Remote Sensing and Artificial Intelligence

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Artificial Intelligence

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

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It’s here with us.

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Fei Fei Li
American Computer Science Professor

Artificial Intelligence

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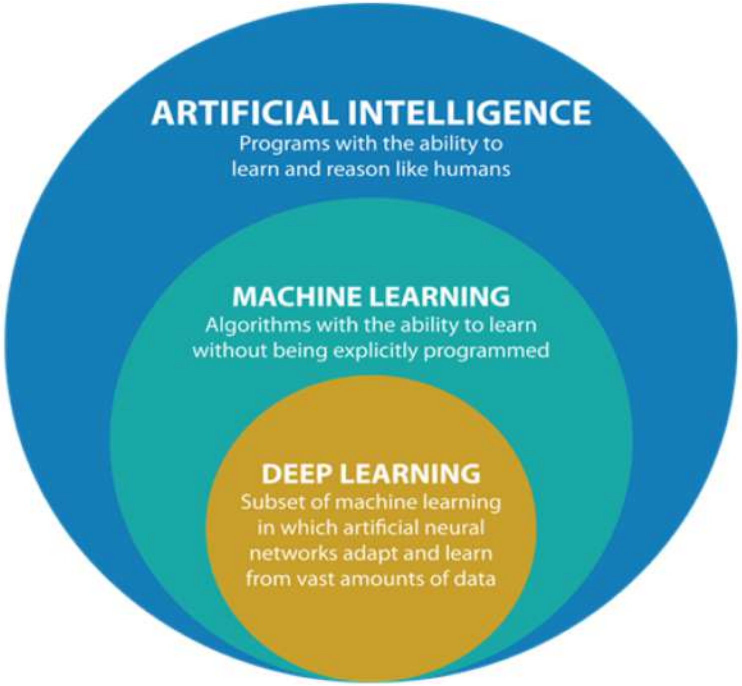
American Computer Science Professor
1976 / 27 av. LISTIC

Artificial Intelligence



Data, data, data…
HPC
Algorithms

Remote sensing

- Sensing: Observing, measuring, monitoring
- Remotely: from a distance (close range… or from far away)

Platforms:

- ❖satellites
- ❖airplanes
- ❖UAV (drones)

Sensors:

- ❖Optical
- ❖Hyperspectral
- ❖Radar
- ❖Lidar

Remote sensing

- Sensing: Observing, measuring, monitoring
- Remotely: from a distance (close range… or from far away)

Characteristics:

- ❖ Spatial resolution
- ❖ Spectral resolution
- ❖ Revisit time (temporal resolution)

Advantages:

- ❖ Large spatial coverage
- ❖ Low cost
- ❖ Agility (UAV)

Remote sensing

- Sensing: Observing, measuring, monitoring
- Remotely: from a distance (close range… or from far away)

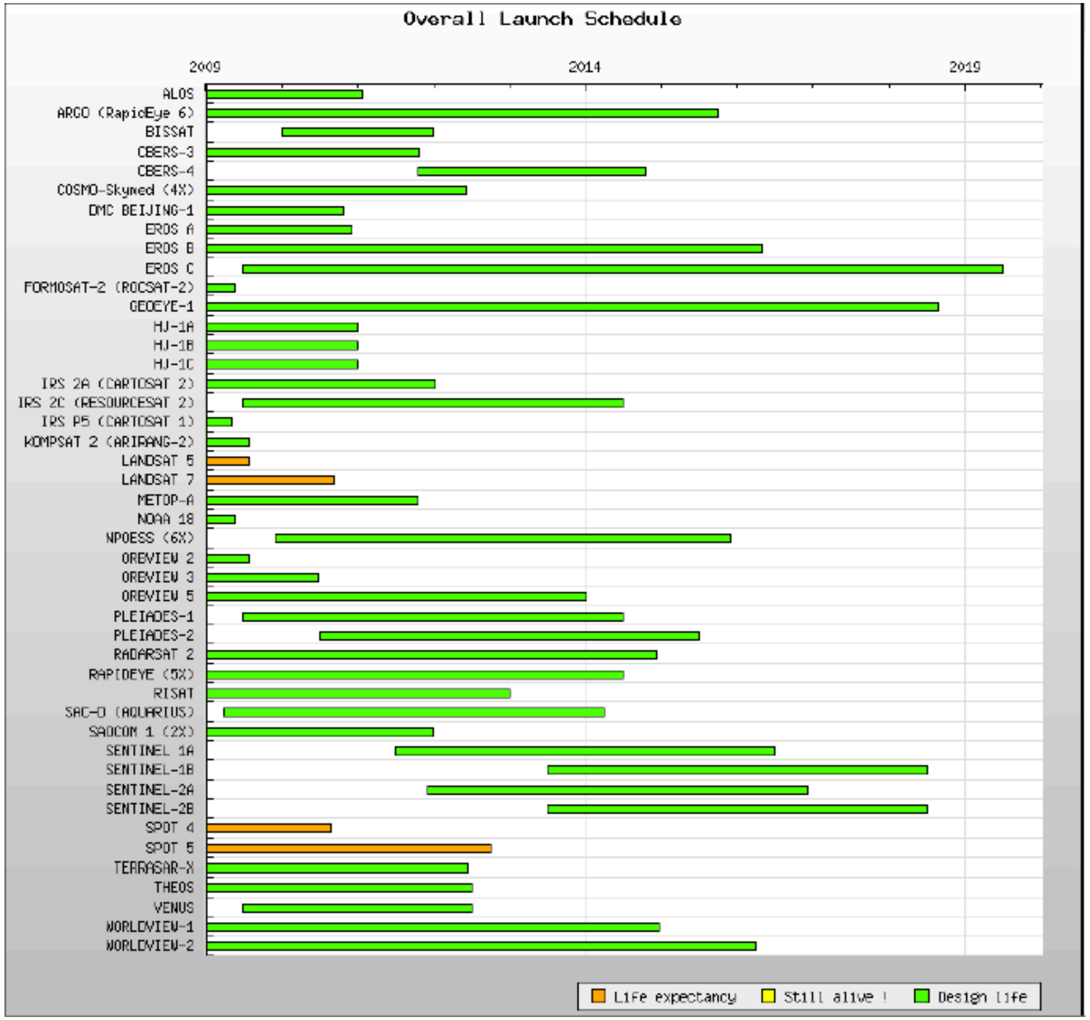
Opportunities:

- ❖ Monitoring of the environment
- ❖ Disaster management
- ❖ Urban planning
- ❖ Precision farming
- ❖ Defense and security

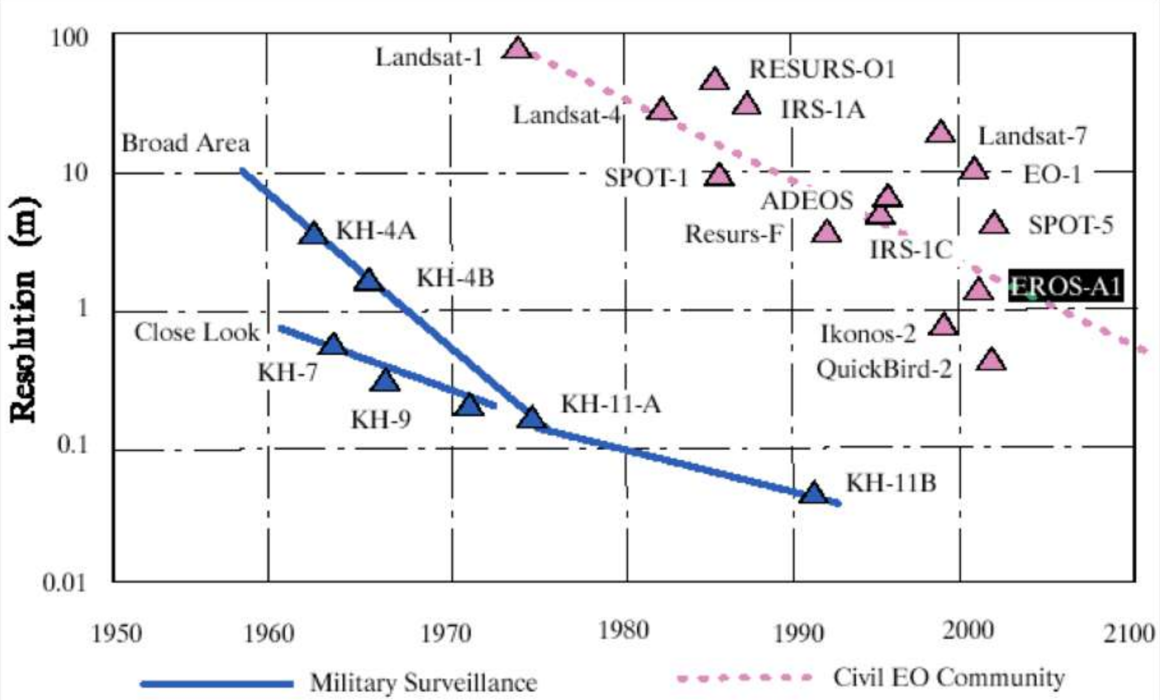
Challenges:

- ❖ (Big)Data processing
- ❖ High Performance Computing

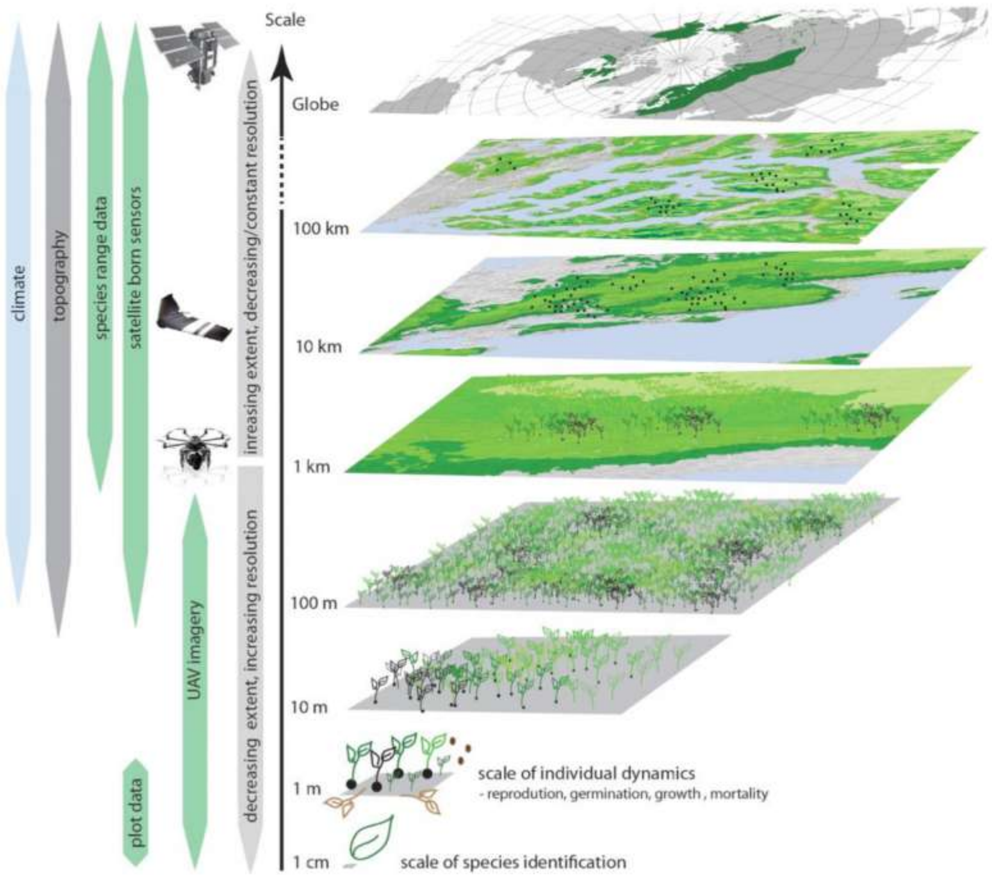
DeepRed: l'IA au service de l'imagerie infra-rouge



Overall Launch Schedule
2009
2014
2019
ALOS
ARGO (RapidEye 6)
BISSAT
CBERS-3
CBERS-4
COSMO-Skymed (4X)
DMC BEIJING-1
EROS A
EROS B
EROS C
FORMOSAT-2 (ROCSAT-2)
GEOEYE-1
HJ-1A
HJ-1B
HJ-1C
IRS 2A (CARTOSAT 2)
IRS 2C (RESOURCESAT 2)
IRS P5 (CARTOSAT 1)
KOMPSAT 2 (ARIRANG-2)
LANDSAT 5
LANDSAT 7
METOP-A
NOAA 18
NPOESS (6X)
OREVIEW 2
OREVIEW 3
OREVIEW 5
PLEIADES-1
PLEIADES-2
RADARSAT 2
RAPIDEYE (5X)
RISAT
SAC-D (AQUARIUS)
SAOCOM 1 (2X)
SENTINEL 1A
SENTINEL-1B
SENTINEL-2A
SENTINEL-2B
SPOT 4
SPOT 5
TERRASAR-X
THEOS
VENUS
WORLDVIEW-1
WORLDVIEW-2
Life expectancy
Still alive !
Design life



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]



Scale
Globe
100 km
10 km
1 km
100 m
10 m
1 m
1 cm
climate
topography
species range data
satellite born sensors
plot data
UAV imagery
inreasing extent, decreasing/constant resolution
decreasing extent, increasing resolution
scale of individual dynamics
- reprodution, germination, growth , mortality
scale of species identification

Low spatial resolution

Schönefeld airport
Landsat

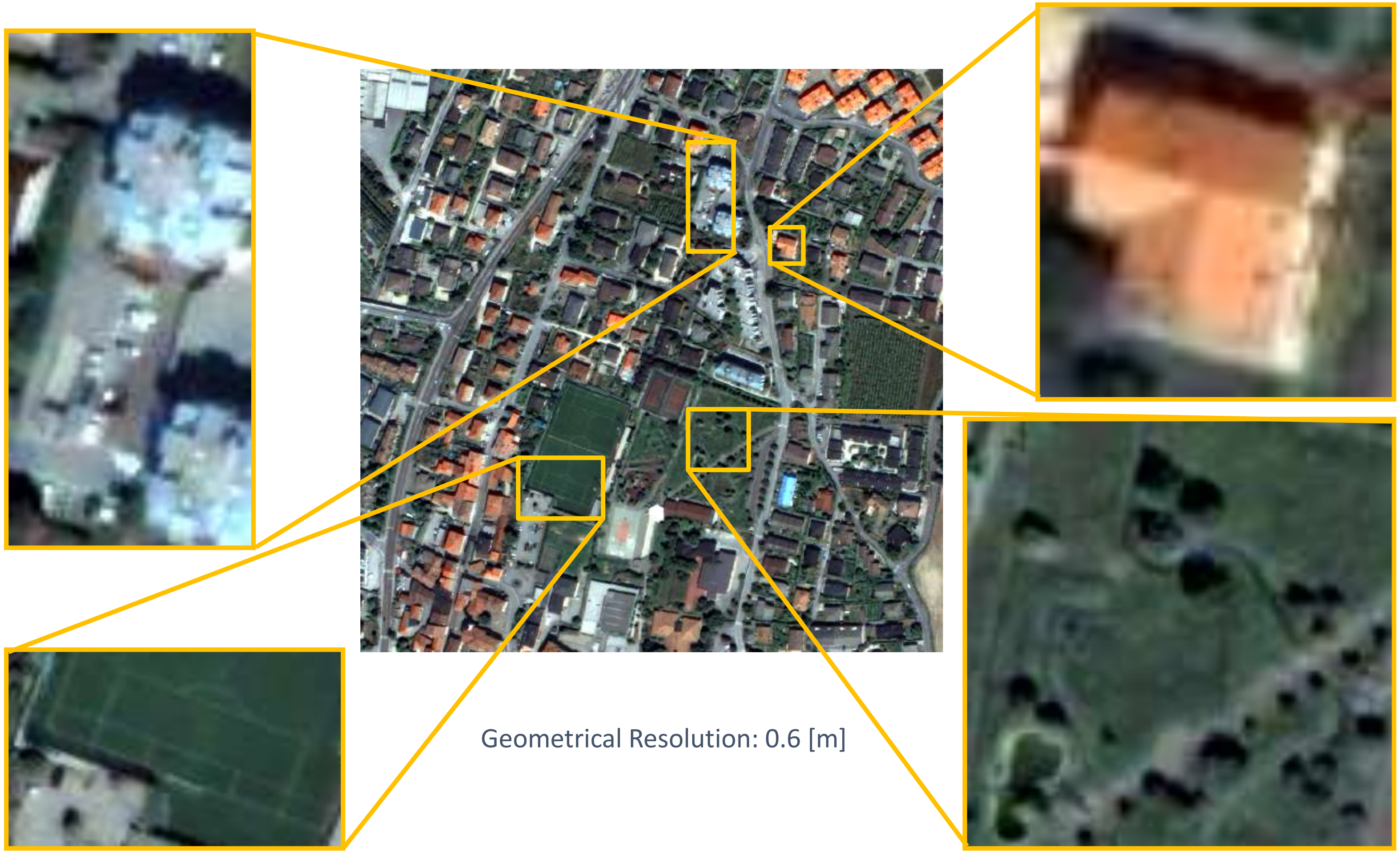
Very high spatial resolution

Reykjavik
Ikonos

Very high spatial resolution

Sunnyvale airport
Quickbird
Multispectral diversity

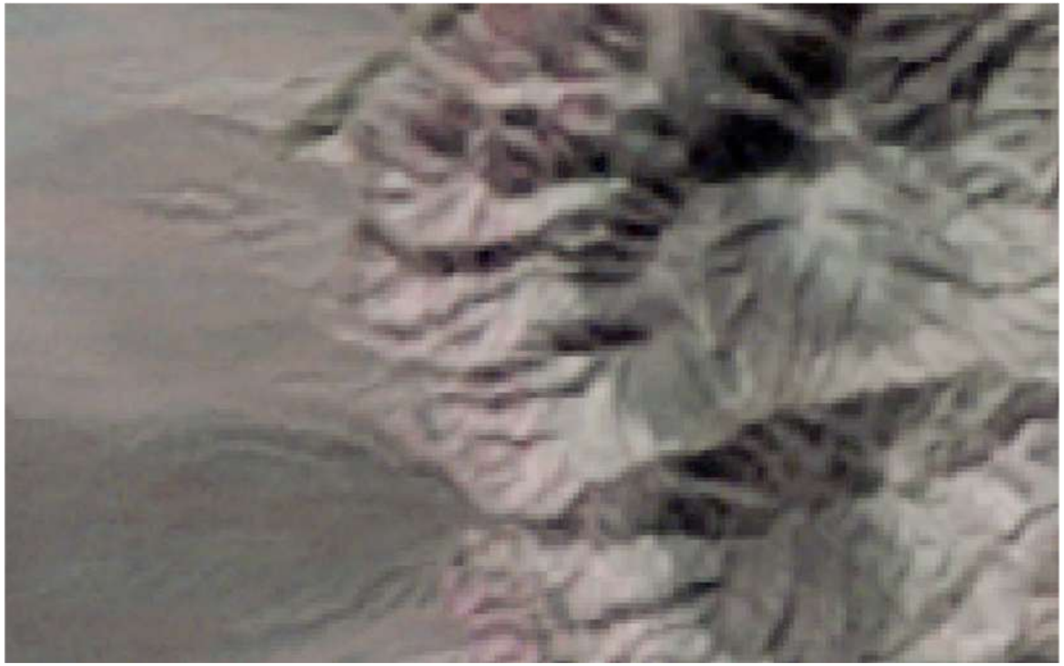
Very high spatial resolution



Geometrical Resolution: 0.6 [m]

