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CNIG
Conseil national de l'information géolocalisée

Intelligence artificielle & informations géolocalisées

Atelier – 8 janvier 2026

Atelier 2

Les IA métier pour la production de données : état des lieux (Extraction, structuration et traitement d'images géographiques)

Jocelyn Chanussot, INRIA

Nicolas Gonthier, IGN

Matthieu Porte, MTE Ecolab

AI and Remote Sensing

Jocelyn Chanussot

Future INRIA project team:
ReSeT
Remote Sensing Team @ Inria

ReSeT
Remote Sensing Team

THOTH
Modeling visual knowledge from large-scale data

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Remote sensing

Sensing: Observing, measuring, monitoring

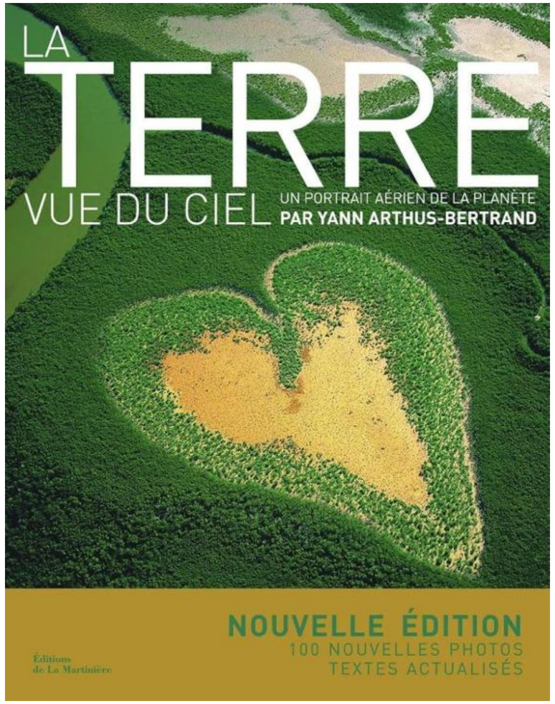
Remotely: from a distance (close range… or from far away)

Platforms:

- satellites
- airplanes
- UAV (drones) *and more*

Sensors:

- Optical
- Hyperspectral
- Radar
- Lidar *and more*



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La plus vieille photographie aérienne de Nadar

1858

vue aérienne de Paris (1866)

Remote sensing

1903, système développé par Julius Neubranner

Remote sensing

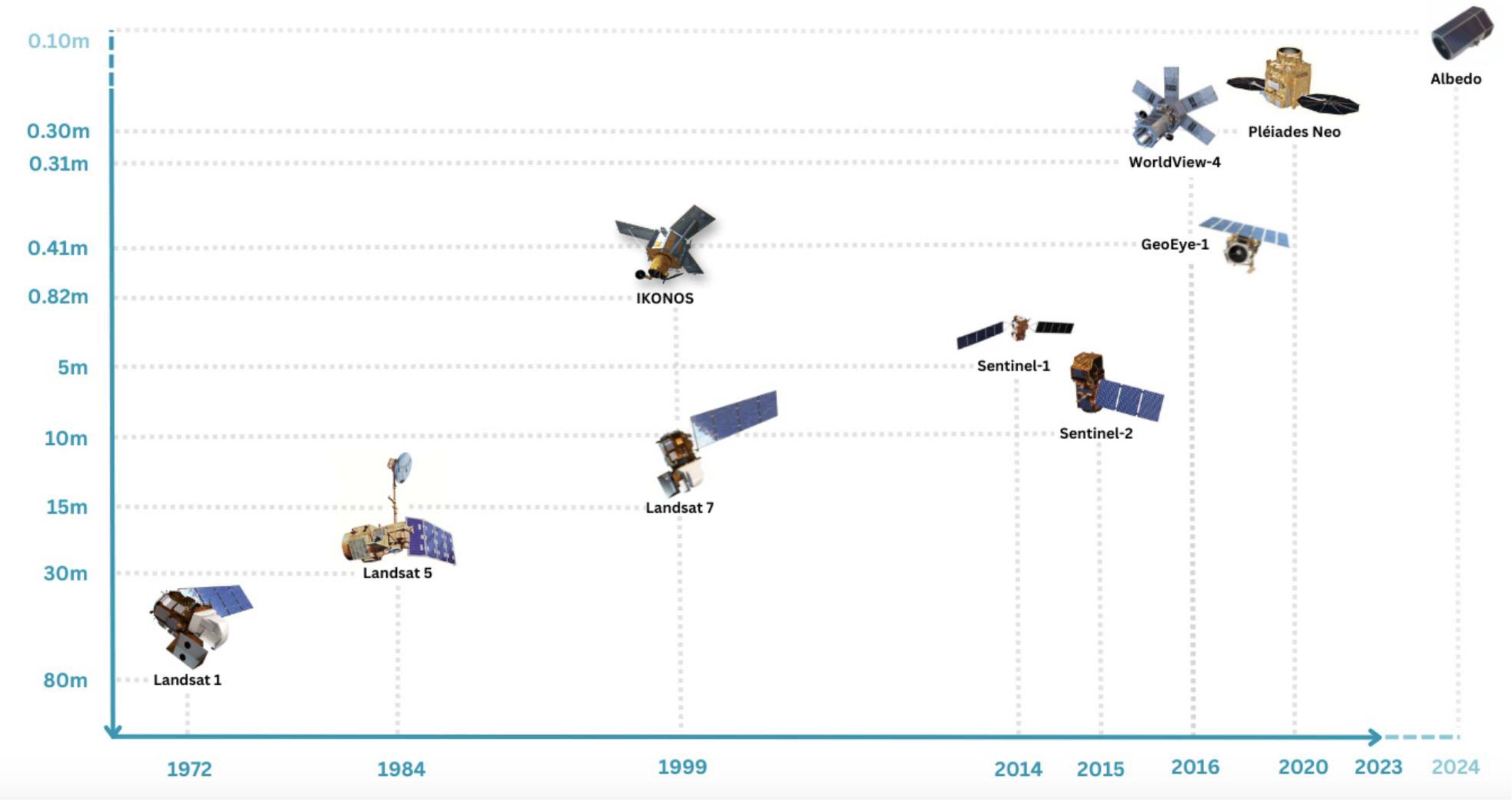

Illustration @FlypixAI

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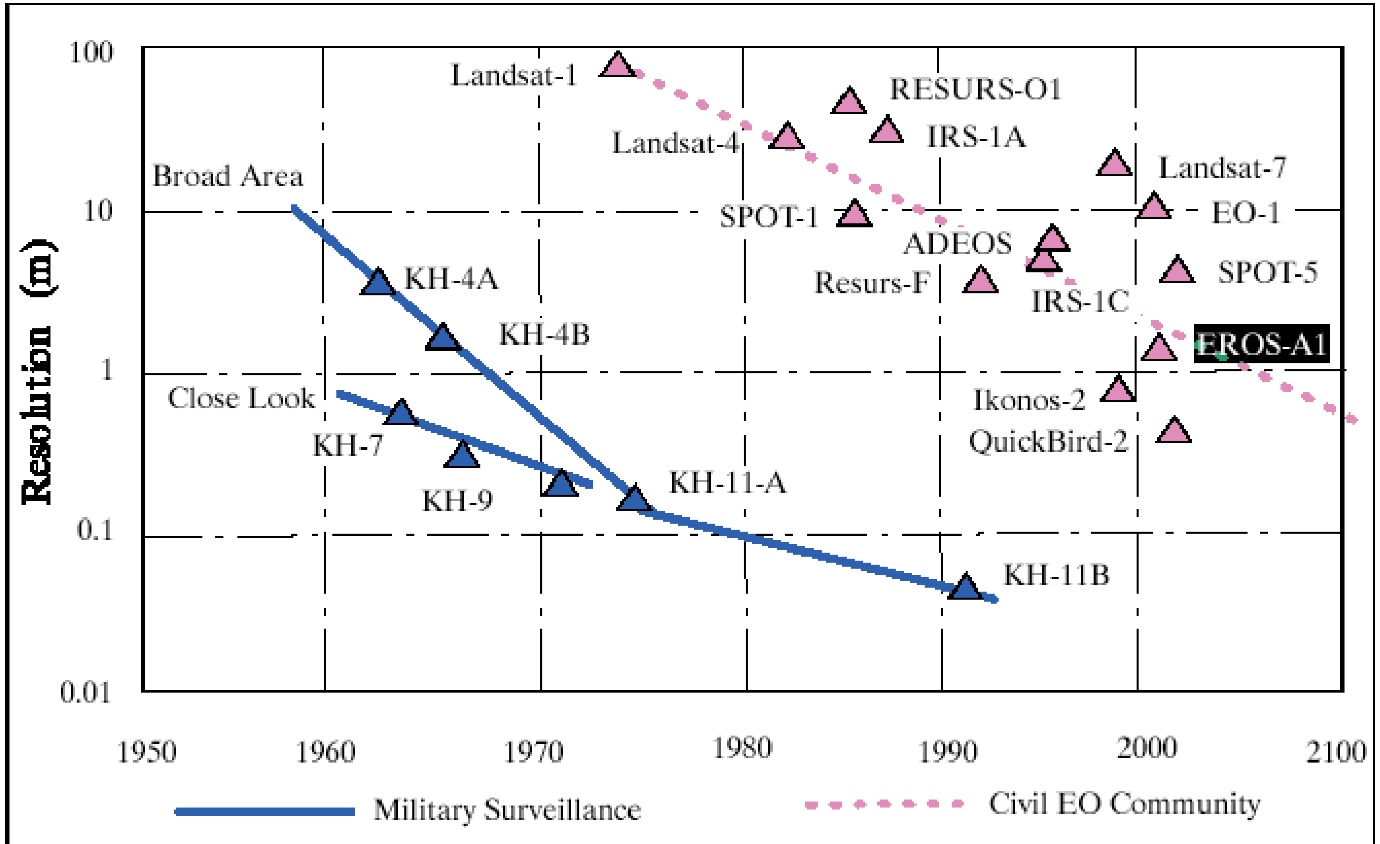
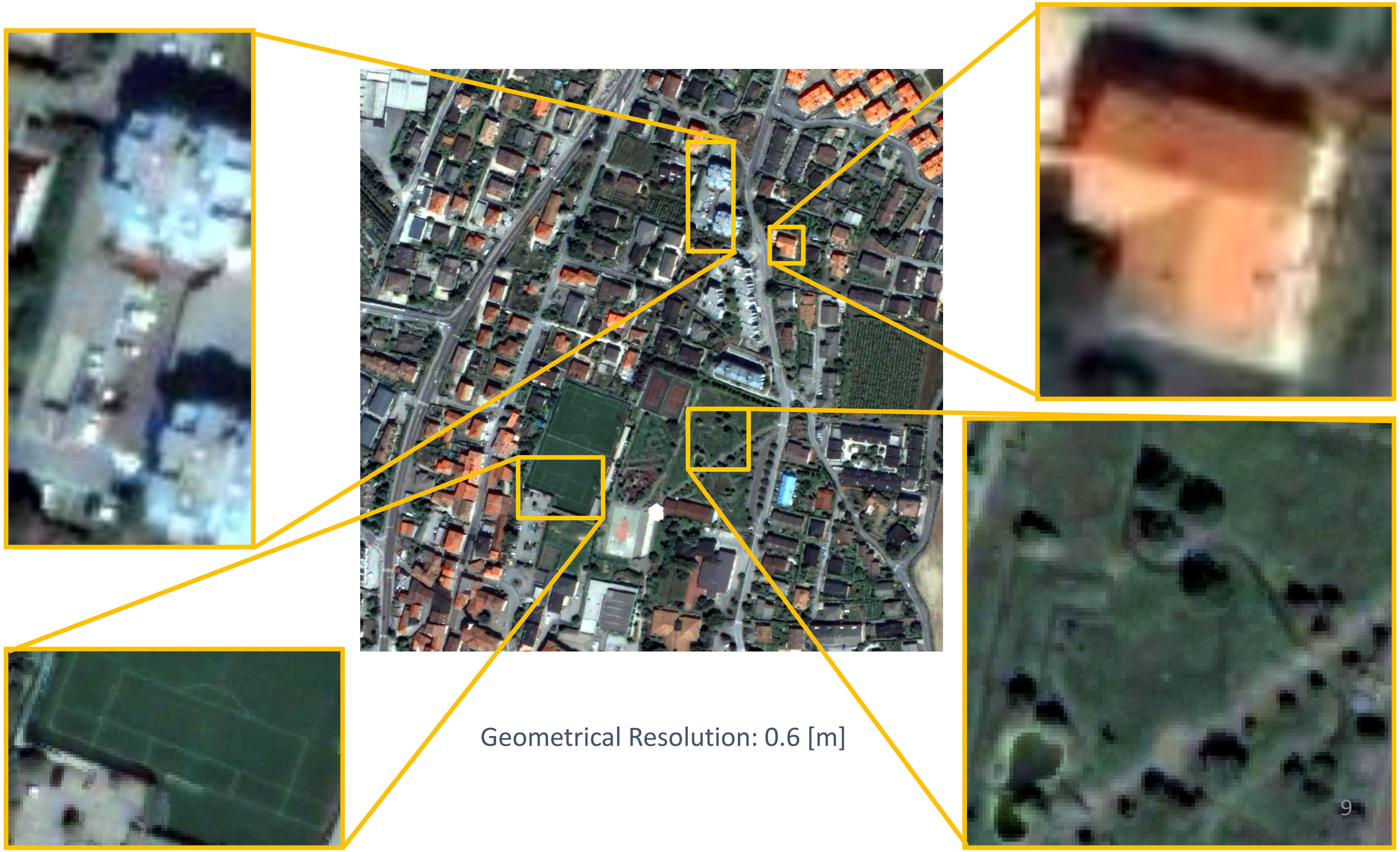


Note: KH=Keyhole [designates several DoD reconnaissance satellite series, such as CORONA, ARGON, LANYARD, and LACROSSE - as well as the principal camera system of the S/C]

Remote sensing



Geometrical Resolution: 0.6 [m]

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Active government satellites [edit]

Name	Status	Agency	Launch [note 1]	Description
ALOS-2	Active	JAXA	2014	
ALOS-4	Active	JAXA	2024	
Alsat-2A and 2B	Active	Algerian Space Agency (ASAL)	2016	
Amazônia-1	Active	Brazil's National Institute for Space Research (INPE)	2021	
Aqua	Active	NASA	2002	Carries six instruments to observe interactions among the four spheres for Earth's systems: oceans, land, atmosphere, and biosphere.[5]
ASNARO-2	Active	JAXA	2018	
Aura	Active	NASA	2004	Studies earth's ozone, air quality, and climate though observation of composition, chemistry, and dynamics of the atmosphere.[6]
Badr-B	Active	Pakistan's Space and Upper Atmosphere Research Commission (SUPARCO)	2001	
Cartosat-1	Active	Indian Space Research Organization (ISRO)	2005	
Cartosat-2A and 2B	Active	ISRO	2007	

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Name	Status	Agency	Launch [note 1]	Description
Cartosat-2C, 2D, 2E, and 2F	Active	ISRO	2016	
Cartosat-3	Active	ISRO	2019	
CBERS-4	Active	Brazil's National Institute for Space Research (INPE) and China National Space Administration (CNSA)	2014	
Chollian 1, 2A, and 2B	Active	KARI	2010	Also known as Communication, Ocean and Meteorological Satellites (COMS). Used for communication, oceanography, and meteorological observation.
CloudSat	Active	NASA	2006	Uses radar to measure the altitude and properties of clouds.[7]
COSMO-SkyMed 1 to 4	Active	Italian Space Agency (ASI)	2007	Used for defense and security assurance in Italy and other countries, seismic hazard analysis, environmental disaster monitoring, and agricultural mapping.
CryoSat-2	Active	ESA	2010	
CYGNSS	Active	NASA	2016	Cyclone Global Navigation Satellite System.
DSCOVR	Active	NASA	2015	Deep Space Climate Observatory. Designed to study the Sun-lit side of Earth from the L1 Lagrange point.[8]
DubaiSat-1 and 2	Active	Mohammed bin Rashid Space Centre (MBRSC)	2009	

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Name	Status	Agency	Launch [note 1]	Description
EarthCARE	Active	ESA and JAXA	2024	Designed to study clouds and aerosols.[9]
Elektro-L No. 1, 2, and 3	Active	Russia's Roscosmos	2011	
Fengyun 2D to 4A	Active	China Meteorological Administration	2006	Translated from Chinese, the word Fengyun means "wind cloud." Series 3 satellites are Sun-synchronous and series 2 and 4 satellites are geosynchronous.
Formosat-5	Active	Taiwan's National Space Organization (NSPO)	2017	
Gaofen-2	Active	CNSA	2014	
Gaofen-3	Active	CNSA	2016	
GOES-16 and 17	Active	NASA	2016	Geostationary Operational Environmental Satellite. Collects weather observations. *See also:* *List of GOES satellites*.
Gokturk-1	Active	Turkish Ministry of National Defense	2016	Used for mapping and planning, landcover survey, geology, ecosystem monitoring, disaster management, environmental control, coastal zone management, and water resources.
Gokturk-2	Active	Turkish Ministry of National Defense	2012	Used for mapping and planning, landcover survey, geology, ecosystem monitoring, disaster management, environmental control, coastal zone management, and water resources.[10]
GPM	Active	NASA and JAXA	2014	Global Precipitation Measurement (GPM) Core Observatory. Used to study rainfall and snowfall.[11][12]

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Name	Status	Agency	Launch [note 1]	Description
GOES-16, -17	Active	NASA	2016	monitors weather for NOAA.
GRACE-FO	Active	NASA	2018[13][14]	Gravity and climate. The mission will track changes in global sea levels, glaciers, and ice sheets, as well as large lake and river water levels, and soil moisture.[15]
GOSAT	Active	JAXA	2009	Greenhouse Gases Observing Satellite. The first precise carbon dioxide observing satellite and precursor to OCO-2.
Himawari 8 and 9	Active	Japan Meteorological Agency	2014	Similar to NASA's GOES satellites.
ICESat-2	Active	NASA	2018	Measures ice sheet height changes for climate change diagnoses.[16][17]
IMS-1	Active	ISRO	2008	
ISS	Active	NASA, Roscosmos, JAXA, ESA, and CSA	1998	The International Space Station (ISS) has long been used as a central satellite platform for other sensors, including Earth observation sensors. For example: LIS, SAGE III, TSIS-I, ECOSTRESS, GEDI, OCO-3, Diwata-1, and HICO.
Jason-3	Active	NASA and CNES	2016	Radar altimeter used to monitor ocean surface height.
KhalifaSat	Active	MBRSC	2018	Also known as DubaiSat-3.
KOMPSAT-2	Active	KARI	2006	Korean Multi-purpose Satellite-2. Also known as Arirang-2.
KOMPSAT-3, 3A, and 5	Active	KARI	2012	Korean Multi-purpose Satellite-3, 3A, and 5. Also known as Arirang-3, 3A, and 5.

