Image processing for Earth Observation

Welcome

Devis TUIA

EPFL, fall semester 2024

École polytechnique fédérale de Lausanne

Welcome to the image processing for Earth Observation course

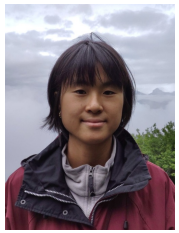
- First of all, some introductions are in order.
- I am Devis, I come from Ticino, I run the ECEO lab in Sion

- With me, the hosts for the semester will be

Christel

Gaston

Giacomo



Thien-Anh

Manon

Jan

We will talk about images that look like that

We will talk about images that look like that

We will talk about images that look like that

The IPEO course

- Aim: introduce the students to general concepts of remote sensing image processing

- No satellite design nor missions planning

- We focus on optical remote sensing of the Earth by satellites
  - Remote sensing of other planets => have a look at Space Minor courses
  - Remote sensing active (radar and SAR) => A. Berne - Remote sensing Bachelor course
  - Remote sensing from aerial platforms => photogrammetry course

The IPEO course learning objectives

- At the end of this course you will know about
  - Remote sensing systems & existing spaceborne platforms
  - List main applications using Earth observation data
  - Know current limitations & foreseen developments of spaceborne EO
  - Design a remote sensing workflow to get a geospatial product (e.g. a land cover map)
  - Use image processing & machine learning to extract relevant information

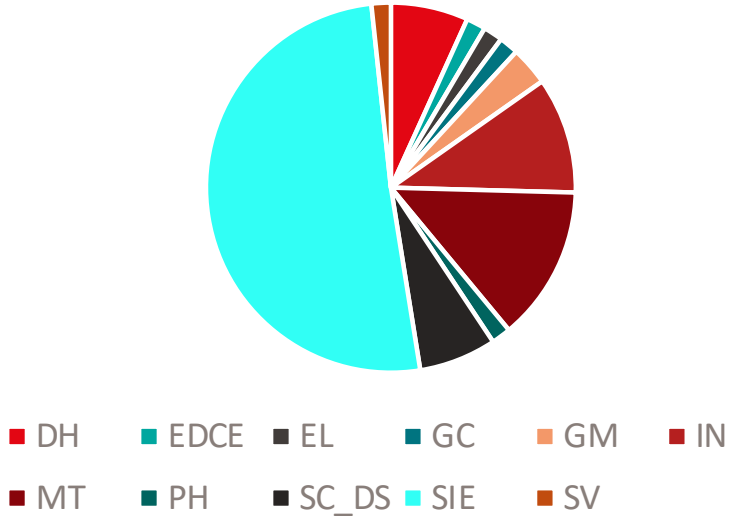
The IPEO course rough table of contents

1. Intro on imaging sensors & python programming
2. Information extraction
   - Vegetation indices
   - Spatial context and indices
3. Image classification with machine learning
   - Feature – then – classify approaches
   - Deep learning

Week-by-week schedule on moodle!

IPEO administration

- Elective master course
  - Environmental sciences and engineering master
  - Civil and environmental doctoral program
  - Space technology minor
  - Urban planning and territorial development minor



- 4 credits ECTS
- 4h / week,

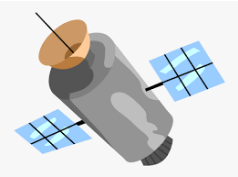
  +1-2h of work from home

  ~50% lectures, paper reading club

  ~50% exercises and project (Python-based)

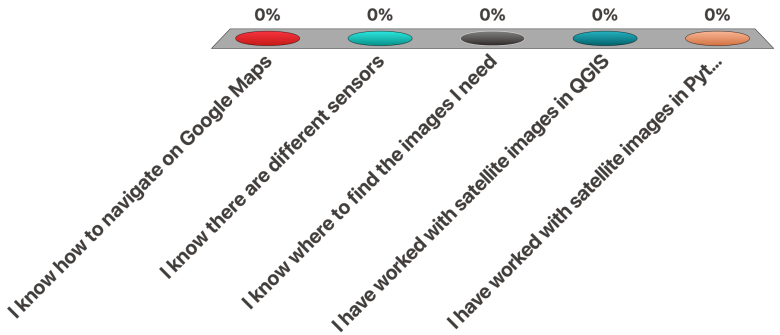
- Room: INF3 (here)

You and satellite images



URL: ttpoll.eu
Session ID: ipeo23

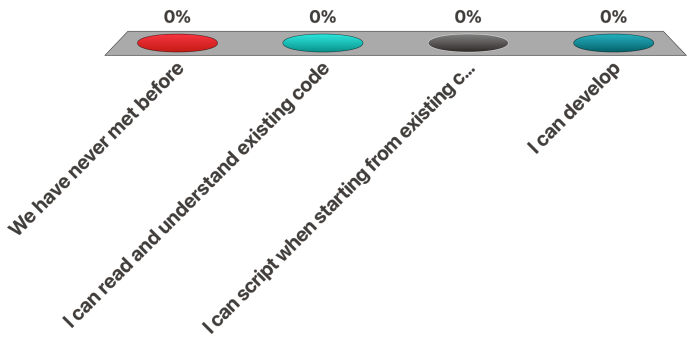
A. I know how to navigate on Google Maps
B. I know there are different sensors
C. I know where to find the images I need
D. I have worked with satellite images in QGIS
E. I have worked with satellite images in Python



You and Python

URL: ttpoll.eu
Session ID: ipeo23

A. We have never met before
B. I can read and understand existing code
C. I can script when starting from existing code
D. I can develop

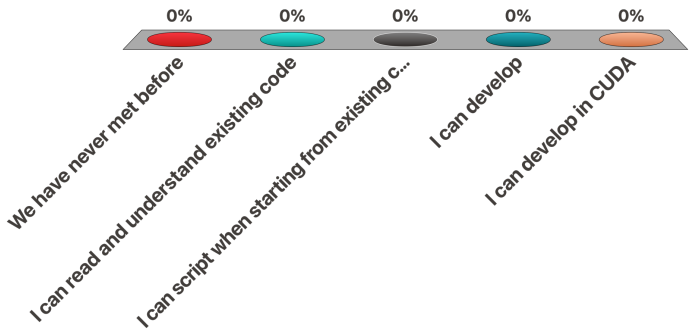


You and Pytorch

PyTorch

URL: ttpoll.eu
Session ID: ipeo23

A. We have never met before
B. I can read and understand existing code
C. I can script when starting from existing code
D. I can develop
E. I can develop in CUDA



IPEO evaluation

- 1 written evaluation, with theoretical questions and short calculation exercises
  - 50% of the grade, exam on 29.11.2024
- 1 project to be provided at the end of the semester, composed of a final report (10 pages) and appendix (code, etc)
  - 50% of the grade

