Active and Multitemporal Remote Sensing

Satellite Image Time Series (SITS):

A case study with SITS classification

Charlotte PELLETIER
charlotte.pelletier@monash.edu

September 15 2020

Why do we need temporal information?

Why do we need temporal information?

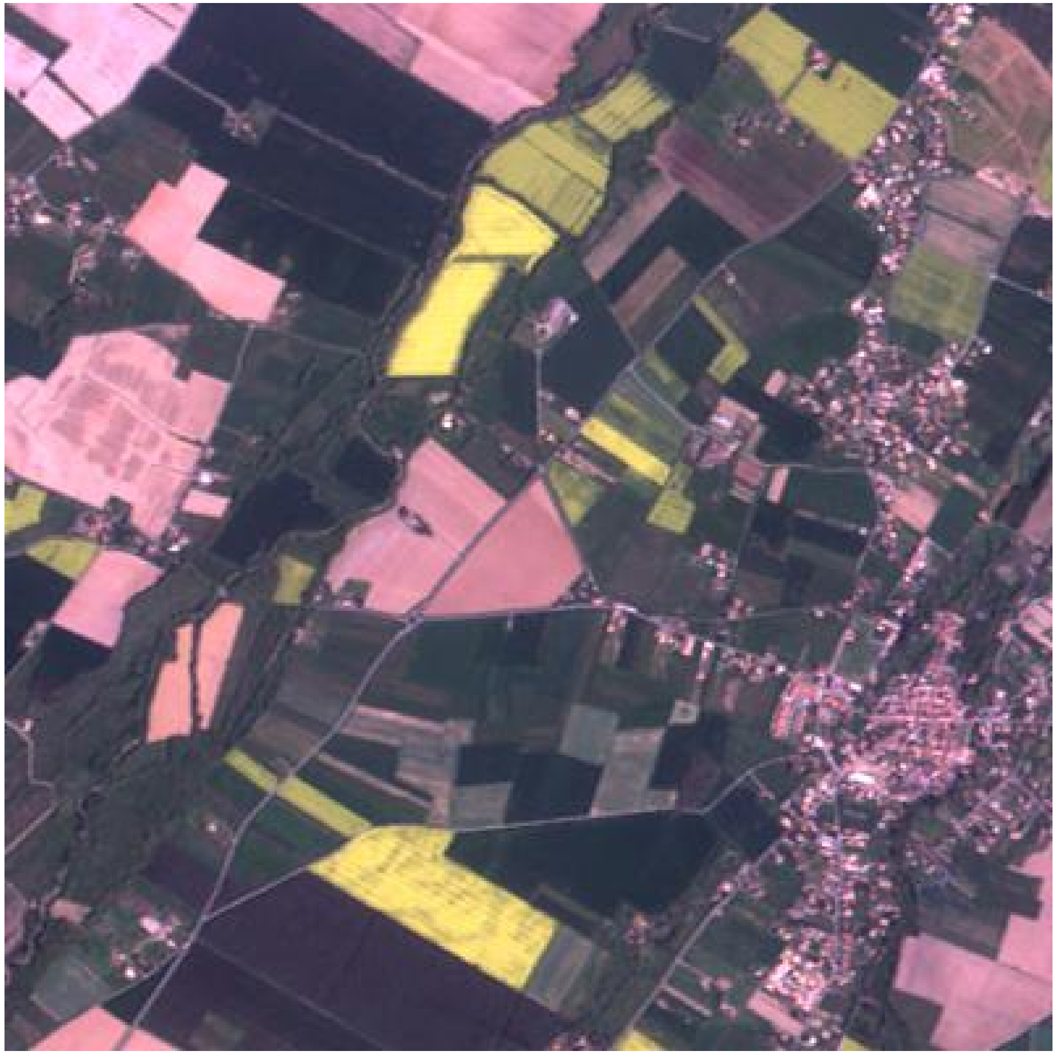
An example: vegetation monitoring

Rapeseed in May?

http://www.cesbio.ups-tlse.fr/multitemp/?p=1192

Why do we need temporal information?

An example: vegetation monitoring



Rapeseed in April

Rapeseed in May?

http://www.cesbio.ups-tlse.fr/multitemp/?p=1192

Why do we need temporal information?

An example Landsat-8 time series

14/04/2013

Interest

- vegetation monitoring
- landscape evolution
- large scale study

Change detection: major disaster

Hurricane Isaac (end August 2012) + Hurricane Sandy (end October)

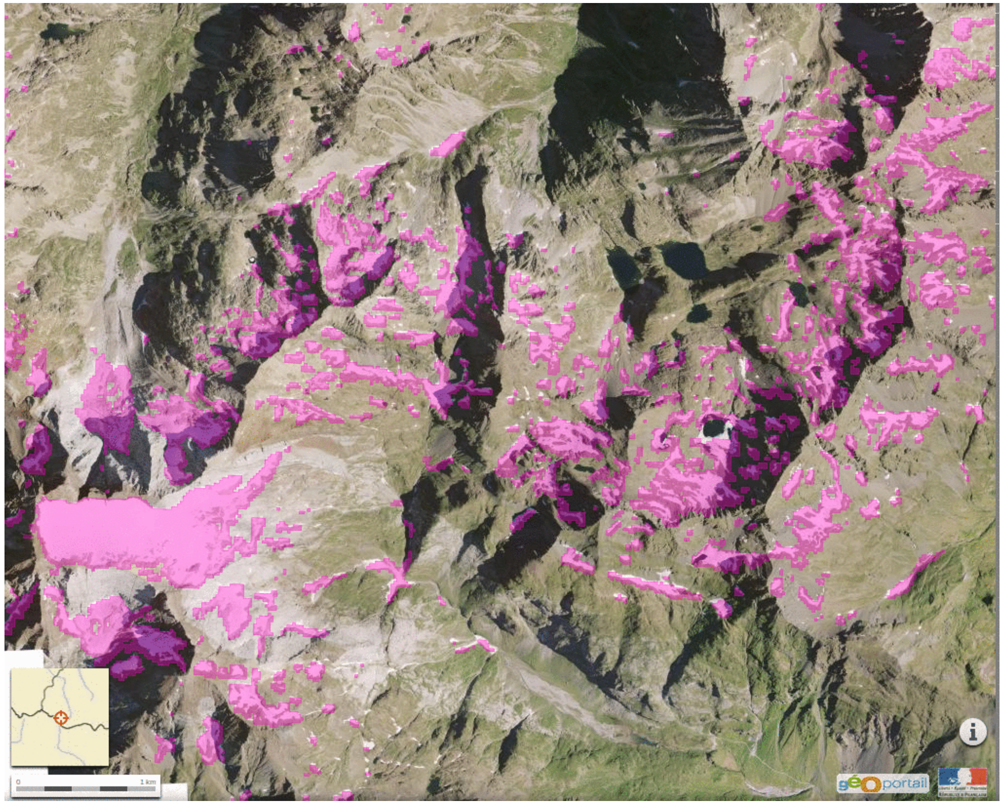
19/07/2012

02/11/2012

Deforestation in Amazonia

https://earthobservatory.nasa.gov/

Snow Cover



Source: `https://labo.obs-mip.fr/multitemp/first-sentinel-2-snow-map/`

Urban Planning

1952 – aerial photography

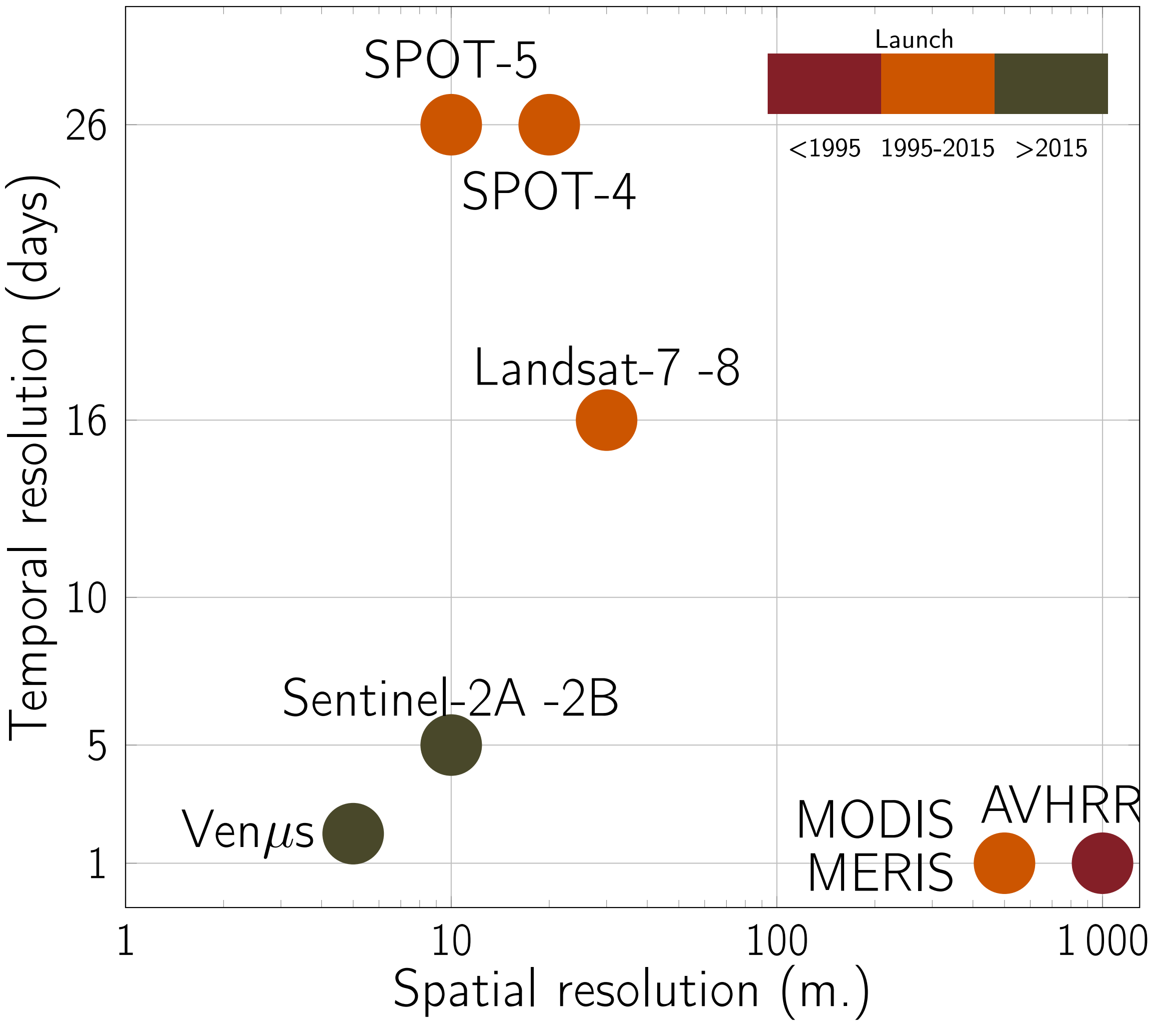
Urban Planning

1952 – aerial photography

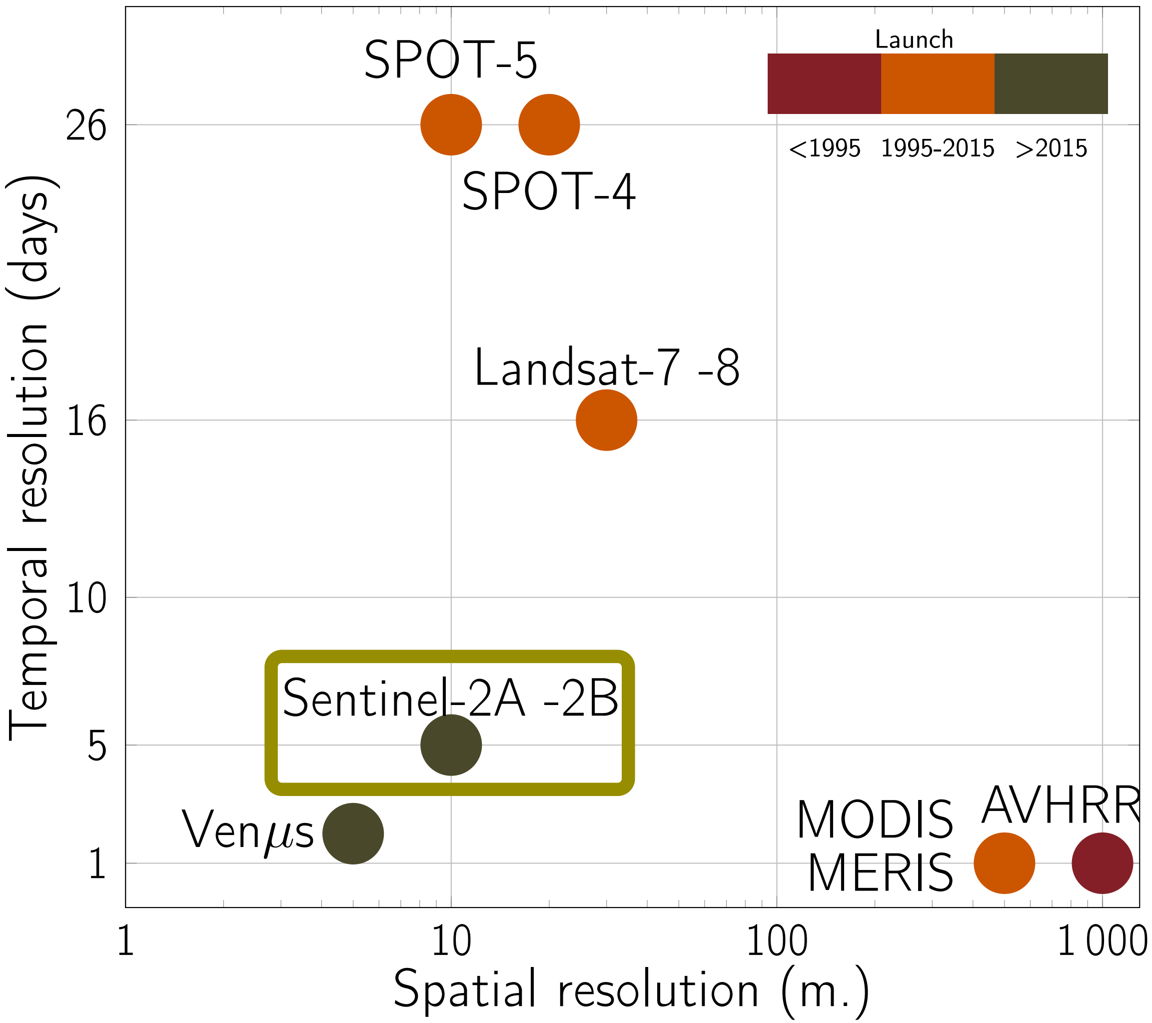
2019 – photographie aérienne

Source: `https://remonterletemps.ign.fr/` (city of Vannes)

Passive satellites (optical images)



Passive satellites (optical images)



Novelty of Sentinel-2 satellites

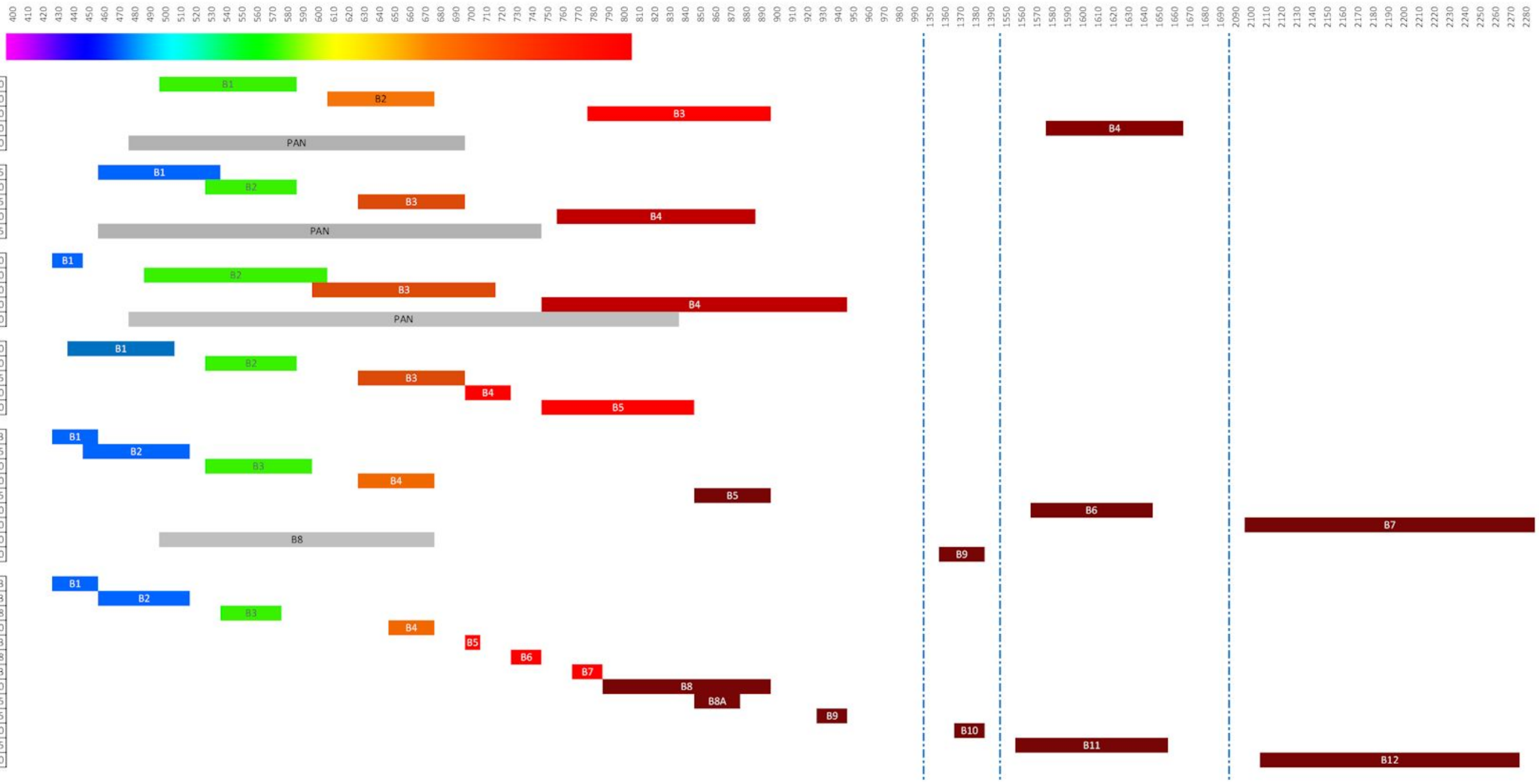
- spectral resolution: 13 bands
- spatial resolution: from 10 to 60 metres
- temporal resolution: 10 days (5 days with two satellites)
- swath: 290 kilometres
- constant view angle