Name	Status	Agency	Launch [note 1]	Description
LAGEOS-1 and 2	Active	NASA	1976	LAGEOS 1 launched in 1976 and LAGEOS 2 launched in 1992. Used as an orbiting benchmark for geodynamical studies.[18]
Landsat-7	Active	NASA and USGS	1999	Images Earth's land surfaces and coastal areas with global coverage at high spatial resolution.[19]
Landsat-8	Active	NASA and USGS	2013	Follow on to Landsat-7 with improved imager OLI and thermal sensor TIRS.
Landsat-9	Active	NASA and USGS	2021	Follow on to Landsat-8 with OLI sensor and thermal sensor TIRS-2. Landsat-9 will extend the Landsat program to maintain the time series of these type of data.
Megha-Tropiques	Active	CNES and ISRO	2011	
Meteor-M No. 1 and 2	Active	Roscosmos	2009	
Meteosat 8	Active	EUMETSAT	2002	Also known as MSG 1.
MetOp A, B, and C	Active	NASA, ESA, and NOAA	2006	Meteorological Operational satellite. Part of the Polar Operational Environmental Satellites (POES) program.
Mohammed VI-A and VI-B	Active	Arianespace and Morocco	2017	*See also: Vega flight VV11 and Vega flight VV13*
NigComSat-1R	Active	NASRDA	2009	DFH-4 satellite and replacement for the failed NigComSat-1
NigeriaSat-1 and 2	Active	NASRDA	2003	Part of the worldwide Disaster Monitoring Constellation System

Name	Status	Agency	Launch [note 1]	Description
NOAA-15, 18, and 19	Active	NASA, ESA, and NOAA	1998	Part of the Polar Operational Environmental Satellites (POES) program.
NOAA-20	Active	NASA and NOAA	2017	Part of the Joint Polar Satellite System (JPSS) program.
Oceansat-2	Active	ISRO	2009	
OCO-2	Active	NASA	2014	Orbiting Carbon Observatory 2. Part of the A-Train. The second precise carbon dioxide observing satellite after GOSAT.
PACE	Active	NASA	2024	Plankton, Aerosol, Cloud, and ocean Ecosystem measures hyperspectral and polarimetric characteristics of solar radiation reflected off Earth's surface and atmosphere.
PakTES-1A	Active	SUPARCO	2018	
Paz	Active	Spain's Instituto Nacional de Técnica Aeroespacial	2018	
Pleiades 1A and 1B	Active	CNES	2011	
PRISMA	Active	Italian Space Agency (ASI)	2019	PRecursore IperSpettrale della Missione Applicativa, in English: Hyperspectral PRecursor of the Application Mission.
PROBA-V	Active	ESA	2013	Continues the traditional Vegetation (the "V" in PROBA-V) products that began with the SPOT satellites.[20]
PRSS-1	Active	SUPARCO	2018	Pakistan Remote Sensing Satellite 1.
RCM	Active	CSA	2019	RADARSAT Constellation Mission.

Name	Status	Agency	Launch [note 1]	Description
RADARSAT-2	Active	CSA	2007	C-band synthetic aperture radar (SAR-C) satellite.
RASAT	Active	TÜBITAK-UZAY	2011	
Resourcesat-1 and 2	Active	ISRO	2003	
Resurs-P No.1 and 2	Active	Roscosmos	2013	
SAOCOM	Active	CONAE	2018	
SARAL	Active	ISRO	2013	
Sentinel-1A, B and C	Active	ESA	2014	Constellation of two, each satellite carries C-SAR sensor. Part of the Copernicus Programme.
Sentinel-2A, B, and C	Active	ESA	2015	Constellation of three, each satellite carries MSI sensor for high spatial resolution imaging. Part of the Copernicus Programme.
Sentinel-3A and B	Active	ESA	2016	Constellation of two, each satellite carries sensors OLCI and SLSTR. Slightly coarser spatial resolution and more spectral bands than Sentinel-2. Part of the Copernicus Programme.
Sentinel-6A	Active	ESA	2020	Continuing the legacy of the Jason series missions, Sentinel-6/Jason-CS will extend the records of sea level (sea surface height) and provide information for operational oceanography, marine meteorology, and climate studies.[21]

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Name	Status	Agency	Launch [note 1]	Description
SMAP	Active	NASA	2015	Soil Moisture Active Passive. Measures soil moisture and its freeze/thaw state, which enhance understanding of processes that link water, energy, and carbon cycles to extend the capabilities of weather and climate models. Radar payload failed in July 2015, leaving a radiometer as the primary instrument of the mission.[22]
SORCE	Active	NASA	2003	monitors total output from the Sun for understanding of Earth's absorption of radiation energy.[16]
Suomi NPP	Active	NASA	2011	Part of the Joint Polar Satellite System (JPSS) program.
SWOT	Active	NASA	2022	
TanDEM-X	Active	DLR	2010	
Terra	Active	NASA	1999	Carries five instruments to observe the state of the atmosphere, land, and oceans, as well as their interactions with solar radiation and with one another.[23]
TerraSAR-X	Active	DLR	2007	
THEOS	Active	GISTDA	2008	Also known as Thaichote.
TIMED	Active	NASA	2001	Thermosphere, Ionosphere, Mesosphere, Energetics, and Dynamics.
VNREDSat-1A	Active	VAST	2013	The Vietnamese Natural Resources, Environment and Disaster Monitoring Satellite.
VRSS-1 and 2	Active	ABAE	2012	The Venezuelan Remote Sensing Satellite.

Name	Status	Agency	Launch [note 1]	Description
Sentinel-5 Precursor (S5P)	Active	ESA	2017	
SMOS	Active	ESA	2009	

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Name	Status	Owner/Agency	Launch [note 1]
Disaster Monitoring Constellation[40]	Active	DMC International Imaging	2009
EROS A and B	Active	ImageSat International	2000
Flock-1 Constellation	Active	Planet	2014
GeoEye-1	Active	DigitalGlobe (Maxar)	2008
GRUS [ja]-1A to E[41]	Active	Axelspace [ja][42]	2018
ICEYE	Active	ICEYE	2018
Jilin-1 (Hyperspectral)	Active	Chang Guang Satellite Technology	2019
Jilin-1 (Optical	Active	Chang Guang Satellite Technology	2015
NovaSAR-S1[42]	Active	UK Space Agency and Surrey Satellite Technology	2018
PlanetScope-2[43]	Active	Planet	2016
SkySat-1 to 3	Active	Planet	2013
SkySat-4 to 7	Active	Planet	2016
SkySat-8 to 13	Active	Planet	2017
SPOT 6 and 7	Active	EADS Astrium Azercosmos, and CNES	2012
SuperView-1[44]	Active	Beijing Space View Technology	2018
TripleSat (UK-DMC 3)[45][46]	Active	DMC International Imaging	2015
Vivid-i 1 to 5[47]	Active	Earth-i[48]	2018
WorldView-1	Active	DigitalGlobe (Maxar)	2007
WorldView-2 and 3	Active	DigitalGlobe (Maxar)	2009
Pleiades Neo 3	Active	Airbus Defence and Space	2021
Pleiades Neo 4	Active	Airbus Defence and Space	2021

Conclusion:

We have A LOT of multimodal, highly heterogeneous, data
New acquisitions and archives

Artificial intelligence

Artificial intelligence

Artifical Intelligence is not that big, scary thing in the future.

Artificial intelligence

Artifical Intelligence is not that big, scary thing in the future.
It’s here with us.

Artificial intelligence

Artifical Intelligence is not that big, scary thing in the future.
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Fei Fei Li
American Computer Science Professor

Artificial intelligence

Artifical Intelligence is not that big, scary thing in the future.
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Fei Fei Li
American Computer Science Professor
1976

Artificial intelligence

Artifical Intelligence is not that big, scary thing in the future.
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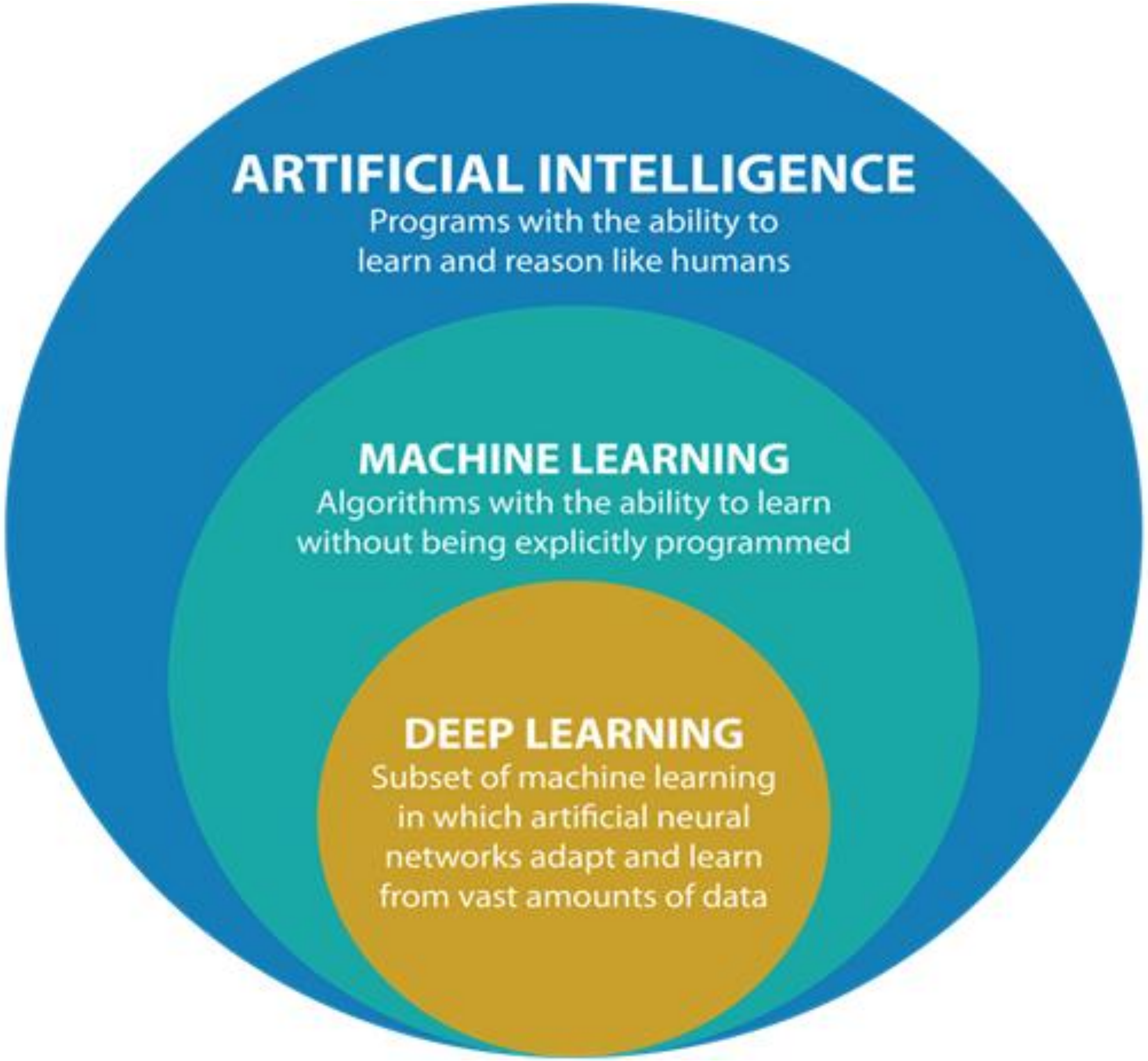
Fei Fei Li
American Computer Science Professor
1976

2025

Artificial intelligence



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Conclusion:

We have A LOT of AI algorithms.

High Performance Computing

AI and remote sensing

AI and remote sensing

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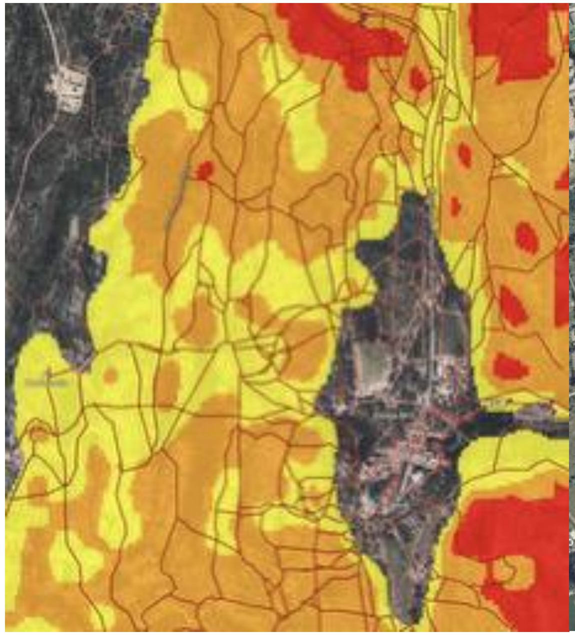
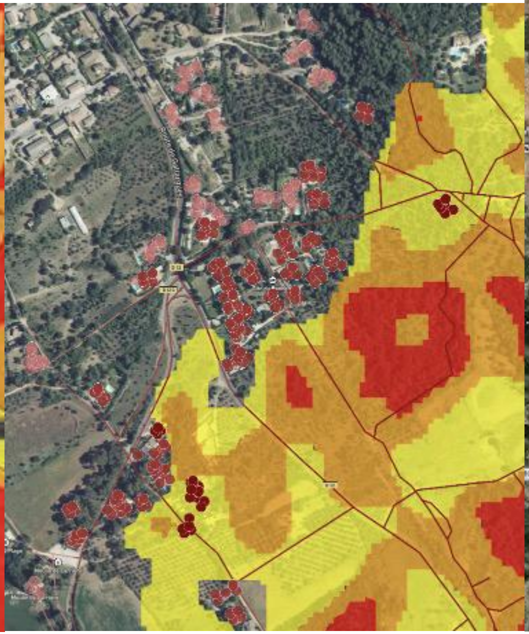
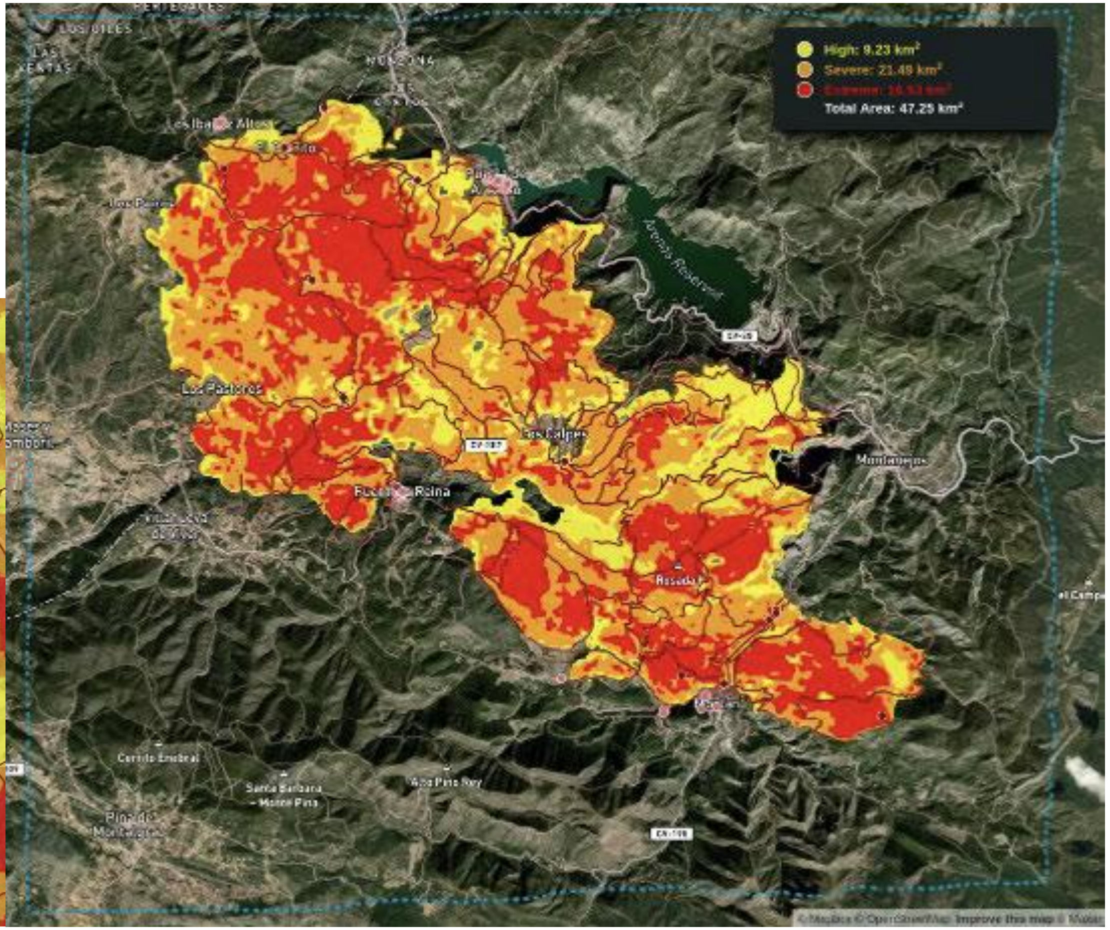
Monitoring of wildfires







AI and remote sensing

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Monitoring of floods

Richmond (Australia) flood

Water depth

Impact on housing and roads

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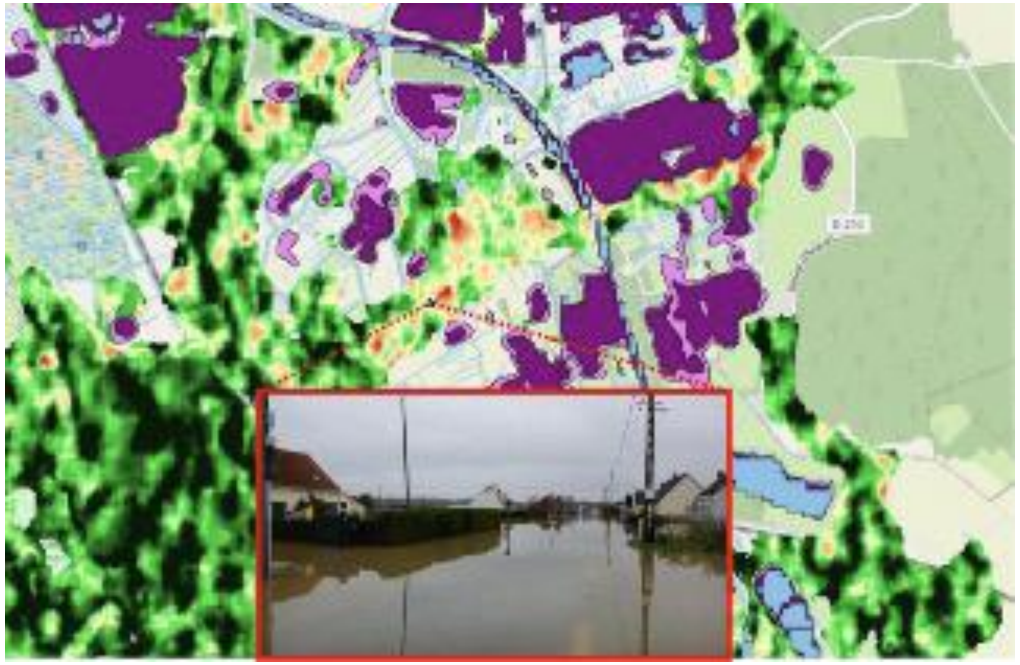
Monitoring of floods



AI and remote sensing

**Conclusion: AI and deep learning:
a game changer for the analysis of remote sensing data**

- **A lot of data**
- **High performance computing**
- **Advanced algorithms (optimization)**

Remote sensing differs from standard computer vision:

Not a lot of annotated data
-> importance of self-supervised techniques / few shot learning

Observations = physical quantities
-> importance of the interplay between physics and AI

AI and remote sensing

A few recent papers published in IEEE TGRS (just a drop in the ocean…)

- DASNet: Dual Attentive Fully Convolutional Siamese Networks for Change Detection in High-Resolution Satellite
- SNUNet-CD: A Densely Connected Siamese Network for Change Detection of VHR Images
- LANet: Local Attention Embedding to Improve the Semantic Segmentation of Remote Sensing Images
- TEMDnet: A Novel Deep Denoising Network for Transient Electromagnetic Signal With Signal-to-Image Transformation
- SemiCDNet: A Semisupervised Convolutional Neural Network for Change Detection in High Resolution Remote-Sensing Images
- SCAttNet: Semantic Segmentation Network With Spatial and Channel Attention Mechanism for High-Resolution Remote Sensing Images
- MAP-Net: Multiple Attending Path Neural Network for Building Footprint Extraction From Remote Sensed Imagery

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SwinSUNet: Pure Transformer Network for Remote Sensing Image Change Detection
DLA-MatchNet for Few-Shot Remote Sensing Image Scene Classification
DABNet: Deformable Contextual and Boundary-Weighted Network for Cloud Detection in Remote Sensing Images
SSR-NET: Spatial–Spectral Reconstruction Network for Hyperspectral and Multispectral Image Fusion
TransUNetCD: A Hybrid Transformer Network for Change Detection in Optical Remote-Sensing Images
BockNet: Blind-Block Reconstruction Network With a Guard Window for Hyperspectral Anomaly Detection
F3Net: Adaptive Frequency Feature Filtering Network for Multi-modal Remote Sensing Image Registration
EMYNet-BDD: EfficientViTB Meets Yolov8 in the Encoder–Decoder Architecture for Building Damage Detection Using Postevent Remote Sensing Images