IPEO logistics moodle

- http://moodle.epfl.ch
- Course: “Image Processing for Earth observation” (ENV-540)
- Inscription code: empty enrollment key
- On moodle:
  - Schedule
  - Lecture slides
  - Exercises
  - References & readings
  - News and communications
- Slack channel: ipeo-2024.slack.com (invitation link on moodle)

What we do

- We provide **starting concepts** in the lectures
- We provide help in the computer room when you are severely blocked
- We provide (detailed) **explanations** for understanding
- We provide the **solution of the expected model one week after**

What we do not do

you are 60. So:

- We do not answer questions if you haven't even tried
- We are not there to give the solution away, we're helping you to find it
- If we are busy with your colleagues, interact with your neighbours (they might have a solution for you)
- We do not accept any kind of disrespect or harassment in the classroom

References

- This course has been strongly inspired by:

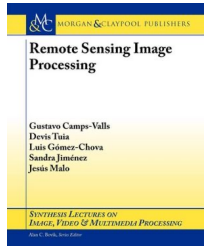
  The course “Imagery of Territory” by D. Tuia, © EPFL, 2012-2014

  The course “Remote Sensing of the Earth by Satellites by M. Borgeaud, © EPFL, 2009

- Remote sensing image processing (M&C)

  Camps-Valls, Tuia, Gomez-Chova, Jimenez, Malo

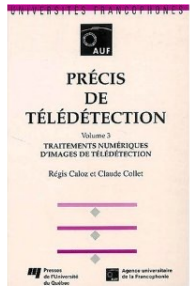
  available at: http://www.morganclaypool.com/



- Précis de télédétection, Vol 4 (Presses du Québec)

  Caloz and Collet

  En français!



What is Earth observation?

A bit of history

Defining Earth observation today

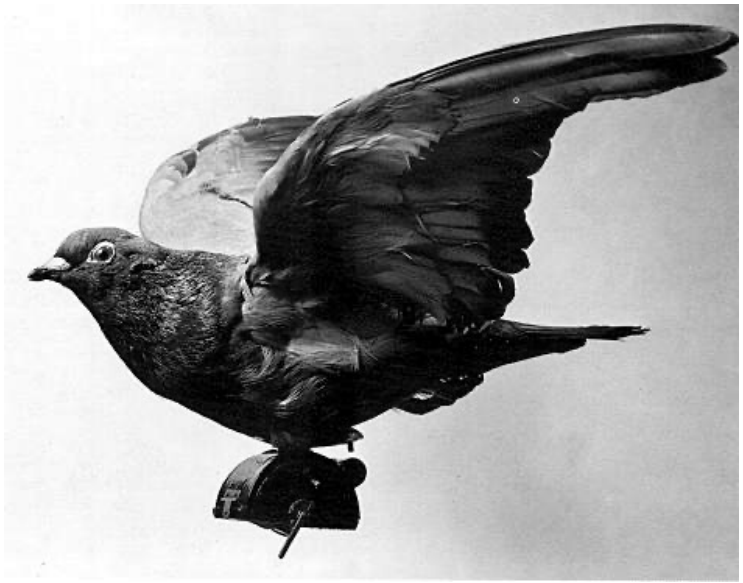
The EO system (and what we cover in IPEO)

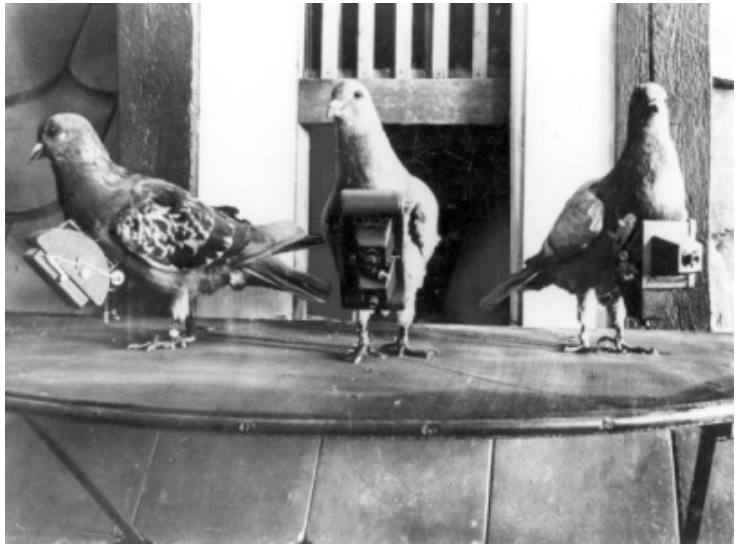
A bit of history

1858: First aerial image by Gasper Felix Tournachon “Nadar"

A bit of history

1902-1914: Aerial images by The Bavarian Pigeon Corps





A bit of history

1902-1914: Aerial images by The Bavarian Pigeon Corps

In pictures: World's hero pets

Other animals not buried at Ilford but which have receive the Dickin medal include GI Joe, a pigeon which prevented troops in an Italian village from becoming victims of 'friendly fire'.

Nr. 192864 Klasse 49a

SCHWEIZERISCHE EIDGENOSSENSCHAFT

EIDGEN. AMT FÜR GEISTIGES EIGENTUM

PATENTSCHRIFT

Veröffentlicht am 1. Dezember 1937

Gesuch eingereicht: 3. Februar 1936, 18 Uhr. — Patent eingetragen: 15. September 1937.

HAUPTPATENT

Christian Adrian MICHEL, Waldo (Aargau, Schweiz).

Photographieapparat mit schwenkbarem, mit selbsttätiger Auslösung versehenem Objektiv, insbesondere für Brieftauben.

Die vorliegende Erfindung betrifft einen Photographieapparat mit schwenkbarem, mit selbsttätiger Auslösung versehenem Objektiv, der insbesondere für Brieftauben bestimmt ist. Dieser Photographieapparat unterscheidet sich von bekannten ähnlichen Apparaten durch zwei Federwerke, von denen das erste Mittel zur Einstellung der Zeit, nach welcher das Objektiv ausgeschwenkt werden soll, aufweist und zur Inganggetzung und zum Anhalten des zweiten Federwerkes dient, welches mit dem Objektiv in Antriebsverbindung steht und dessen Ausschwenkung, Auslösung und Rückführung in die Ruhelage bewirkt. Das zweite Federwerk weist zudem Mittel auf, welche den Film zwischen zwei aufeinanderfolgenden Belichtungen um Bildlänge vorwärtsschalten. Ein Ausführungsbeispiel des Erfindungsgegenstandes sowie Detailvarianten sind in der Zeichnung schematisch dargestellt.