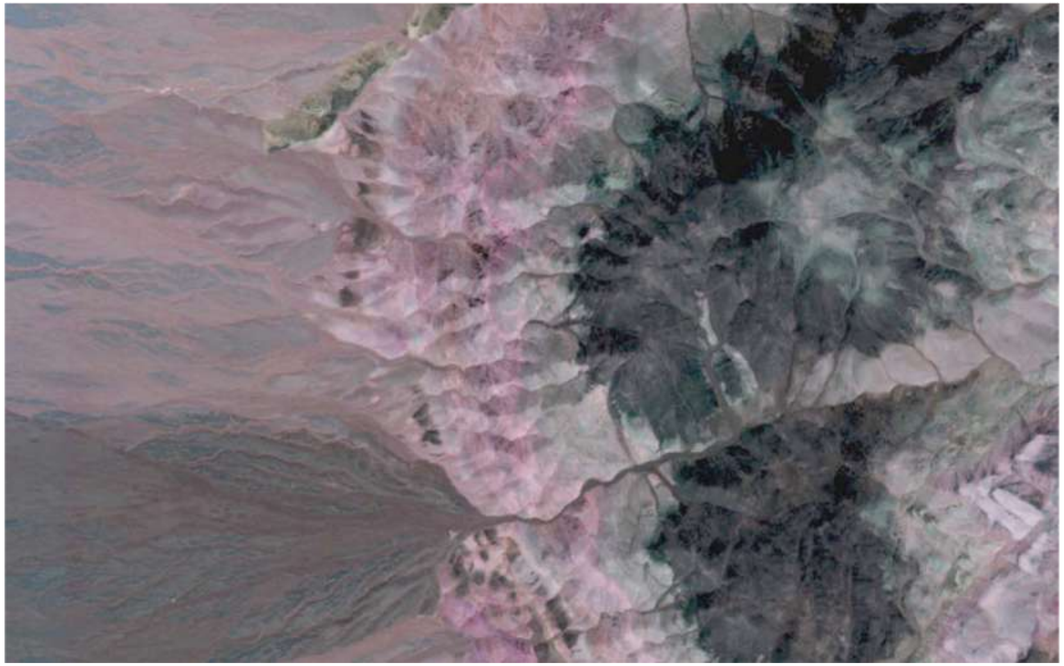
From low spatial resolution…

- ASTER image 30m



… to high spatial resolution

- WorldView 3 (<1m)



Spatial details in satellite optical images

- WorldView 3 (<1m)

Spatial details in aerial optical images

- True color composite. Transacqua, Italy. Credit: Fondazione Bruno Kessler

Spatial details in images acquired from a drone

- Povo Trento, Italy. Credit: F. Remondino, Fondazione Bruno Kessler

Spatial details in images acquired from a drone

- Tsuruoka, Japan. Credit: K. Uto, JST PRESTO HyperLeaf

Spatial details in images acquired from a drone

- Tsuruoka, Japan. Credit: K. Uto, JST PRESTO HyperLeaf

Multi-angular optical remote sensing

Multiangular data open new doors :

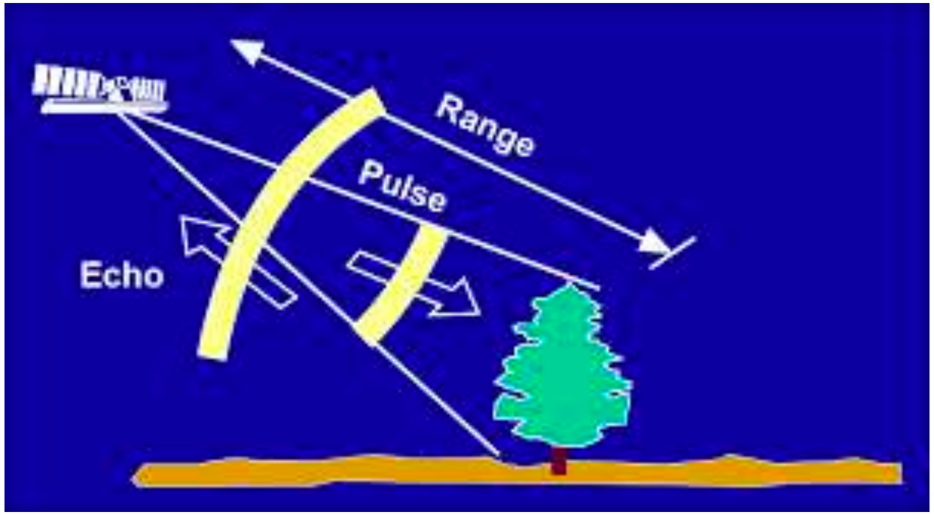
- atmospheric correction,
- movement estimation,
- 3D reconstruction…

But require new algorithms

Rio de Janeiro
Worldview II
Angular diversity

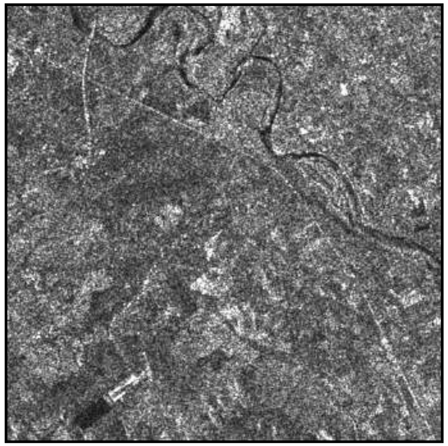
Radar remote sensing

- Works night and day
- See through the clouds
- Interaction with the canopy…



Radar remote sensing

- Active remote sensing faces the same increase of resolution
- Data are highly corrupted by speckle noise (VHR → Non gaussian distribution, new statistical models are required)



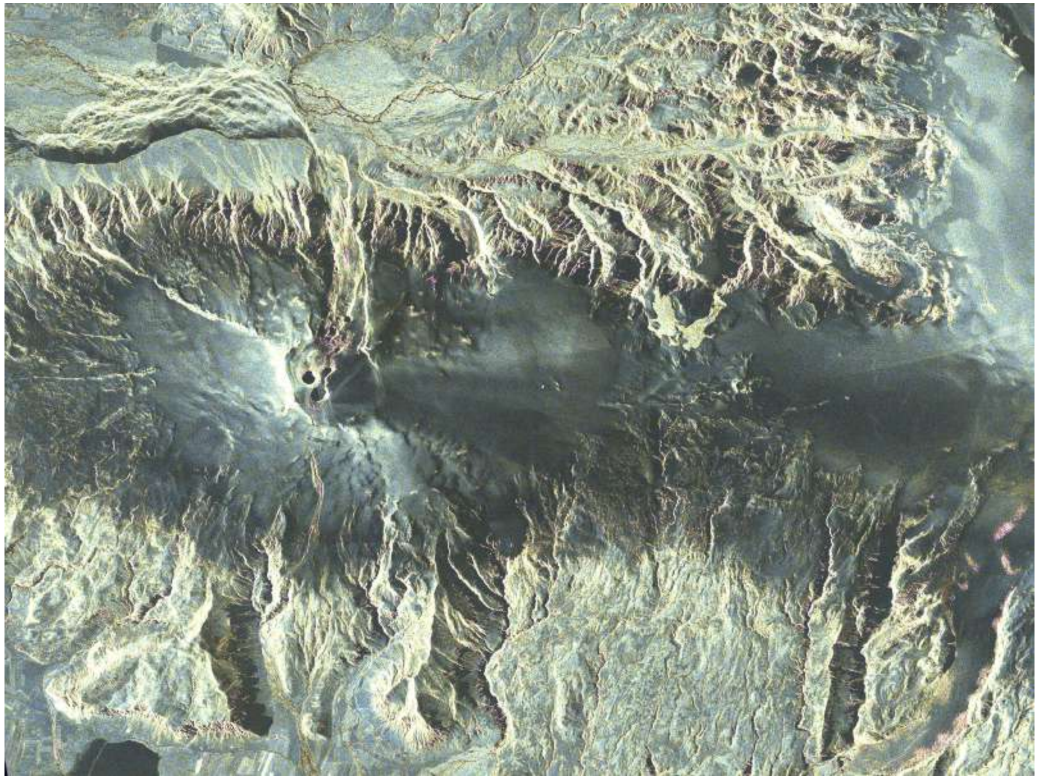
ERS 2
Saragosse

VHR SAR
Pentagon

Radar remote sensing

Toulouse
Ramses sensor
Airborne platform

Radar remote sensing

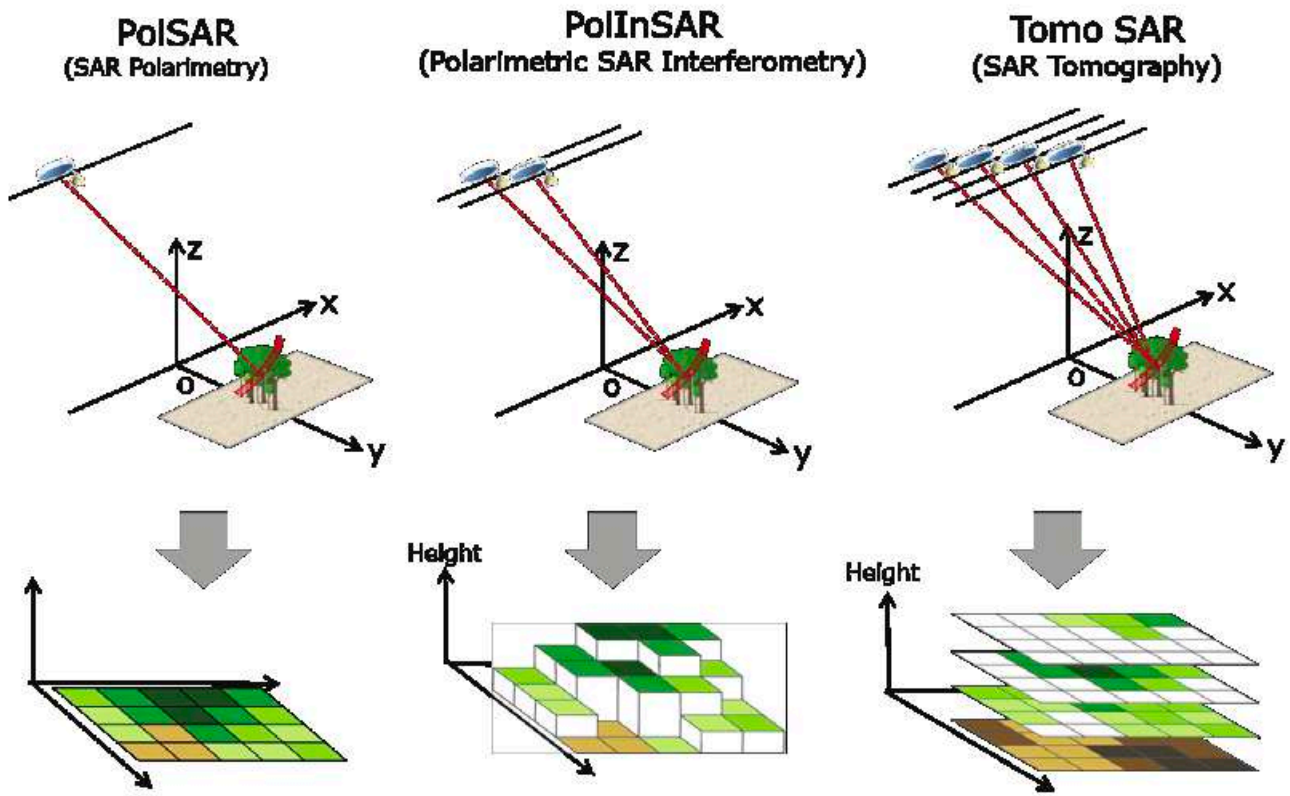


Eyjafjallajokul
TerraSAR-X

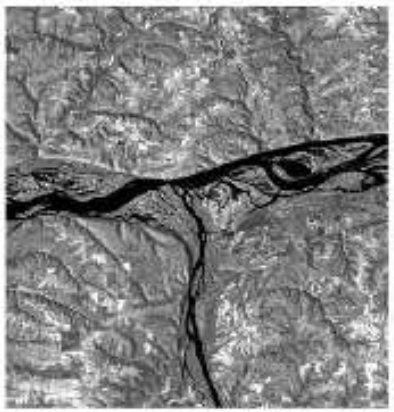
Polarimetric information

Tandem-X
WorldDEM

Radar remote sensing



Multi-temporal remote sensing

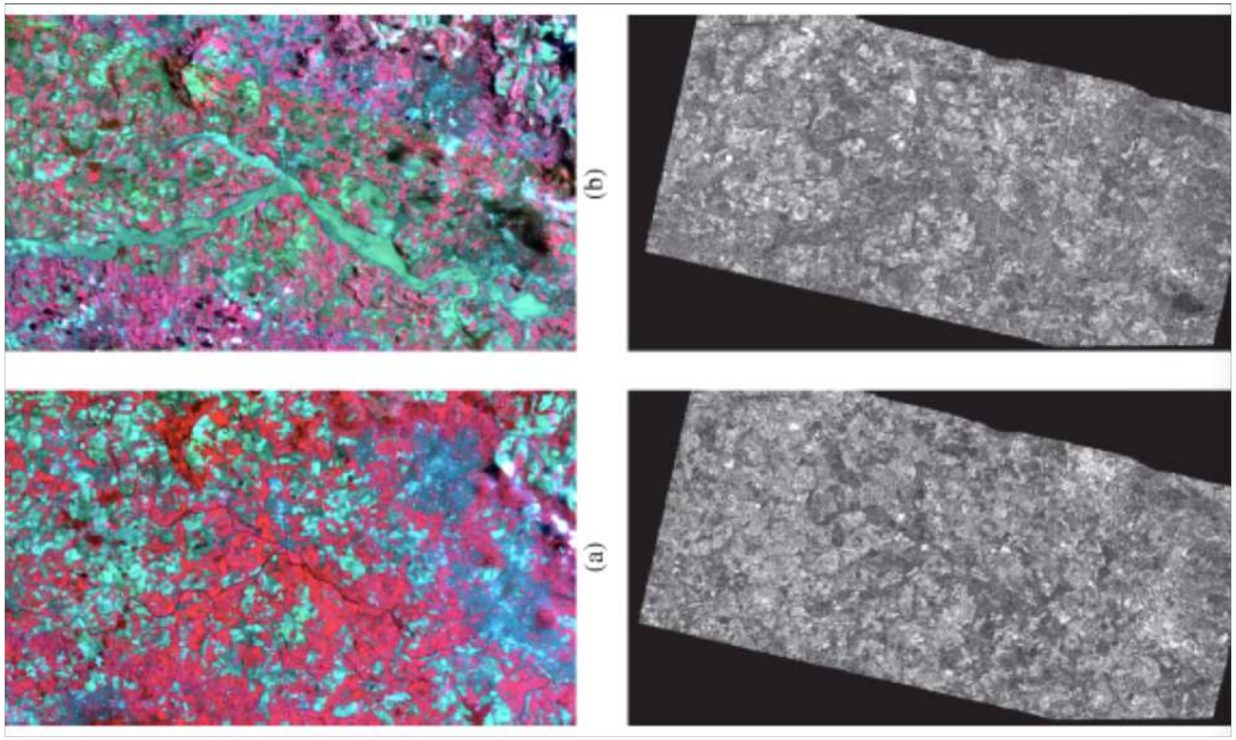


Multitemporal data analysis and change detection
Same challenges :

- Data with different resolution
- Varying acquisition conditions
- Need for high level representation

Multiscale Unsupervised Change Detection on Optical Images by Markov Random Fields and Wavelets
Moser, G. ; Angiati, E. ; Serpico, S. B.
IEEE GRSL 2011

Multi-temporal remote sensing



Multi-temporal remote sensing

- MODIS 250m t1

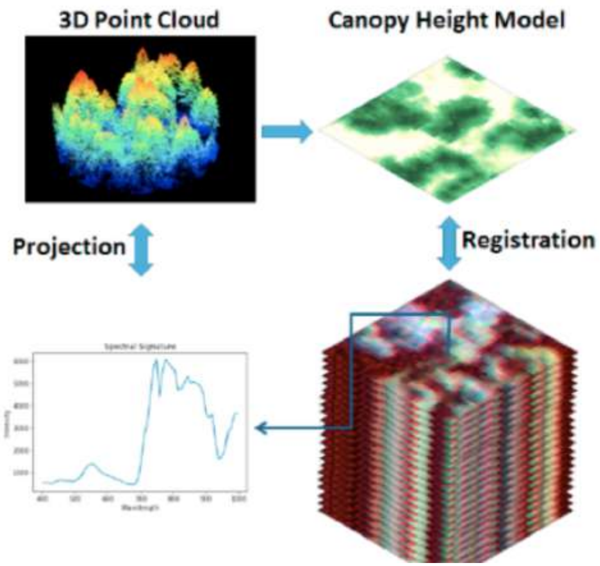
Multi-temporal remote sensing

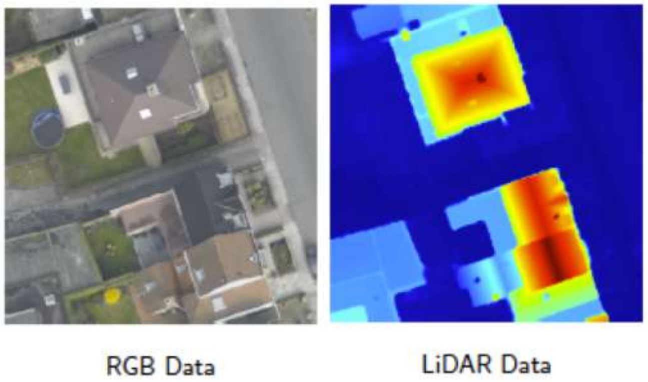
- MODIS 250m t2

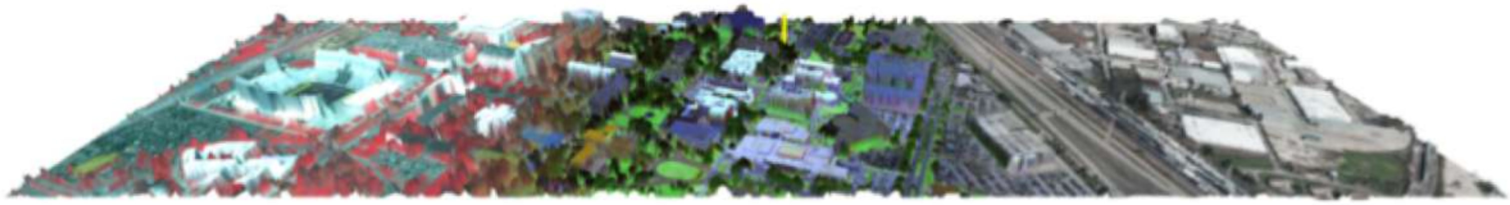
Multi-temporal remote sensing

- MODIS 250m t3

Multi-modal remote sensing







Multi-modal remote sensing

Quickbird DigitalGlobe

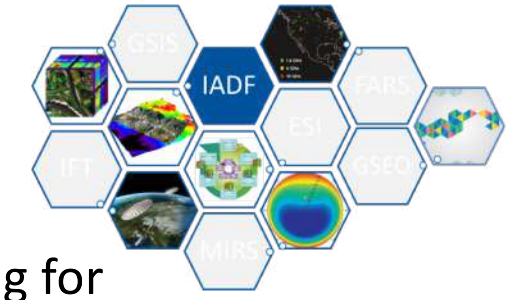
TerraSAR-X, Infoterra

Multimodal data fusion :
-optical + radar data
-Data from constellations of satellites
-Data with different resolutions, different geometries etc…

→Need for high level (semantic) representation of the information

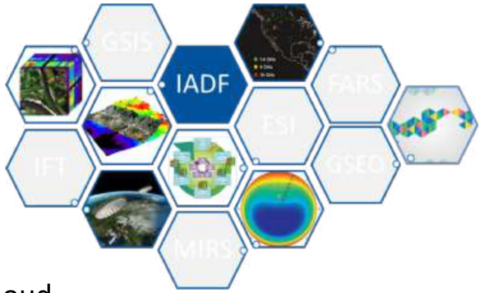
Extraction and Three-Dimensional Reconstruction of Isolated Buildings in Urban Scenes From High-Resolution Optical and SAR Spaceborne Images
Sportouche, H. ; Tupin, F. ; Denise, L
IEEE TGRS 2011