AI and remote sensing

Your next publication:

Jane/JohnDoeNet:
a great architecture for a critical application using specific remote sensing data

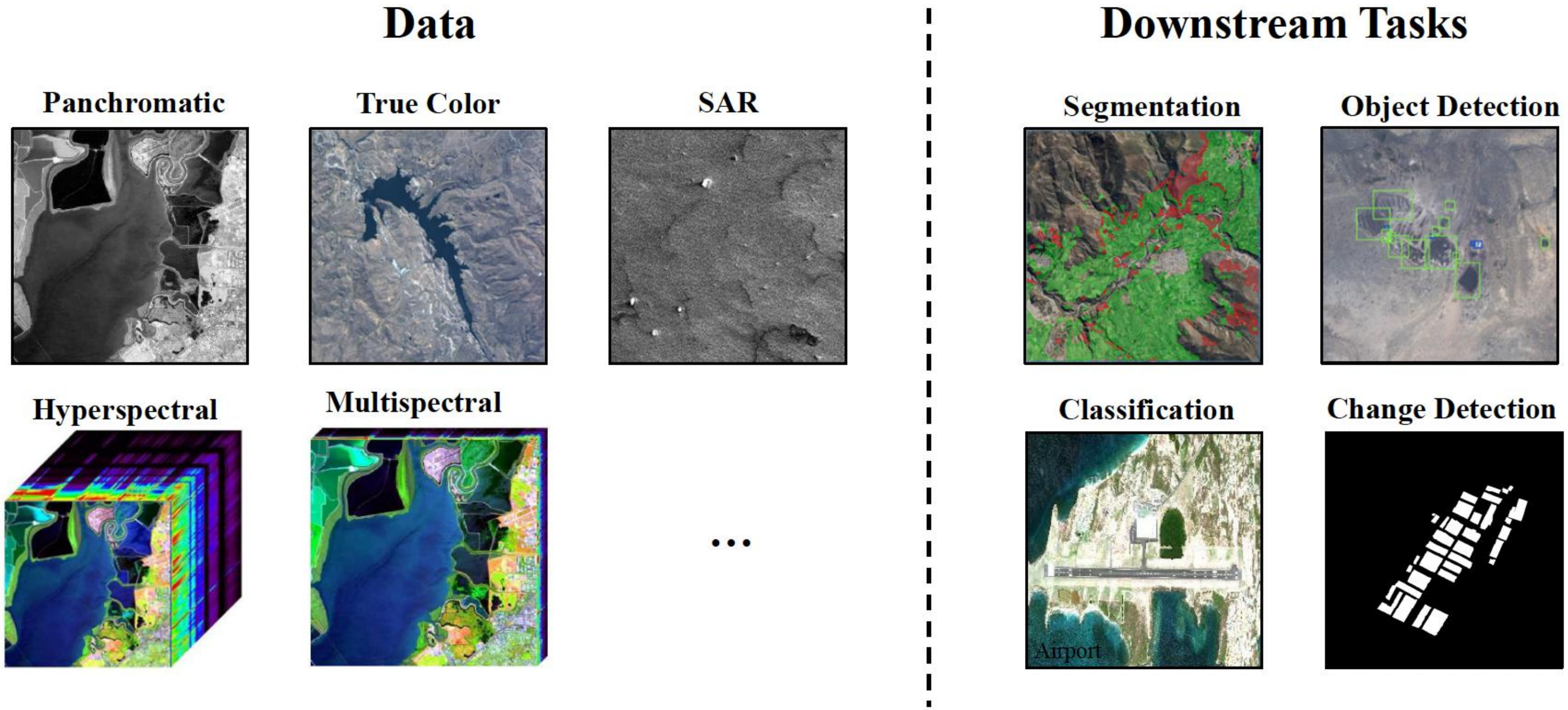
Foundation models

Move from *John/JaneDoeNet* to

- Large scale pre-trained AI models
- Able to address a wide array of tasks
- Finetuneable

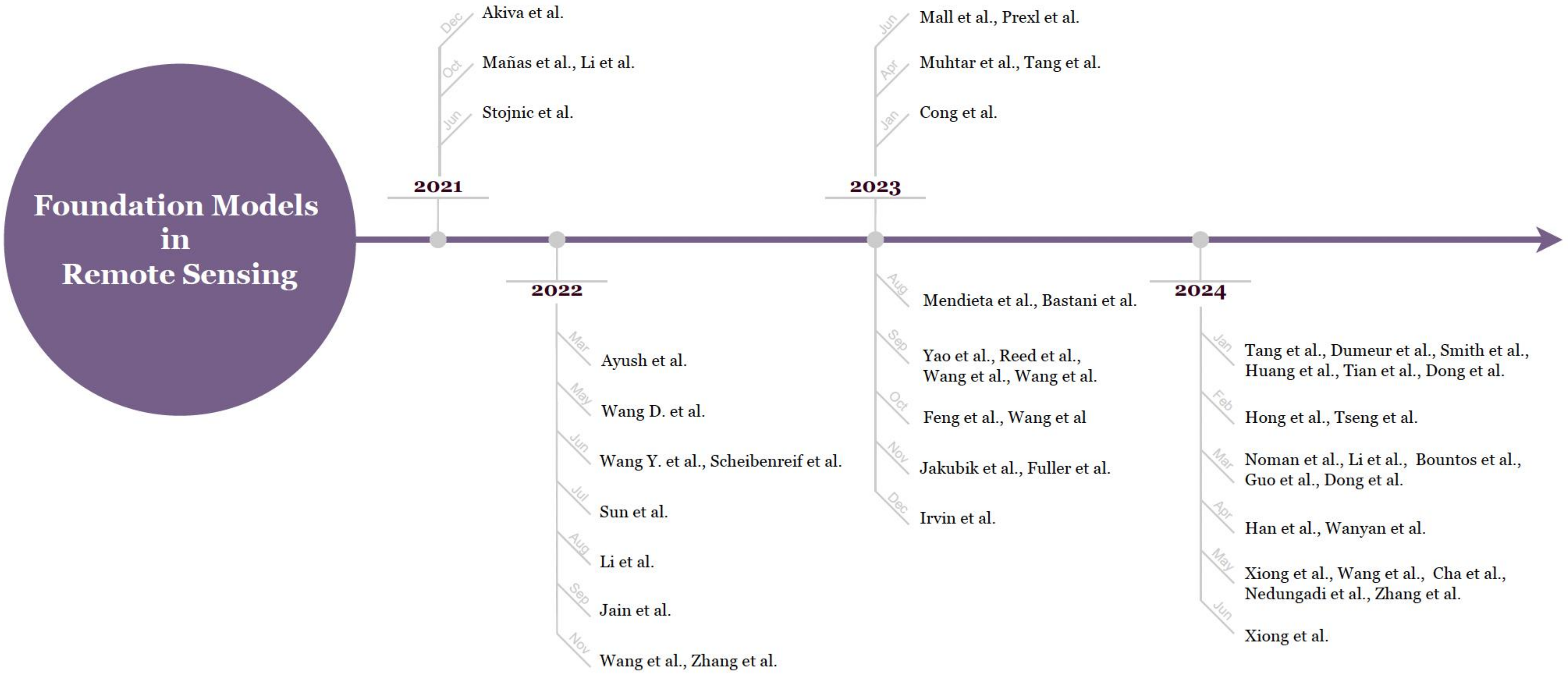
- **A lot of data**
- **High performance computing**
- **Advanced algorithms (optimization)**

Foundation models: specific models for remote sensing data



AI and remote sensing

Foundation models: specific models for remote sensing data



AI and remote sensing

Foundation models:
specific models
for remote sensing data

Year-Month	Architecture	Model Name	Scene Classification	Semantic Segmentation	Object Detection	Change Detection
2021 Jun	ResNet-50	CMC-RSSR [59]	✓			
2021 Oct	ResNet-50	SeCo [46]	✓			✓
2021 Oct	ResNet-50	GeoKR [39]	✓	✓	✓	
2021 Dec	ResNet-34	MATTER [1]	✓	✓		✓
2022 Mar	ResNet-50	GASSL [3]	✓	✓	✓	
2022 May	ViTAEv2-S	RSP [69]	✓	✓	✓	✓
2022 Jun	ViT-S/8	DINO-MM [73]	✓			
2022 Jun	Swin Transformer	Scheibenreif, et al. [56]	✓	✓		
2022 Jul	ViT/Swin Transformer	RingMo [61]	✓	✓	✓	✓
2022 Aug	ResNet-50	GeCO [40]	✓	✓	✓	
2022 Sep	BYOL	RS-BYOL [32]	✓	✓		
2022 Nov	ViT-B	CSPT [87]	✓		✓	
2022 Nov	ViT	RVSA [71]	✓	✓	✓	
2023 Jan	MAE-based Framework	SatMAE [11]	✓	✓		
2023 Apr	TOV	TOV [63]	✓	✓	✓	
2023 Apr	Teacher-student Self-distillation	CMID [49]	✓	✓	✓	✓
2023 Jun	CACo	CACo [47]	✓	✓		✓
2023 Jun	ResNet-18	IaI-SimCLR [54]	✓			
2023 Aug	Teacher-Student	GFM [48]	✓	✓		✓
2023 Aug	Swim Transformer	SatLasPretrain [4]	✓	✓		
2023 Sep	Multi-Branch	RingMo-Sense [85]		✓		
2023 Sep	ViT	Scale-MAE [55]	✓	✓		
2023 Sep	CNN-Transformer	RingMo-lite [76]	✓	✓	✓	✓
2023 Sep	Multimodel SSL	DeCUR [72]	✓	✓		
2023 Oct	MSFE+MMFH	Feng et al. [21]	✓	✓	✓	✓
2023 Oct	ViT	FG-MAE [75]	✓	✓		
2023 Nov	ViT	Prithvi [33]		✓		
2023 Nov	Multimodal Encoder	CROMA [22]	✓	✓		
2023 Dec	ViT	USat [31]	✓			
2024 Jan	ViT-B	Cross-Scale MAE [62]	✓	✓		
2024 Jan	Unet+Transformer	U-BARN [20]	✓	✓		
2024 Jan	Autoregressive Transformer	EarthPT [58]	✓			
2024 Jan	Teacher-Student Network	GeRSP [29]	✓	✓	✓	
2024 Jan	Dual-Branch	SwiMDiff [65]	✓			✓
2024 Jan	Generative ConvNet	SMLFR [17]		✓	✓	
2024 Feb	3D GPT	SpectralGPT [28]	✓	✓		✓
2024 Feb	MAE-based Framework	Presto [66]		✓		
2024 Mar	SatMAE	SatMAE++ [52]	✓			
2024 Mar	Joint-Embedding Predictive Architecture	SAR-JEPA [41]	✓			
2024 Mar	ViT	FoMo-Bench [5]	✓	✓	✓	
2024 Mar	Factorized Multi-Modal Spatiotemporal Encoder	SkySense [24]	✓	✓	✓	✓
2024 Mar	Multi-Modules	UPetu [18]	✓	✓		✓
2024 Apr	Swim Transformer	msGFM [25]	✓	✓		
2024 Apr	DINO	DINO-MC [77]	✓			✓
2024 May	OFA-Net	OFA-Net [84]	✓	✓		
2024 May	Shared Encoder, Task-Specific Decoders	MTP [70]	✓	✓	✓	✓
2024 May	ViT	BFM [7]		✓	✓	
2024 May	MP-MAE	MMEarth [51]	✓	✓		
2024 May	ViT	CtxMIM [86]	✓	✓	✓	
2024 May	HiViT	SARATR-X [37]	✓		✓	
2024 Jun	Dynamic OFA	DOFA [83]	✓			

Foundation models: specific models for remote sensing data

Foundation models refer to **large-scale**, **pretrained models** that provide a **robust starting point** for **various downstream tasks** across different domains. These models leverage extensive datasets and advanced architectures, enabling them to capture complex patterns and features that can be fine-tuned for specific applications with minimal additional training.

Foundation models: specific models for remote sensing data

Foundation models face the usual challenges:

- Need for high-quality and diverse training data
- Need for significant computational resources
- Need for effective domain adaptation for specific applications

Foundation models: Methodologies

Self-supervised learning training strategies:

The model learns part of the input data from other parts of the input data
-> reduces the need for large ***labeled*** datasets.

- Contrastive learning:
  Learns representations by comparing different views (data augmentation) of the same data point

- Predictive coding:
  Learns to predict missing (masked) parts of the data from the observed parts

SSL methods: MoCo, SimCLR, BYOL, DINO…

SPECTRAL EARTH: TRAINING HYPERSPECTRAL FOUNDATION MODELS AT SCALE

Nassim Ait Ali Braham, Conrad Albrecht, Julien Mairal, Jocelyn Chanussot, Yi Want, Xiao Xiang Zhu

EO Data Science, Remote Sensing Technology Institute, DLR

Data Science in Earth Observation, Technical University of Munich, Germany

Univ. Grenoble Alpes, Inria, CNRS, Grenoble INP, LJK, 38000 Grenoble, France

DLR

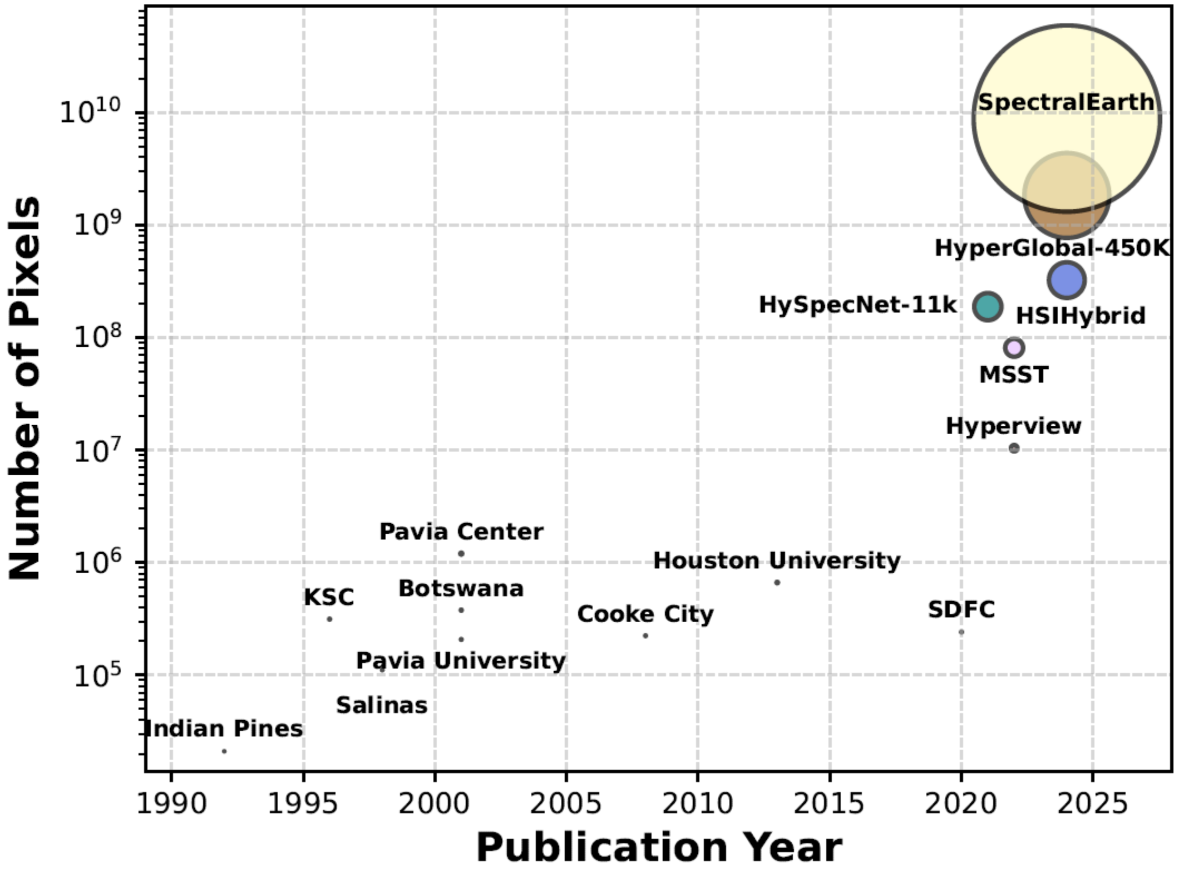
Motivation

- A lot of research on foundation models for **MSI**: SatMAE, ScaleMAE, Prithvi, DOFA, SkySense, etc.

- Less research on foundation models in **HSI**

- **No suitable dataset for pre-training hyperspectral foundation models**

- **Contribution:** **SpectralEarth** a globally distributed dataset, pre-trained models and benchmark



https://doi.org/10.48550/arXiv.2408.08447

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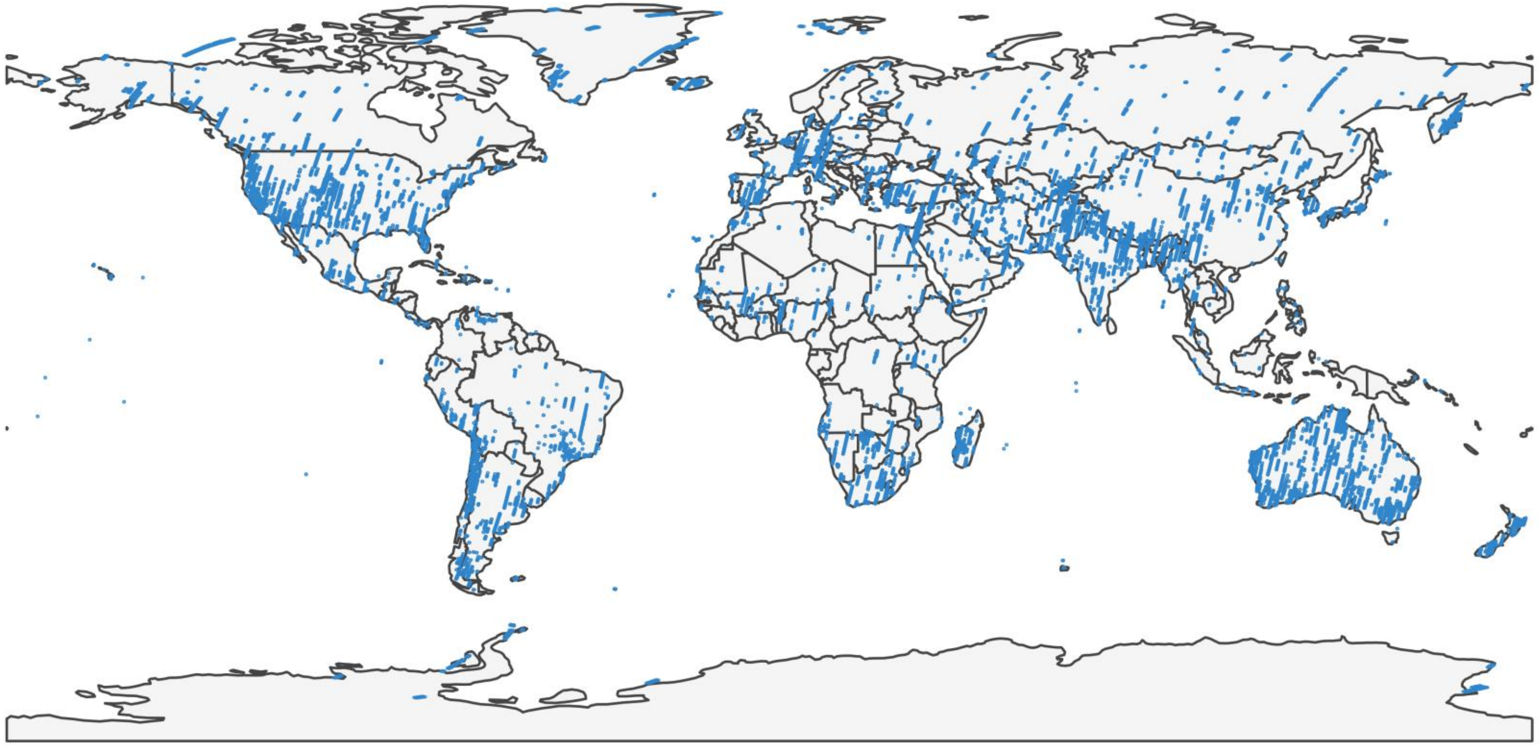
SpectralEarth: A large-scale HSI dataset

