapped)



Estimated ionospheric screen [rad]



Corrected phase (re-wrapped)

The estimated ionosphere reaches several radians across the frame, **larger than the displacement itself**

Nepal Slow Moving Landslides

Why automatic detection matters

ECGS | CEGS

- It is **impractical to map landslides by hand** in Nepal
- The 2015 Mw 7.8 Gorkha earthquake alone triggered **more than 25,000 landslides**

There is a need for **automated detection of slow-moving landslides**



Geomorphology 301 (2018) 121–138

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

The size, distribution, and mobility of landslides caused by the 2015 M_w7.8 Gorkha earthquake, Nepal☆

Kevin Roback [a], Marin K. Clark [a,*], A. Joshua West [b], Dimitrios Zekkos [c], Gen Li [b], Sean F. Gallen [d], Deepak Chamlagain [e], Jonathan W. Godt [f]

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[f] Natural Hazards Mission Area, Landslide Hazards Program, U.S. Geological Survey, Denver, CO 80225, USA

ARTICLE INFO

Article history:
Received 12 August 2016
Received in revised form 16 January 2017
Accepted 22 January 2017
Available online 16 February 2017

ABSTRACT

Coseismic landslides pose immediate and prolonged hazards to mountainous communities, and provide a rare opportunity to study the effect of large earthquakes on erosion and sediment budgets. By mapping landslides using high-resolution satellite imagery, we find that the 25 April 2015 M_w7.8 Gorkha earthquake and aftershock sequence produced at least 25,000 landslides throughout the steep Himalayan Mountains in central Nepal. Despite early reports claiming lower than expected landslide activity, our results show that the total number, area, and volume of landslides associated with the Gorkha event are consistent with expectations, when compared to prior landslide-triggering earthquakes around the world. The extent of landsliding mimics the extent of fault rupture along the east-west trace of the Main Himalayan Thrust and increases eastward following the progression of rupture. In this event, maximum modeled Peak Ground Acceleration (PGA) and the steepest topographic slopes of the High Himalaya are not spatially coincident, so it is not surprising that landslide density correlates neither with PGA nor steepest slopes on their own. Instead, we find that the highest landslide density is located at the confluence of steep slopes, high mean annual precipitation, and proximity to the deepest part of the fault rupture from which 0.5–2 Hz seismic energy originated. We suggest that landslide density was determined by a combination of earthquake source characteristics, slope distributions, and the influence of precipitation on rock strength via weathering and changes in vegetation cover. Determining the relative contribution of each factor will require further modeling and better constrained seismic parameters, both of which are likely to be developed in the coming few years as post-event studies evolve. Landslide mobility, in terms of the ratio of runout distance to fall height, is comparable to small volume landslides in other settings, and landslide volume-runout scaling is consistent with compilations of data on larger slope failures. In general, the size ratios of landslide source area to full landslide area are smaller than global averages, and hillslope length seems to largely control runout distance, which we propose reflects a topographic control on landslide mobility in this setting. We find that landslide size dictates runout distance and that more than half of the landslide debris was deposited in direct connection with stream channels. Connectivity, which is defined as the spatial proximity of landslides to fluvial channels, is greatest for larger landslides in the high-relief part of the High Himalaya. Although those failures are less abundant than those at lower elevations, they may have a disproportionate impact on sediment dynamics and cascading hazards, such as landslide reactivation by monsoon rainfall and landslide dams that lead to outburst floods. The overall high fluvial connectivity of coseismic landsliding in the Gorkha event suggests coupling between the earthquake cycle and sediment/geochemical budgets of fluvial systems in the Himalaya.

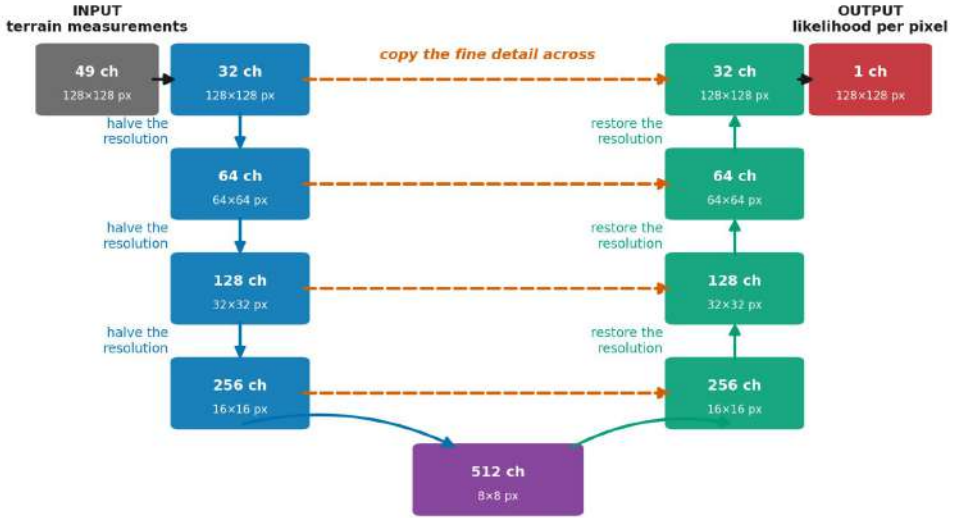
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Roback et al. (2018), Geomorphology

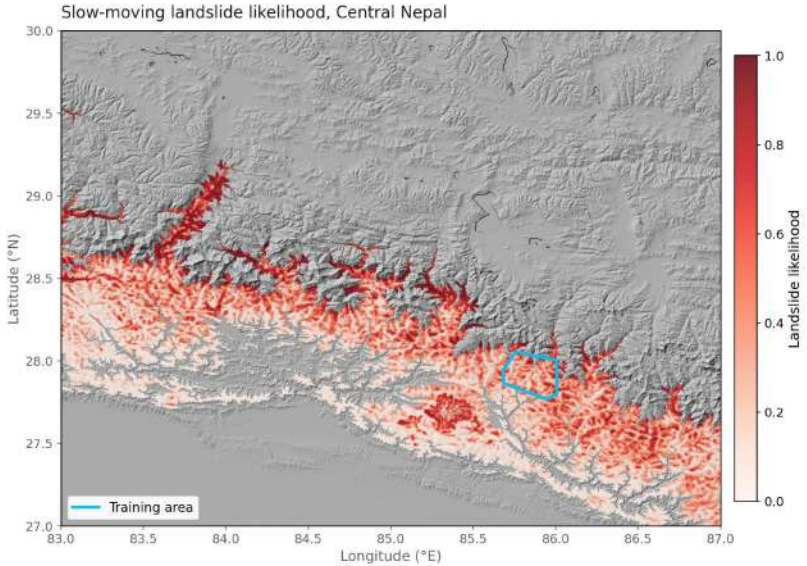
Nepal Slow Moving Landslides

Automatic detection with a U-Net

Inputs: elevation, slope, curvature, MSBAS velocity and its temporal statistics



U-Net encoder-decoder used for the per-pixel likelihood



Concluding words

Take-home messages, computing and collaboration



AMSTer Summer School, Luxembourg

Take-home messages

What radar brings to fires, floods, ice and landslides

ECGS | CEGS

1

Fires

Coherence drops where the fire changed the surface, then recovers: together they outline the burnt area.

2

Floods

Open water is dark in radar amplitude. Adding coherence separates flooded land from forests, fields and towns.

3

Antarctica

Offset tracking measures ice-shelf flow, double-differential InSAR locates the grounding line, and wet-snow masks correct melt in a climate model.

4

Landslides

Multi-geometry InSAR time series, L-band data and a U-Net help detect slow-moving landslides across Central Nepal.

Radar brings its own light: **these maps come through clouds, smoke and darkness**

Need for High Performance Computing Infrastructure

The computing behind the processing



SAR remote sensing needs strong computing facilities

Several solutions exist:

- **ECGS servers:** nodes of 64-192 CPU cores, 512 GB to 1 TB RAM, and more than 300 TB of storage
- **CÉCI:** partnership with Belgian institutions, with access to Tier-2 and Tier-1 HPC (more than 30,000 CPU cores and GPU partitions)
- **ESA cloud:** recent collaboration through the Geohazards Exploitation Platform (GEP)
- **Computation capabilities is a recurrent cost to be aware**

Availability and collaboration

Working with AMSTer

ECGS | CEGS

Welcoming new users

AMSTer welcomes new users, but is designed for researchers with SAR / InSAR knowledge. It is a powerful research-grade toolbox, not a push-button solution. Best-effort support is provided through GitHub Issues and direct contact.

On-site training

ECGS can welcome visiting researchers and students for hands-on training and collaborative work. Availability is limited, contact us to discuss.

Active user community

Students, PhD candidates, post-docs, and institutional researchers across Europe and beyond are using AMSTer in their work.

AGPL v3, open source

Free for research use. Service use requires source disclosure. GitHub repository with documentation and installer scripts.

Training and community building

Summer schools and trainings



AMSTer Summer School: students, PhD researchers and institutional partners learning InSAR processing, Chamber of Commerce, Luxembourg

Summer School in InSAR, time series processing and deformation modelling

"If you need InSAR... MasTer it!"

22-26 May 2023
Training at the Chamber of Commerce, Luxembourg (20 participants)

MDIS-FormaTerre 2026

Mesure de la Déformation par Imagerie Satellitaire

14-15 Sept 2026
Training at ENSG Nancy, France (85 participants)

16-18 Sept 2026
Scientific symposium, Xonrupt-Longemer (Vosges, France), 115 speakers, guests and scientists

Co-organised by OTELo (Nancy) & ECGS (Luxembourg)

mdis-2026.sciencesconf.org

Merci fir Är Opmierksamkeet!

Hutt Dir Froen?

quentin.glaude@ecgs.lu

ALOS-2 SpotLight images were acquired through the JAXA 3rd Research Announcement on the Earth Observations Project ER3A2N008 and through the ESA–JAXA 2019–2024 mutual cooperation project on Using Synthetic Aperture Radar Satellites In Earth Science and Applications.

The AMSTer Toolbox is available at https://github.com/AMSTerUsers/AMSTer_Distribution. MSBAS was developed by S. Samsonov (https://insar.ca/multidimensional-small-baseline-subset-msbas/).

ECGS | CEGS

AMSTer

Applying a multi-parameter toolbox to track harmful cyanobacteria blooms in Luxembourgish bathing waters

Jean-Baptiste Burnet, PhD
Luxembourg Institute of Science and Technology

Earth from Above: How Satellites, Drones and Sensors Reveal Our Planet's Environment, Climate and Landscapes

Grevenmacher, October 29, 2026

LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY | LIST

TEAM

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with support of


Olivier O'Nagy


Frank Minette


Adriano Gama

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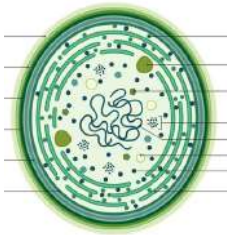
LE GOUVERNEMENT
DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de l'Environnement, du Climat
et du Développement durable

CYANOBACTERIA

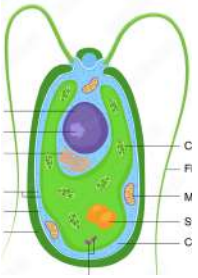
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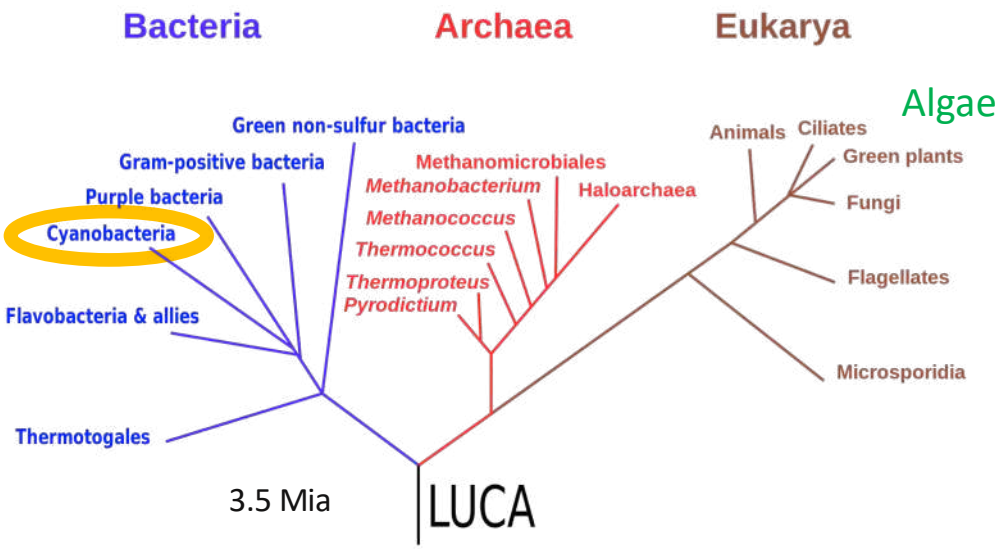
- Prokaryotic microorganisms (unicellular) without cell nucleus
- Photoautotrophic - energy source = sunlight
  - carbone source = CO_2
- Capture of atmospheric N_2

Cyanobacteria



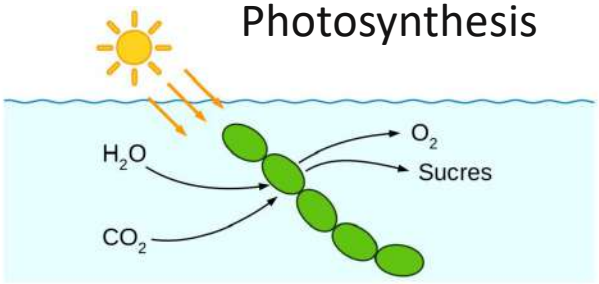
Algae





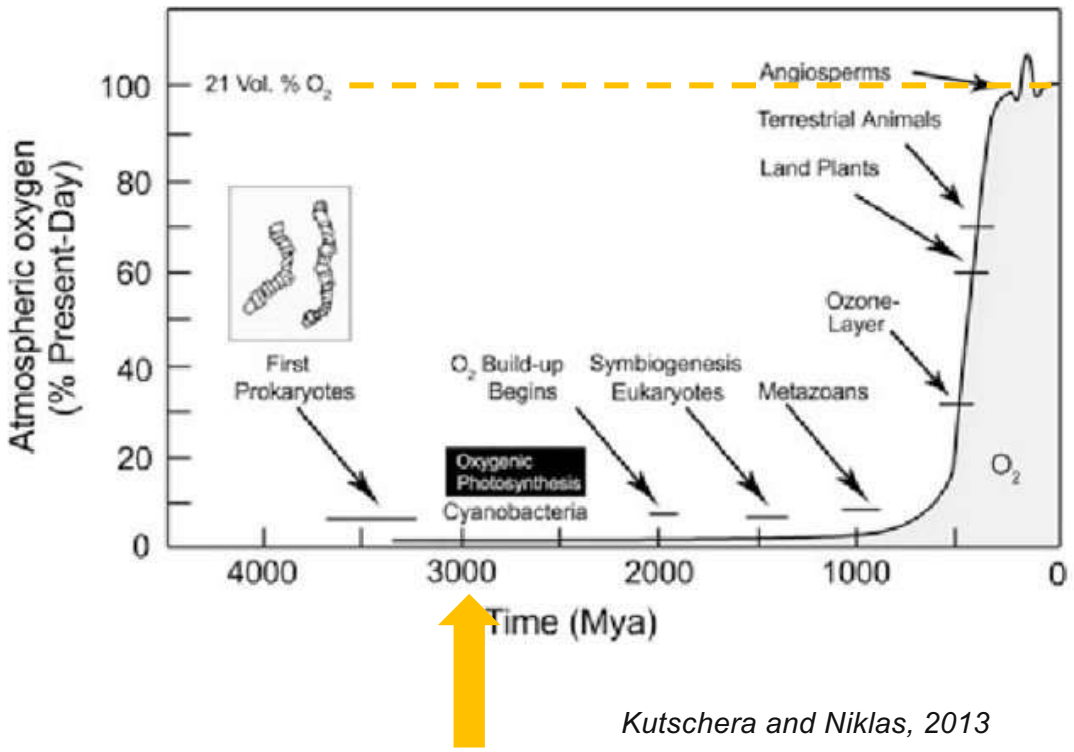
«Last universal common ancestor»

Photosynthesis



CYANOBACTERIA

… at the origin of life



Kutschera and Niklas, 2013



Stromatolites ©*Wikimedia*

CYANOBACTERIA

…can bloom

- Global increase over the last decades

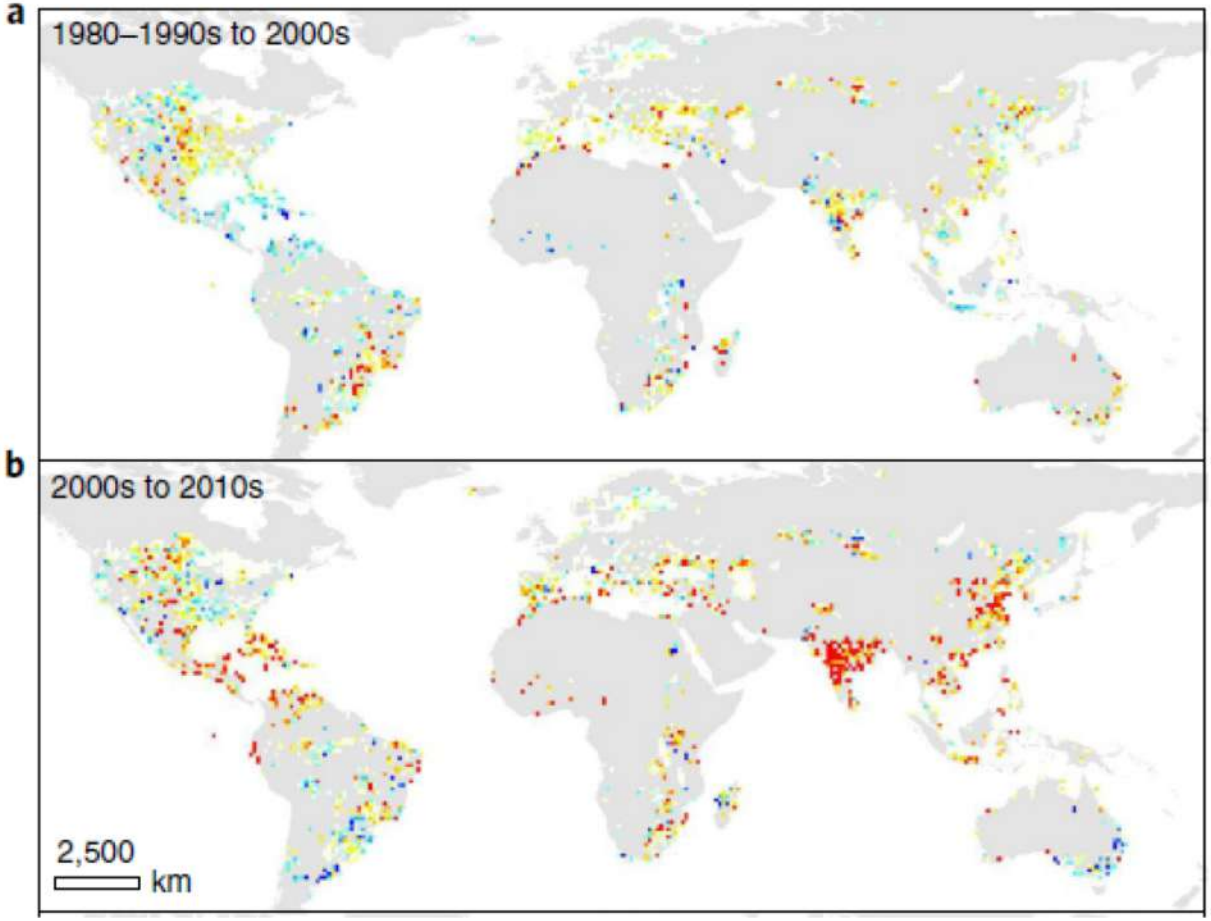
Article

Widespread global increase in intense lake phytoplankton blooms since the 1980s

https://doi.org/10.1038/s41586-019-1648-7 Jeff C. Ho[1,2*], Anna M. Michalak[1*] & Nima Pahlevan[3,4]

Landsat images (1982-2019)

Bloom occurrence (%)





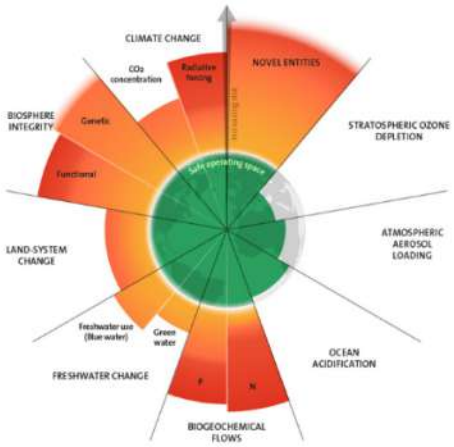


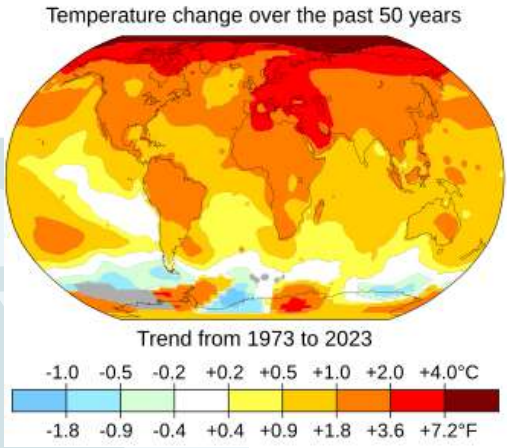
https://www.mbari.org

Hou et al., 2022

CAUSES AND IMPACT OF CYANOBACTERIAL BLOOMS

Planetary boundaries







The High Cost of Algae Blooms in U.S. Waters: More Than $1 Billion in 10 Years

By **Anne Schechinger**, Senior Analyst, Economics

WEDNESDAY, AUGUST 26, 2020

https://www.theatlantic.com/



Lake Taihu water crisis (China, May 2007)



Toledo water crisis (USA, August 2014)



LUXEMBOURG IS NO EXCEPTION





Upper-Sûre reservoir

First cyanobacteria blooms reported in 1973-74 in Upper-Sûre Lake

Bericht über Blaualgenblüten an der Sauer-Talsperre sowie über mögliche Ursachen und Gegenmaßnahmen.

Das massenhafte Auftreten planktischer Cyanophyceen (Blaualgen) in einer Trinkwassertalsperre, wie es 1973 und 1974 in der Sauer-Talsperre beobachtet wurde, muß Anlaß geben zu Besorgnissen verschiedener Art.

2023



AU LUXEMBOURG 16 octobre 2017 17:46; Act: 17.10.2017 11:12

Les activités sont interdites au lac de la Haute-Sûre

LUXEMBOURG - Le gouvernement a indiqué ce lundi que le lac de la Haute-Sûre est pollué. Il est interdit d'y pratiquer la moindre activité nautique ou d'en consommer les poissons.

A recurring phenomenon …

2021



2016



LUXEMBOURG IS NO EXCEPTION

Upper-Sûre reservoir









© Police Grand-Ducale

LUXEMBOURG IS NO EXCEPTION

Growing number of affected water bodies

- Additional water bodies are impacted by recurring cyanobacteria blooms
  - Ex. Moselle since 2018-2019







© Police Grand-Ducale





Cyanobactéries : elles ont pourri l'été 2026, et ce n'est pas près de s'arrêter

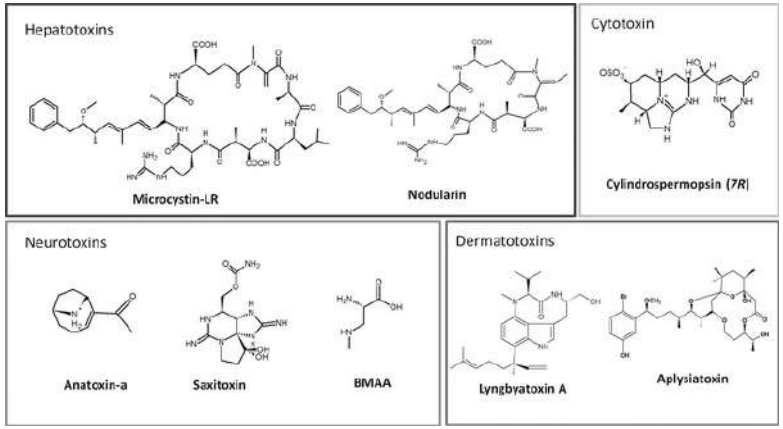
De: Le Républicain Lorrain Dans Grande Région, Premium Mis à jour le 27/10/26 16:57 | Publié le 27/10/26 11:49

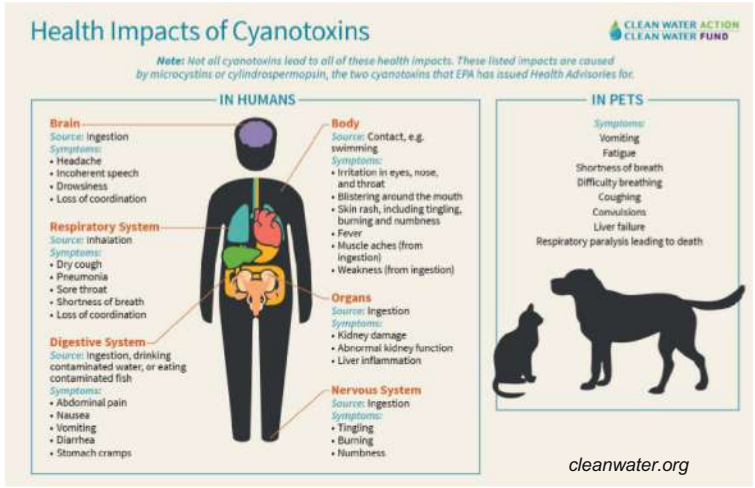


Les cyanobactéries vont devenir une préoccupation récurrente. Mais les moyens d'action immédiats sont limités... (Photo : archives le républicain lorrain)

TOXICITY OF HARMFUL CYANOBACTERIA BLOOMS

Exposure to toxins during bathing activities





cleanwater.org

Actu › Pays de la Loire › Maine-et-Loire › Rochefort-sur-Loire

Maine-et-Loire. Un chien meurt intoxiqué aux cyanobactéries

Two suspect cases of blue-green algae poisoning in pets swimming in Nicola lake

July 16, 2025

As of July 16, 2025, there have been two suspect cases of blue-green algae (cyanobacteria) poisoning in pets swimming in Nicola lake near Merritt. Beaches in the area have been closed as a precaution.

Berlin-Reinickendorf

Hund gestorben - Warnung vor Blaualgen am Tegeler See

Fr 30.05.2025, 11:40 Uhr



© hab.whoi.edu

© National Geographic

MONITORING OF HARMFUL CYANOBACTERIA-RELATED RISKS

LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY | LIST

Regulatory framework

EU Bathing Water Directive 2006/7/EC

Article 8

Cyanobacterial risks

1. When the bathing water profile indicates a potential for cyanobacterial proliferation, appropriate monitoring shall be carried out to enable timely identification of health risks.

2. When cyanobacterial proliferation occurs and a health risk has been identified or presumed, adequate management measures shall be taken immediately to prevent exposure, including information to the public.



MEMORIAL
Journal Officiel du Grand-Duché de Luxembourg

MEMORIAL
Amtsblatt des Großherzogtums Luxemburg

RECUEIL DE LEGISLATION

A — N° 204 — 18 septembre 2012

Sommaire

EAUX DE BAIGNADE

Règlement grand-ducal du 23 août 2012 modifiant le règlement grand-ducal du 19 mai 2009 déterminant les mesures de protection spéciale et les programmes de surveillance de l'état des eaux de baignade ..... page 2896

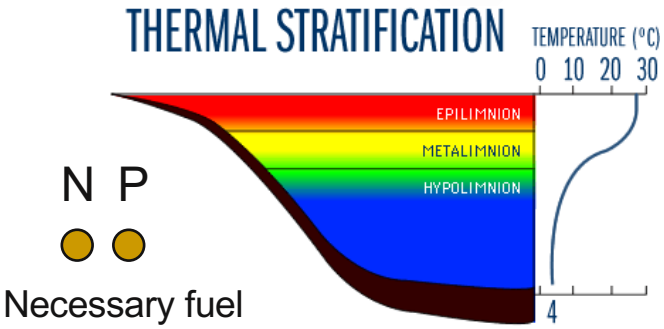
Texte coordonné du règlement grand-ducal modifié du 19 mai 2009 déterminant les mesures de protection spéciale et les programmes de surveillance de l'état des eaux de baignade 2897

BLOOMS ARE VERY DYNAMIC ACROSS TIME AND SPACE

Gradual increase in biomass

Weeks





Short term appearance, movement, disapearance

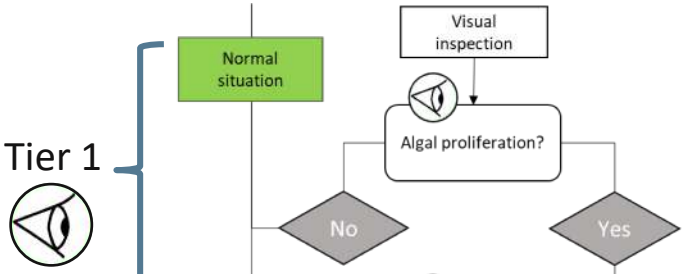
Days to hours



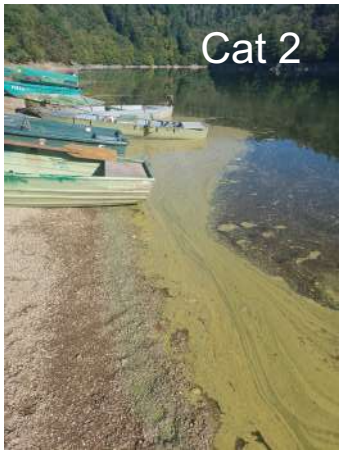
How to accurately assess bloom-related risks?