Fig. 1 bis 3 zeigen das Triebwerk, in drei Einzelwerke zerlegt;

Fig. 4 ist ein Querschnitt durch den Apparat;

Fig. 5 ist ein Längsschnitt nach der Linie V—V in Fig. 4, und

Fig. 6 zeigt einen Gehäusedeckel, welcher das Triebwerk nach aussen abschliesst;

Fig. 7 ist ein Querschnitt durch eine zweite Ausführungsform einer die Objektivachse mit dem Antriebswerk verbindenden Schleppkupplung;

Fig. 8 und 9 sind Einzelheiten der letzteren;

Fig. 10 und 11 zeigen eine Ausführungsform zur Einstellung der Spannung der das Objektiv in seine Ruhestellung zurückführenden Feder;

Fig. 12 zeigt in grösserem Massstabe die Anordnung des Triebwerkes innerhalb des Apparatengehäuses;

Fig. 13 ist ein Schnitt nach der Linie XIII—XIII in Fig. 12, und

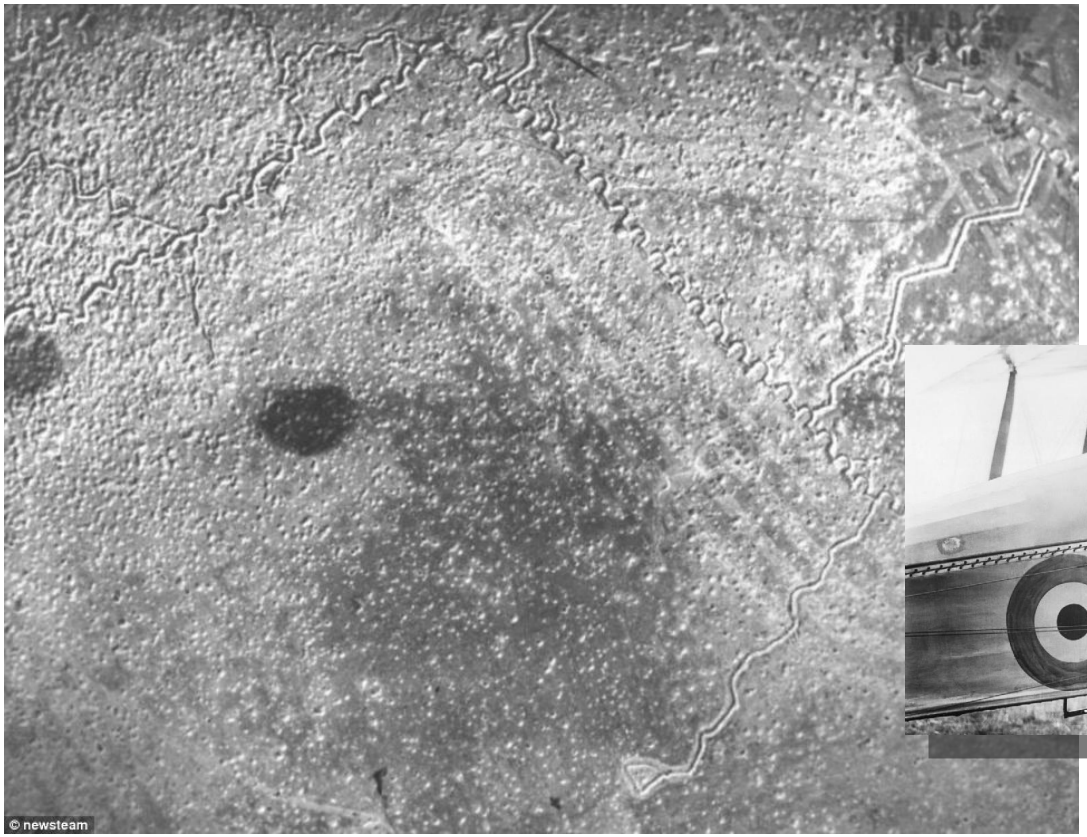
Fig. 14 ist ein Schnitt nach der Linie XIV—XIV in Fig. 12.

Christian Adrian Michel

Patent Nr. 192864
2 Blatter. Nr. 1

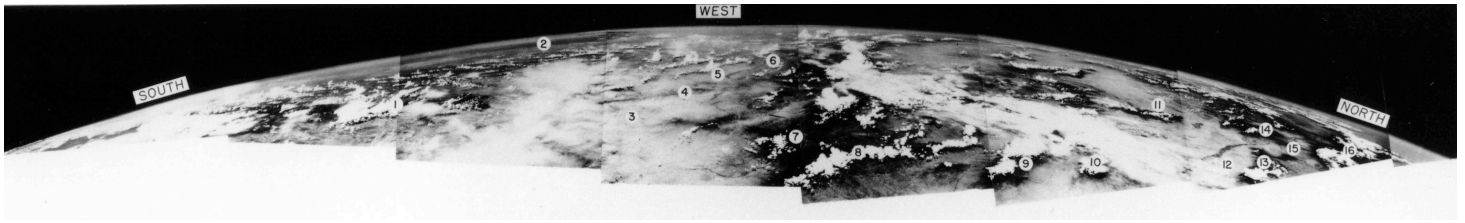
A bit of history

1914-1918: Aerial imagery for military purpose during WWI



A bit of history

1946: First images from space using V2 rocket launched from US



1- MEXICO
2- GULF OF CALIFORNIA
3- LORDSBURG, NEW MEXICO
4- PELONCILLO MTS.
5- GILA RIVER
6- SAN CARLOS RESERVOIR
7- MOGOLLON MTS.
8- BLACK RANGE
9- SAN MATEO MTS.
10- MAGADALENA MTS.
11- MT. TAYLOR
12- ALBUQUERQUE, NEW MEXICO
13- SANDIA MTS.
14- VALLE GRANDE MTS.
15- RIO GRANDE
16- SANGRE DE CRISTO RANGE

ROCKET FIRED AT WHITE SANDS PROVING GROUND, JULY 26,1948

DISTANCE FROM CAMERA TO HORIZON-700 MILES

AREA SHOWN APPROXIMATELY 800,000 SQ.MILES

DISTANCE ALONG HORIZON-2700 MILES

INSTRUMENTATION AND PHOTOGRAPHY BY APPLIED PHYSICS LABORATORY OF THE JOHNS HOPKINS UNIVERSITY FOR THE BUREAU OF ORDNANCE, U.S.NAVY