Data Fusion Contest 2018



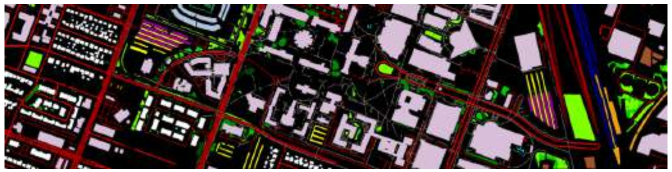
- Advanced multi-sensor optical remote sensing for urban land use and land cover classification
- Guest organizer: Saurabh Prasad (Univ. of Houston)

Data Fusion Contest 2018

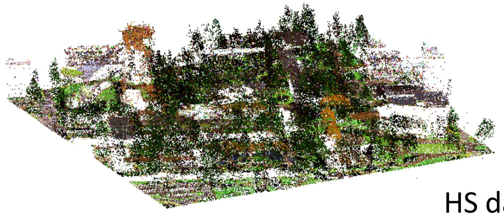


VHR imagery

20-class ground-truth



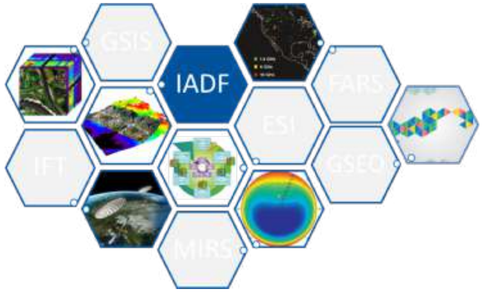
MS LiDAR point cloud



HS data cube

- Multi-sensor data with exciting new sensors:
  - Hyperspectral imagery (**VNIR**, 1-m GSD)
  - **VHR** RGB imagery (5-cm GSD)
  - **Multispectral-LiDAR** point clouds, intensity rasters and DSMs (0.5-m GSD)

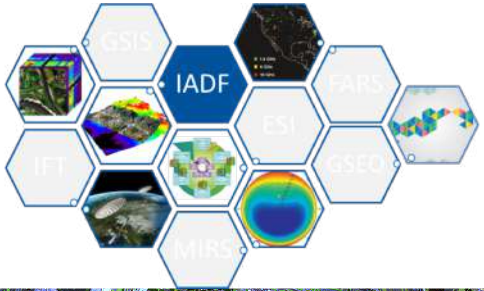
Data Fusion Contest 2018



- Benchmark for urban land use and land cover classification (20 detailed urban classes with materials and vegetal subclasses):
  - Healthy grass
  - Stressed grass
  - Artificial turf
  - Evergreen
  - Deciduous trees
  - Bare earth
  - Water
  - Residential buildings
  - Commercial buildings
  - Roads
  - Sidewalks
  - Crosswalks
  - Major thoroughfares
  - Highways
  - Railways
  - Paved parking lots
  - Unpaved parking lots
  - Cars
  - Trains
  - Stadium seats

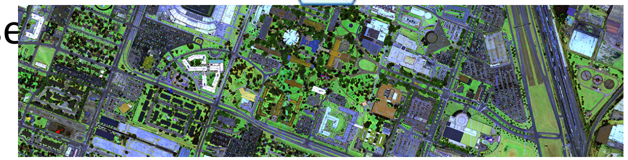
- Data fusion and per-sensor tracks

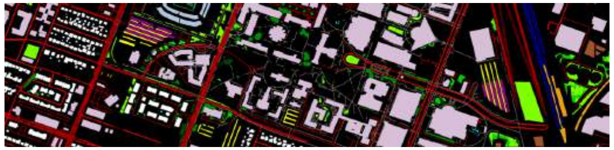
Data Fusion Contest 2018



Calendar:

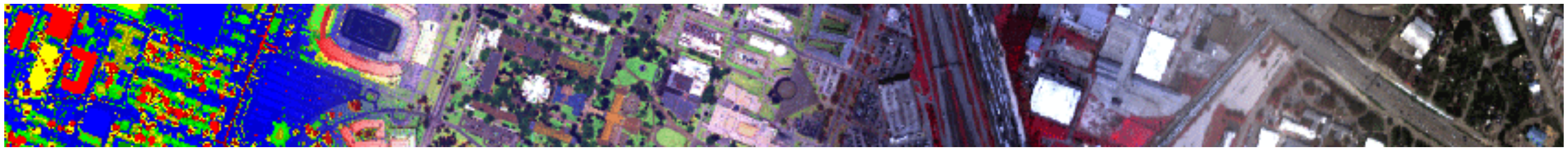
- Training set (1.4km² in central Houston) was release on Jan. 15th
- Test set (3.5km²) will be disclosed on March 13th
- Submission deadline on DASE is March 25th

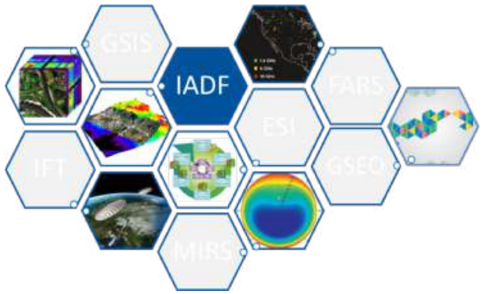




Prizes:

- 1st to 4th teams: IEEE Certificates of Recognition + IGARSS invited session
- 1st and 2nd teams: co-author JSTARS submission
- 1st team: NVIDIA GPU graphic card

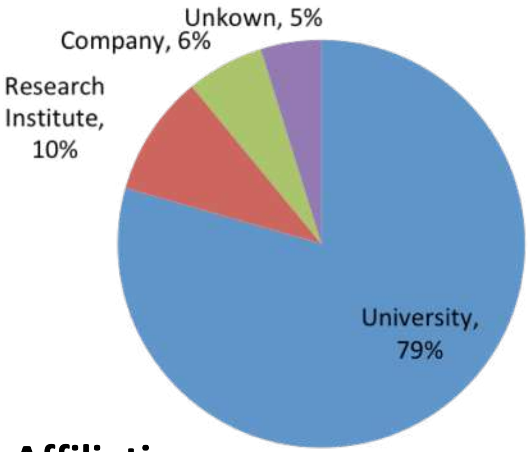




DFC 2018 Outcome

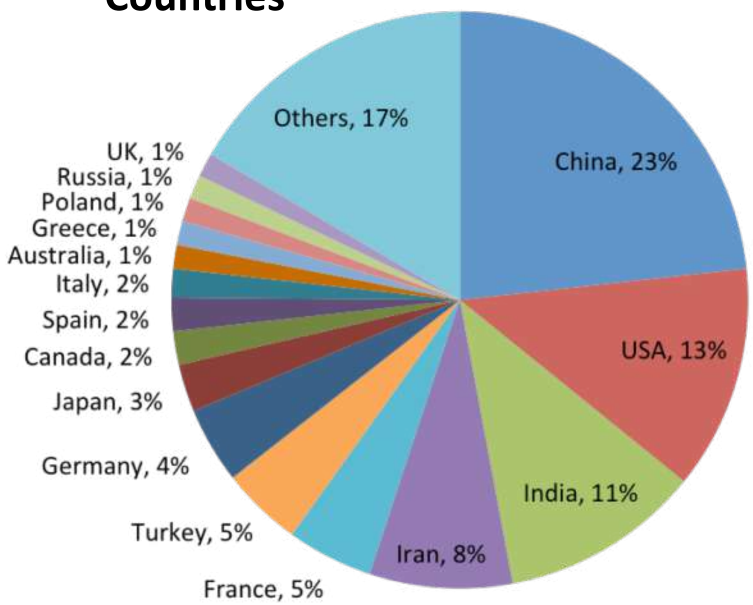
374 unique registrations (teams)
52 countries represented

Promoted through
Mailing lists (IADF, imageworld, …)
Social media, GRS e-newsletter
Column in the March issue of IEEE GRSM

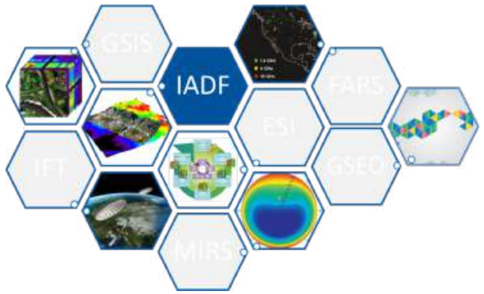


Affiliations

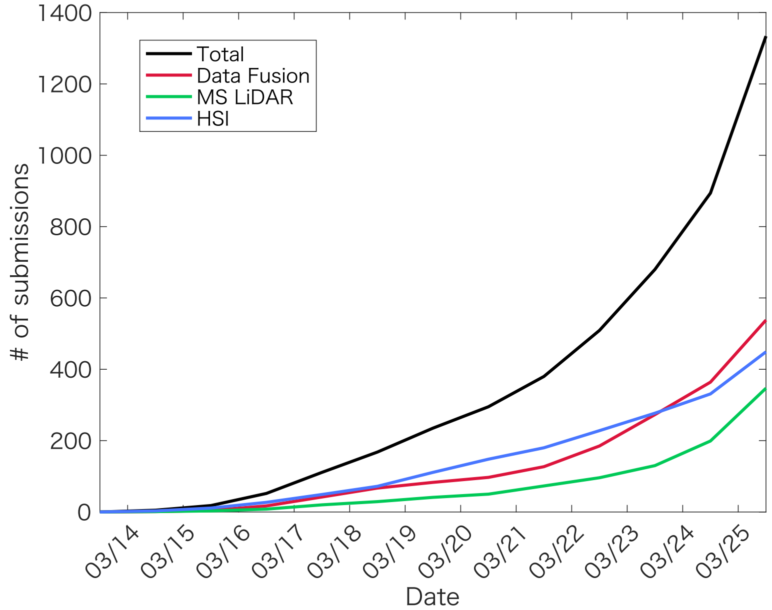
Countries



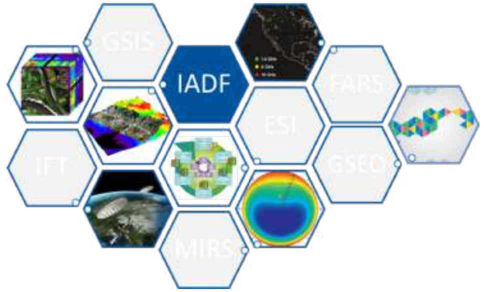
Submission Statistics



- **1334** submissions (Total)
  - 538 submissions (Data Fusion)
  - 347 submissions (MS LiDAR)
  - 449 submissions (HSI)
- The contest as an education tool: many student projects in the competition



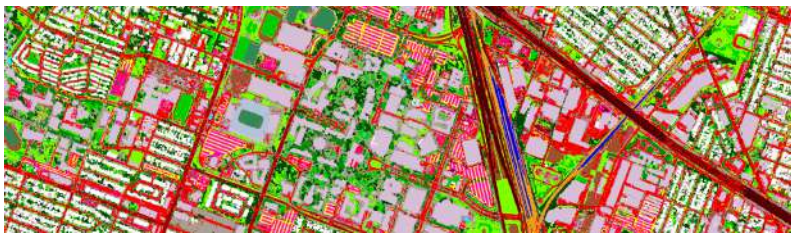
The Winners



3rd place: Shuai Fang, Dou Quan, Shuang Wang, Lei Zhang, and Ligang Zhou (*challenger*, Xidian University, China)
OA = 77.39 kappa = 0.73 (1^{st} rank in Hyperspectral Classification Challenge)
A Two-Branch Network with Semi-Supervised Learning for Hyperspectral Classification

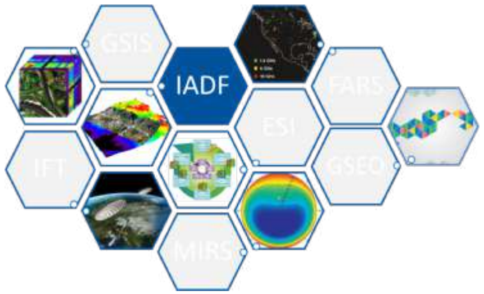
Classification map of *challenger* in Hyperspectral Classification Challenge

3rd place, ex aequo: Sergey Sukhanov, Dmitrii Budylskii, Ivan Tankoyeu, Roel Heremans, and Christian Debes (*AGTDA*, AGT International, Germany)
OA = 79.79 kappa = 0.79 (3^{rd} rank in Data Fusion Classification Challenge)
OA = 78.05 kappa = 0.77 (2^{nd} rank in Multispectral LiDAR Classification Challenge)
Fusion of LiDAR, Hyperspectral and RGB Data for Urban Land Use and Land Cover Classification

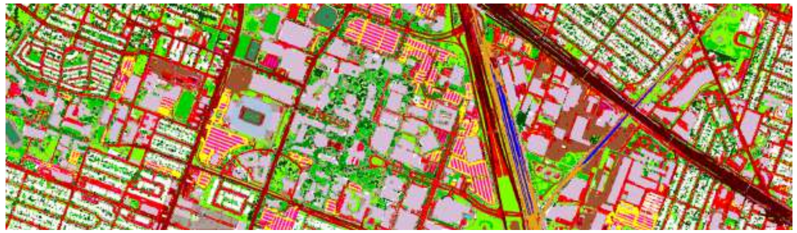


Classification map of *AGTDA* in Data Fusion Classification Challenge

The Winners

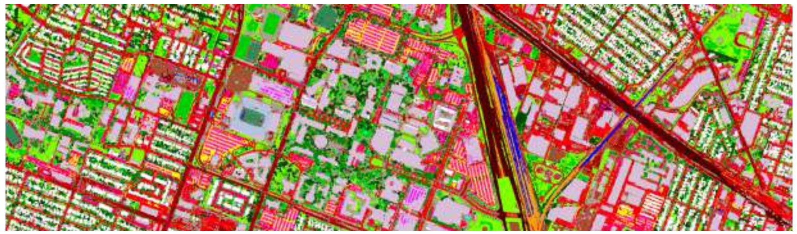


1st place: Yonghao Xu, Bo Du, and Liangpei Zhang
(*Gaussian*, Wuhan University, China)
OA = 80.78% kappa = 0.80 (1st rank in Data Fusion Classification Challenge)
OA = 81.07% kappa = 0.80 (1st rank in Multispectral LiDAR Classification Challenge)
Multi-Source Remote Sensing Data Classification via Fully Convolutional Networks and Post-Classification Processing



Classification map of *Gaussian* in Data Fusion Classification Challenge

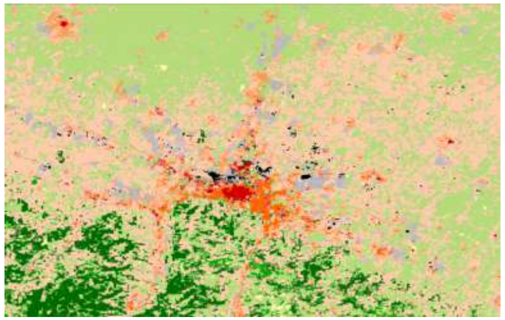
2nd place: Daniele Cerra, Miguel Figueiredo Vaz Pato, Emiliano Carmona, Jiaojiao Tian, Seyed Majid Azimi, Rupert Müller, Ksenia Bittner, Corentin Henry, Eleonora Vig, Franz Kurz, Reza Bahmanyar, Pablo d'Angelo, Kevin Alonso, Peter Fischer, and Peter Reinartz (*dlrpba*, German Aerospace Center, Germany)
OA = 80.74% kappa = 0.80 (2nd rank in Data Fusion Classification Challenge)
Combining Deep and Shallow Neural Networks with Ad Hoc Detectors for The Classification of Complex Multi-Modal Urban Scenes



Classification map of *dlrpba* in Data Fusion Classification Challenge

Data Fusion Contest 2017

le: Bologna (IT)



Multi-city and crowd-sourced Local Climate Zone classification

We released free open data on 5 cities for training:

- Landsat / Sentinel-2
- OpenStreetMap
- Crowdsourced class labels (from Geo-Wiki)

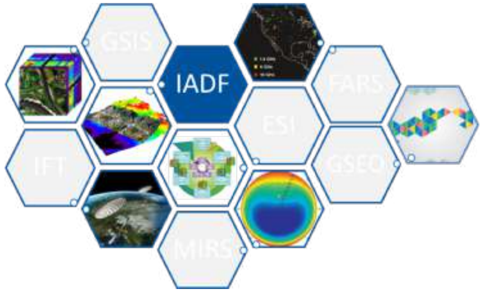
We ask participants to submit classification maps on 4 other cities (undisclosed so far) **using DASE.**

Guest organizers

Benjamin Bechtel, Uni. Hamburg

Linda See, International Institute for Applied Systems Analysis (resp. Geo-Wiki)

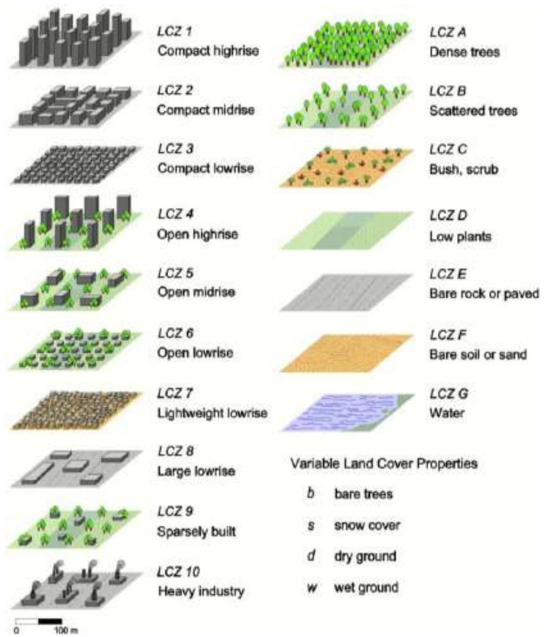
Data Fusion Contest 2017



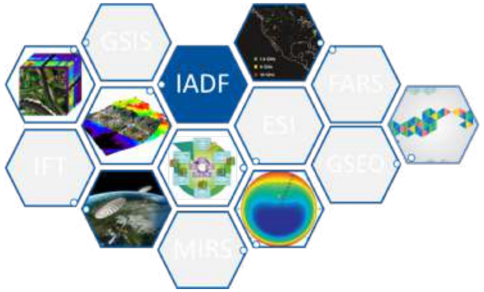
Classes are Local Climate Zones (LCZ, Stewart and Oke, 2012)

Essentially urban structure types

Prediction is requested on a 100m grid



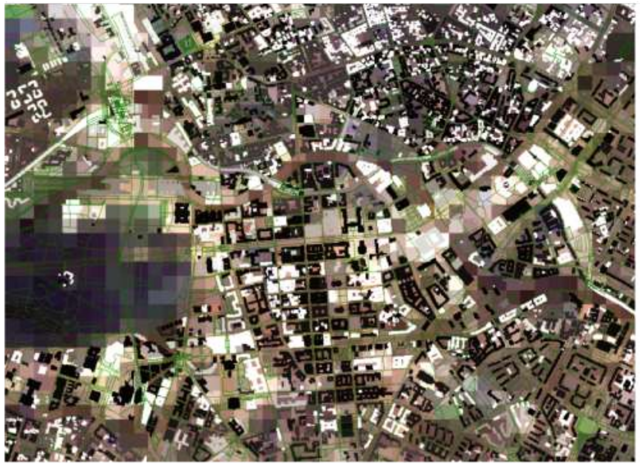
Data Fusion Contest 2017

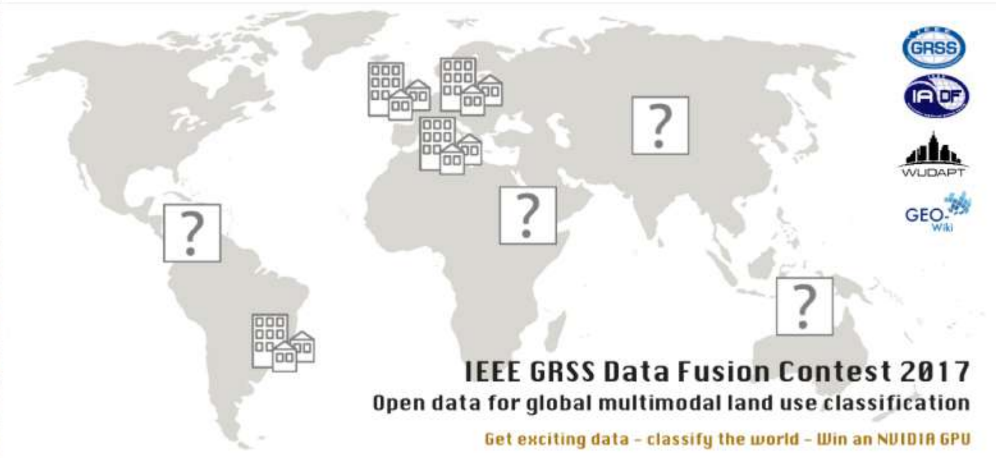


Training cities (Berlin, Rome, Paris, Sao Paulo, and Hong Kong) **were disclosed on January 9.** The contest is open.