NATIONAL CYANOBACTERIA ALERT PLAN

Tier-based approach to assess blooms and associated risks



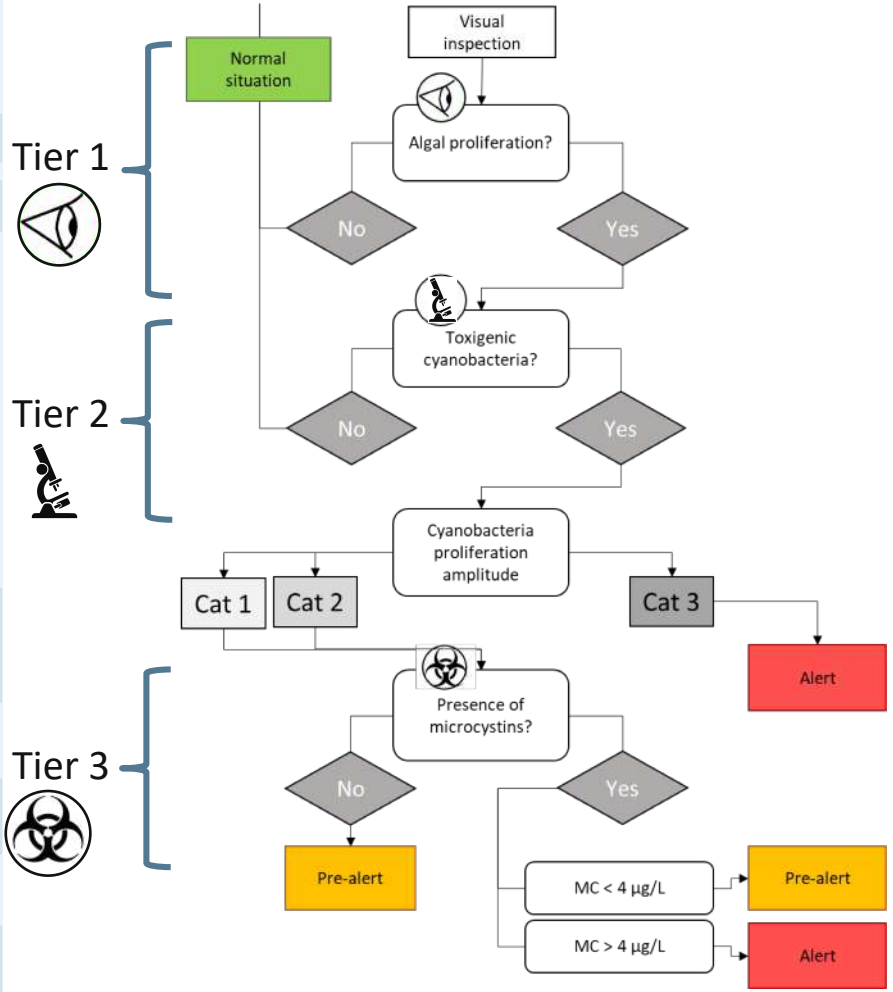






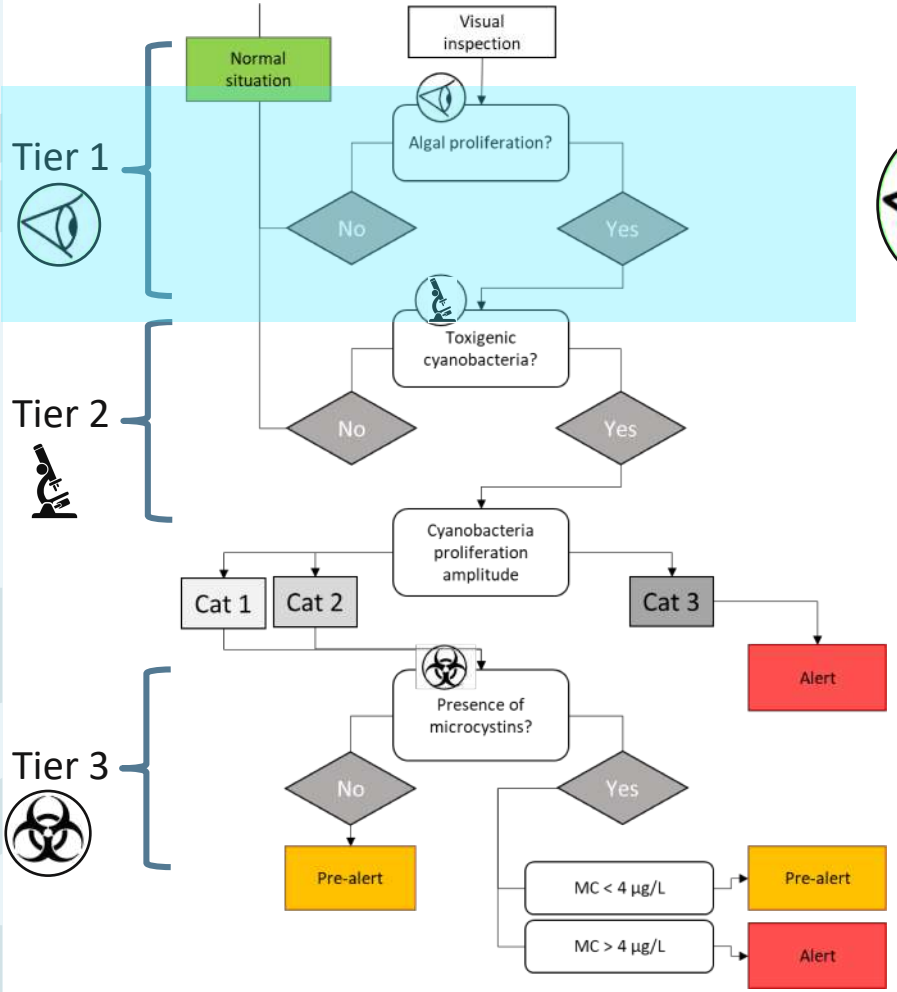
NATIONAL CYANOBACTERIA ALERT PLAN

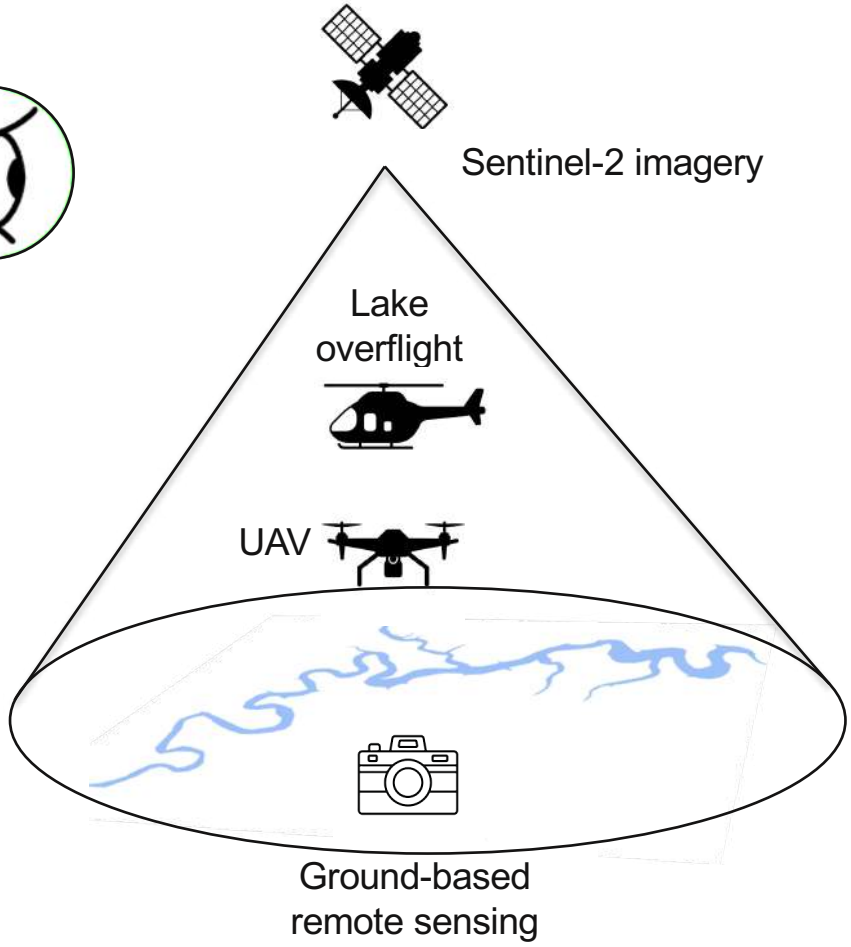
Tier-based approach to assess blooms and associated risks



MULTI-PARAMETER MONITORING APPROACH

Testing a combination of tools to assess blooms and associated risks

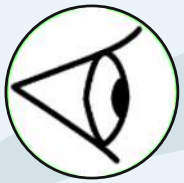




REMOTE SENSING (SENTINEL-2 IMAGERY)

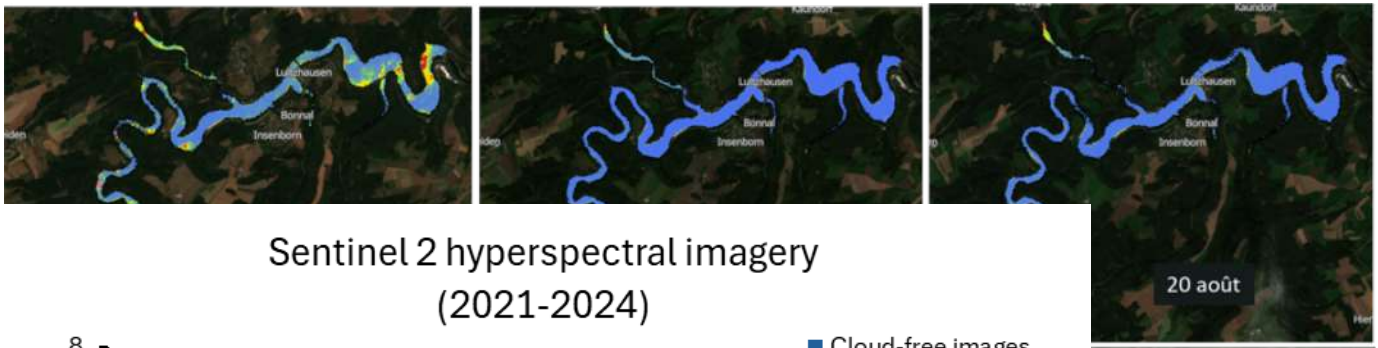
+ : Visualization of cyanobacteria prevalence/blooms at large scale

- : Cloud cover – limited amount of exploitable images



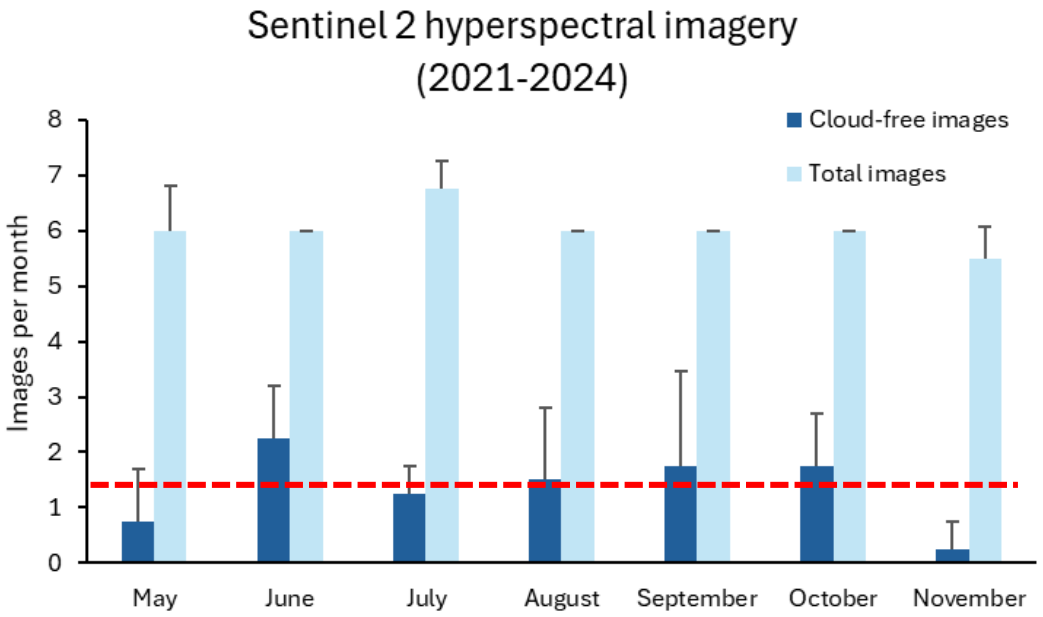


2023





Cloud-free:
<1.5/month



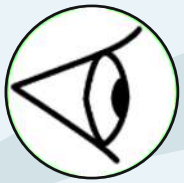
inel-hub.com/eo-browser

GROUND-BASED REMOTE SENSING (PHOTO TRAPS)



+ : high frequency acquisition of bloom images

- : sun reflection/mirroring, limited spatial coverage



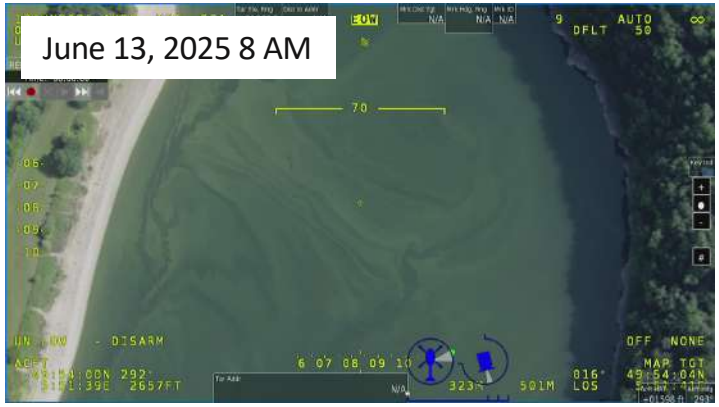




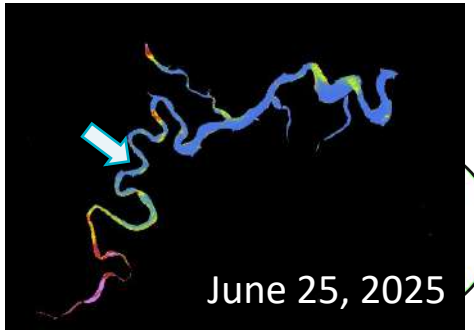
INTEGRATED MONITORING USING OBSERVATION TOOLS

Complementarity of photo traps – overflight and satellite imagery

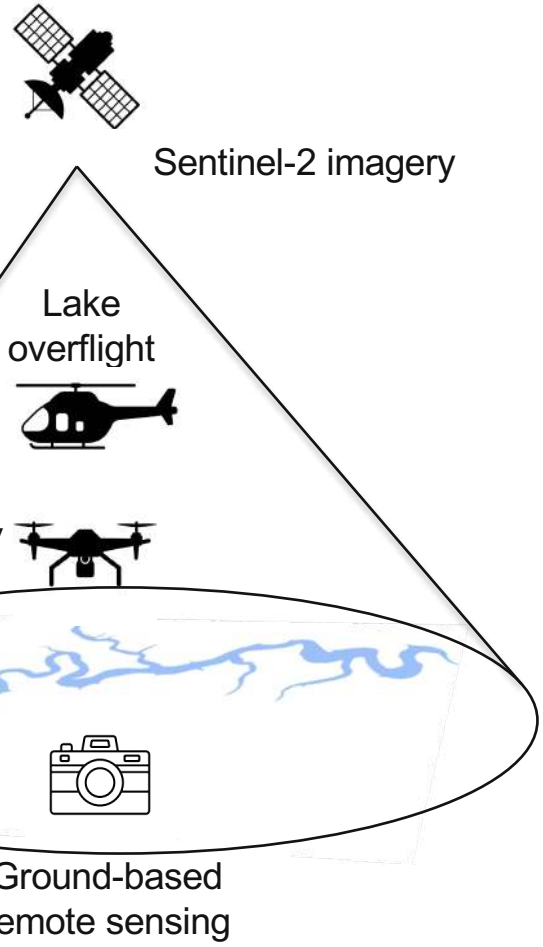












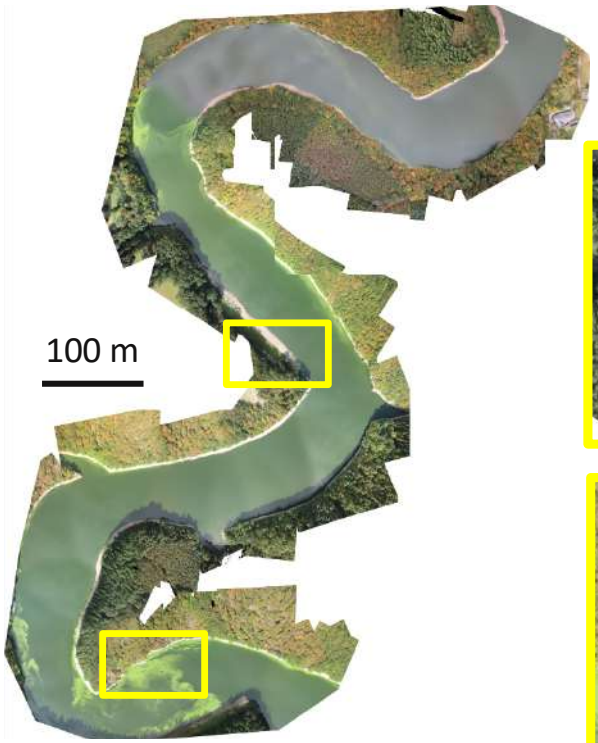
INTEGRATED MONITORING USING OBSERVATION TOOLS

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UAV fixed-wing technology for mapping

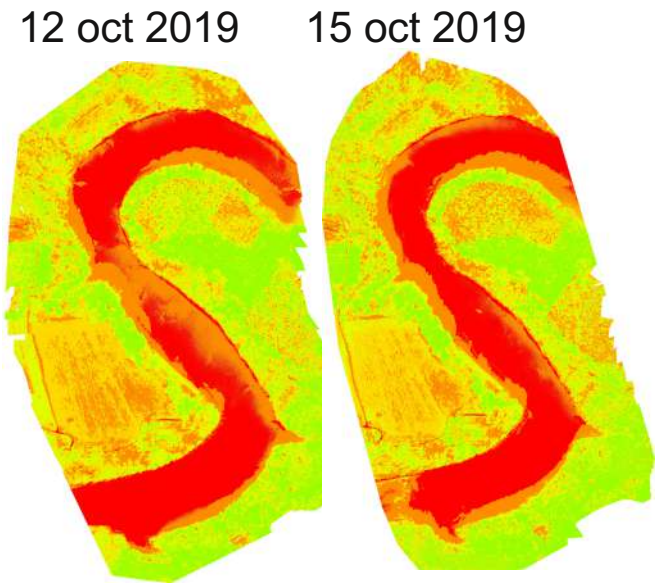
+ : high-precision mapping, multispectral information

- : limited spatial coverage, regulatory and meteorological constraints, heavy workload









INTEGRATED MONITORING USING OBSERVATION TOOLS

UAV – quadricopter technology

+ : rapid high-precision screening and mapping, user-friendly

- : limited spatial coverage, meteorological constraints



DJI Mini 4 pro

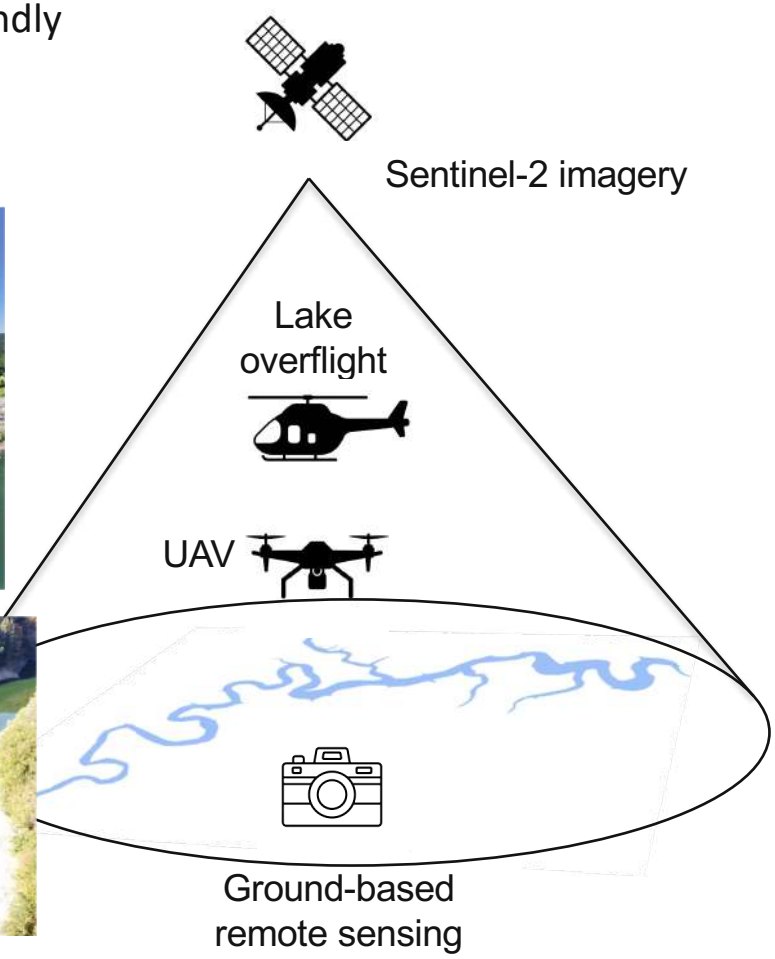
Data provided by

SEBES
DrénkWaasser





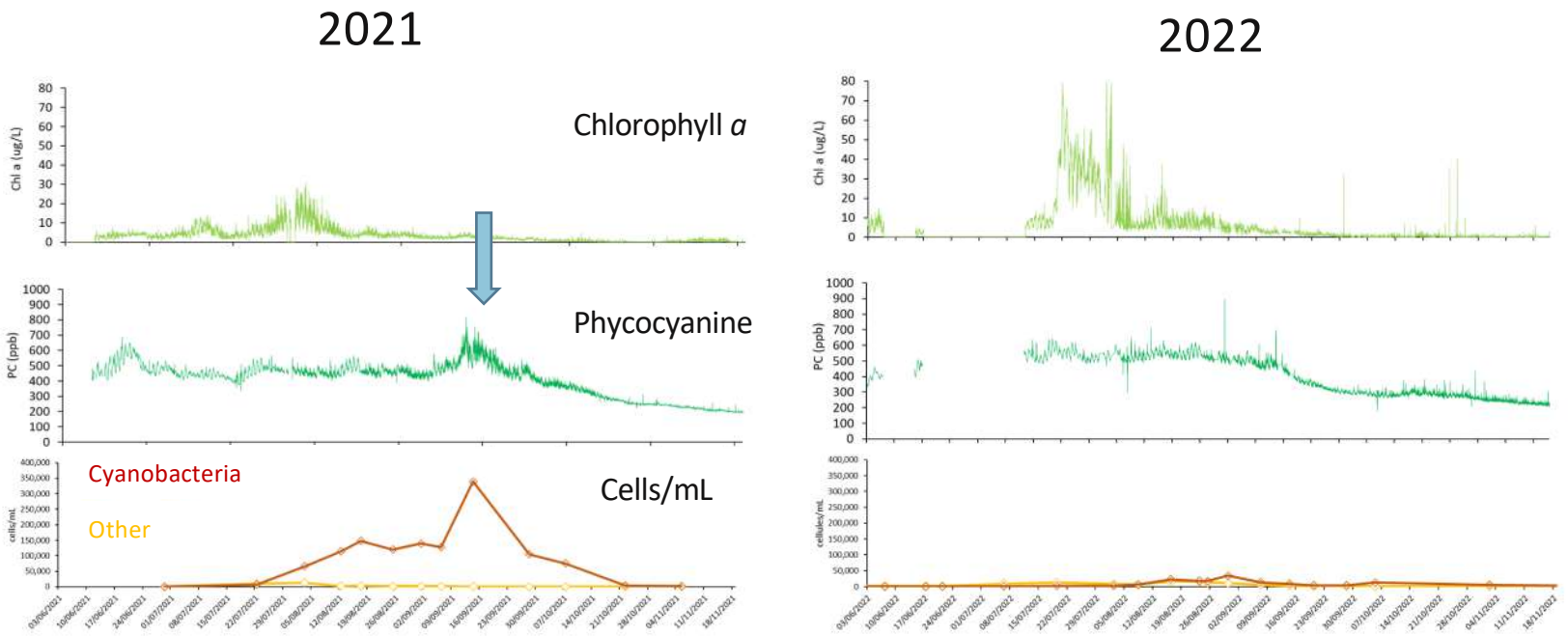




IN SITU SENSING OF ALGAL PIGMENTS

+ : automated *in situ* continuous monitoring of multiple parameters, long term datasets

- : localized datasets, analytical biais associated with algal pigment sensors



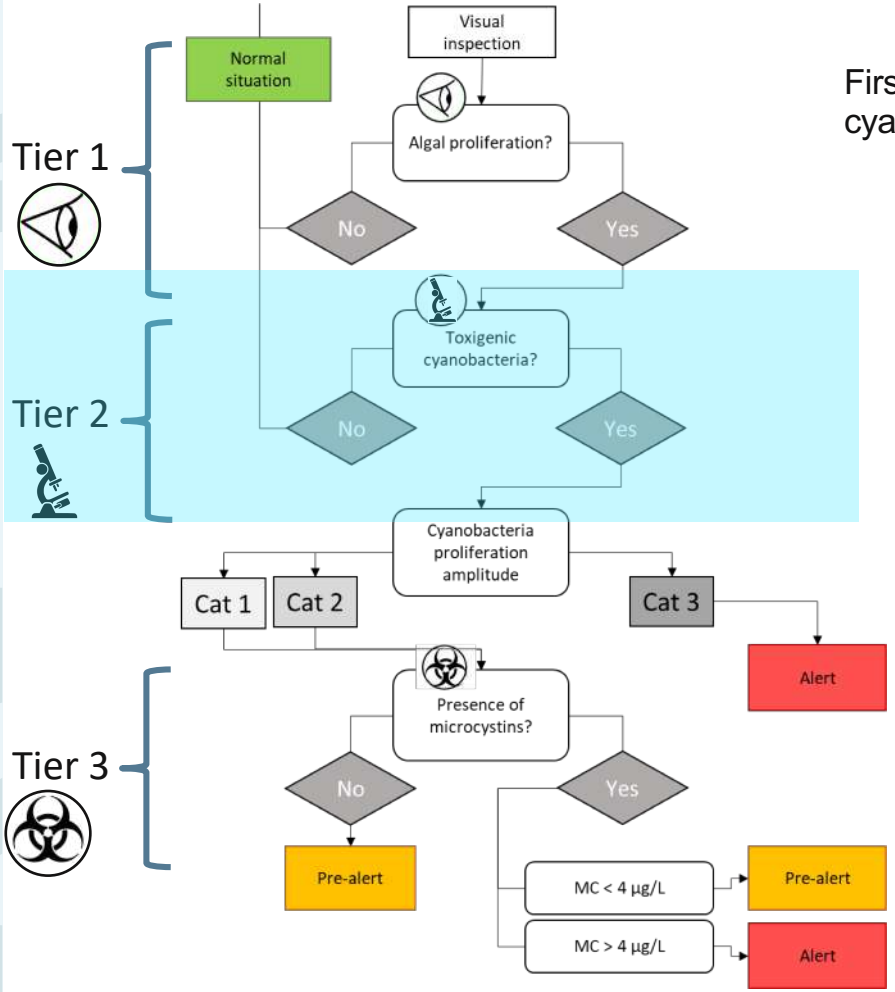
RISK AND BATHING RESTRICTIONS ARE DRIVEN BY CYANOTOXINS

Obtaining quick results for timely management of beach access

RISK AND BATHING RESTRICTIONS ARE DRIVEN BY CYANOTOXINS

Obtaining quick results for timely management of beach access





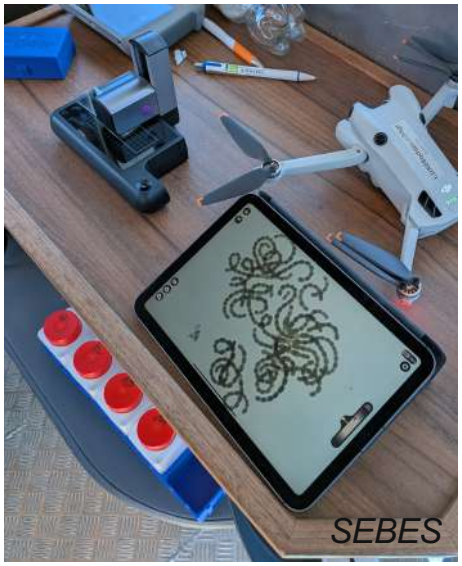
First indication of the risk – identification of dominant cyanobacteria genus/species



Field microscope

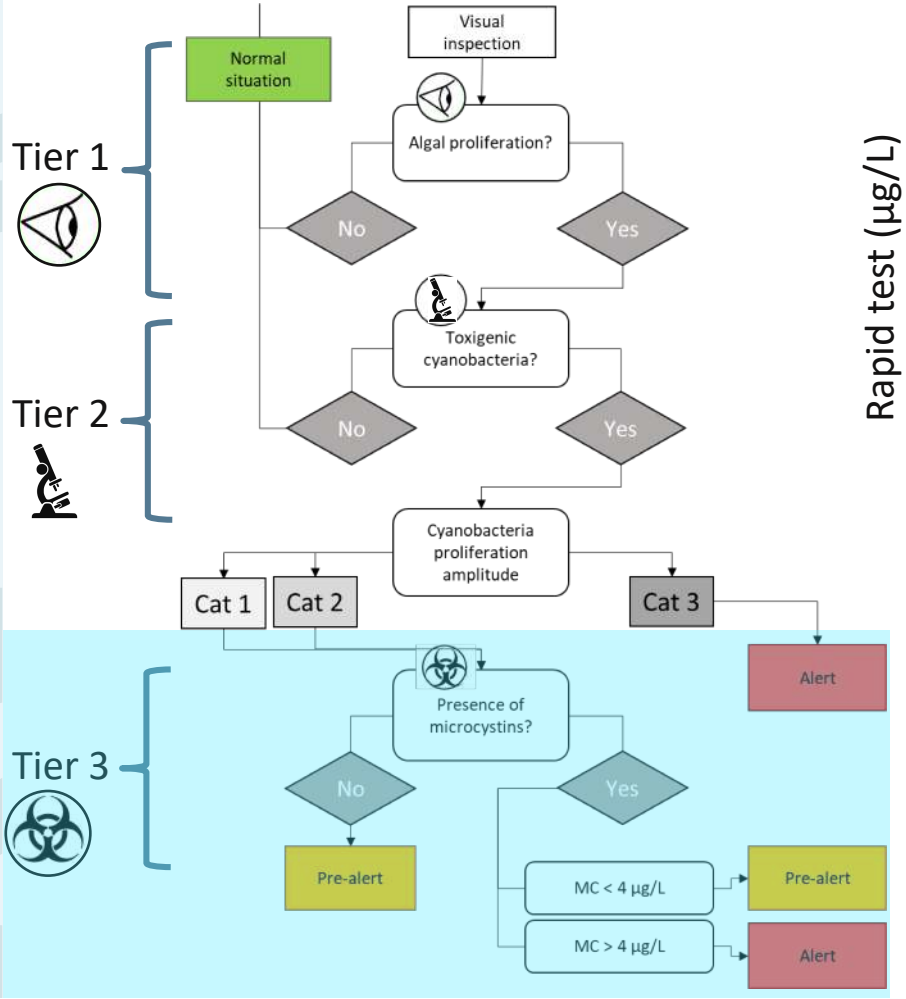


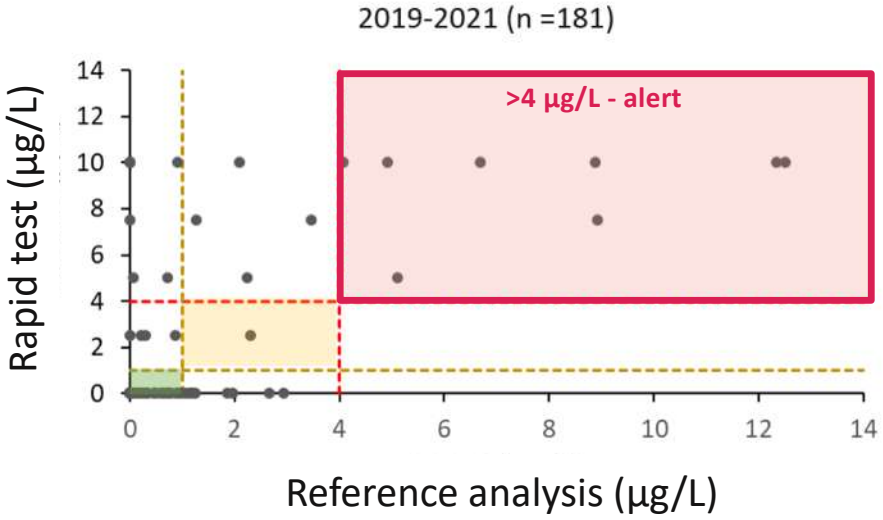
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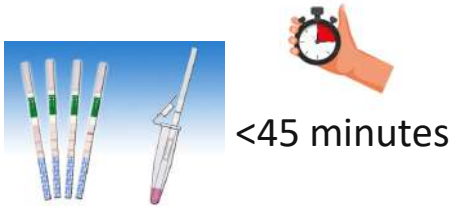


RISK AND BATHING RESTRICTIONS ARE DRIVEN BY CYANOTOXINS

Obtaining quick results for timely management of beach access



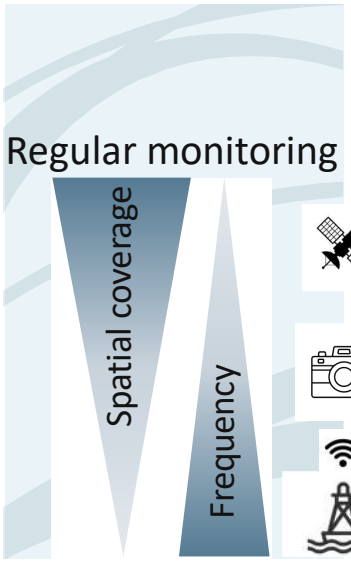




<45 minutes

Strip tests for microcystins

TOOLBOX FOR OPERATIONAL MONITORING



Technology	Avdantages	Limitations	CAPEX	OPEX	Application
Satelite imagery					
Ground-based remote sensing					
In situ sensing of algal pigments					

TOOLBOX FOR OPERATIONAL MONITORING



Technology	Avdantages	Limitations	CAPEX	OPEX	Application
Satelite imagery	Large scale visualization of cyanobacteria prevalence/blooms	Cloud cover – limited amount of exploitable images	-	-	Understand bloom dynamics at large scale, long term observations
Ground-based remote sensing	Visualization of CyanoHAB dynamics at high temporal resolution	Limited spatial coverage, sun reflection, no hyperspectral information	€	€	Understanding bloom dyamics at high spatio-temporal resolution Potential for early warning
In situ sensing of algal pigments	Multi-parameter sensing of water quality at high temporal resolution, robustness	Sensitivity (phycocyanin), fixed point in the reservoir, risk of vandalism	€€€	€	Understanding bloom dyamics at high temporal resolution and long term. Potential for early warning
In situ microcystin testing	Simple rapid assessment of the risk for humans and animals	Semi-quantitative information	€	-	Rapid screening for microcystins for near real-time decision making
In situ identification	Simple rapid identification of dominant taxa	Limited magnification power/flexibility Species identification not guaranteed	€	-	Rapid screening of a sample for identification of toxin-producing cyanobacteria
UAV quadricopter	Rapid overview of bloom extent Access to remote spots otherwise difficult to access	Deployement limited by weather conditoins and regulatory restrictions	€	-	Rapid mapping of bloom extent on multiple spots within hours
UAV fixed-wing	Fully automated mapping of area of interest, multi-spectral information	Limited spatial coverage, regulatory and meteorological constraints for deployment	€€/€€€	€	Bloom mapping to understand bloom dynamics at local scale

TOOLBOX FOR OPERATIONAL MONITORING



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TAKE HOME MESSAGES

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- Cyanobacteria blooms are a symptom of unsustainable management of natural resources
- Mitigation only possible by limiting nutrient fluxes (=long term catchment management)
- Meanwhile, we have to cope with cyanobacteria blooms → risk monitoring is essential
- Technological toolbox to optimize information richness/cost

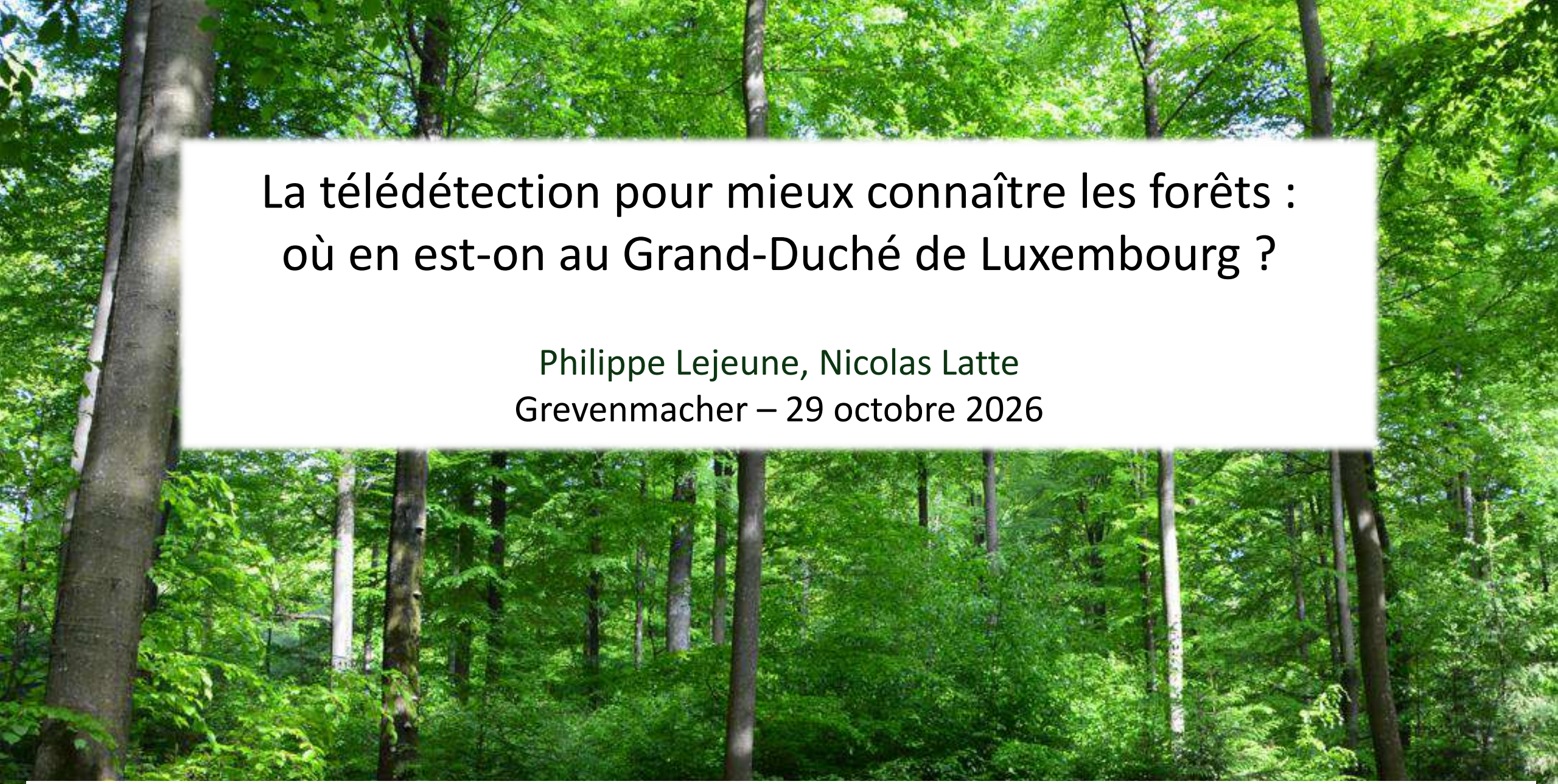
Thank you for your attention!





