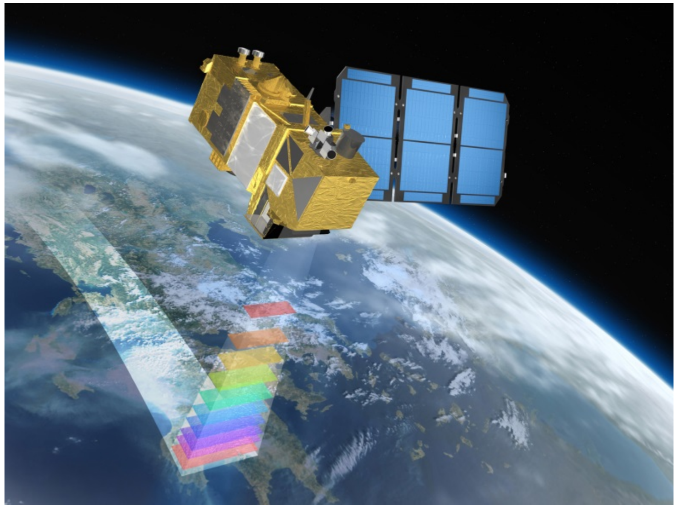
Sentinel-2: opportunities and challenges for research and applications

Gérard DEDIEU
CESBIO/CNES

Toulouse, France

gerard.dedieu@cesbio.cnes.fr

Sentinel 2: a new era for land remote sensing



- **Revisit**: 5 days at equator (with 2 satellites) under same viewing conditions

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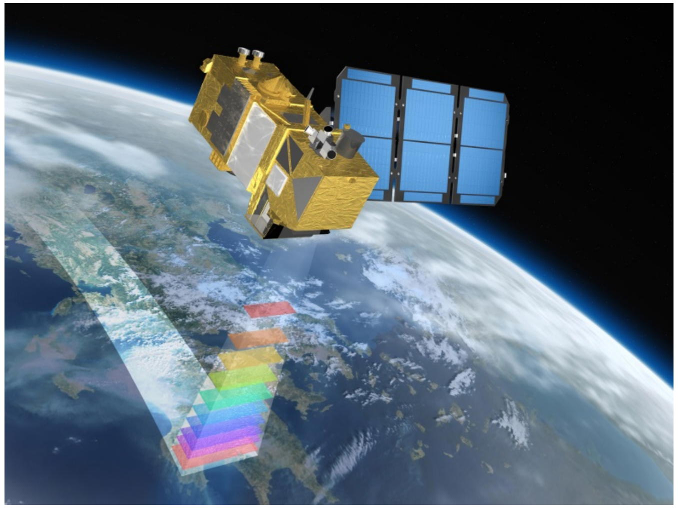
- Nearly global geographical **coverage**



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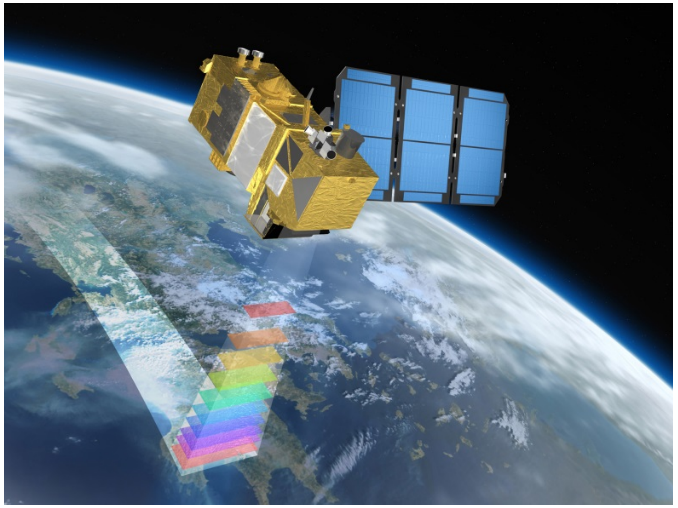

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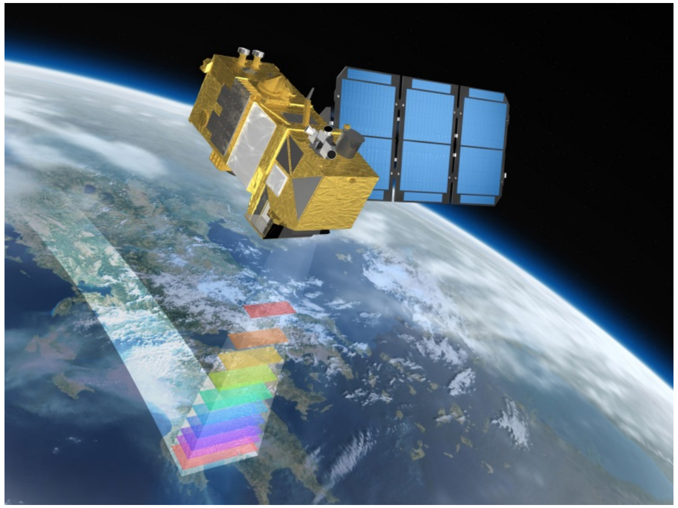

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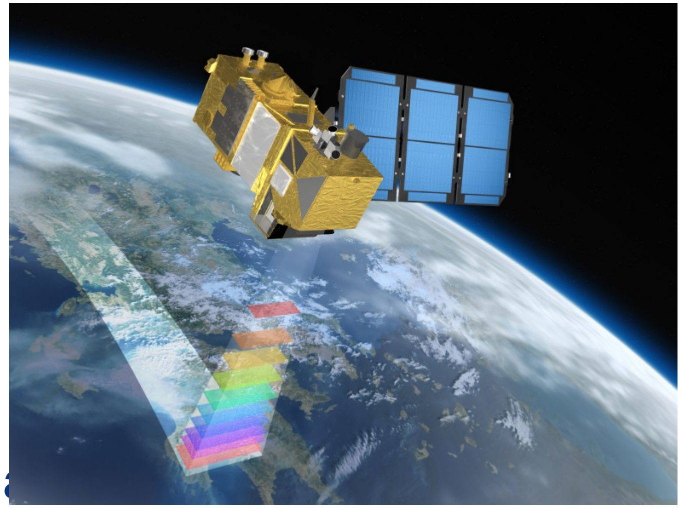

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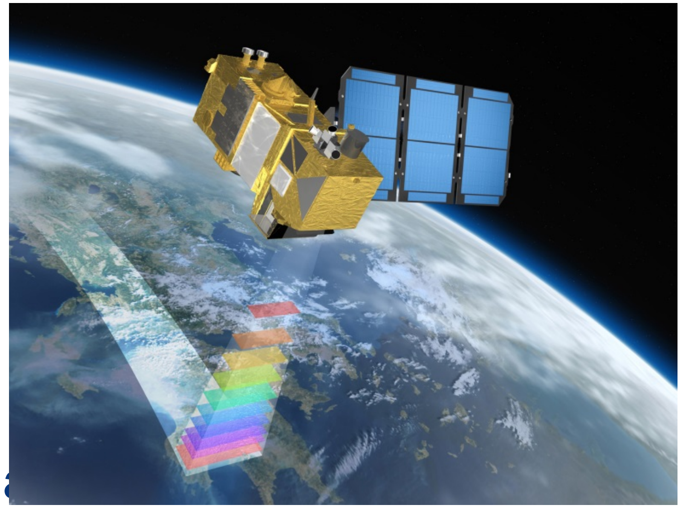

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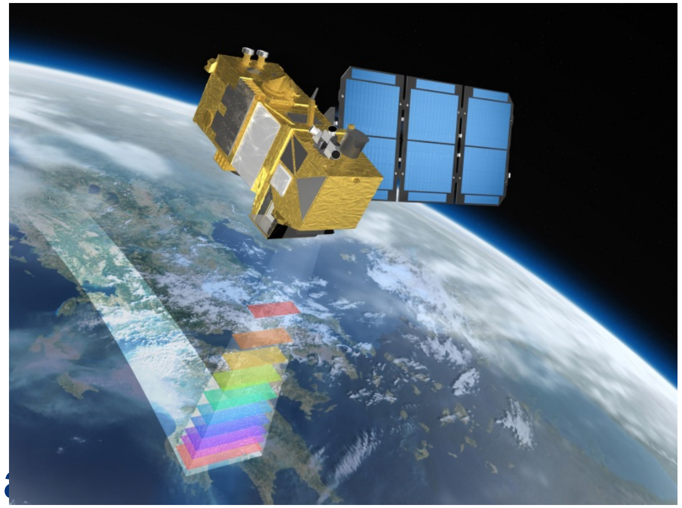

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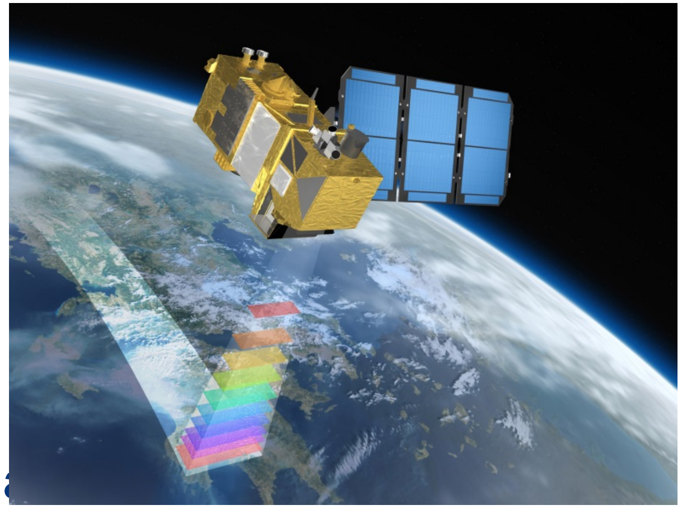

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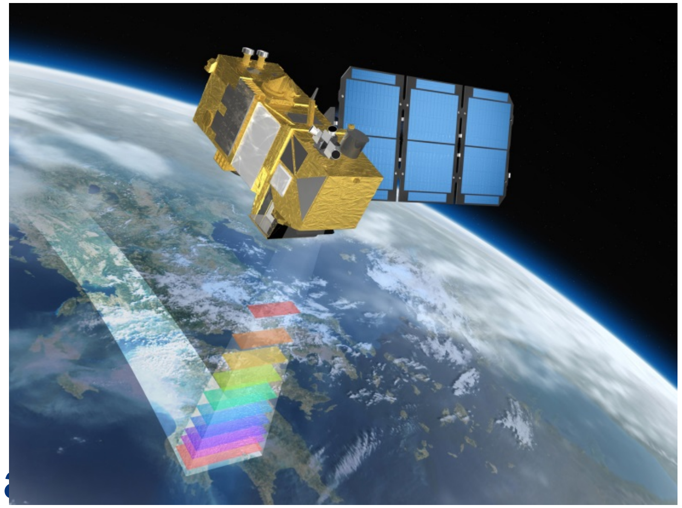

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☞ **No other system offers all these capabilities together**

Sentinel 2: opportunities

- **Free access to high quality and frequent data, everywhere**
  - **Temporal sampling of the dynamics of phenomena**
    - Snow and ice

Time series – Boreal regions– River ice melt monitoring

9 April 2015

- SPOT5 (Take5) images of Ienissei (Russia), April-June 2015
  - White : snow
  - Black :Water
  - Pink : bare soil
  - Green : vegetation
- Applications
- River Ice melt modelling
- Carbon discharge in the water after melting
- Boreal vegetation growth
- Date of vegetation onset monitoring