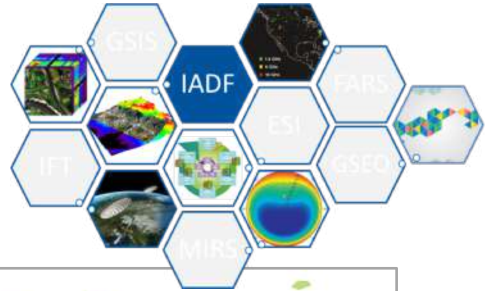
Test (Amsterdam, Madrid, Chicago, Xi'an**) cities were released on March 13.**

Submission deadline on DASE (automatic accuracy scoring) was **April 1.**

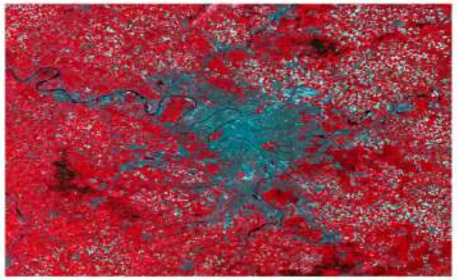




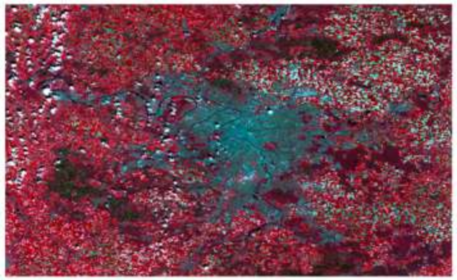
Data Fusion Contest 2017



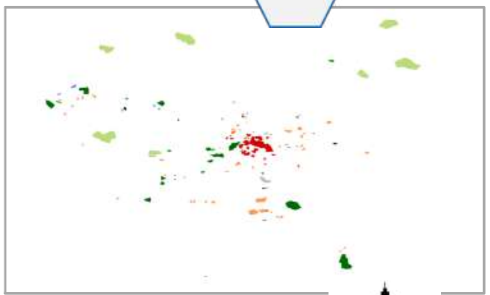
Paris city (Sentinel-2/Landsat/land use)



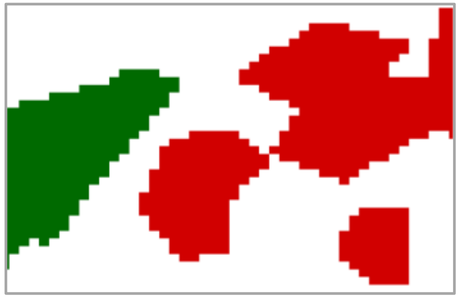
Contains modified Copernicus Data 2016

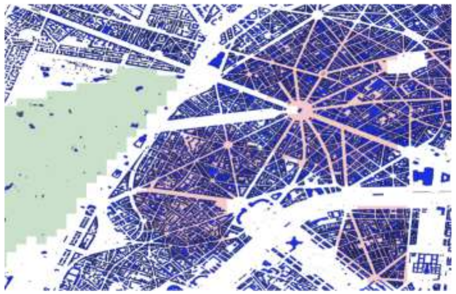


Courtesy of the U.S. Geological Survey



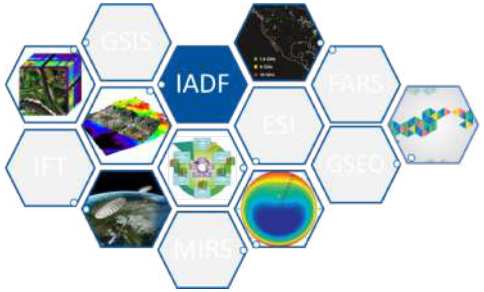
... and zoom (land use / OSM building footprint / OSM roads)





Data © OpenStreetMap contributors, available under the Open Database Licence

Data Fusion Contest 2018



856 submissions of classification maps!

… with an exponential rush as
the deadline came closer

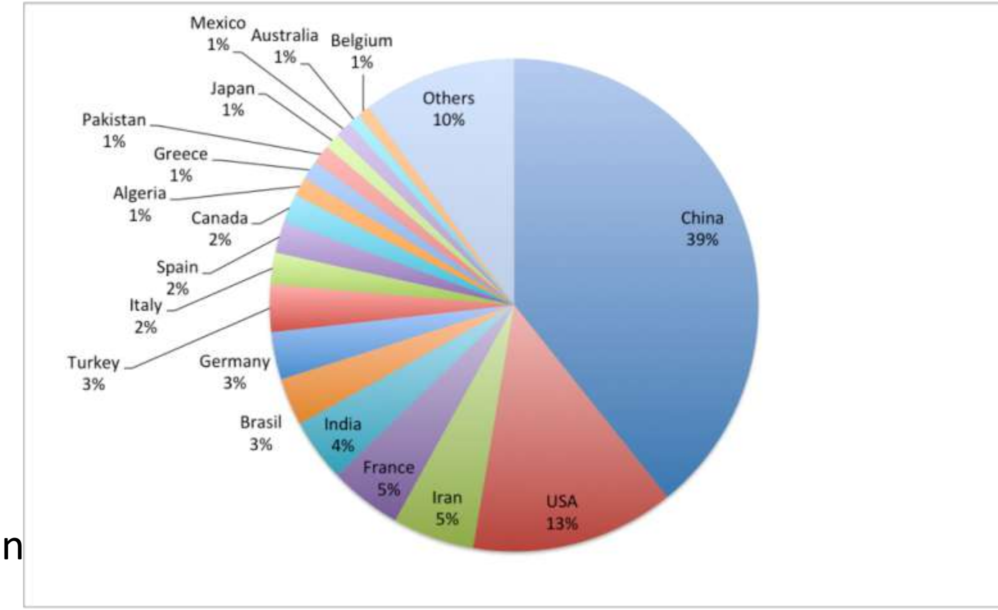
Most works combined image and semantic layers

Teams with various backgrounds

GIS, satellite imagery, image processing

The contest as an education tool

Many student projects in the competition



Data Fusion Contest 2017

1st place: Naoto Yokoya, Pedram Ghamisi, Junshi Xia,
University of Tokyo, Japan, and DLR/TU München, Germany (OA = 74.9%, K = 0.71).
Multimodal, multitemporal, and multisource global data fusion for local climate zones classification based on ensemble learning

2nd place: **Sergey Sukhanov, Roel Heremans, Ivan Tankoyeu, Jérôme Louradour, Darya Trofimova, Christian Debes**,
AGT International, Switzerland (OA = 72.6%, Kappa = 0.68)
Multilevel ensembling for local climate zones classification

3rd place: **Camila Souza dos Anjos Lacerda, Marielcio Gonçalves Lacerda, Leidiane do Livramento Andrade, Roberto Neves Salles**
Institute of Advanced Studies – Brazilian Air Force, Brazil (OA = 72.4%, Kappa = 0.68)
Classification of urban environments using feature extraction and random forest

4th place: **Yong Xu, Fan Ma, Deyu Meng, Chao Ren, Yee Leung**,
Chinese University of Hong Kong and Xi'an Jiaotong University, China (OA = 69.9%, Kappa = 0.65).
A co-training approach to the classification of local climate zones with multi-source data

Data Fusion Contest 2016

VHR & video data

VHR data: Deimos-2 satellite, 2 dates

- 4 bands, 4m resolution
- 1 pan, 1m resolution

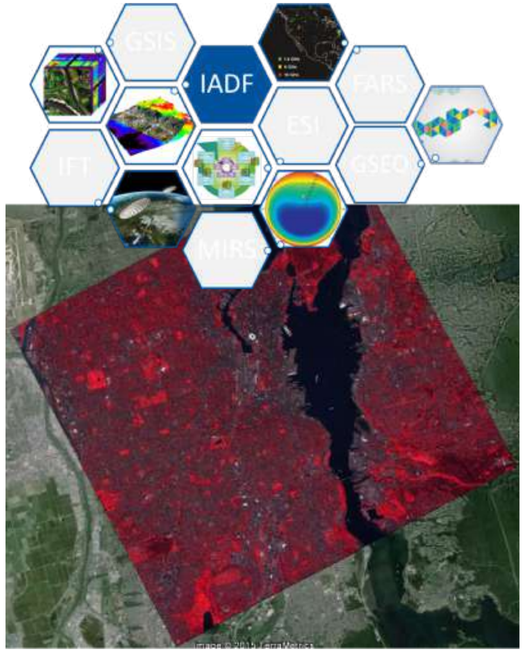
Video from ISS (Iris camera,

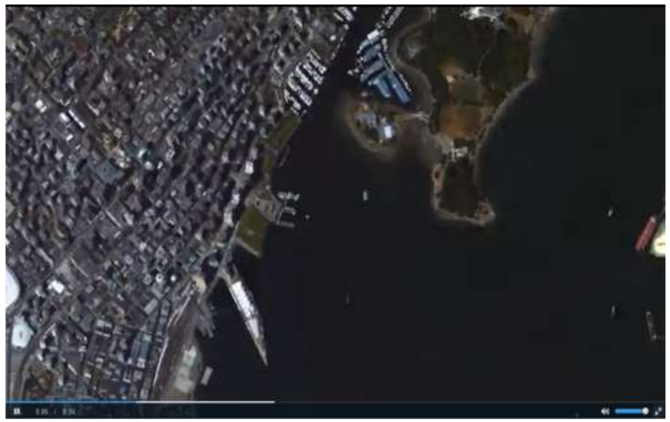
- 60s length, 1m resolution)

Area: Vancouver, Canada

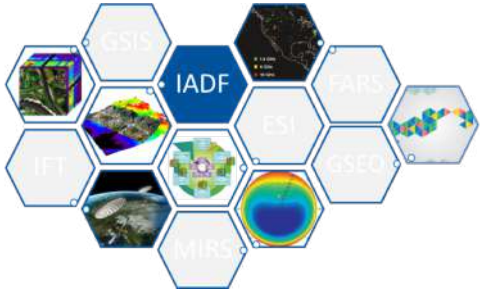
Guest organizers

Roberto Fabrizi, DeimosImaging/Urthecast

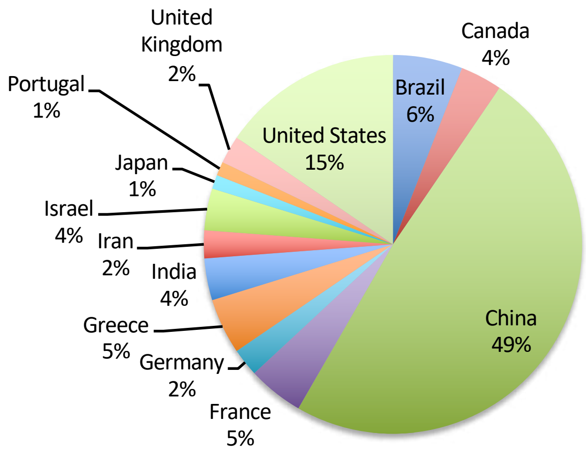




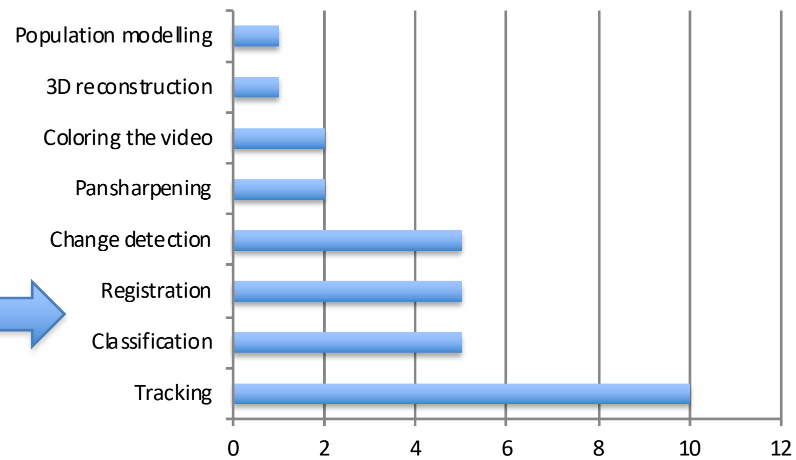
Data Fusion Contest 2016

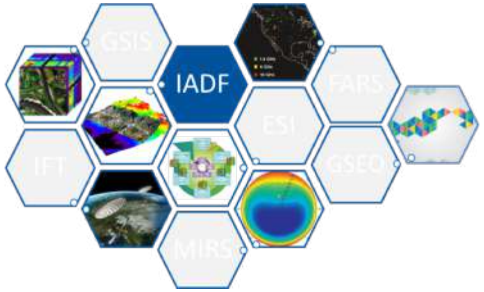


24 paper submissions



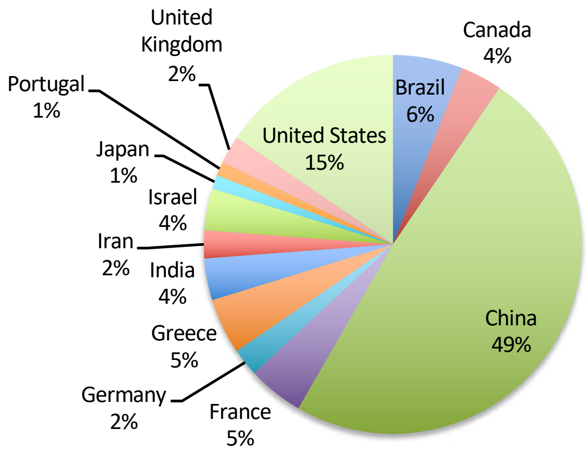
Tracking and registration as new topics!



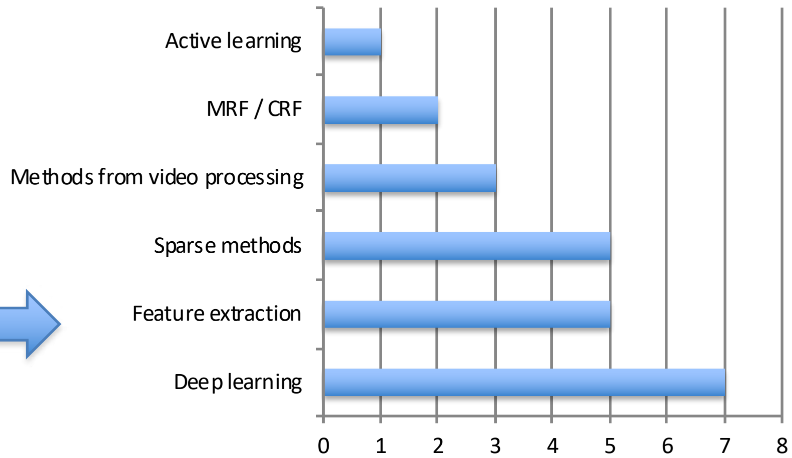


Data Fusion Contest 2016

24 paper submissions



Sparse and deep methods
Are the new trends!



1st place

Lichao Mou and Xiaoxiang Zhu

"Spatiotemporal scene interpretation of space videos via deep neural network and tracklet analysis"

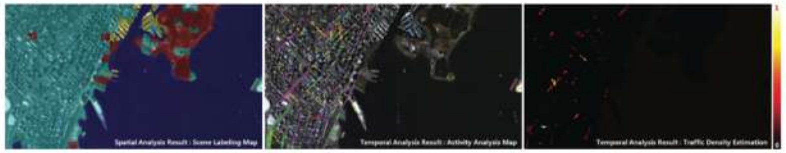


Fig. 4. Our final results. From left to right: spatial scene labeling, temporal activity analysis, and traffic density estimation.

2nd place

Maria Vakalopoulou, Christos Platias, Maria Papadomanolaki, Nikos Paragios and Konstantinos Karantzalos

"Simultaneous registration, segmentation and change detection from multisensor, multitemporal satellite image pairs"

Fig. 2: Chessboard visualization with the resulted registered multisensor data.

Fig. 4: Change Detection from multitemporal, multi-sensor between: (a) a Deimos March'15 and a Deimos May'15 (*D1-D2*, left), (b) an Iris video sequence (first frame) and a Deimos May'15 (*V-D2*, right).

3rd place

Dave Kelbe, Devin White, Andrew Hardin, Jessica Moehl and Melanie Phillips.

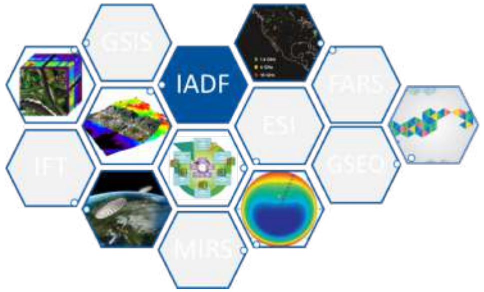
"Sensor-agnostic photogrammetric image registration with applications to population modeling"

4th place

Zuming Huang, Guangliang Cheng, Hongzhen Wang, Haichang Li, Limin Shi and Chunhong Pan.