- Based on *EnMAP* imagery
- 30m resolution, 202 bands
- **~538,974** patches, 128x128 pixels.
  - **~415,153** unique locations
  - **~73,000** locations with > 1 timestamp
  - Sampled from **11,636** tiles
- **~3.3 TB** of data
- Mostly cloud free

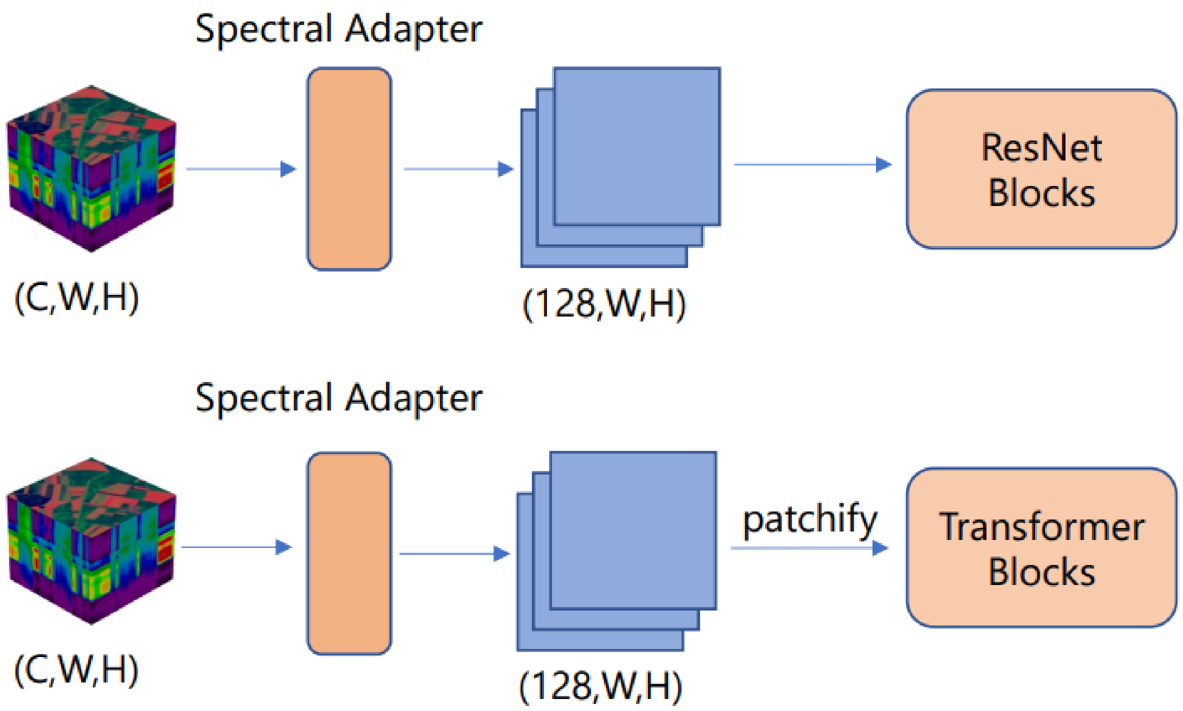


Geographical distribution of SpectralEarth

Models

- **Network Architectures**
  - Simple variation of classical CNN and Vision Transformer architectures
  - 1D convolutions to extract spectral features
  - Models ranging from **22M** to **1.1B** parameters

- **3** SSL Algorithms
- **> 10** pre-trained models



Backbone architectures

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AI and Remote Sensing

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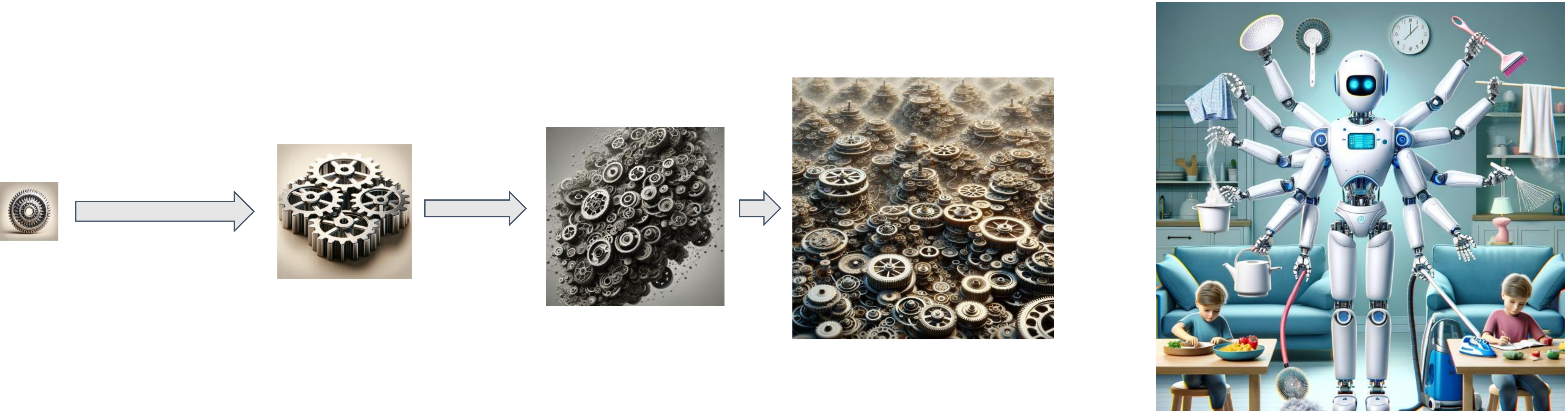

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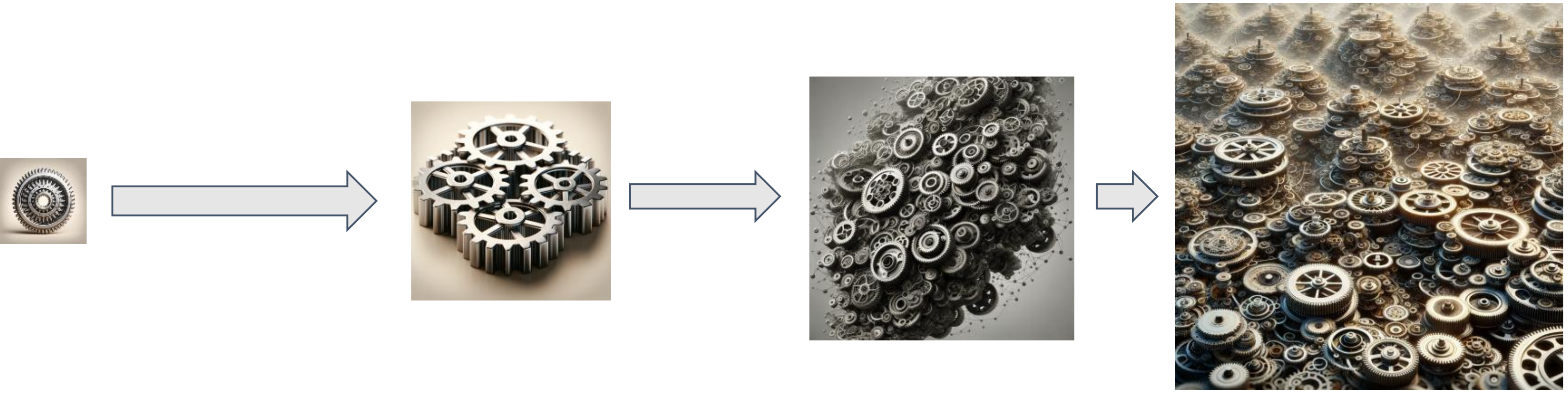
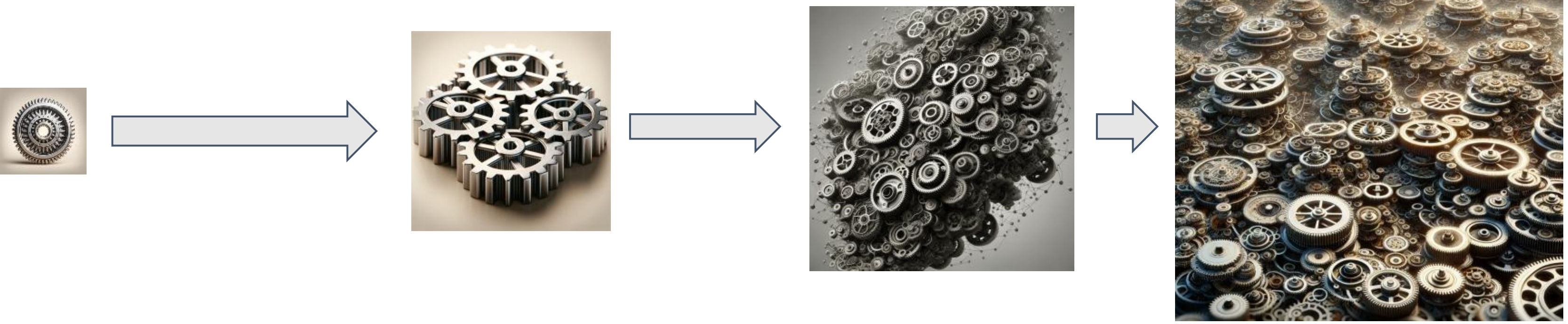


AI and Remote Sensing



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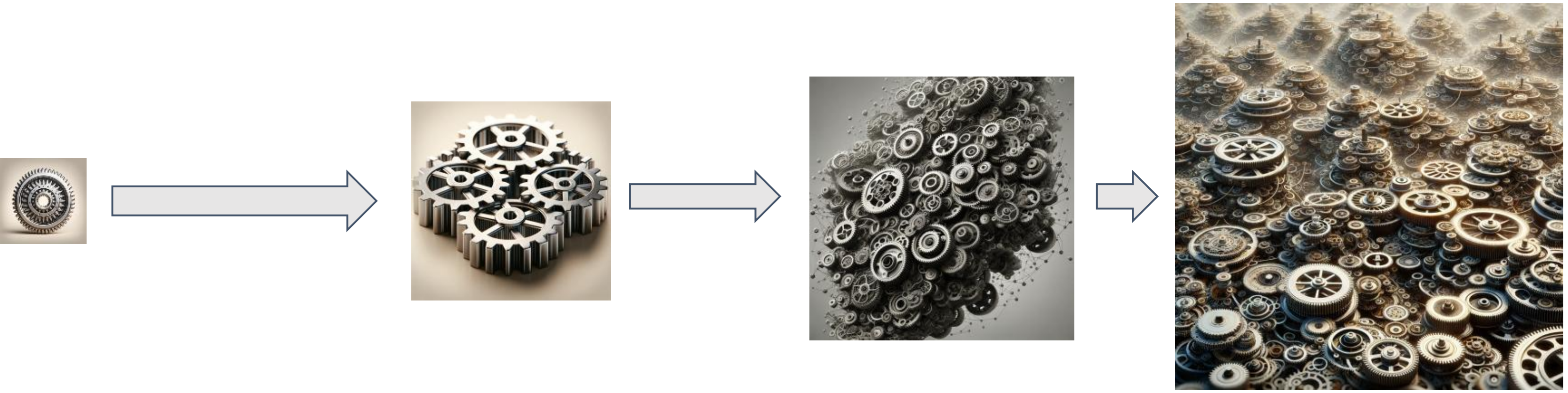
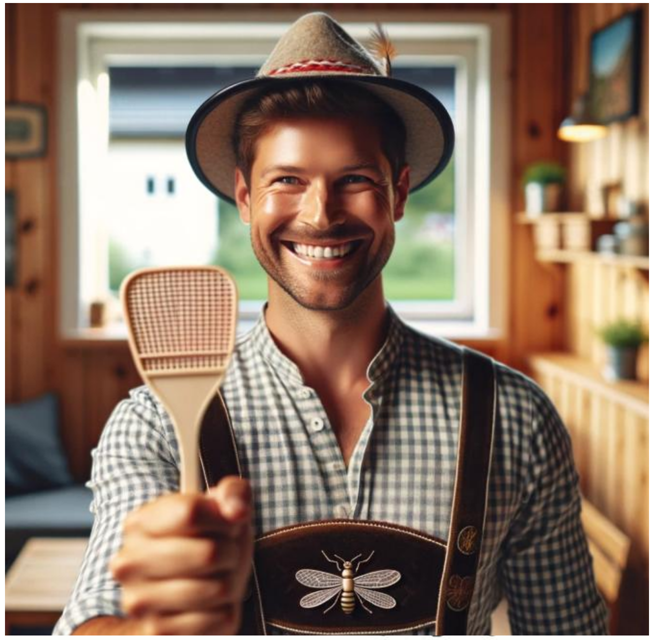
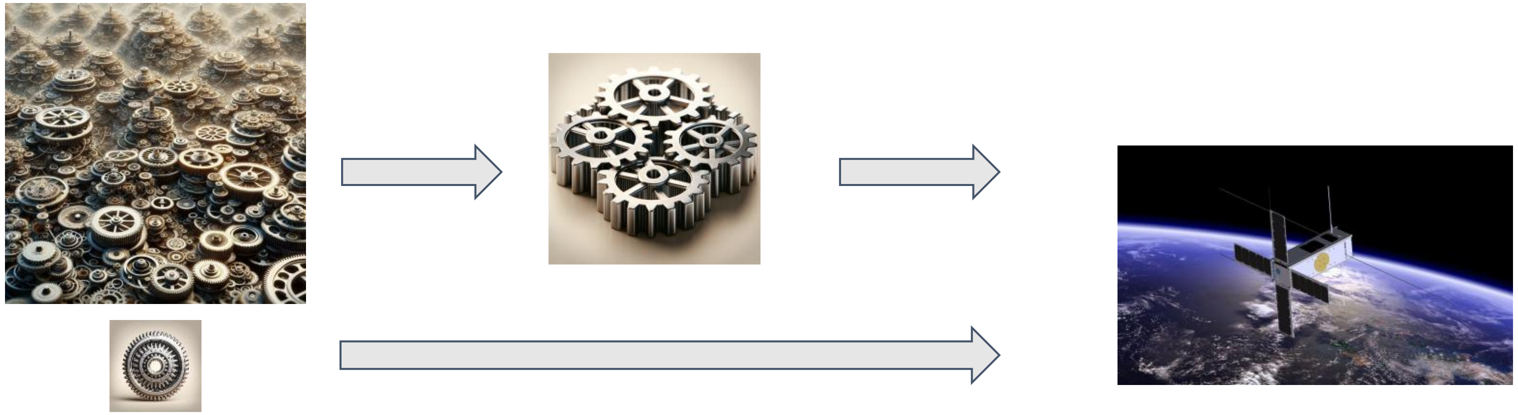
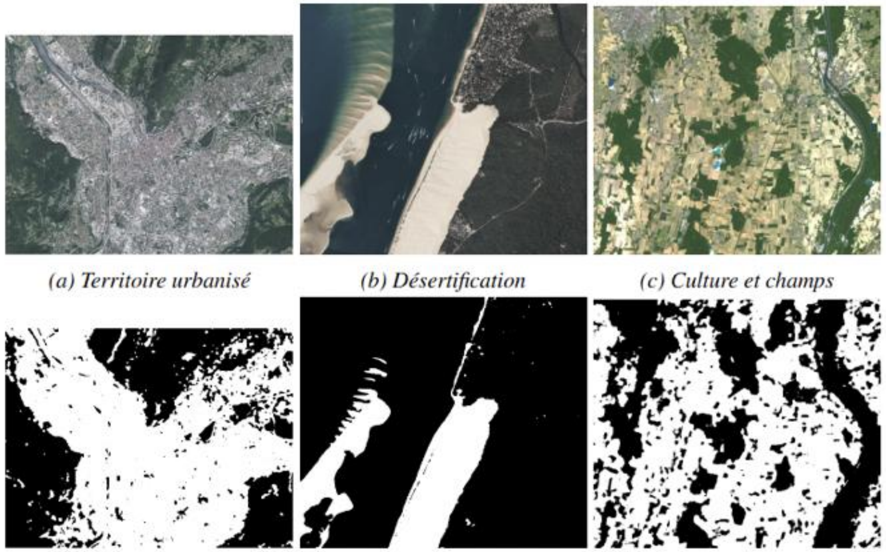




AI and Remote Sensing

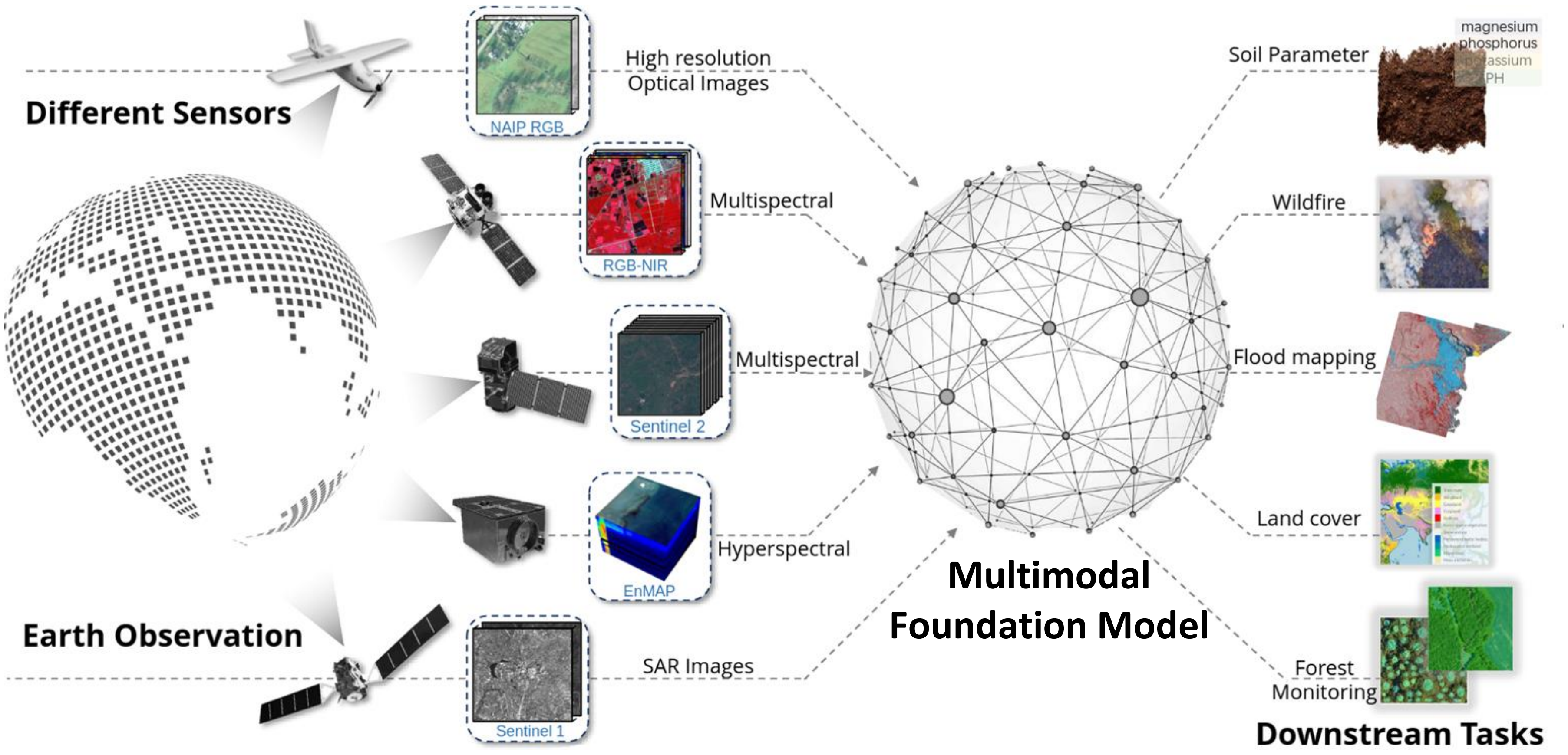




(a) Territoire urbanisé (b) Désertification (c) Culture et champs

Next challenges ?