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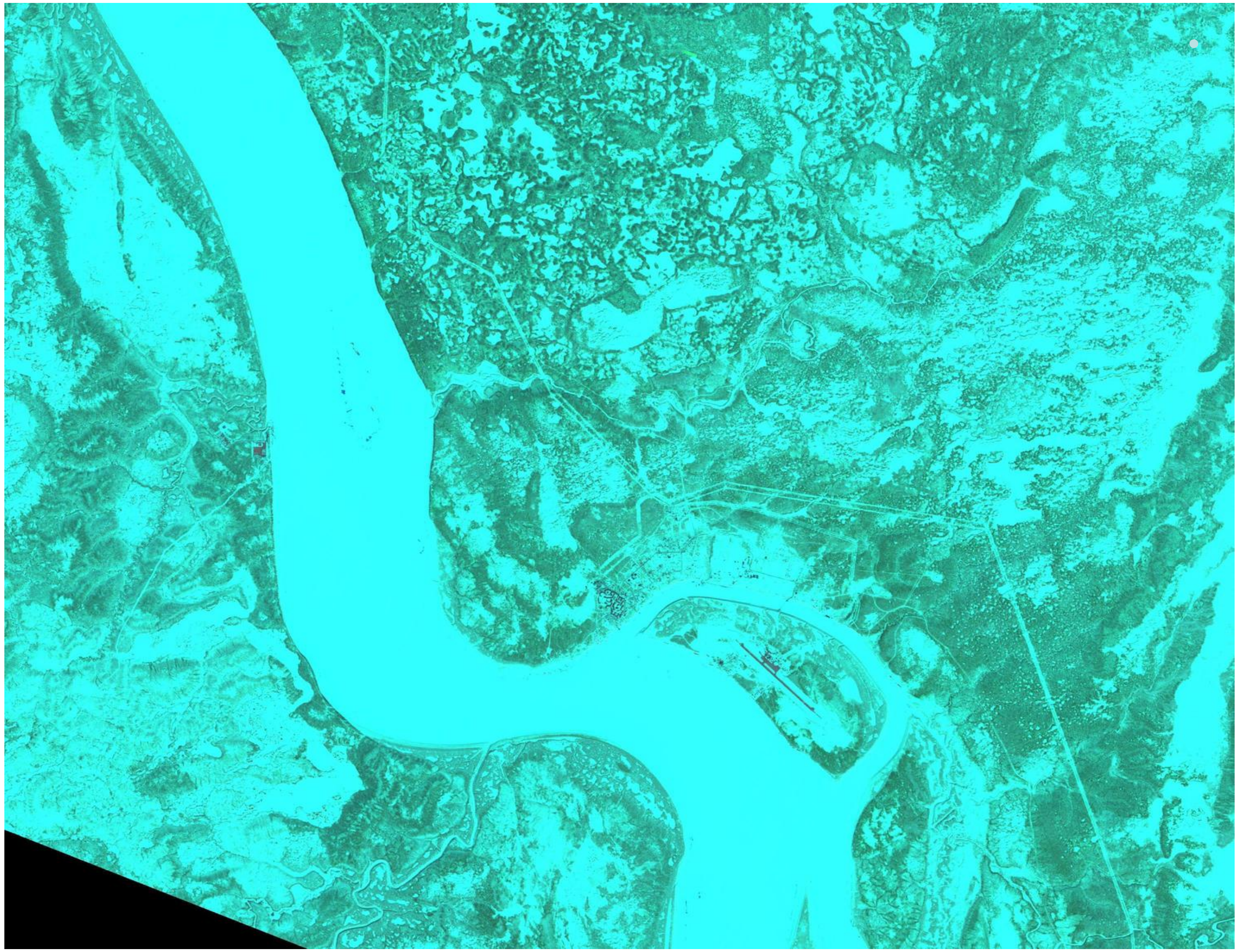

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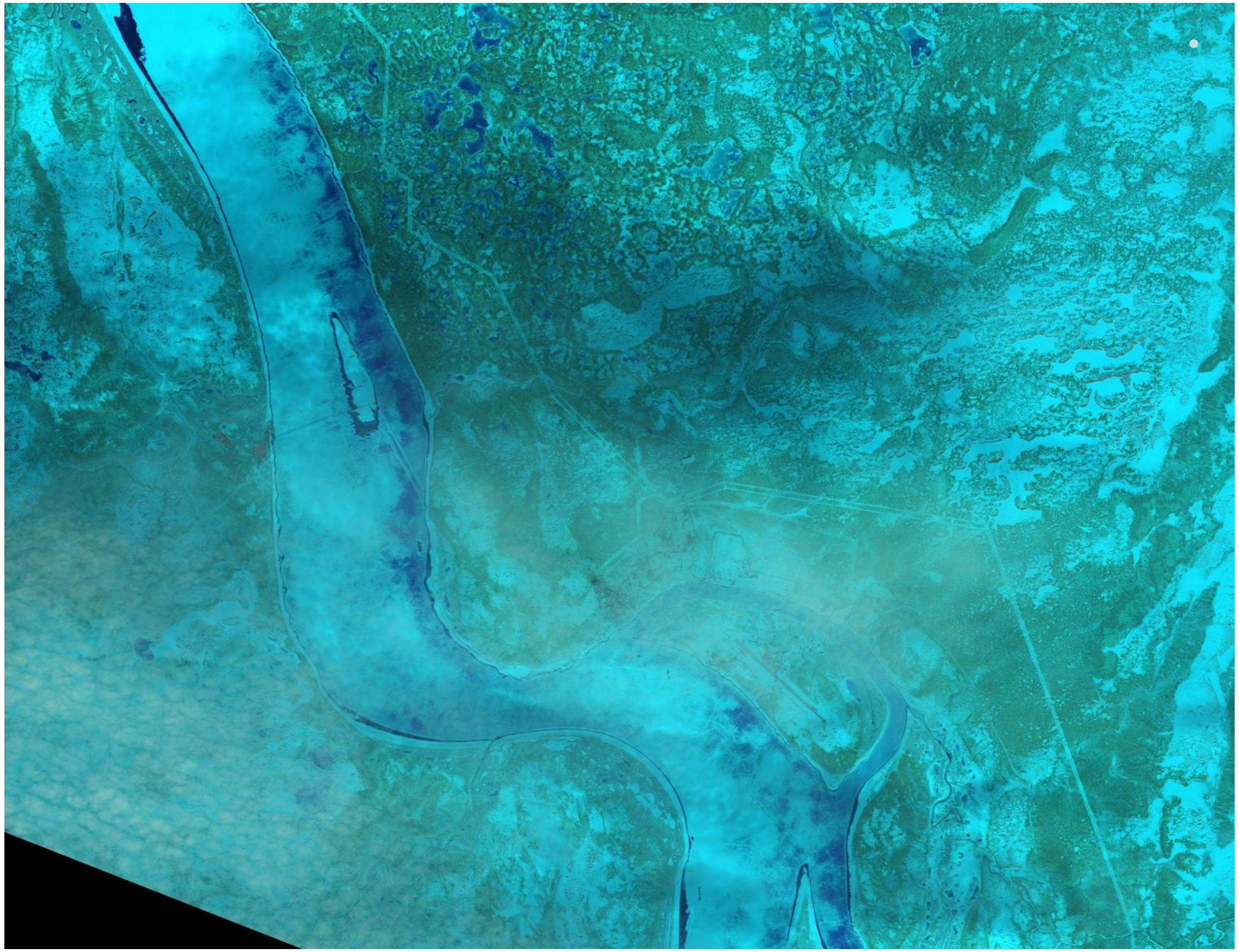

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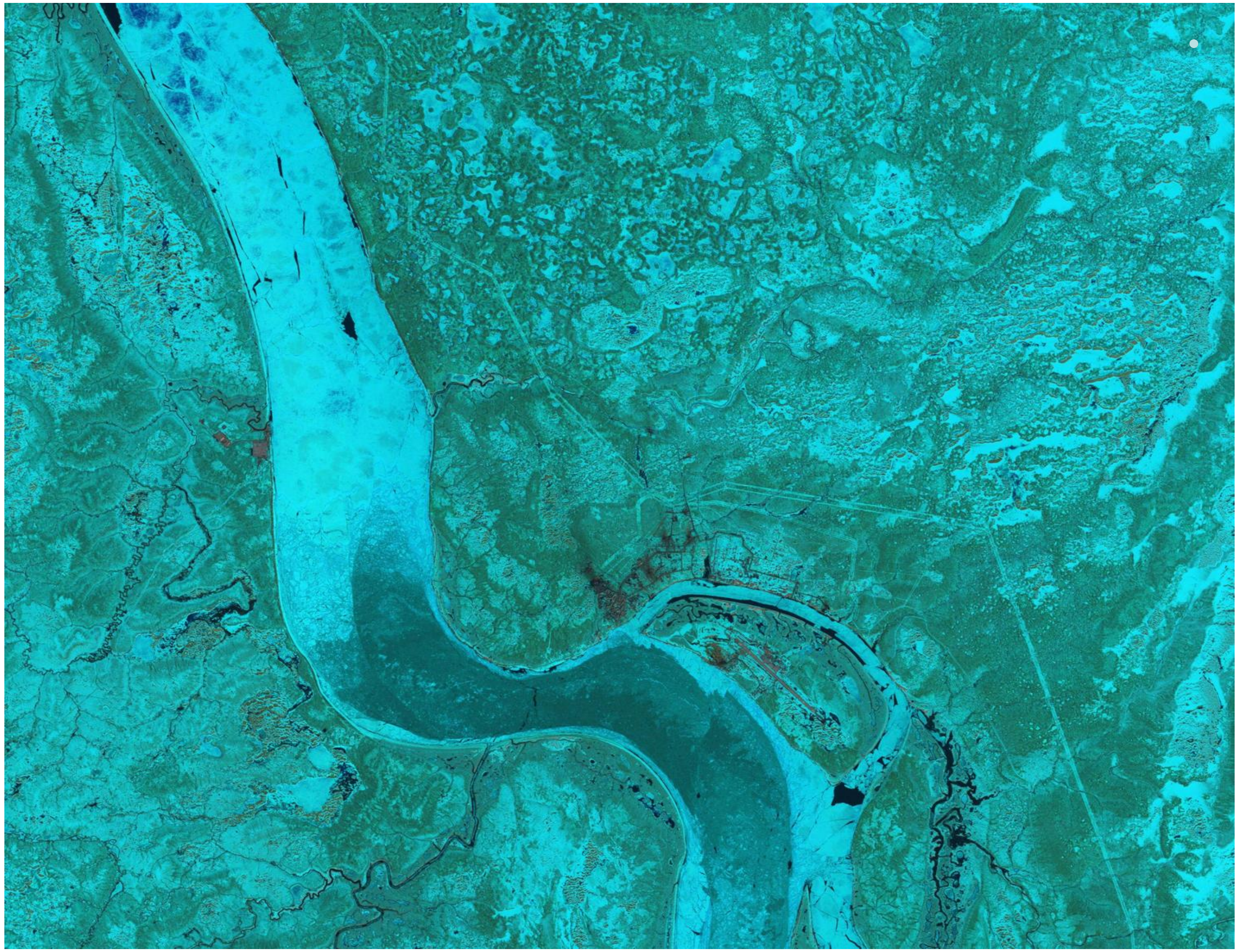