Evolution of passive satellites (optical images)

Spectral bands

Longueur d'onde

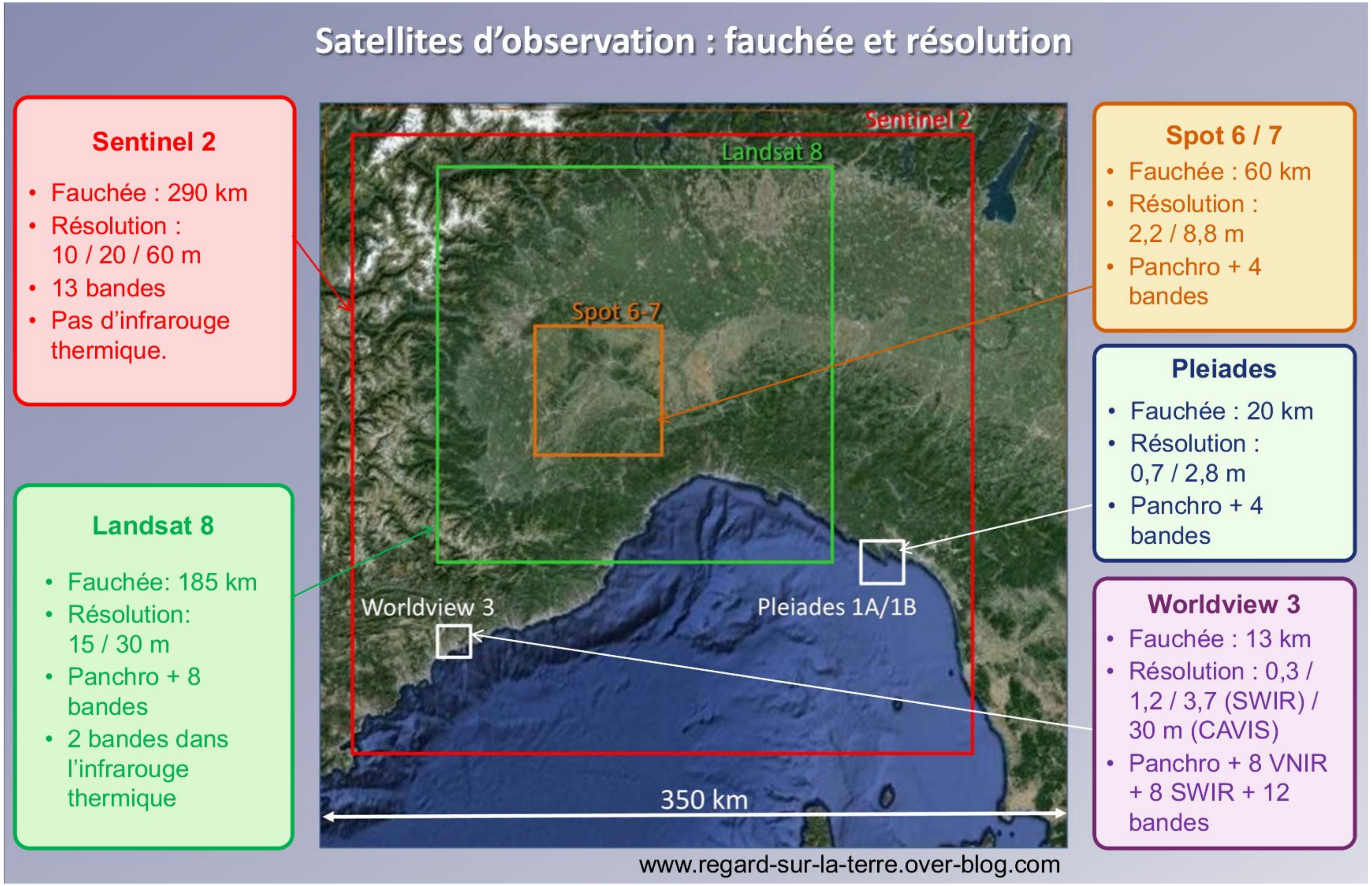
	#	GSD	λmin	λmax
Spot 5	B1	10	500	590
	B2	10	610	680
	B3	10	780	890
	B4	10	1 580	1 750
	PAN	2,5/5	480	700
Spot 6	B1	8,6	455	525
	B2	8,6	530	590
	B3	8,6	625	695
	B4	8,6	760	890
	PAN	2,15	455	745
Pleiades 1A et 1B	B1	2,8	430	450
	B2	2,8	490	610
	B3	2,8	600	720
	B4	2,8	750	950
	PAN	0,7	480	830
Rapid Eye	B1	6,5	440	510
	B2	6,5	520	590
	B3	6,5	630	685
	B4	6,5	690	730
	B5	6,5	760	850
Landsat 8 - OLI	B1	30 m	433	453
	B2	30 m	450	515
	B3	30 m	525	600
	B4	30 m	630	680
	B5	30 m	845	885
	B6	30 m	1 560	1 660
	B7	30 m	2 100	2 300
	B8	15 m	500	680
	B9	30 m	1 360	1 390
Sentinel 2 - MSI	B1	60 m	433	453
	B2	10 m	458	523
	B3	10 m	543	578
	B4	10 m	650	680
	B5	20 m	698	713
	B6	20 m	733	748
	B7	20 m	773	793
	B8	10 m	785	900
	B8a	20 m	855	875
	B9	60 m	935	955
	B10	60 m	1 360	1 390
	B11	20 m	1 565	1 655
	B12	20 m	2 100	2 280



www.regard-sur-la-terre.over-blog.com

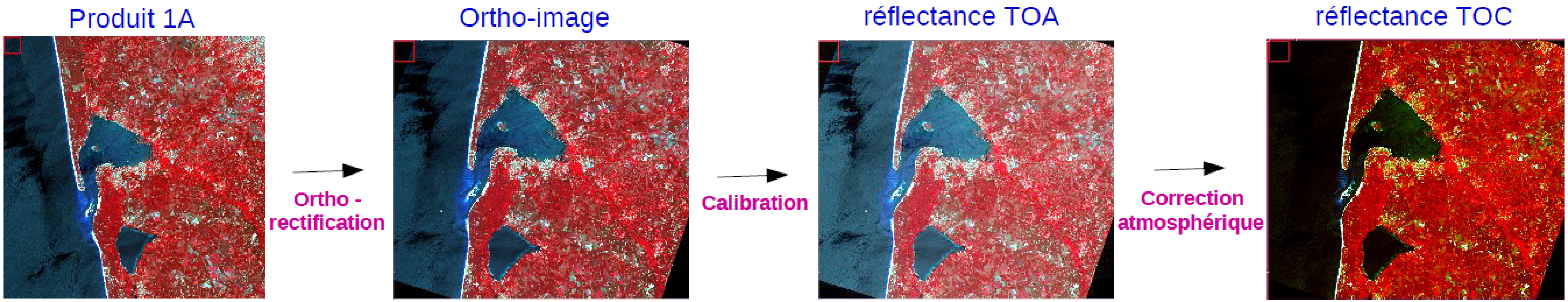
Evolution of passive satellites (optical images)

Swath and spatial resolution



Content

A simplify preprocessing chain



- TOC: Top Of Canopy
- TOA: Top of Atmosphere

Geometric correction

Geometric corrections \ Give a coordinate to each pixel

Geometric correction

Geometric corrections \ Give a coordinate to each pixel

Geometric correction

Geometric corrections \ Give a coordinate to each pixel

Geometric correction

Geometric corrections \ Give a coordinate to each pixel

Geometric correction

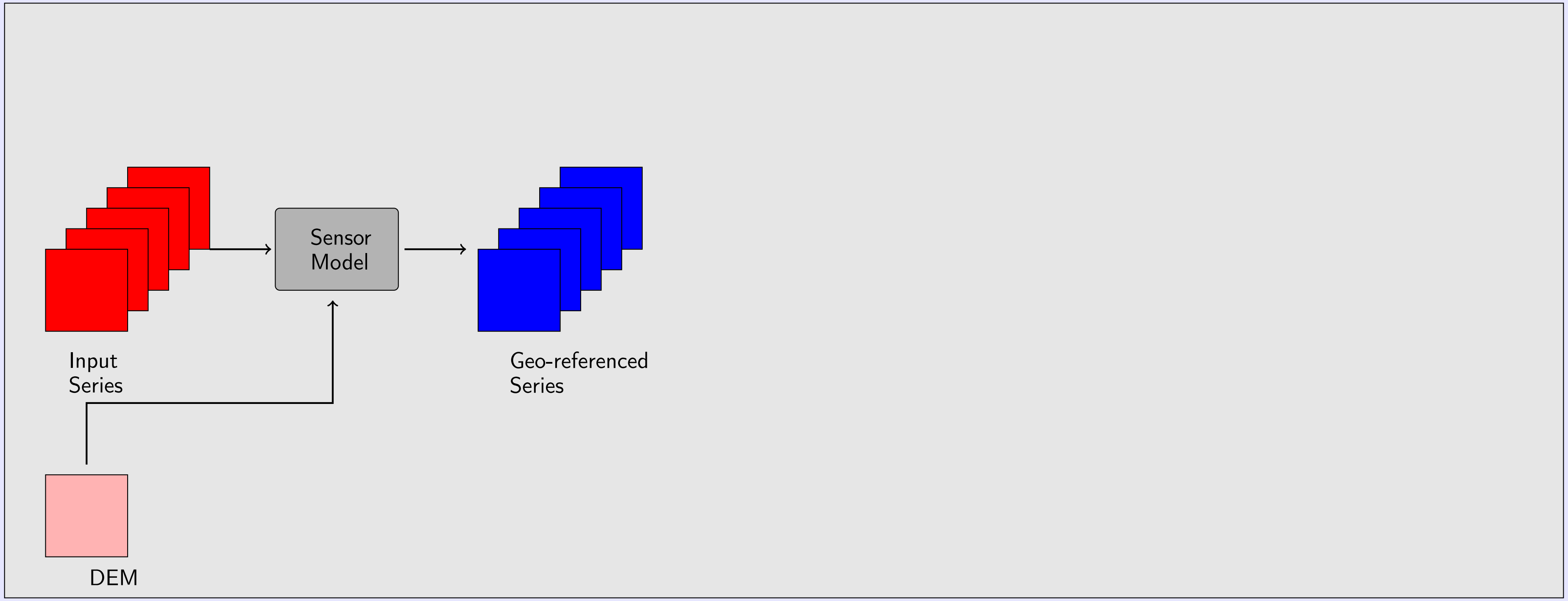
Geometric corrections \ Give a coordinate to each pixel