Future directions: multimodal data integration



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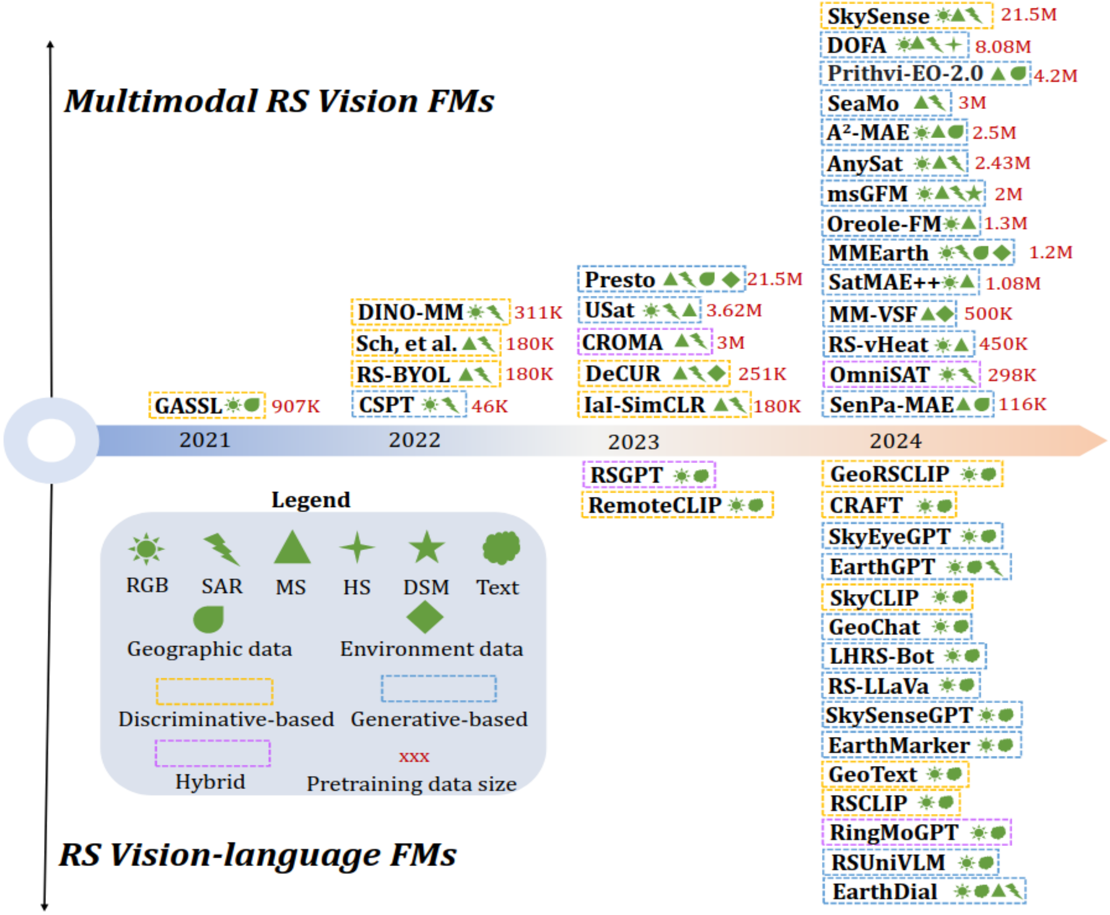
Future directions: multimodal data integration



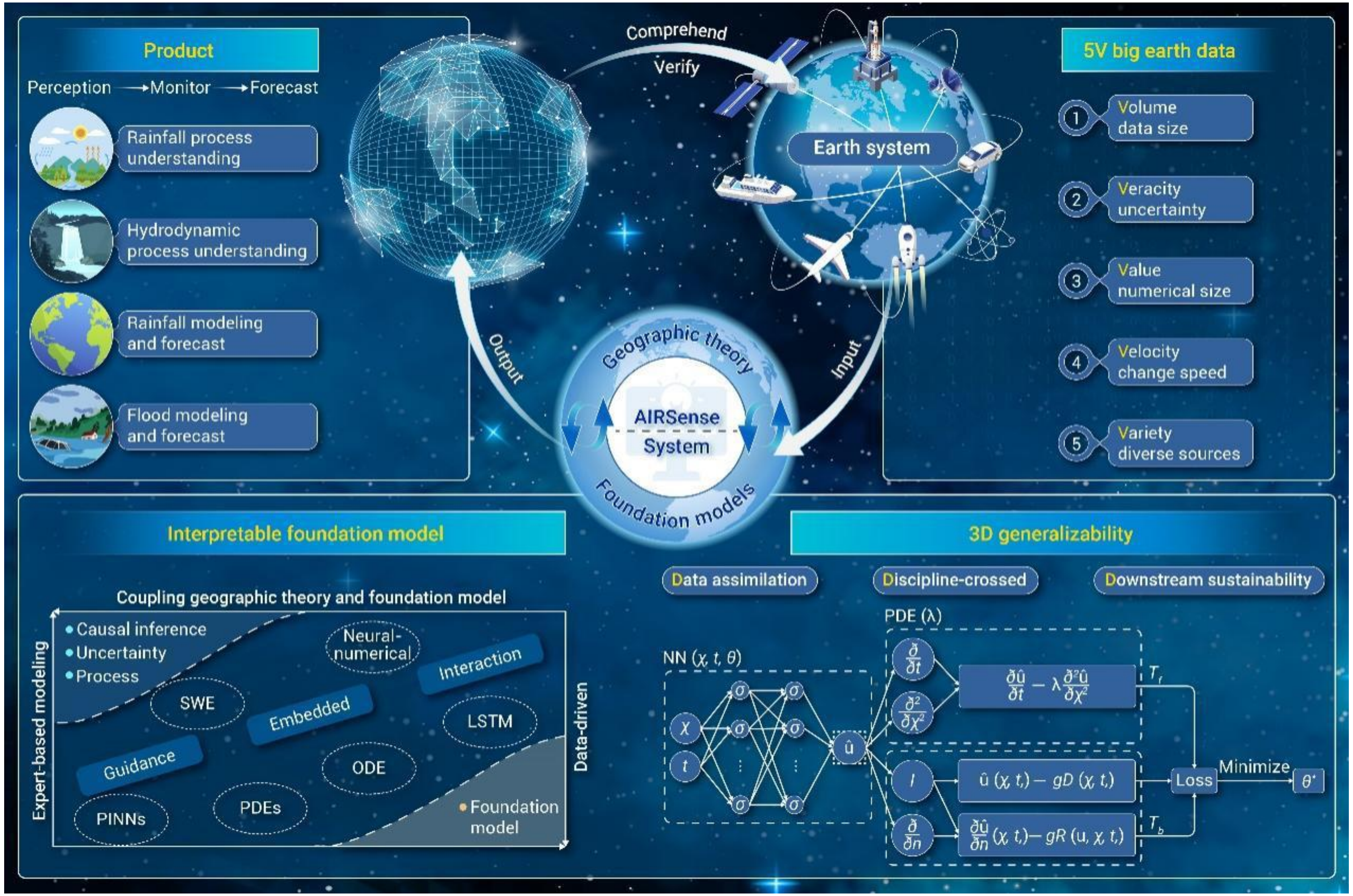
AI and Remote Sensing

Conclusion and next challenges:

- Multi-scale / multi-modal / multi-temporal integration
- Foundation models
- Lightweigth / frugal AI
- Explainable AI
- Physical modeling

Thank you for your attention.

Future directions: interpretable foundation models



Discovering *what* interactions drive the model's predictions?

Verifying *why* certain features are instrumental in driving model's decision-making process?

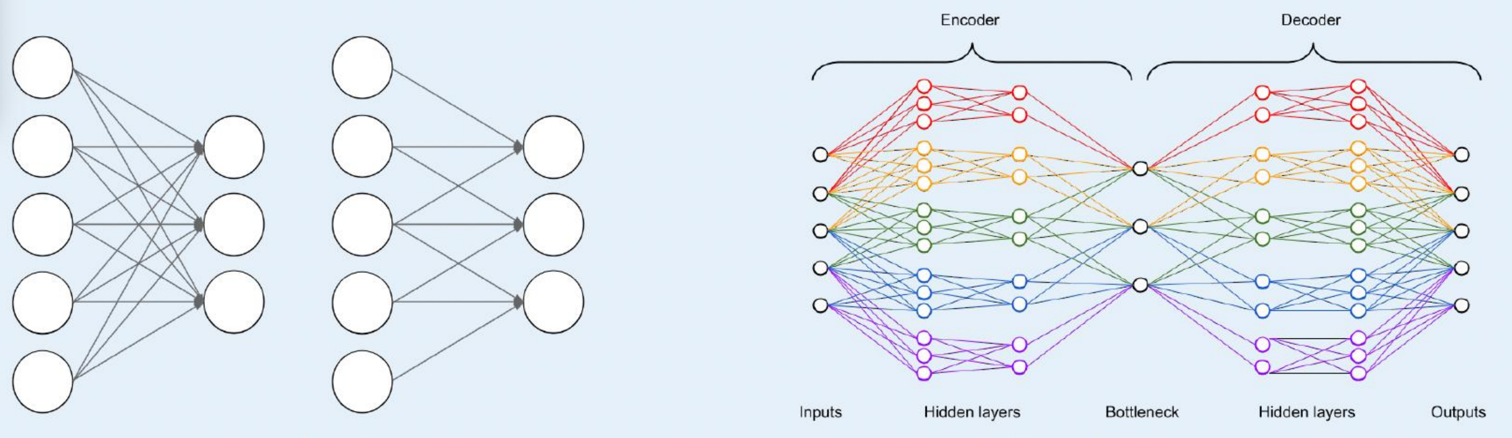
Assessing *how* the effectiveness of decisions is validated by real-world data?

Interpretable foundation models as decryptor peering into Earth system
Chenyu Li *et al*

Université Grenoble Alpes

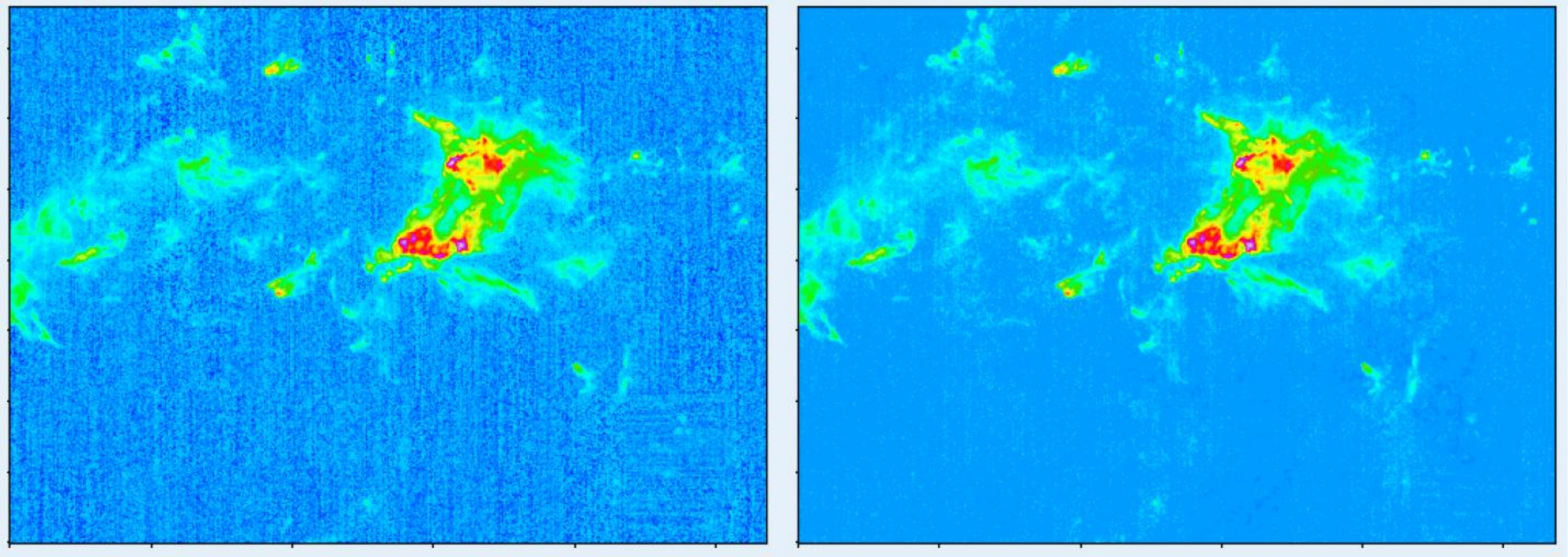
(iii) areas of research

Applications in radioastronomy (A&A)



Dense and locally dense layers

Example of locally dense autoencoder



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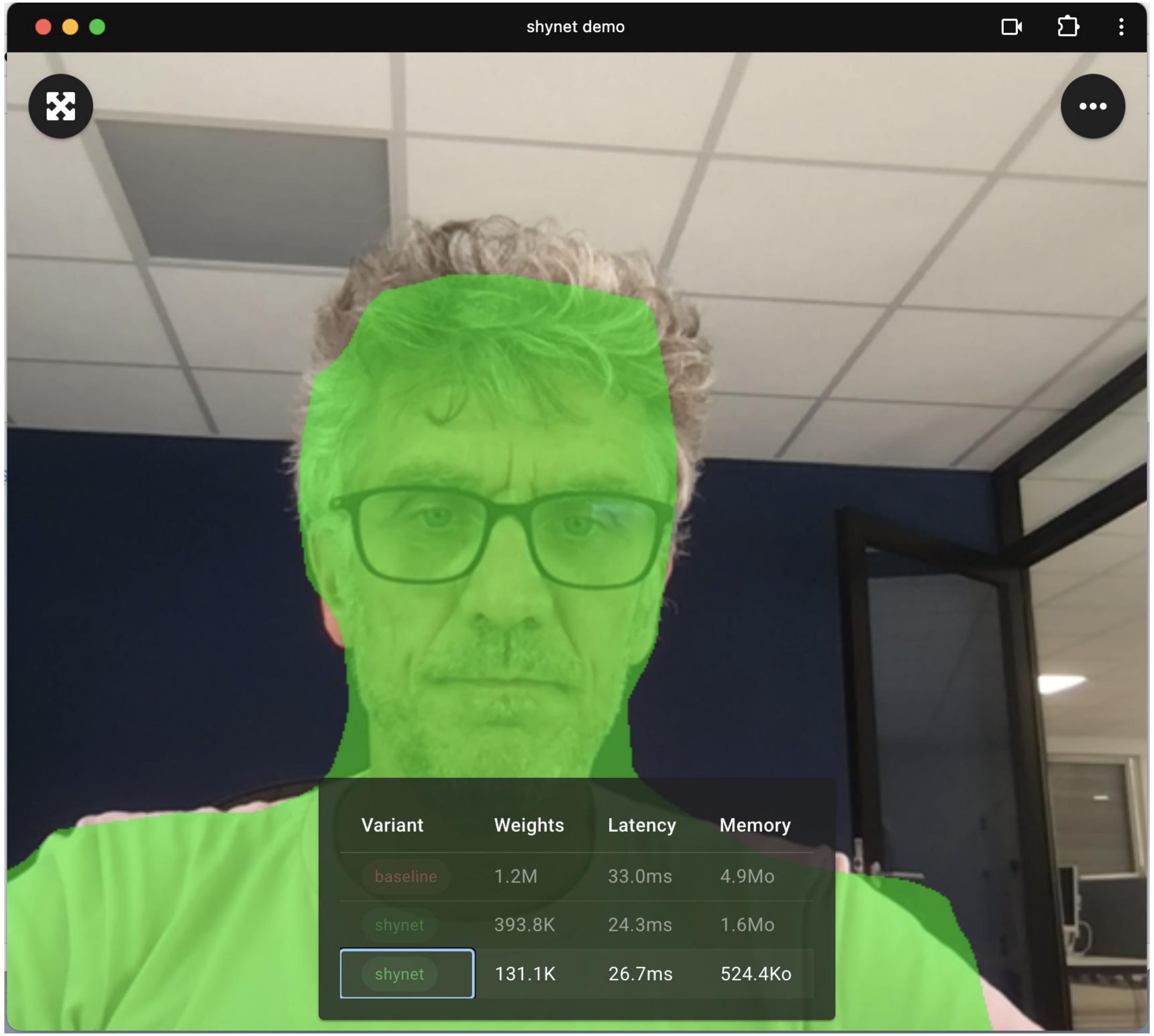
(iii) areas of research



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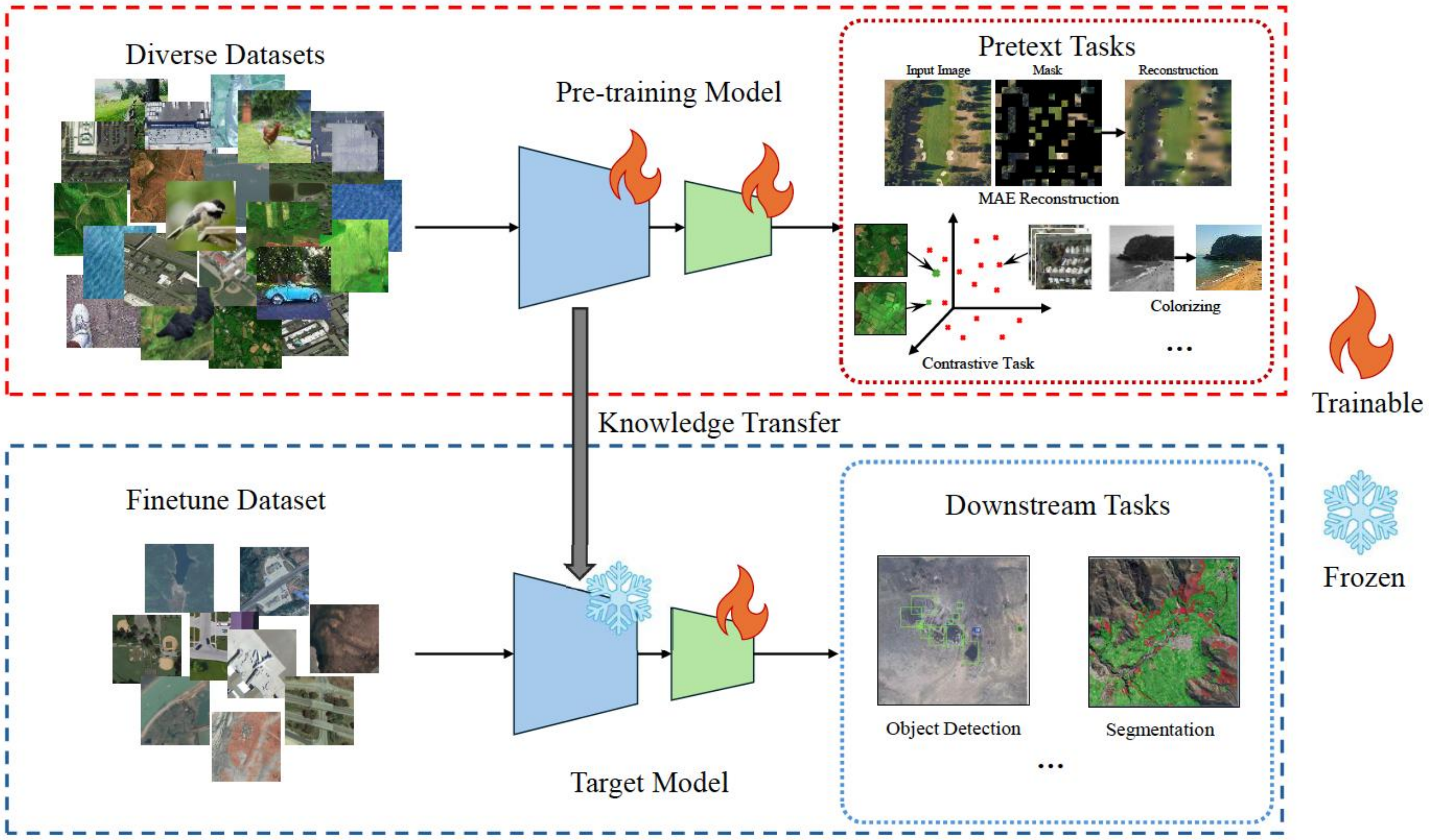
Foundation models: Methodologies

Self-supervised learning training strategies:

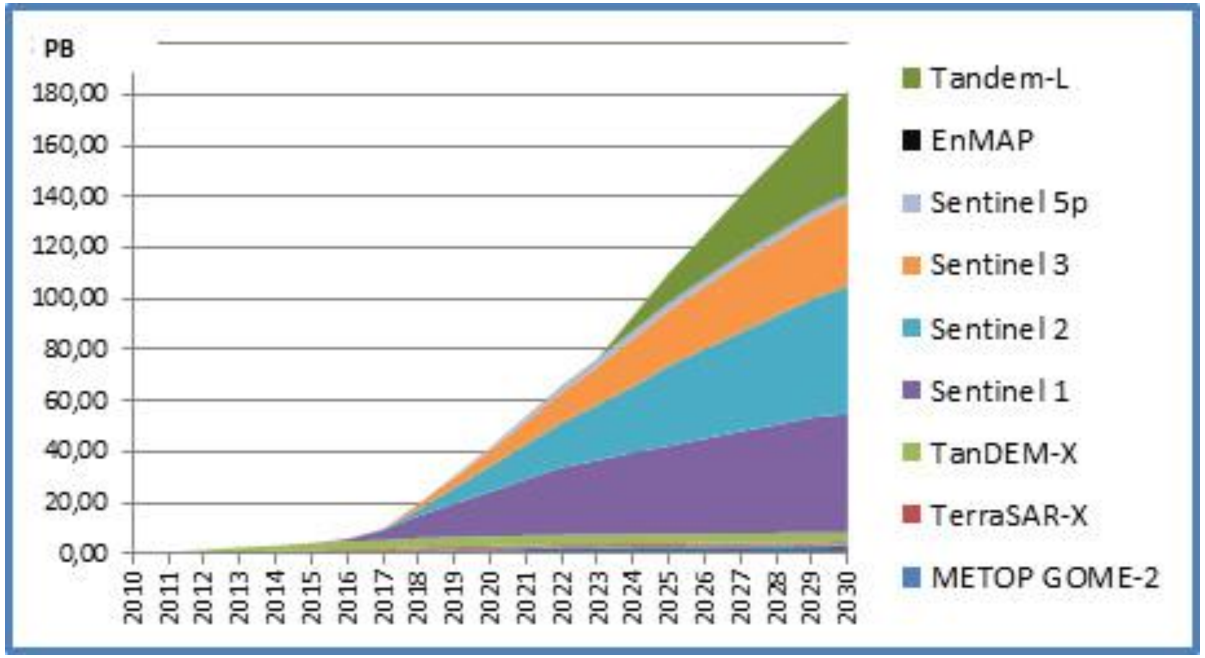


Labeled vs. Unlabeled Data in EO

- Deep Learning requires annotated data

- Labeled data is rare
  - Costly to obtain
  - Tedious annotation process

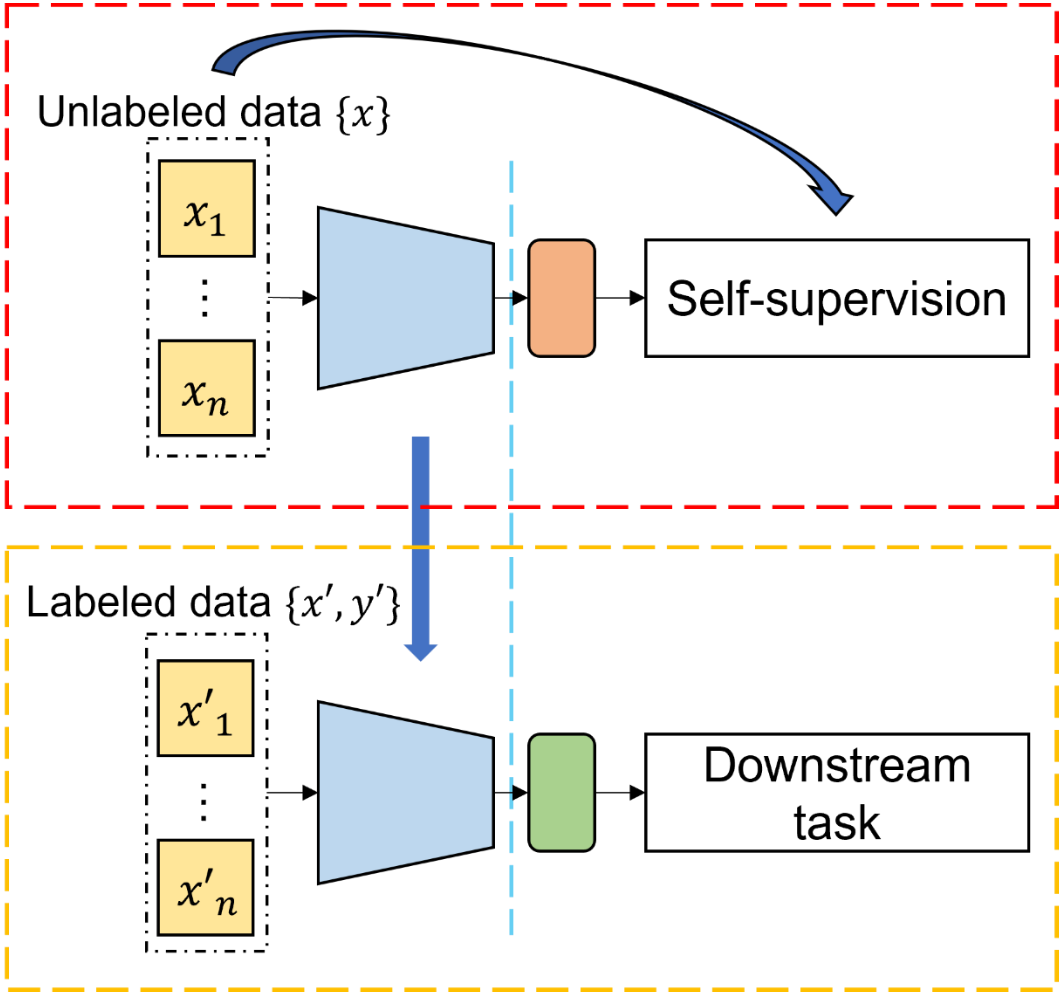
- Unlabeled data is abundant
  - Satellite archives with Petabytes of data



How to exploit unlabeled data for deep learning with hyperspectral imagery? → **Self-Supervised Learning**

Self-Supervised Learning

- **Goal**
  - Obtain *training feedback* from the data itself
  - Learn representations in a self-supervised fashion
    - no human annotation
- **Why?**
  - A pre-trained model can be transferred to downstream tasks
  - Improve **accuracy** and **label efficiency**



Overview of Self Supervised Learning*

*Wang, Yi, et al. "SSL4EO-S12: A large-scale multimodal, multitemporal dataset for self-supervised learning in Earth observation [Software and Data Sets]." IEEE Geoscience and Remote Sensing Magazine 11.3 (2023): 98-106.

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2023 Global Ranking of Academic Subjects

Remote Sensing | 100 Institutions | SHANGHAI RANKING

World Rank	Institution	Country/Region
1	Wuhan University	
2	Xidian University	
3	University of Maryland, College Park	
4	California Institute of Technology	
5	Beijing Normal University	
6	Technical University of Munich	
7	University of Electronic Science and Technology of China	
8	Université Grenoble Alpes	

https://www.shanghairanking.com/

East Coast (Goddard)

West Coast (JPL)

NASA

DLR

Inria

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2024 Global Ranking of Academic Subjects

1	Wuhan University	China
2	Xidian University	China
3	Technical University of Munich	Germany
4	University of Electronic Science and Technology of China	China
5	Northwestern Polytechnical University	China
6	Beijing Normal University	China
7	Sun Yat-sen University	China
8	China University of Geosciences	China
9	University of Maryland, College Park	USA
10	California Institute of Technology	USA
11	Université Grenoble Alpes	France

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2025 Global Ranking of Academic Subjects

Rank	University	Country/Region
1	Wuhan University	China
2	Xidian University	China
3	China University of Geosciences	China
4	Northwestern Polytechnical University	China
5	University of Electronic Science and Technology of China	China
6	Sun Yat-sen University	China
7	Technical University of Munich	Germany
8	Beijing Normal University	China
9	Peking University	China
10	Tongji University	China
11	The University of Hong Kong	Hong Kong, China
12	University of Extremadura	Spain
13	Beijing Institute of Technology	China
14	Université Grenoble Alpes	France

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IGN
INSTITUT NATIONAL DE L'INFORMATION GÉOGRAPHIQUE ET FORESTIÈRE

CHANGER D'ÉCHELLE

LA TRANSFORMATION IA DE L'IGN

NICOLAS GONTHIER (DSI/SIMV)
CHEF DE PROJET INNOVATION

Suivi d'occupation des sols par IA

16 classes de
Couverture du Sol

- Bâtiment
- Zone imperméable
- Zone perméable
- Piscine
- Serre
- Sol nu
- Surface eau
- Neige
- Conifère
- Feuillu
- Coupe
- Broussaille
- Pelouse
- Culture
- Terre labourée
- Vigne
- Autre

- Systèmes IA alliés de choix pour la cartographie
- Valeur concentrée sur le ***passage à l'échelle***

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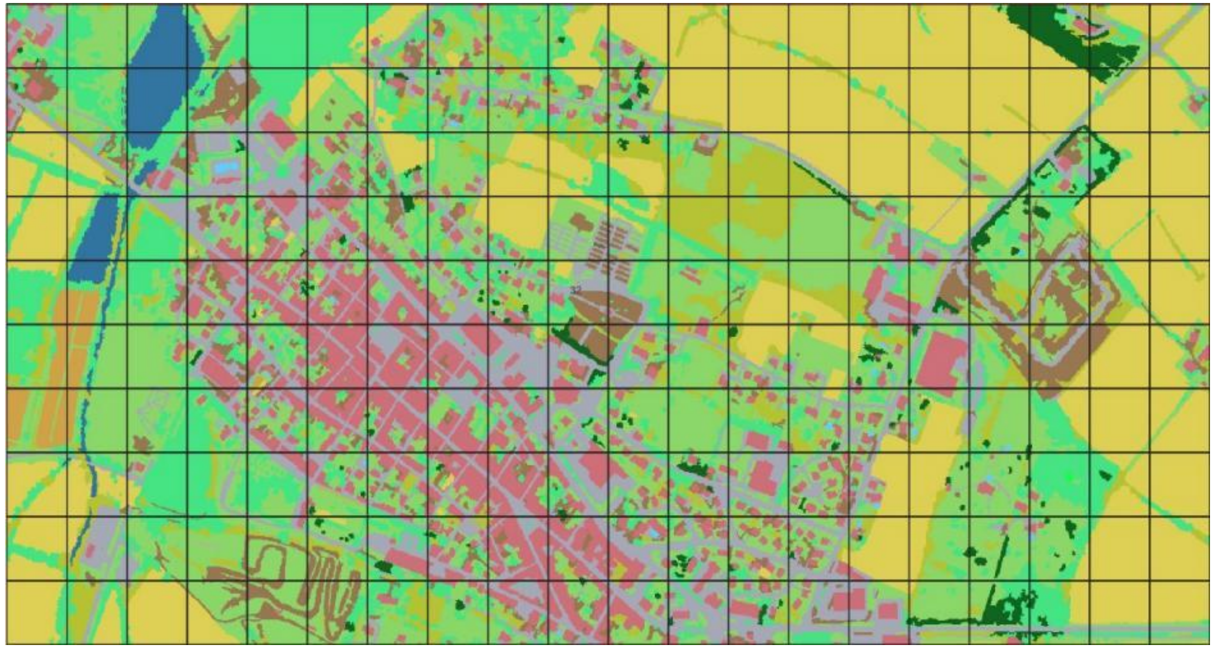
IGN CHANGER D'ÉCHELLE

Production de données d'apprentissage



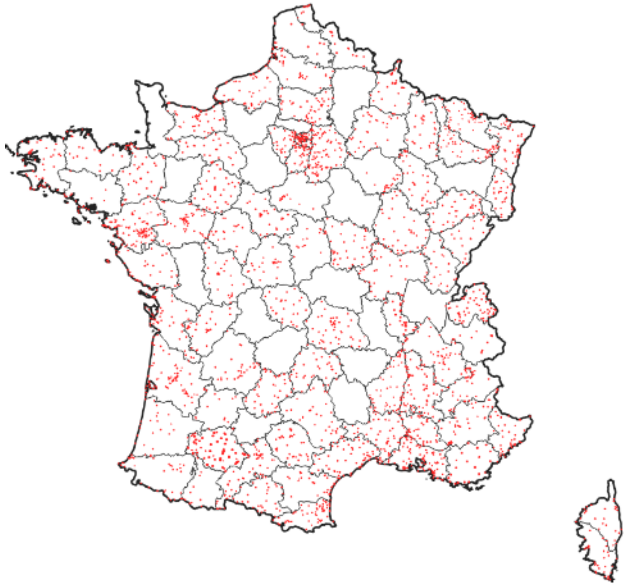


Fig. 2: Spatial domains, areas and patches.

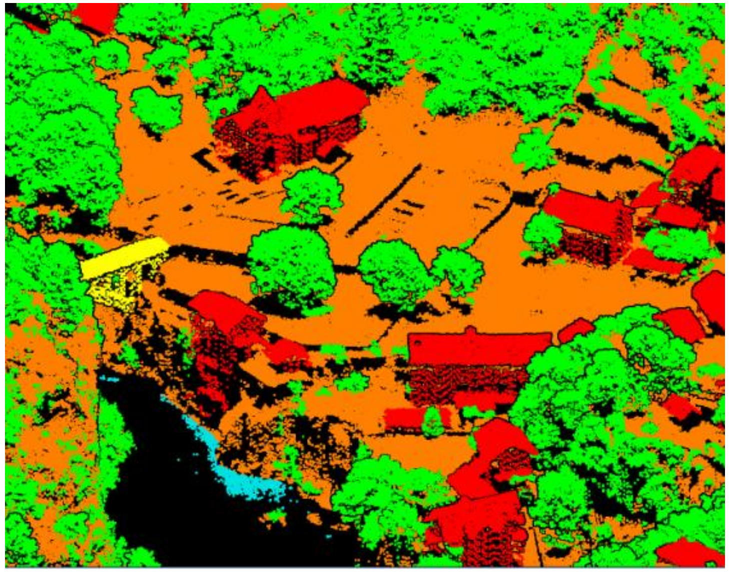
~ 2500 km^2 d'annotations

=> Applicable sur le territoire national > 500 000 km^2

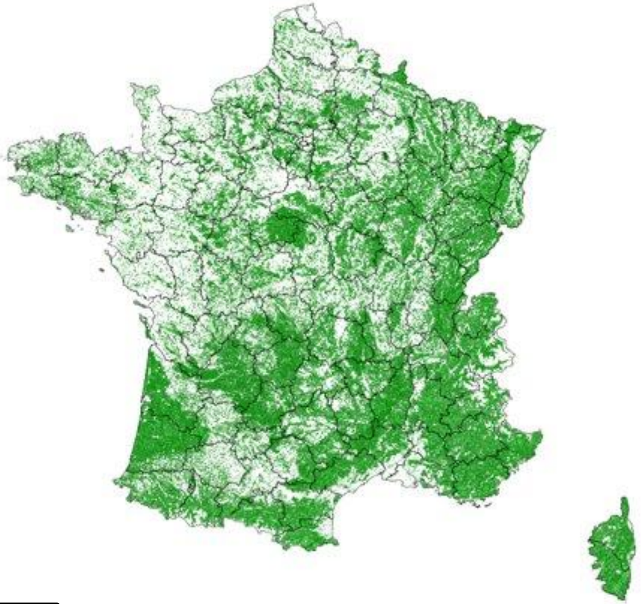
Usages de l'occupation des sols

Généralité de la démarche

LIDAR HD

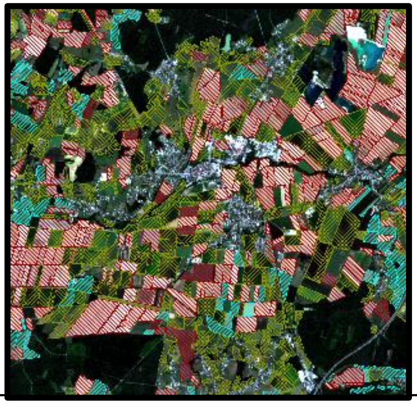


Forêt



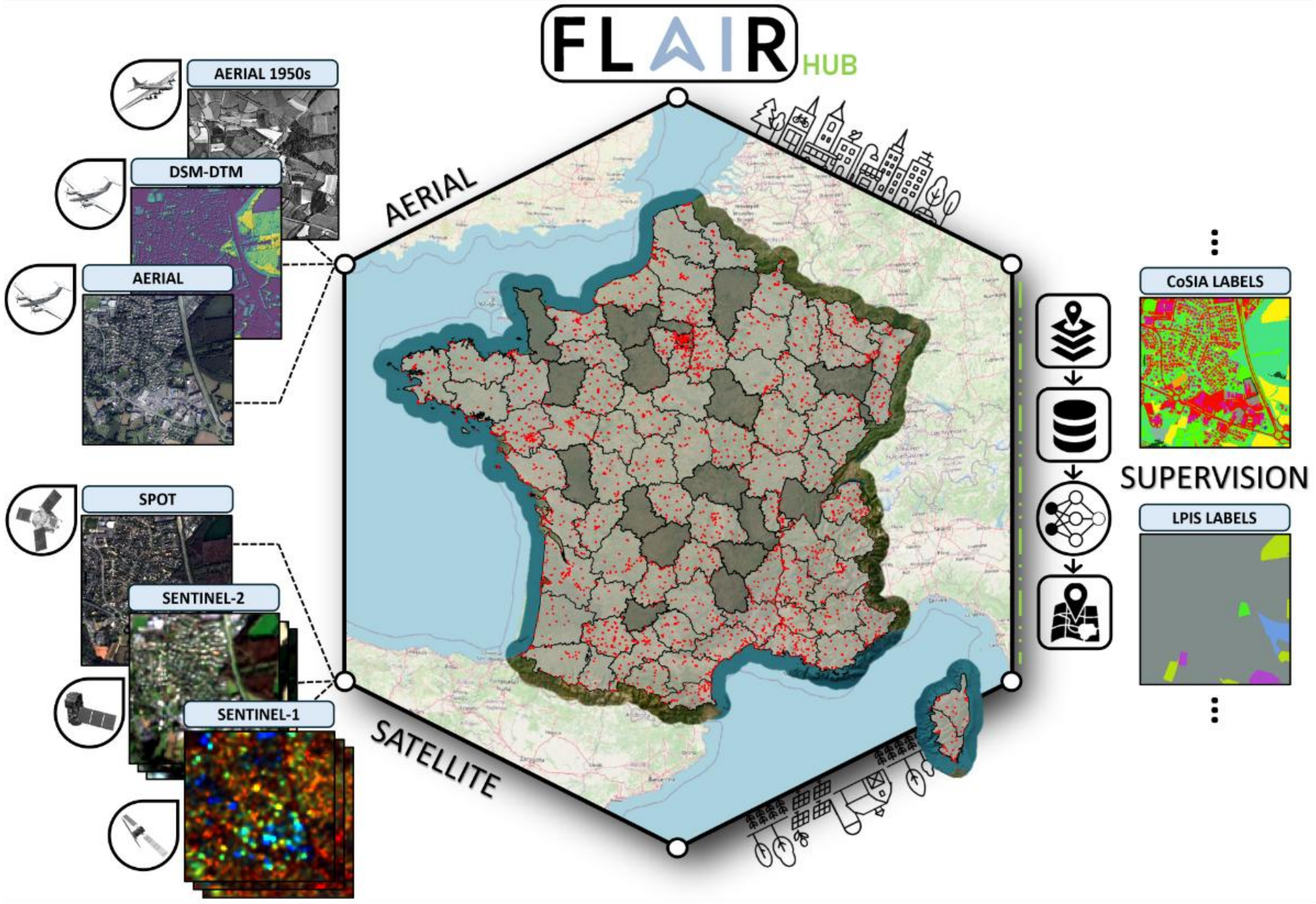
Détection de changements

Cartographie agricole



Richesse technique liée à la diversité des thématiques et des structures de données

ANIMER DES ÉCOSYSTÈMES IA



FLAIR : défis scientifiques
et techniques, ouverture données
(apprentissage & évaluation) & modèles.

Peu de grands jeux de données massifs, diversifiés, de qualité. L'un des plus grands jeux de données OCS THR ouverts.