"Building extraction from multi-source remote sensing images via deep deconvolution neural networks"

Data Fusion Contest 2008

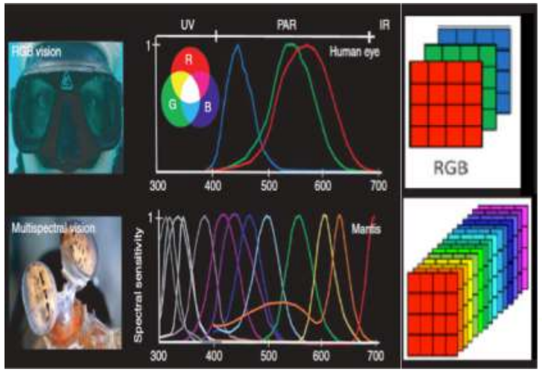


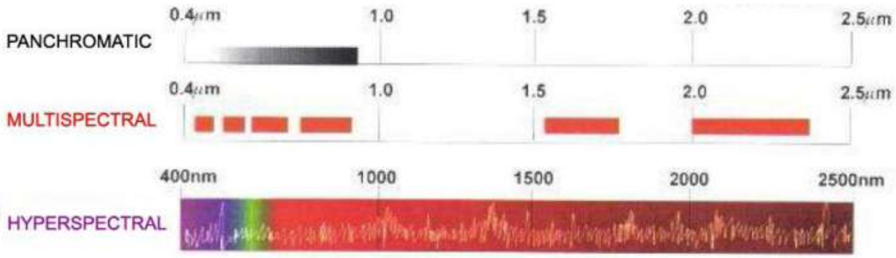
IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 47, NO. 11, NOVEMBER 2009 3857

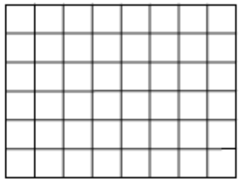
Decision Fusion for the Classification of Hyperspectral Data: Outcome of the 2008 GRS-S Data Fusion Contest

Giorgio Licciardi, Fabio Pacifici, *Student Member, IEEE*, Devis Tuia, *Student Member, IEEE*, Saurabh Prasad, *Member, IEEE*, Terrance West, *Student Member, IEEE*, Ferdinando Giacco, Christian Thiel, Jordi Inglada, Emmanuel Christophe, Jocelyn Chanussot, *Senior Member, IEEE*, and Paolo Gamba, *Senior Member, IEEE*

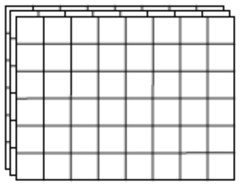
Hyperspectral imaging



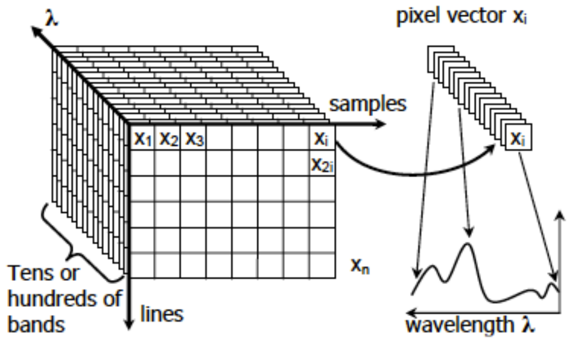




1 band



2-10 bands

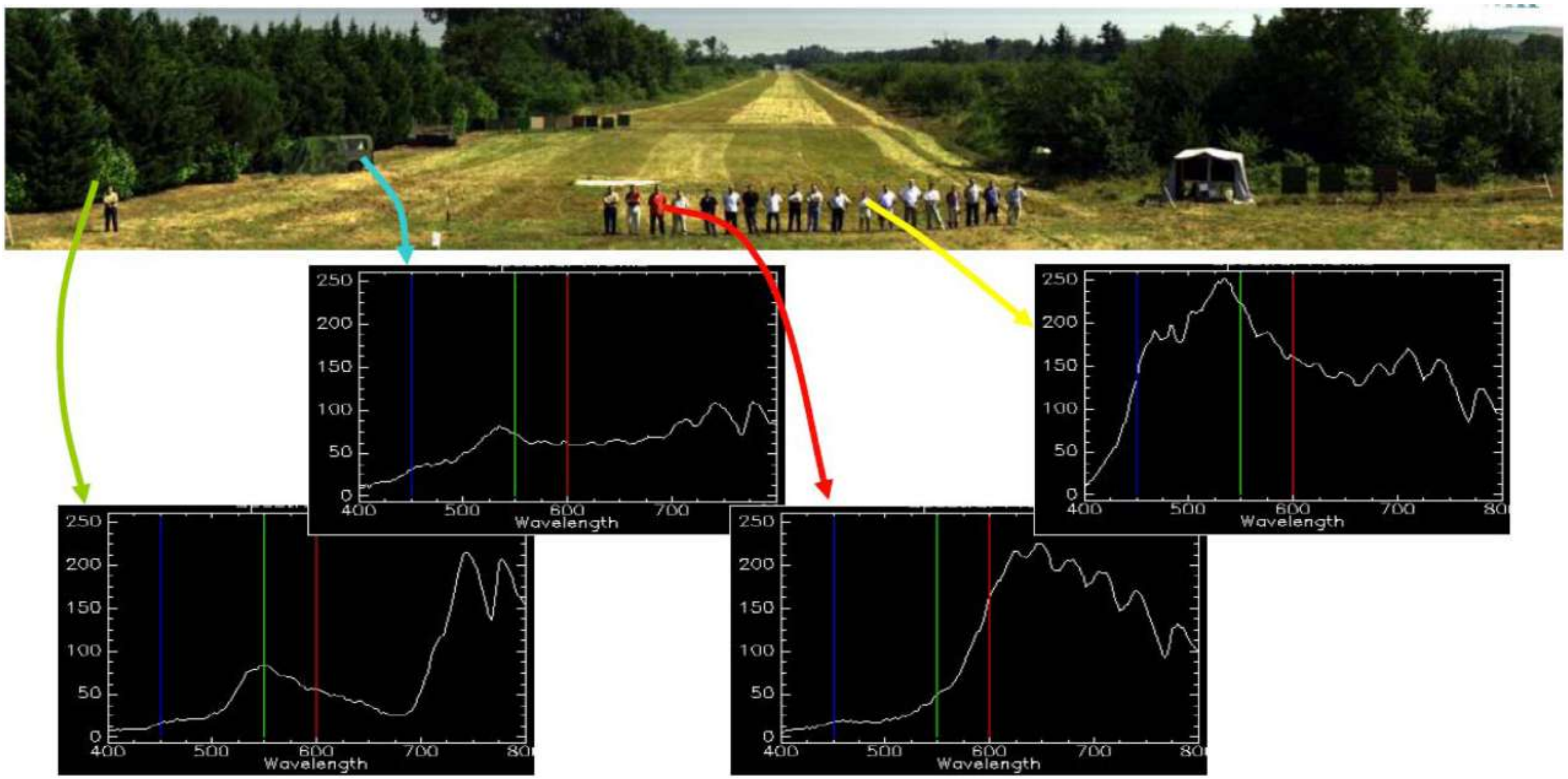


Panchromatic
. one grey level
  value per pixel

Multispectral
. 2-10 bands
. limited
  spectral info

Hyperspectral
. tens or hundreds of
  narrow bands
. detailed spectral info

Hyperspectral imaging

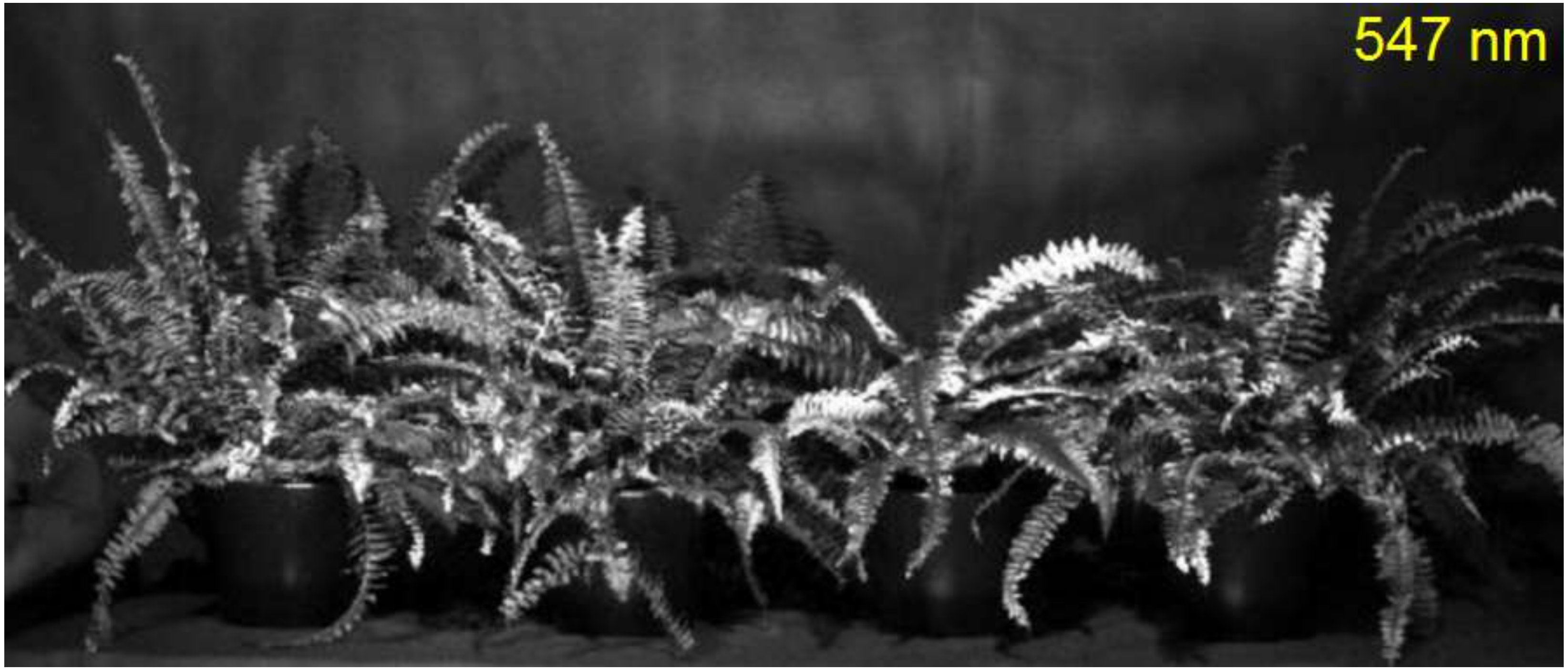


Improved spectral diversity : hyperspectral imagery

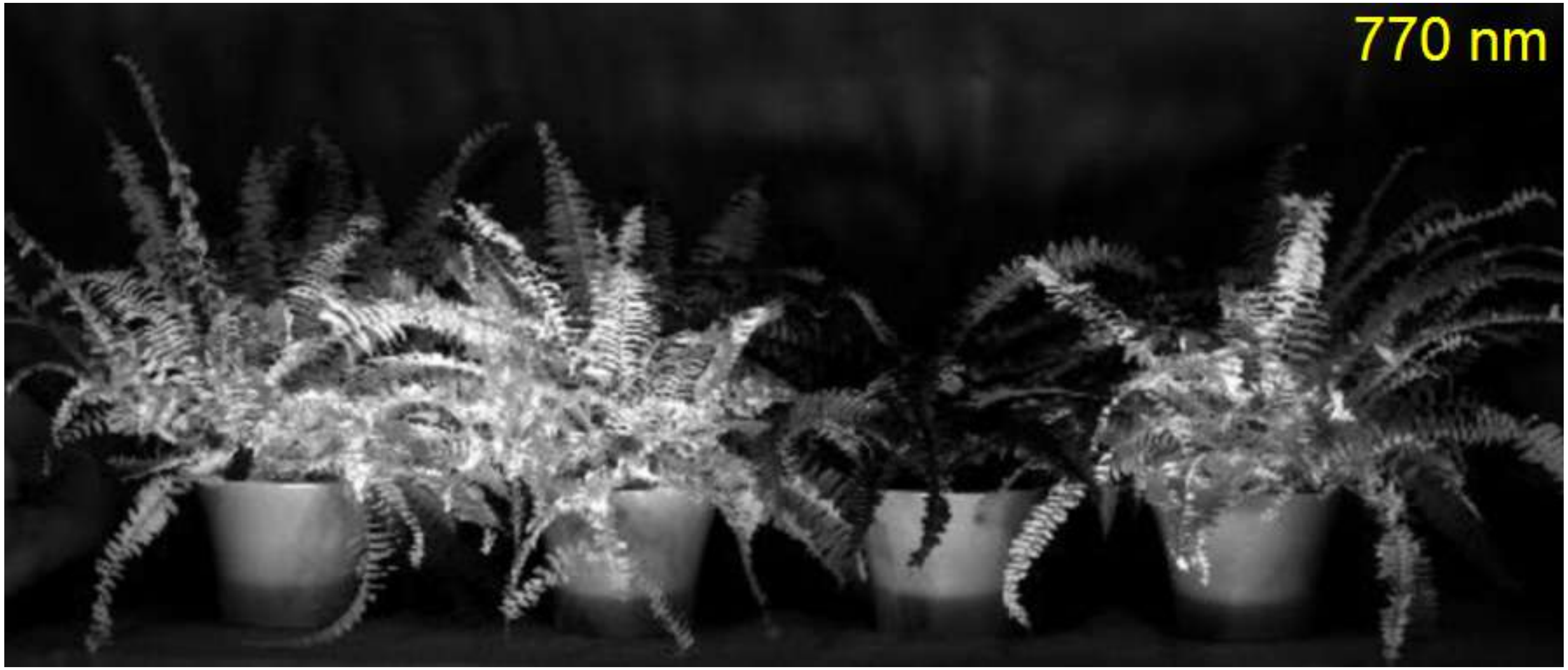
Hyperspectral imaging

Hyperspectral imaging

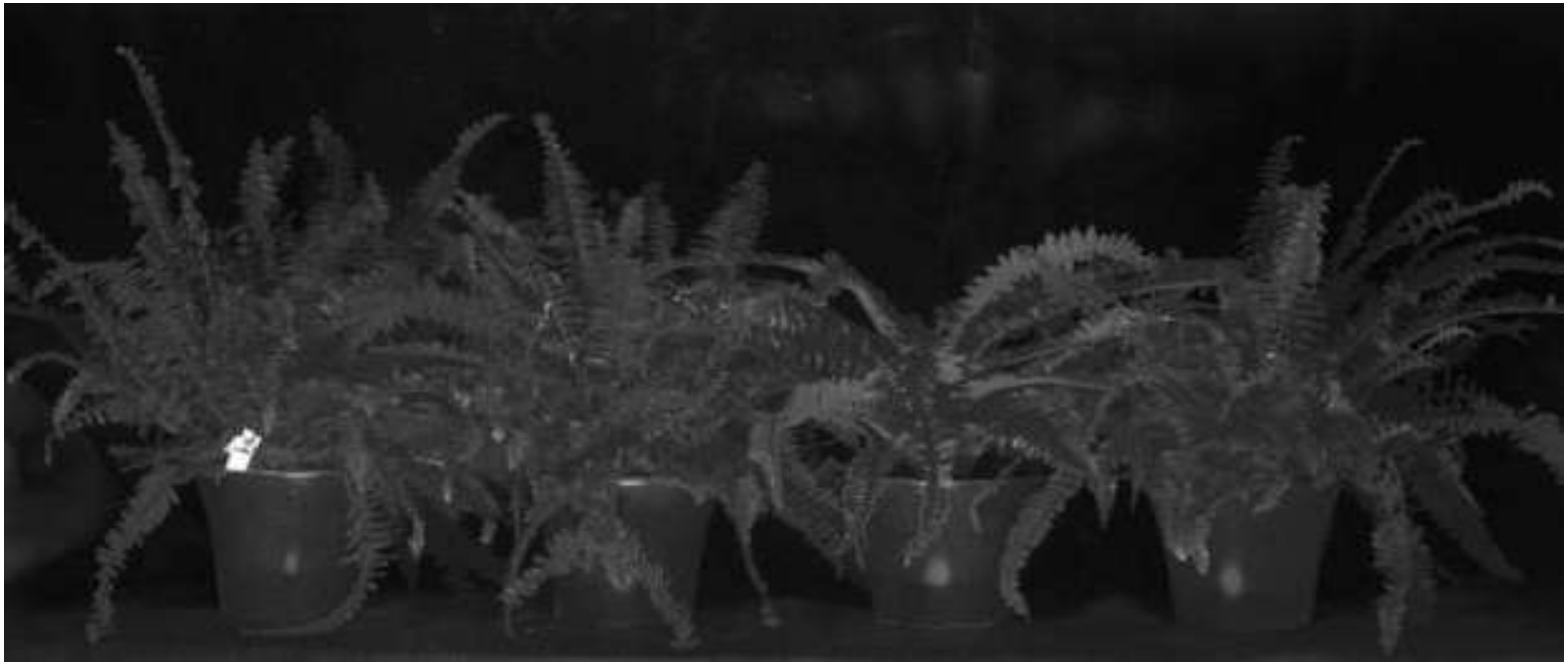
Hyperspectral imaging



Hyperspectral imaging

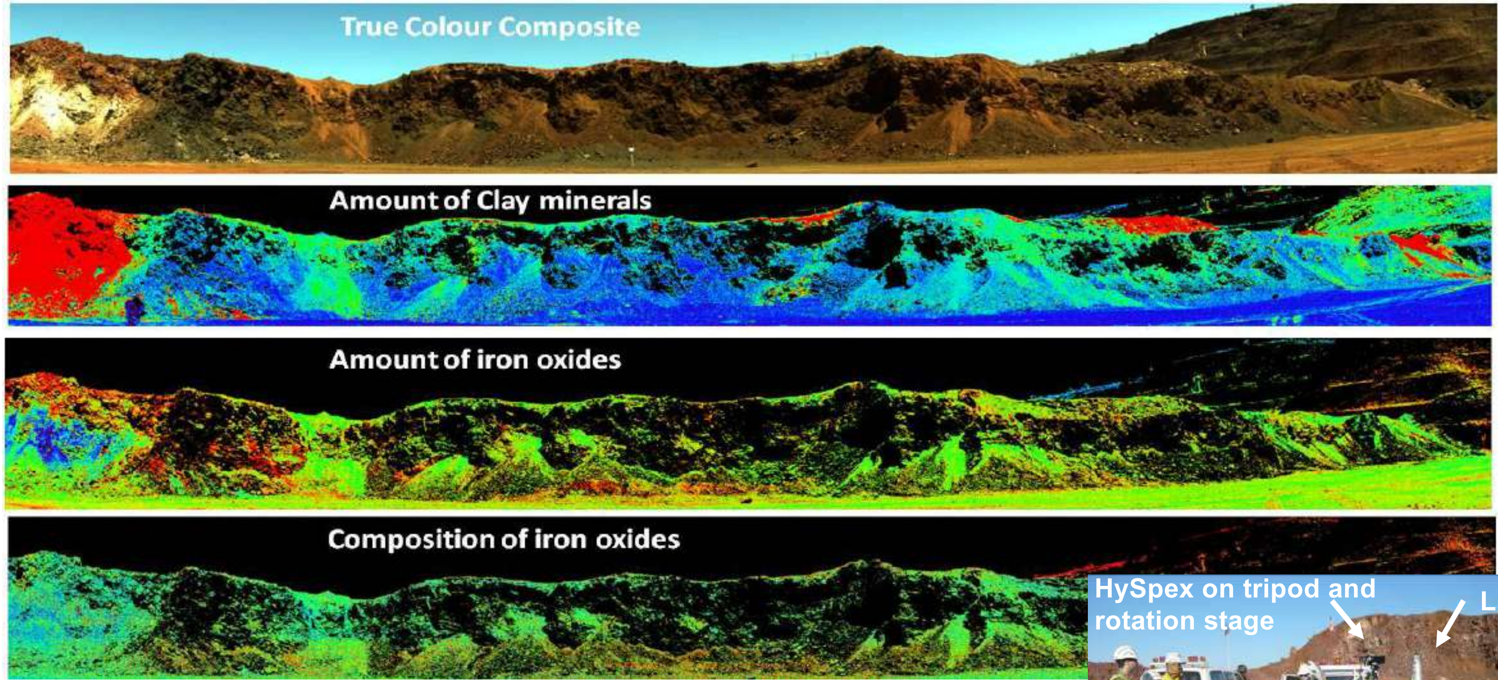


Hyperspectral imaging



Hyperspectral imaging: applications

Spectral Mine Imaging



Scanning time: a few minutes

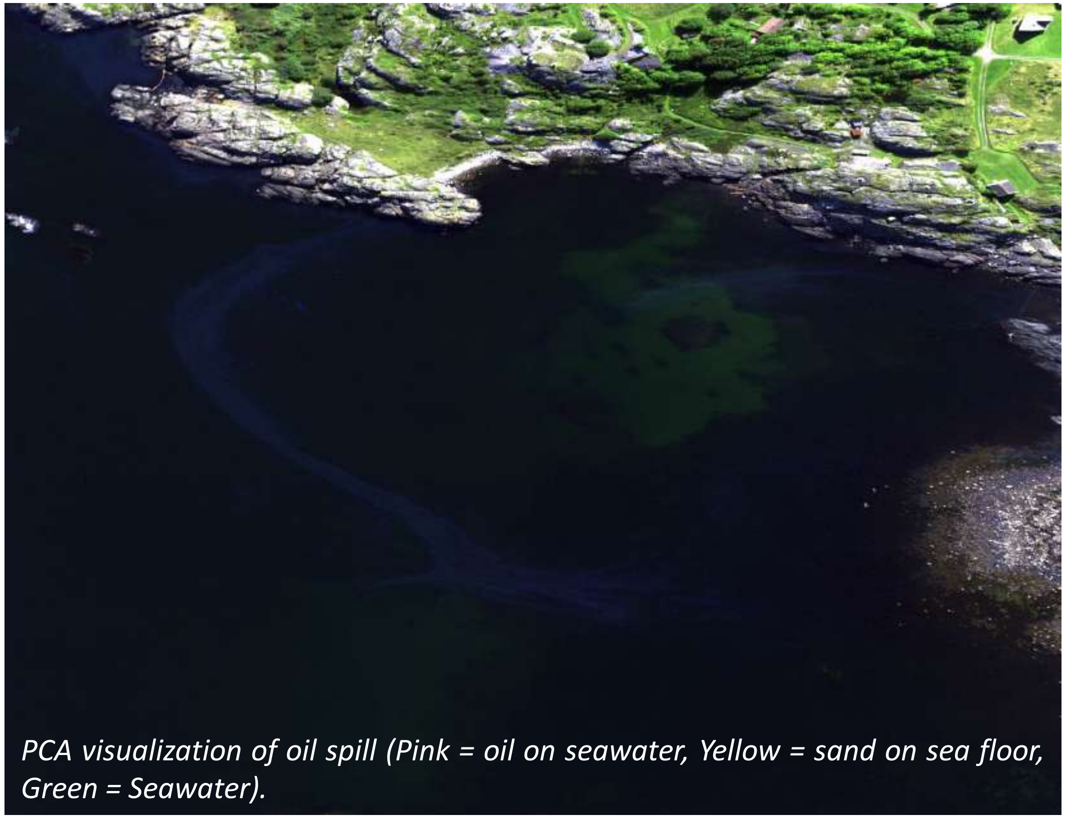
Courtesy of CSIRO

HySpex norsk elektro optikk

Hyperspectral imaging: applications

Oil spill detection - MV "Full City" Grounding

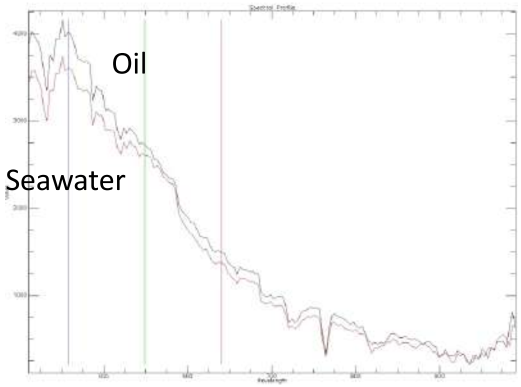
(~1000 tons of heavy bunker oil (IF 180) & ~120 tons of marine diesel oil on board)