A bit of history

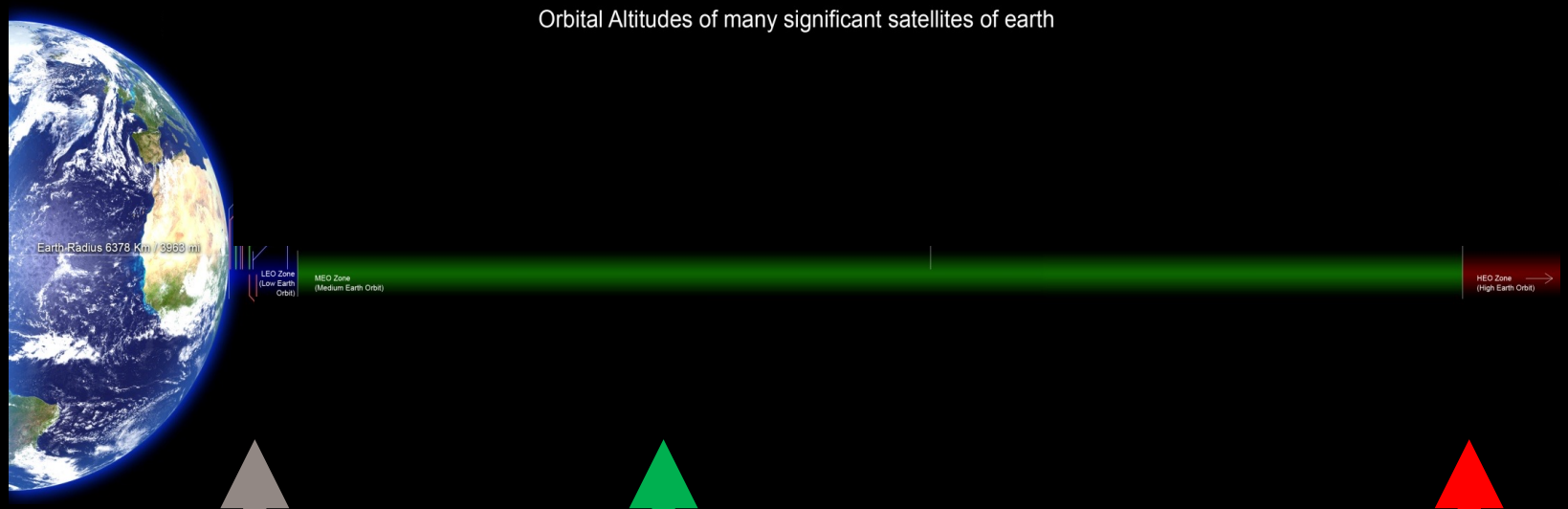
1960: military, 2000s commercial

Keyhole satellite

Quickbird satellite

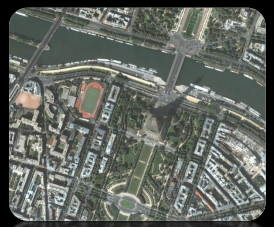
The place of Earth observation in the... near solar system

Orbital Altitudes of many significant satellites of earth



< 2'000 KM

LOW EARTH ORBIT

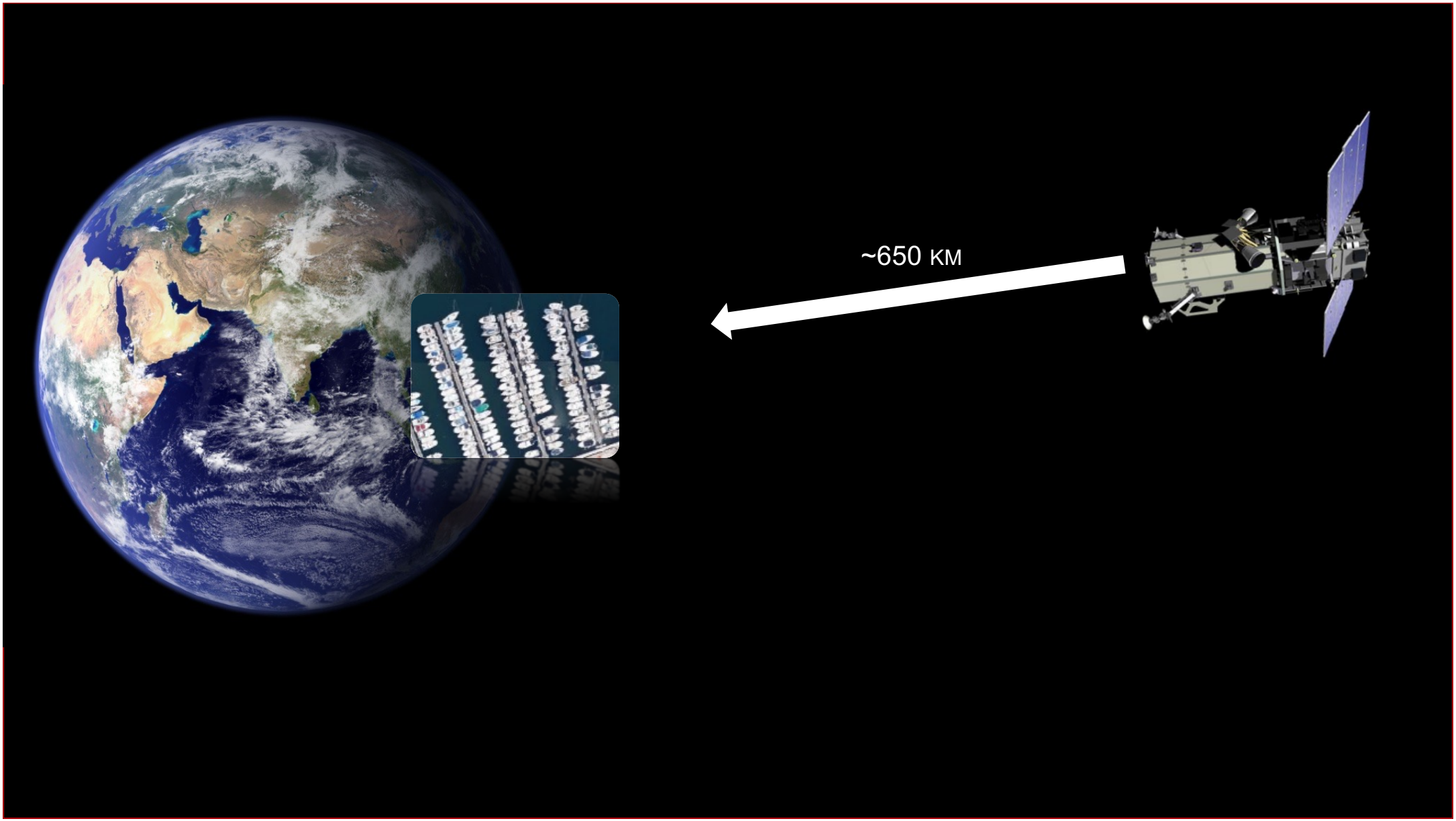


MEDIUM EARTH ORBIT

> 36'000 KM

HIGH EARTH ORBIT

(GEO-STATIONARY)