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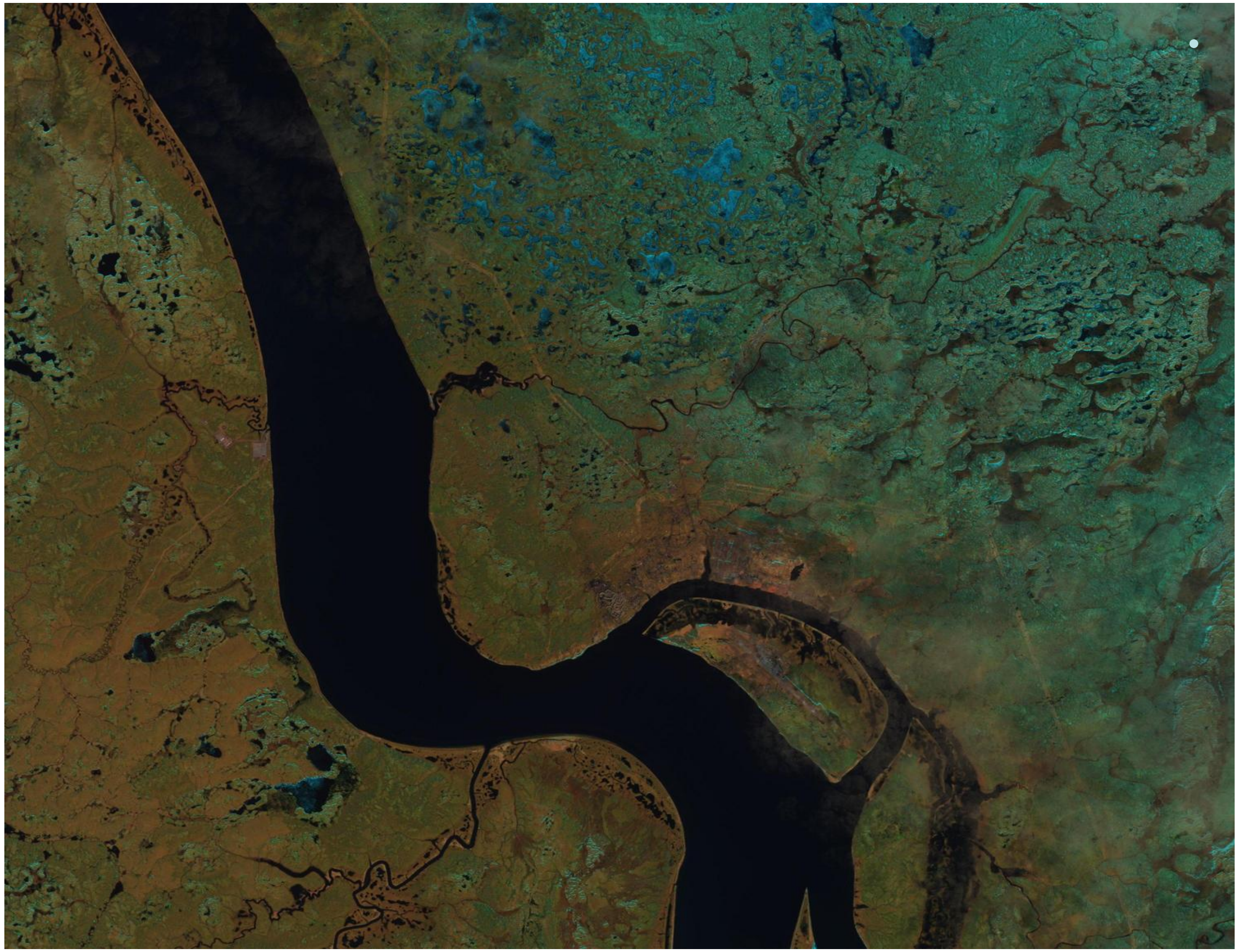

3 June 2015

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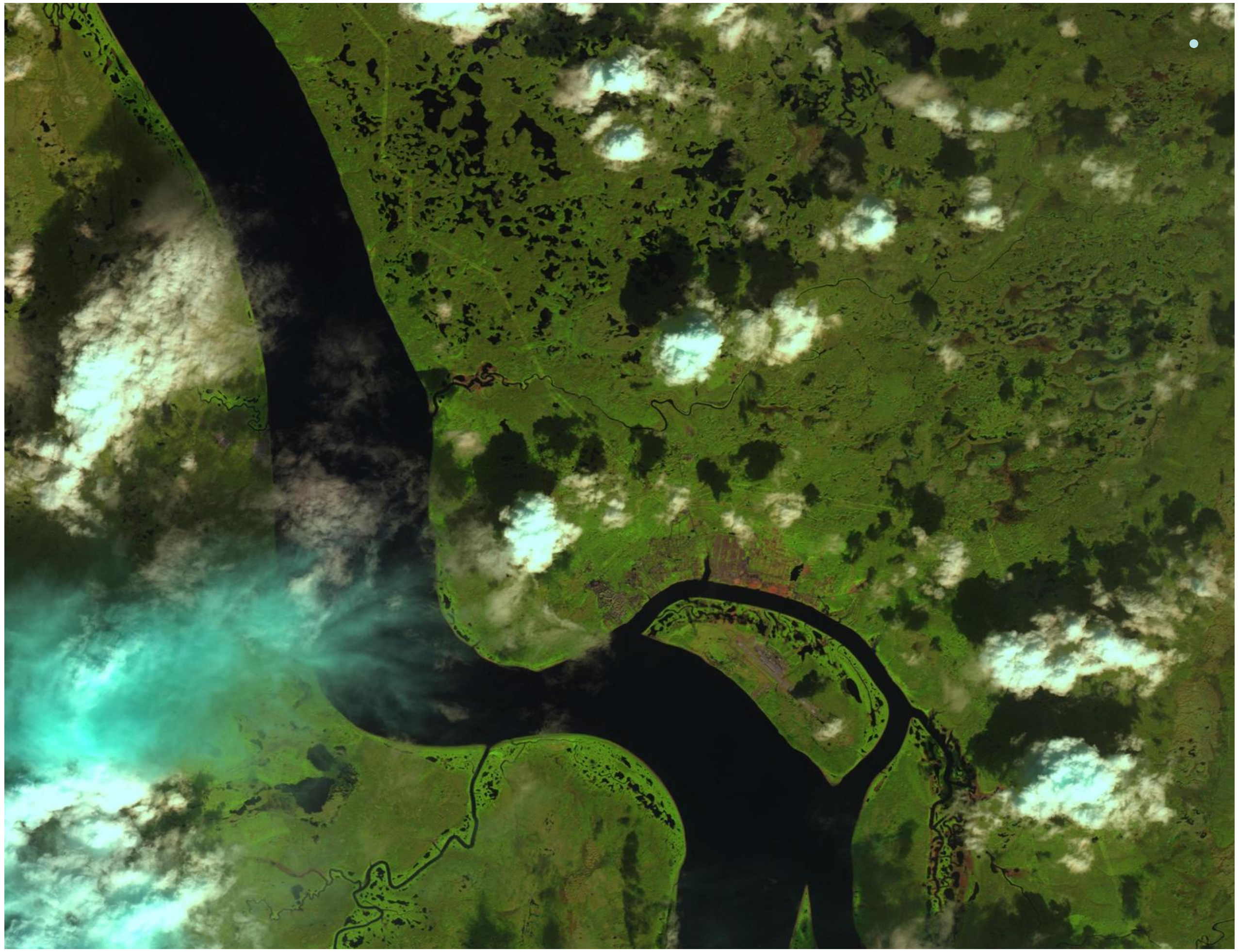

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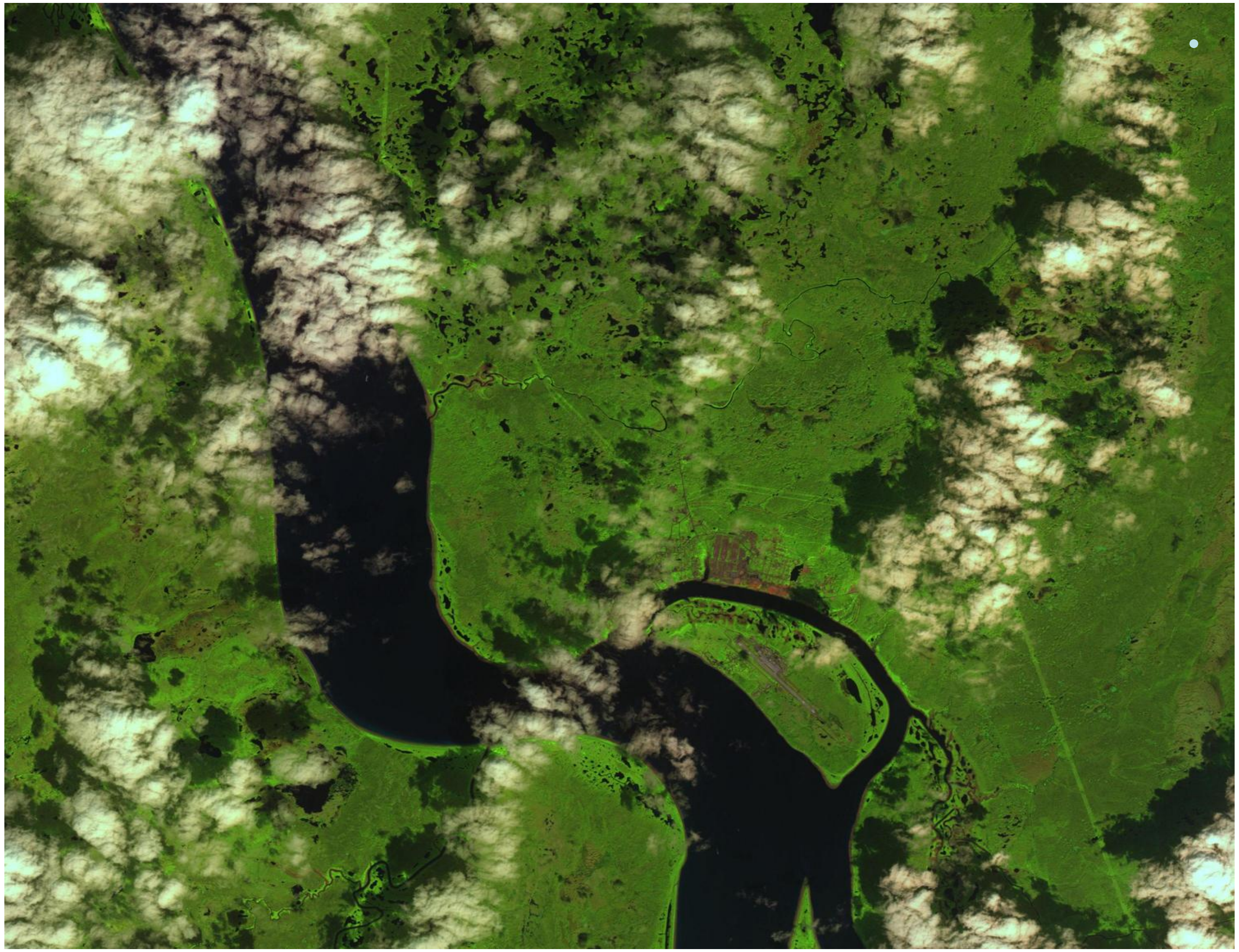

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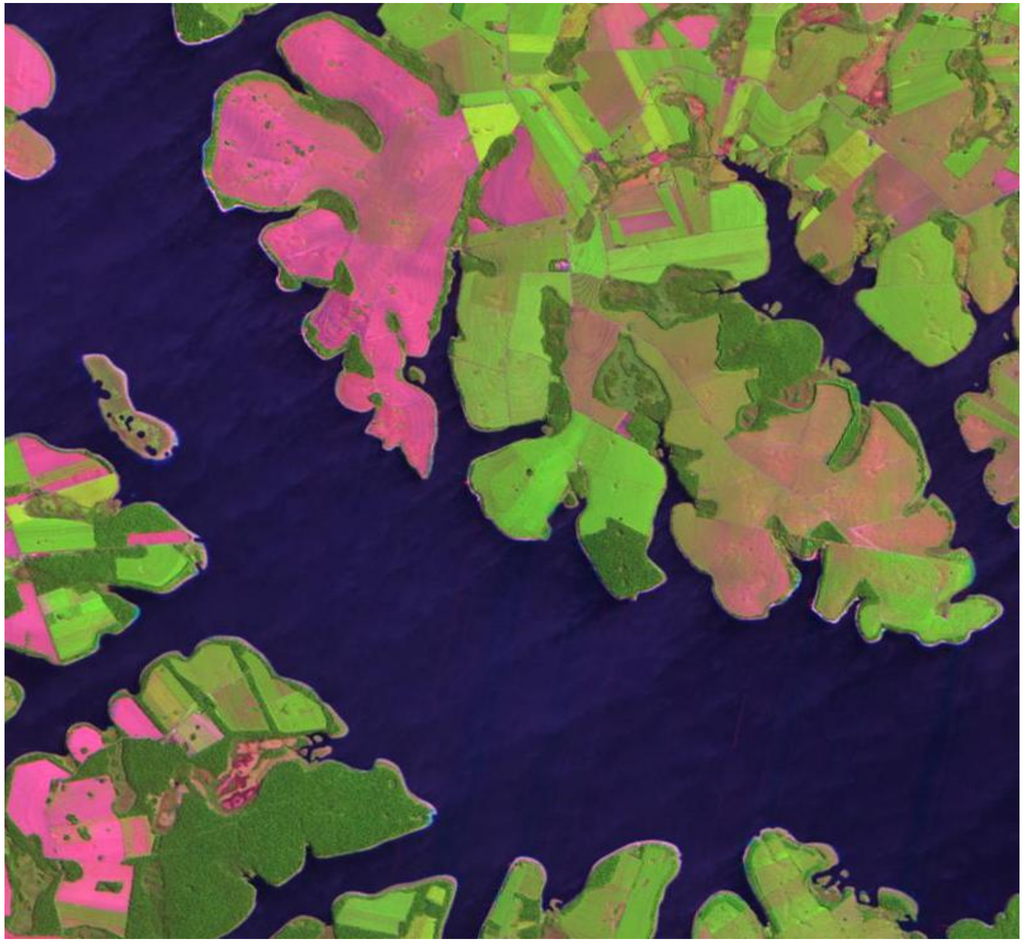
    - Land cover