PCA visualization of oil spill (Pink = oil on seawater, Yellow = sand on sea floor, Green = Seawater).

norsk elektro optikk

HySpex



Hyperspectral imaging: applications

Oil spill detection - MV “Full City” Grounding

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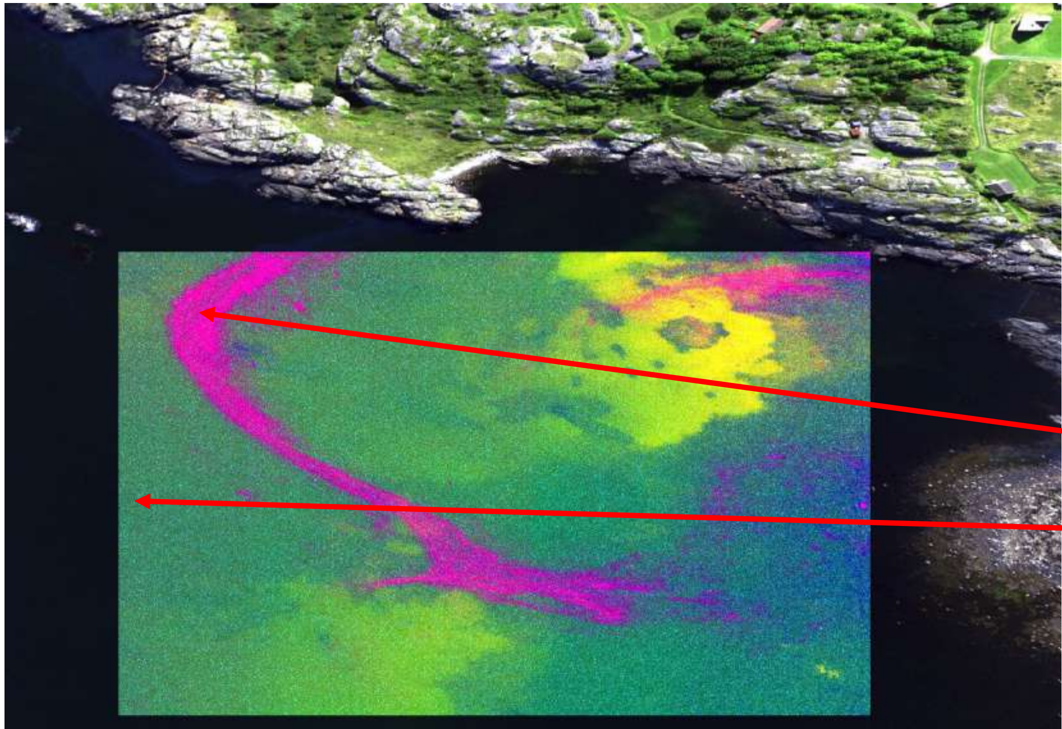

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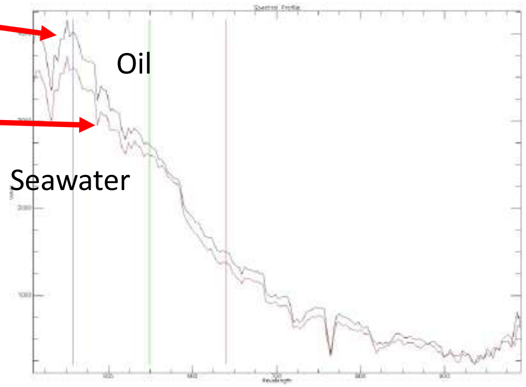
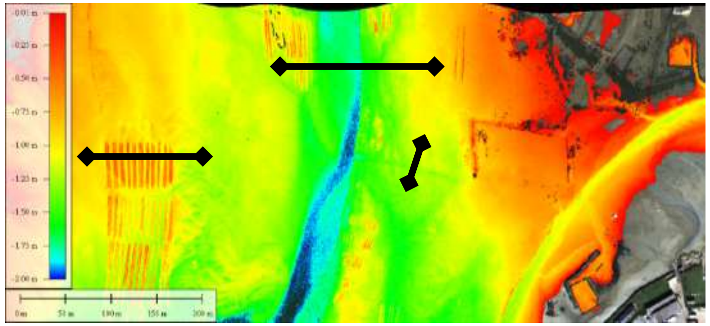
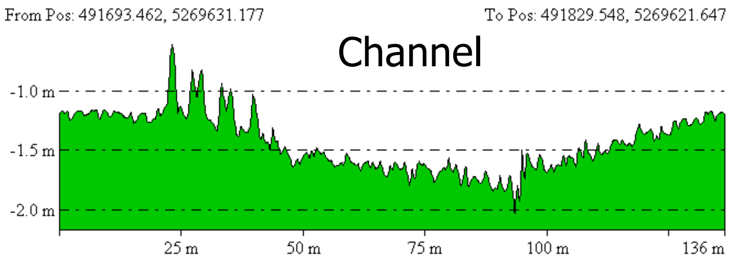
norsk elektro optikk

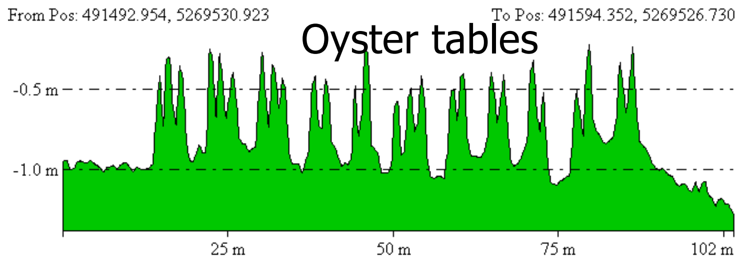
HySpex

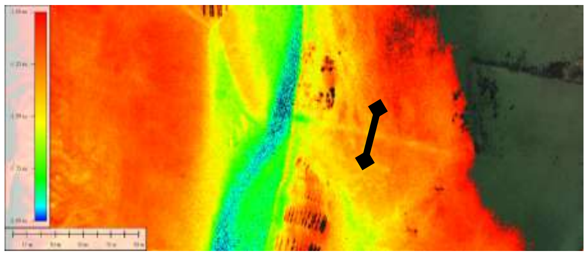


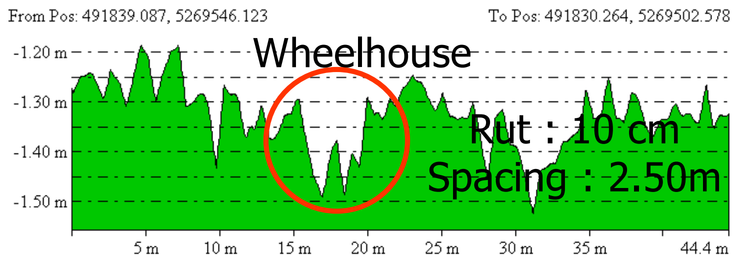
Hyperspectral imaging: applications



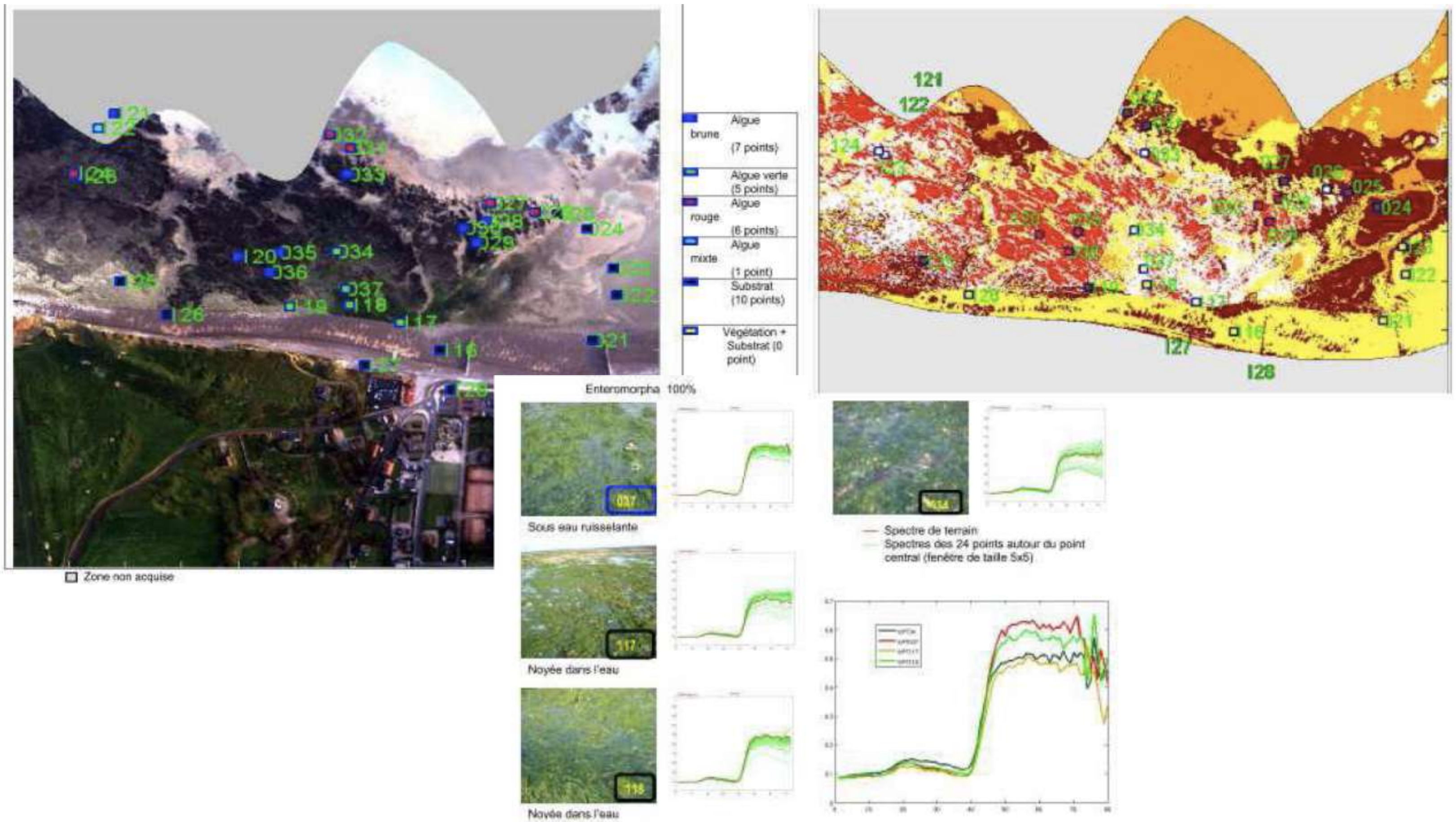




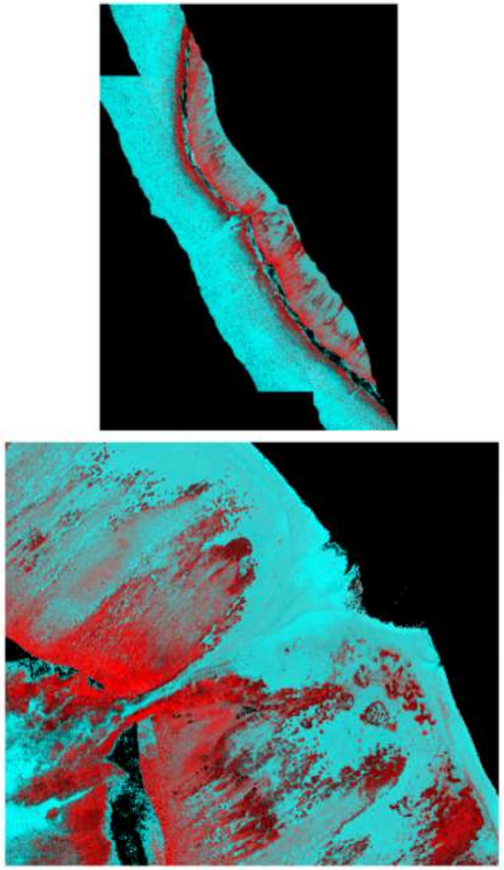




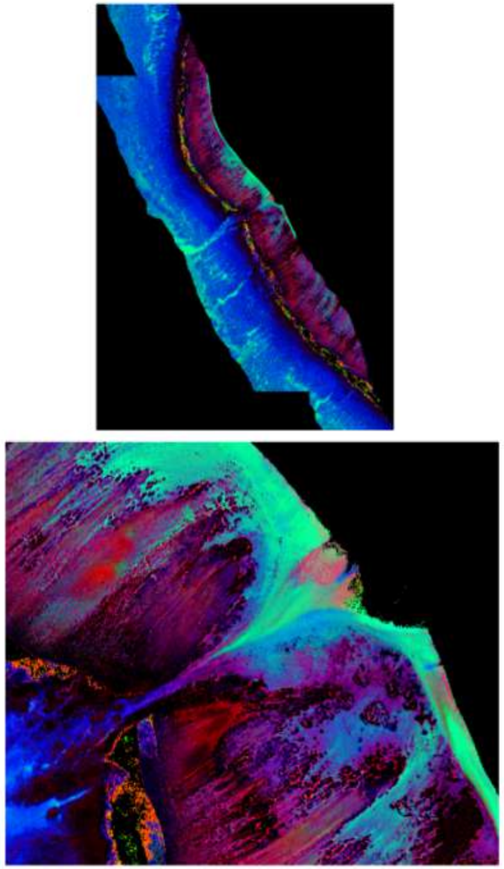
Hyperspectral imaging: applications



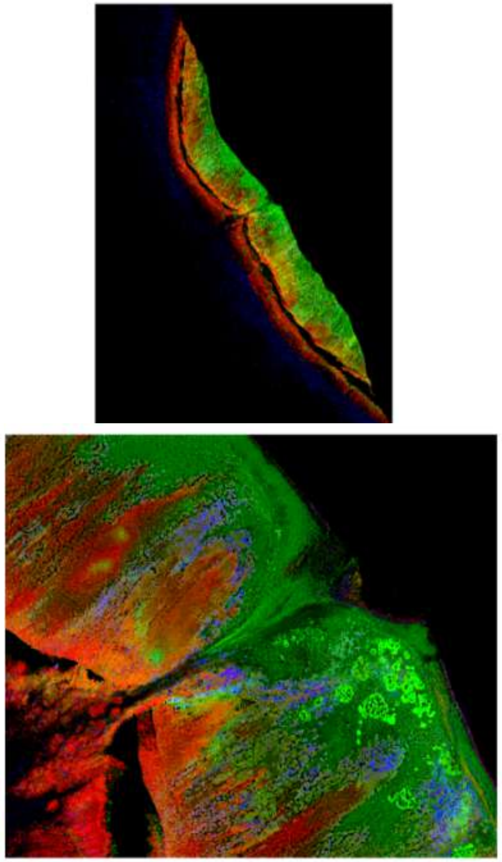
Hyperspectral imaging: applications



Submarine
« Vegetation Index »



Description of minerals
Sand / rocks



Description of vegetals and corals
Seaweeds / Algaes / corals

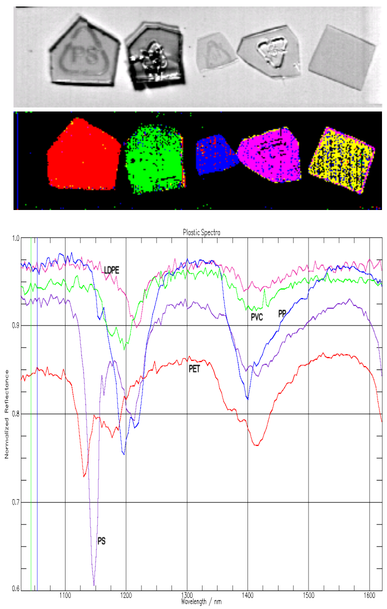
Hyperspectral imaging: applications

Recycling - Sorting

NIR spectral imaging

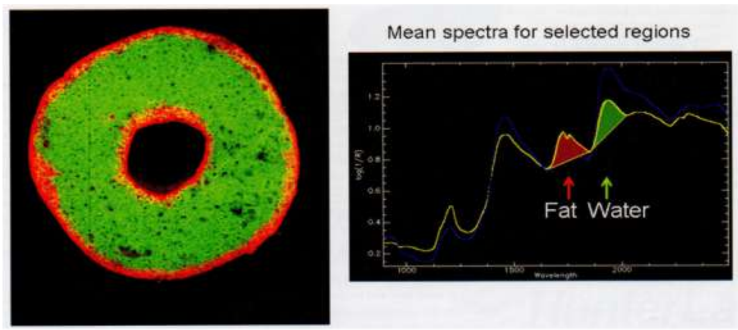
Plastics sorting

PS, PET, LDPE, PVC…



Mapping food composition

- VNIR and SWIR range
- Based on C-H, O-H and N-H bonds
- Fat, protein, carbohydrate and water content



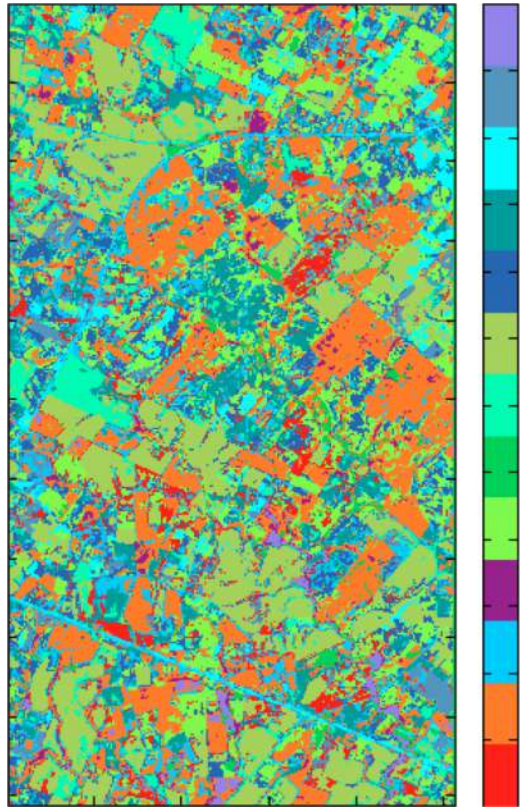
Frying - Fat and Water content in a donut