Contact

Jean-Baptiste Burnet, PhD
Luxembourg Institute of Science and Technology
jeanbaptiste.burnet@list.lu



La télédétection pour mieux connaître les forêts : où en est-on au Grand-Duché de Luxembourg ?

Philippe Lejeune, Nicolas Latte

Grevenmacher – 29 octobre 2026

Interreg
Grande Région | Großregion
Cofinancé par l'Union Européenne
Kofinanziert von der Europäischen Un
W.A.V.E.
Administration de la nature et des forêts
Grand-Duché de Luxembourg
Wallonie environnement SPW
LIÈGE université Gembloux Agro-Bio Tech

Contexte

- Changements climatiques
- Dépérissements forestiers
- Pertes de croissance
- Feux de végétation
- Erosion de la biodiversité





www.florenville.be



www.canopea.be

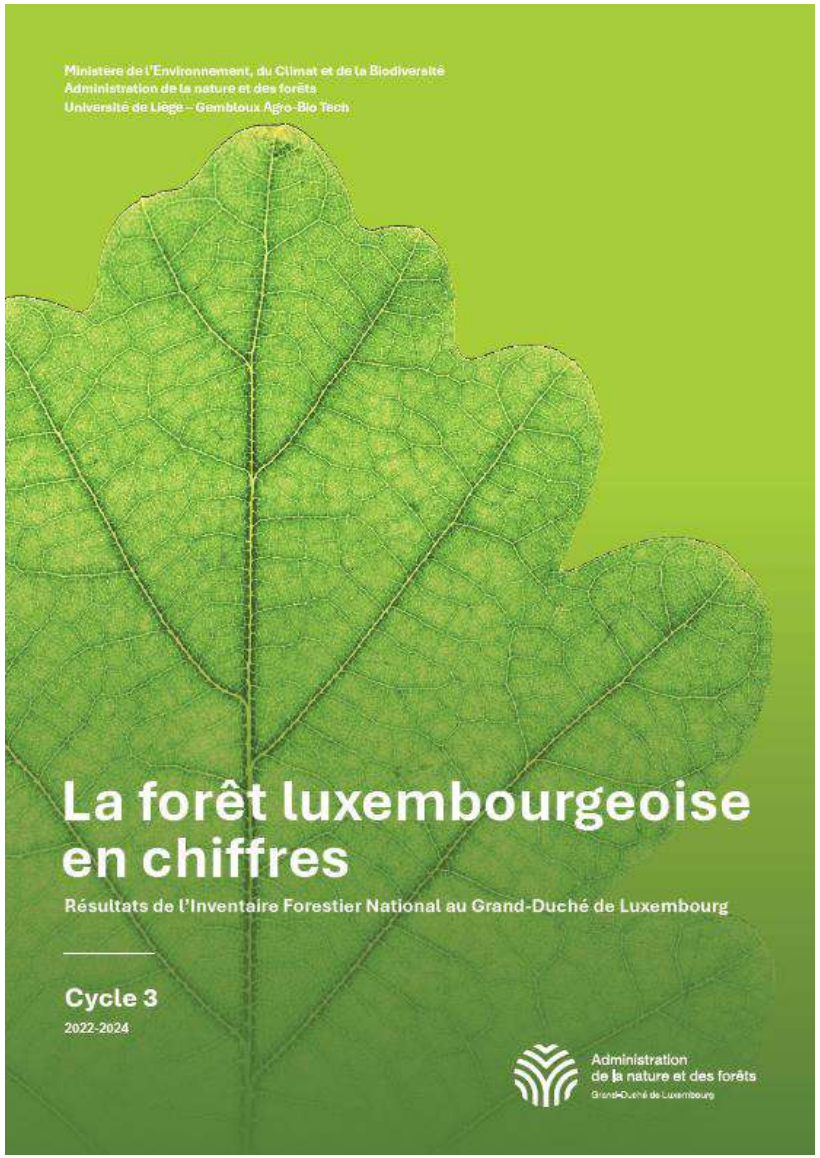
Les inventaires forestiers nationaux

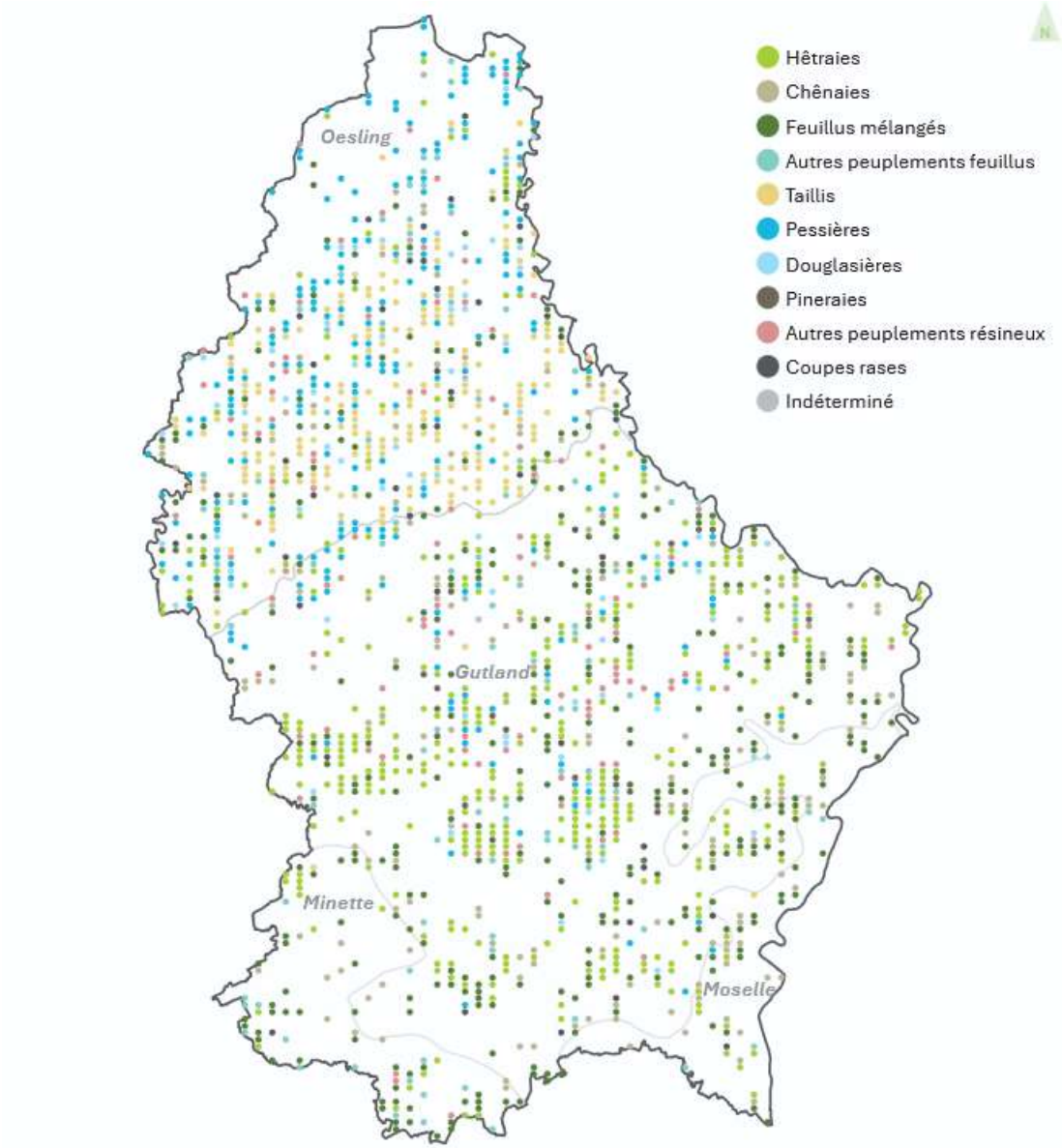


Objectifs :

- Suivi « en continu » de l'état global de la forêt à l'échelle nationale
- Orienter la politique forestière
- Estimer la disponibilité des ressources en bois
- Suivre l'évolution de la biodiversité végétale en forêt

Les inventaires forestiers nationaux





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Les inventaires forestiers nationaux

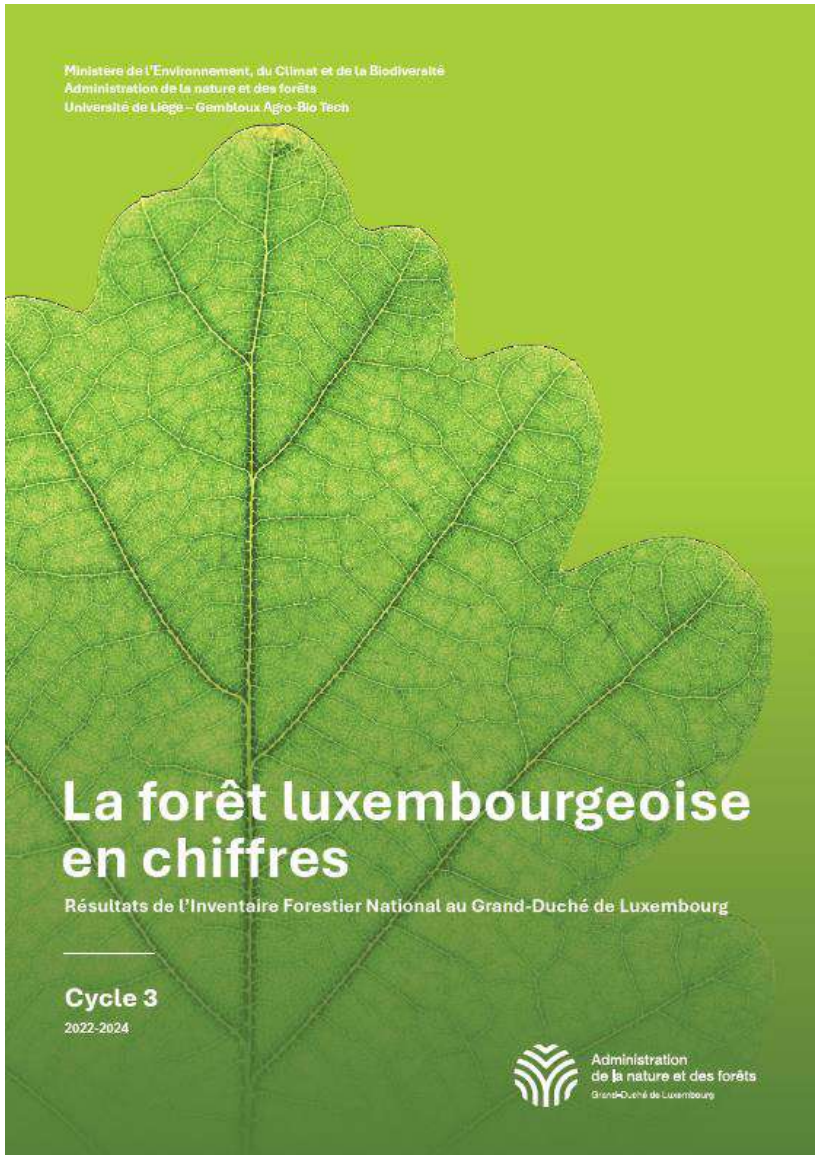


Tableau 2.1. Surfaces par types d'occupation (en ha)

Analyse basée sur les points de sondage installés au sein des « Terres boisées » et des « Autres terres en milieu forestier »

TYPE D'OCCUPATION					CYCLE 1 (2000)	CYCLE 2 (2010)	CYCLE 3 (2023)
SURFACE EN MILIEU FORESTIER	SURFACE BOISÉE	SURFACE FORESTIÈRE	SURFACE PEUPLEMENT	Peuplements sur pied	86 200	85 750	84 050
				Coupes à blanc	550	850	2 050
				Total « Surface peuplement »	**86 750**	**86 600**	**86 100**
			Broussailles, friches, clairières, éléments linéaires		1 850	2 550	2 950
			Total « Surface forestière »		**88 600**	**89 150**	**89 050**
		Autres terres boisées			1 900	1 600	1 800
		Bosquets			1 150	850	550
		Total « Surface boisée »			**91 650**	**91 600**	**91 400**
	Autres terres en milieu forestier				800	750	850
	Total « Surface en milieu forestier »				**92 450**	**92 350**	**92 250**

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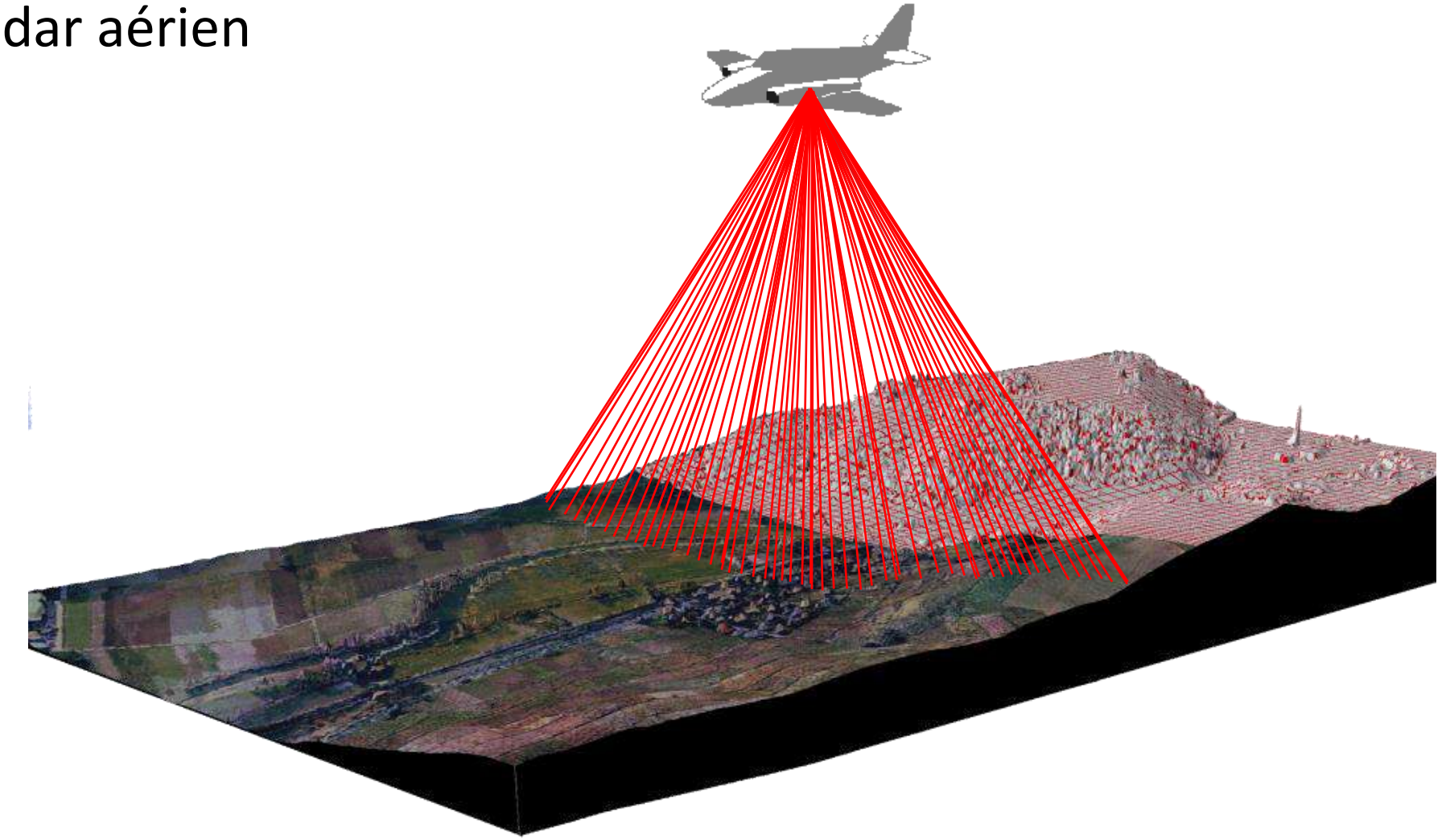
Les inventaires forestiers multi-source



Renaud, J.-P., Cordonnier, T., Véga, C., Pulkkinen, M. et Bastick, C. (2024). Un inventaire forestier multisource, vous connaissez ? Revue forestière française, 75(3), 233-241. https://doi.org/10.20870/revforfr.2024.8338

Les inventaires forestiers multi-source

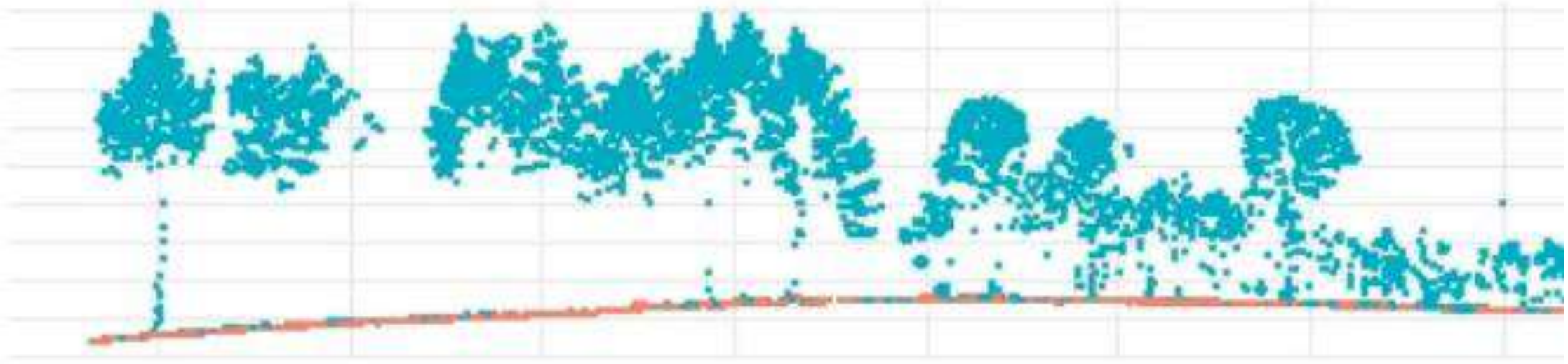
- Lidar aérien



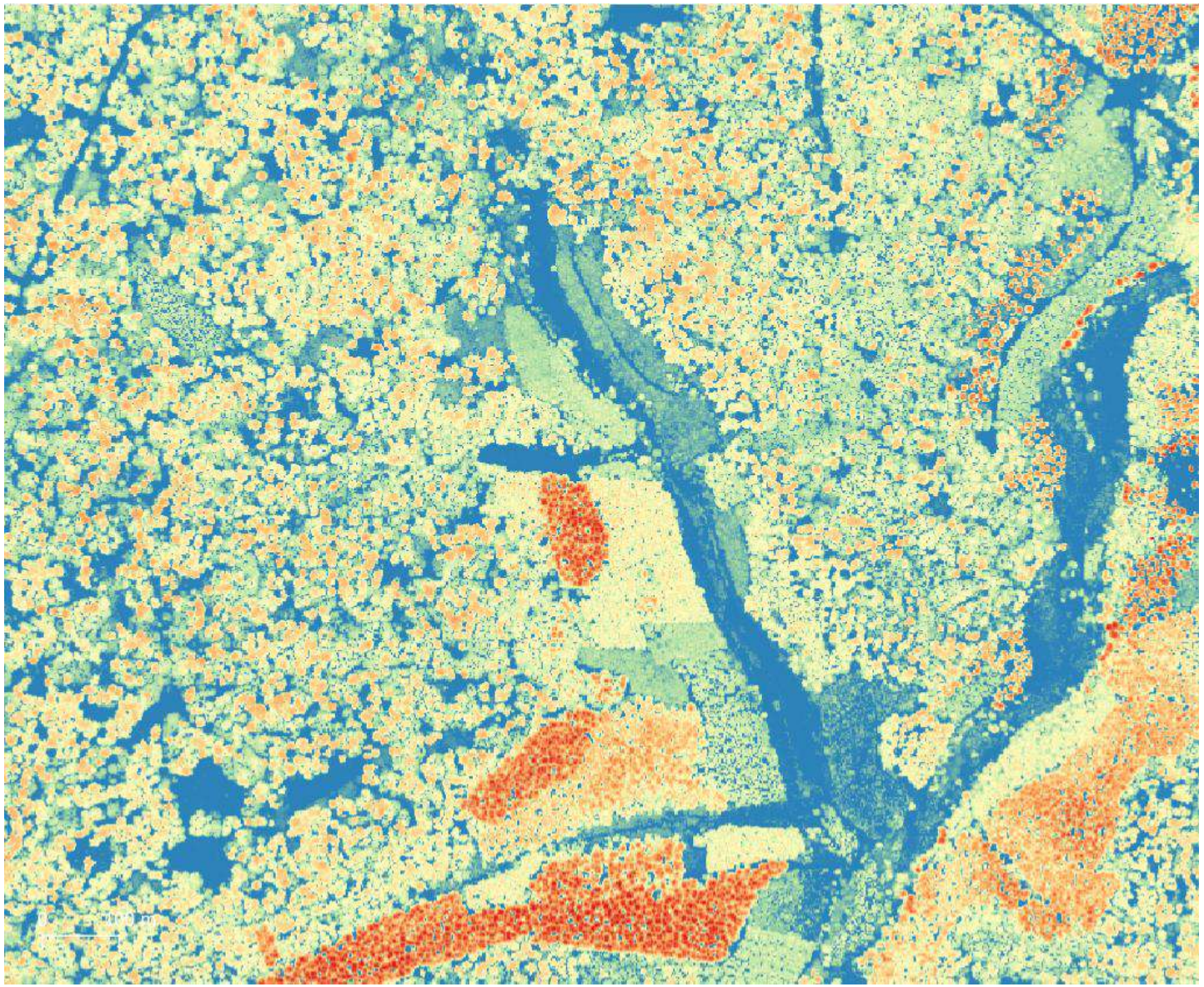
©Toposys

Les inventaires forestiers multi-source

- Lidar aérien : structure verticale de la végétation forestière

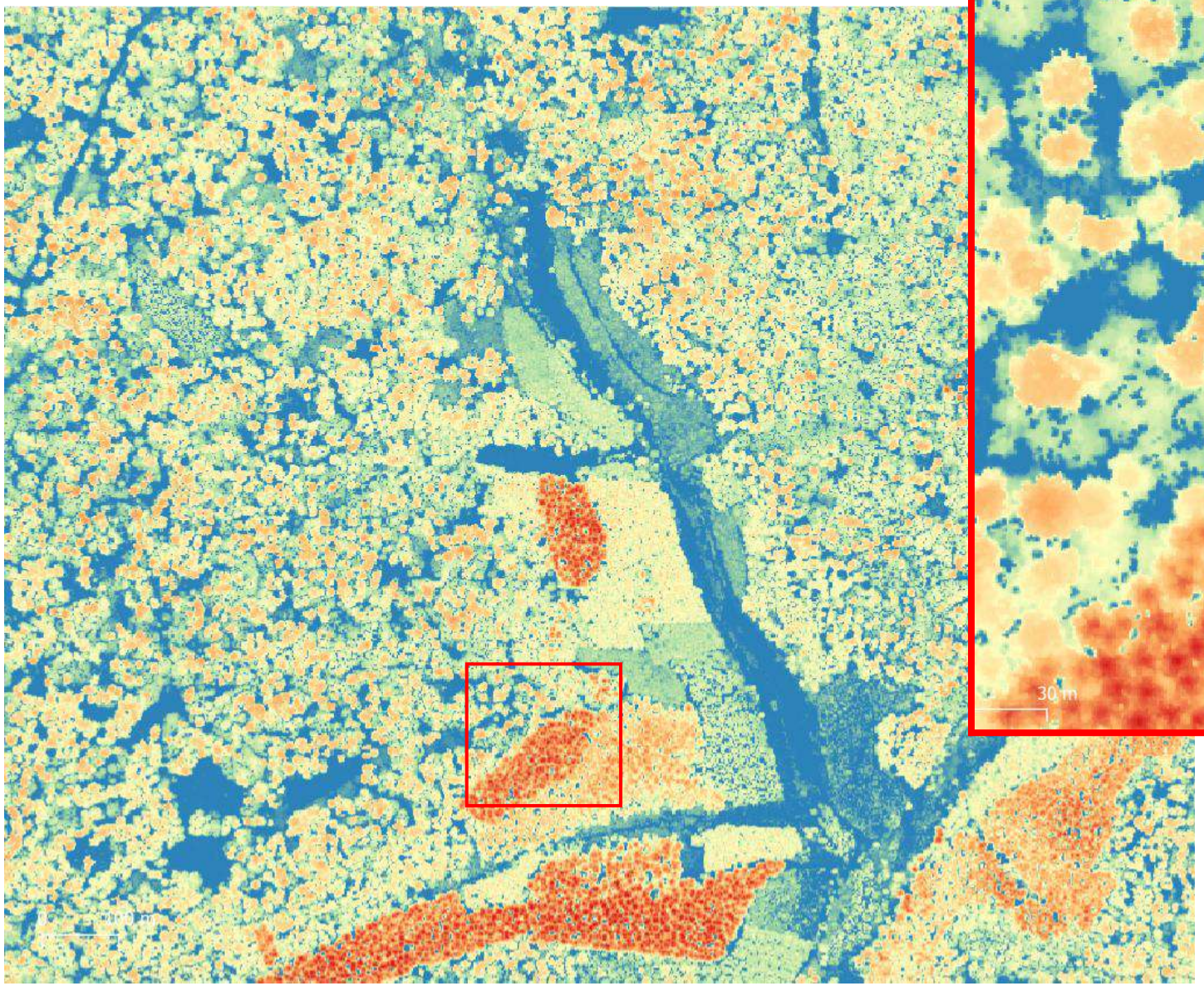


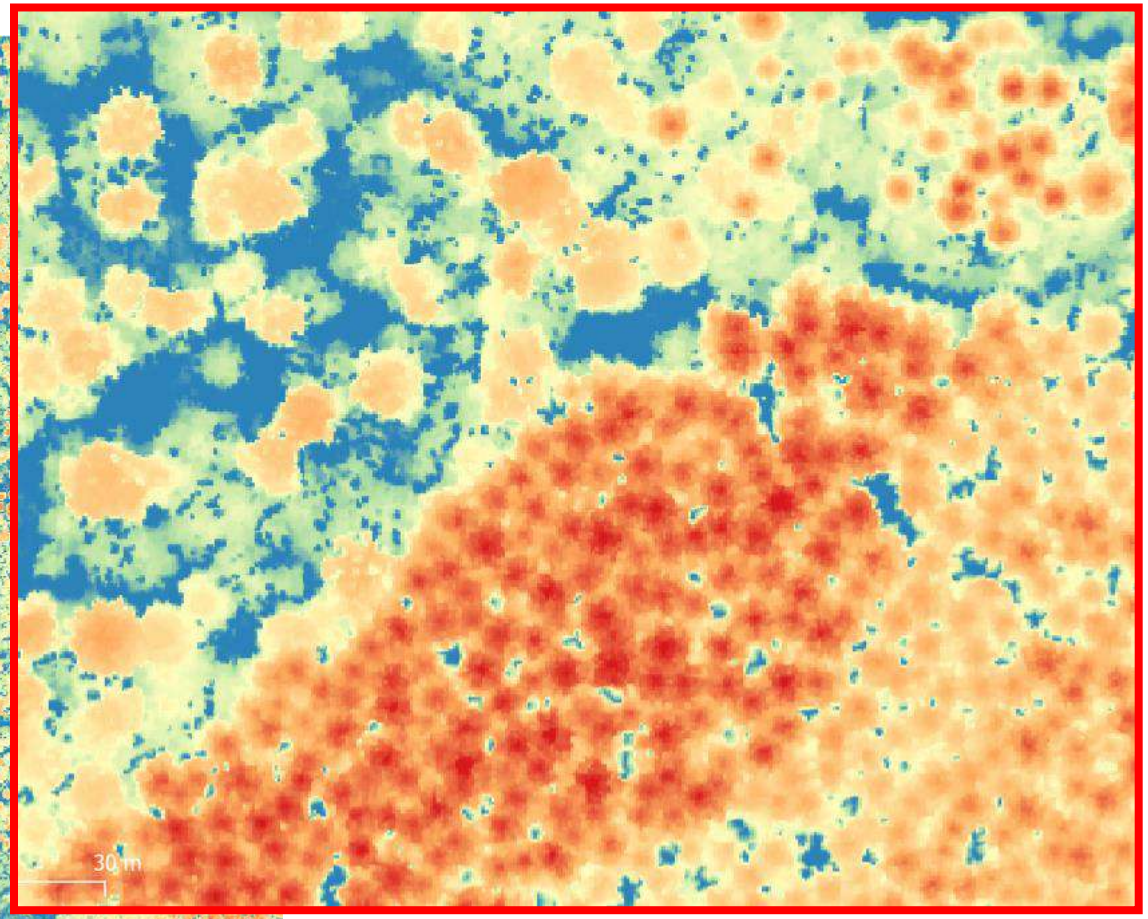
Les inventaires forestiers multi-source



- Modèle Numérique de Hauteur
- Résolution : 50 cm

Les inventaires forestiers multi-source





ur

Hauteur (m)