Time series – Agriculture – Land cover



30 March 2013

- SPOT4 (Take5) images in Paraguay (March-April 2013)
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- Different crops are sowed at different times in the year
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  - Land Cover (crop type)
  - Farming practices monitoring
  - Biomass, Yield, Water demand

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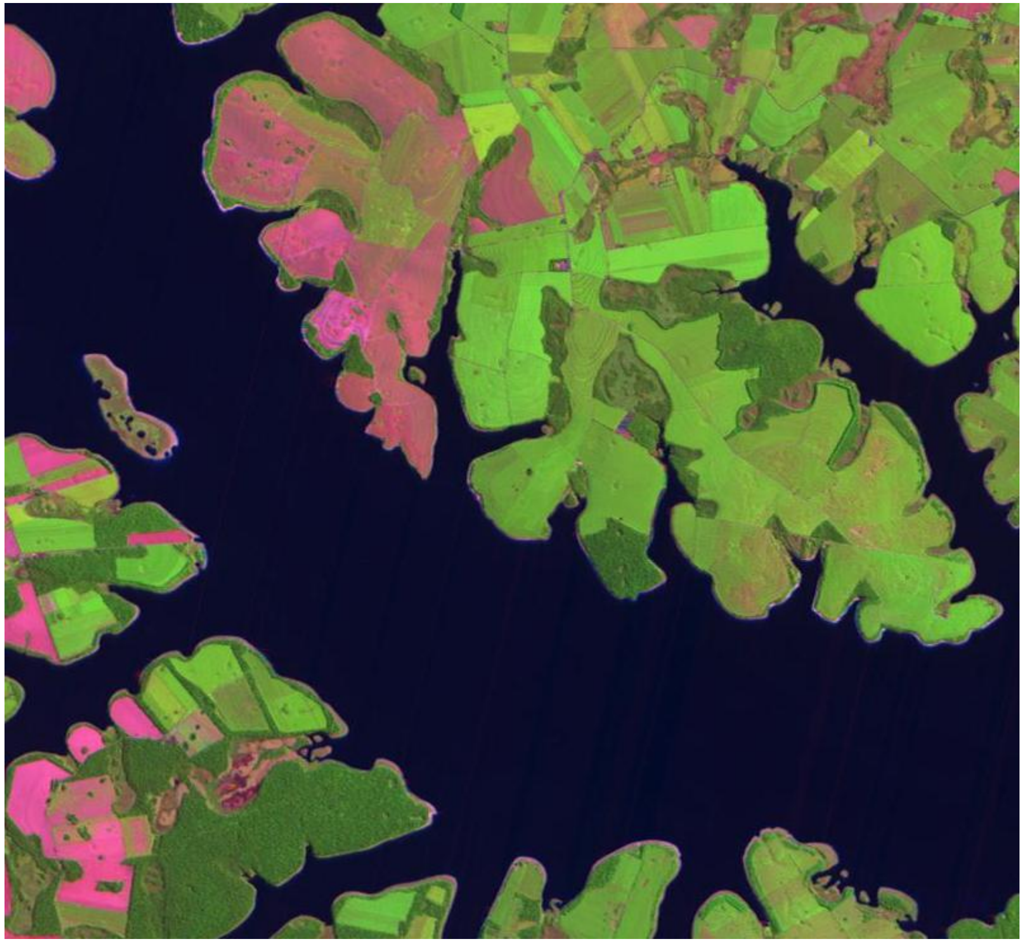

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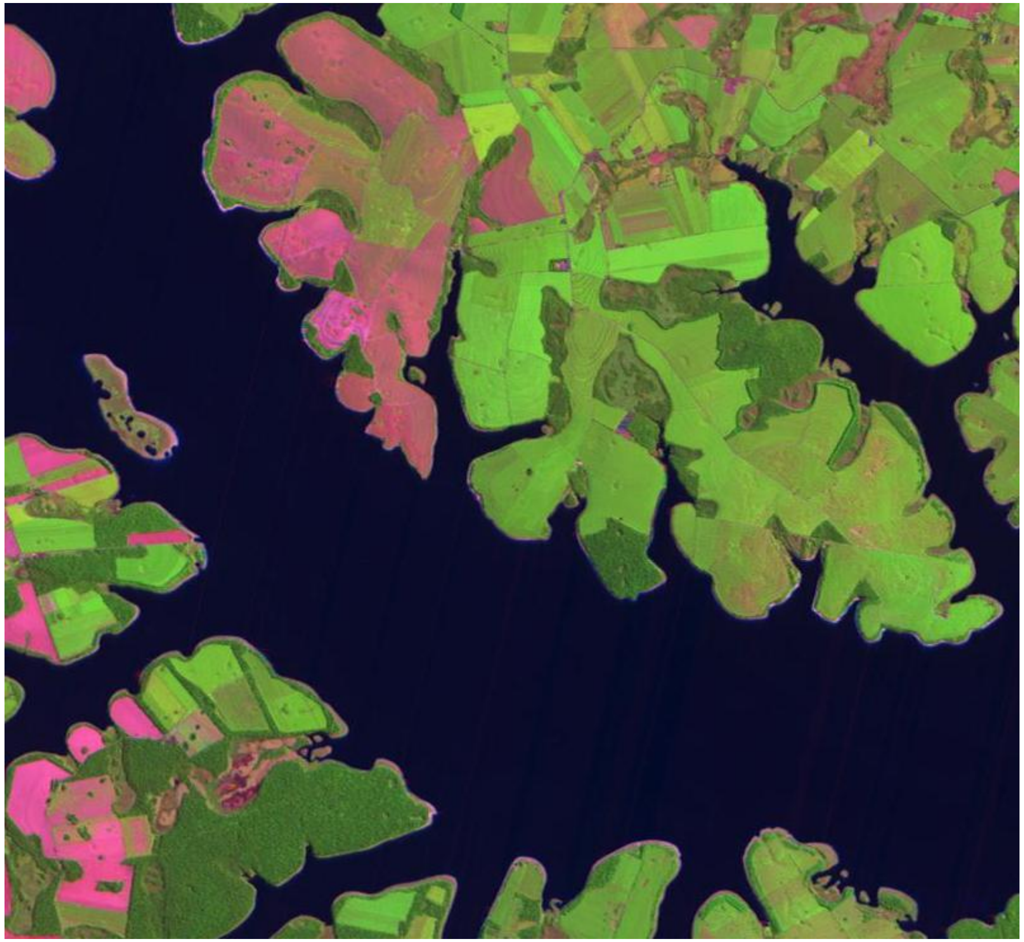

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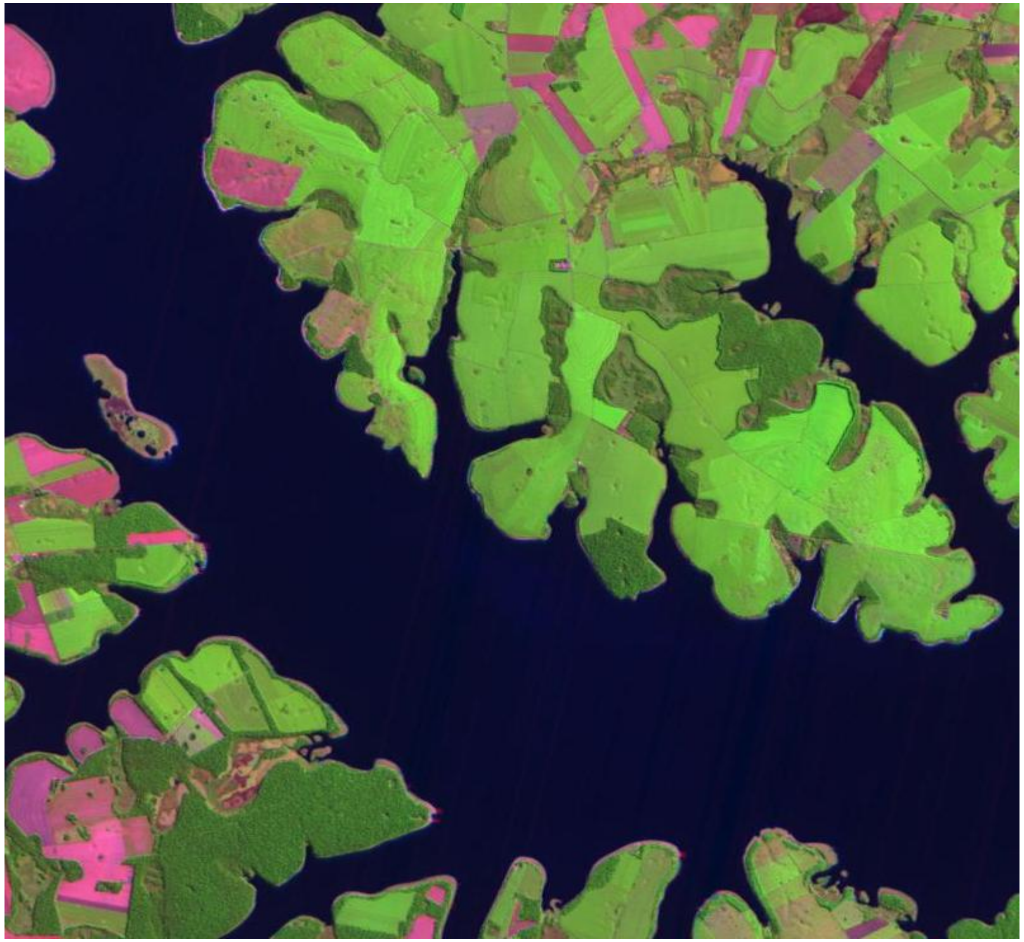