Reference: CCFRA, Campden, UK

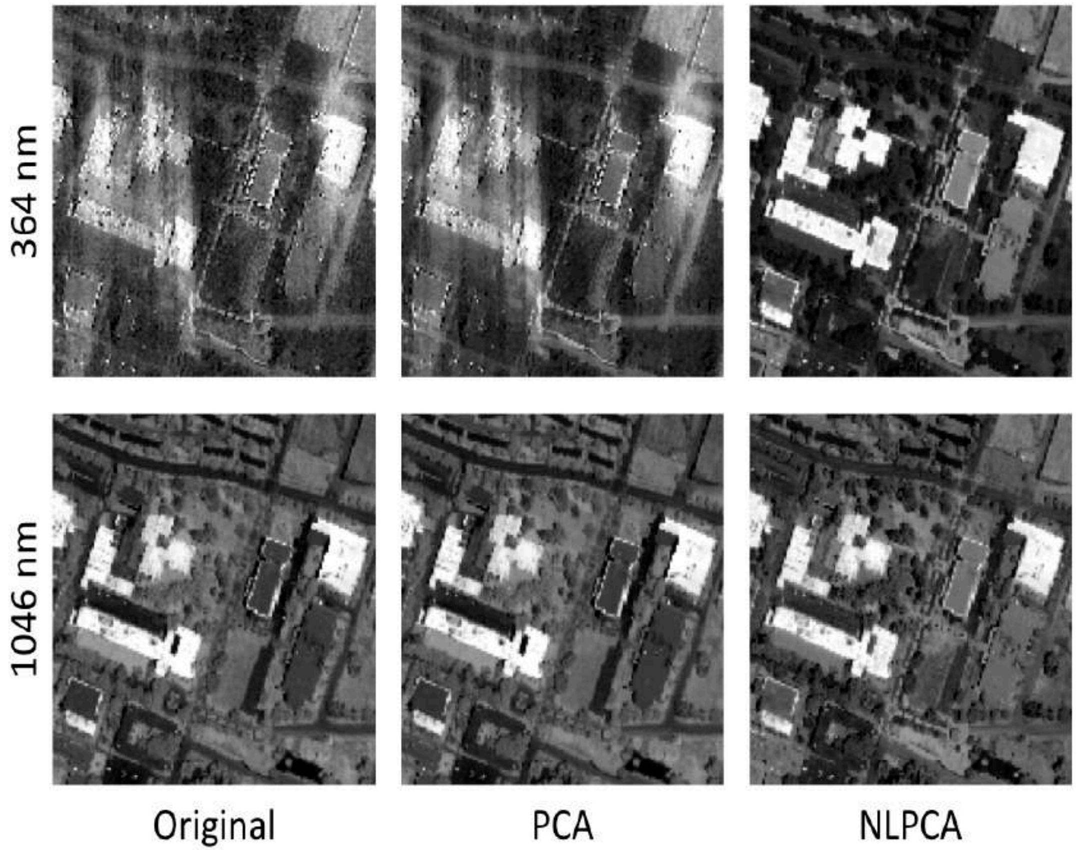
Specim

Hyperspectral imaging: applications

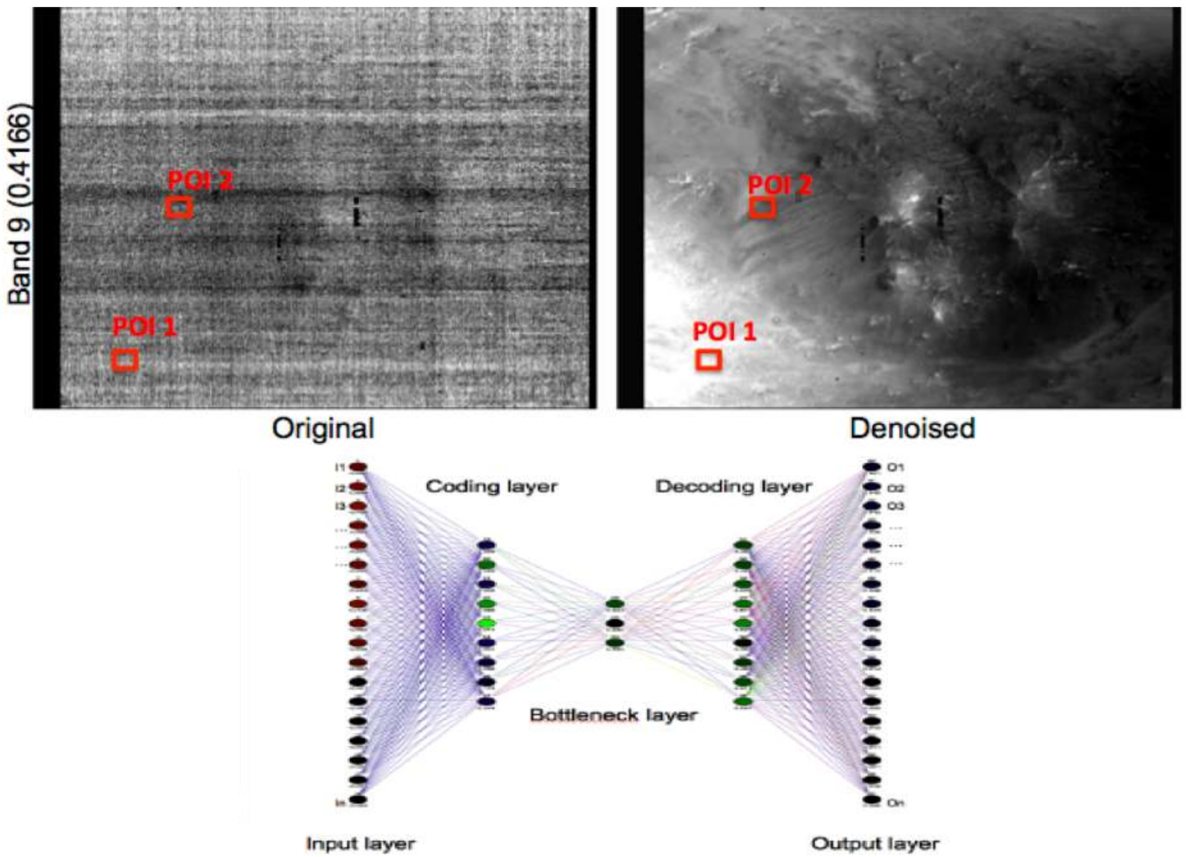
- Study in Uruguay



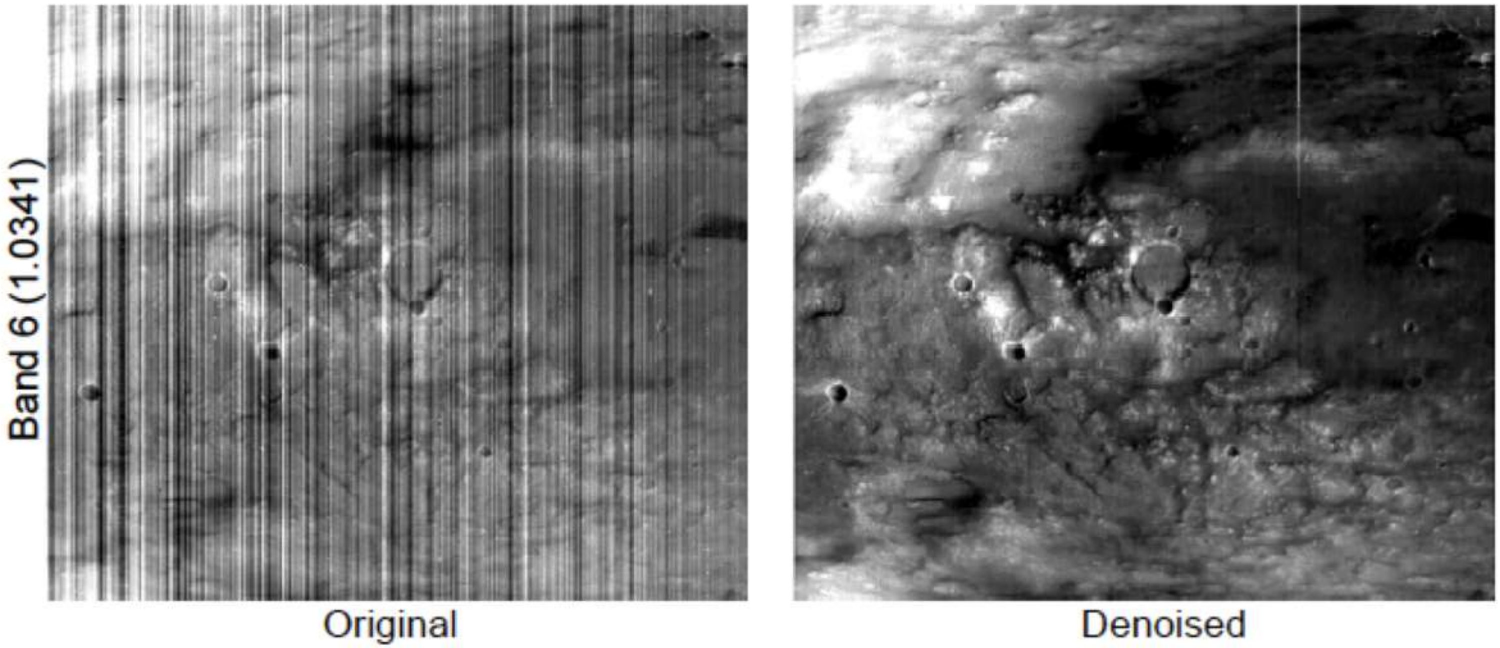
Hyperspectral imaging: noise



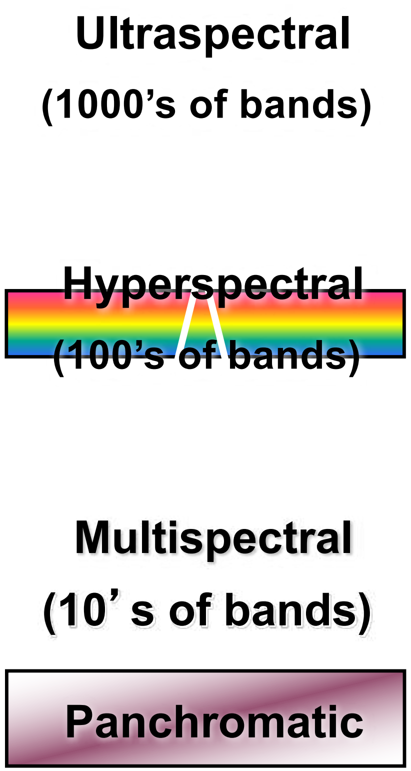
Hyperspectral imaging: noise



Hyperspectral imaging: noise



Hyperspectral imaging: opportunities



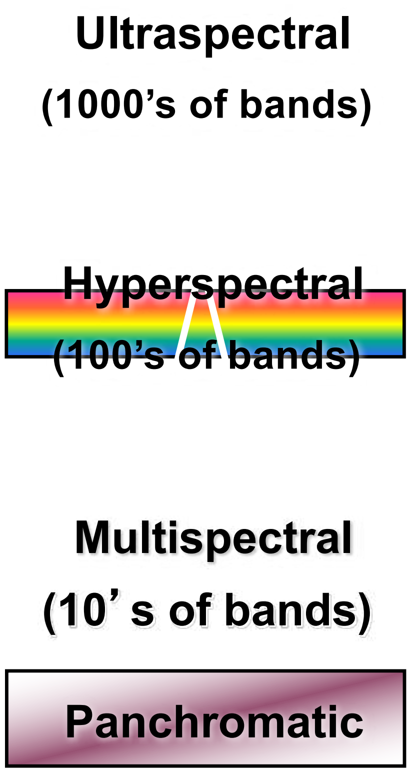
Spectral mixture analysis / source separation: Determines the abundance of materials

Characterization: Determines variability of identified material (e.g. wet/dry sand, soil particle size effects).

Classification: Separates materials into spectrally similar groups (e.g., urban data classification).

Detection: Determines the presence of materials, objects, activities, or events.

Hyperspectral imaging: challenges



Dimension of the data: high performance computing required

Dimensionality of the data: a curse… and a blessing… band selection, feature extraction

Understanding the physics: of the studied object and of the acquisition (incl. calibration, corrections…)

And including it in the models: linear, non linear

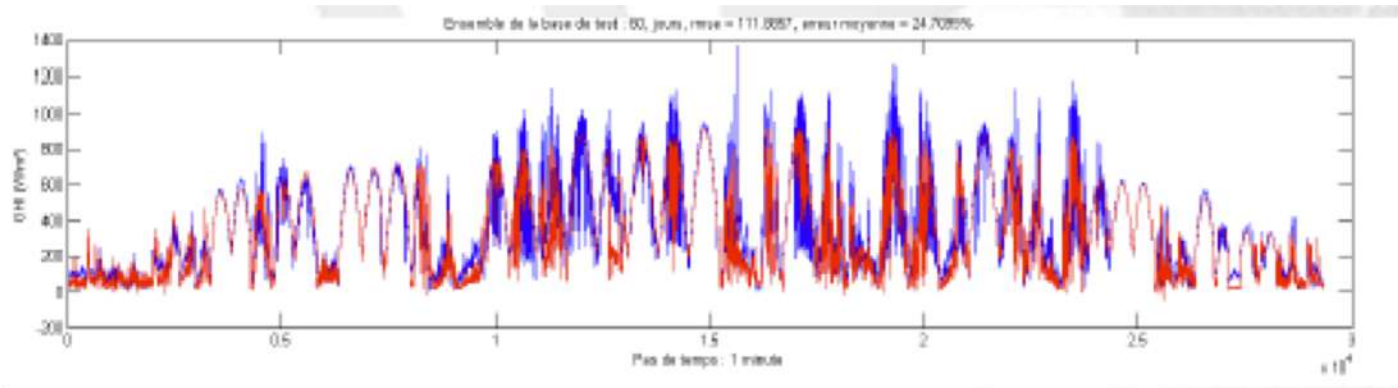
And including it in the processing: signal, image

Data Science Experts (DSE)

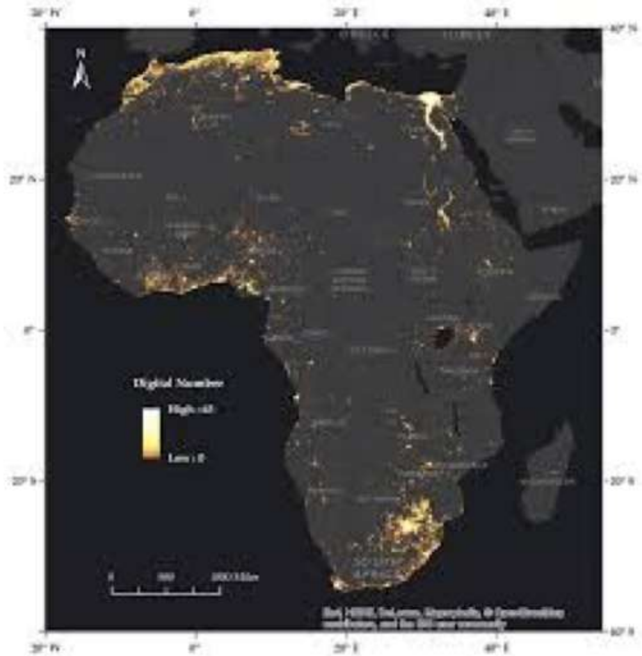
- Top 50 in Europe in the industrial space landscape (European Space Agency start-up competition, 2020)
- Copernicus Masters France Award (ESA, CNES, 2020)
- i-Nov award (BPI, 2021)
- Creative Destruction Lab (Canada) and Copernicus Accelarator (Europe)

Energy

- Forecast of the production of photovoltaic energy



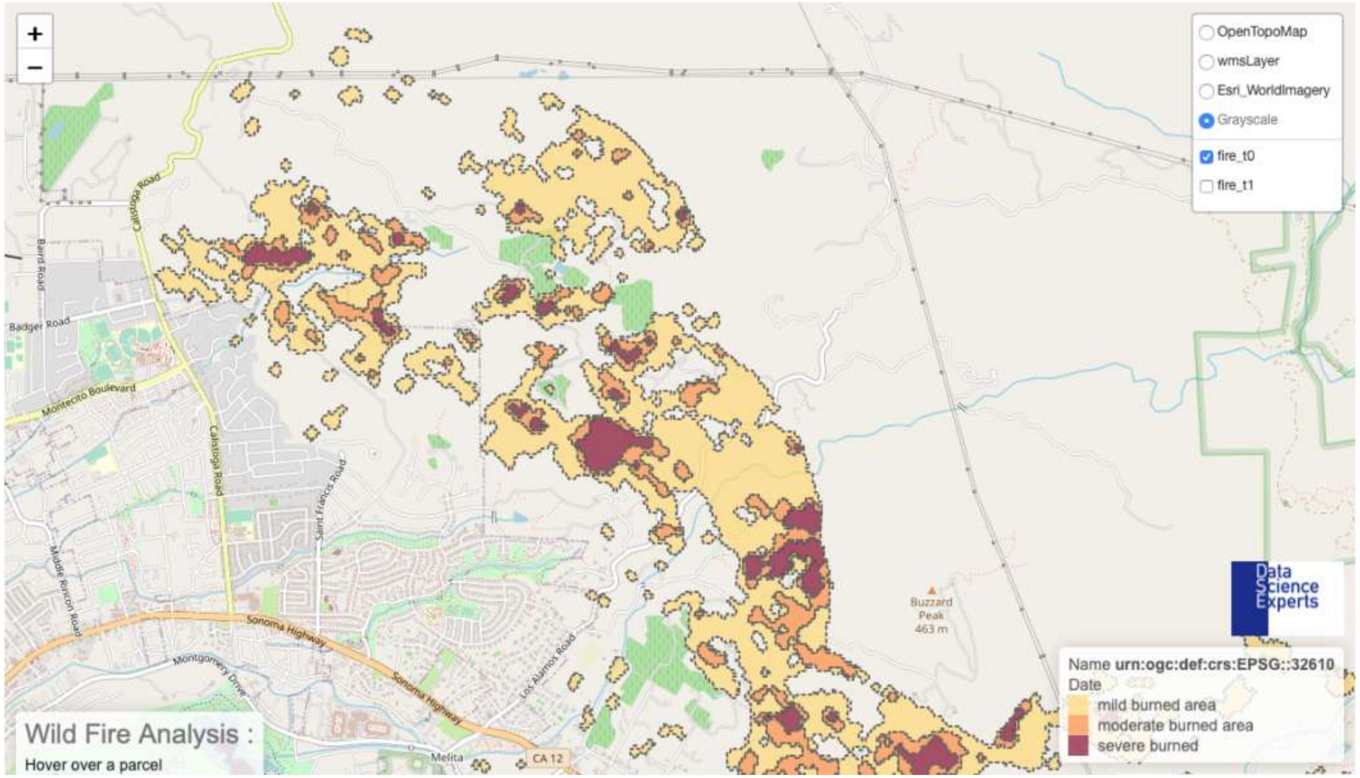
Daytime / Nighttime remote sensing



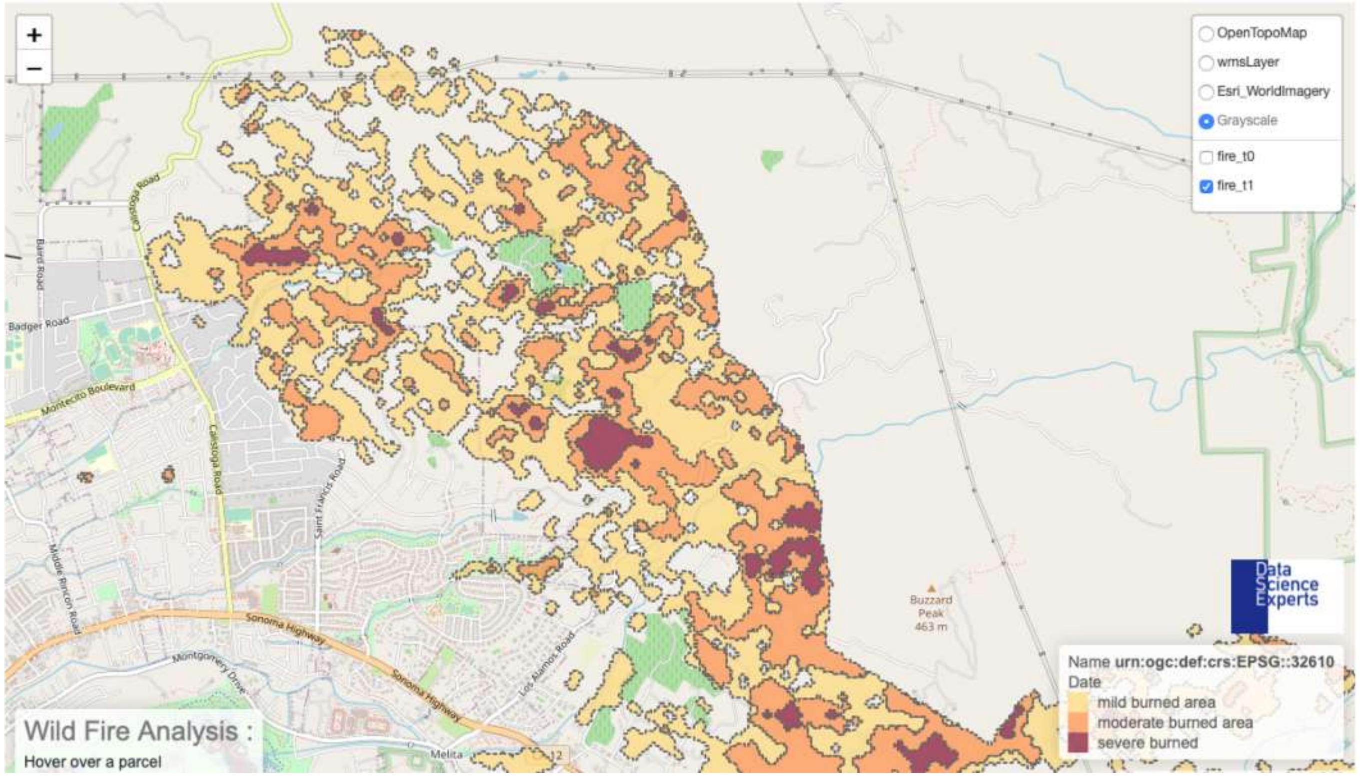
Drone-based acquisitions

- Detection of archeological remains in Atacama desert (Chile)