40

0



Les inventaires forestiers multi-source

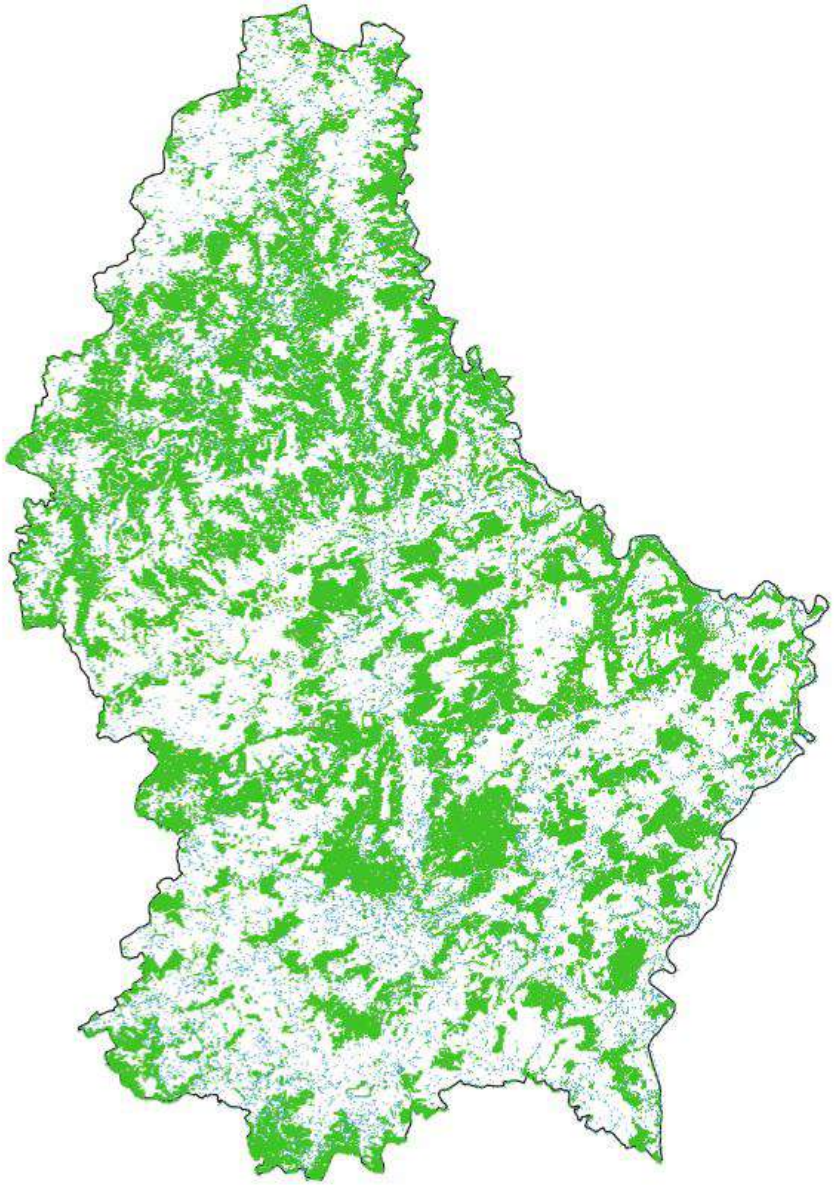
- Production de cartes thématiques forestières
  - Masque forestier ligneux
  - Composition des peuplements
  - Variables dendrométriques
  - Mortalité des peuplements
  - Suivi de la vitalité des peuplements



Cartographier les forêts

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Cartographier les forêts



Masque forestier ligneux 2024 (rés. 1m)

Cartographier les forêts

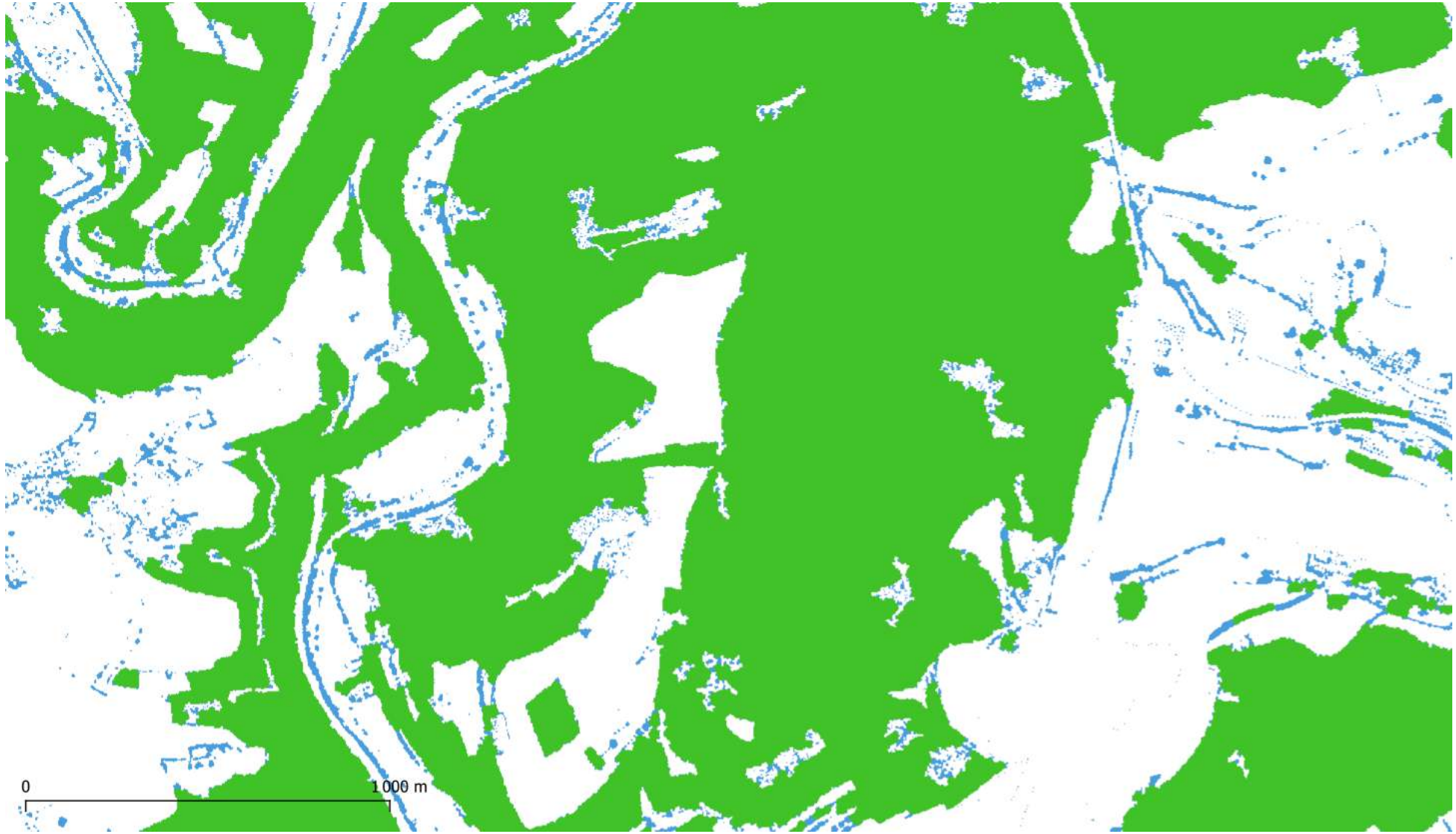
- Masque forestier ligneux
  - Définition : « zones avec un couvert arboré dont la surface ≥ 0,1 ha et la largeur ≥ 20 m »
  - Couvert arboré → premiers retours lidar avec hauteur ≥ 2m
  - Résolution : 1 m
  - Produit avec les données lidar 2019 et 2024
  - Couche de référence pour les autres produits cartographiques forestiers

Cartographier les forêts



Orthoimage 2023 (rés. 10cm)

Cartographier les forêts

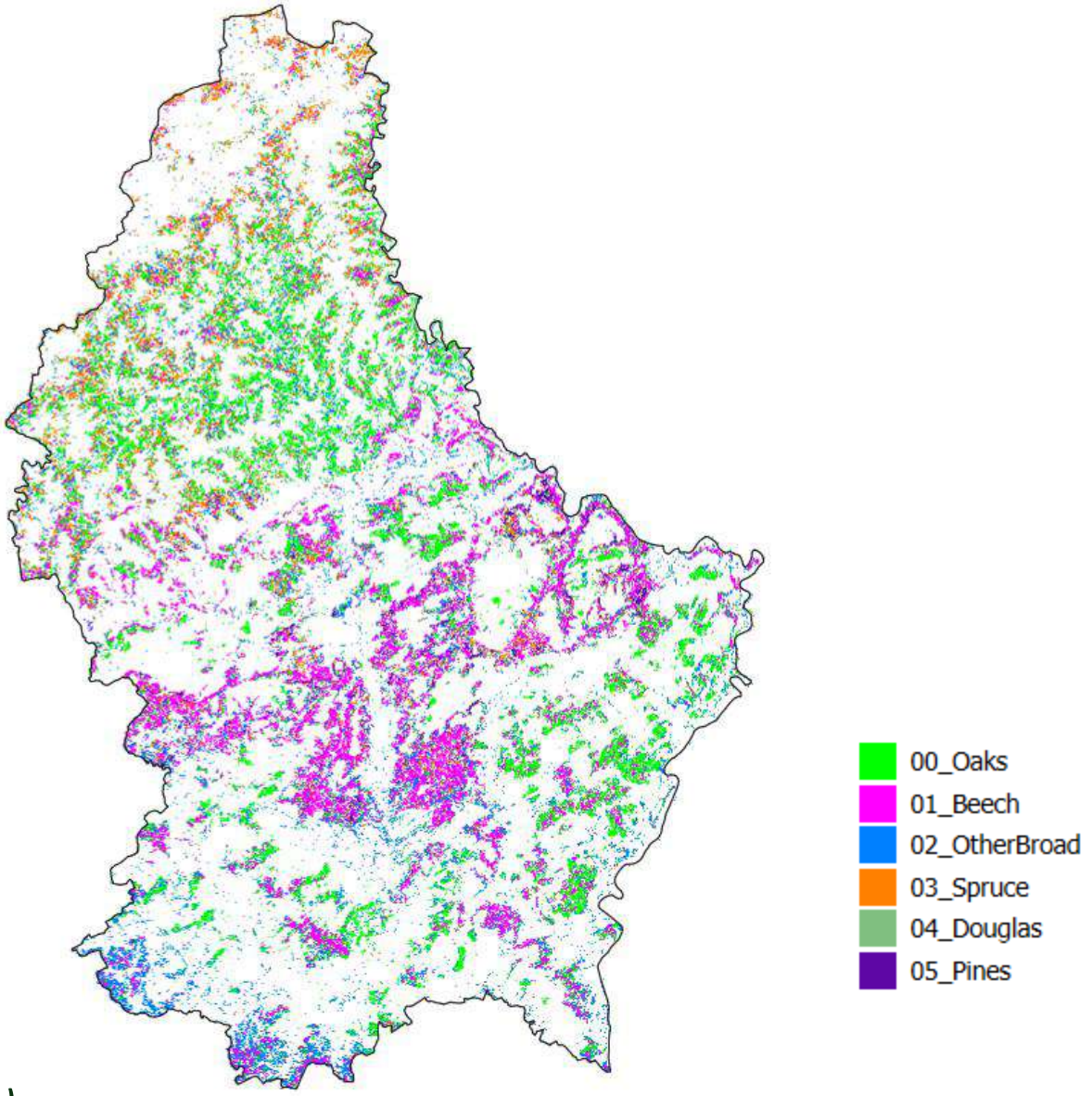


Masque ligneux 2023 (rés. 10cm)



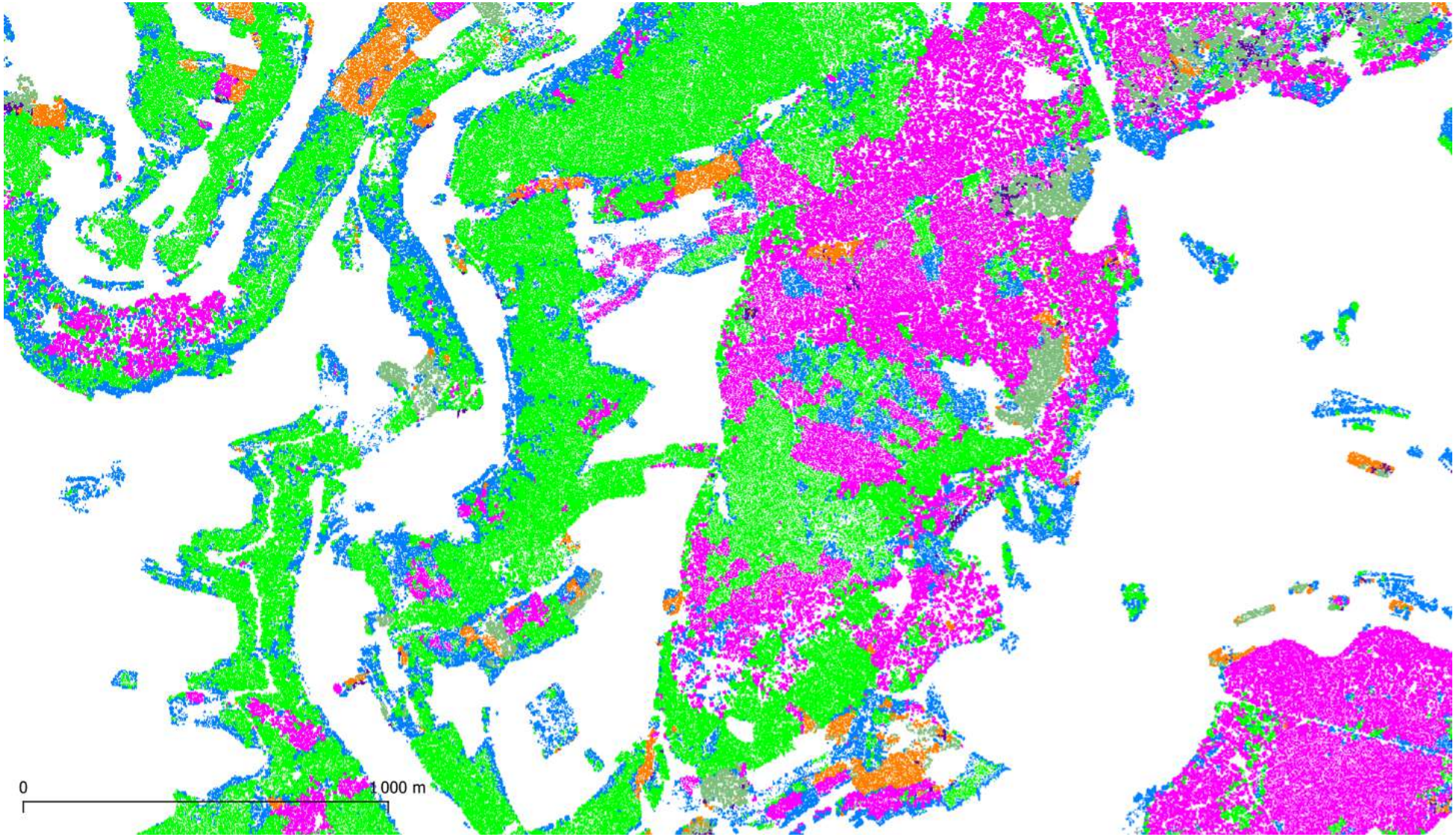
Composition des forêts

Composition des forêts



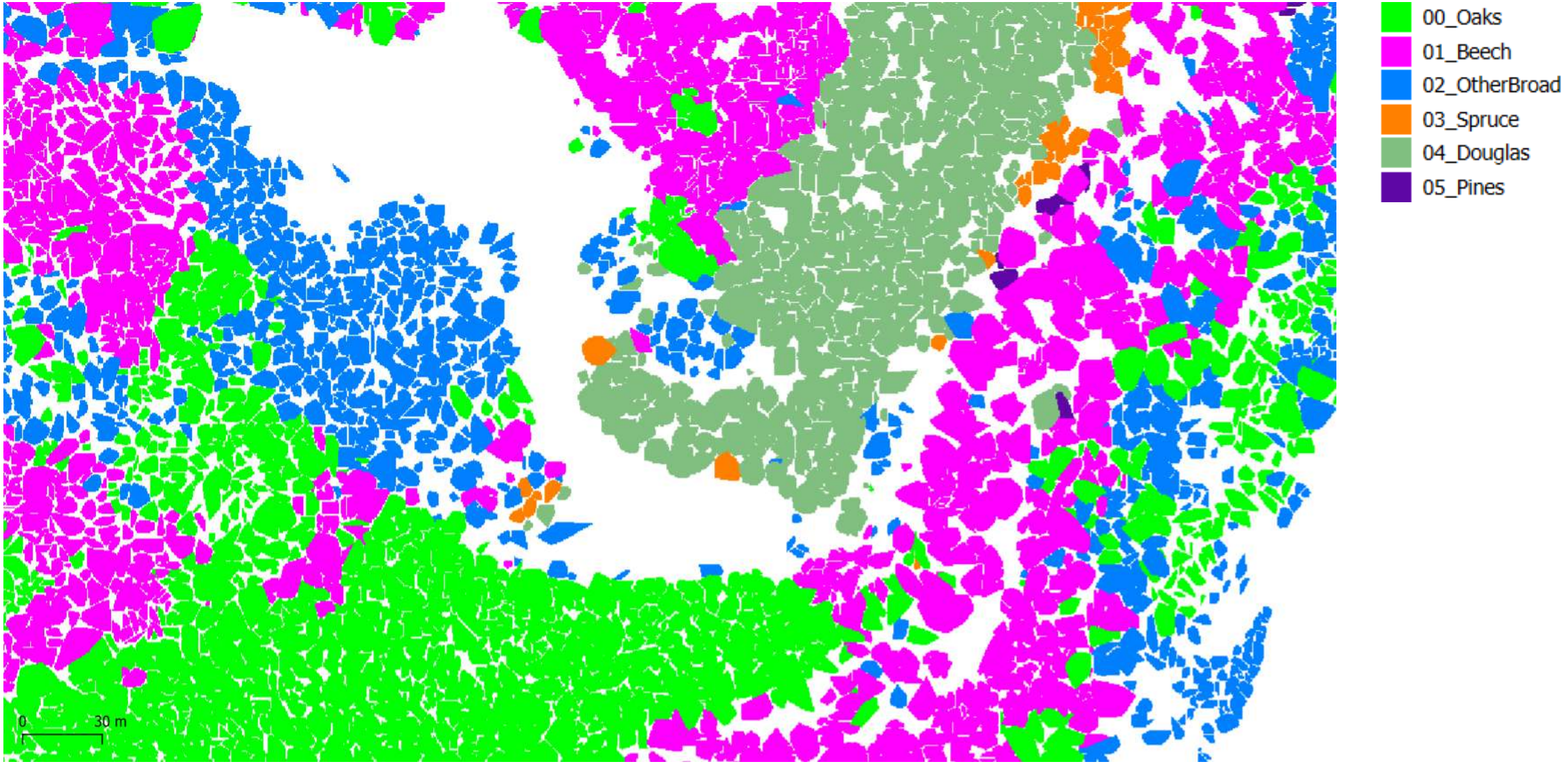
Composition forestière 2023 (rés. 50 cm)

Composition des forêts



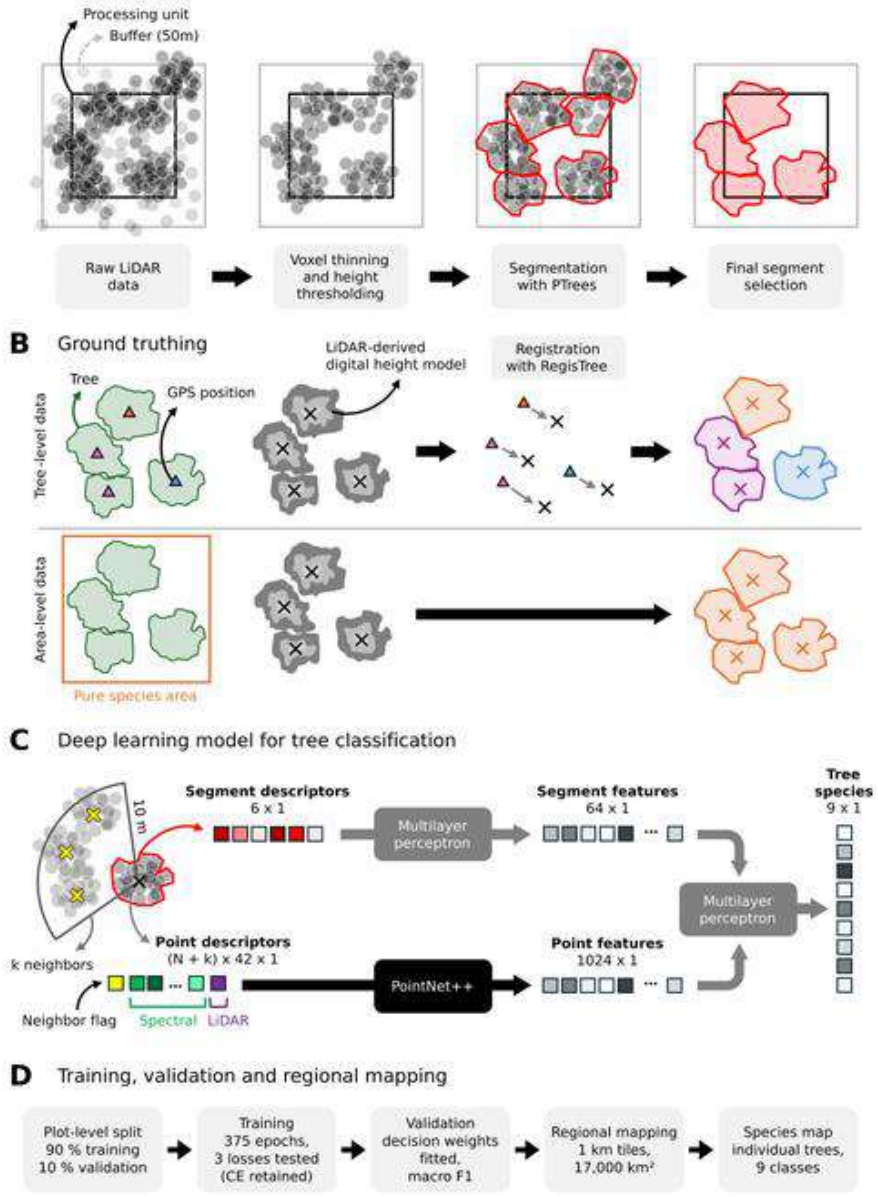
Composition forestière 2023 (rés. 50 cm)

Composition des forêts



Composition forestière 2023 (rés. 50 cm)

Composition des forêts



Données de référence : IFL3, parcellaire ANF

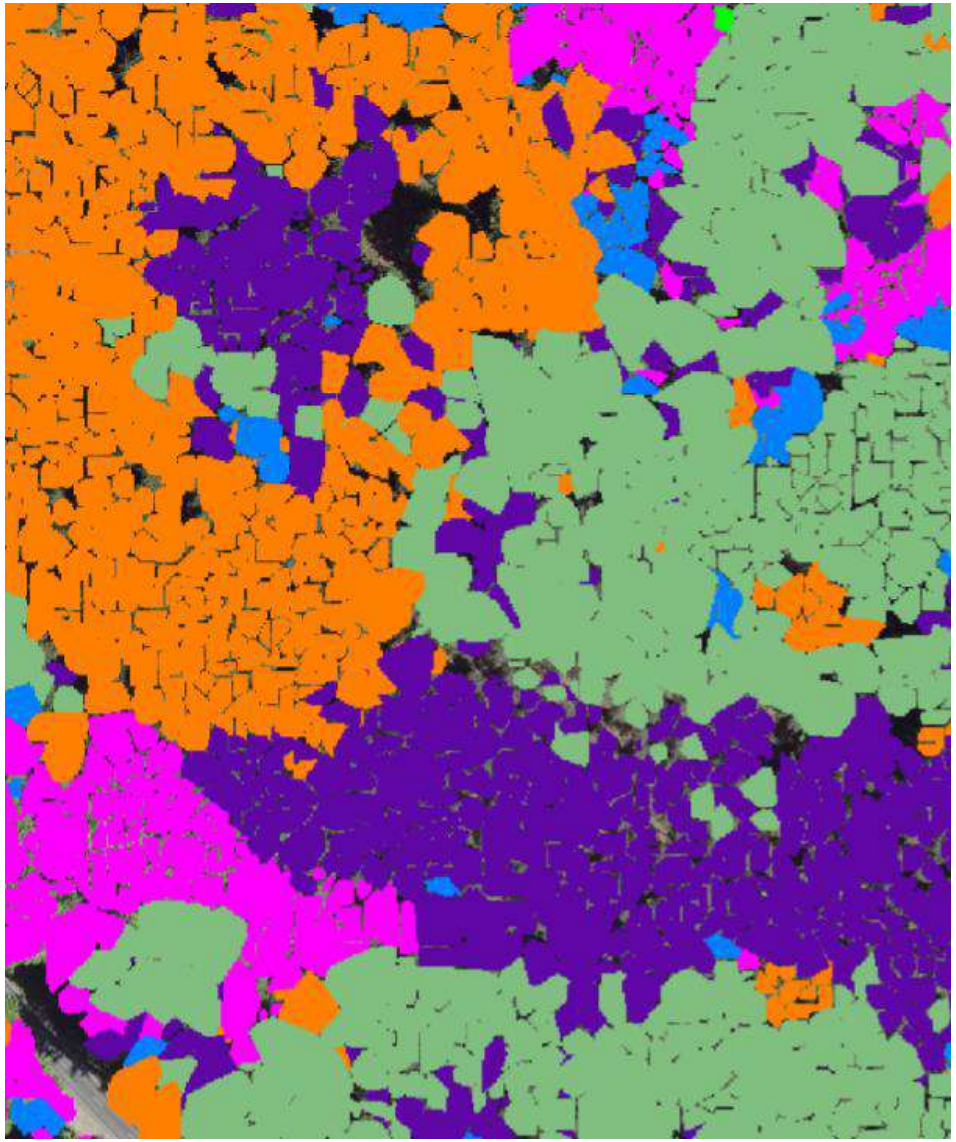
Class	Precision	Recall	F1-score	Segment Number
00_Oaks	85.4%	85.5%	85.5%	7,613
01_Beech	94.6%	90.7%	92.6%	9,283
02_OtherBroad	51.7%	61.5%	56.2%	1,506
03_Spruce	89.8%	92.1%	91.0%	1,691
04_Douglas	93.5%	90.6%	92.1%	1,036
05_Pines	83.9%	91.9%	87.7%	811
Total	**Accuracy = 87.1%**			**21,940**

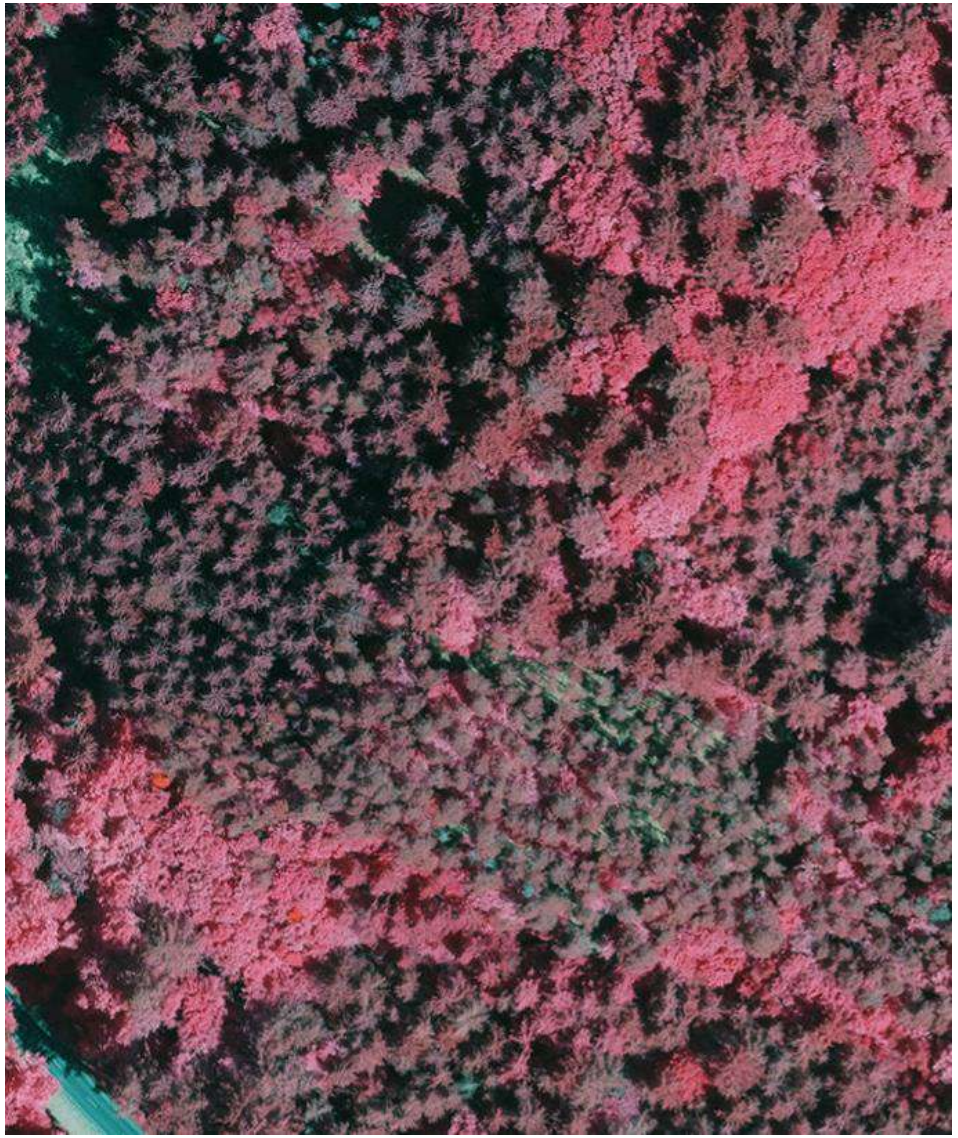
Version 1

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Composition des forêts

00_Oaks
01_Beech
02_OtherBroad
03_Spruce
04_Douglas
05_Pines





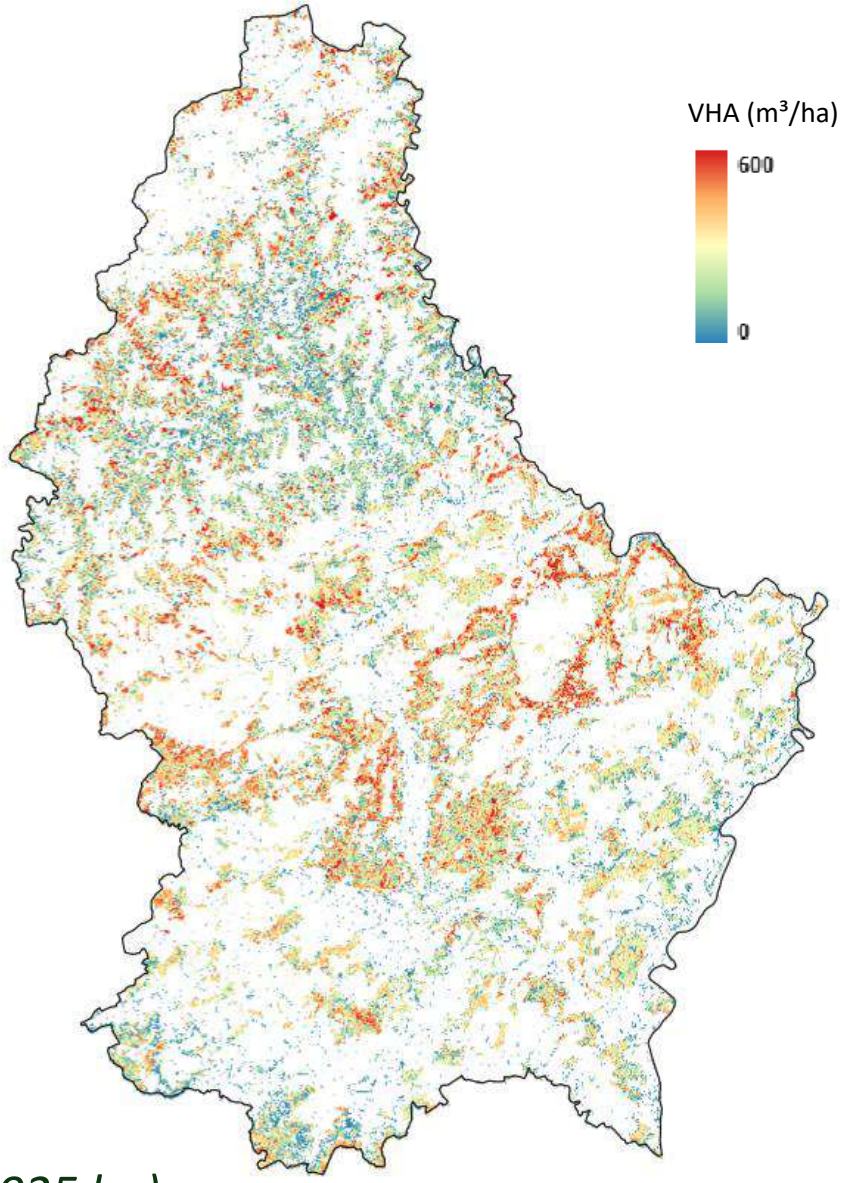
Version 1



Ressource en bois

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Agro-Bio Tech

Ressource en bois



Volume de bois sur pied en 2024 (rés. 0,025 ha)