2500 km^2, 63 Md pixels, 19 classes d'occupation des sols et 23 de type de culture

Amélioration des productions IGN

Réutilisations académiques
& industrielles

Modèles pré-entrainés : réduction de coûts et de barrières à l'entrée

Atténuer la concentration dans le secteur IA

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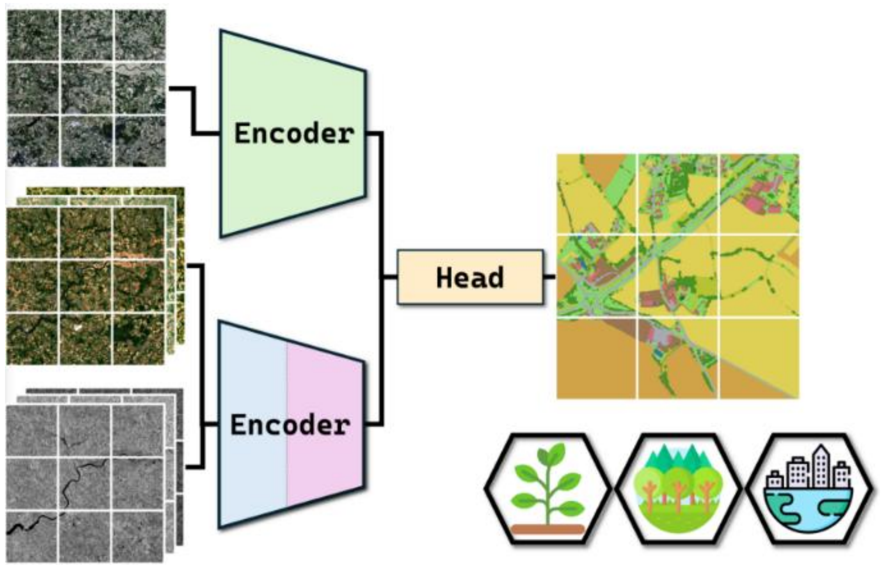
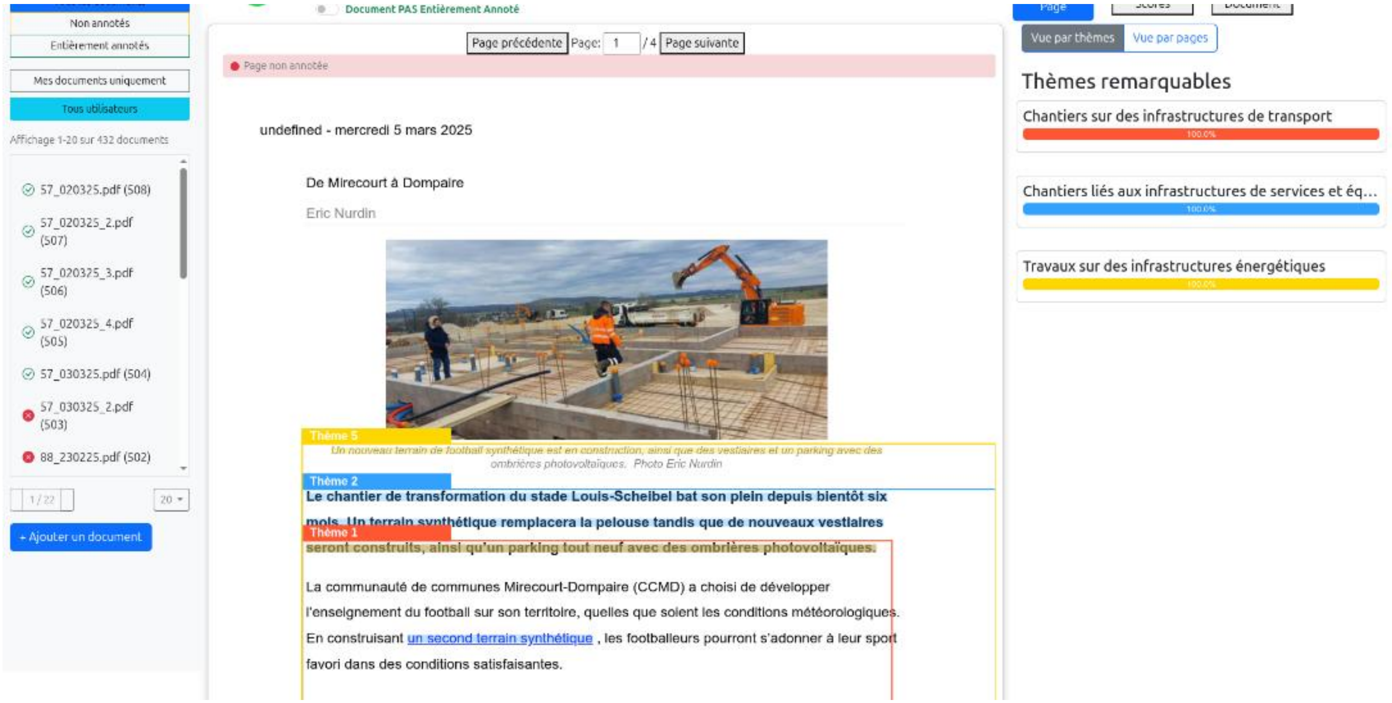
IGN CHANGER D'ÉCHELLE

Se maintenir à l'état de l'art et être proactif

- Modèles de Fondation multimodaux pour les données de télédétection
- Grands Modèles de Langue
- Feuille de route technologique sur la détection de changements





- Maintenir dialogue entre recherche et équipes opérationnels
- Faire communauté pour arriver à une veille pertinente

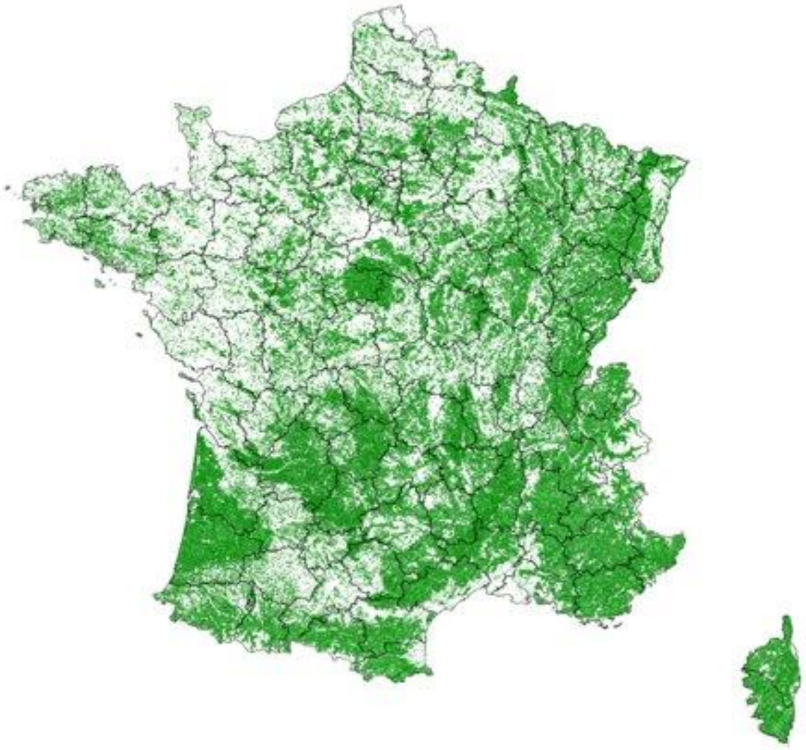
Ressources humaines & organisation

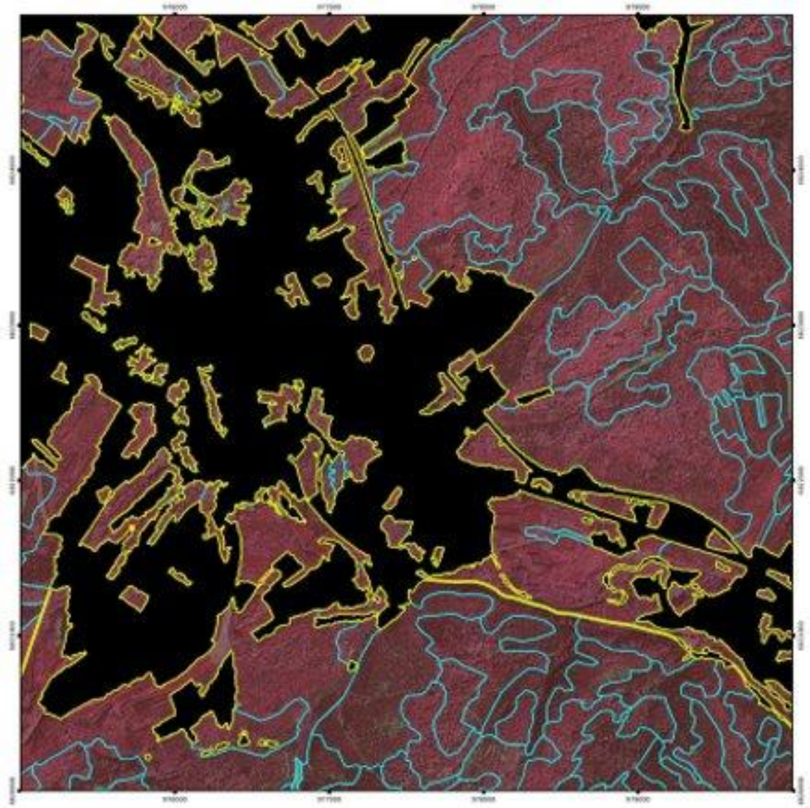
- Développement expertise IA. 30 experts IA + Recherche.
- **Compétition forte** pour les talents IA. Atouts : **sens des missions**; open source ; crédibilité scientifique et technique ; **contributions à grande échelle.**
- Importance d'équipe **pluridisciplinaires** : itérations fréquentes **nécessitant experts IA + métiers + géomaticiens + photo-interprète** + dev
- **Projets exigeants** : intenses en ressources humaines et de calcul
- Contraintes projets innovation + co-dépendance données/modèle/code.

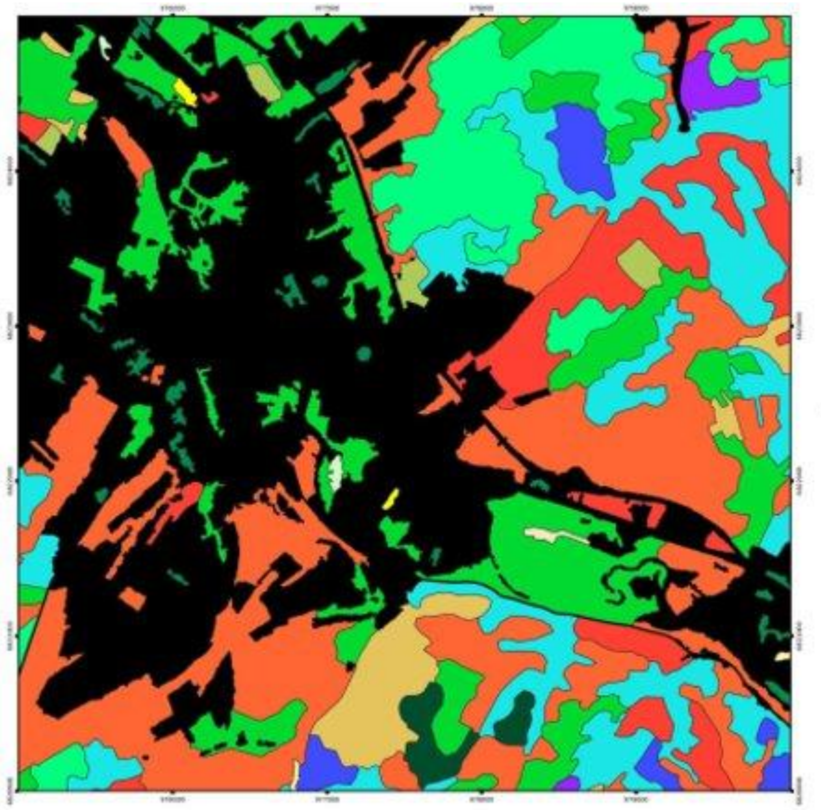
Appui dans la sphère publique

- Plusieurs années d'expérience sur l'IA / apprentissage profond (à partir de 2018)
  - Recul sur une dizaine de projets industrialisés
  - Démarche structurée tôt : feuille de route dédiée à partir de 2021
  - Nombreuses conditions pour le succès des projets IA → **Nécessite l'alignement de plusieurs unités** et implication encadrement supérieur
  - Pas de *quick win* : gains réels, mais issus d'efforts soutenus, **Approche empirique & pragmatique.**
- **Masse critique** : permet présence sur plusieurs thématiques + sur tout le spectre recherche <-> production

Cartographie forestière – Segmentation d'essences à partir d'images aériennes – BD Forêt V3

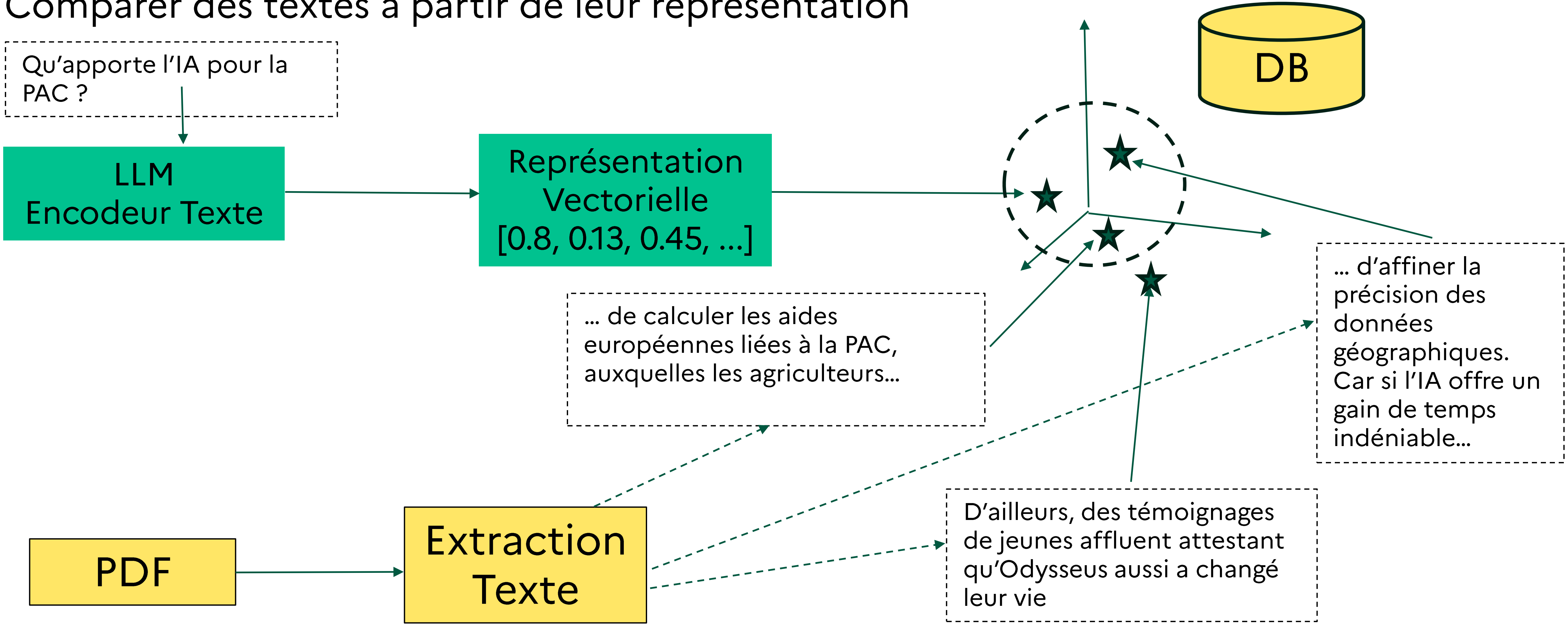




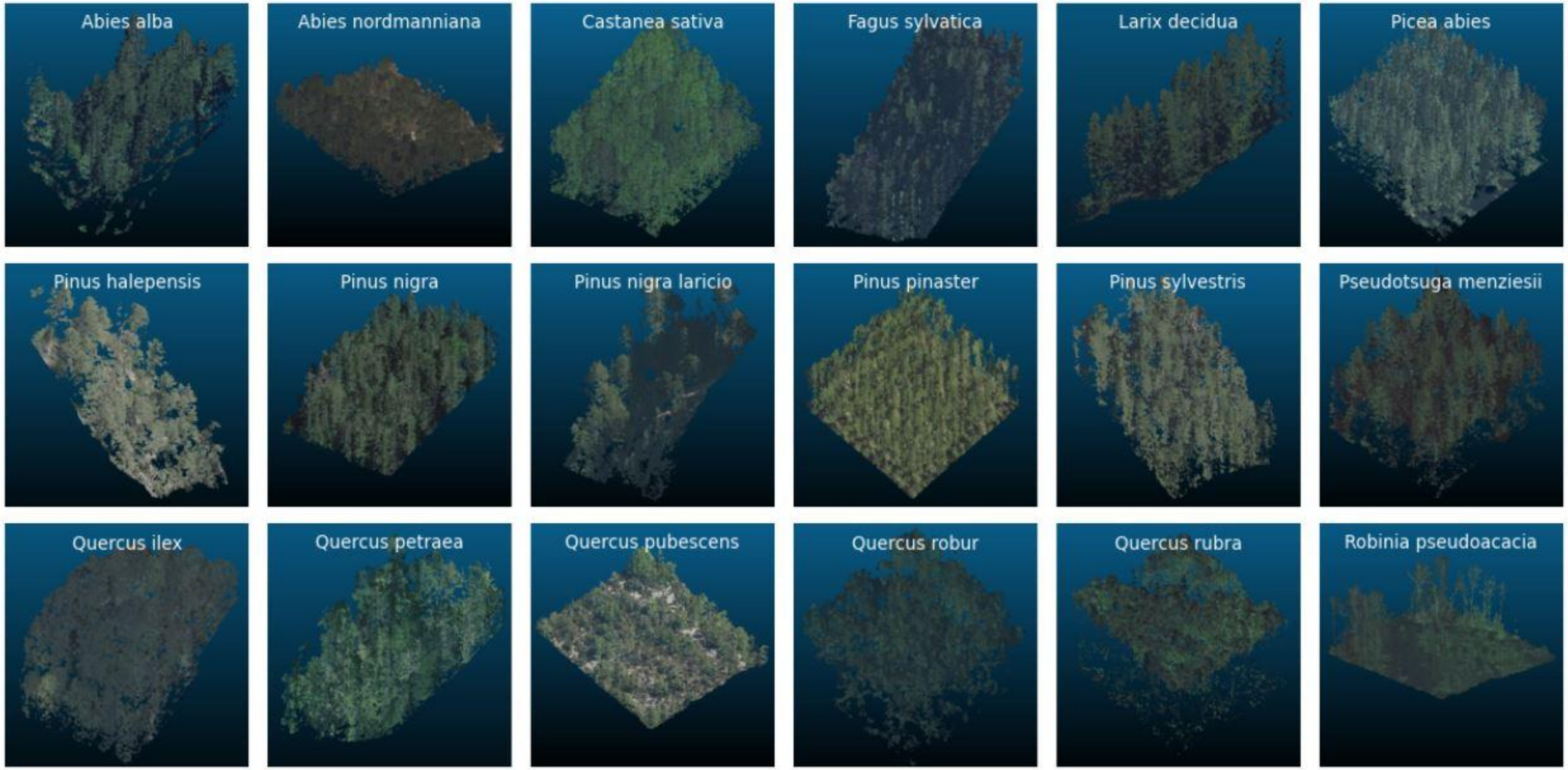


Extraction d'informations textuelles avec des LLM

Comparer des textes à partir de leur représentation



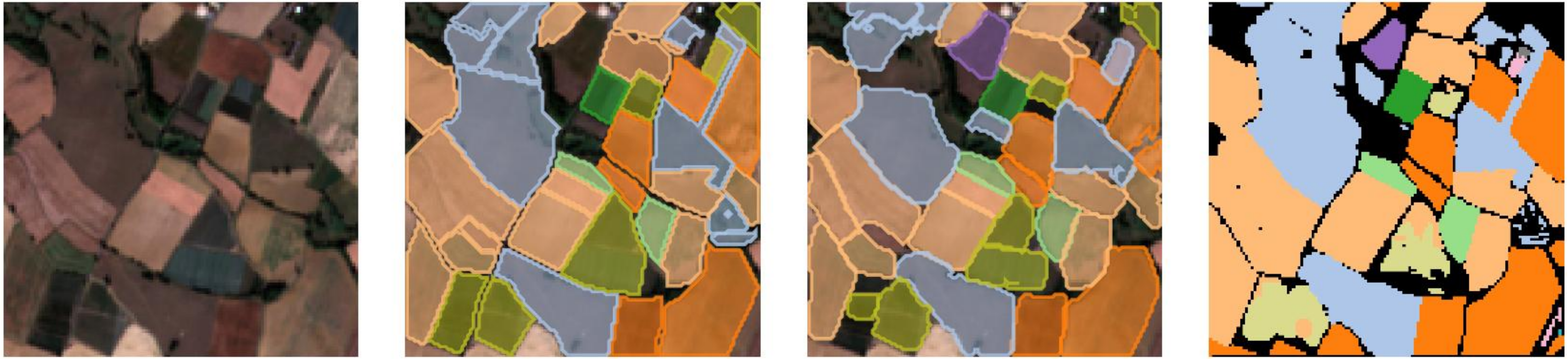
Classification de nuages de points de forêt



Plus grand dataset de classification de nuages de points :

LIDAR ALS 40 pts/m^2
18 essences
33900 ha
23.7M .Arbres
[Gaydon WACV 2024]

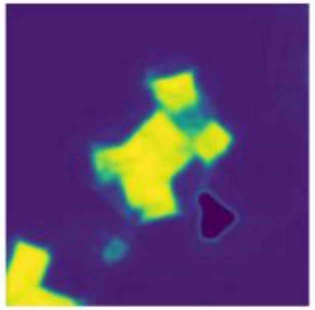
Agriculture & analyse de séries temporelles optiques



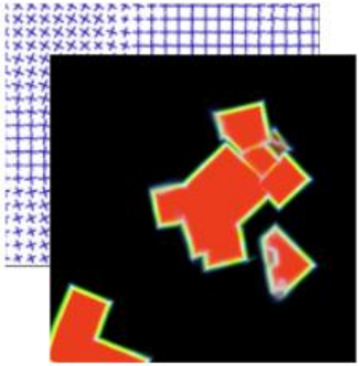
(a) Image from the sequence. (b) Panoptic annotation. (c) Panoptic segmentation. (d) Semantic segmentation.