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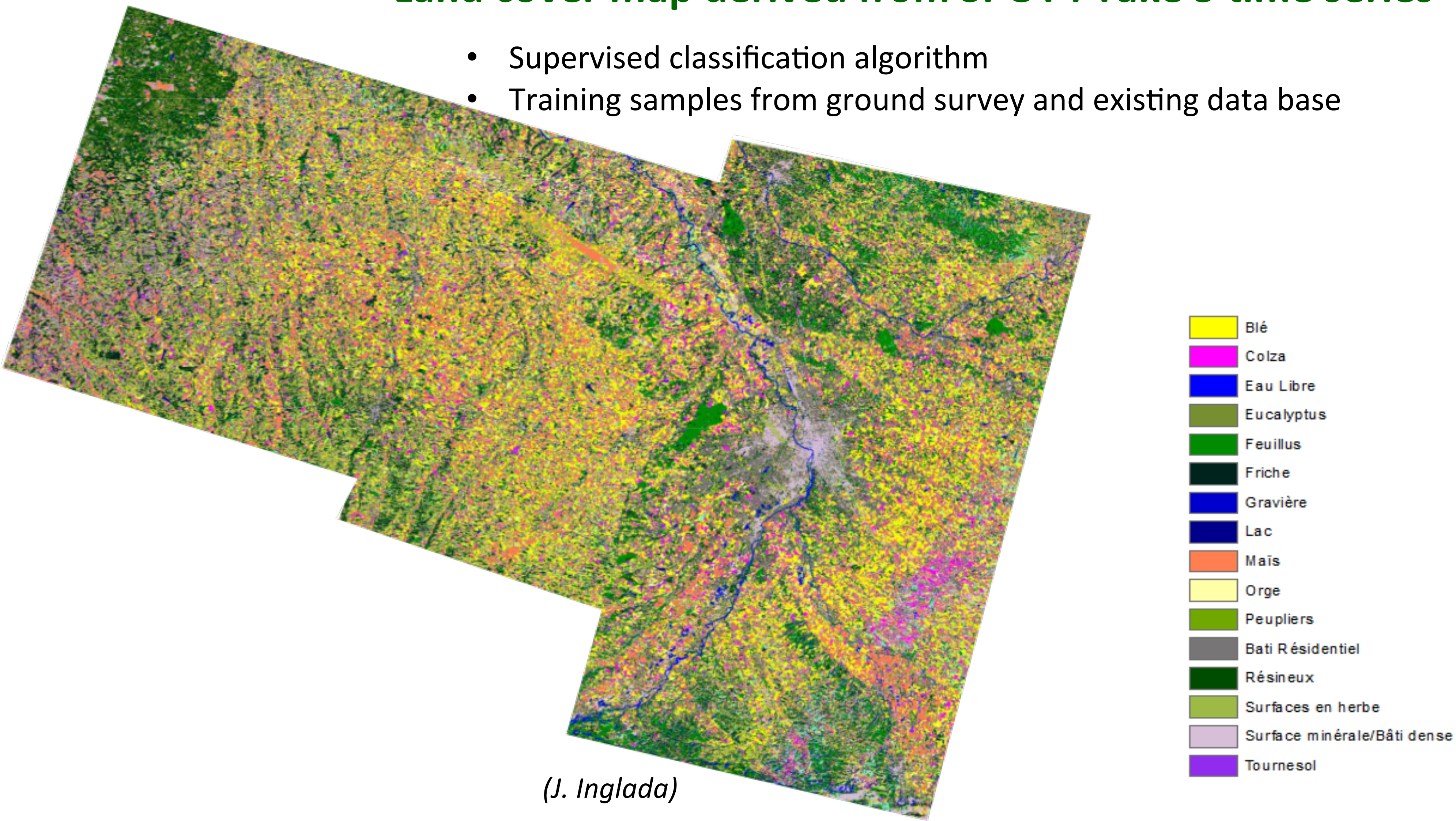
Sentinel 2: opportunities
High resolution land cover mapping over large areas

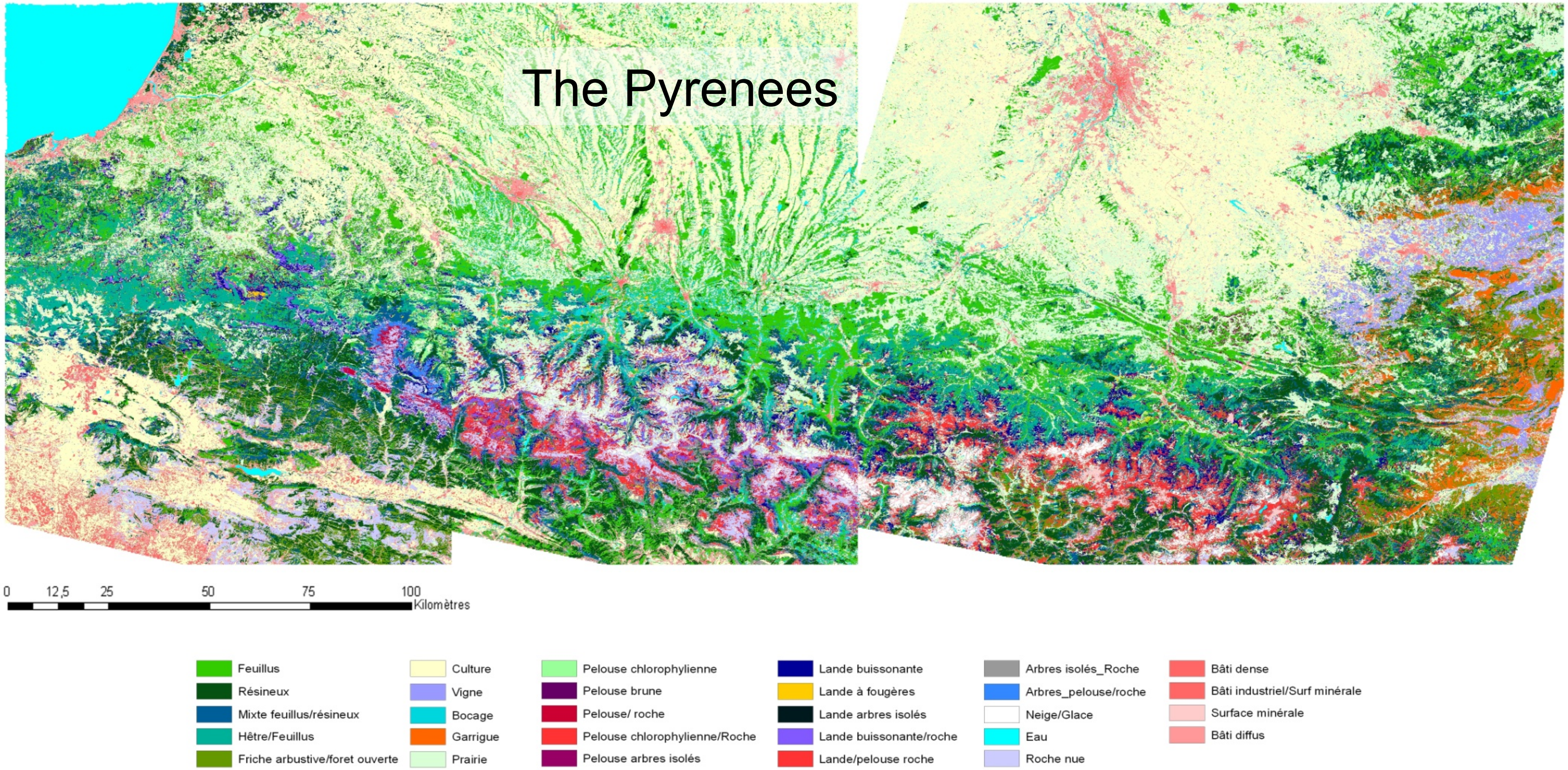
Land cover map derived from SPOT4 Take 5 time series

- Supervised classification algorithm
- Training samples from ground survey and existing data base



(J. Inglada)

Sentinel 2: opportunities
High resolution land cover mapping over large areas



Images : Landsat 5 & 7

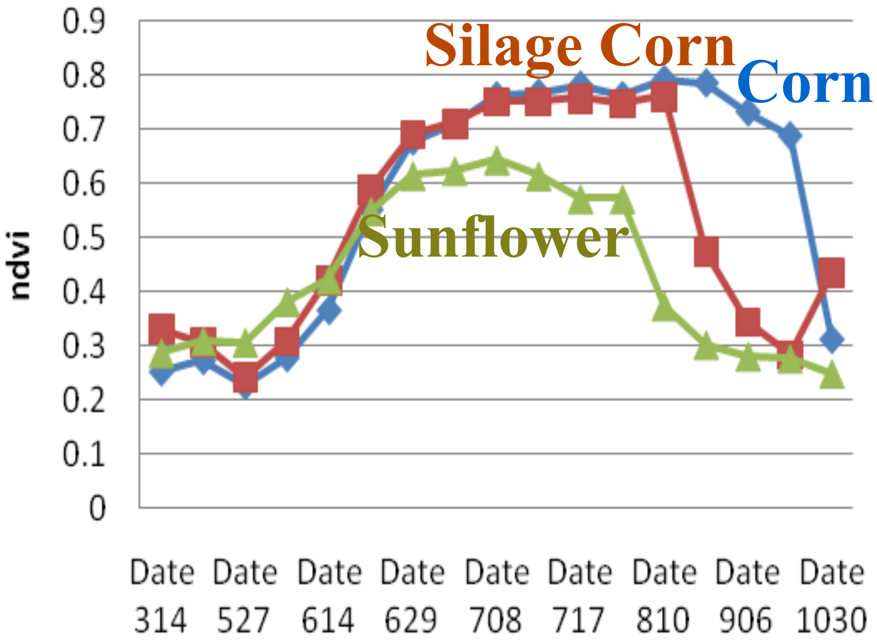
(Ducrot et al.)

D. Ducrot, A. Masse, P.Y Lecourt, R. Lagnous, J. Lacourt et M. Kadiri - (CESBIO)

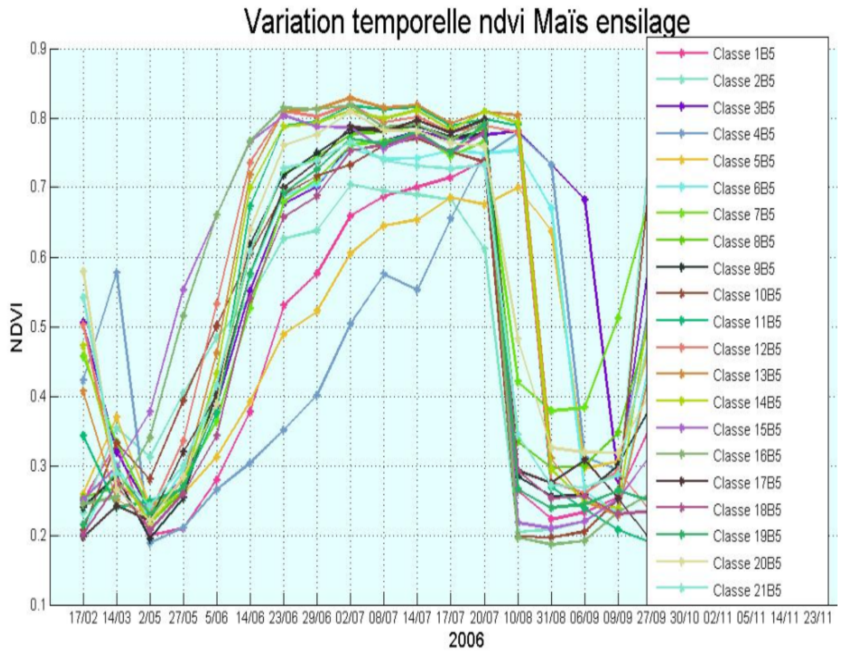
Sentinel 2: opportunities
High resolution land cover mapping over large areas

Time series allow a better accuracy and a higher number of classes

- **Solving Corn/Sunflower confusions**
- **More classes: distinction between silage and grain corns**
- **Heterogeneity of classes can be better accounted for**