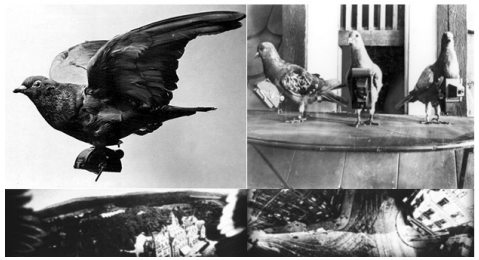

~650 KM

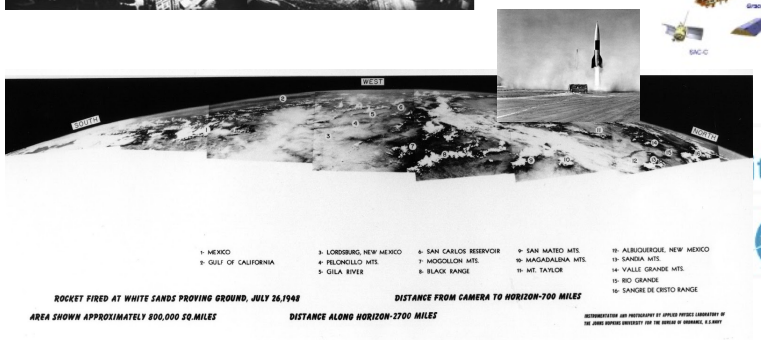
~650 km

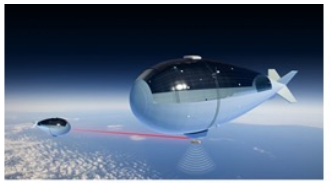
~650 km

Earth observation past-present-future

1902-1914: Aerial images by The Bavarian Pigeon Corps

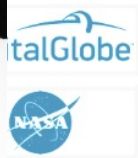






Thales Aliena Space

Airbus



What is Earth observation?

A bit of history

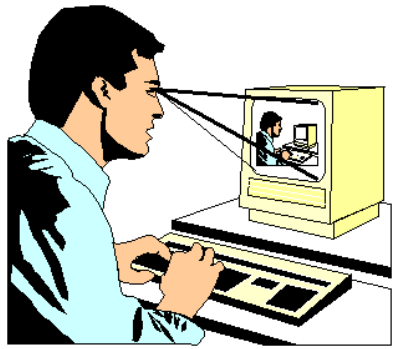
Defining Earth observation today

The EO system (and what we cover in IPEO)

Image processing for Earth Observation

- For some time, people called it *remote sensing*
- In that case, it means observing from a distance
- So working from a PC is also remote sensing

- In this course, we want to focus on one object of interest: Earth.



http://www.fas.org/irp/imint/docs/rst/Intro/Part2_1.html

Image processing for Earth Observation

- Here we mean observing Earth using digital sensors.
- We deal with electromagnetic radiation
- We deal with satellites, aircrafts or drones

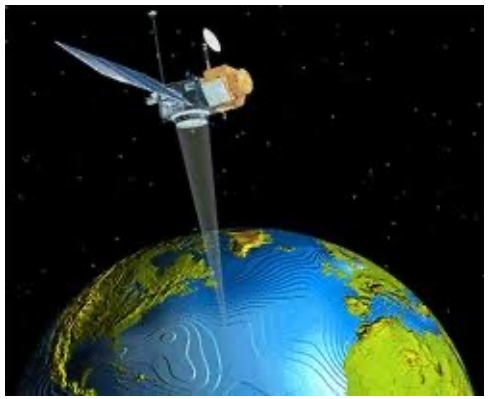
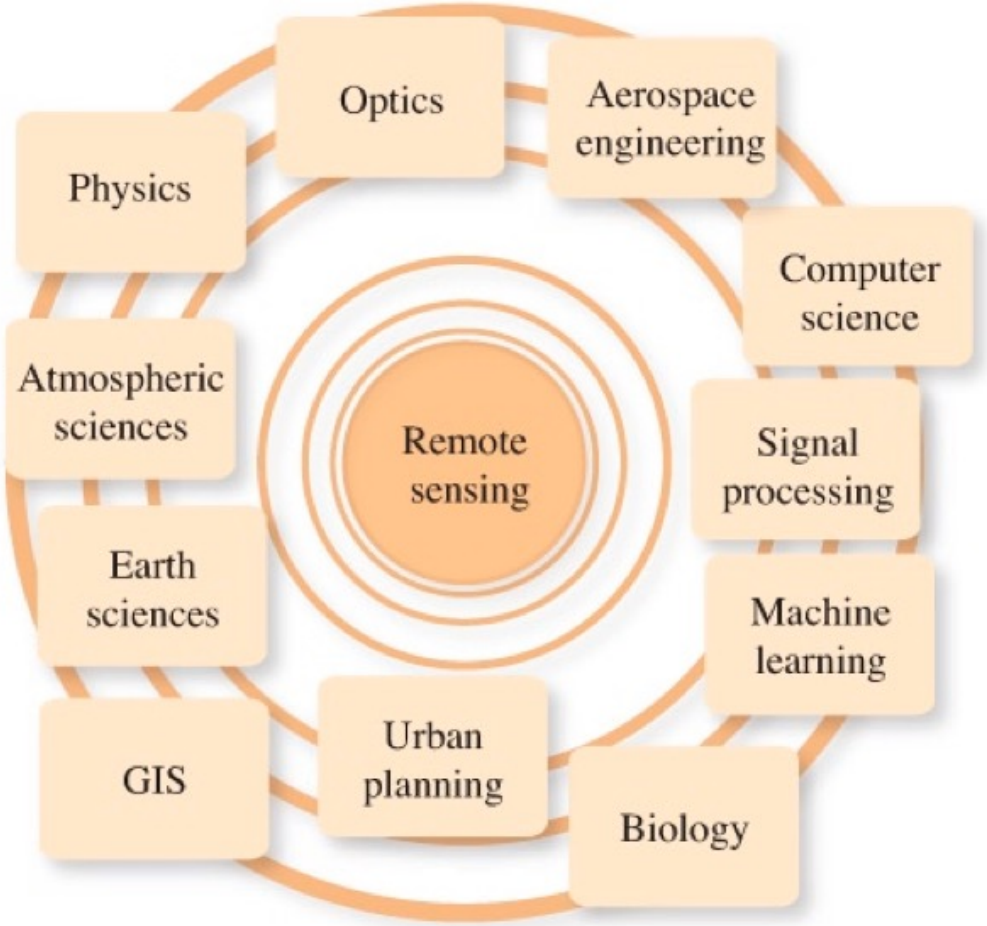


Image processing for Earth Observation

- We can use EO for
  - Monitoring and modelling the processes at the surface of Earth
  - Obtain quantitative measures and estimations of geo-bio-physical variables
  - Identify materials
  - Describe and track changes