Geometric correction

Geometric corrections \ Give a coordinate to each pixel

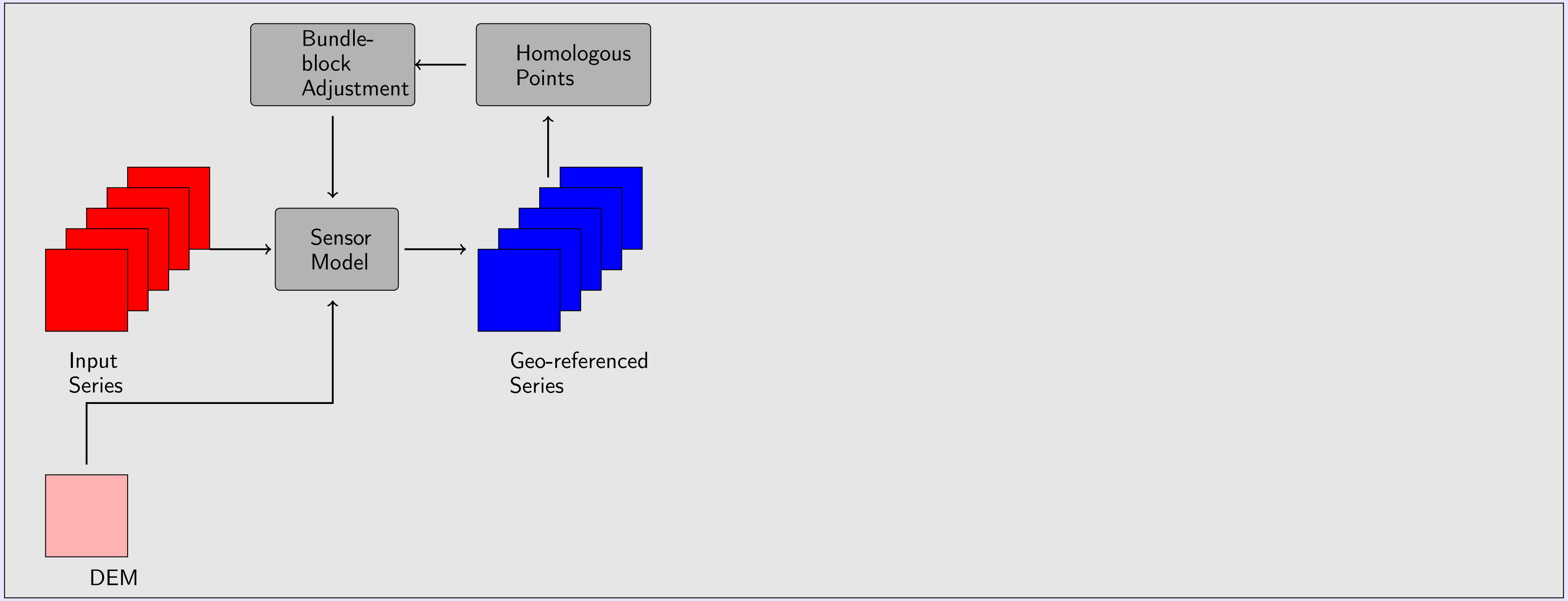
Geometric correction

Geometric corrections \ Give a coordinate to each pixel



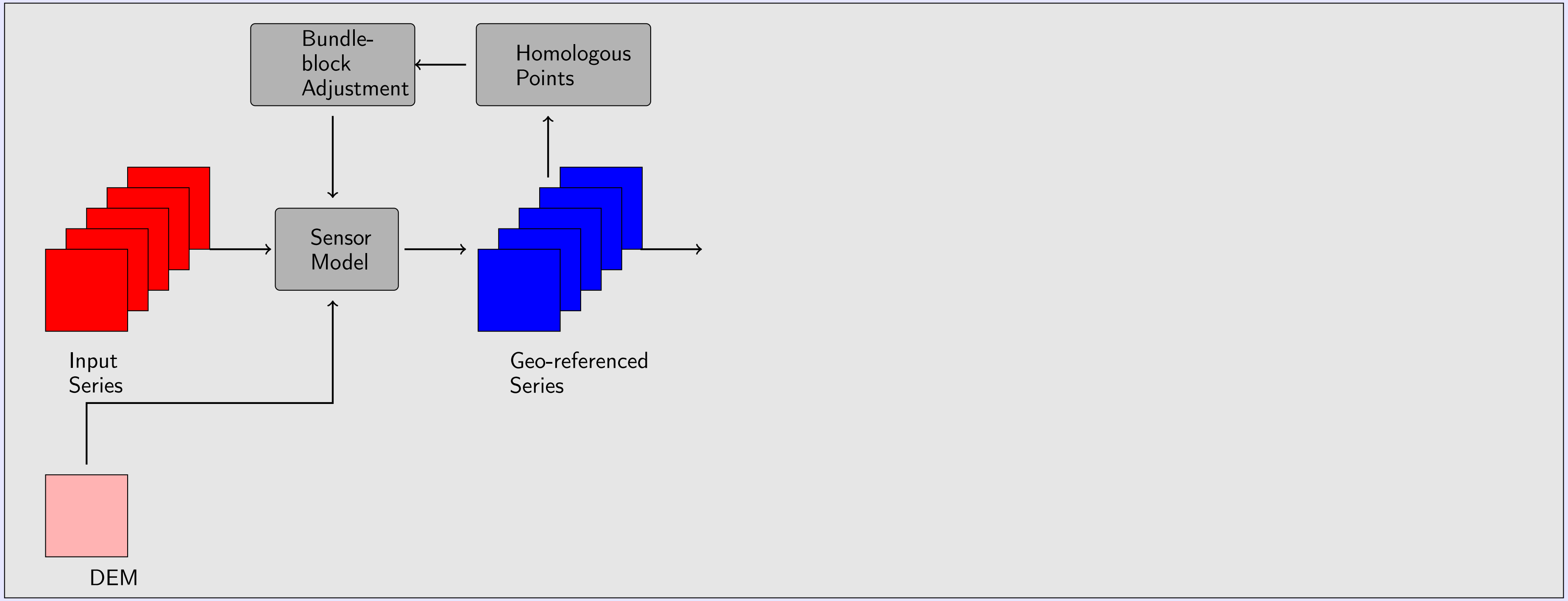
Geometric correction

Geometric corrections \ Give a coordinate to each pixel



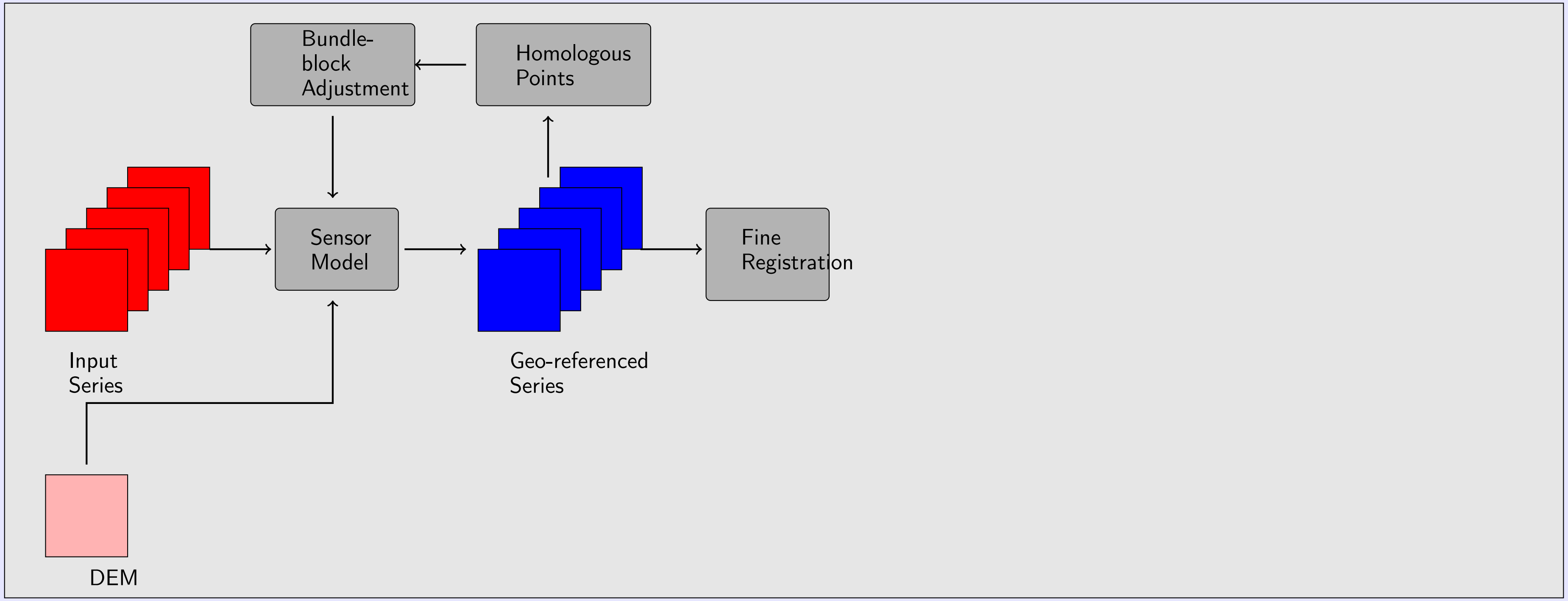
Geometric correction

Geometric corrections \ Give a coordinate to each pixel



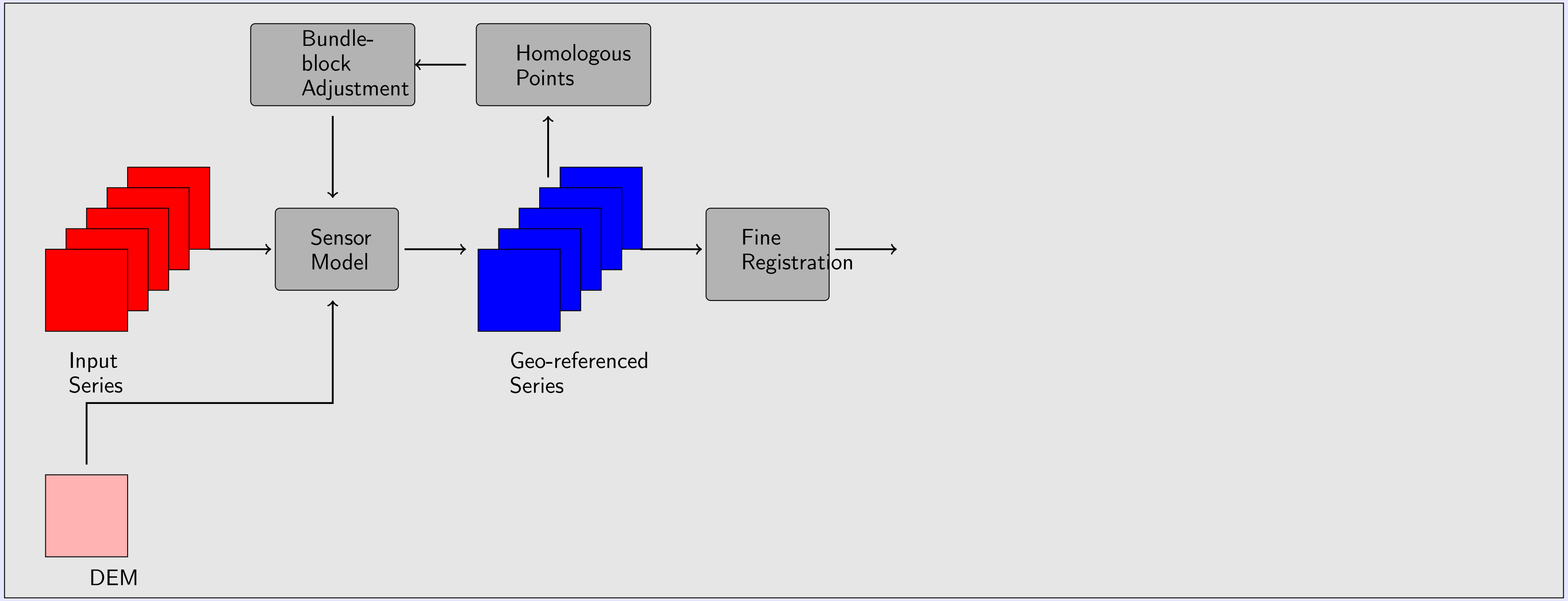
Geometric correction

Geometric corrections \ Give a coordinate to each pixel



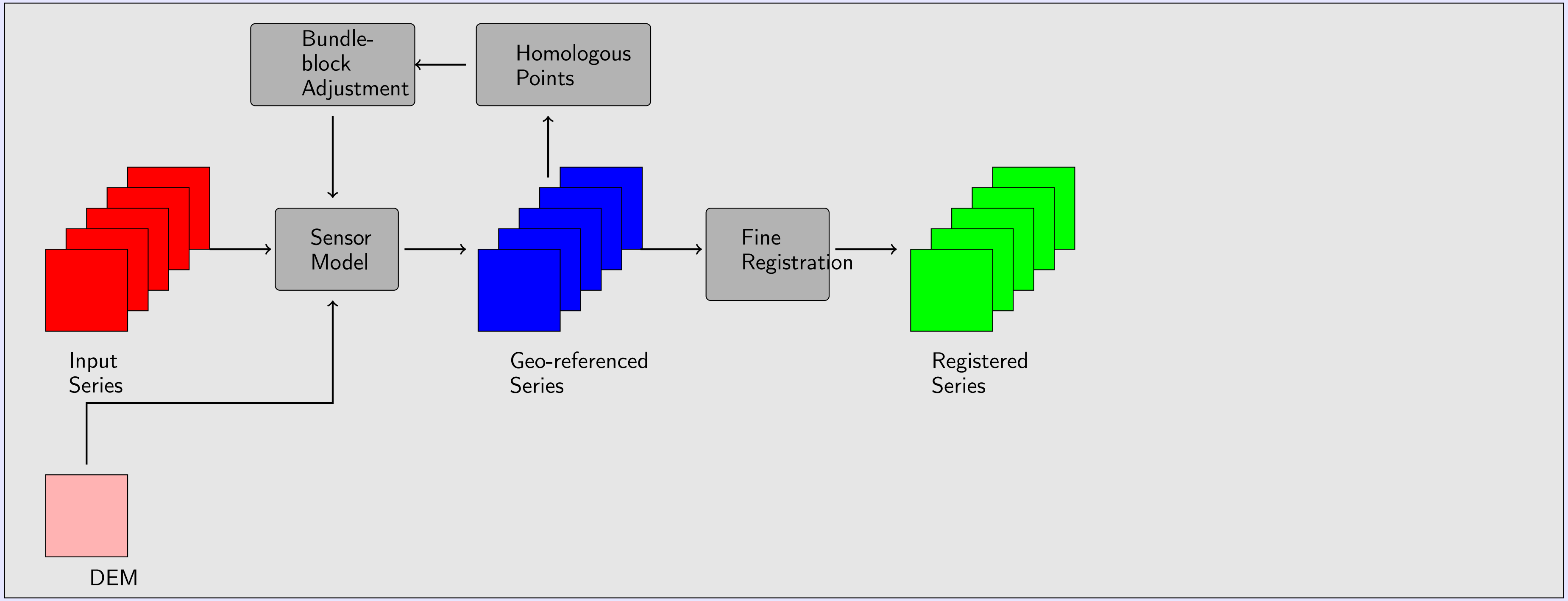
Geometric correction

Geometric corrections \ Give a coordinate to each pixel



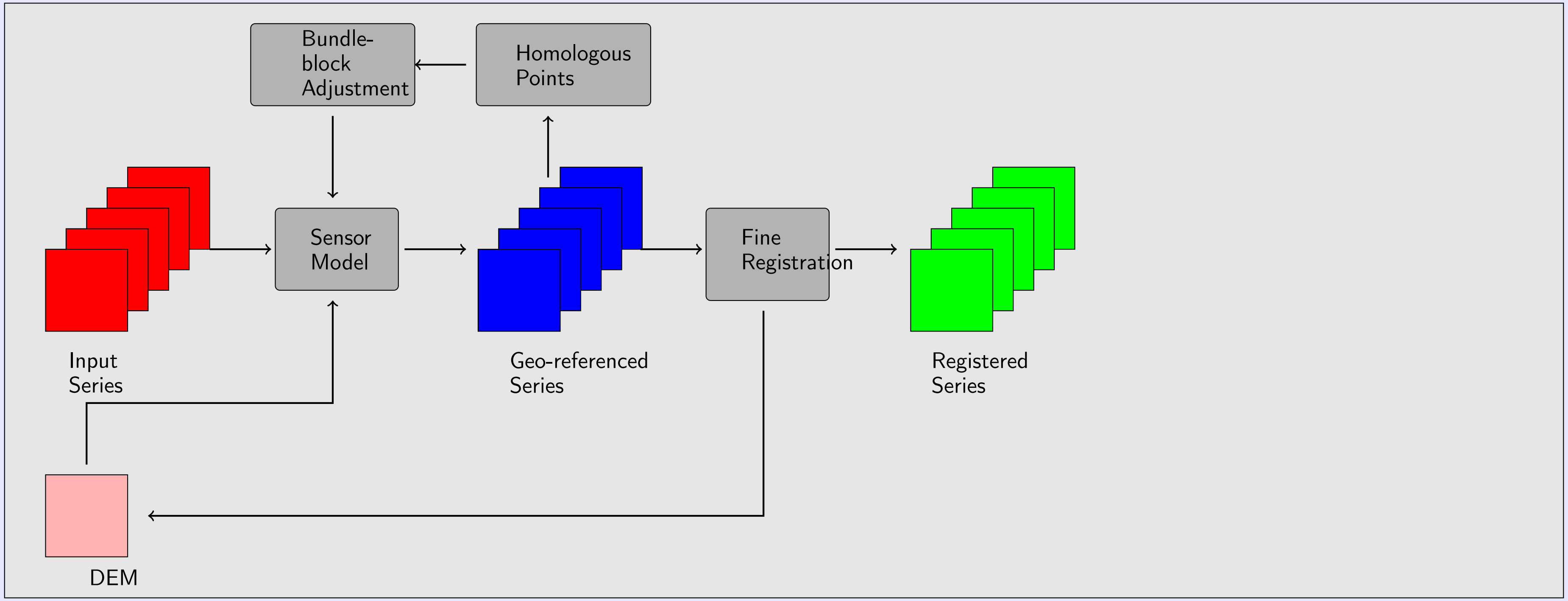
Geometric correction

Geometric corrections \ Give a coordinate to each pixel



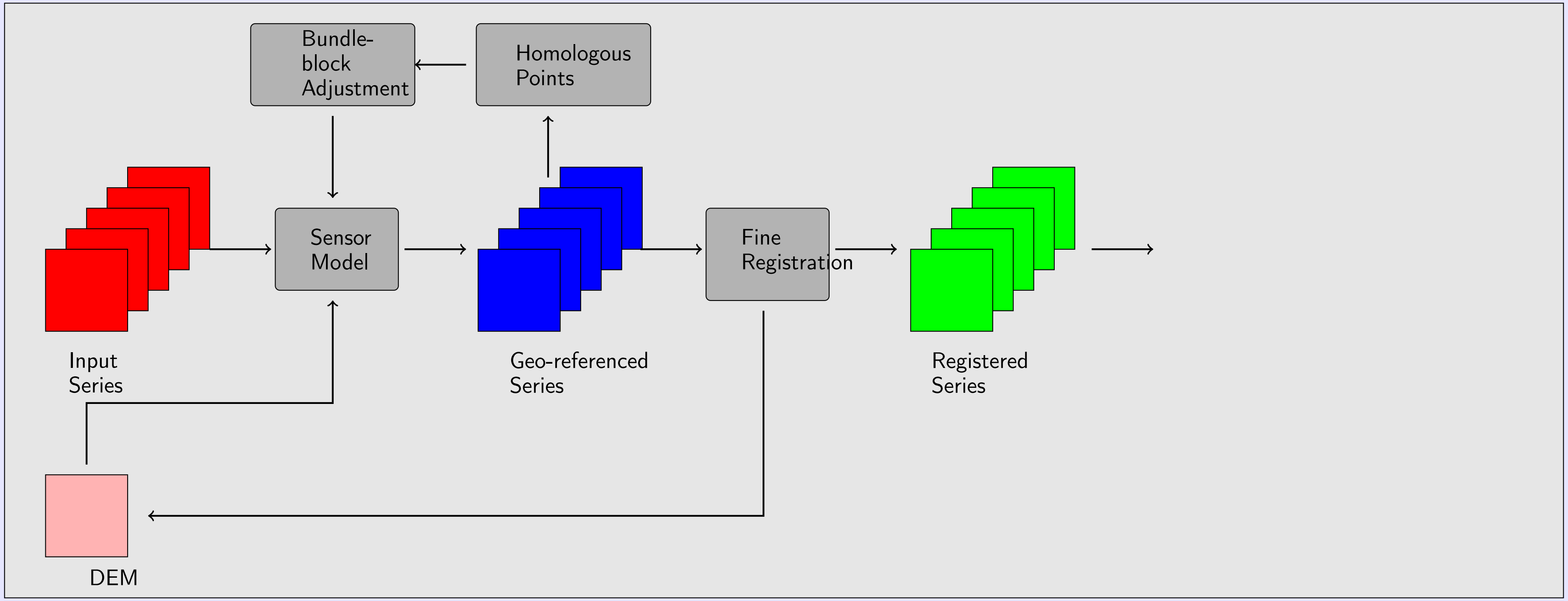
Geometric correction

Geometric corrections \ Give a coordinate to each pixel