Ressource en bois



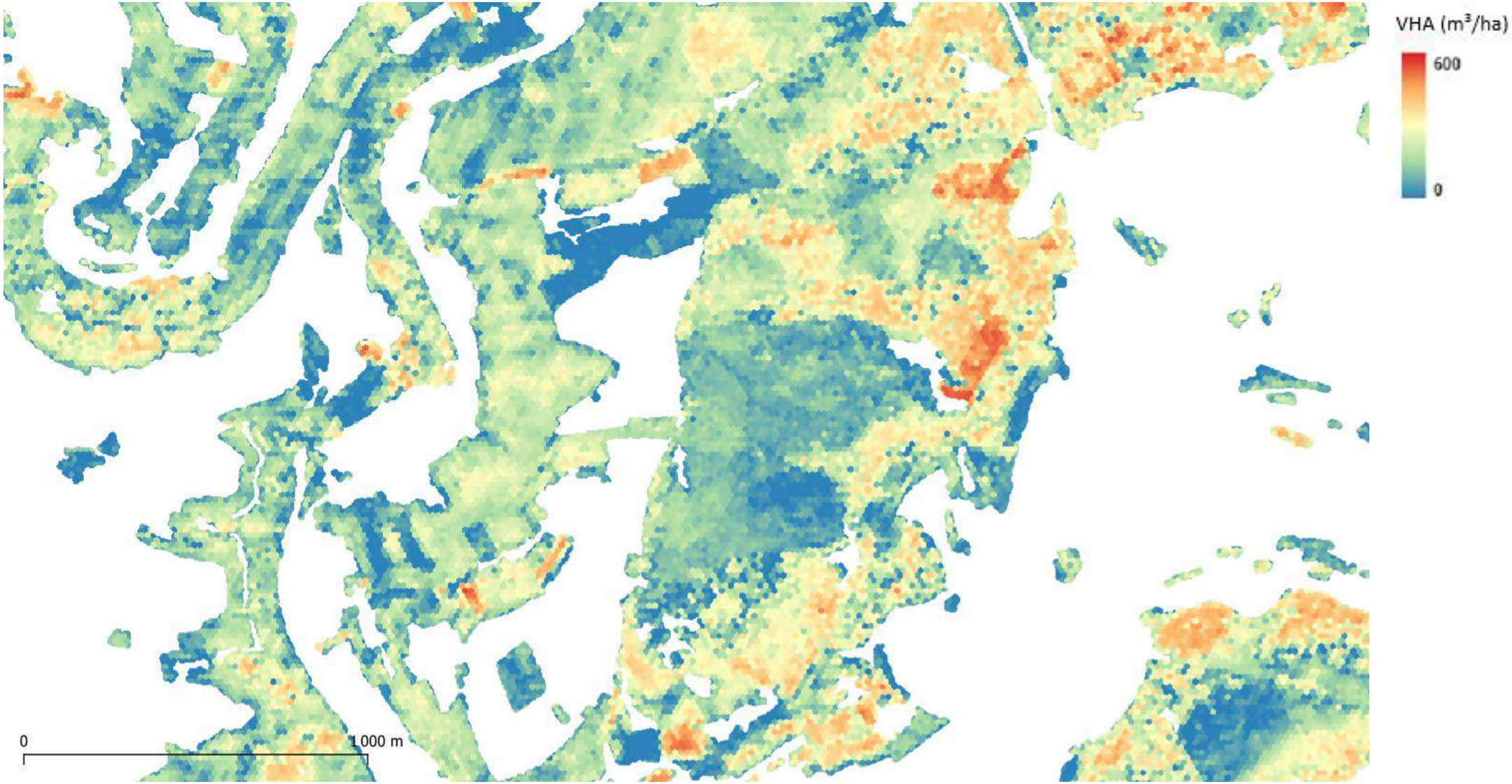
Orthoimage 2023 (rés. 10cm)

Ressource en bois



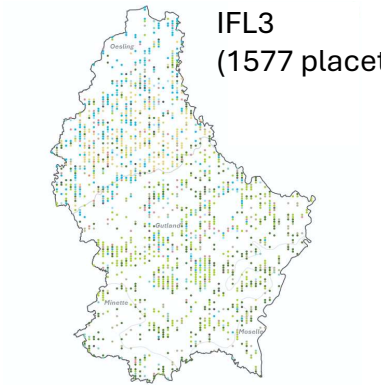
Découpage en cellules hexagonales (250 m²)

Ressource en bois

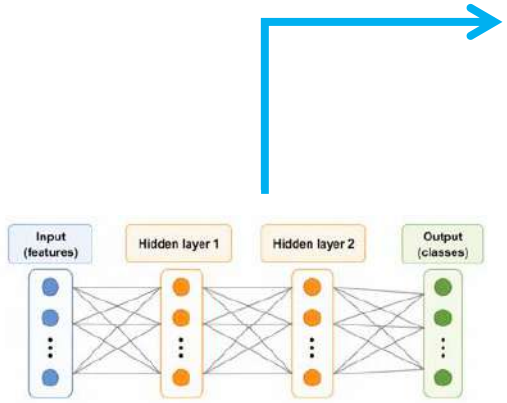


Volume de bois sur pied en 2024 (rés. 0,025 ha)

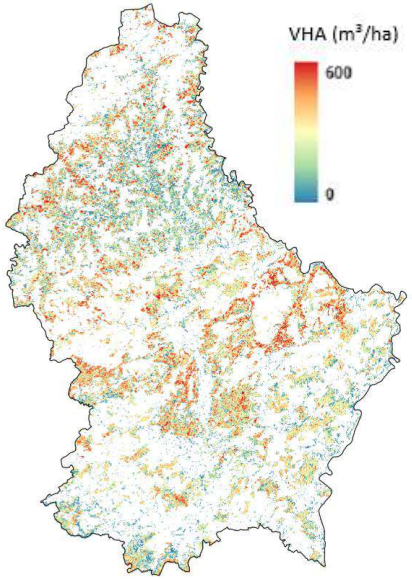
Ressource en bois

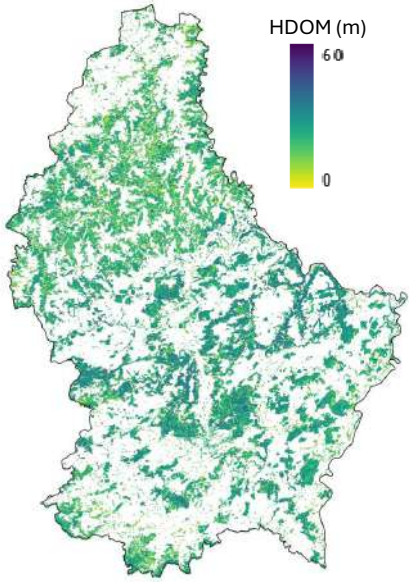


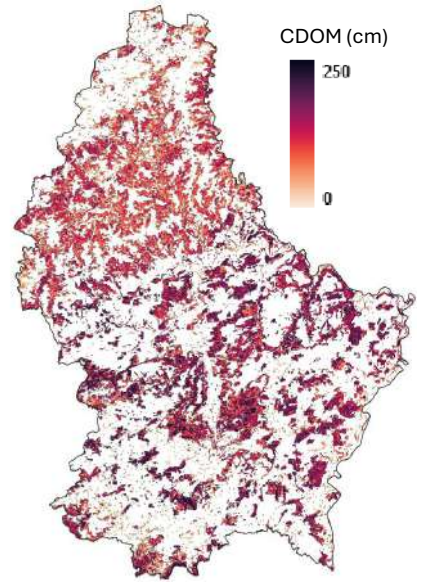
IFL3
(1577 placettes)

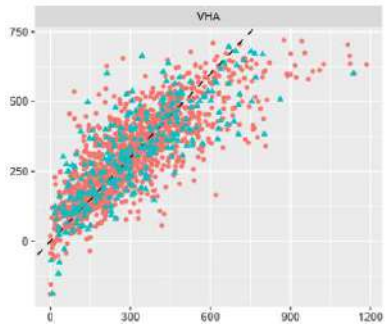


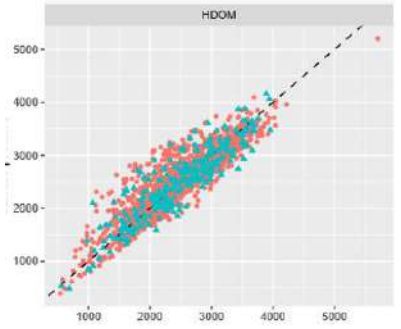
MLP Network

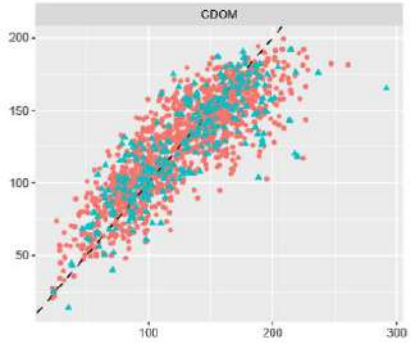


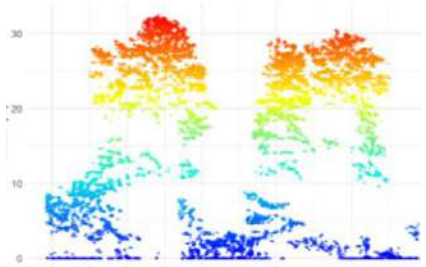




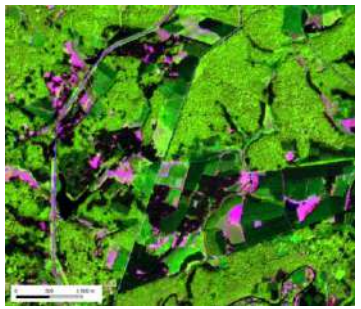








lidar 2024



Sentinel-2 2023-24

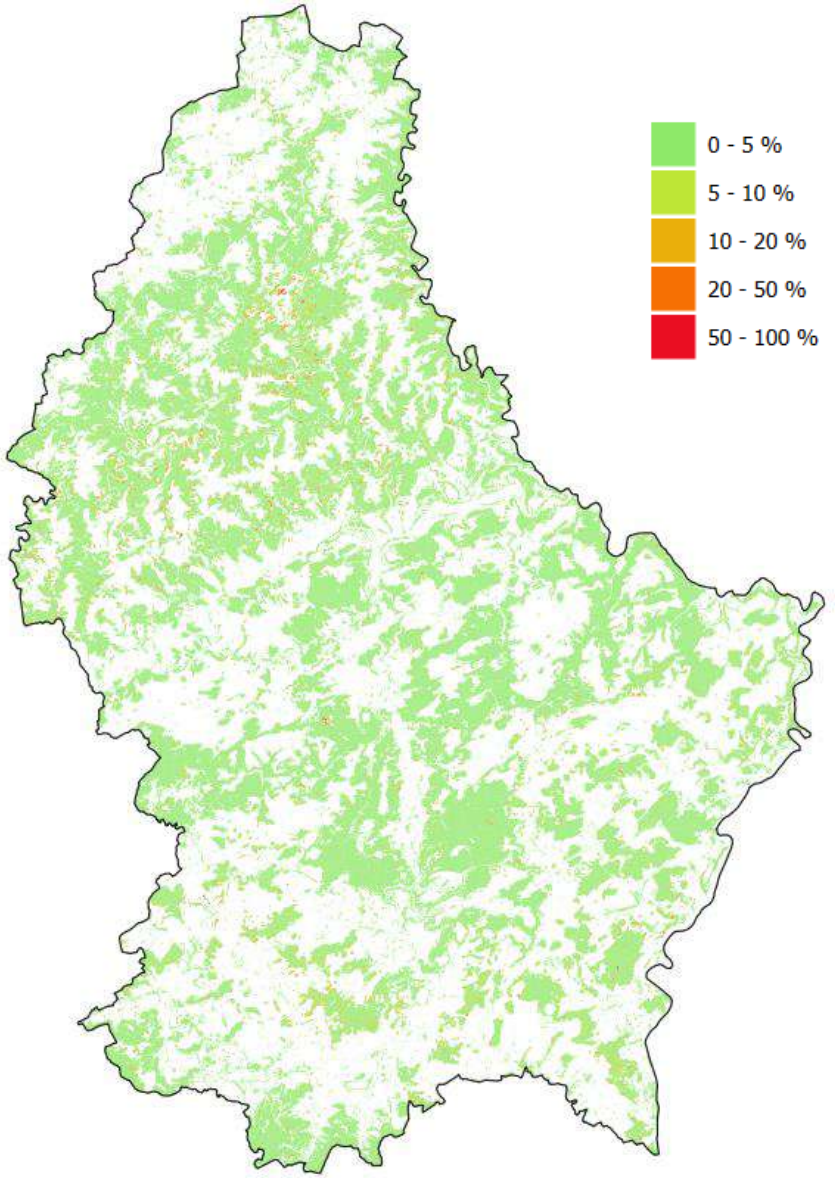
Prédictions basées sur un réseau neuronal perceptron multicouches
(VHA, GHA, NHA, Hdom, Cdom)



Vitalité/mortalité des arbres

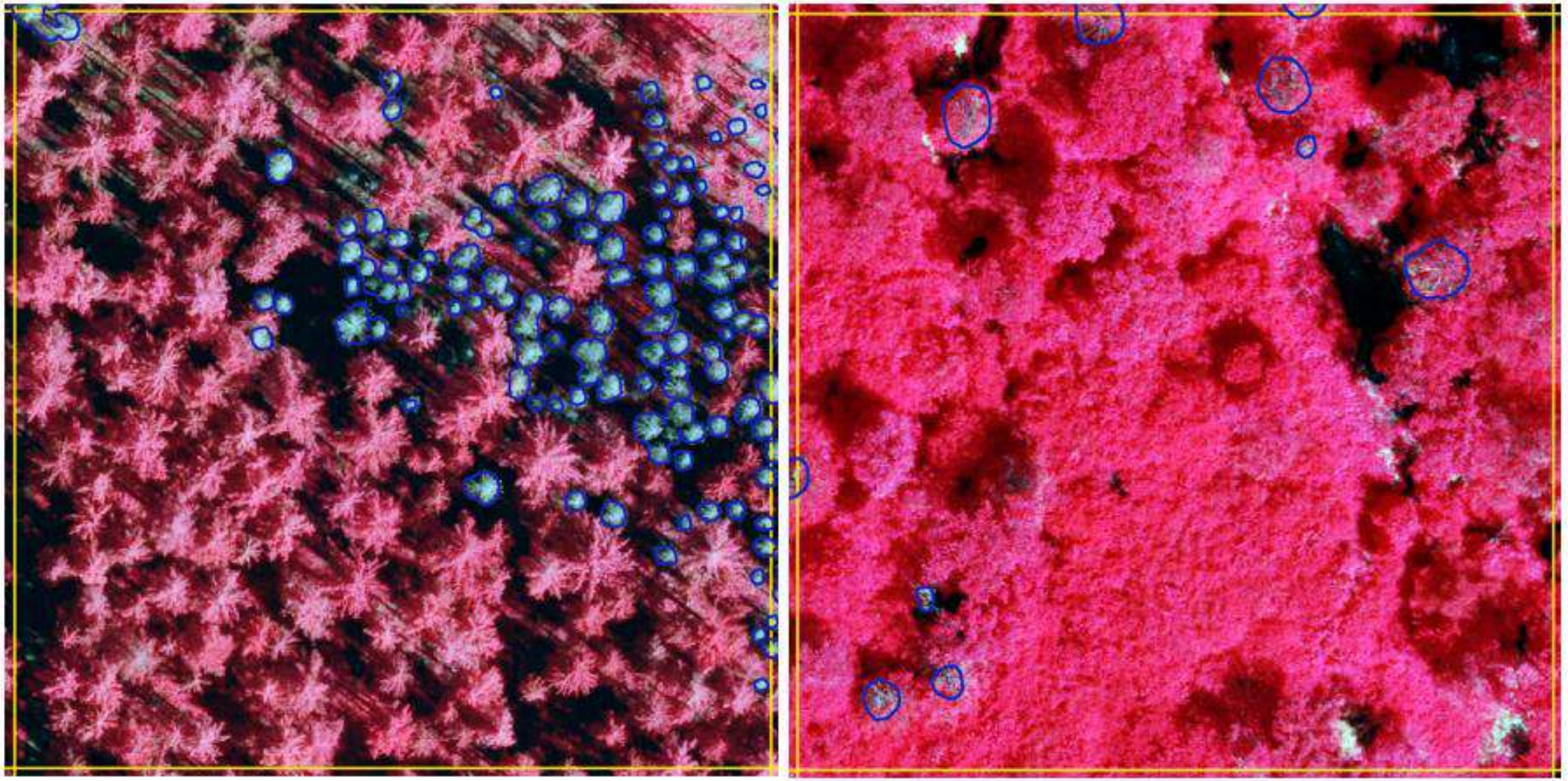
LIÈGE université
Gembloux
Agro-Bio Tech

Vitalité/mortalité des arbres et des peuplements



Pourcentage d'arbres morts en 2024 (rés. 0,1 ha)

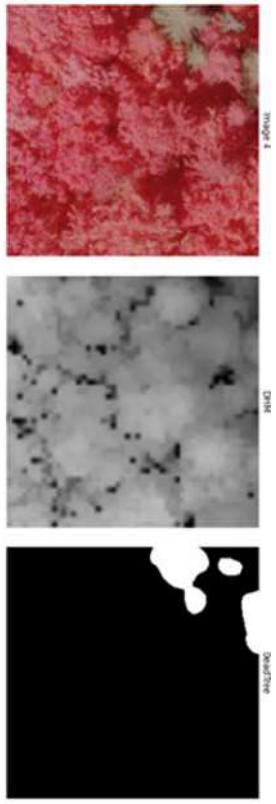
Vitalité/mortalité des arbres et des peuplements

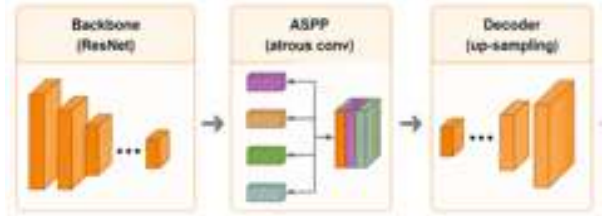


Numérisation de données d'entraînement (2300 ha)

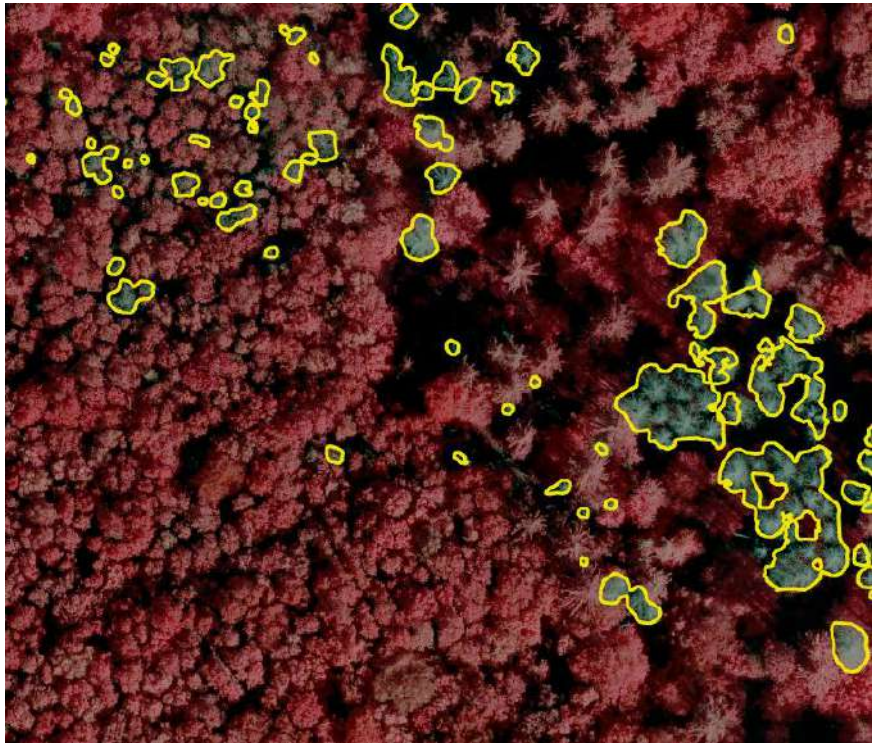
Orthoimage 2023 (rés. 10cm)

Vitalité/mortalité des arbres et des peuplements



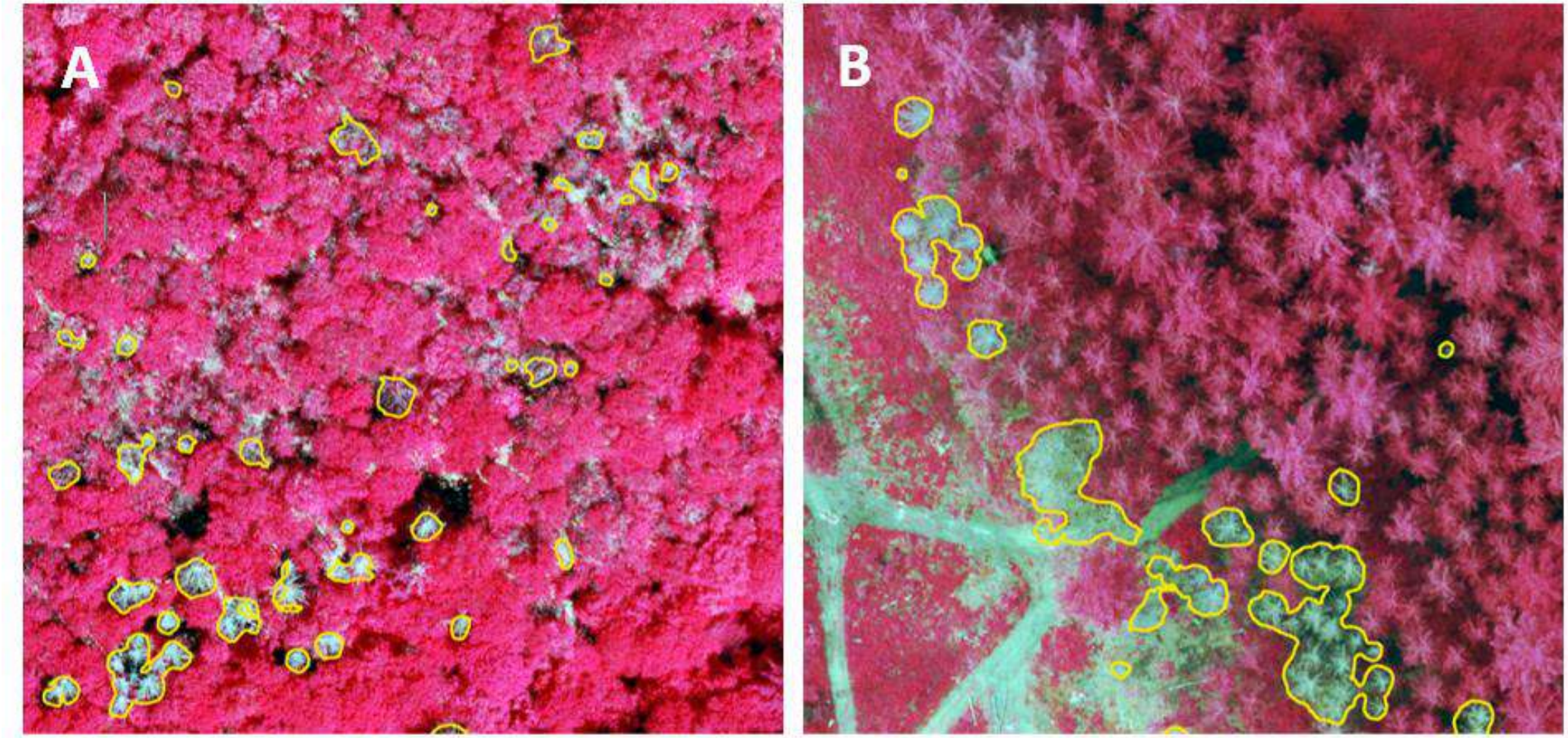


CNN



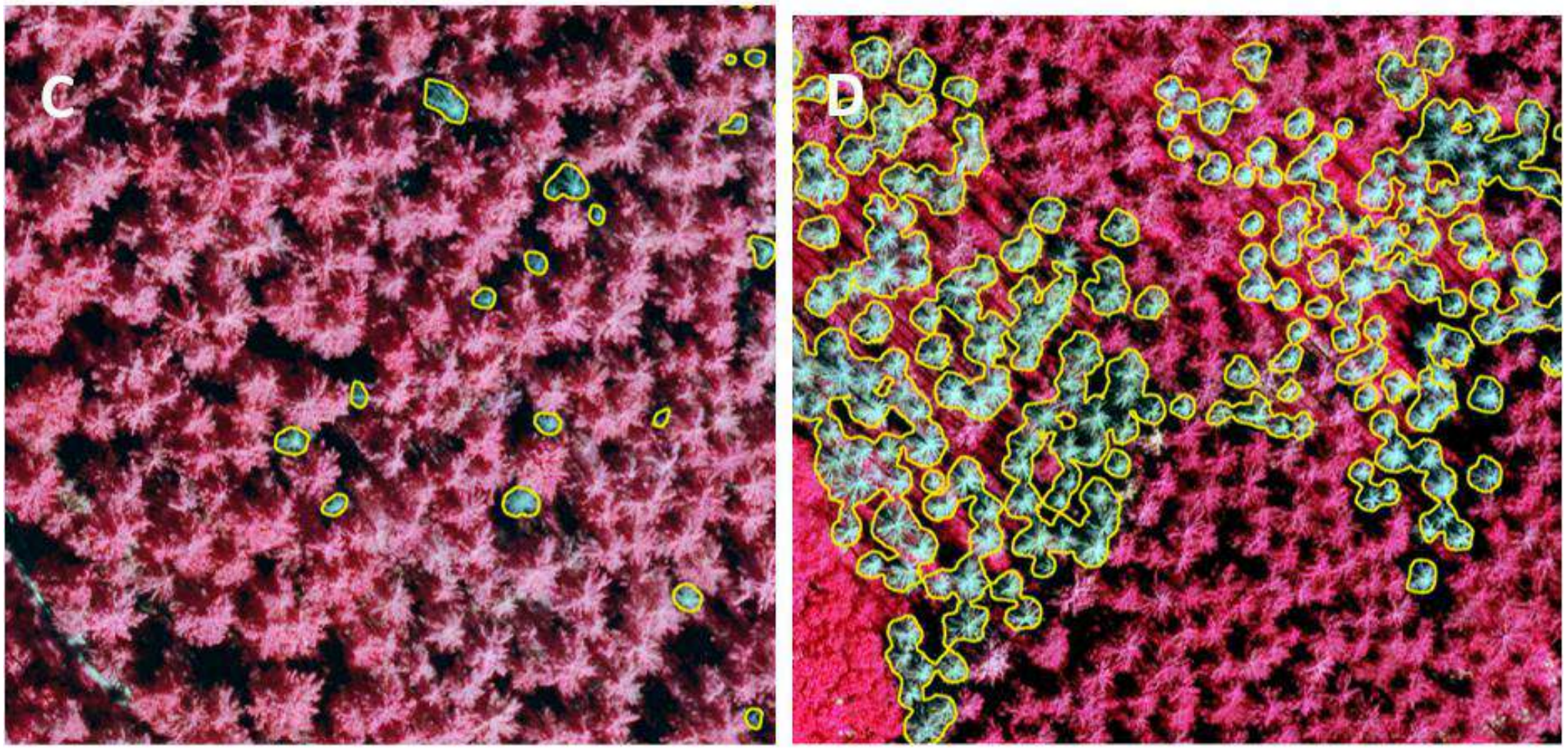
Utilisation d'un modèle de détection des arbres morts
par apprentissage profond (réseau neuronal convolutif)

Vitalité/mortalité des arbres et des peuplements



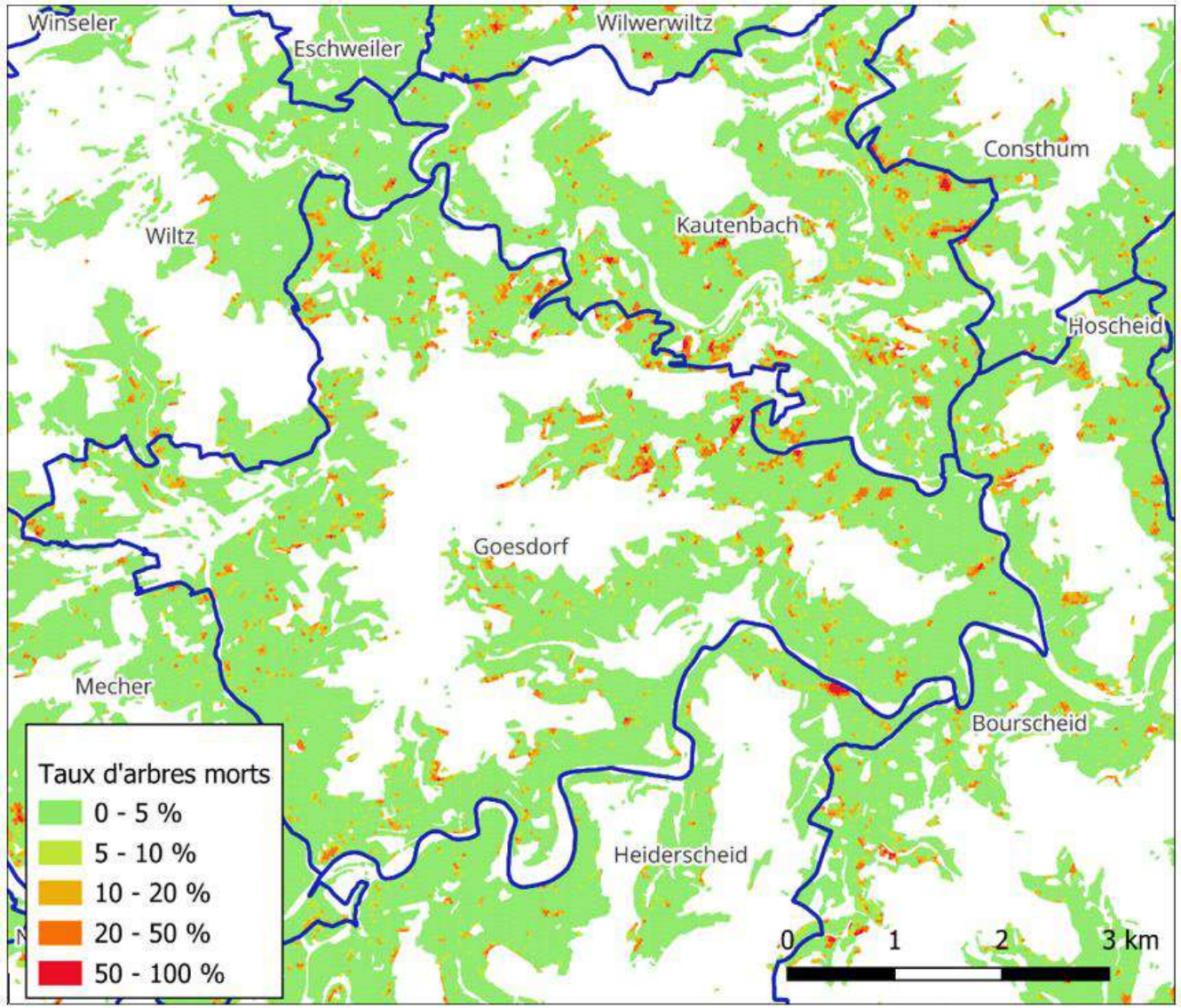
Précision de la prédiction : 98 %

Vitalité/mortalité des arbres et des peuplements



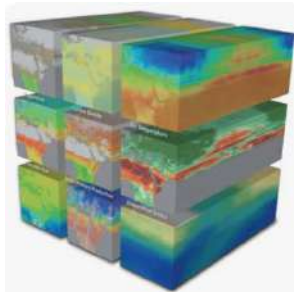
Précision de la prédiction : 98 %

Vitalité/mortalité des arbres et des peuplements



Agrégation des résultats à 0,1 ha

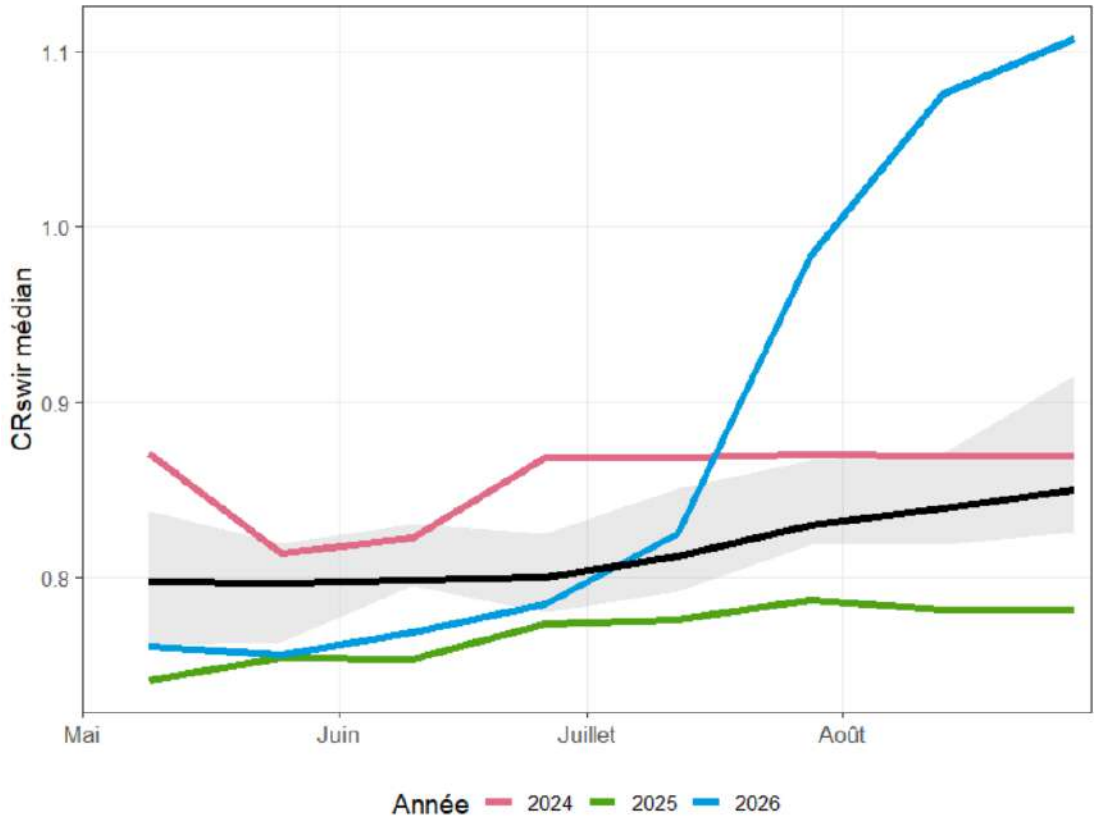
Vitalité/mortalité des arbres et des peuplements