An interdisciplinary field



An interdisciplinary field

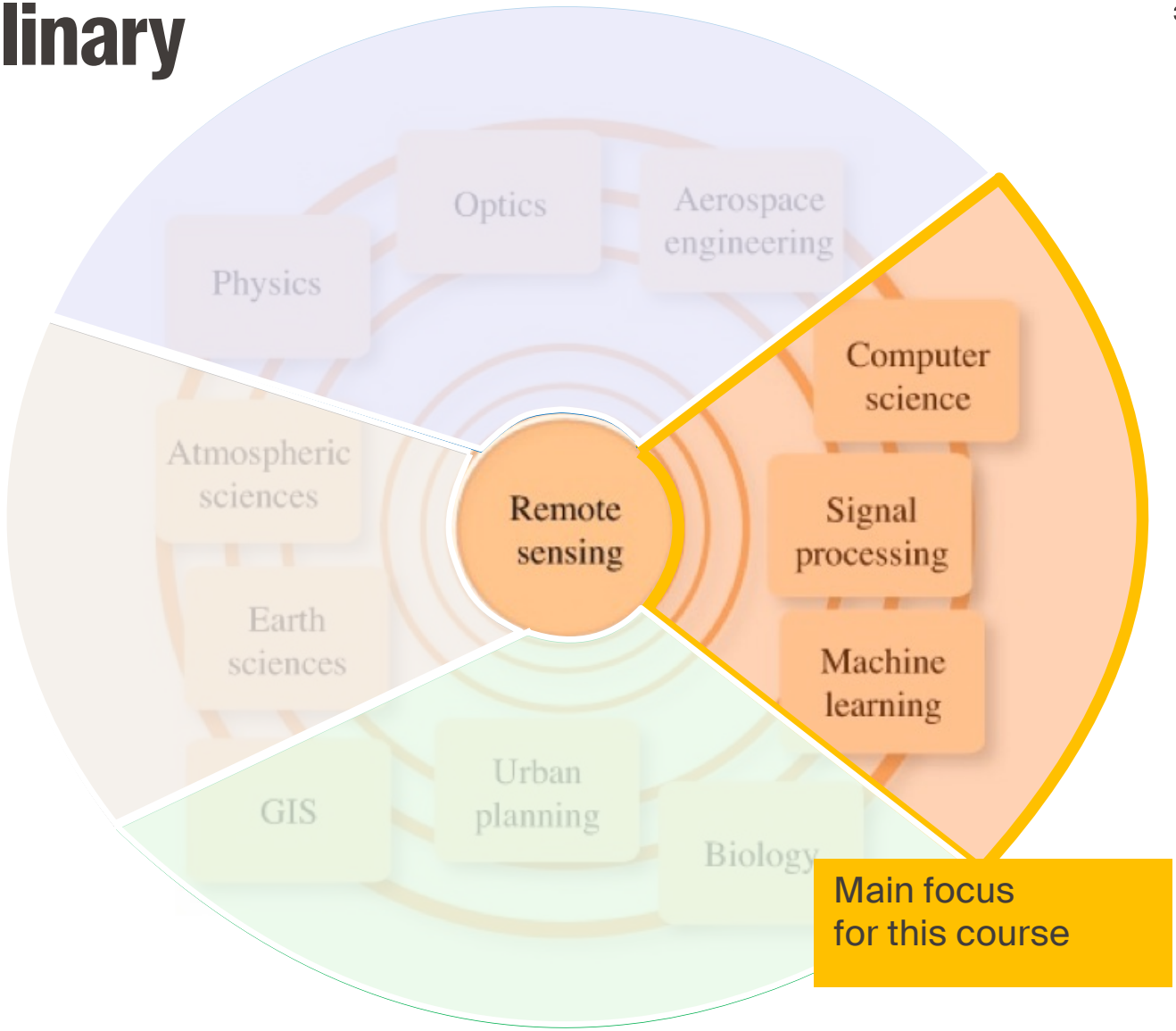
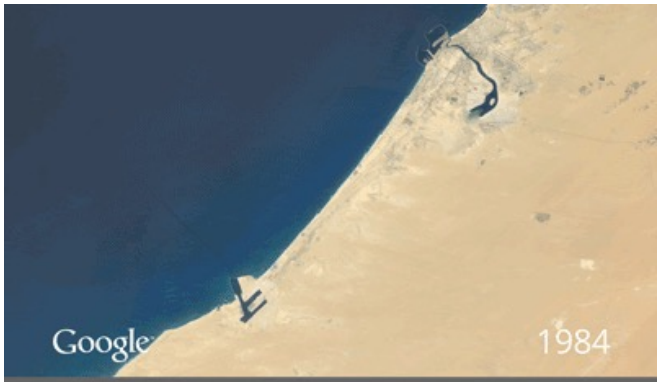


Image processing for Earth Observation

- EO is relevant in a number of domains

  - Geology, geomorphology (minerals identification, landslides)
  - Toppography, cartography (thematic maps, landuse)
  - Agriculture (crops monitoring, phenology, yield estimation)
  - Forestry (trees mapping, height, DBH estimation)
  - Hydrology (detection of floods, reservoir modeling, water quality)
  - Cryospheric sciences (ice charting, roughness)
  - Planning (3D reconstructions, scenarios)
  - Forensics (proofs of events, 3D scene reconstruction)
  - Insurances (damages estimation, verification of claims)
  - ...