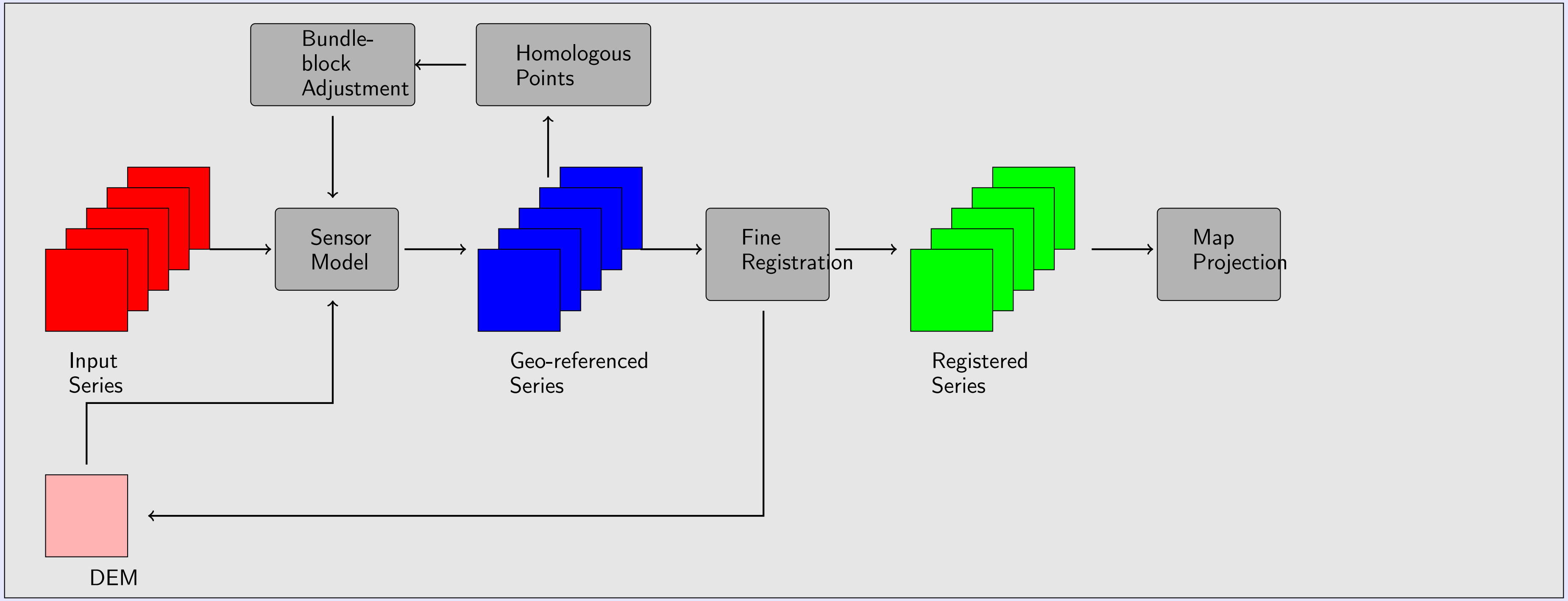
Geometric correction

Geometric corrections \ Give a coordinate to each pixel



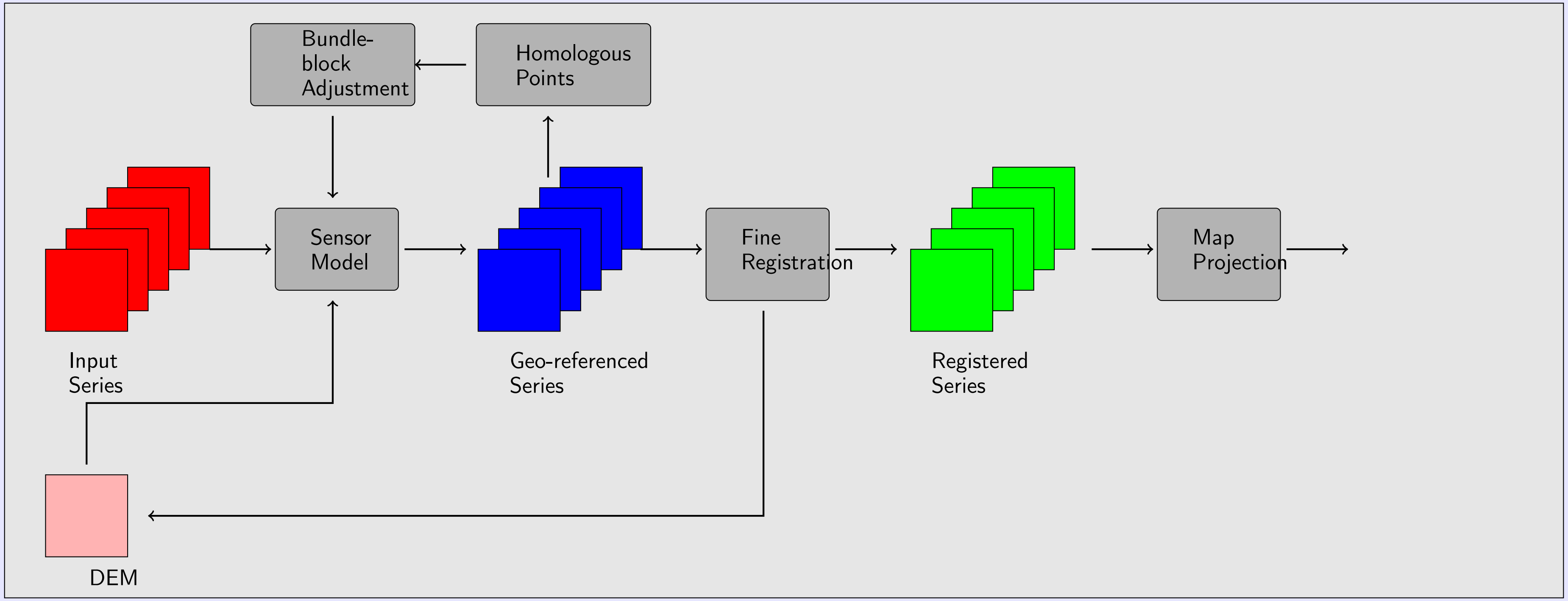
Geometric correction

Geometric corrections \ Give a coordinate to each pixel



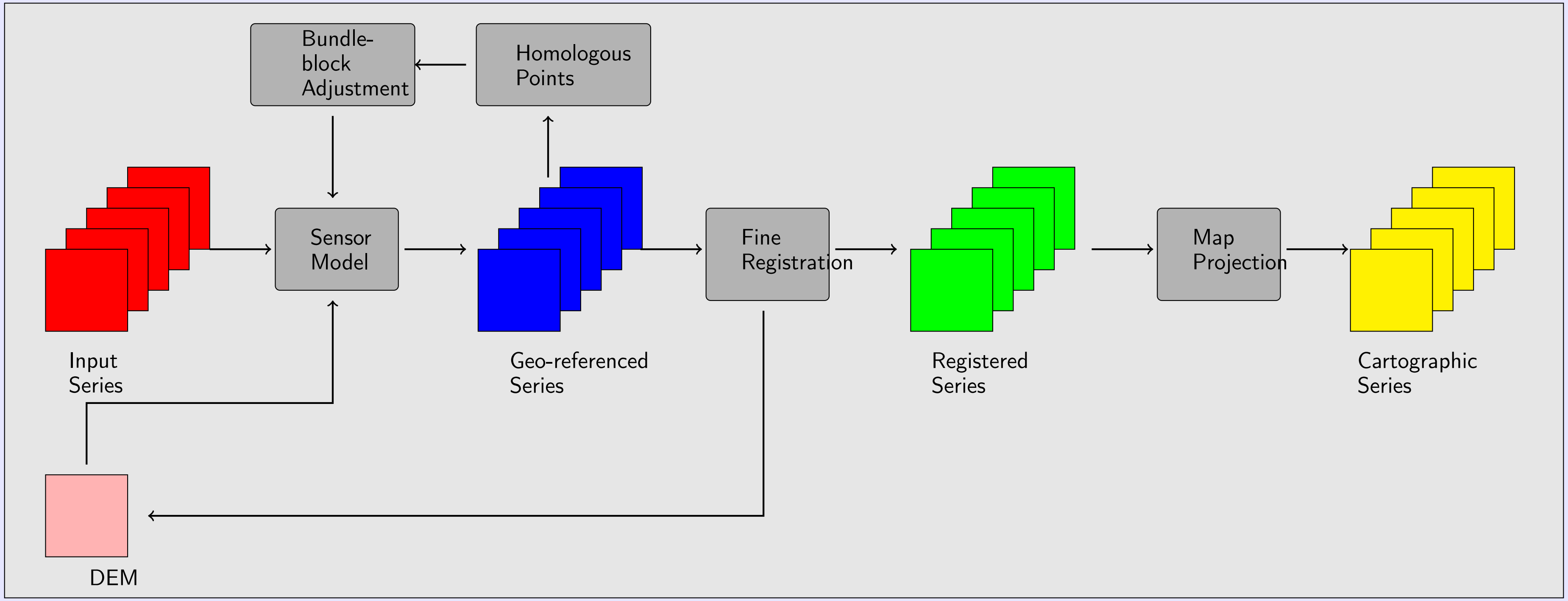
Geometric correction

Geometric corrections \ Give a coordinate to each pixel

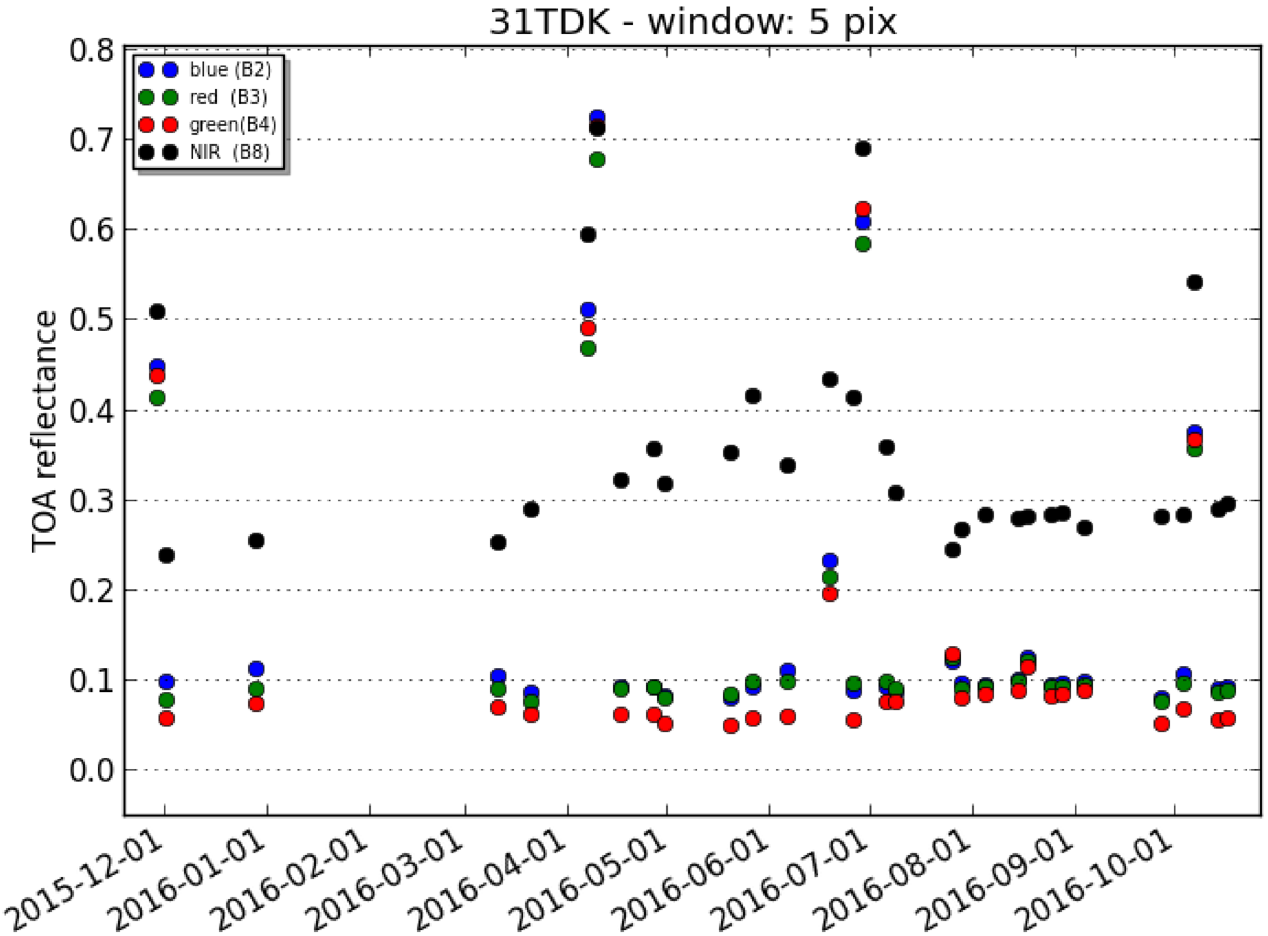


Geometric correction

Geometric corrections \ Give a coordinate to each pixel



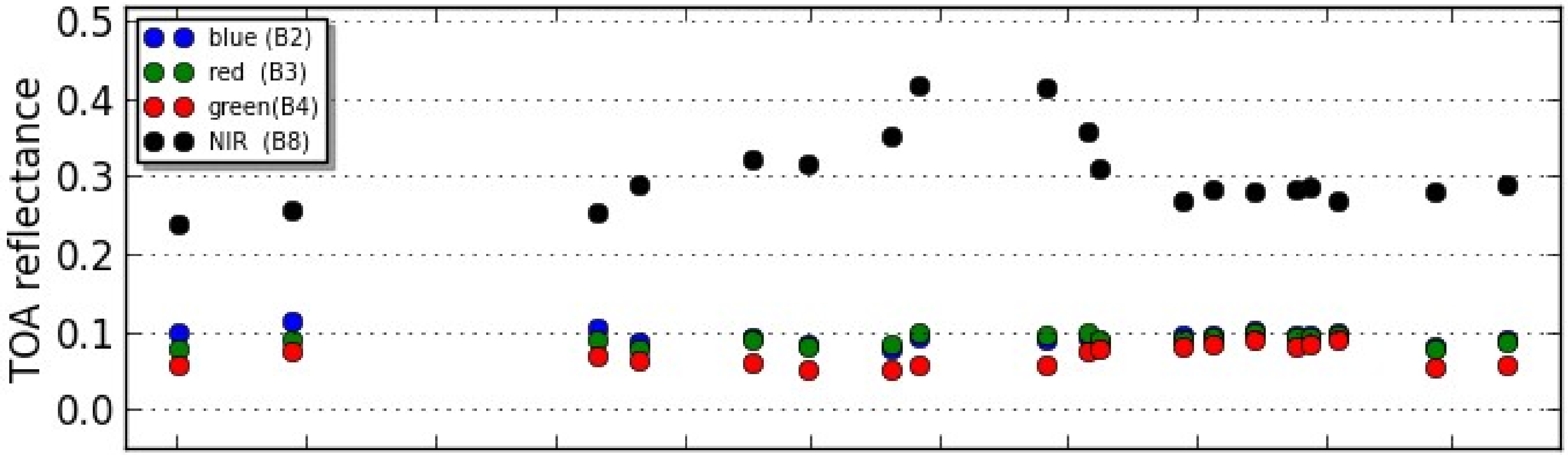
Importance of radiometric preprocessing



An example satellite image time series: reflectance TOA (L1C product)

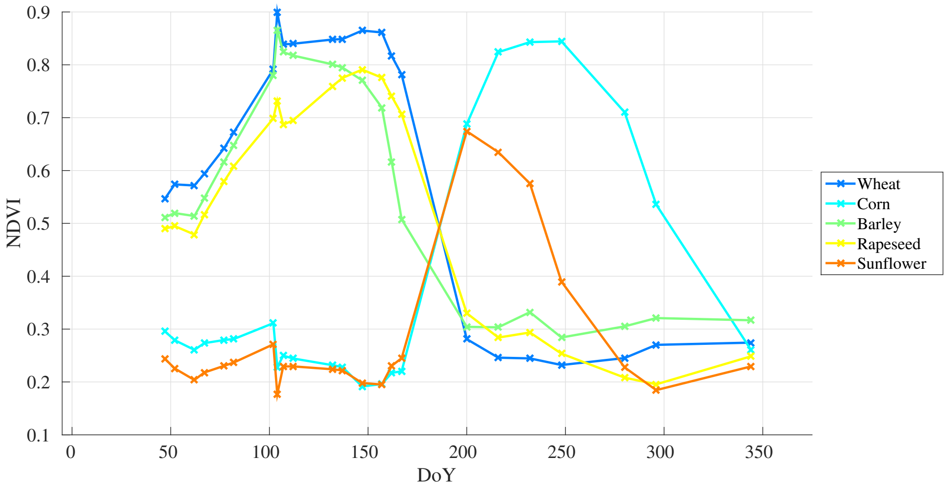
`http://www.cesbio.ups-tlse.fr/multitemp/?p=9423`

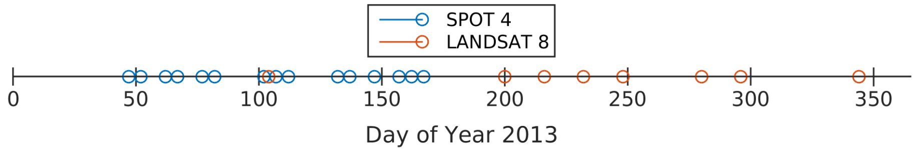
Importance of radiometric preprocessing



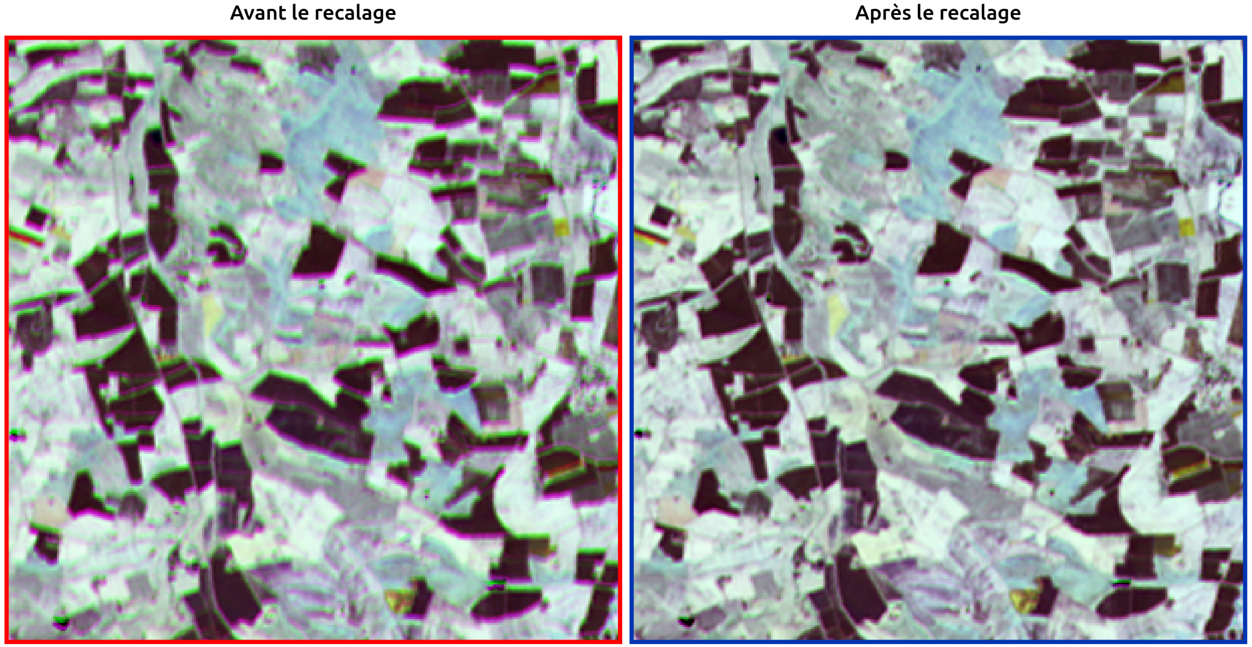
An example satellite image time series: reflectance TOC (L2A product)