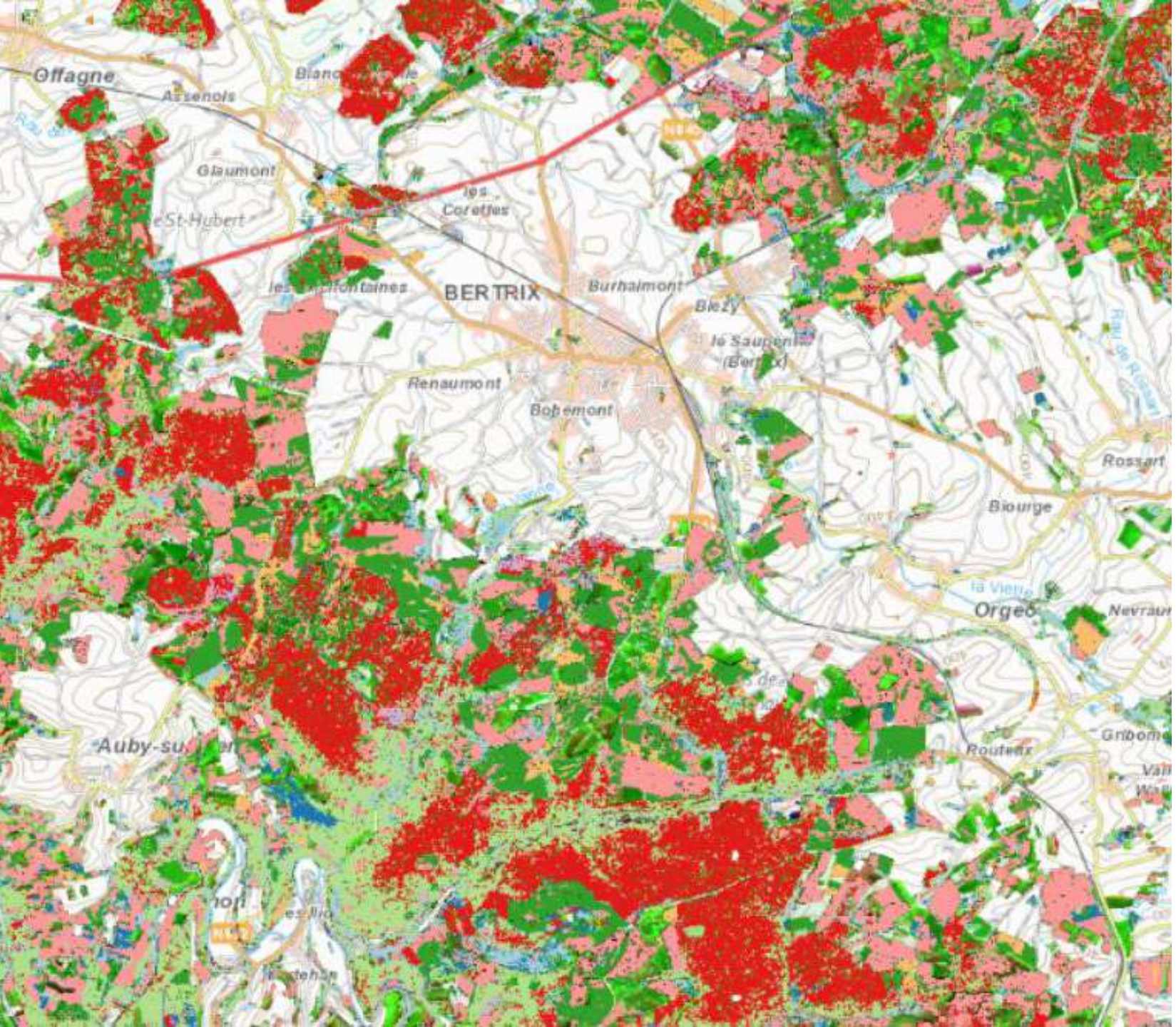
Exploitation d'un datacube Sentinel-2







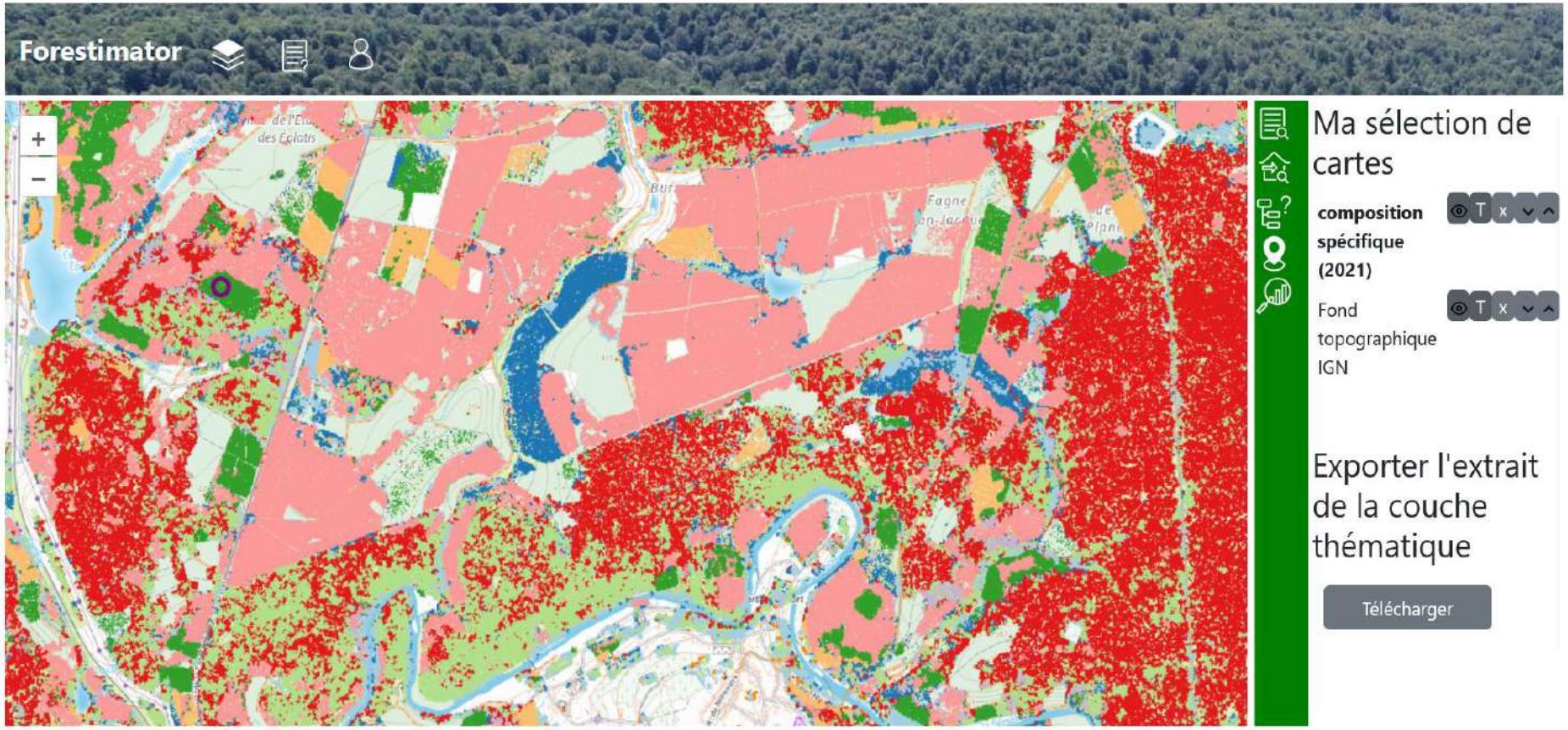
Vallée de la Semois (Belgique)

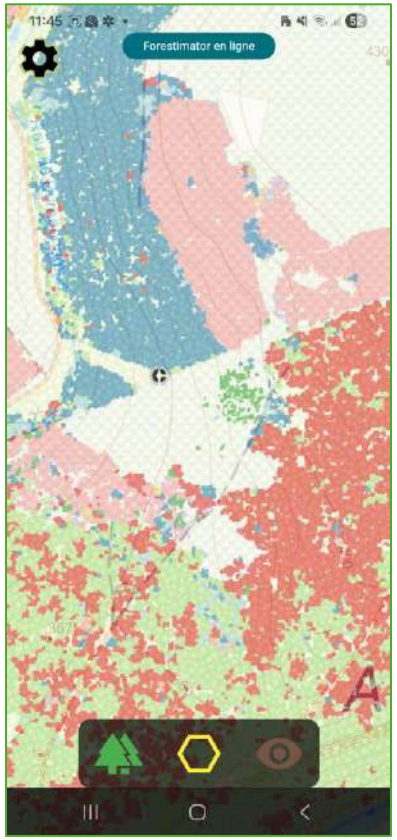


Accès aux données

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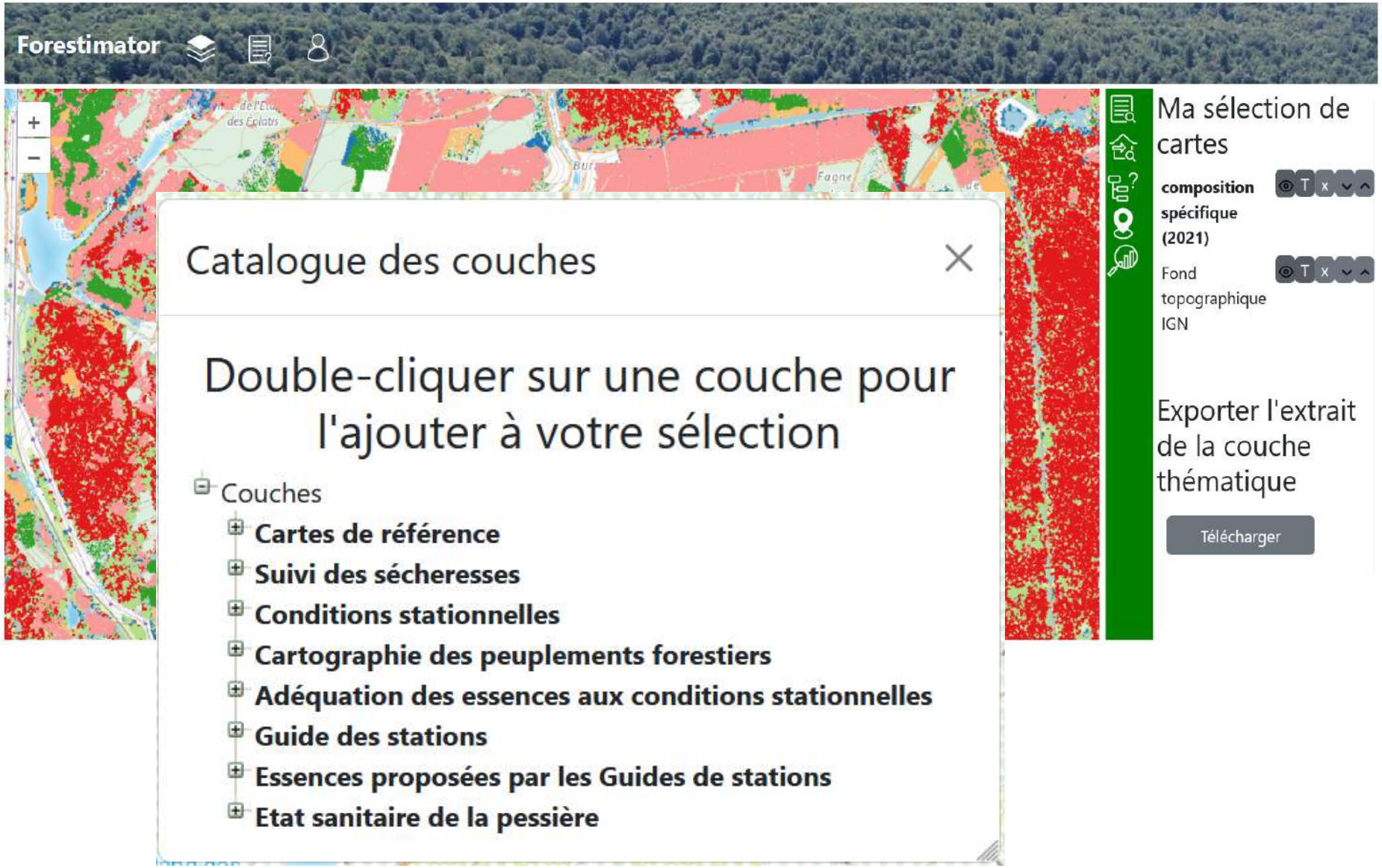
Accès aux données

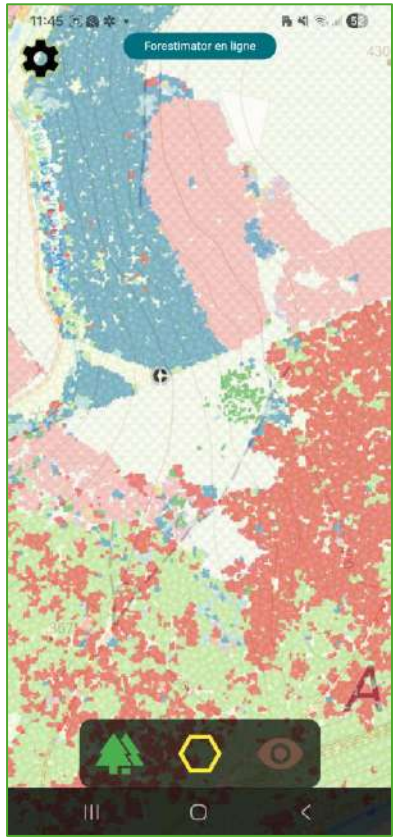




Forestimator web et Forestimator mobile (Wallonie)

Accès aux données





LIÈGE université Gembloux Agro-Bio Tech



Merci pour votre attention

LIÈGE université
Gembloux
Agro-Bio Tech
Forest Is Life

Administration
de la nature et des forêts
Grand-Duché de Luxembourg

Interreg
Grande Région | Großregion
Cofinancé par l'Union Européenne
Kofinanziert von der Europäischen Union

W.A.V.E.

Wallonie
environnement
SPW

29.10.2026

Wind Turbines and Camera Systems for Detecting Bird Activity

Guy Uhres
Head of Renewable Energies, Soler

soler

ENERGY FROM LUXEMBOURG
LET'S MAKE IT HAPPEN

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Key facts

Shareholders:

- **50% Société Électrique de l'Our (SEO) S.A.** – Operator of the Vianden pumped-storage power plant, with approximately 1,300 MW of installed capacity, making it the most powerful storage facility in the German high-voltage grid.
- **50% Enovos Luxembourg S.A.** – Luxembourg's largest energy supplier, providing electricity and gas, engaging in energy trading, and offering regional energy solutions as part of the Encevo Group.

Share capital: EUR 19,440,000

Chronological Overview and Activities:

Founded on 27 June 2001.

Since late 2011: Joint platform of SEO and Enovos for the development and management of renewable energy projects and facilities in Luxembourg and the Greater Region.

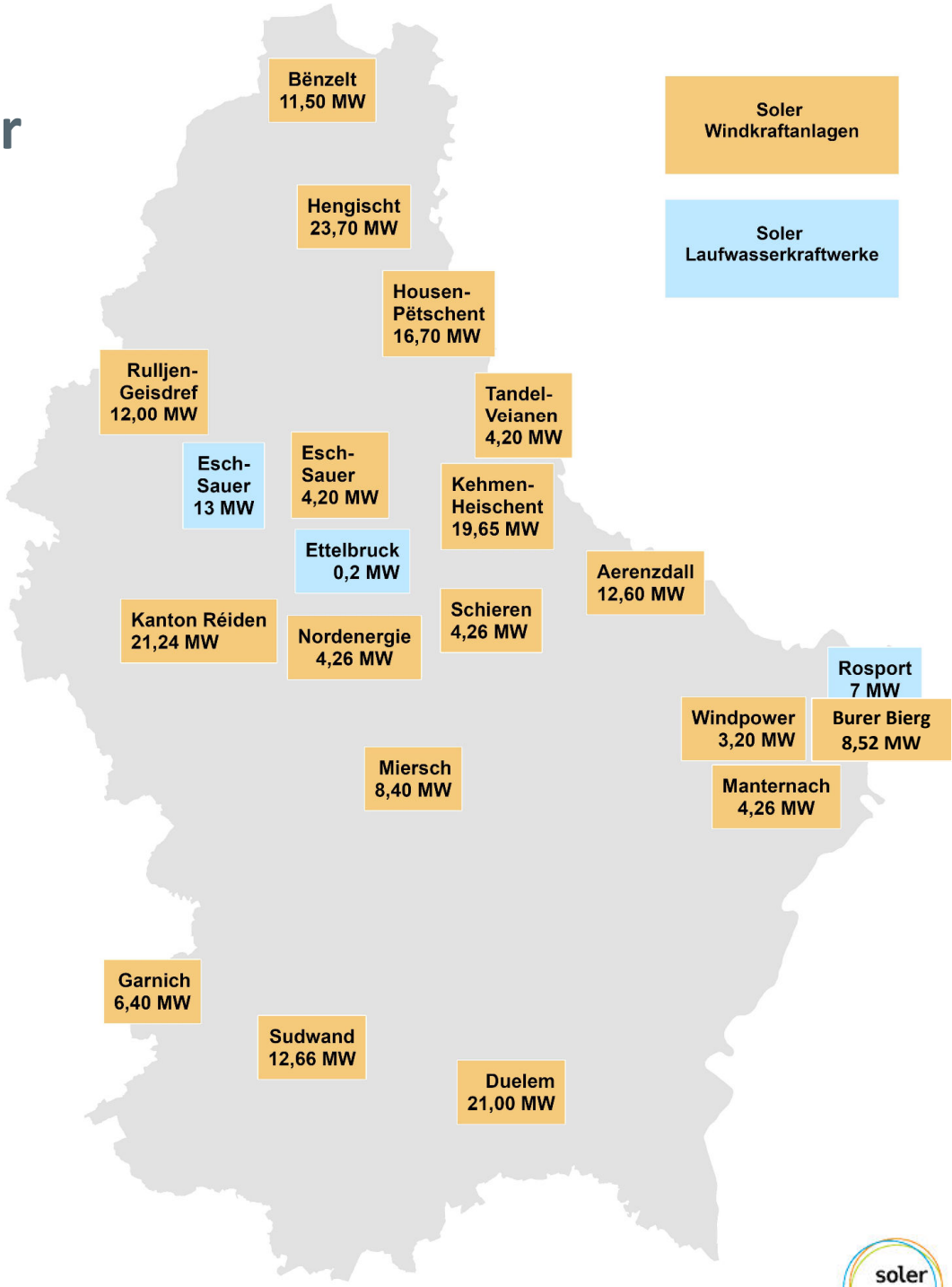
Since 1 April 2023: Independent developer and producer of renewable energy.

Activities

Wind Energie and Hydro Power

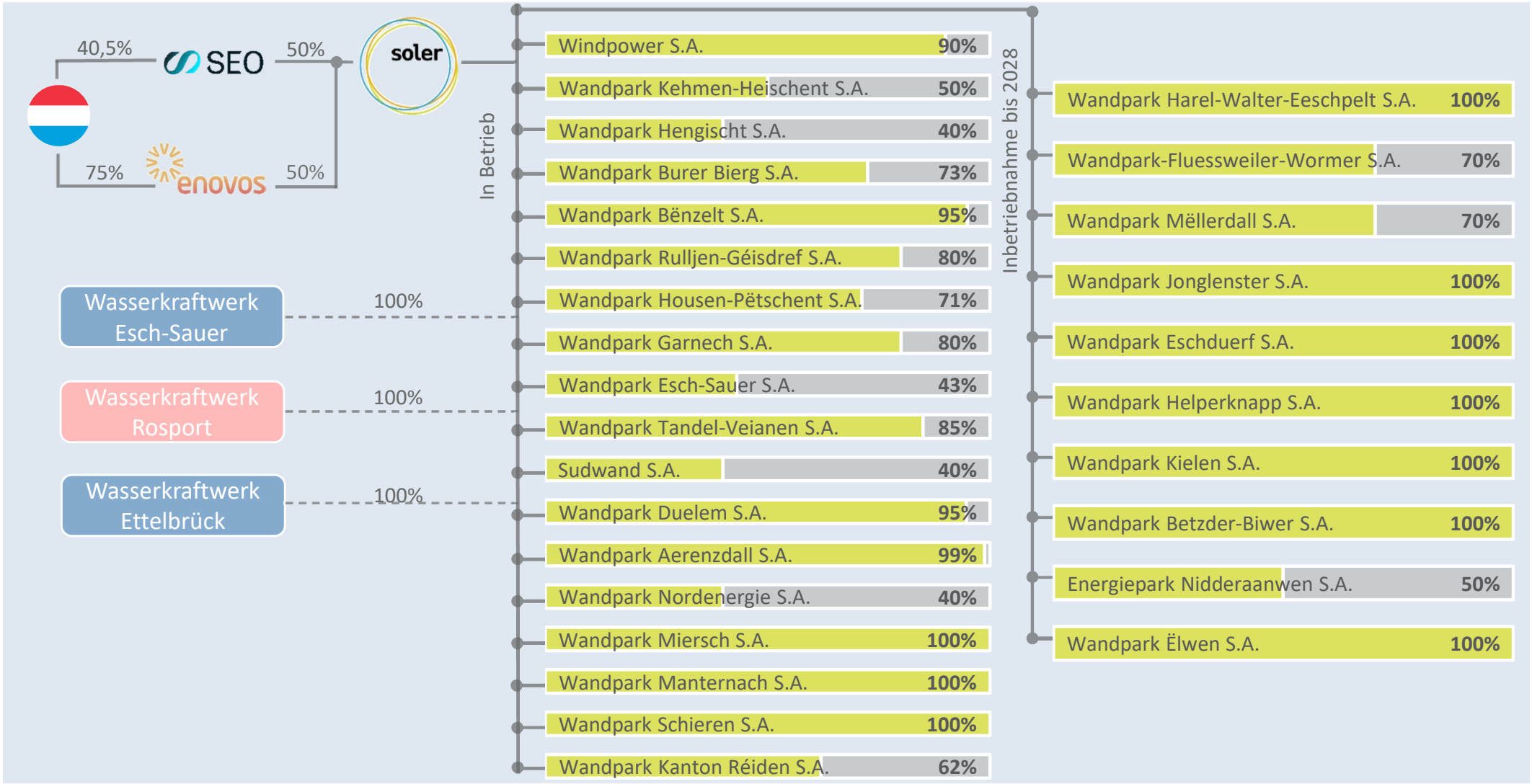
18 wind farms with a total of 57 wind turbines

Installed capacity of 198.75 MW



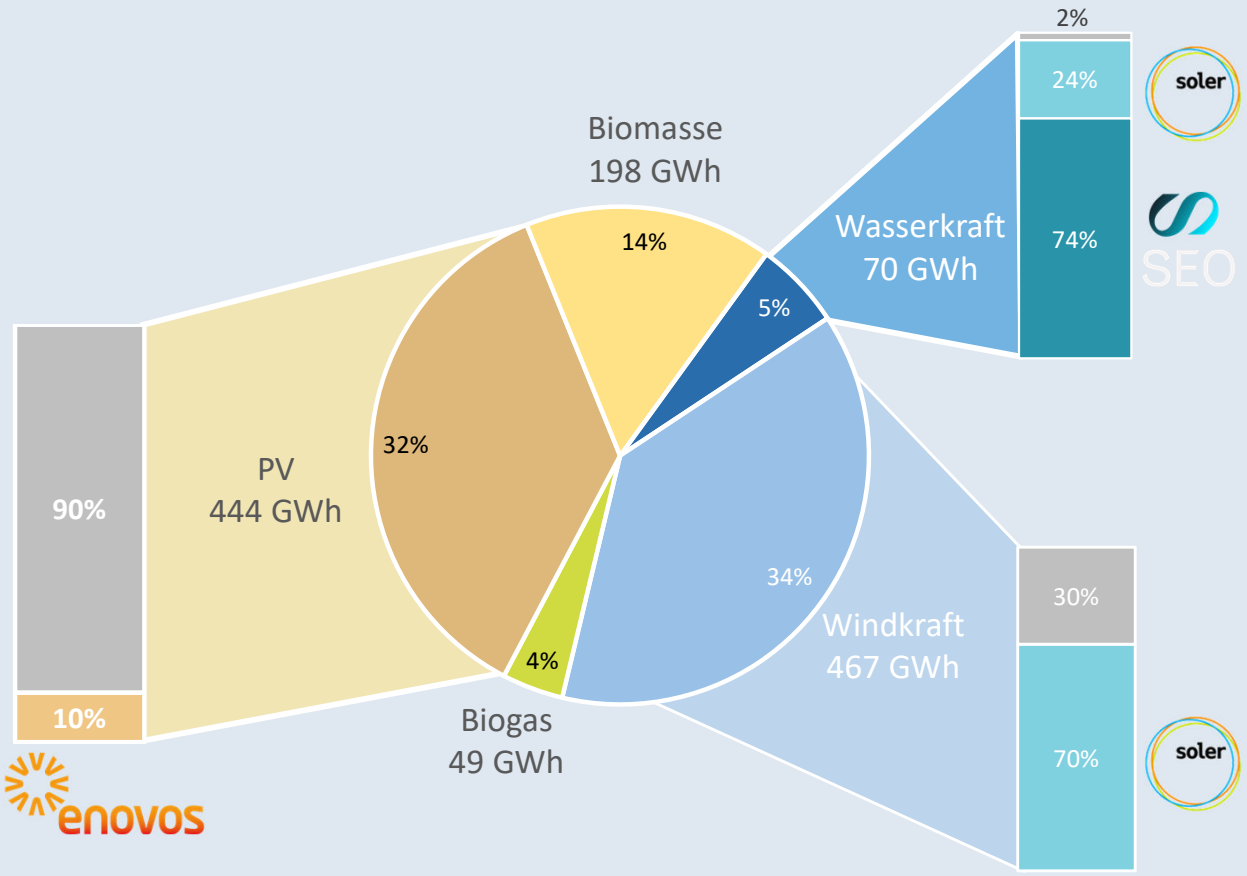
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Corporate Structure

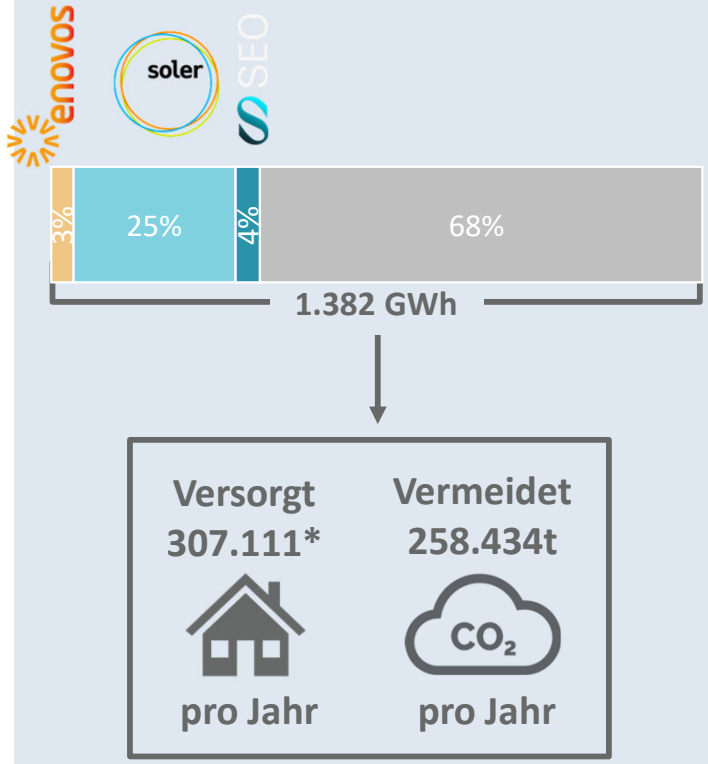


National Renewable Energy Production

Nationale EE-Produktion 1.382 GWh im Jahr 2025



Anteil an der nationalen EE-Produktion



**4 Personen Haushalte*

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Biodiversity Studies, Mitigation and Compensation Measures

- **In-house Environmental Specialist coordinating nature conservation measures**
  - **Preliminary Studies:**
  - Fauna surveys
  - Bat studies
- **Mitigation and Compensation Measures:**
  - Tree planting: 717 trees - mostly fruits
  - Native hedgerows (plantation): 3,645 m
  - Ecological extensification of land: 123.67 ha
  - And more …









Maintenance and Active Management of Nature Conservation Measures

Establishment of an in-house environmental department

Coordination of ecological monitoring programmes

Planning and management of compensation and CEF (Continuous Ecological Functionality) measures

Relationship with farmers, authorities and external environmental consultants

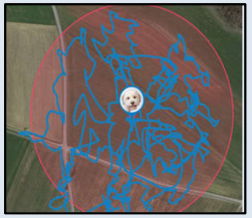




Support for Research and Pilot Projects

- SMART-System (Intelligent Bat Detector)
- Infrared-cameras (Bat Monitoring)
- Cooperation WIN-WIND
- Carcass searches (bird and bat mortality monitoring
- Red Kite monitoring (BIOSECO)
- Telemetry tracking of Red Kites and Black Kites


UNI Lëtzebuerg: Aufnahme Infrarot-Kamera






UNI Lëtzebuerg: Infrarot-Kamera


Fränk Kraus: Installation SMART-System 2025 Peppange

Milvus mulvus

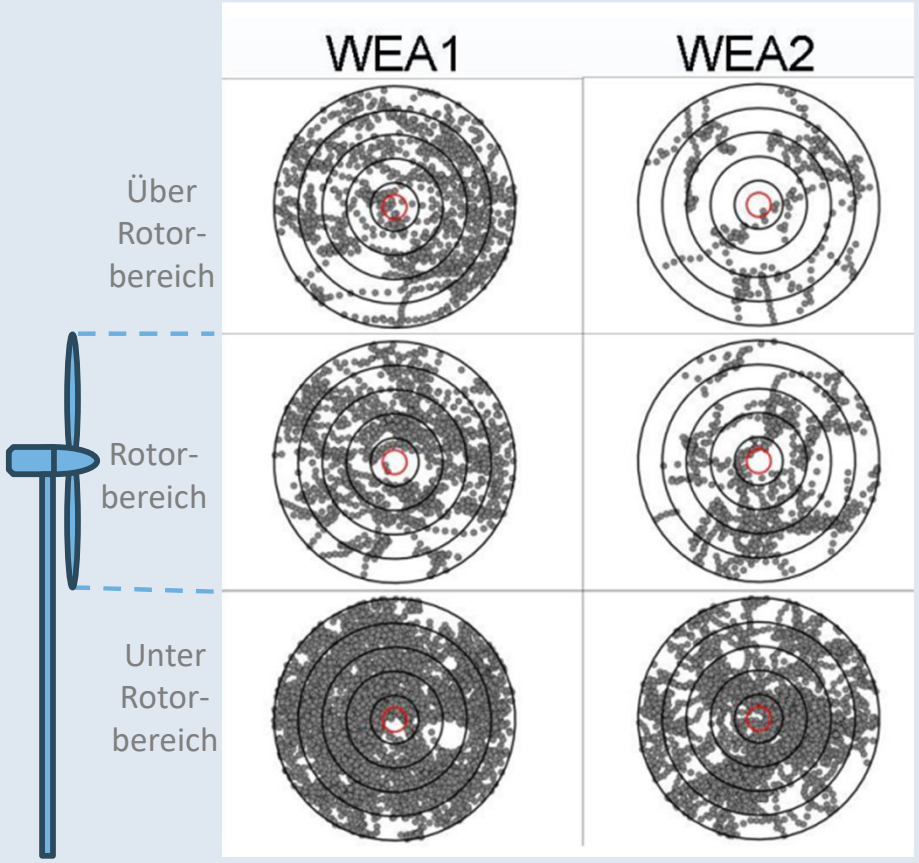
- Species listed in Annex I of the EU Birds Directive (Natura 2000)
- Luxembourg Red List: Vulnerable (VU)
- Species of open landscapes, nesting mainly in isolated trees and small groups of trees
- Declining across Europe due to habitat destruction and degradation, and poisoning, but increasing in Luxembourg and Belgium



Operational Monitoring
Raptor Telemetry to Assess Operational Risk



GPS-Punkte Draufsicht 500m-Radius



- Telemetric tracking of flight movements in the vicinity of the wind turbines from 2019 to 2021
- Height-specific monitoring within a 500 m radius of two wind turbines at Housen-Petschent
- Mapping of relevant distance zones in relation to the rotor-swept area