Détection et vectorisation du bati Frame Field learning

DeepLabv3+



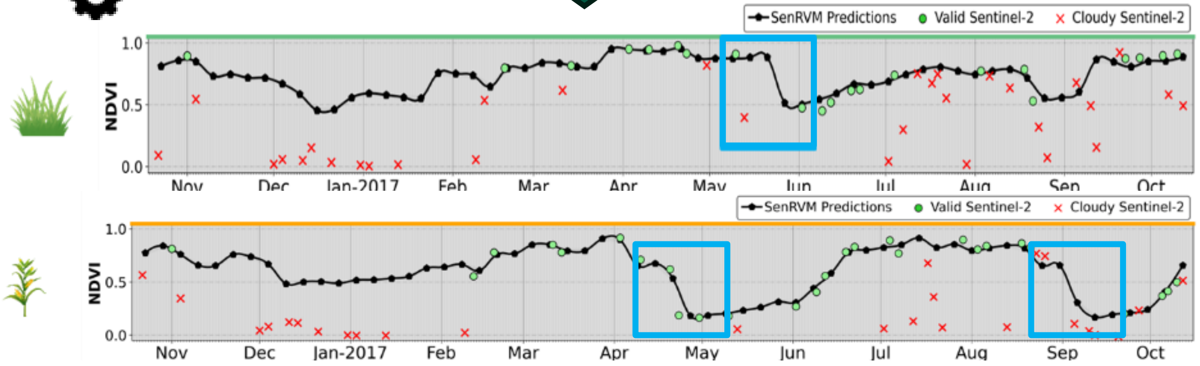
Framefield

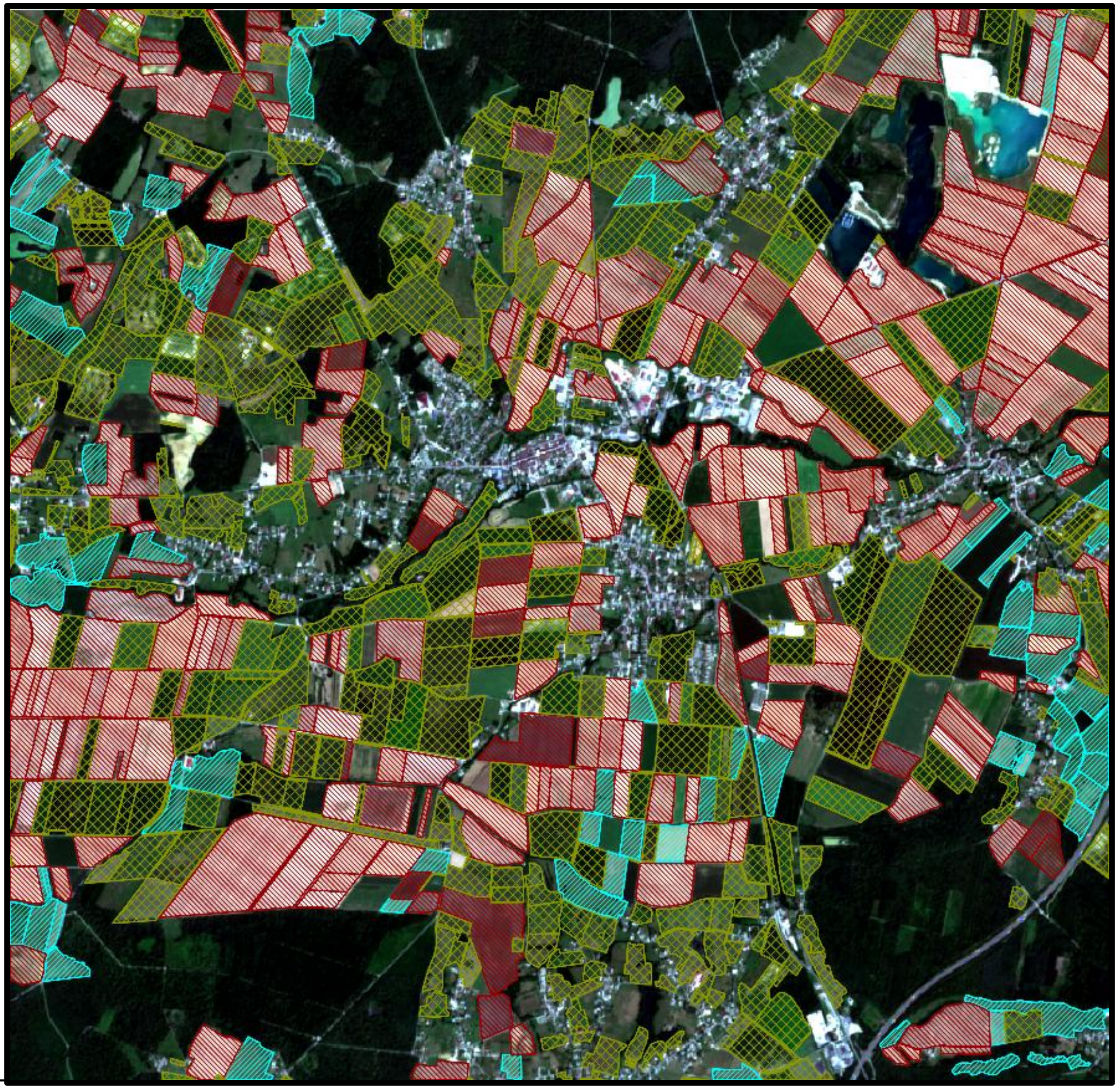


Pratiques agricoles

Récolte, fauche, pâture

DL regression modèle





Comment être générique entre capteurs ?

Les modèles actuels ne sont pas asssez génériques, c'est pourquoi il est nécessaire de les fine-tuné sur des plus petits datasets cibles

Model IA IGN ORTHO (RVBI) --> IGN ORTHO (Aerial Imagery 20cm RGB+IR)

Model IA Aerial IGN ORTHO (RGBI) --> PNEO (Satellite Imagery 30 cm RGB+IR)

INNOVATION & AMELIORATION DES MODELES

Orthoimage RGB | U-Net-like, conv. | Vision Transformers

MERCI POUR VOTRE ATTENTION

MINISTÈRES
TRANSITION ÉCOLOGIQUE
AMÉNAGEMENT DU TERRITOIRE
TRANSPORTS
VILLE ET LOGEMENT

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Commissariat Général au Développement Durable

ECO LAB
Innovation - Écologie - Territoires

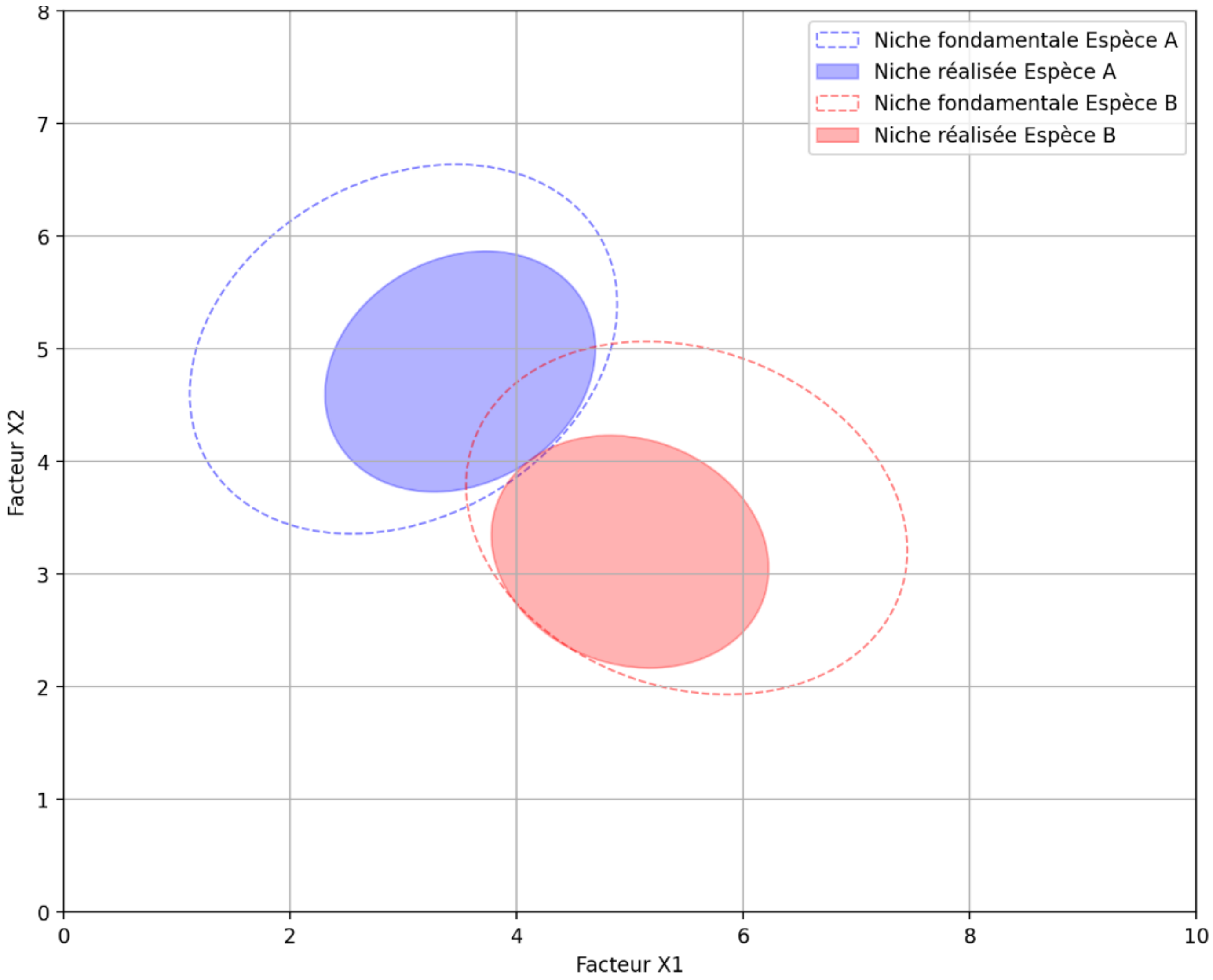
IA métiers et production de données

Matthieu PORTE (Ecolab du CGDD)

~ 10 ans d'historique sur l'IA « métier »

Où en est-on ?

Niche écologique



Déploiement très diversifié de l'IA pour l'info géo

- Diversité des contextes : secteurs, échelles
- Diversité des tâches & techniques
- Diversité des fonctions endossées par les systèmes IA

Exemple : cartographie nationale de l'occupation des sols (IGN)

MINISTÈRES TRANSITION ÉCOLOGIQUE AMÉNAGEMENT DU TERRITOIRE TRANSPORTS VILLE ET LOGEMENT

Commissariat Général au Développement Durable

ECOLAB Innovation - Écologie - Territoires

Exemple : détection précoce de feux de forêts (Pyronear)

Exemple : prévision ressources en eau (Climate Data Hub CVDL)

Tours métropole · NEC Nouvel Espace du Cher · VAL DE LOIRE NUMÉRIQUE · brgm · PRISME · LAB'IA Loire Valley · anteagroup

Exemple : détection et catégorisation de déchets (Metz)

Exemple : détection de panaches de méthane (UNEP / IMEO)

Figure 1
The first two images show plumes detected by NASA's EMIT in Chubut, Argentina, on 13 and 21 November 2024. No further emissions have been detected at the location since 8 January 2025.

Déploiement très diversifié de l'IA pour l'info géo

- Secteurs : climat, météo, biodiversité, aménagement, transports, déchets, risques, agriculture…
- Tâches : détection d'objets, segmentation sémantique, prédiction…
- Données : images aériennes, satellites, 2D, 3D, images naturelles, données structurées…
- Toutes échelles du local au mondial, et lien entre échelles
- Fonctions : massifier production de données, complétude données manquantes, prédire/simuler, détecter des anomalies, priorisation de contrôles…

Déploiement très diversifié de l'IA pour l'info géo

- Population des systèmes IA a pris très largement place pour la production d'info géo : modèles spécialisés, mais grande généralité de l'intégration de l'IA

Ressources

- Données : instrumentation & capteurs, labellisation…
- Compétences multiples
- Capacités de calcul

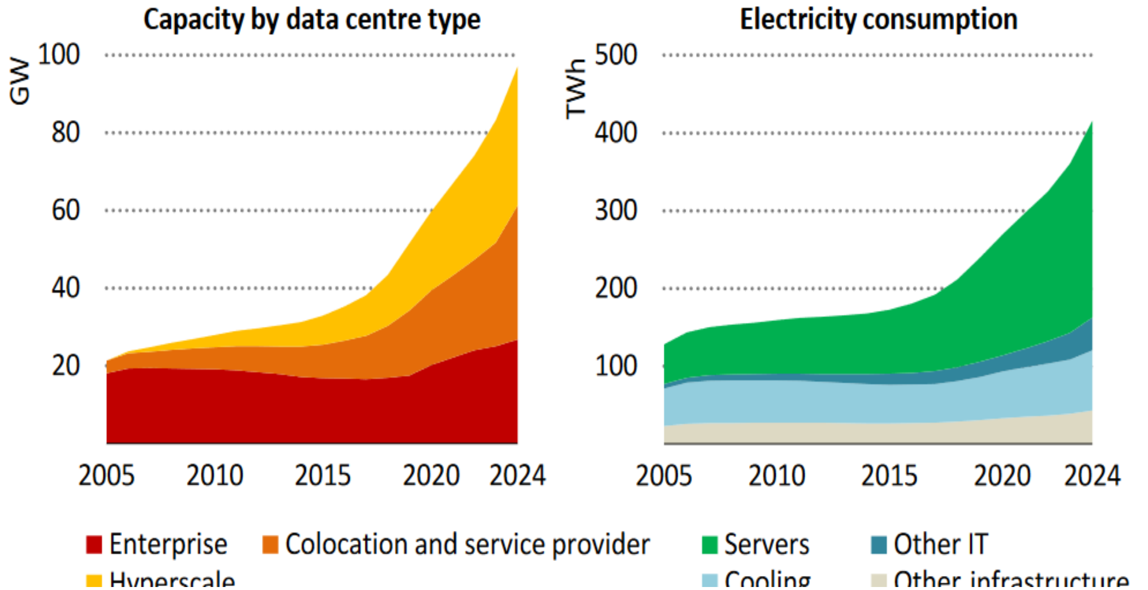
Etudes sur les impacts environnementaux des centres de données à l'échelle mondiale et prospection

En 2025

- Data centers = 1,5% de consommation mondiale en électricité, soit **415 TWh**
- Croissance de **12% par an** depuis 5 ans

Prospection pour 2030

- Centres de données = 3% de consommation mondiale en électricité, soit **945 TWh**
- Croissance de **30% par an** (adoption de l'IA)



Consommation totale d'électricité des centres de données par type d'équipement et par type de centre de données, 2005- 2024

Agence Internationale de l'énergie : Energie et IA (2025)

Etudes sur les impacts environnementaux des centres de données à l'échelle mondiale et prospection

La filière centres de données justifie les infrastructures fossiles

- Relance massive des infrastructures fossiles (gaz)
- Annulation de fermeture programmée de centrales à charbon

Et l'IA dans tout ça ?

- En 2025, 15% des usages en centre de données
- Prédiction pour 2030 : **55%**

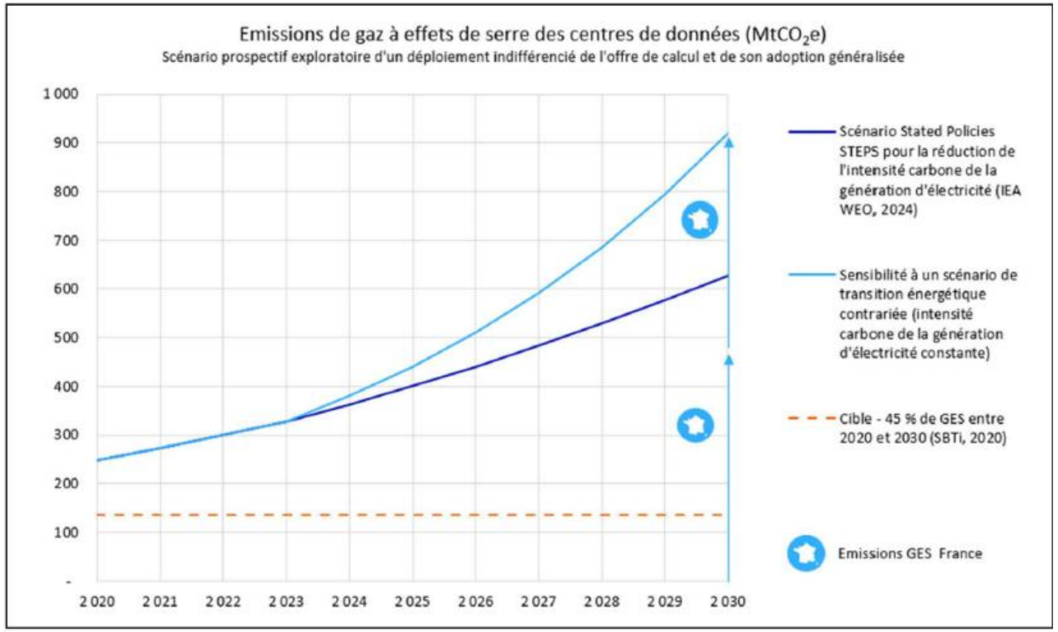


Figure 2 - Traduction en émissions de gaz à effet de serre ($MtCO_2e$) de notre scénario prospectif exploratoire d'un déploiement indifférencié de l'offre de calcul et de son adoption généralisée pour différentes intensités carbone de l'électricité et comparaison au scénario cible. Source : (The Shift Project, 2025b)

Shift Project : Intelligence artificielle, données, calculs : quelles infrastructures dans un monde décarboné (2025)

Limites & Dynamiques en cours

- Multimodalité
- Frugalité
- Réplicabilité & capitalisation