Importance of geometric correction



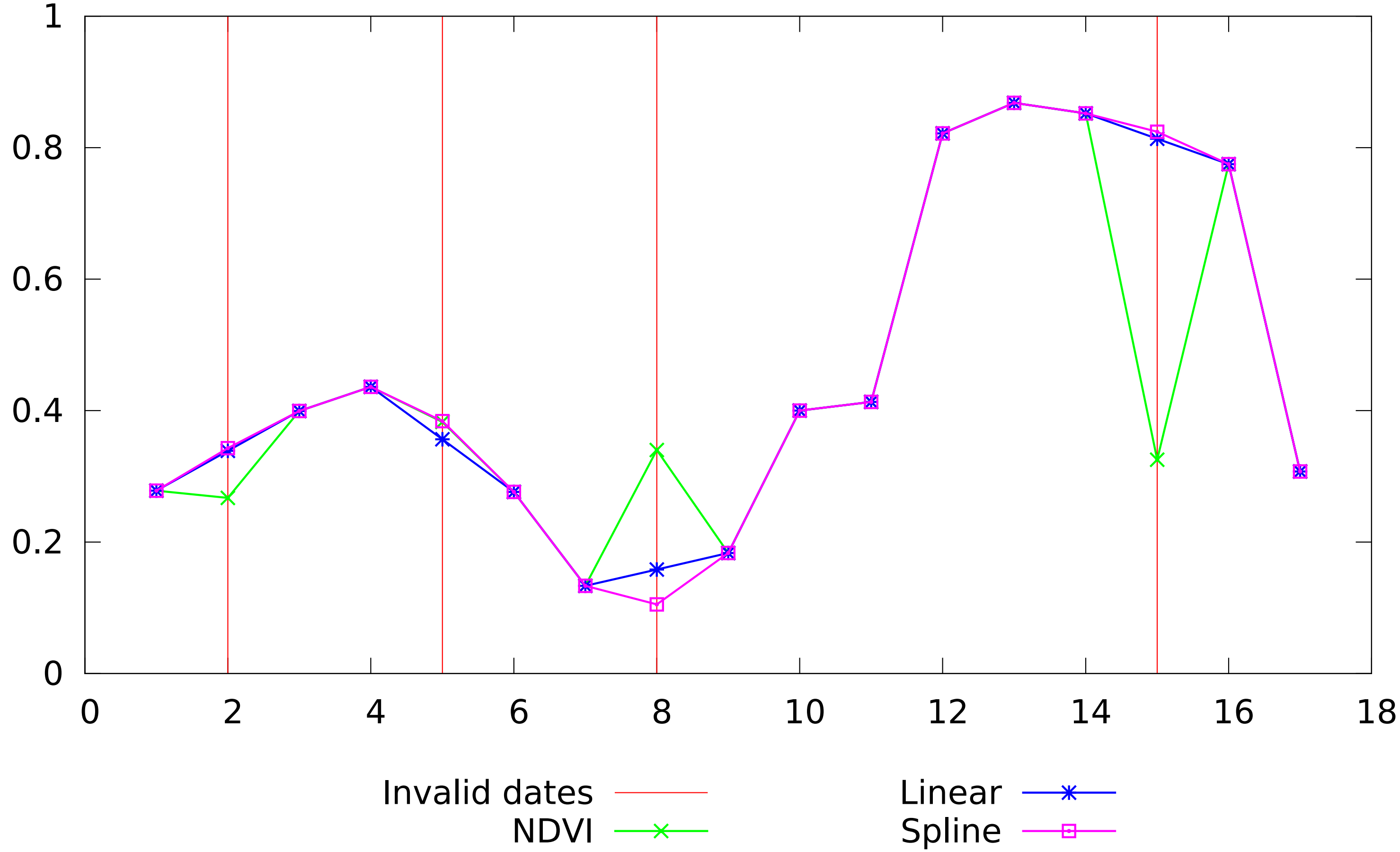


An example multi-sensor SITS: SPOT-4 et Landsat-8

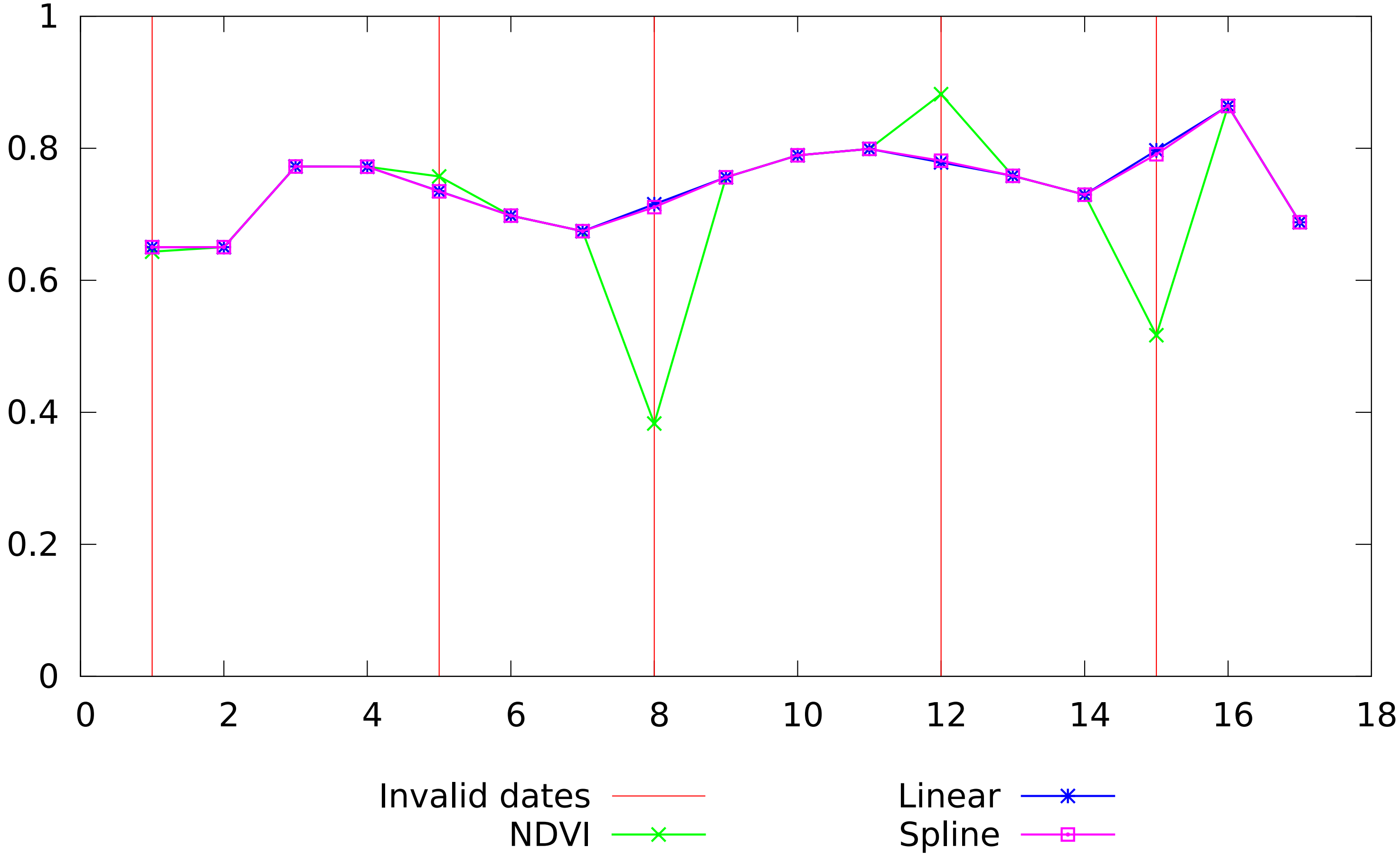


NDVI coloured composition: (R) SPOT-4 12/04/2013, (G) Landsat-8 14/04/2013, (B) SPOT-4 17/04/2013

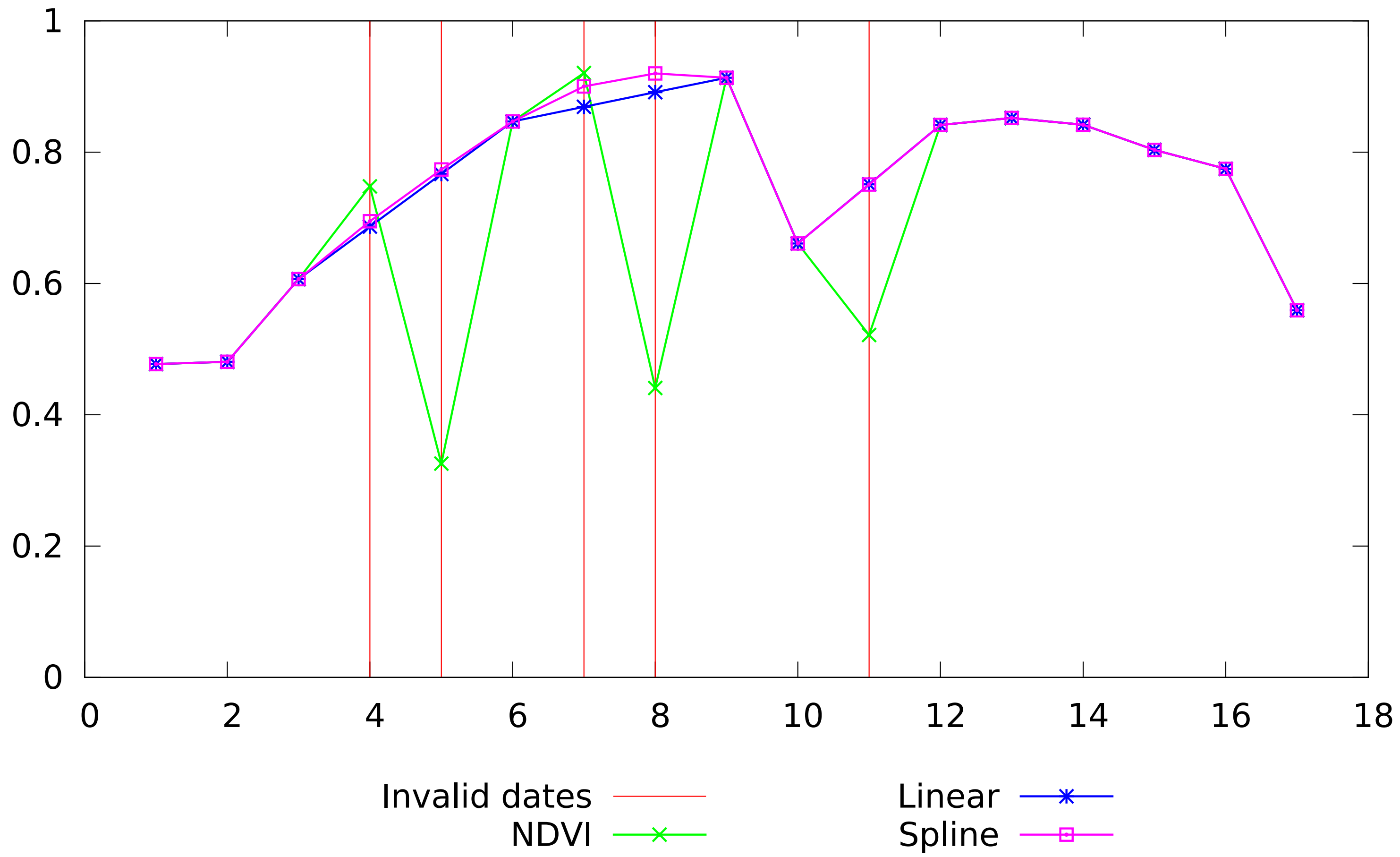
Noisy data: the case of cloudy pixels



Noisy data: the case of cloudy pixels



Noisy data: the case of cloudy pixels



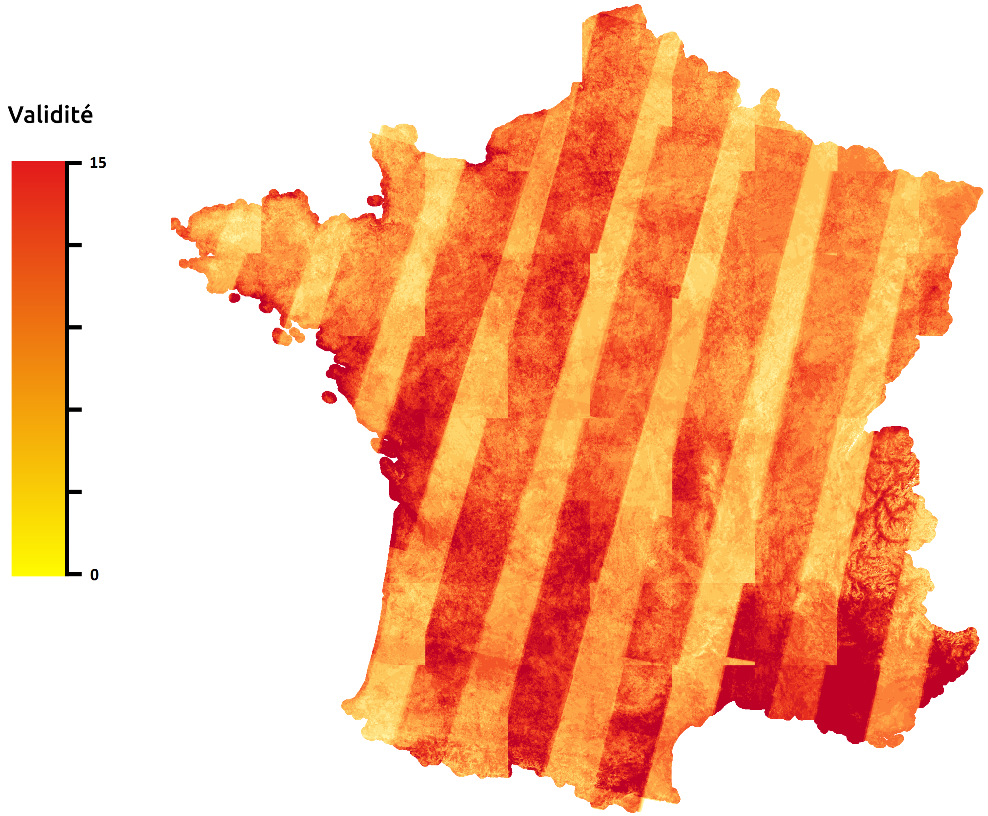
Gapfilling is an active research field

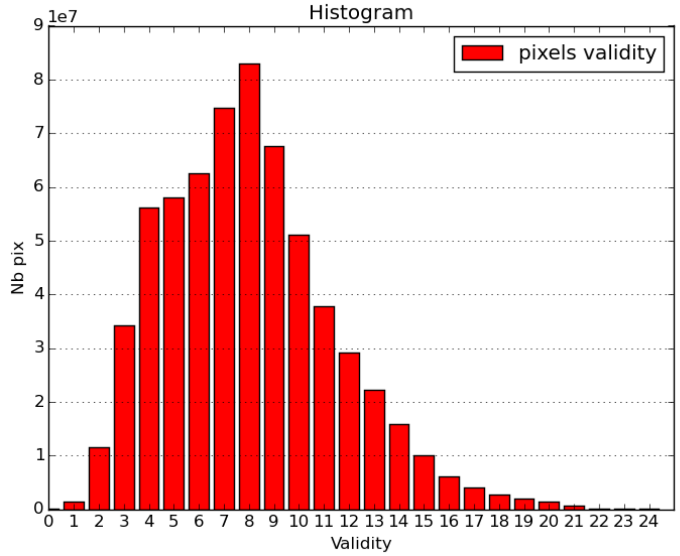
Other approaches

- deep learning-based approaches
- using spatio-temporal information contained in SITS

Noisy data: the case of cloudy pixels

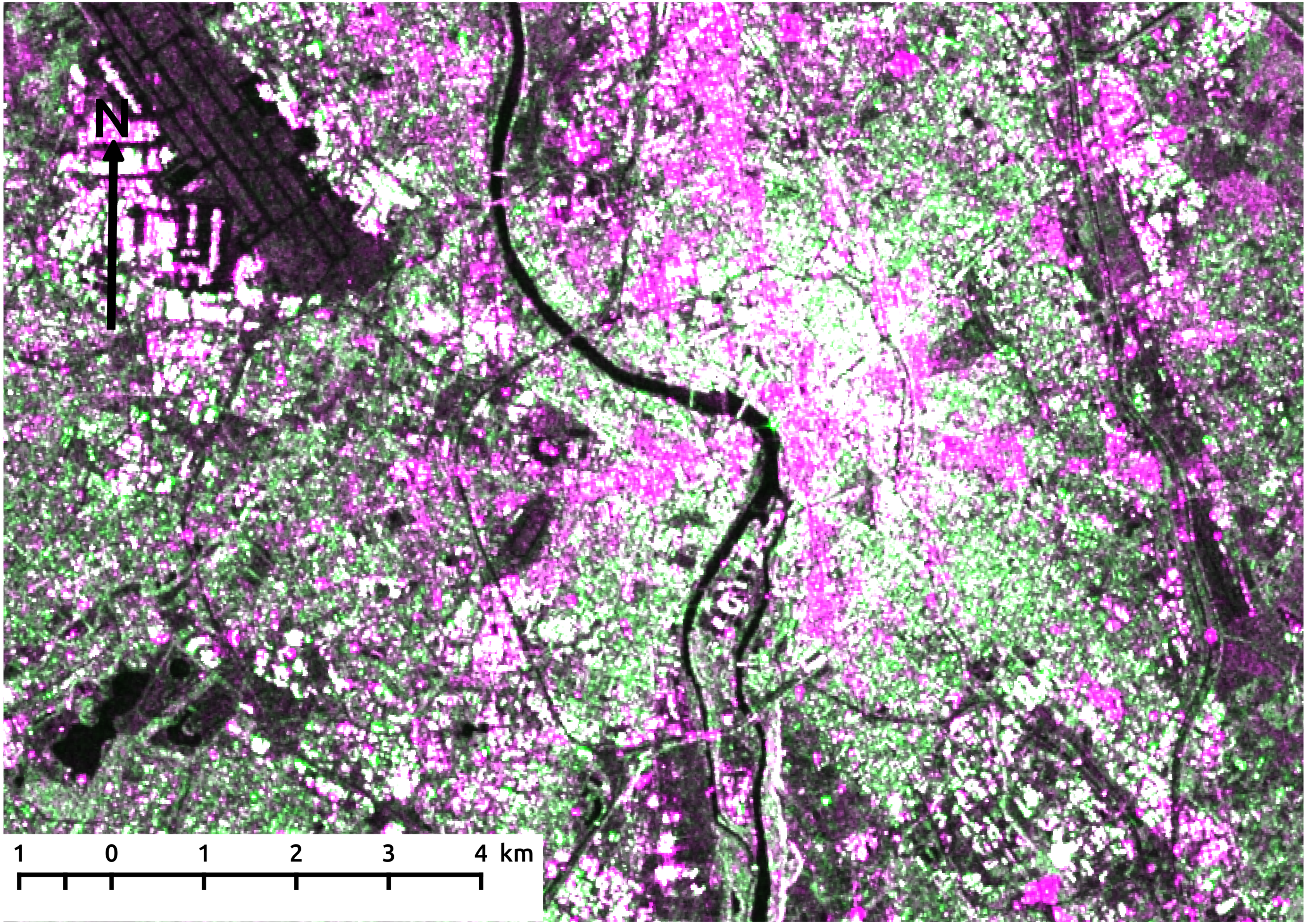
Available data: an example time series from 2017