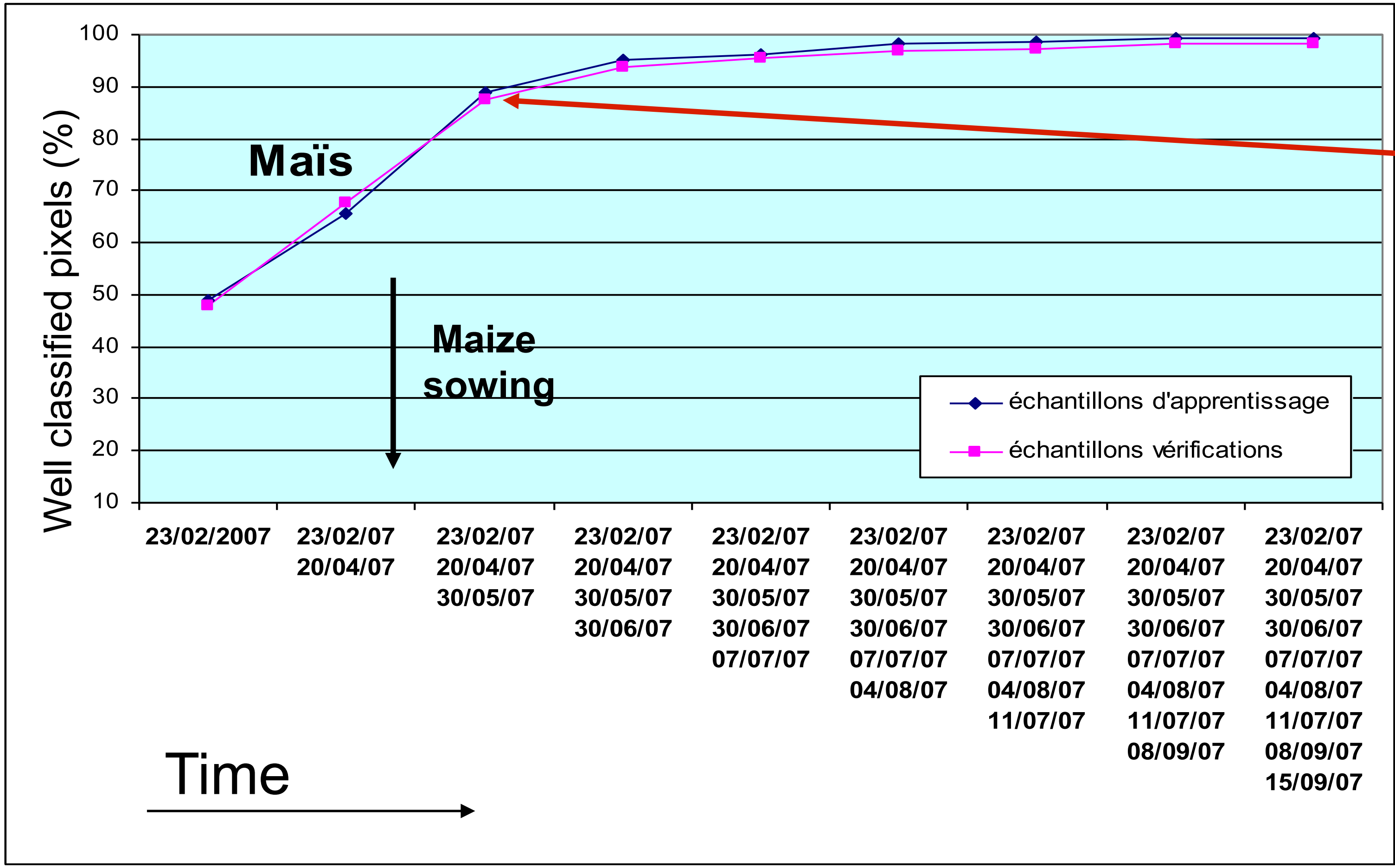
(Sicre & Dejoux)



Formosat-2 images

Sentinel 2: opportunities
Towards near real time land cover mapping

Multidate and « near real time » land cover maps using the images acquired from the start of growing Season



~monthly Spot data

In May, 90% of Maize is well classified

=> Irrigation water forecast

(Ducrot)

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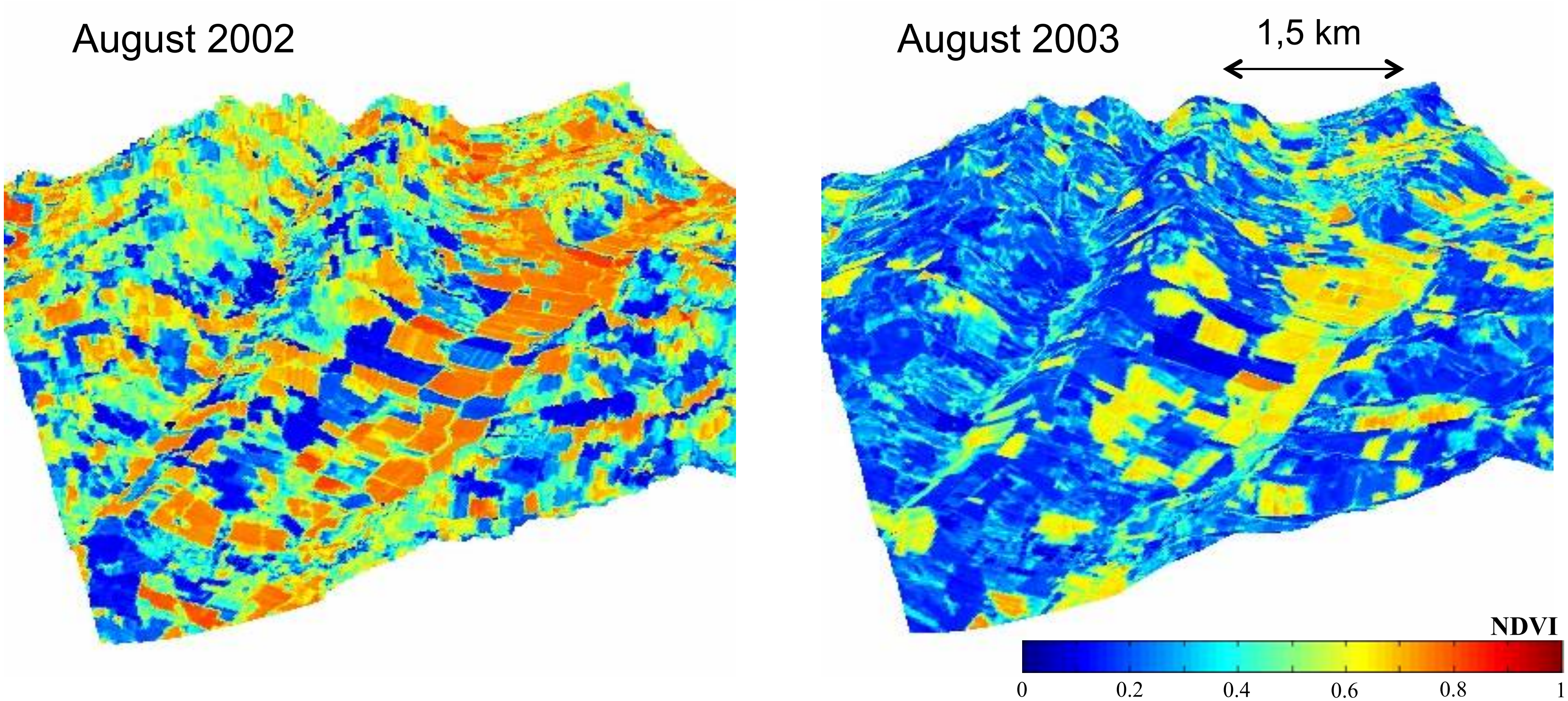
Sentinel 2: opportunities
Vegetation monitoring and weather impacts

Example: impact of the 2003’s drought and heat wave (May- late August)

SPOT Vegetation indices (2002 et 2003)



Sentinel 2: opportunities
Vegetation monitoring and weather impacts

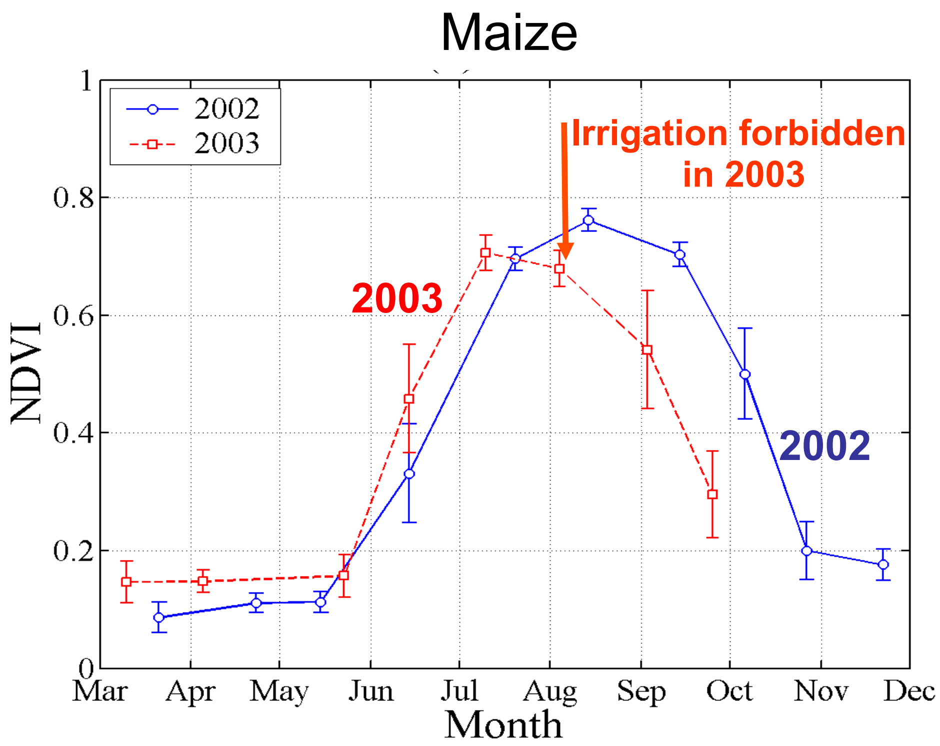
Example: impact of the 2003's drought and heat wave (May- late August)

High ground resolution (20m here) time series allow to monitor the impact of weather on specific vegetation species (maize here)

Sentinel-2 will allow more accurate and easier analysis of the impact of extreme events than when using moderate resolution sensors

On the longer term, more accurate studies of the impacts of the global changes: land cover and vegetation functioning.

Multiscale capabilities : from local to global



SPOT NDVI for corn in 2002 and 2003. Average and standard deviation for maize fields of a whole 50x50 km^2 area

(Coret et al.)

Sentinel 2: opportunities

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    - Snow and ice
    - Land cover
    - Vegetation monitoring
    - Vegetation modeling

Sentinel 2: opportunities

Frequent data can be used to drive vegetation growth model, SVATs: forcing (LAI), optimization, assimilation …

High ground resolution accounts for land cover heterogeneity and allows plant specific parameterization of the models

Leaf Area Index [m^2/m^2]

Dry Biomass [kg/m^2]

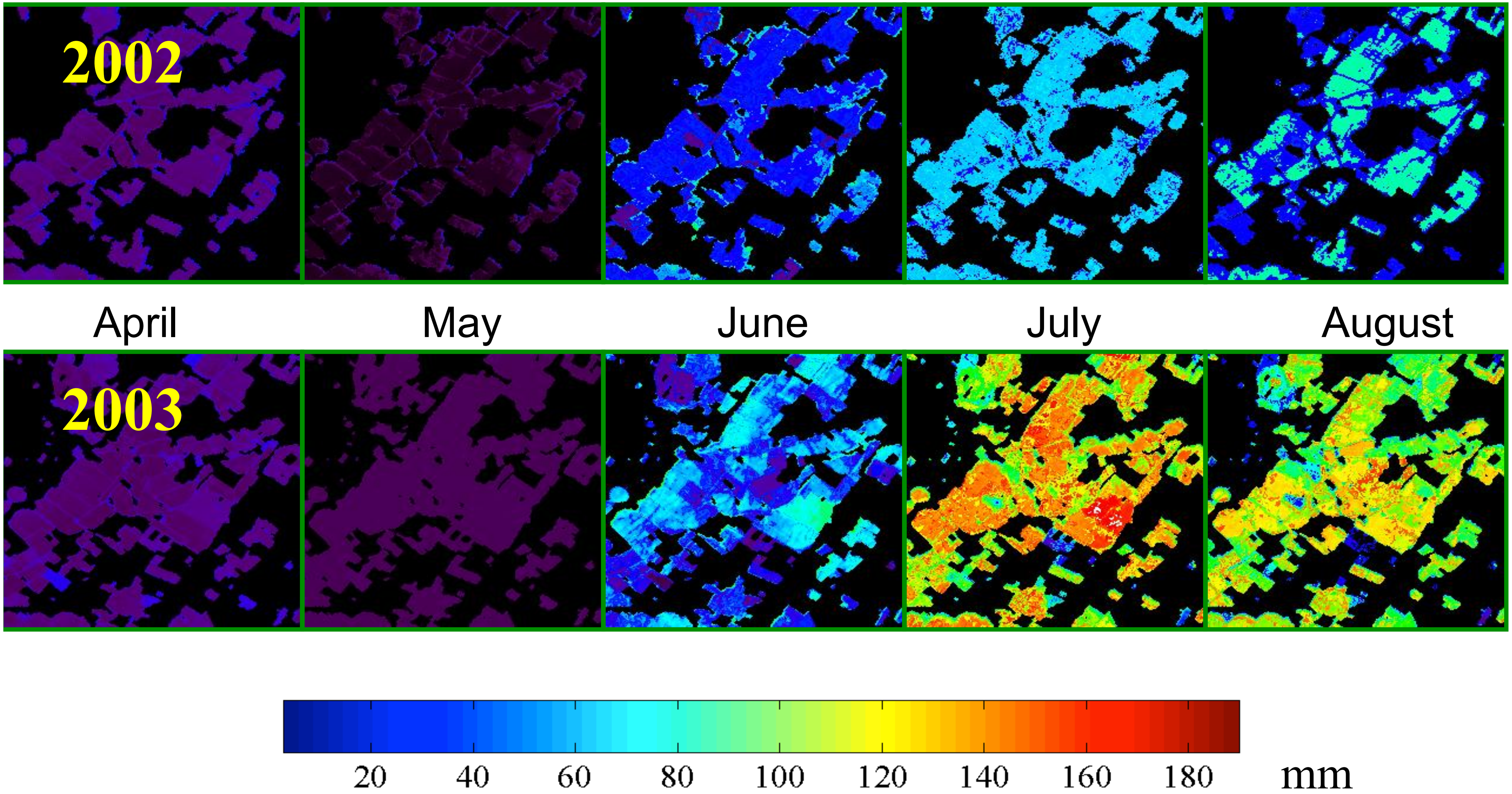
Crop growth model

(Claverie & al.)