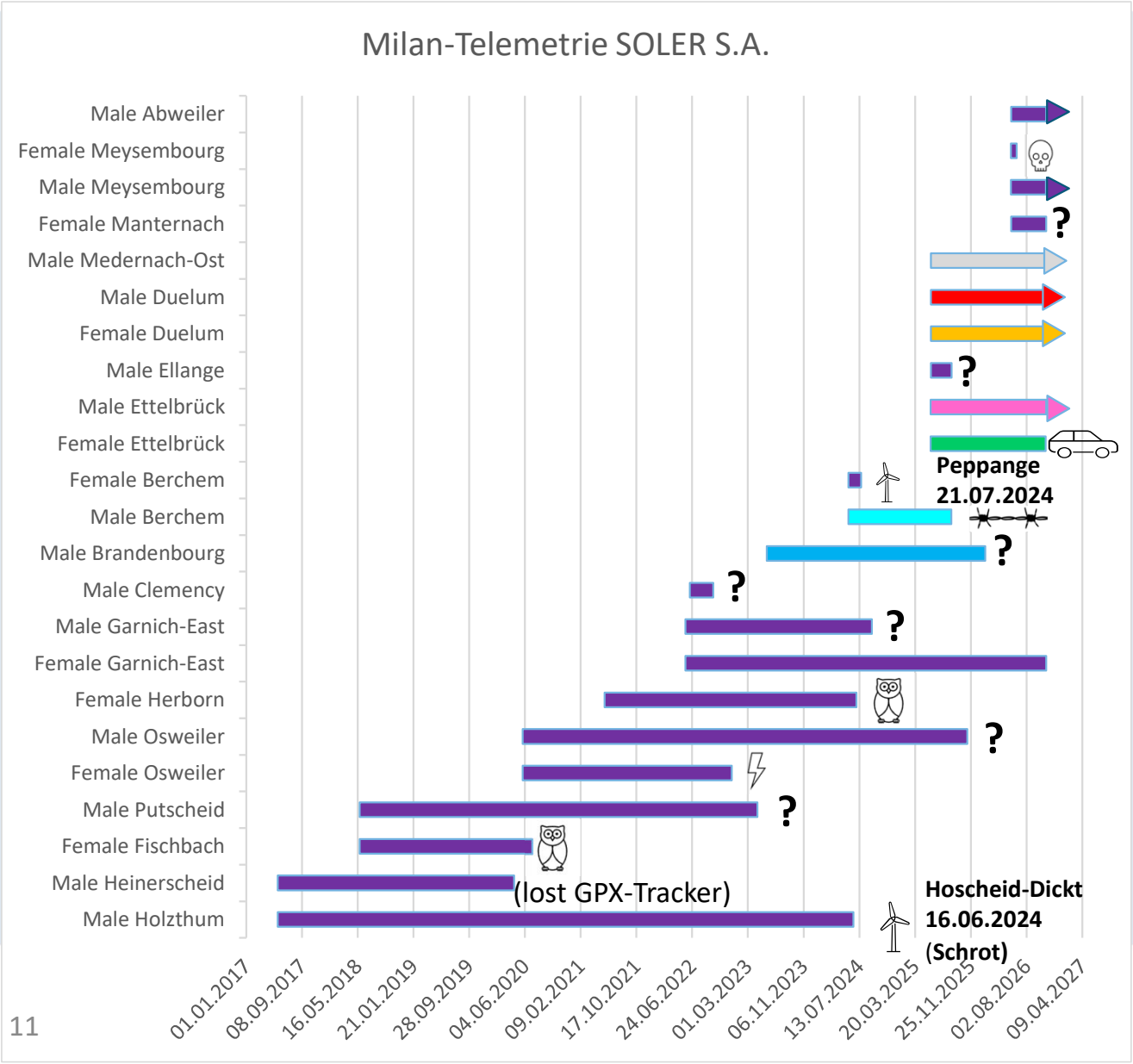
Rotorbereich

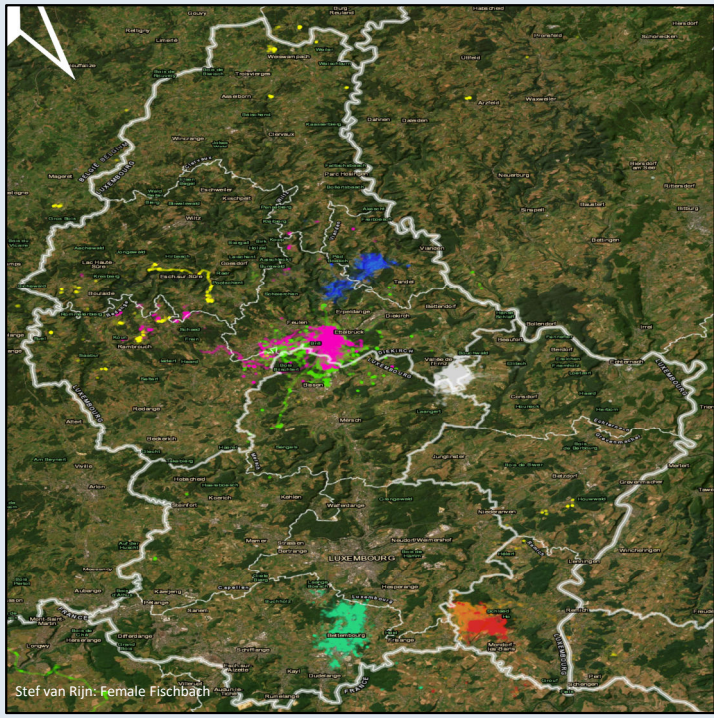
Distanzzonen in 100m-Schritten

Detailed Analysis

Red- and Black Kite Telemetrie







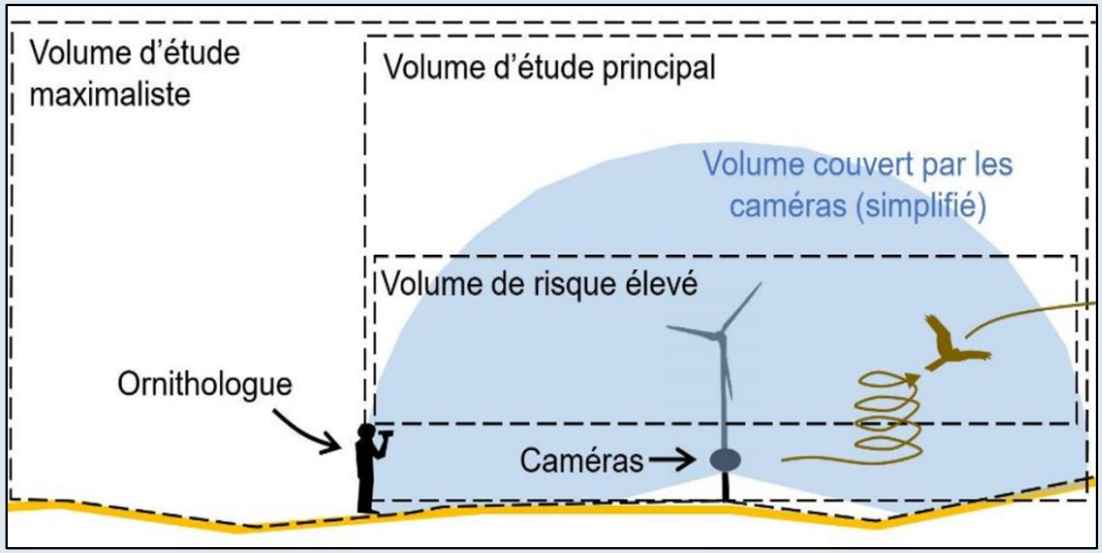
Todesgrund:

- Verkehr
- WEA
- Stacheldraht
- Raubvogel
- Stromschlag
- Vergiftet
- ? Grund unbekannt

Operational Monitoring

BIOSECO-System → Pilotproject WP Aerenzdall

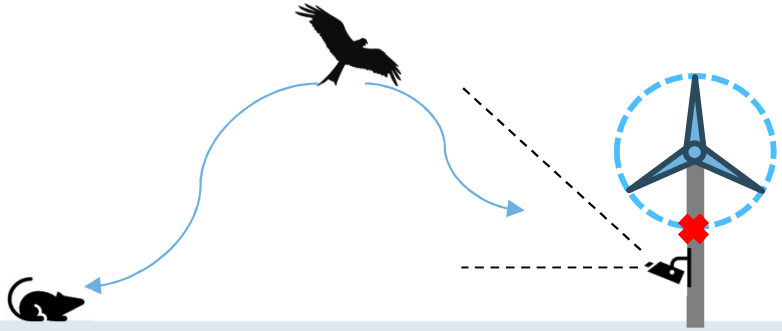
- AI-powered camera system for bird detection
- Automated real-time detection of potential collision risks
- Reduction of bird collision risk



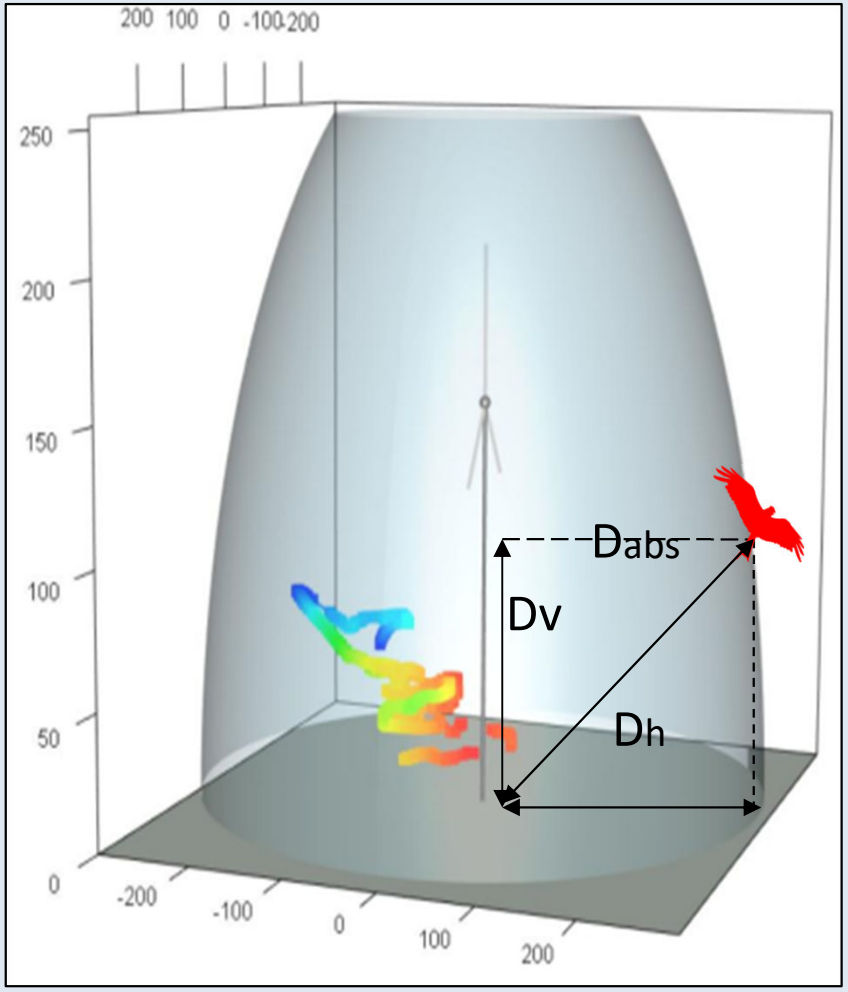


Operational Monitring

BIOSECO-System



- Shutdown Criteria:
  - Wingspan > 1.2 m (large birds)
  - Horizontal distance < 300 m
  - Vertical distance < 260 m
- Unlike conventional systems, no deterrent measures such as sirens or strobe lights are used.



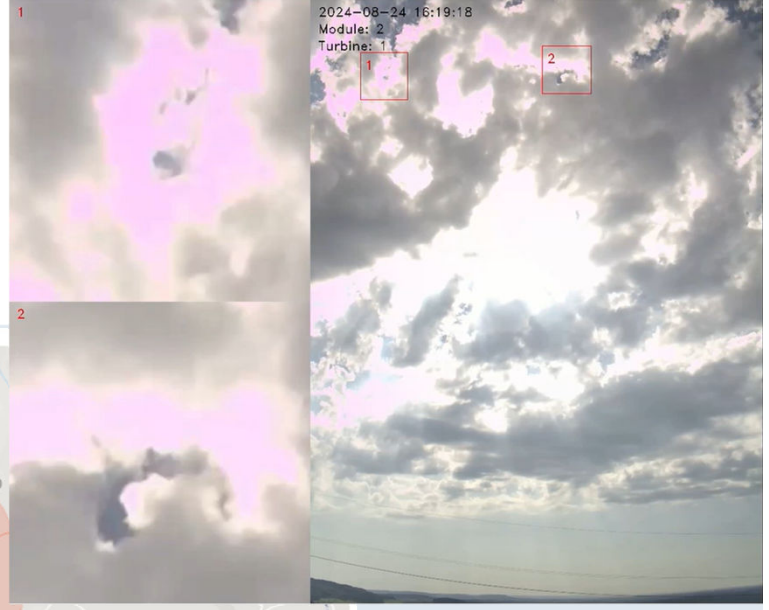
Operational Monitoring

BIOSECO-System



False Alarms

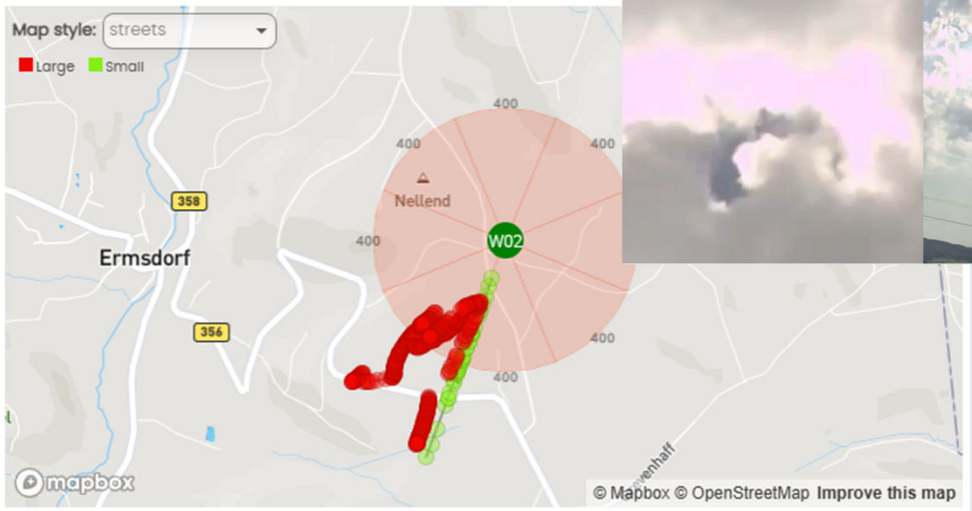
Unintended Shutdowns in Diffuse Cloud Cover



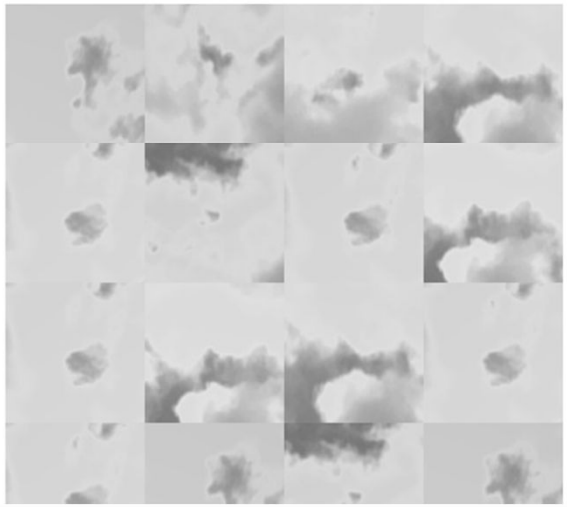
Turbine	WTG 02
Date	2024-08-24 16:19:14
Size category	Large
Turbine stopped	YES
Turbine stop request	from: 16:17:33 to: 16:22:33

Show video

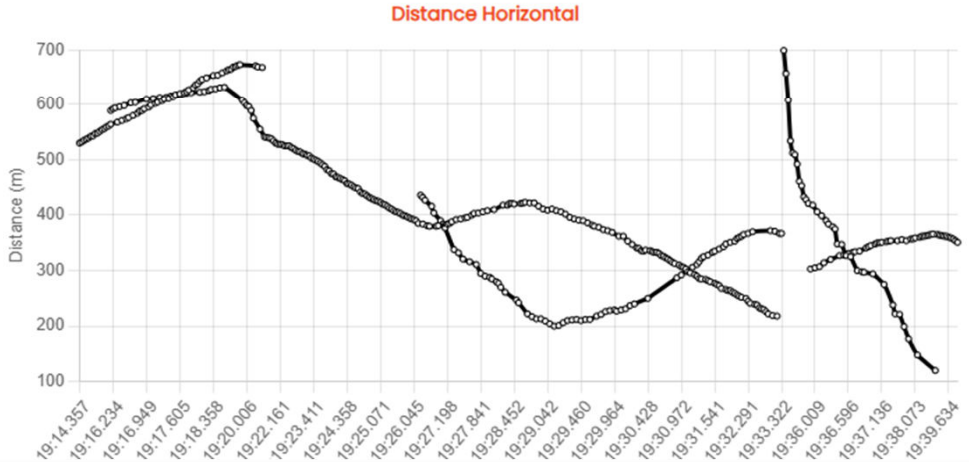
Show rotor video



Miniatures



Distance Absolute | Distance Vertical | Distance Horizontal



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False Alarms

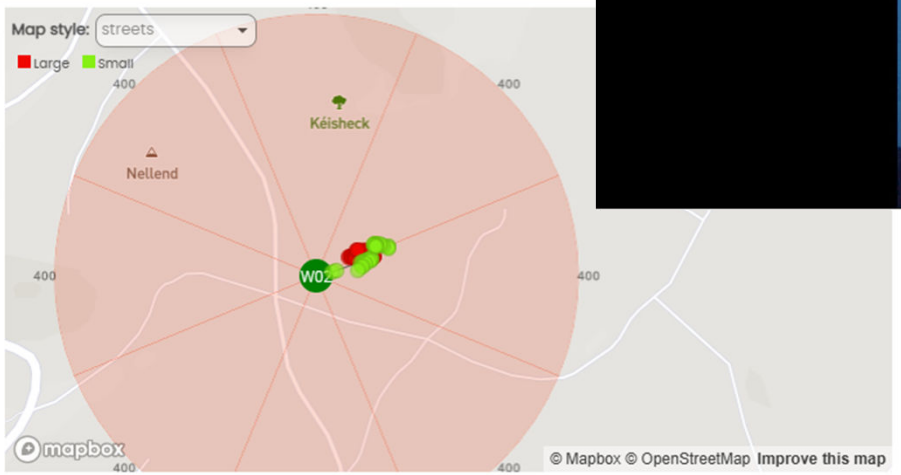
Increased False Detection Rates Under Twilight Conditions



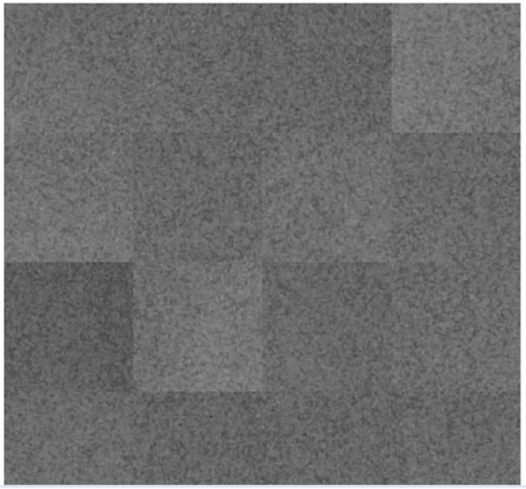
Turbine	WTG 02
Date	2024-08-24 20:36:05
Size category	Large
Turbine stopped	YES
Turbine stop request	from: 20:33:15 to: 20:39:24

Show video

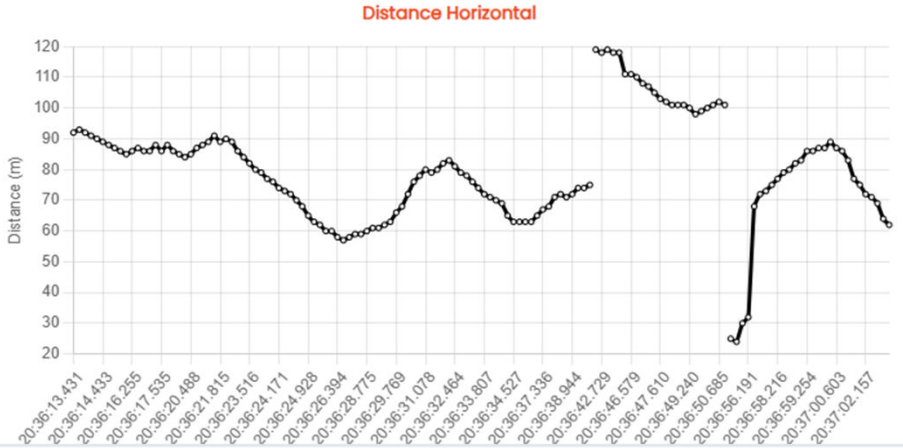
Show rotor video



Miniatures



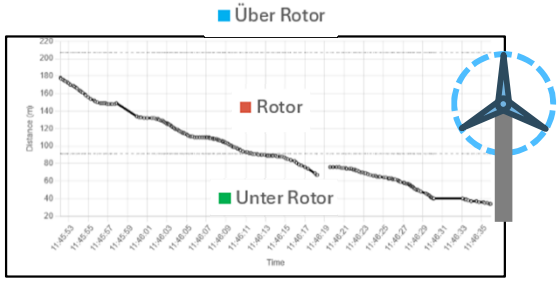
Distance Absolute | Distance Vertical | Distance Horizontal



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Operational Monitoring

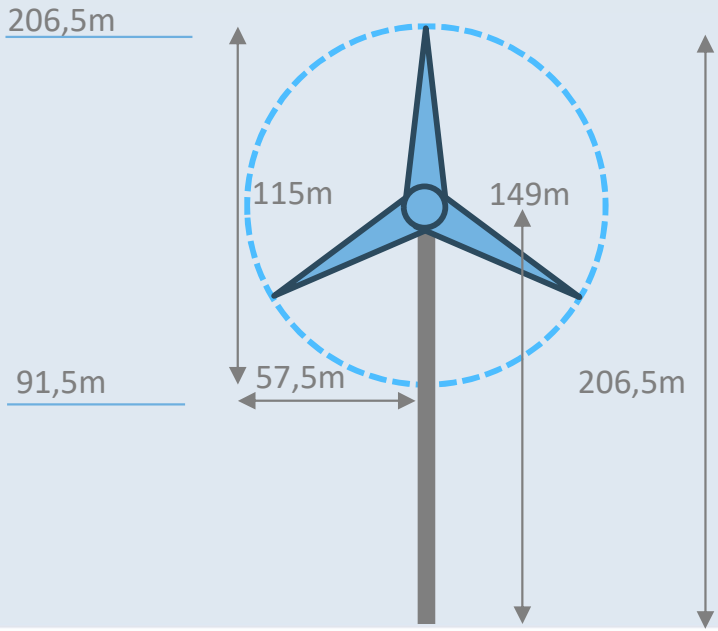
BIOSECO-System → Evaluation of the Aerenzdall Pilot Project



Radius / Flughöhe	300m	57,5m
Gesamt Detektionspunkte Bezüglich Gesamtpunkte Bezüglich Radius	799.851 76,28% 100%	121.511 11,59% 100%
Detektionspunkte Über Rotor Bezüglich Gesamtpunkte Bezüglich Radius	11.606 1,11% 1,45%	0 0% 0%
Detektionspunkte im Rotorbereich Bezüglich Gesamtpunkte Bezüglich Radius	85.811 8,18% 10,73%	156→**3 Vögel** 0,01% 0,13%
Detektionspunkte unter Rotor Bezüglich Gesamtpunkte Bezüglich Radius	702.434 66,99% 87,82%	121.355 11,57% 99,87%

Testphase 01.04.-03.06.2024
Gesamt 1.048.575 Detektionspunkte

Enercon E115



Visualisation

Analysis of 3 Birds (156 Detection Points) Within the Rotor-Swept Area

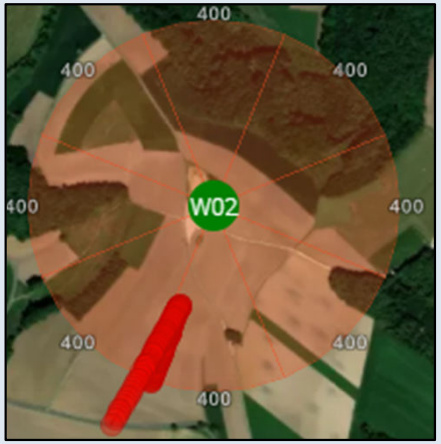


Rotor

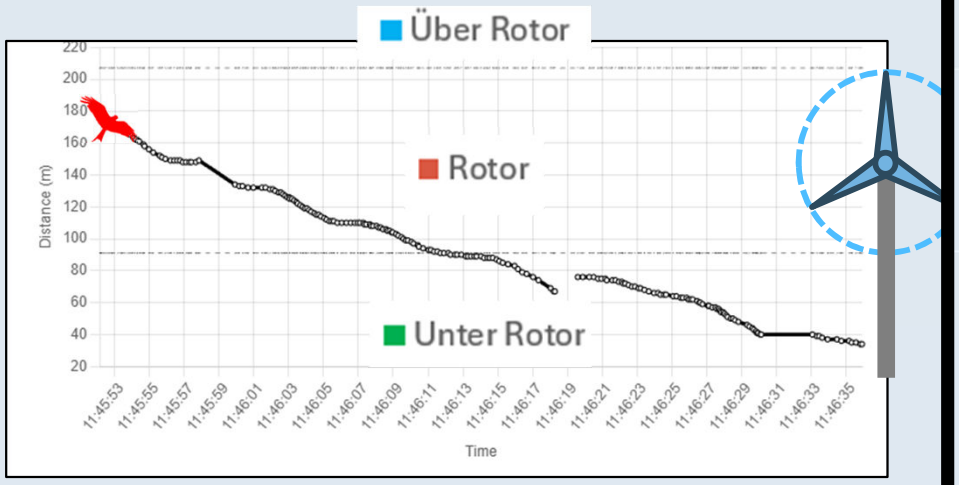
Operational Monitoring

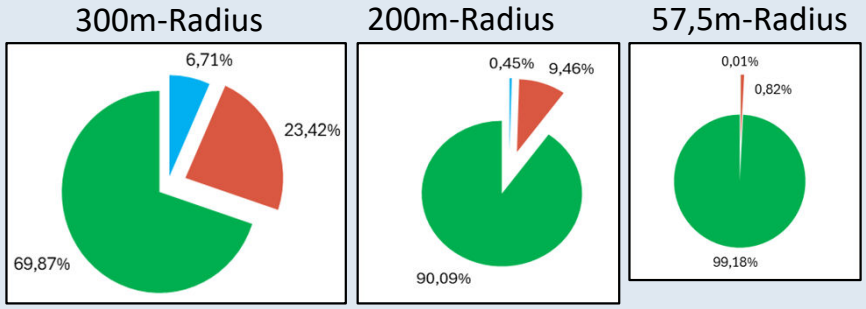
BIOSECO-System → Evaluation of the Aerenzdall Pilot Project

Vögel drehen um

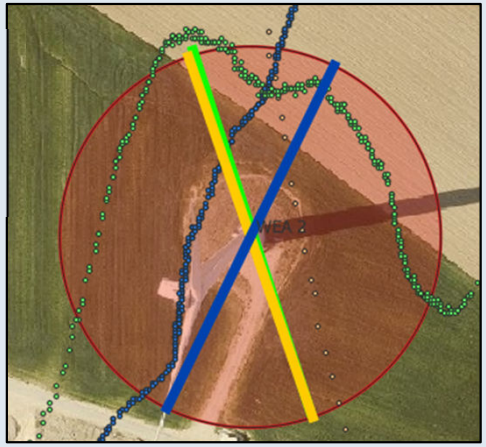


Vögel tauchen ab





Ausweichverhalten



Thank You!

For your attention

Kontakt :

info@soler.lu

www.soler.lu

REGIONALER, PARTIZIPATIVER UND NACHHALTIGER ANSATZ



MINISTÈRE DE L'AGRICULTURE

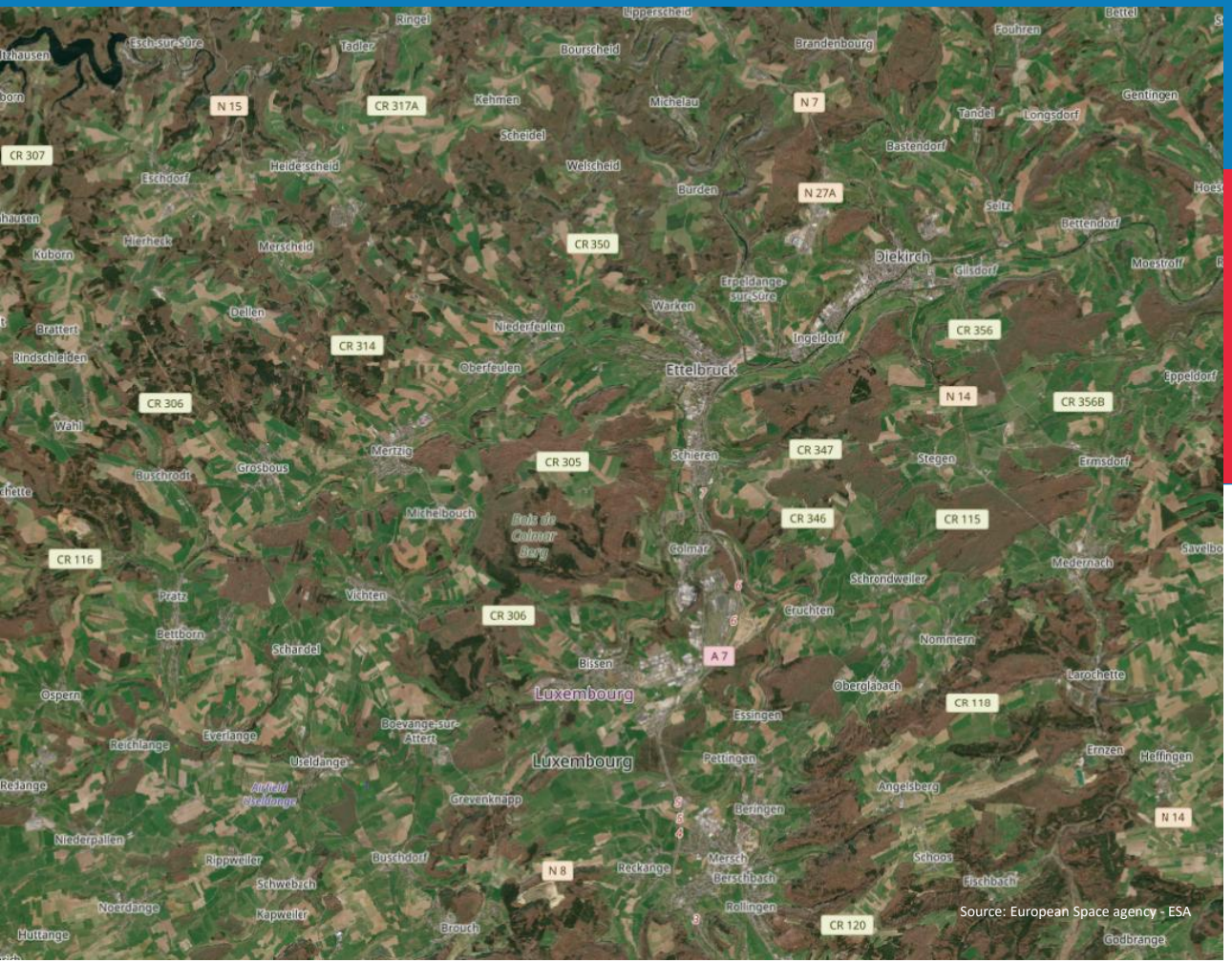
DE L'ALIMENTATION ET DE LA VITICULTURE

Monitoring agricultural activities with satellite data in the framework of the CAP

Colloquium « Earth from above »

29th of october 2026

LE GOUVERNEMENT
DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de l'Agriculture,
de l'Alimentation et de la Viticulture
Service d'économie rurale



Source: European Space agency - ESA

Introduction

The framework of the common agricultural policy

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DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de l'Agriculture,
de l'Alimentation et de la Viticulture
Service d'économie rurale

Overview

The framework of the CAP

- The CAP at a glance
- Implementation timeline of the area monitoring system

Data, algorithms and more

- Imagery used
- Algorithms: Basic principles
- Results
- Timeline of the calculations
- Treatment of the results
- Expert judgment
- Rapid field visits and geo-tagged photos
- Experiences and challenges

Outlook

The framework of the CAP

National Strategic Plan 2023 – 2027:

More than 100 aid options

Geospatial Aid Application

100%
Administrative controls

x %
on the spot controls

Control of the Paying Agency through the Certification body (IGF via KPMG)

Annual Performance Report APR

The framework of the CAP

Implementation timeline:



The area monitoring system is obligatory since 2023

To be ready for 2023, we started the implementation in 2018.