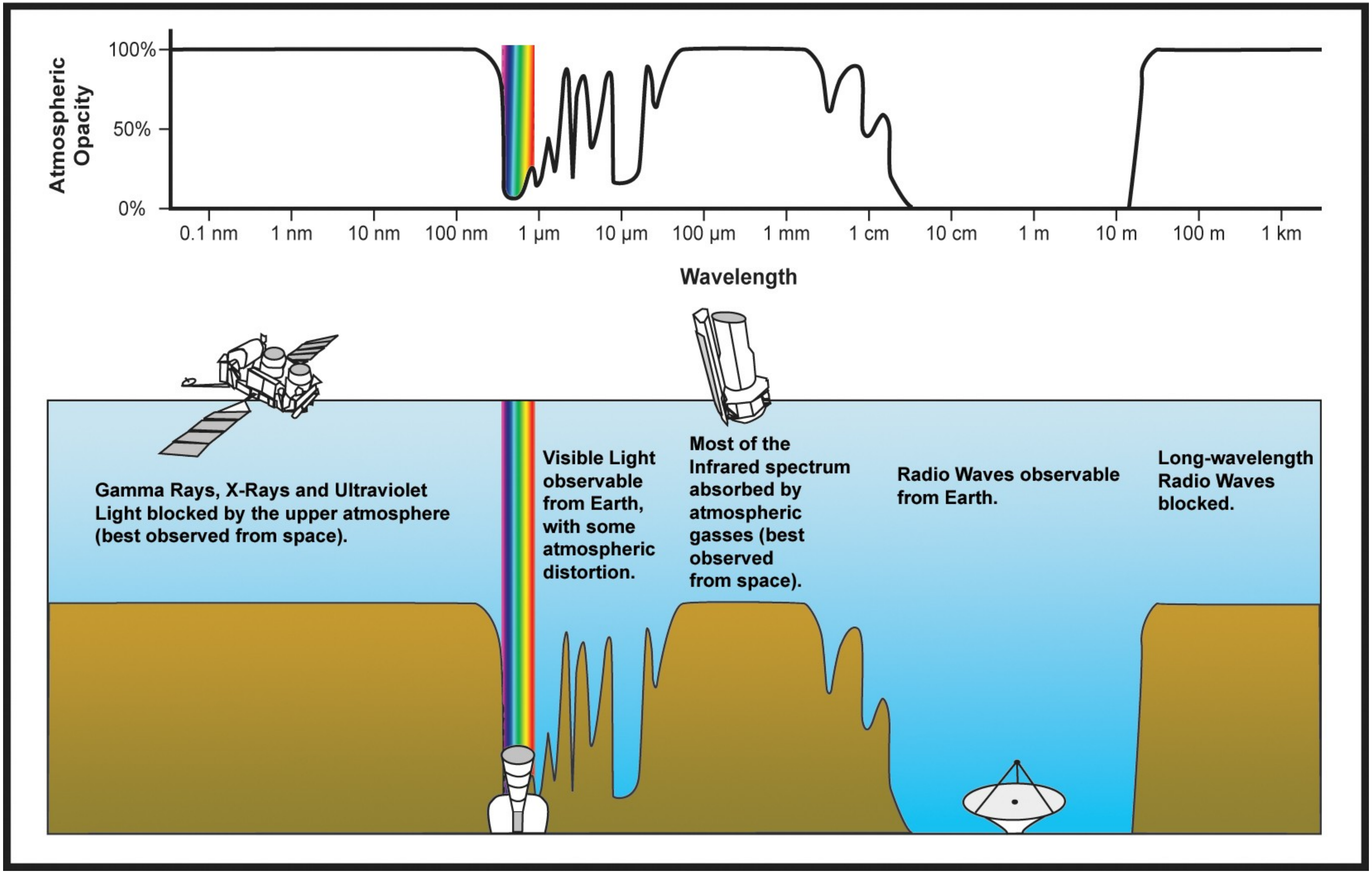
Inglada, J., Vincent, A., Arias, M., Tardy, B., Morin, D., & Rodes, I. (2017). Operational high resolution land cover map production at the country scale using satellite image time series. *Remote Sensing*, 9(1), 95.

What about radar data?



Sentinel-1 image (VV,VH) – Toulouse city, South West of France

What about radar data?

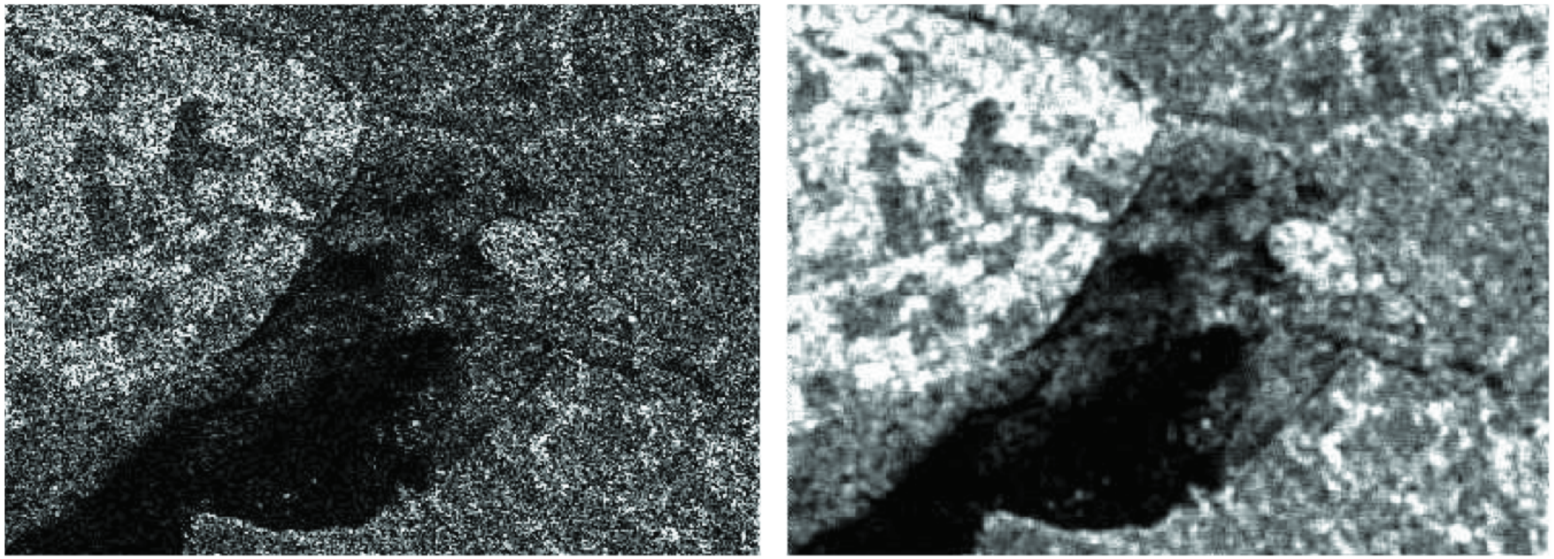


http://gsp.humboldt.edu/OLM/Courses/GSP_216_Online/lesson2-1/atmosphere.html

What about radar data?

+ can penetrate clouds and are independent of atmospheric scattering ⇒ can operate independently of weather or daylight conditions
+ provides complementary information to visible and infrared remote sensing data
+ provides information about surface texture and roughness

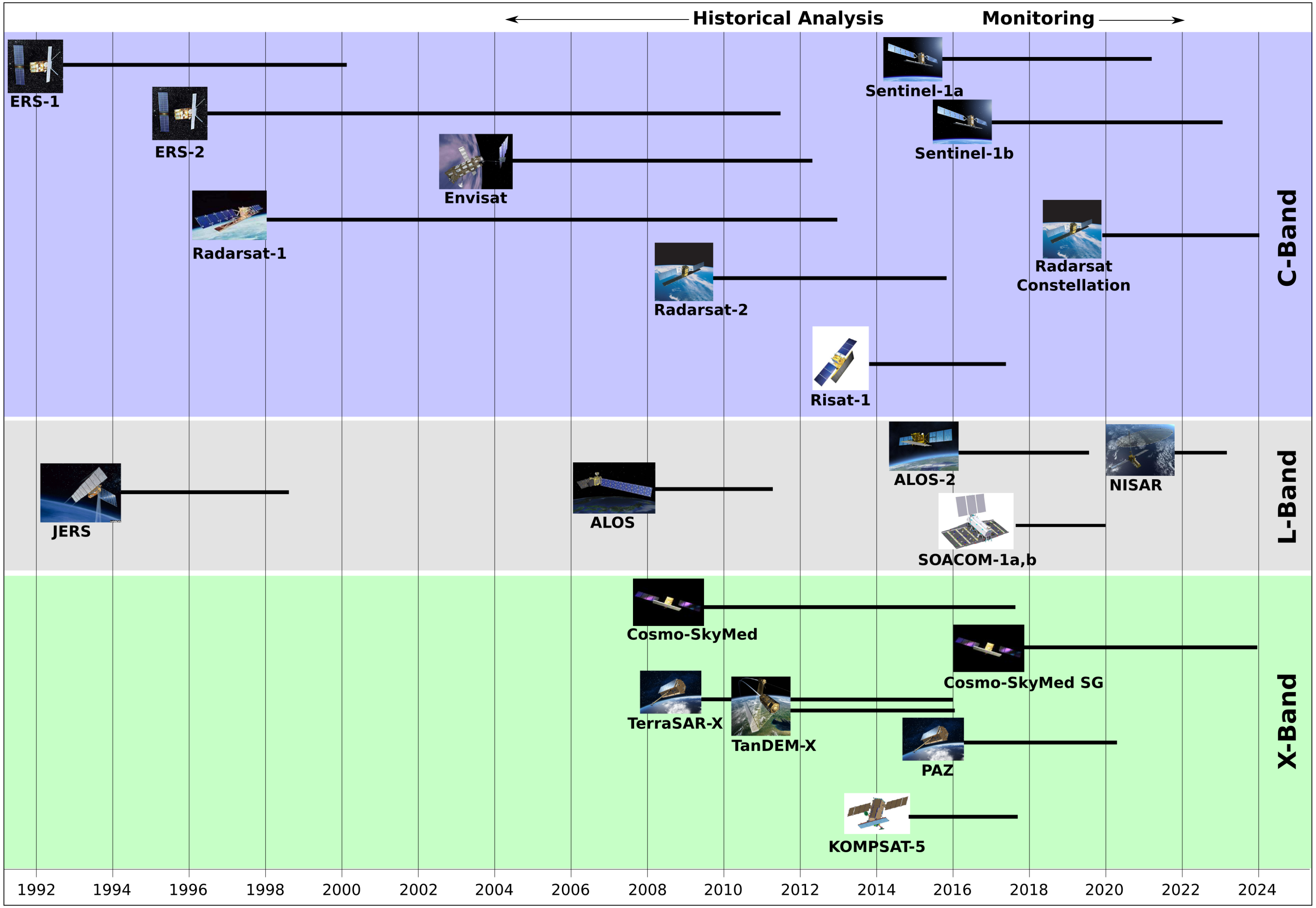
+ applications: biomass estimation, land use and land cover mapping, hydrological modelling, soil moisture estimation, ice monitoring, oceanography, geology
- geometric distortions
- radiometric distortions: *speckle*



Before and after speckle filtering

`https://webapps.itc.utwente.nl/`

What about radar data?



https://www.unavco.org/instrumentation/geophysical/imaging/sar-satellites/sar-satellites.html

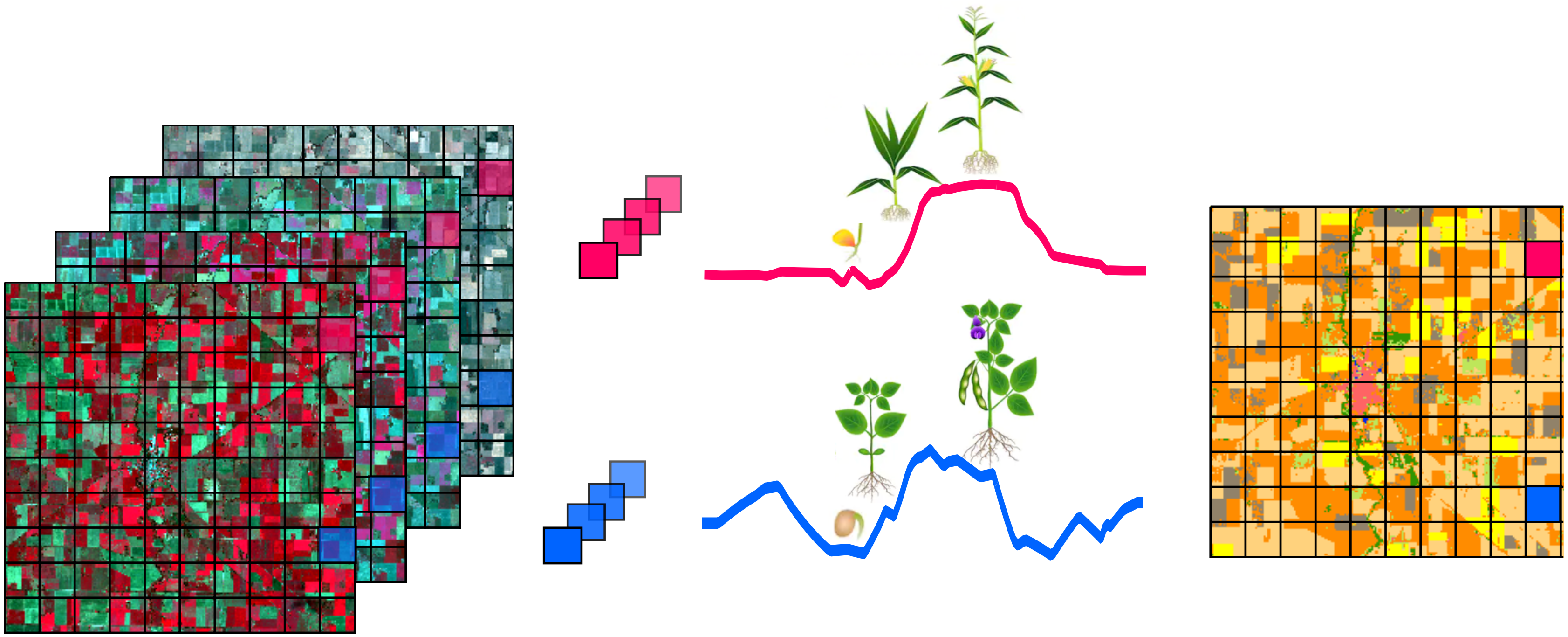
Content

Copernicus Programme

Copernicus Programme: (ex) Global Monitoring for Environment and Security

- satellites and sensors (optical, radar, altimeters)
- collection of in-situ data
- six services
  1. atmosphere monitoring
  2. marine environment monitoring
  3. land monitoring
  4. climate change
  5. emergency management
  6. security

Land cover mapping



Main challenges (research area)

- **Scalability** : massive quantity of data
- **Complex data** : spatio-spectro-temporal data cube, multi-sensor and -modal data
- **Supervision** : mislabelled data and lack of labelled data

Why land cover mapping is crucial?

1. Listing agricultural activities on a territory (agricultural statistics) and estimating the yield of main crops
2. Monitoring the health of crops
3. Analysing the impact of agricultural activities on the environment (biodiversity, natural resources, economics, *etc.*)

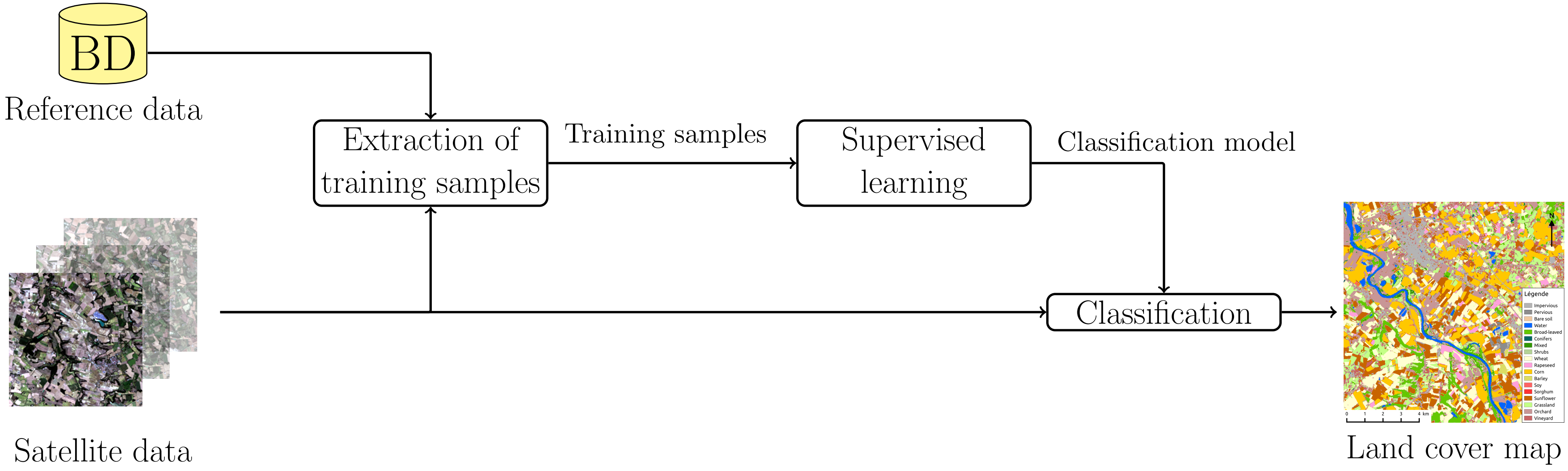
Why land cover mapping is crucial?