Damage assessment: wildfire



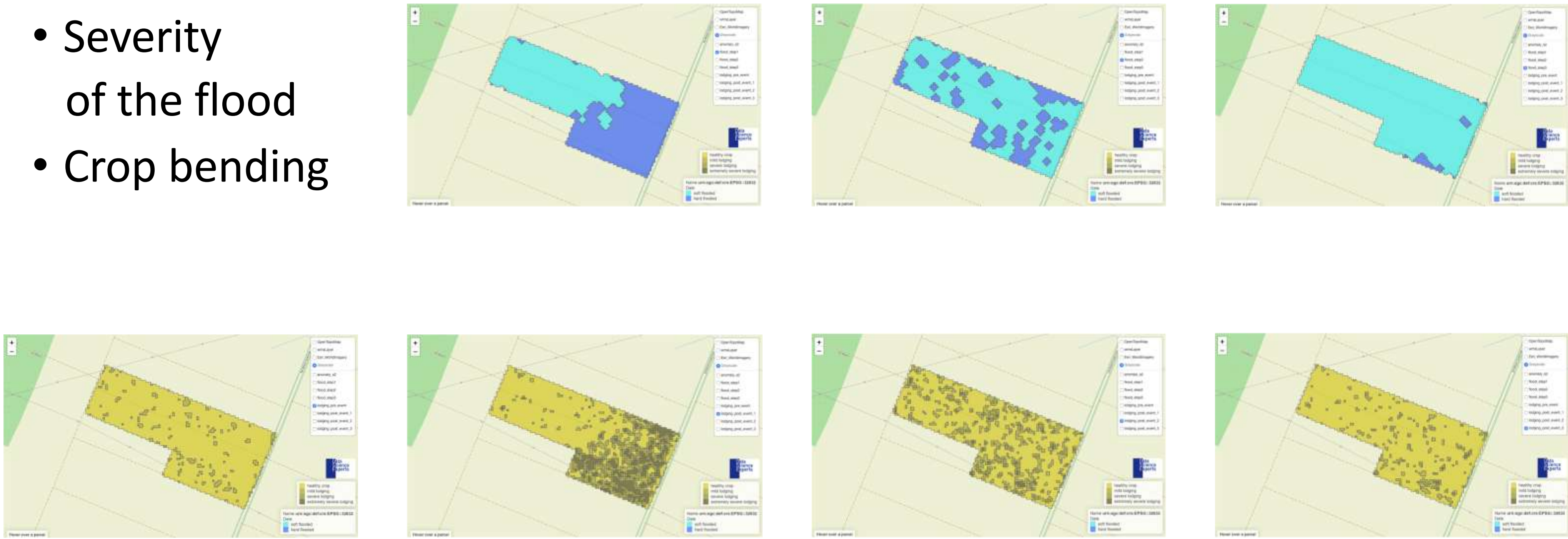
Damage assessment: wildfire



Damage assessment: flood

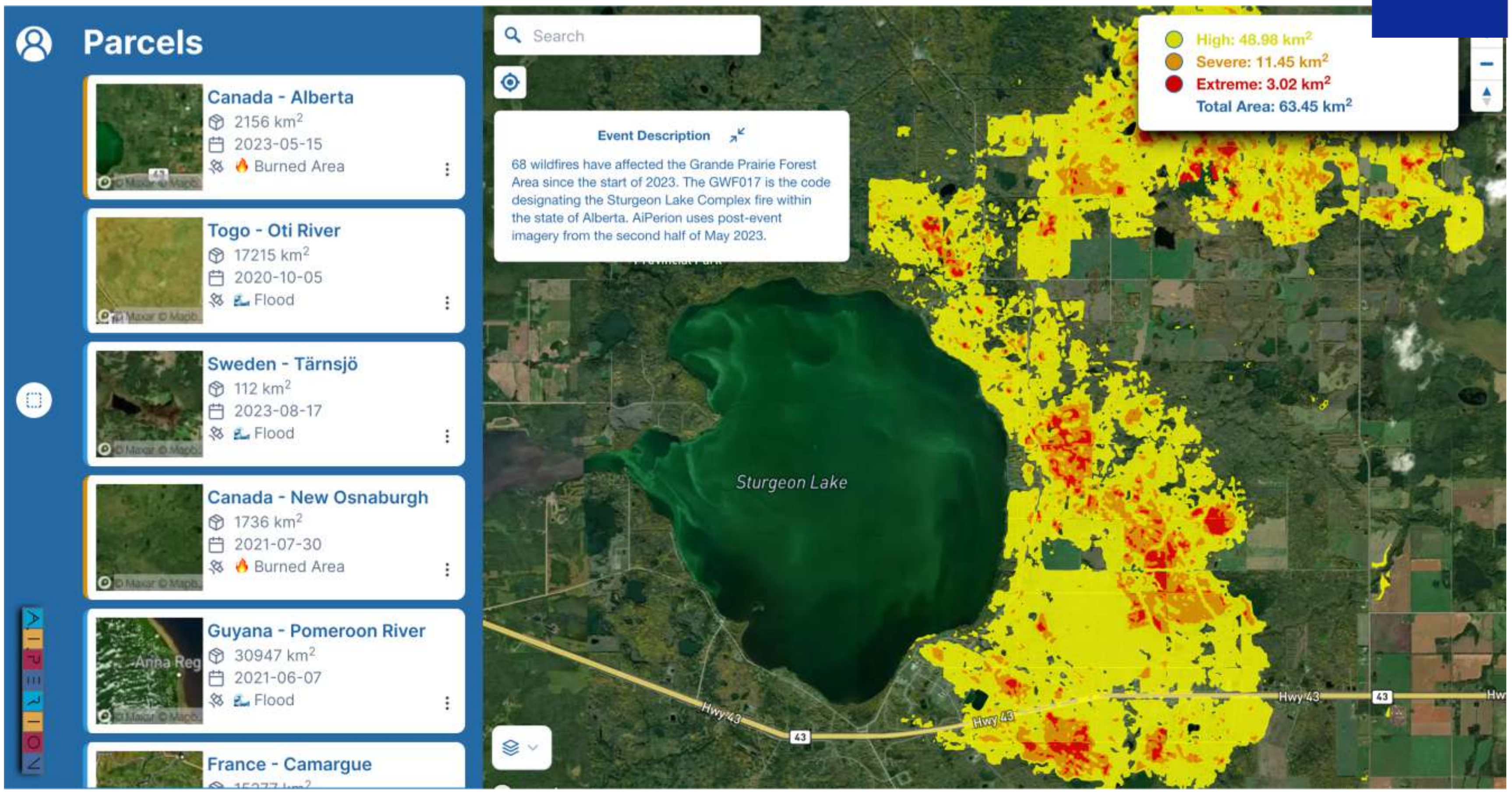
Data Science Experts

- Severity of the flood
- Crop bending



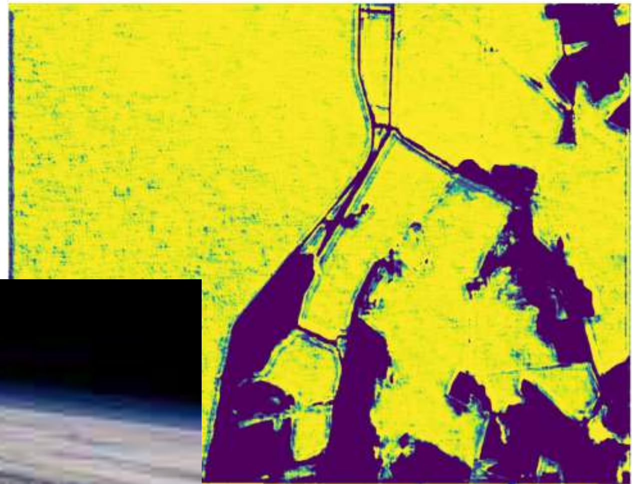
dec. 2, 2020 | dec. 8, 2020 | dec. 14, 2020 | dec. 20, 2020

https://aiperion.earth/



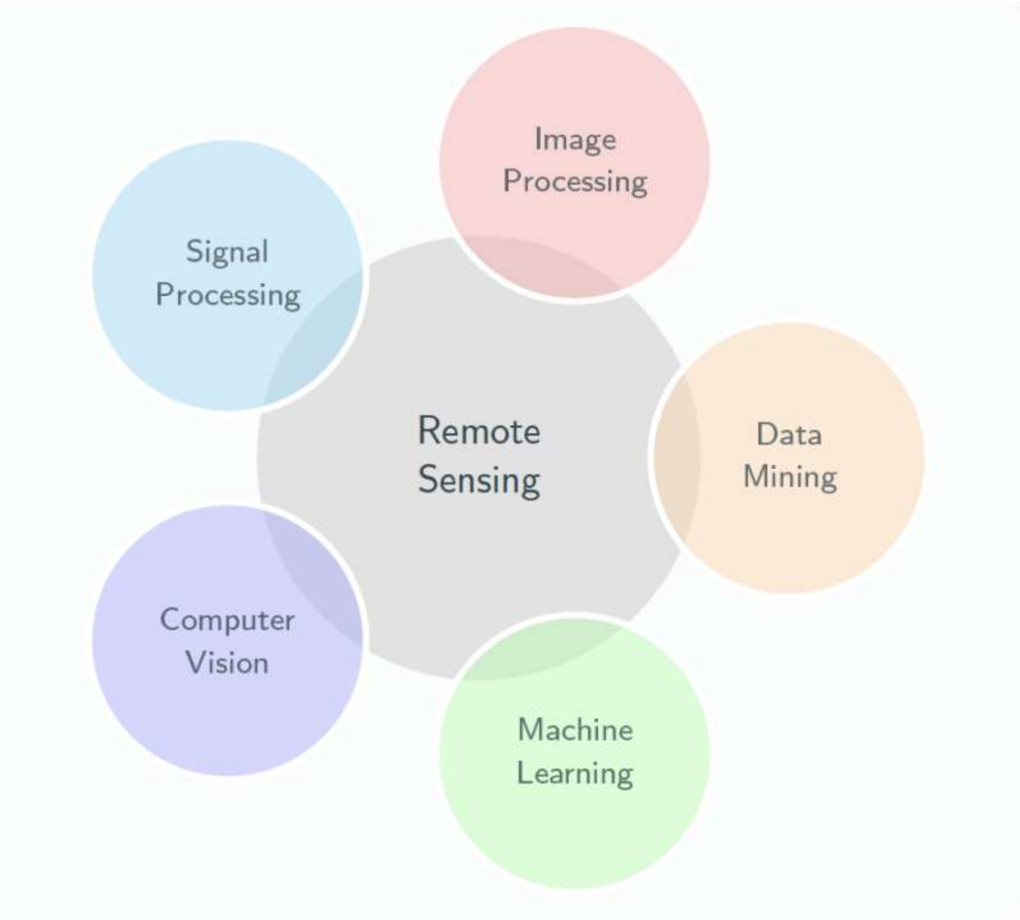
QlevEr Sat

- A cube-sat with embedded AI
  Deforestation in tropical forests




OrbitalAI Challenge
Real-time insights, real-world impact
The winners of the OrbitalAI Challenge have been announced
grEnOble
OHB Hellas
TelePIX+KIOST
Little Place Labs
NLR_AI4EO
IRT ST EXUPERY
TCSA_AI
SAIS
SkyServe
AI4EDofET

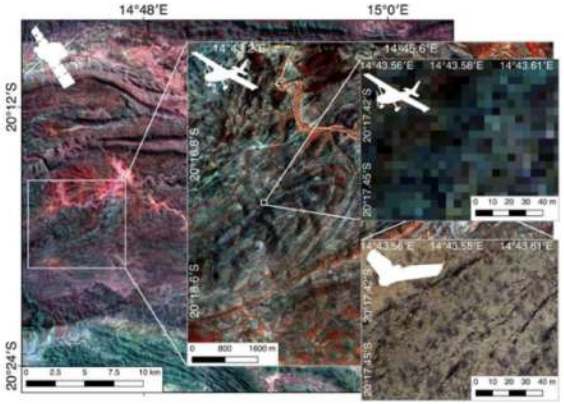
Remote sensing

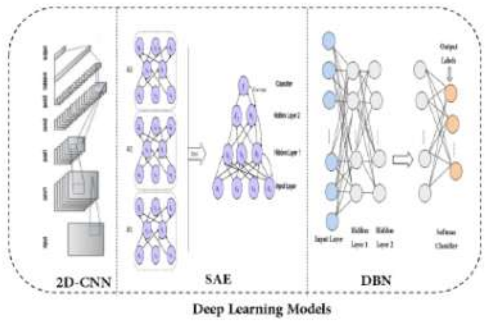


+ physical modeling

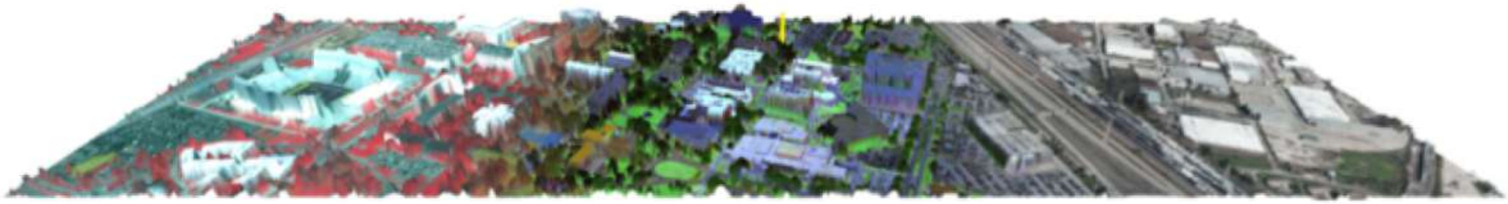
+ interaction with end-users

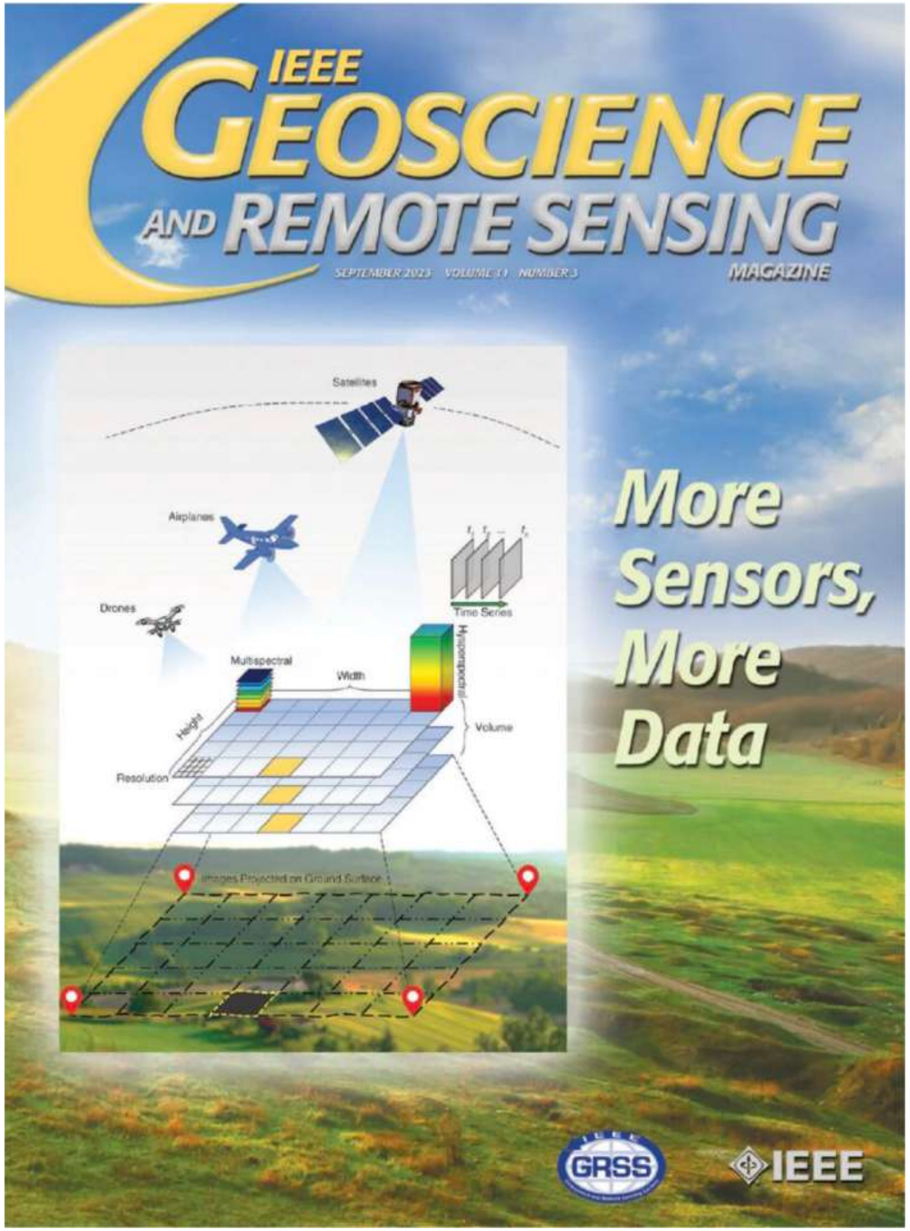
Future challenges





Constellation of small platforms
Artificial Intelligence, distributed computing, HPC, frugal and embedded AI
Incorporating physics into deep learning, incorporating deep learning in physics
Explainable AI
Multiscale, multimodal and multitemporal remote sensing

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