Sentinel 2: opportunities

Monthly cumulated irrigation needs : zoom over a 5x5 km window

Frequent temporal sampling + high ground resolution: reduce the smoothing effect obtained when working with moderate ground resolution sensors



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  - **Temporal sampling of the dynamics of phenomena**
    - Snow and ice
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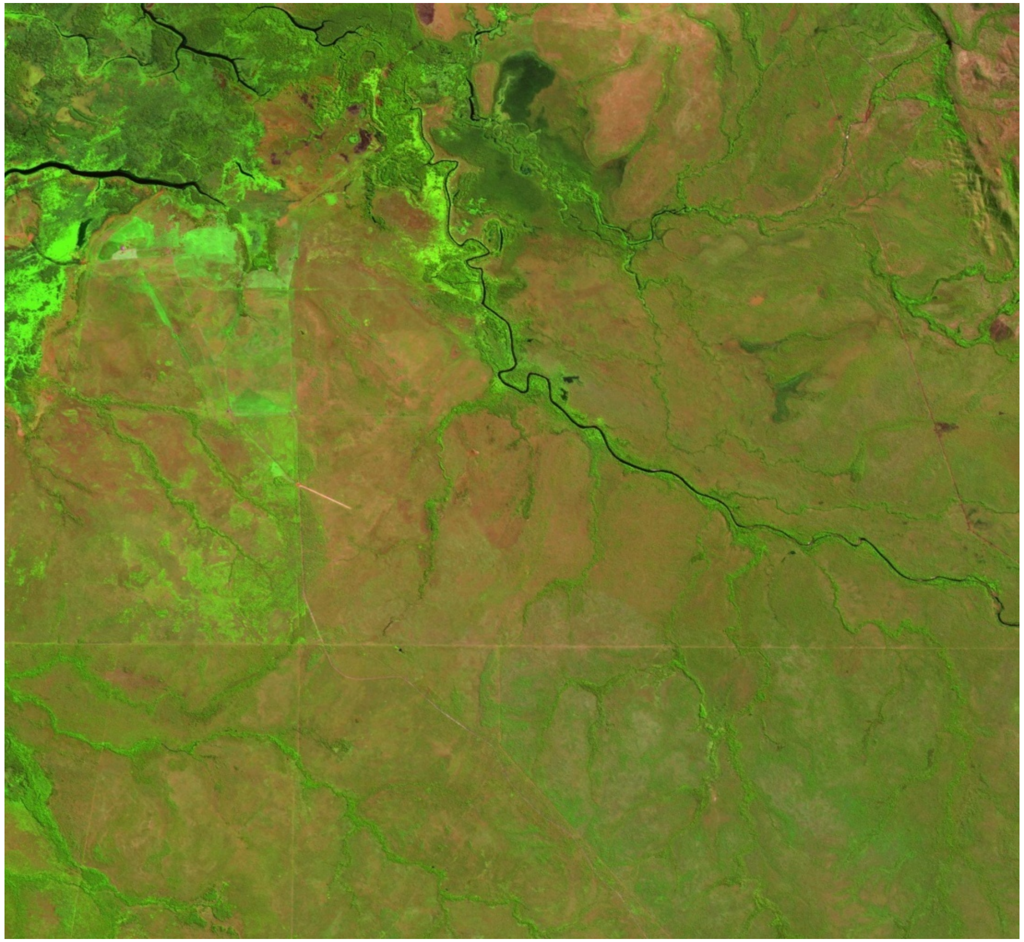
    - Vegetation monitoring
  - **Systematic acquisitions**
    - You will always have the image “before”
      - With constant view angle => less misinterpretation

Time series – Risks – Bush fires



28 April 2015

- SPOT5 (Take5) images in Australia, near Darwin (April-May 2015)
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- Time series catch the evolutions of bush fires
- A recent image before the fire is available
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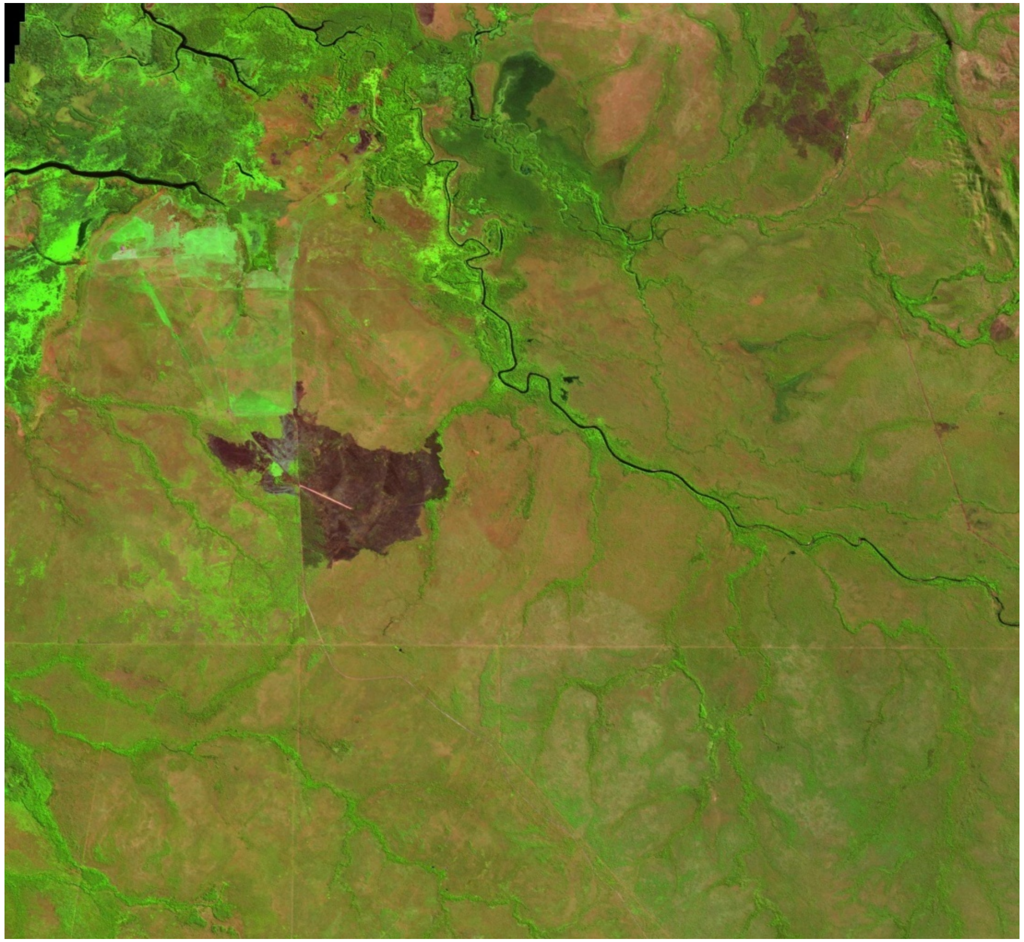
Bush fires



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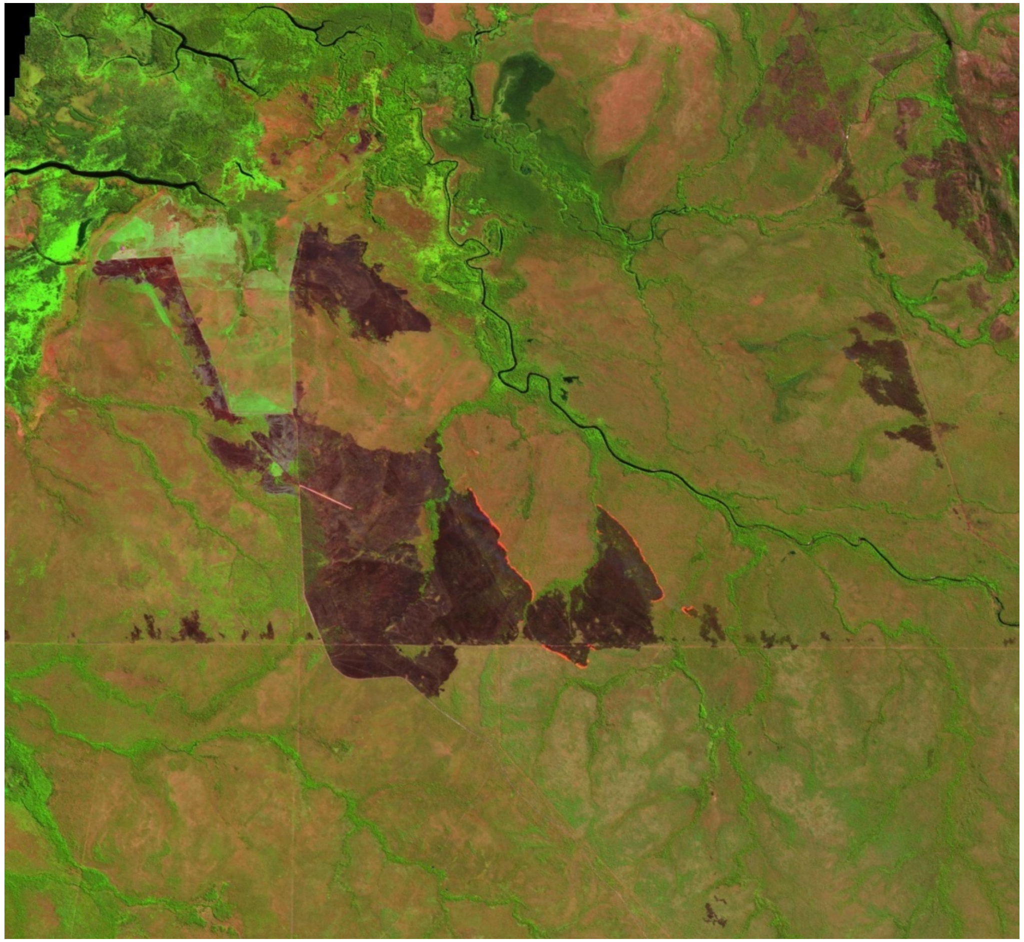