1. Listing agricultural activities on a territory (agricultural statistics) and estimating the yield of main crops
2. Monitoring the health of crops
3. Analysing the impact of agricultural activities on the environment (biodiversity, natural resources, economics, *etc.*)

Current technical challenges

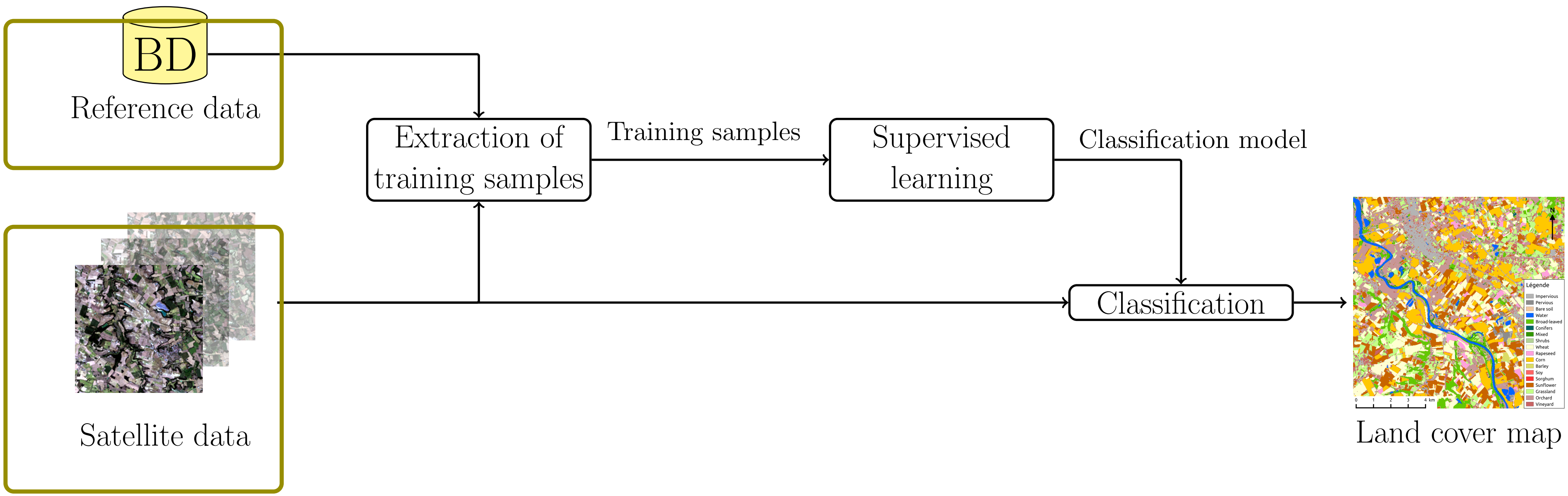
- automation
- large scale study
- timeliness

Supervised classification scheme



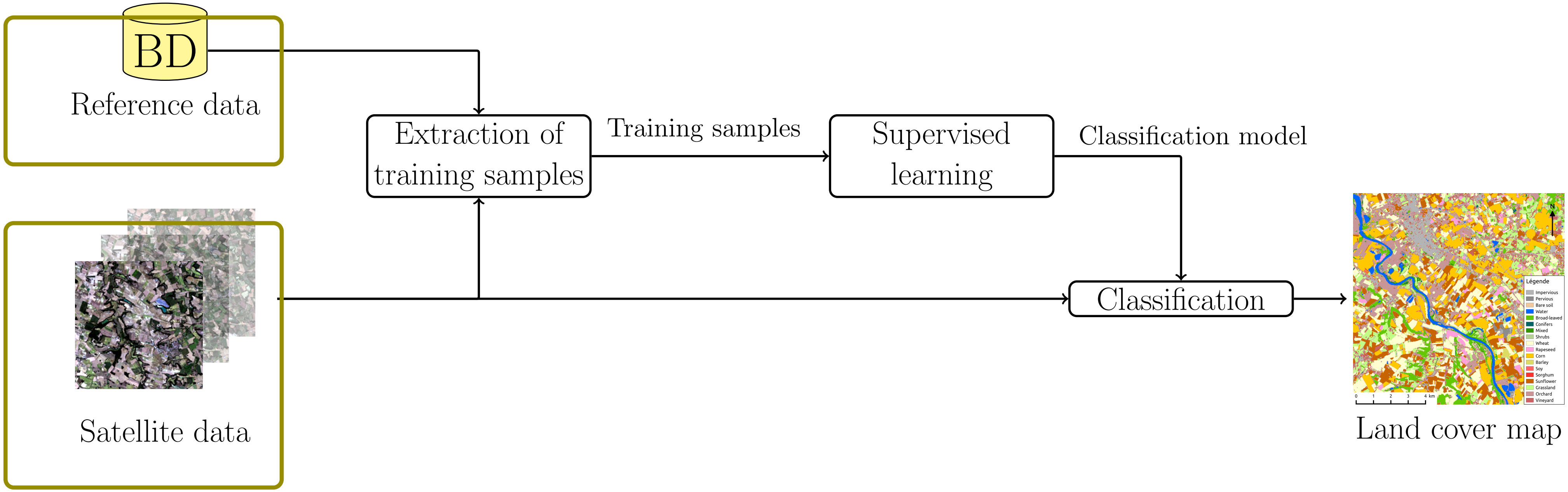
Supervised classification scheme

Input data of the classification framework



Supervised classification scheme

Input data of the classification framework



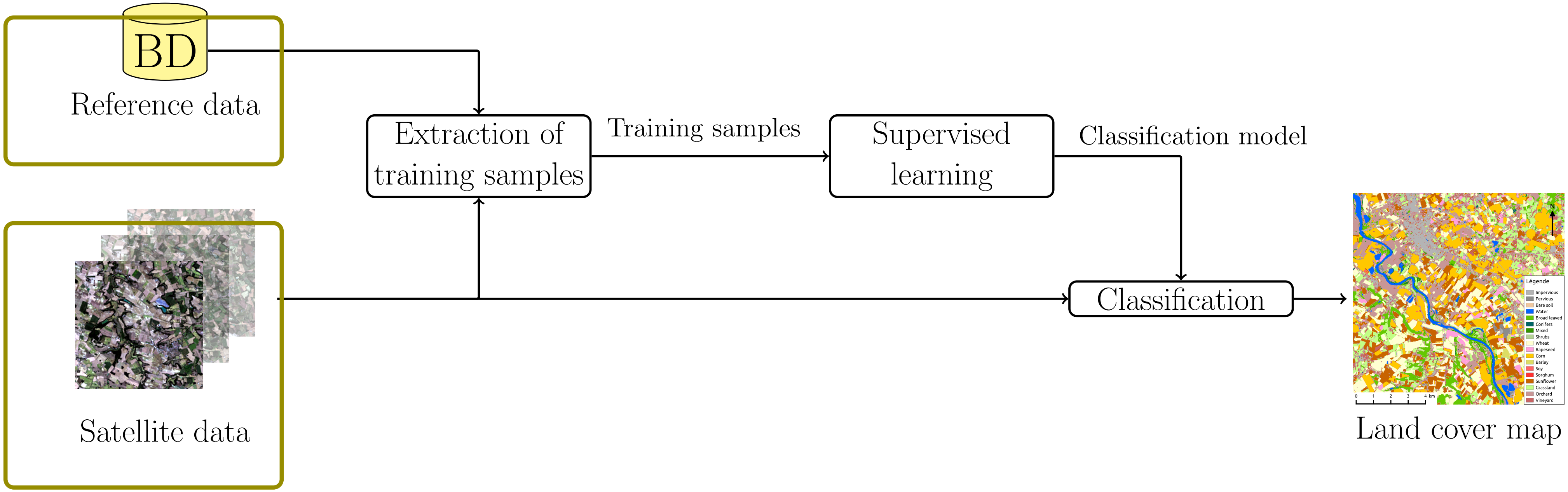
1. Satellite data

↳ feature vector

- spectral bands
- add more features
  - spectral features: *e.g.*, NDVI
  - spatial features: Haralick, attribute profiles, *etc.*
  - temporal features: statistical and phenological features

Supervised classification scheme

Input data of the classification framework



1. Satellite data

↳ feature vector

- spectral bands
- add more features
  - spectral features: *e.g.*, NDVI
  - spatial features: Haralick, attribute profiles, *etc.*
  - temporal features: statistical and phenological features

2. Reference data

↳ label

- photo-interpretation
- field campaigns
- governmental data (*e.g.* Corine Land Cover)
- collaborative data (*e.g.* Open Street Map)

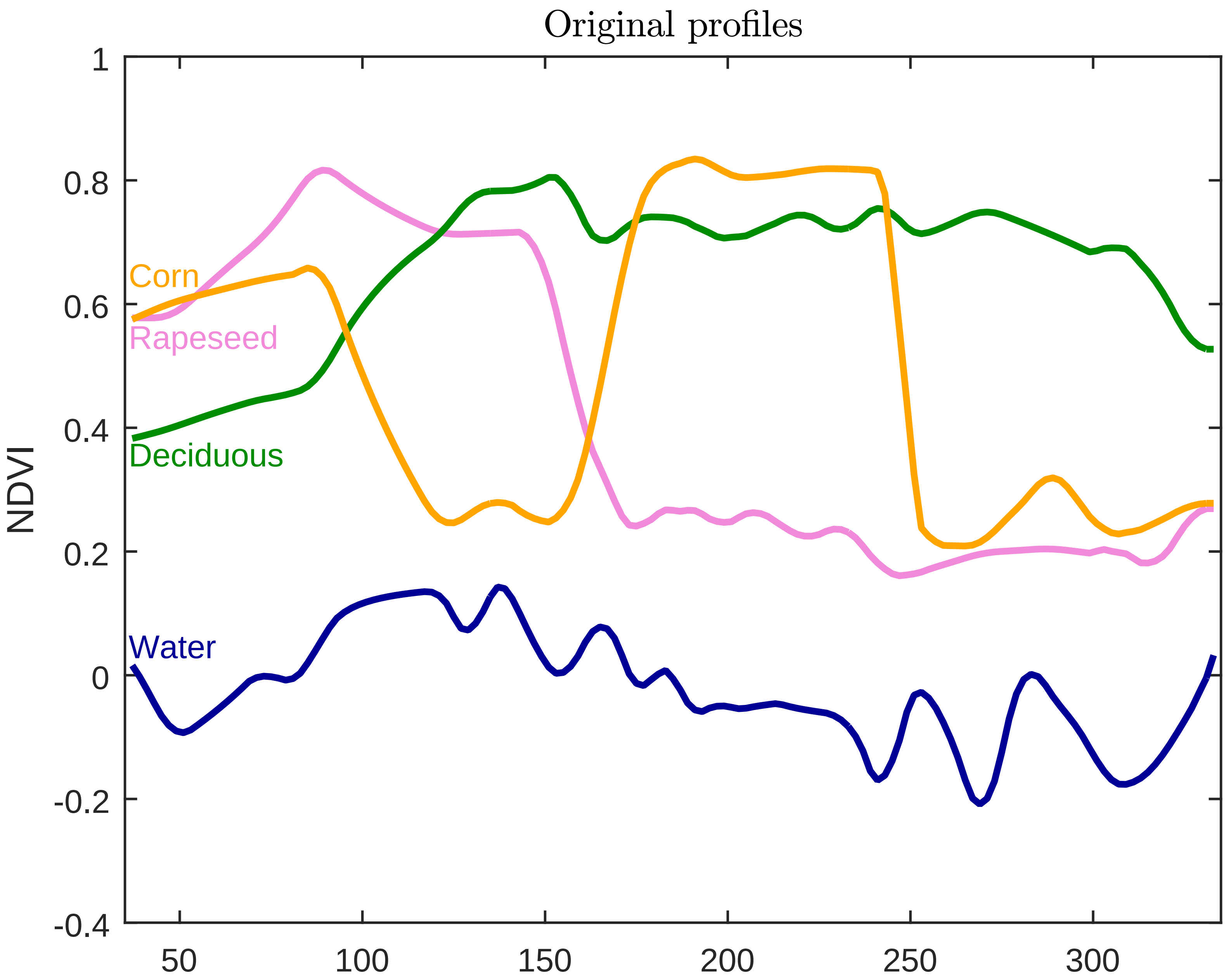
What is the best feature representation for SITS?

- (All) preprocessed images from SITS?
- A new-time based feature representation?

- How to deal with the huge dimensional space?
- How to make the most of the temporal structure of the SITS data?

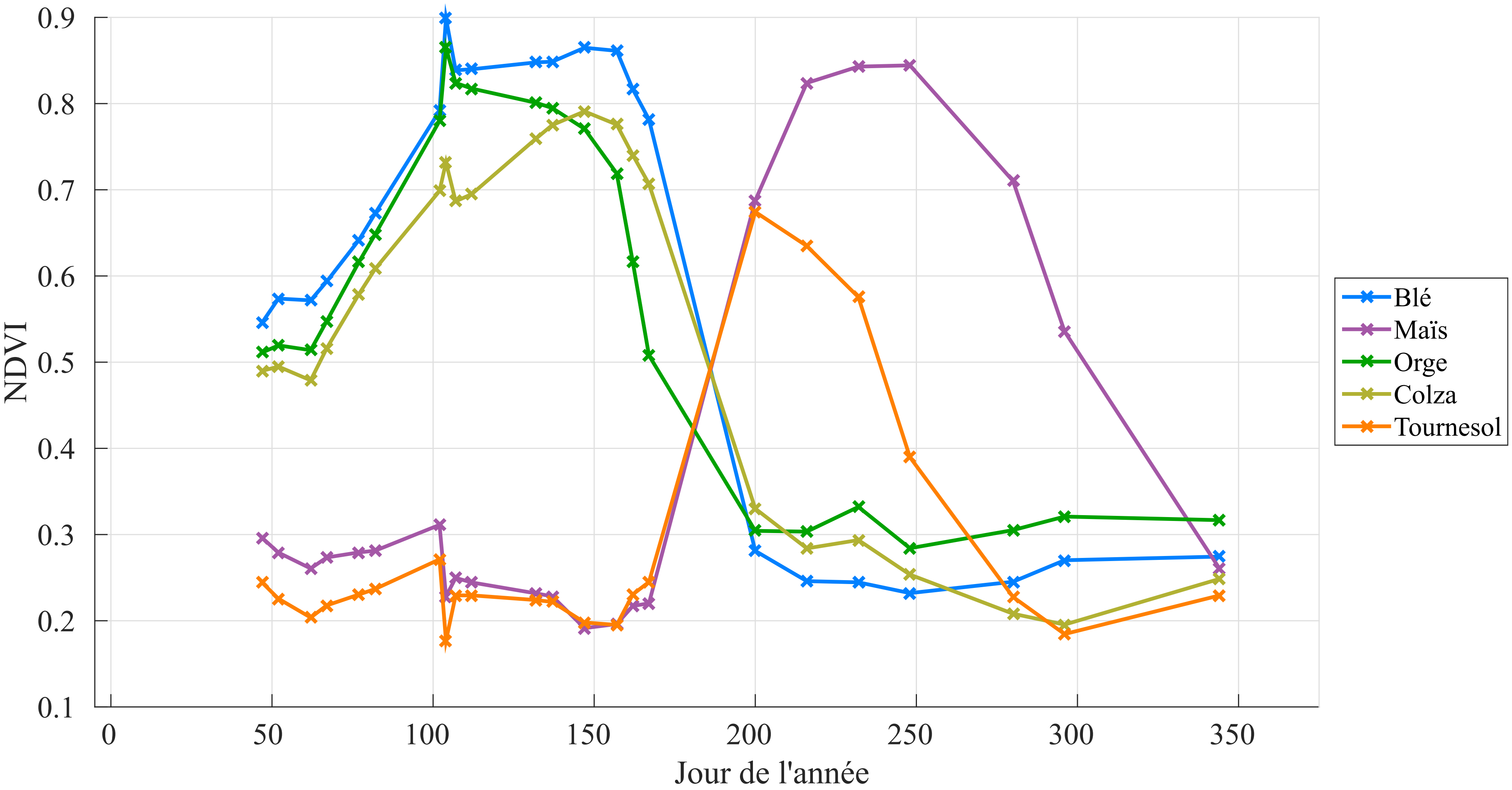
What is the best feature representation for SITS?

Normalized Difference Vegetation Index profiles



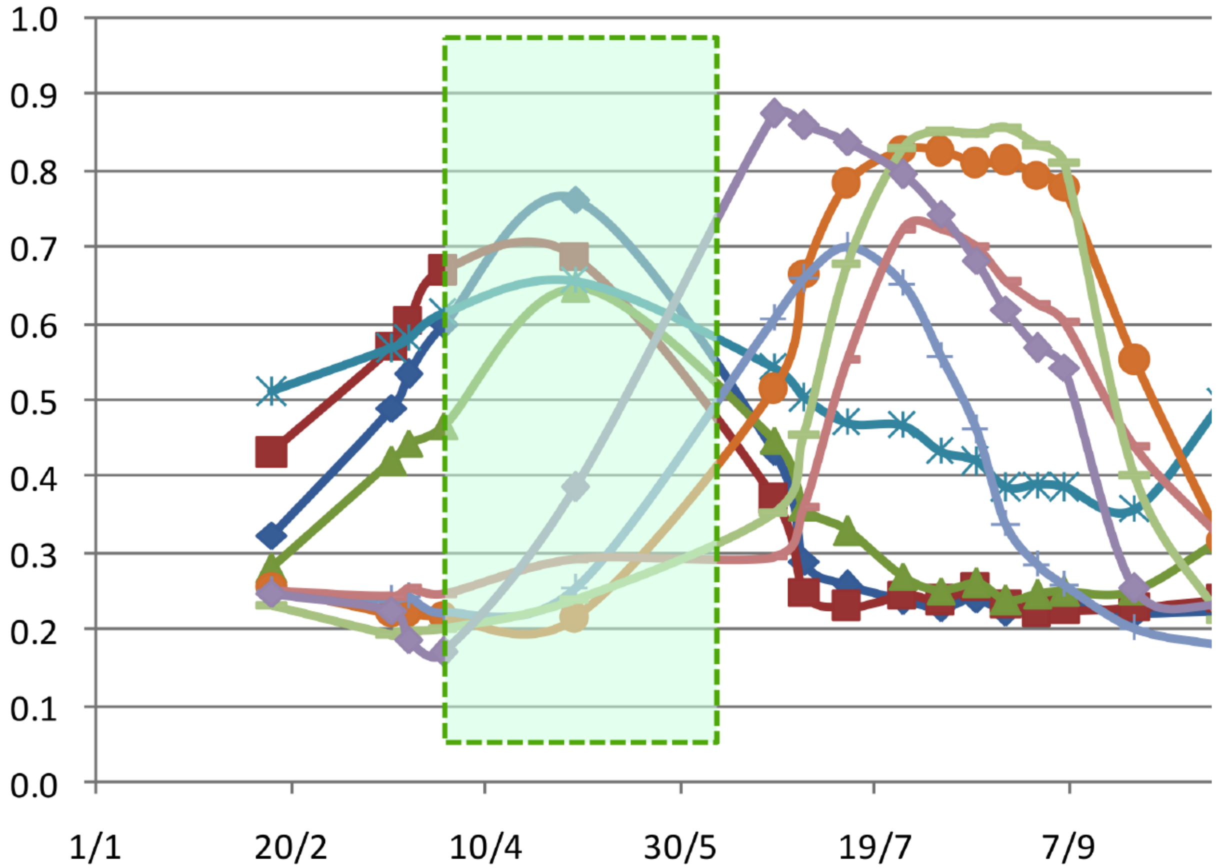
What is the best feature representation for SITS?