Image processing for Earth Observation

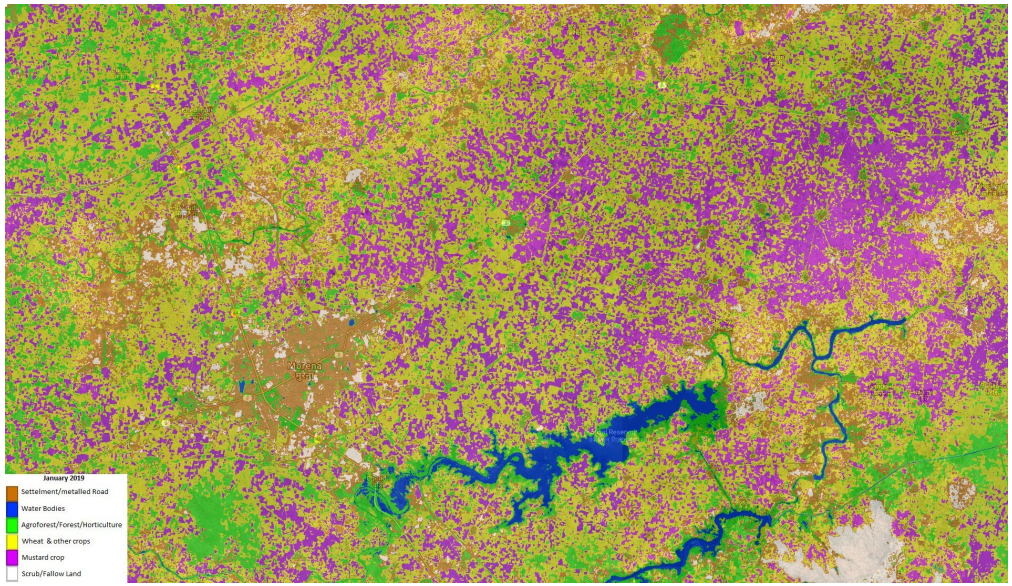


Dubai Coastal Expansion, 1984-2012

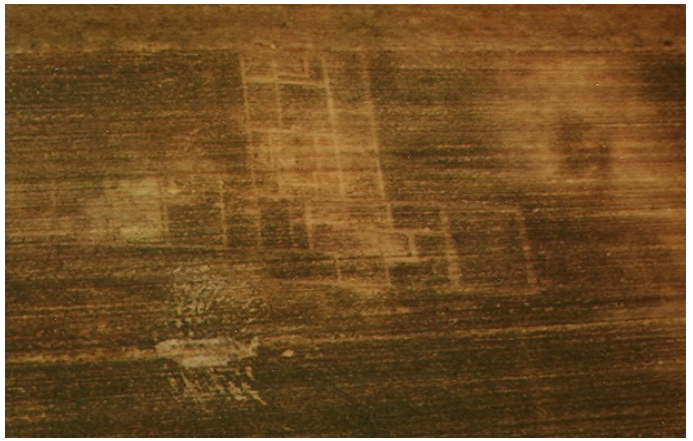
Brazilian Amazon Deforestation, 1984-2012

Columbia Glacier Retreat, 1984-2011

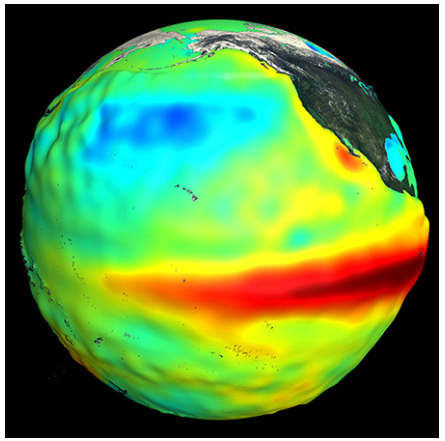
Image processing for Earth Observation



Agricultural land use in Madya Pradesh



Digital archaeology



Sea surface temperature (el Niño)

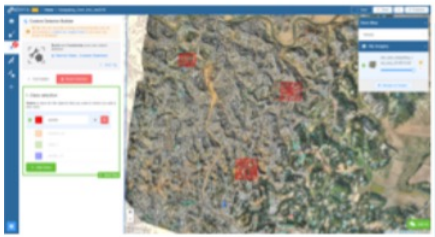
Image processing for Earth Observation

USE OF DRONES AND GIS TO SUPPORT
ROHINGYA REFUGEE EMERGENCY RESPONSE IN COX'S BAZAR, BANGLADESH

NPM
THE UN MIGRATION AGENCY

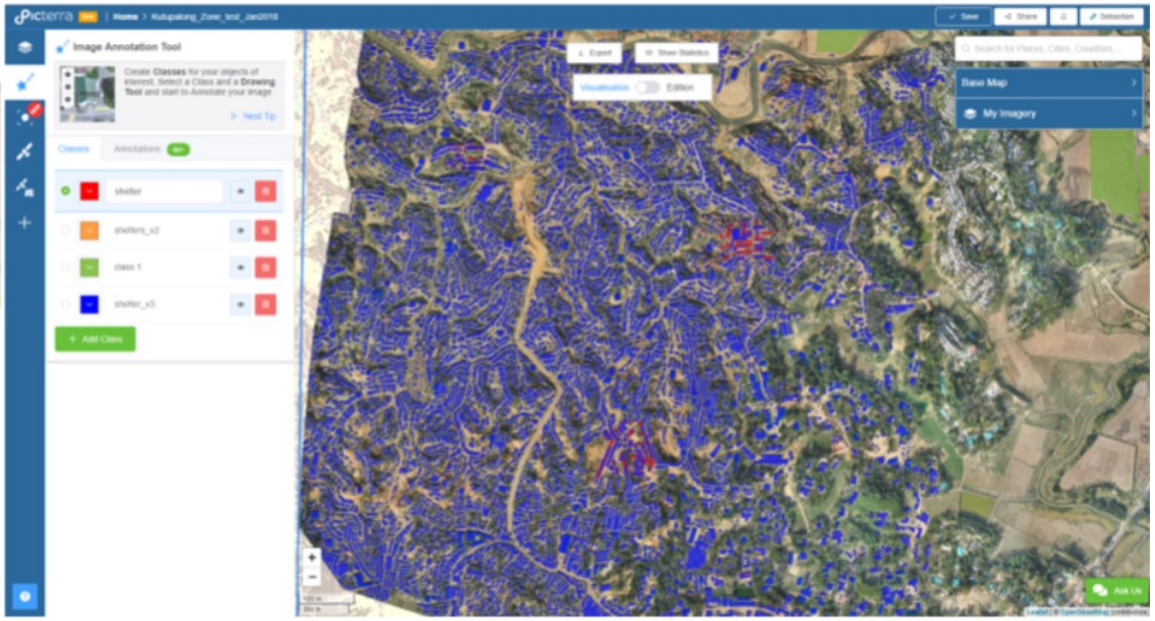
Artificial intelligence and machine learning based on UAV (drone) imagery

Picterra



Training the artificial intelligence (A.I.) with 126 shelters

"Annotated Objects: 126 (overlapping with your training areas)"



Picterra A.I. platform detected automatically more than 26.000 shelters inside the 2.5km2 test area.

INTERNATIONAL ORGANIZATION FOR MIGRATION – JANUARY 2019

EPFL

What is Earth observation?