Pilot Project with UCLouvain 2019-2022 : **LEO4CAP**

3 Use cases are implemented:



- **Correct Division and Reporting of Agricultural Parcels:**

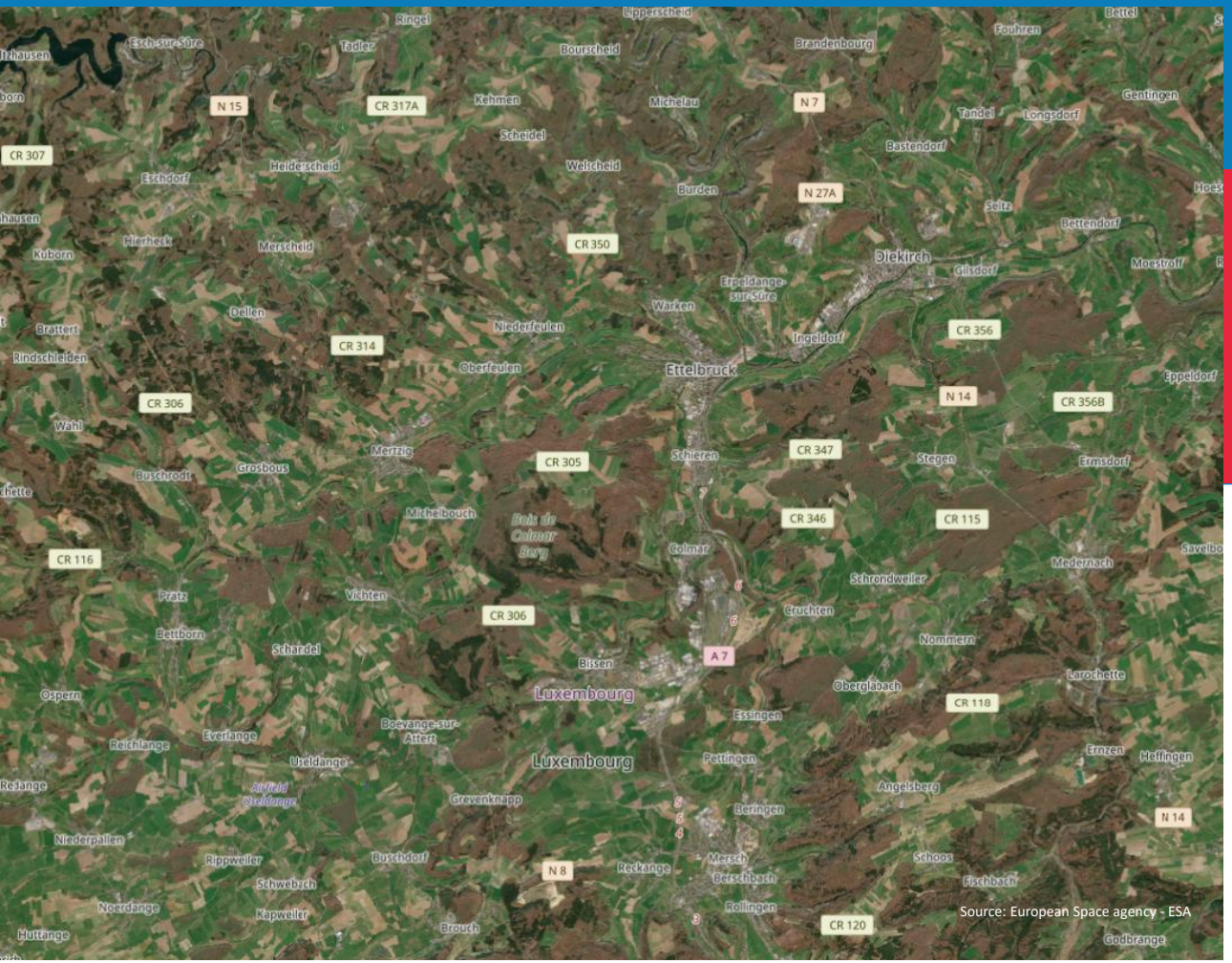
Verification of the correct division of parcels.
Verification of non-agricultural areas reported (construction sites, new buildings, etc.).

- **Crop type identification**

Identification of different crop groups.

- **Verification of a minimum agricultural activity**

Identification of scrub encroachment.



Source: European Space agency - ESA

The Area Monitoring system

Data, algorithms & more

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Service d'économie rurale

Data, algorithms & more

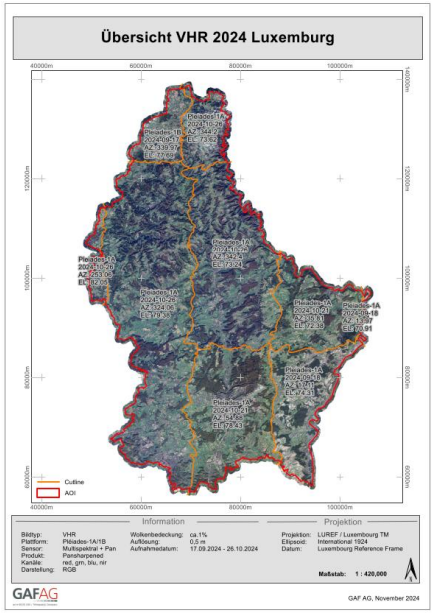
Imagery used

Sentinel 2 & Sentinel 1 : Backbone of the Area Monitoring System.

Sentinel 1 (RADAR)
Pixel resolution: 20 x 20 m
Every 6 days an image

Sentinel 2 (multispectral imager with 13 spectral bands)
Pixel resolution: 10 x 10 m
At least every 5 days an image (less with 3 satellite constellation)

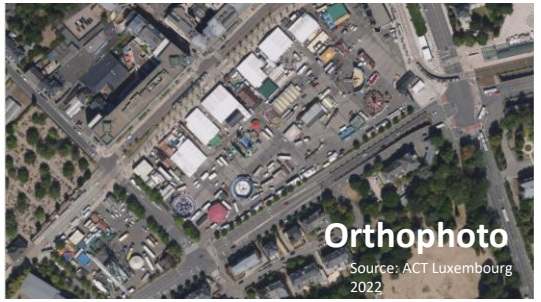




VHR Airbus Pléiades
Pixel resolution: 0,50 x 0,50 m
1 image, mosaic of the whole country
Acquisition window: 15 Mai – 15 August
Delivery in 2 instalments: 1st of July + 15th August



ACT Orthophotos
Pixel resolution: 0,10 x 0,10 m
1 image, mosaic of the whole country
Delivery: December N / January N+1



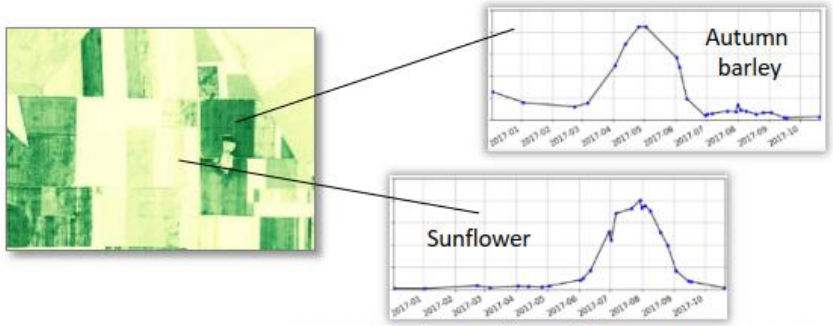
Data, algorithms & more

The use of Sentinel 1 & Sentinel 2 Imagery: Basic principles

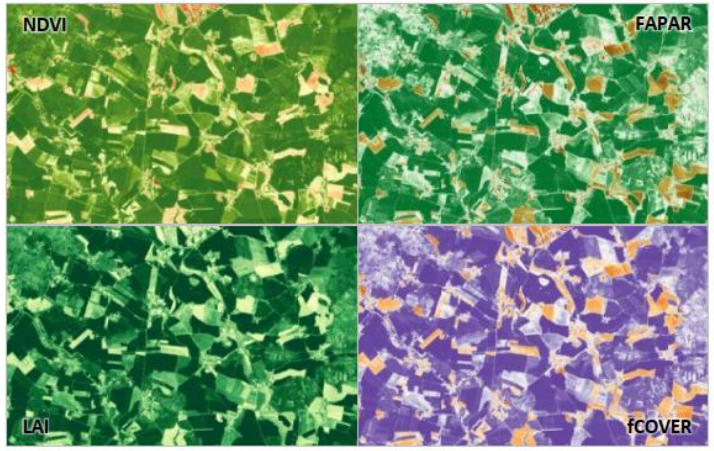
The Sentinels for Common Agricultural Policy - Sen4CAP project aims since 2017 at providing to the European and national stakeholders of the CAP validated algorithms, products, workflows and best practices for agriculture monitoring relevant for the management of the CAP.

IaaS Sen4CAP project (2025 - …), a continuation of Sen4CAP aimed at improving the integration with cloud environments and making the system more flexible and interactive.

Different indicators about the evolution of the green vegetation corresponding to the vegetative development of the crop.



Sen4CAP hands-on training, Belgium, 22-23 January 2020

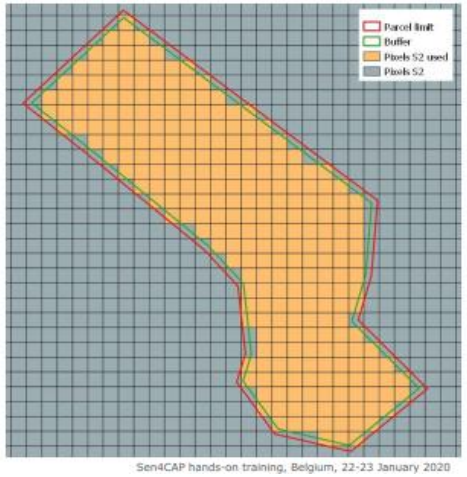


Source: Sen4cap

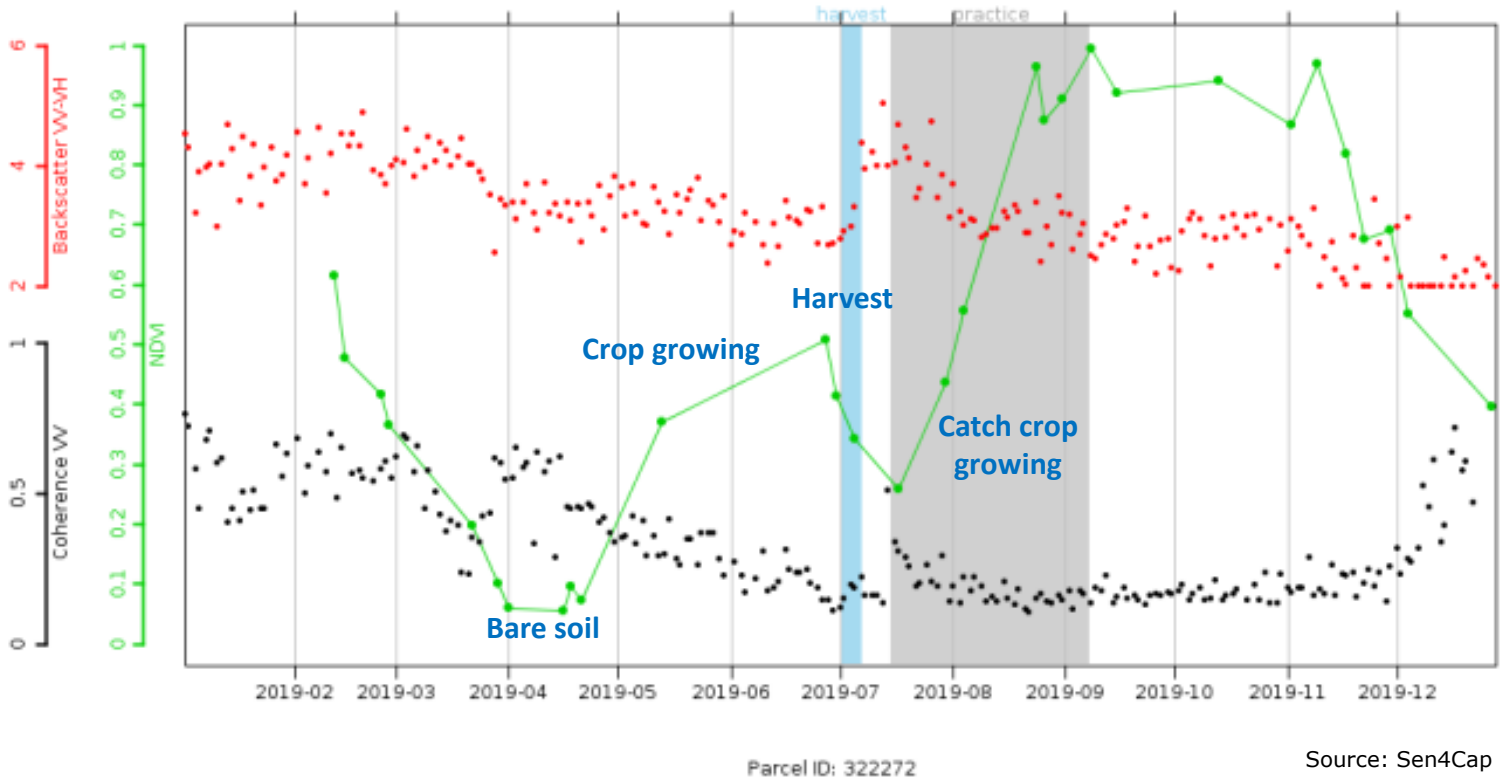
Data, algorithms & more

Basic principles

- What to look for?
- What to look at?
- What to expect?
- What to see?
- What is relevant?



S2 pixel used for a parcel



Source: Sen4Cap

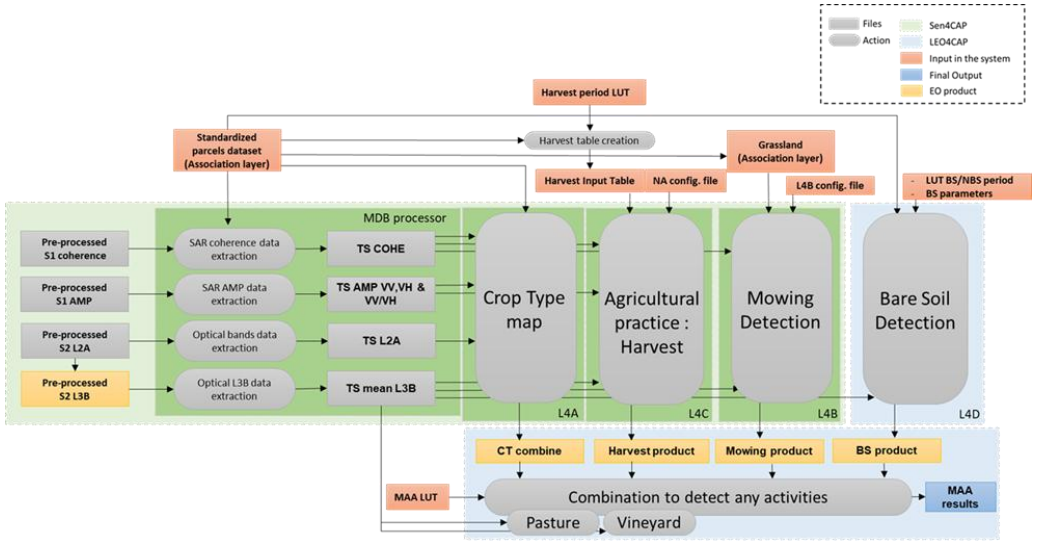
Data, algorithms & more

Basic principles

- What to look for?
- What to look at?
- What to expect?
- What to see?
- What is relevant?



Depends on:



Source: Leo4Cap

What do we want to check?

Definition of different use cases:

- **Crop type identification**

Identification of different crop groups.
126 crop types are grouped in 23 different crop groups.

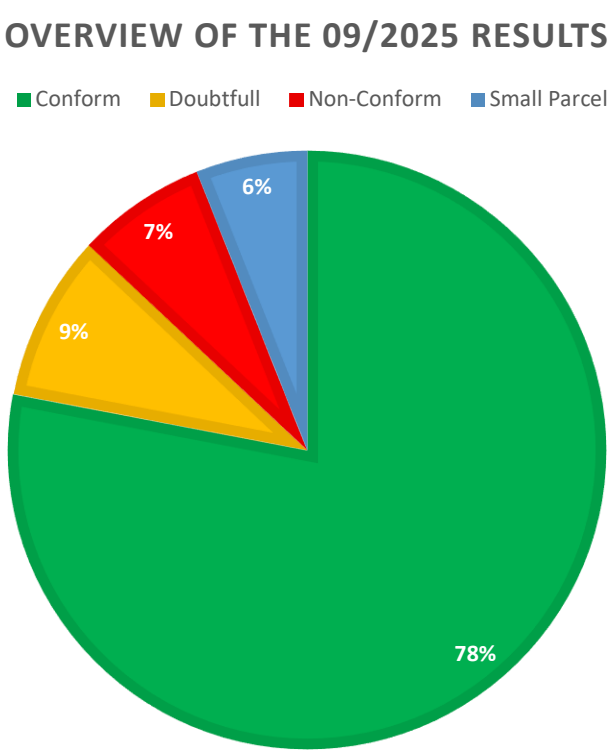
- **Verification of a minimum agricultural activity**

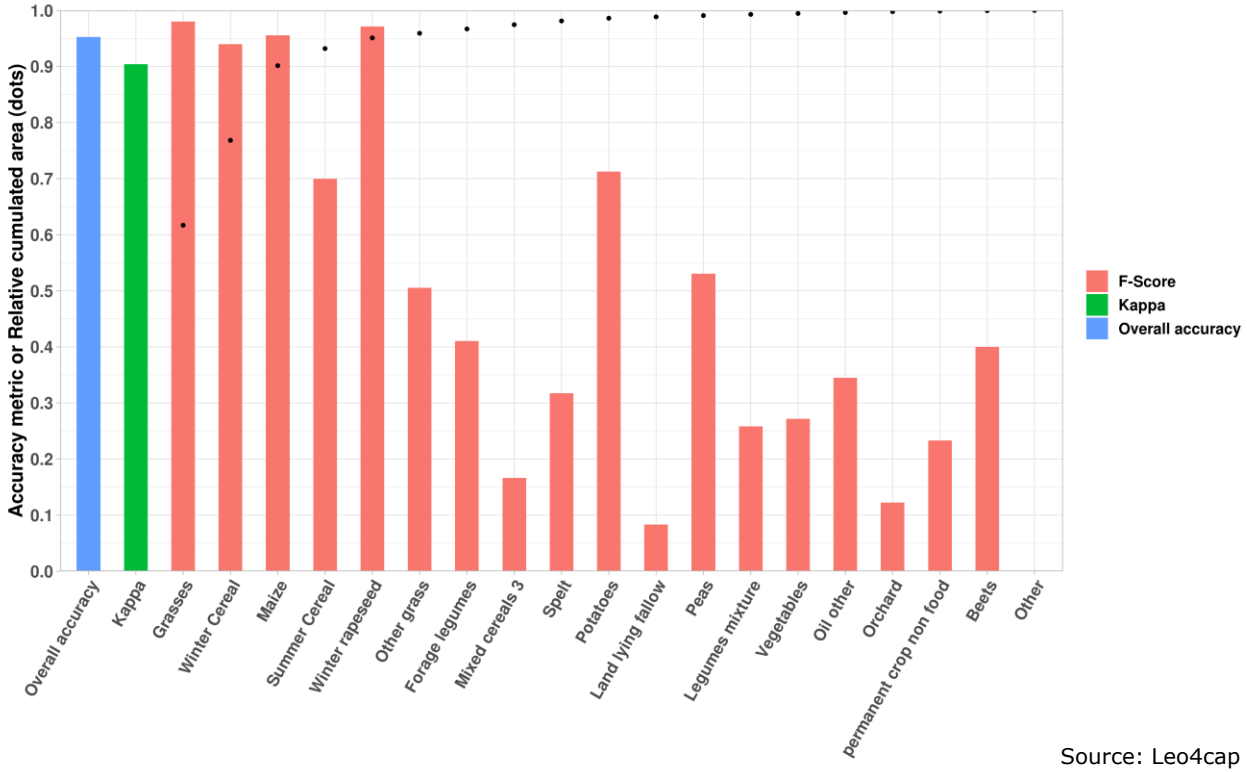
Identification of different crop groups
Bare soil
Harvest
Mowing
Grazing

For different activities, different markers are combined

Data, algorithms & more

Checking the results





Source: Leo4cap

As the phenology of the crops vary during the year, the results depend on the moment in the crop year the calculations are done.

Data, algorithms & more

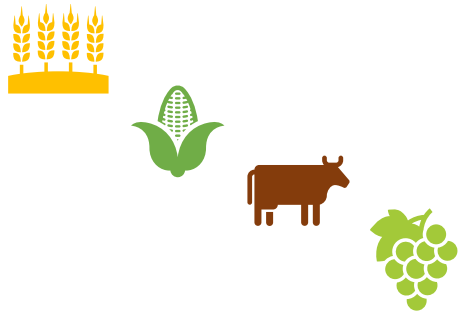
Timeline of the calculations



The results depend on the moment in the crop year the calculations are done.

- What to look for?
- What to look at?
- What to expect?
- What to see?
- What is relevant?
- **At what moment?**

Different calculation runs depending on crops and the related agricultural activities during the year



- **1st Run:** Arable crops with harvest end of June / beginning of July
- **2nd Run:** Arable crops with harvest during September / October
- **3rd Run:** Grassland and permanent crops with minimum agricultural activity until midst of September

Data, algorithms & more

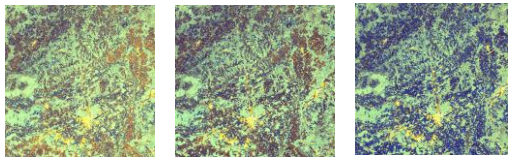
Timeline of the calculations



Before the start of the monitoring period:
System initialization

Monitoring period

Sentinel 1



Sentinel 2



EO data download & processing

Uploading Parcel Declaration set







End of June | **August** | **2nd half of September**



1. Run, Expert judgment & Rapid Field Visits



2. Run, Expert judgment & Rapid Field Visits



3. Run, Expert judgment & Rapid Field Visits

Data, algorithms & more

Results from LEO4CAP

The results are classified in different classes similar to traffic lights:



Yellow: parcel assessed, but insufficient evidence to either explicitly conclude as compliant "green" or non-compliant "red", hence the farmers declaration is considered to be correct.

Green: parcel/holding assessed as compliant.

Red: parcel/holding assessed as non-compliant.

Small parcels with less than 3 S2 pixels and 1 S1 pixels are not analyzed, as well as crop types with less than 30 parcels.

Payments may be made for “**green**” and “**yellow**” parcels. “**Red**” and **small** parcels will continue to be checked:

- Via visual inspection on VHR imagery
- Via rapid field visits

Data, algorithms & more

Expert judgment

Checking agricultural activity on with VHR imagery:

The agricultural activity seen on the VHR imagery depends on the date the imagery.



Mowed parcel



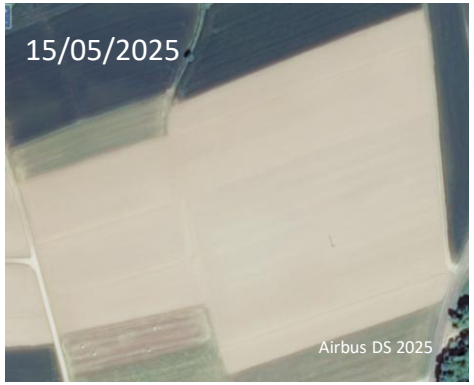
Mowed parcel



Grazed parcel



Cereals



Parcel prepared for sowing or sowed



Harvested parcel



Winter cereal



Parcel with bare soil

Data, algorithms & more

Rapid Field Visits and geo-tagged photos

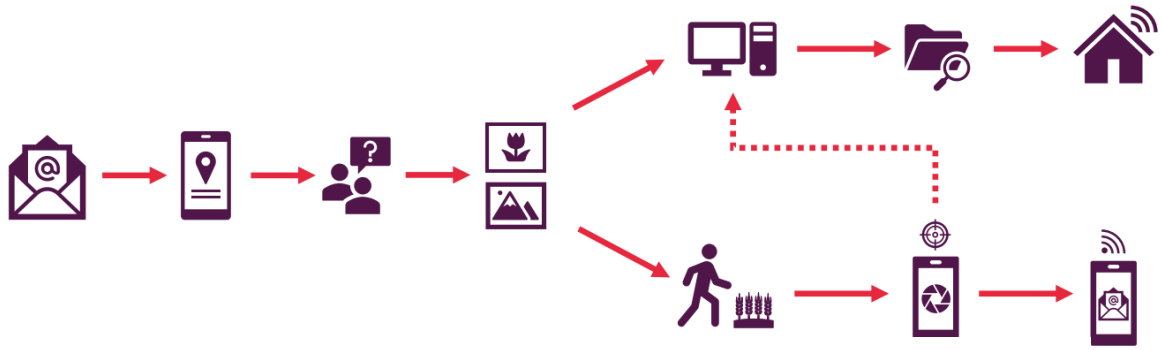
For **arable land, around 75 %** of "**Red**" and **small** parcels can be re-classified as "**Conform**" through visual inspection on VHR imagery.

For **grassland, around 85 %** of "**Red**" and **small** parcels can be re-classified as "**Conform**" through visual inspection on VHR imagery.

For **permanent crops, around 90 %** of "**Red**" and **small** parcels can be re-classified as "**Conform**" through visual inspection on VHR imagery.

The remaining parcels are assessed during a rapid field visit. A geo-tagged photo serves as proof.

The geo-tagged photo is either taken by the farmer or a controller of control unit. It is the farmers choice.



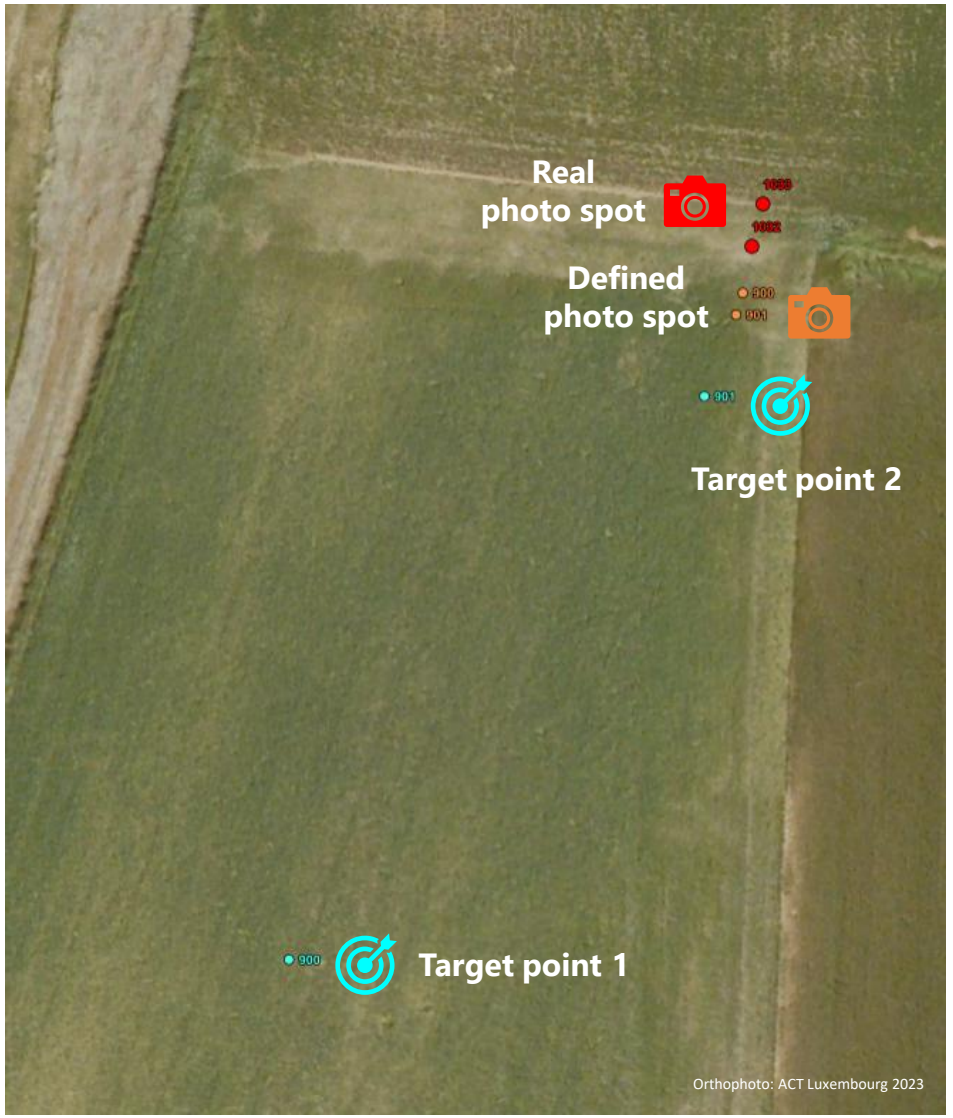
Data, algorithms & more

Rapid Field Visits and geo-tagged photos

Specifications for the requested photos:

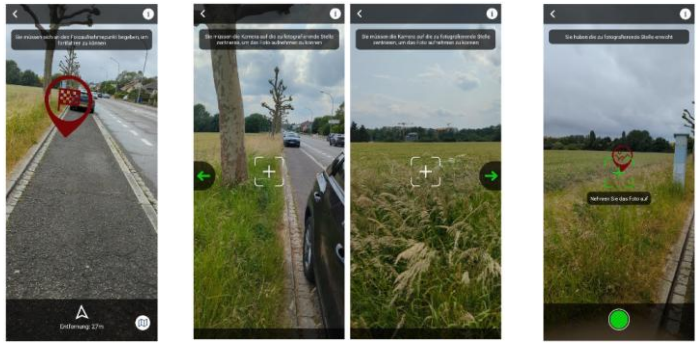
- Location
- Photo information details
- Confirmation / Selection of the crop
- Deadline

The app is guiding the user to the photo spot and helps to find the target point.



Guichet.lu



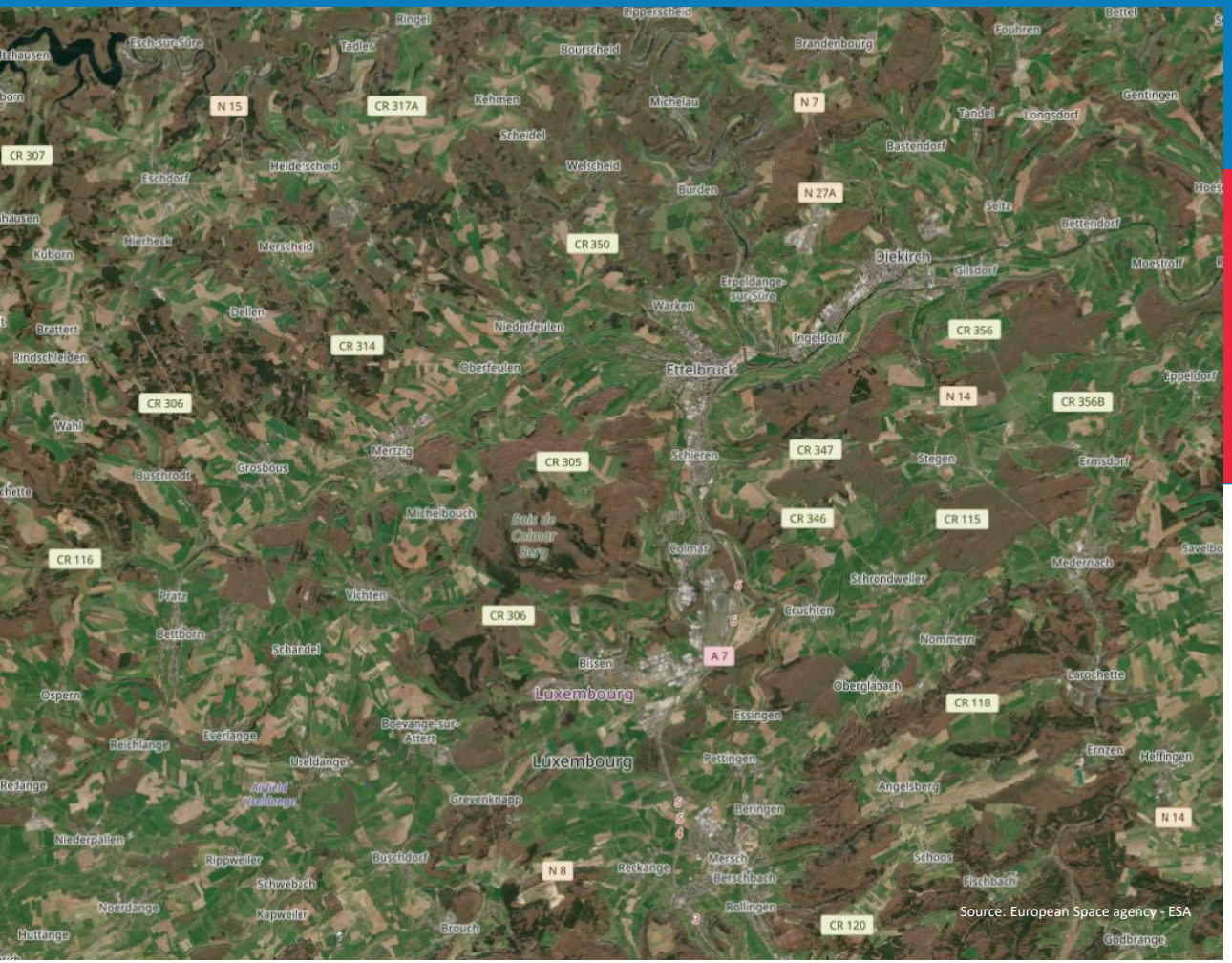


Data, algorithms & more

Experiences & Challenges

- Put in place a monitoring system takes time.
- The results are weather dependent.
- Need to follow the weather forecast from Mai to October.
- When the VHR coverage of the country is complete?
- Every year is different.

- What is the best timing to run the algorithms?
- Need to find a balance between a result of the algorithms of high confidence and still leaving enough time to check the non-conform and small parcels.



Source: European Space agency - ESA

The Area Monitoring system

Outlook

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Outlook

Full integration of the AMS in the Integrated Administration and Control System of the CAP:

- Run the algorithms through an Human – Machine Interface (HMI) instead of IT command lines.
- Moving the administration of the expert judgement from EXCEL files into IACS database.
- Follow the evolution of SEN4CAP and Copernicus Data Space Ecosystem (CDSE): From stand-alone solution to a cloud solution?
- Follow the evolution of markers and algorithms in SEN4CAP.

VHR Data through LUXEOSys:

- More reactive?
- Possibility of more VHR coverage at different dates?
- Sparing money.

CAP Programming period 2028 -2034

- Adaptations due to the new regulation framework of the CAP.
- Re-assessing the monitorability of the obligations foreseen in the new CAP.

Thanks

For your attention

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