Normalized Difference Vegetation Index profiles



What is the best feature representation for SITS?

Dimension reduction: Selection of key dates?



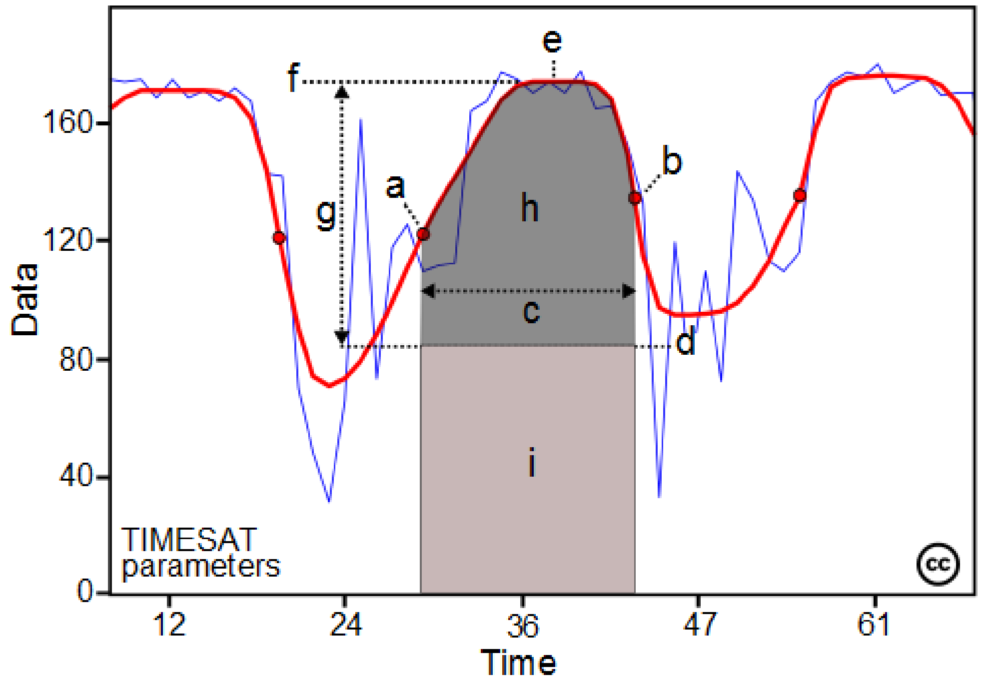
This is not a straightforward process. Key dates change from one year to another.

- climate change
- urbanisation processes
- weather conditions
- agricultural practices

What is the best feature representation for SITS?

Phenology-based representation: TIMESAT

- description of periodic plant life cycle events accross the growing seasons

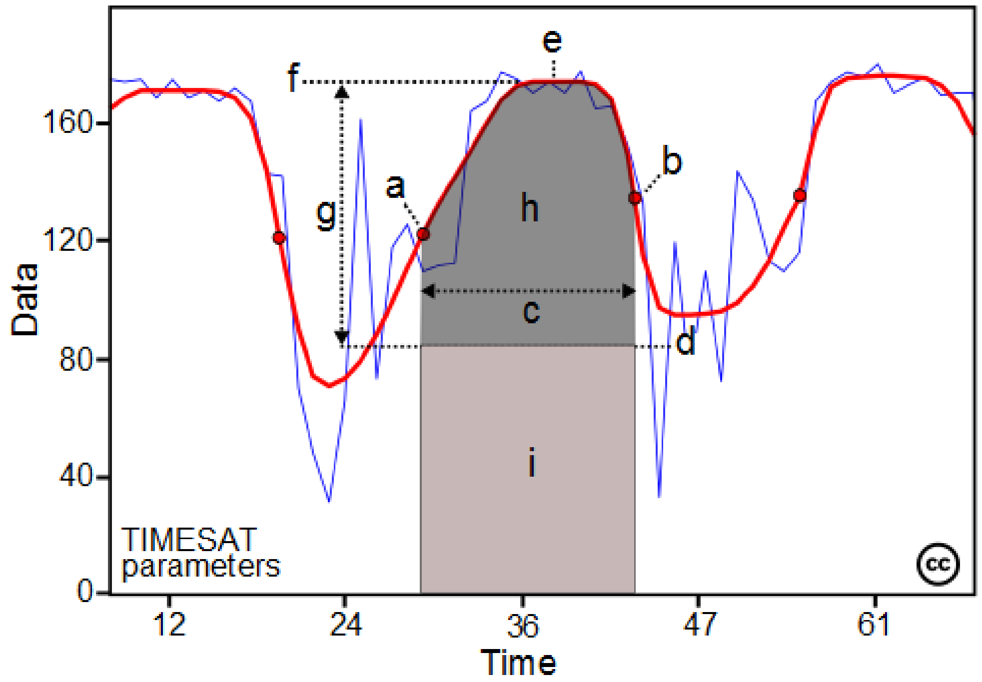


a. beginning of season
b. end of season
c. length of season
d. base value
e. time of middle of season
f. maximum value

What is the best feature representation for SITS?

Phenology-based representation: TIMESAT

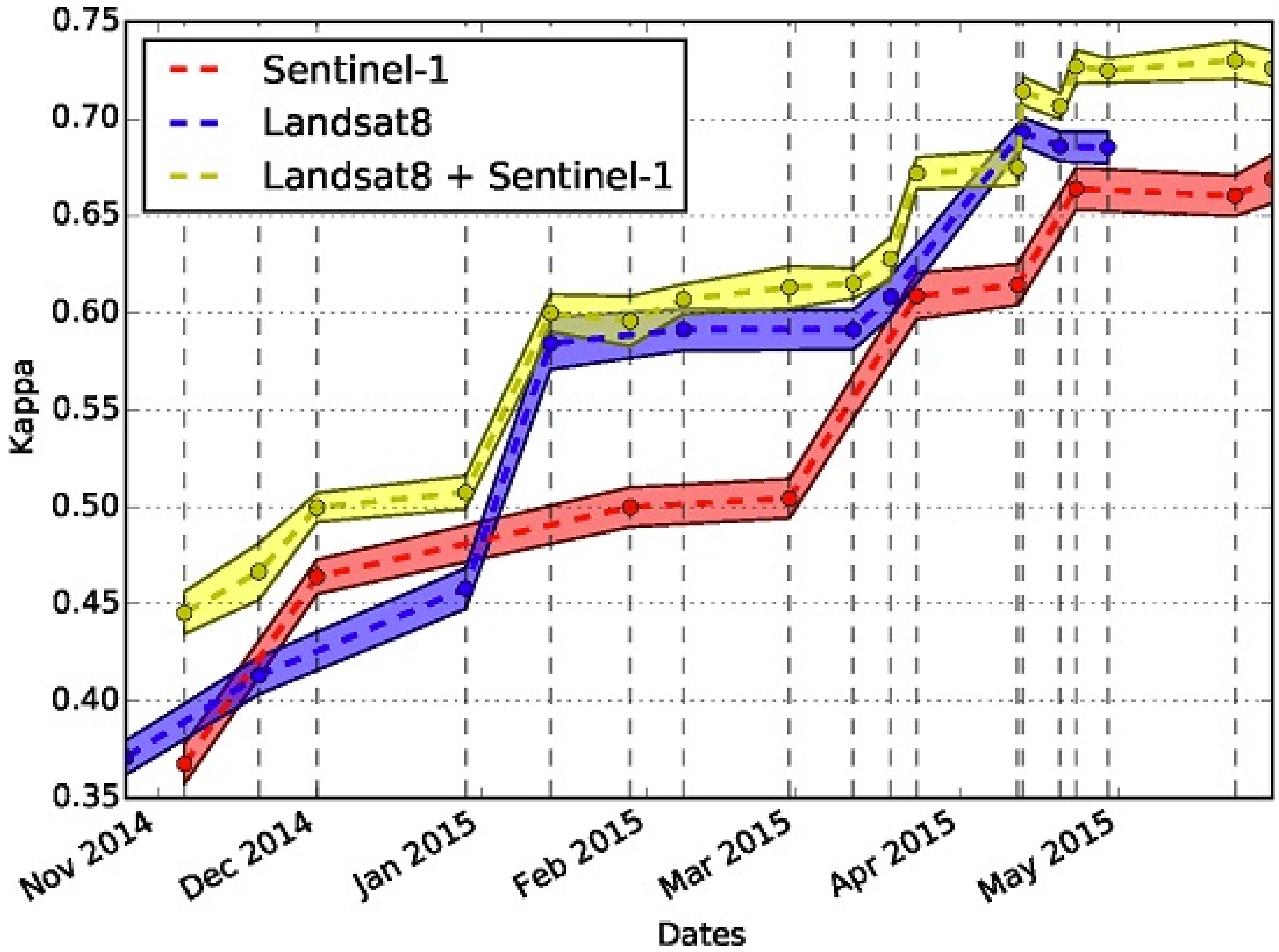
- description of periodic plant life cycle events accross the growing seasons



a. beginning of season
b. end of season
c. length of season
d. base value
e. time of middle of season
f. maximum value

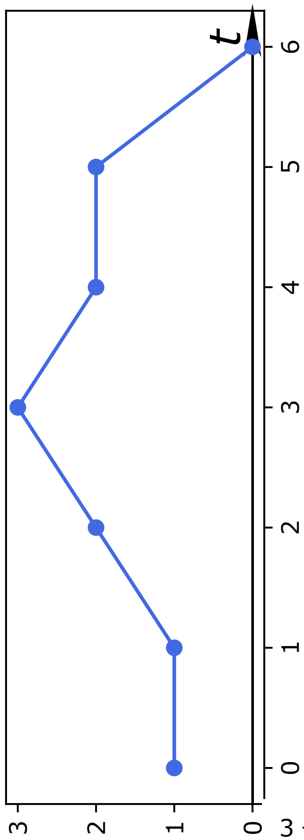
What is the best feature representation for SITS?

Enrich the feature representation by using multi-modal data

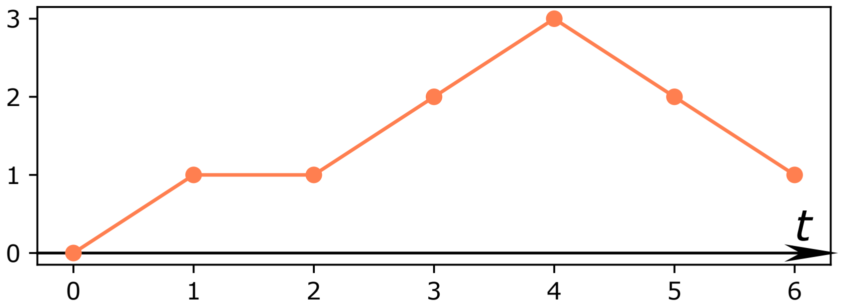


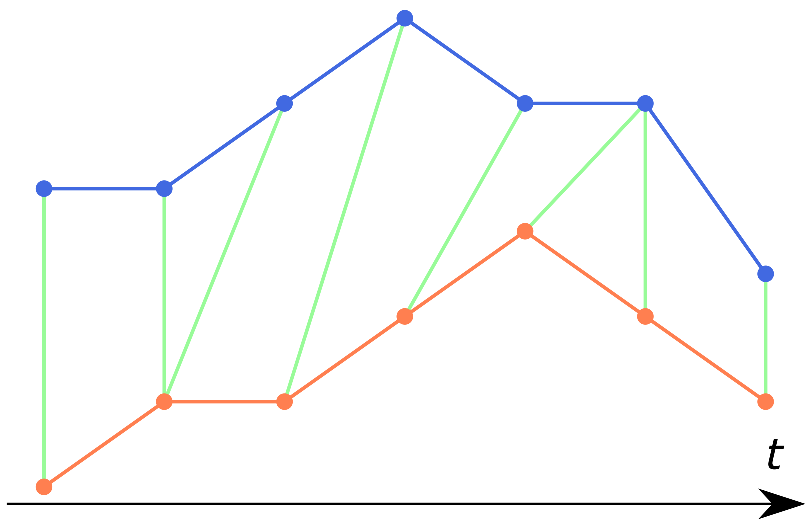
Early crop type mapping

What is the best feature representation for SITS?



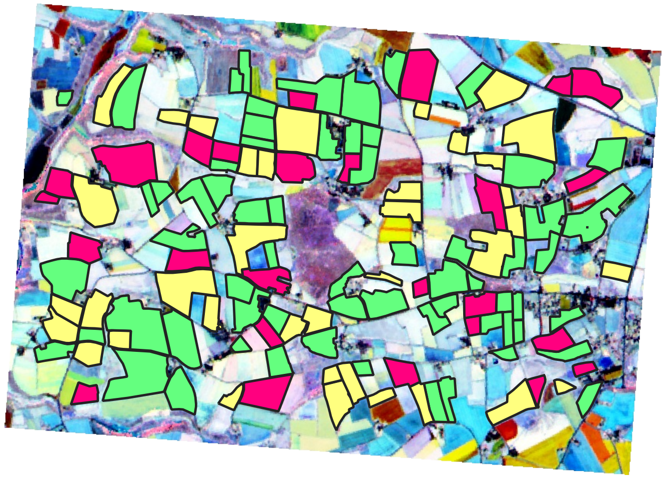
5.0	5.0	3.0	4.0	2.0	2.0	2.0
5.0	5.0	2.0	2.0	1.0	1.0	3.0
4.0	4.0	2.0	1.0	2.0	3.0	5.0
2.0	2.0	1.0	2.0	2.0	2.0	4.0
1.0	1.0	2.0	4.0	5.0	6.0	7.0
1.0	1.0	2.0	4.0	5.0	6.0	7.0
1.0	2.0	4.0	7.0	9.0	11.0	11.0





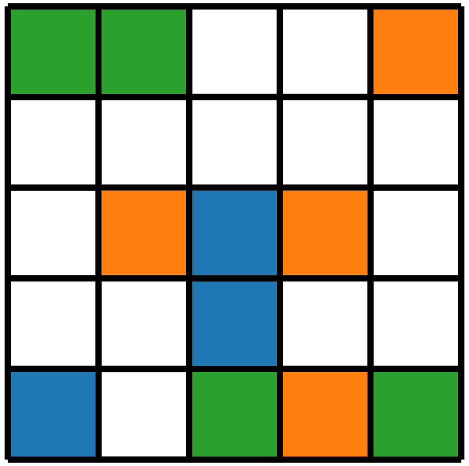
How to measure the similarity between two time series?

What about the reference data?

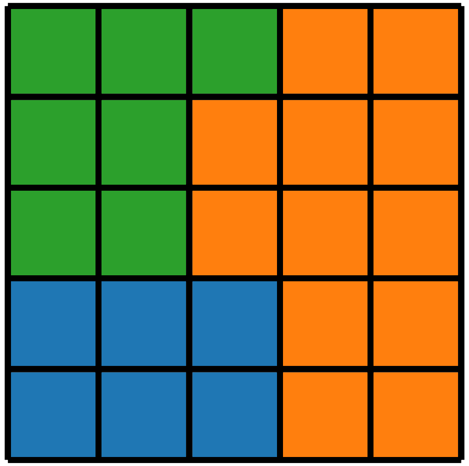


Performance evaluation

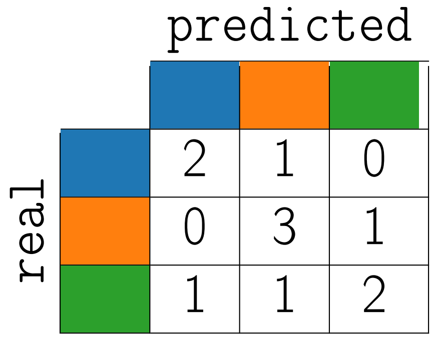
Confusion matrices



Reference data (test instances)



Predictions of the classification algorithm



Introduction to Orfeo Toolbox

Orfeo ToolBox: https://www.orfeo-toolbox.org/

- developed by the French spatial agency (CNES) in 2006 to support the Pléiades Orfeo programme
- free and open-source software written in C++

Primary objectives

- facilitate the use of Very High spatial Resolution
- capitalise on R&D around the processing of satellite images
- provide various and powerful generic tools to the data user

https://tice.agroparistech.fr/coursenligne/courses/COPERNICUSETAGRICULT/document/1200_TP_Occ_Sol/Copernicus_Agri_Ocsol_TP.pdf?chapitre=&cidReq=COPERNICUSETAGRICULT&rand=5481

What can I do with OTB?

1. Write my own C++ code to develop new applications (advanced programming skills)
2. Use OTB applications through command lines, Python script or even QGIS
3. Use Monteverdi2, a satellite image viewer

What can I do with an OTB application?

- **Access to the data**: read metadata, compute some statistics
- **Basic operations**: radiometric and geometric corrections, band extraction, image concatenation, pixel-to-pixel computation (*e.g.* image difference), radiometric index computation
- **Filtering**: noise reduction, morphological filters
- **Attribute extraction**: edge detectors, key point descriptor, texture computation, *etc.*
- **Image segmentation** for object-based image analysis (OBIA)
- *etc.*

Powerful computation

- streaming: all image sizes can be processed
- multi-threading: faster execution due to the use of parallel computing

Content

Extracting a region of interest (ROI)

Step 0: unzip both `OTB-7.1.0-Win64.zip` and `SENTINEL2A_20171208-111549-616_L2A_T30TVT_C_V1-0.zip` files

Step 1: Explore the files (and folders) in the Sentinel-2 image. How are organised these files?

Step 2: Open Monteverdi application (in the `OTB-7.1.0-Win64` folder)

Step 3: Open the band 4 of the Sentinel-2 image in Monteverdi. The image is quite big and can slow down your computer. We will extract an ROI.

Step 4: Open Mapla (Monteverdi application launcher). Search for the `ExtractROI` application.

Step 5: Extract several ROIs and open them to Monteverdi.

Creating a data stack for the image

The objective here is to create a stack of the 10 available spectral bands. This stack can then be used as an input of a classification system. Since the spectral bands have different spatial resolutions, the firs step is to resample all the bands at the same resolution (10 m). The second step is to concatenate the 10 spectral bands.

Step 1: Downsampling each 20 m spectral band image at a 10 m spatial resolution by using the `Superimpose` application.

Step 2: Concatenating all the image bands by using the `ConcatenateImages` application.