A bit of history

Defining Earth observation today

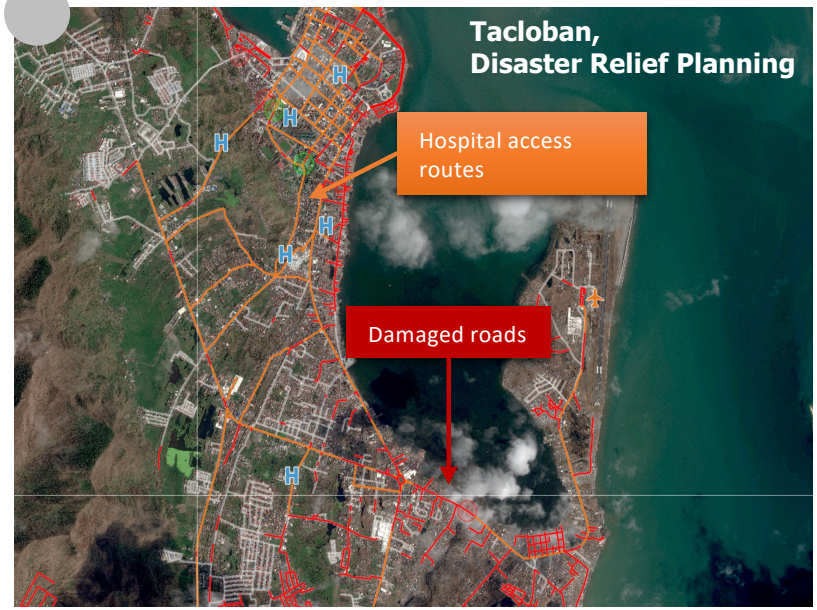
The EO system (and what we cover in IPEO)

Image processing for Earth Observation

Tacloban airport damaged by Yolanda (Photo credits: sunstar.com.ph)

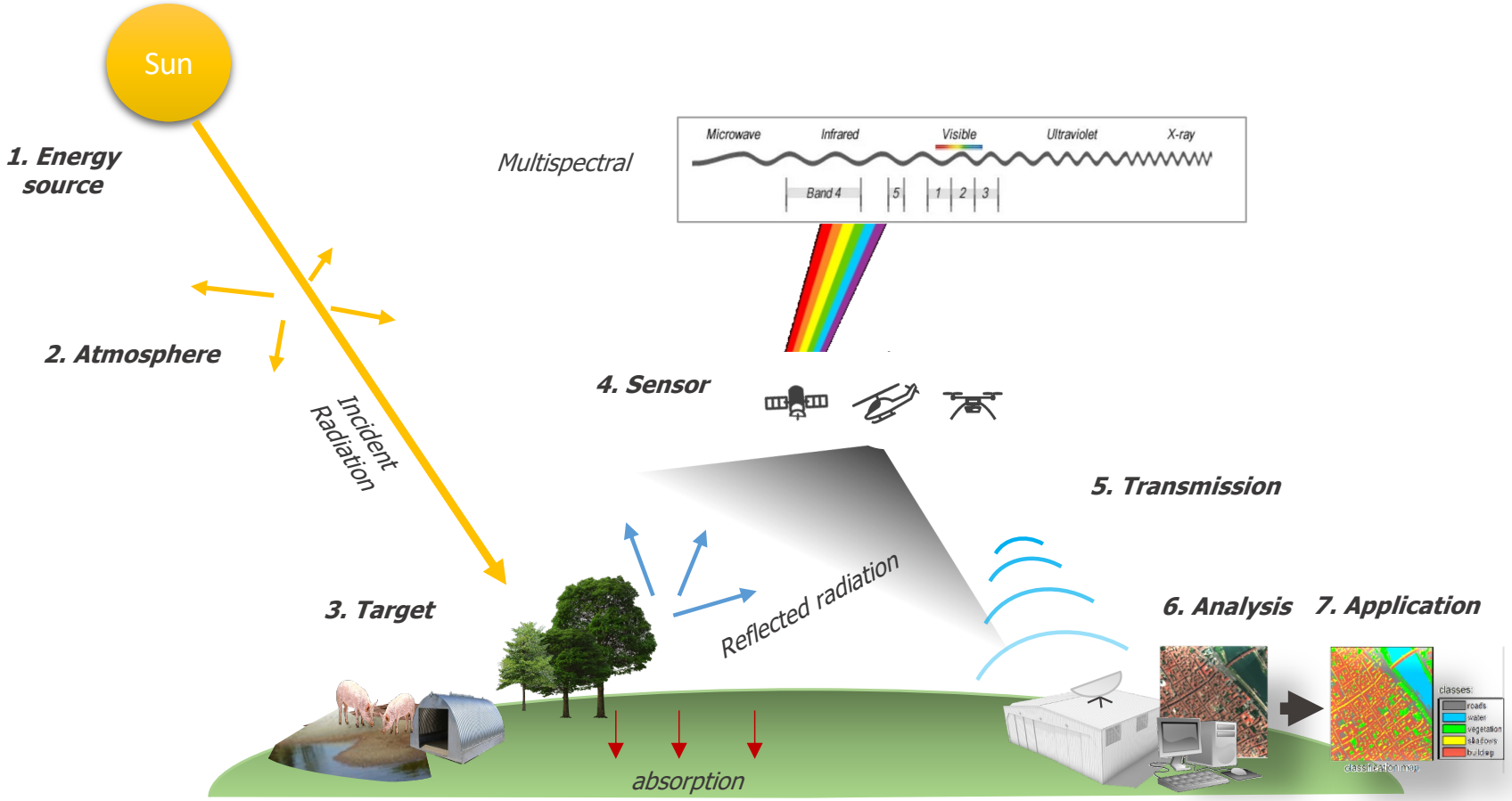
From a physical event

to a map of the situation



Source: Worldview3, Digital Globe

A series of steps



In this course we focus on (4.), 6. and 7.

4. Sensors.

- The different sensors: next course.

6. Analysis.

- Feature extraction: indices and spatial context, next two weeks.
- Classification/segmentation with machine and deep learning (weeks 4-9).

7. Applications.

- You personal projects, for the rest of the semester.

Rough timetable.

		Sensors	h	Exercises	h	Project	h	
1	13.09.2024	Welcome, What is remote sensing Sensors	2	Group work on sensors	2			4
2	20.09.2024	How to access images (sentinelHub, GEE, …) Vegetation indices (1h)	2	Intro python,Vegetation indices on time series	2			4
3	27.09.2024	Spatial support Descriptors	2	Exercise feature extraction	2			4
4	04.10.2024	Classification 1: basics, accuracy	2	Exercise classification	2	Intro projects	0	4
5	11.10.2024	Classification 2: RF and SVMs	2	Exercise classification	2			4
6	18.10.2024	MLP optimizers backprop	2	Intro PyTorch	2			4
	25.10.2024	VACANCES SEMESTRE						
7	01.11.2024	CNNs for classification	2	Exercise CNN	2			4
8	08.11.2024	Semantic segmentation	2	CNN Model Training	2			4
9	15.11.2024	Sequence modelling + change detection	2	Semantic segmentation	2			4
10	22.11.2024	What we do inthe lab Q&A mid-term	2			project	2	4
11	29.11.2024	Mid-term	3			Project	1	4
12	06.12.2024					Project Q&A	4	4
13	13.12.2024					Project time	4	4
14	20.12.2024					Project time	4	4
			23		**18**		**15**	**56**