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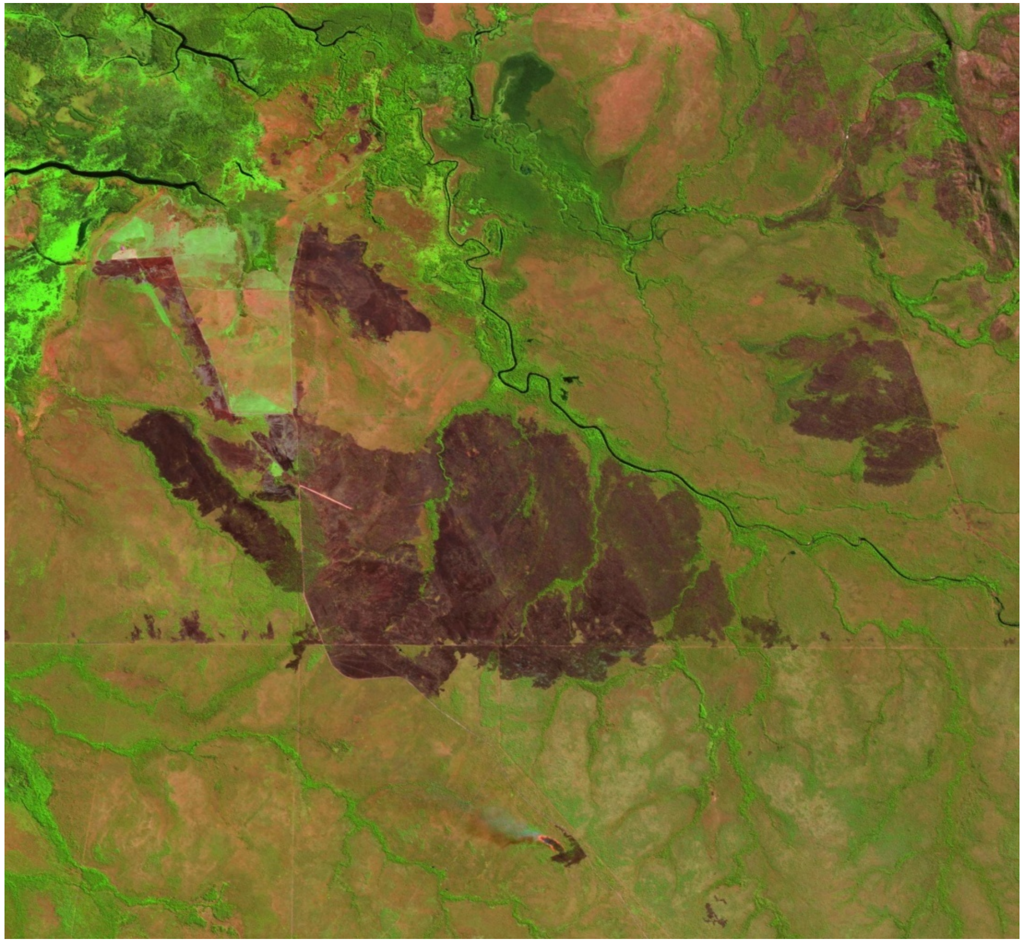

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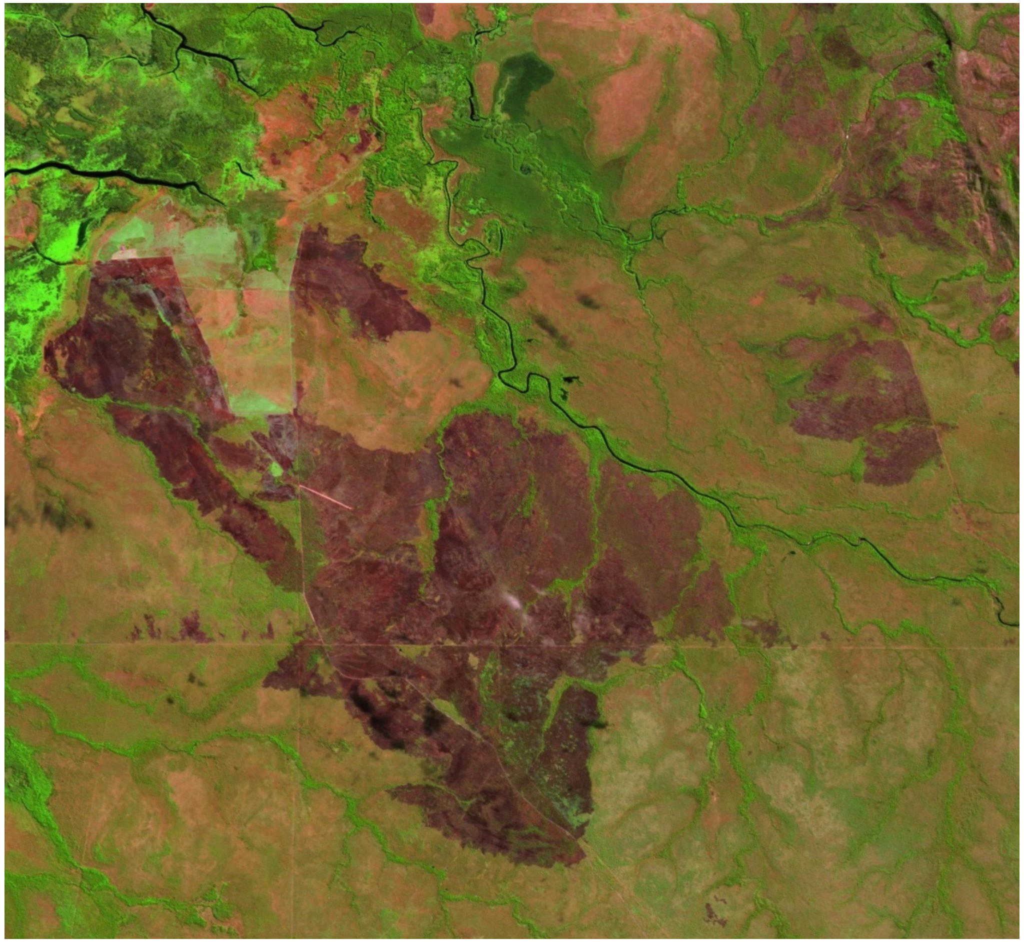

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Sentinel 2: challenges

- **Sentinel-2 makes possible a number of scientific research and applications dealing with crucial issues:**
  - Monitoring of changes: land cover, land use, vegetation functioning (phenology, productivity)
  - Water and carbon fluxes
  - Impacts of global changes on land, cryosphere and water (inland and coastal waters, estuaries) processes
  - Agriculture: sustainable increase of food production to cope with increased population.
  - Management of natural ressources: water, forests, grasslands, soils, …

- **Is the availability of Sentinel-2 data sufficient to answer all the questions we have ? Certainly not.**

What, as scientists, shall we do to get the best of these data ?

What priorities should we assign to ourselves ?

Sentinel 2: challenges

- A number of issues are global issues whose solution requires
  - International incentives or regulations
  - but actions at local, regional or national scales

  For instance: Kyoto protocol, EU water directive, food production challenge, …

- 1st challenge for the scientists :
  - Develop algorithms and methods able to exploit Sentinel 2 (and other as needed) for producing reliable results at local, regional, country and global scales
  - Easy to produce excellent results on a stamp, more difficult at country level (but we still need studies on a stamp)

Sentinel 2: challenges

- **Example : high resolution land cover mapping of whole countries**
  - **Needed by a number of applications :**
    - Monitoring of land consumption by cities, roads,
    - Deforestation/reforestation
    - Agricultural statistics
    - Input of various models: atmospheric meso-scale, hydrology, biodiversity, carbon/ CO_2
    - Impact of extreme events
    - Monitoring changes
    - ….

Sentinel 2: challenges

- **Example : land cover mapping at country scale**

- **Challenges for scientists:**
  - Which land cover classes ?
  - Supervised or unsupervised classification ?
  - How can we get the training samples ? How can we validate the results ? How could we mutualize the large amount of in situ data collected every year ?
  - How can we manage the classification process over a country : different dates (e.g. cloudiness), different number of images (more in Marseille than in Lille), directional effects on the edges, the need to automatise (no way to choose only the clear images)
  - How to produce NRT land cover maps ?
  - How to manage the data, and especially the in-situ data, in order to reprocess the full archive in 10 year, 20 years, 100 years … ?
  - Who should operate the algorithms we produced ? Which property of the results ? Who pays ?
  - How do we involve users ?

Sentinel 2: challenges

- **1st challenge**
  - Develop algorithms and methods able to exploit Sentinel 2 (and other as needed) for producing reliable results at local, regional, country and global scales

- **How can we produce reliable results ?**

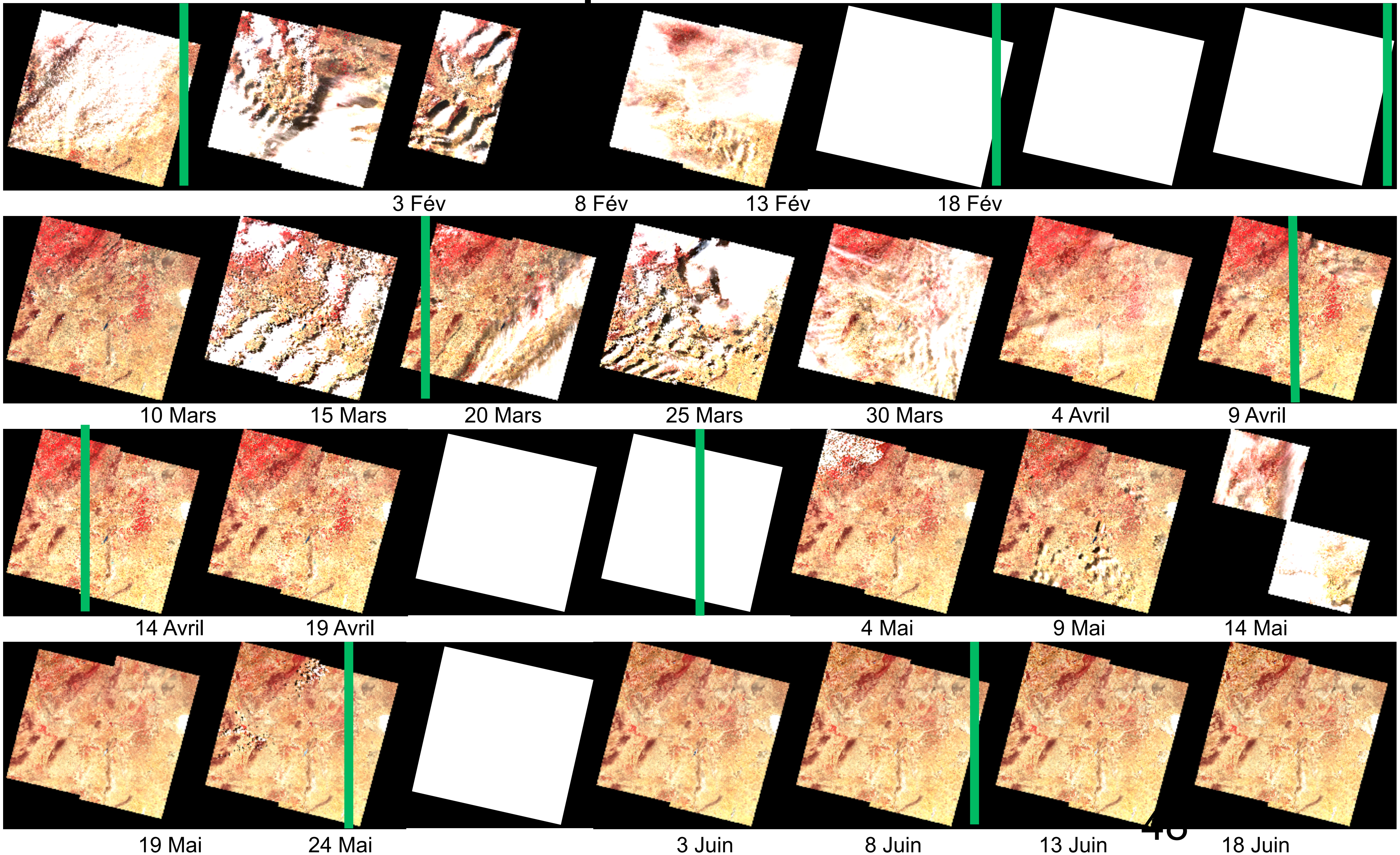
  - **What makes results unreliable ?**

    - Insufficient image quality : work on atmospheric corrections for instance
    - Insufficient temporal sampling

TUNISIA : SPOT4 (Take Five experiment) and clear SPOT5 acquisitions

Lepage et al., 2013

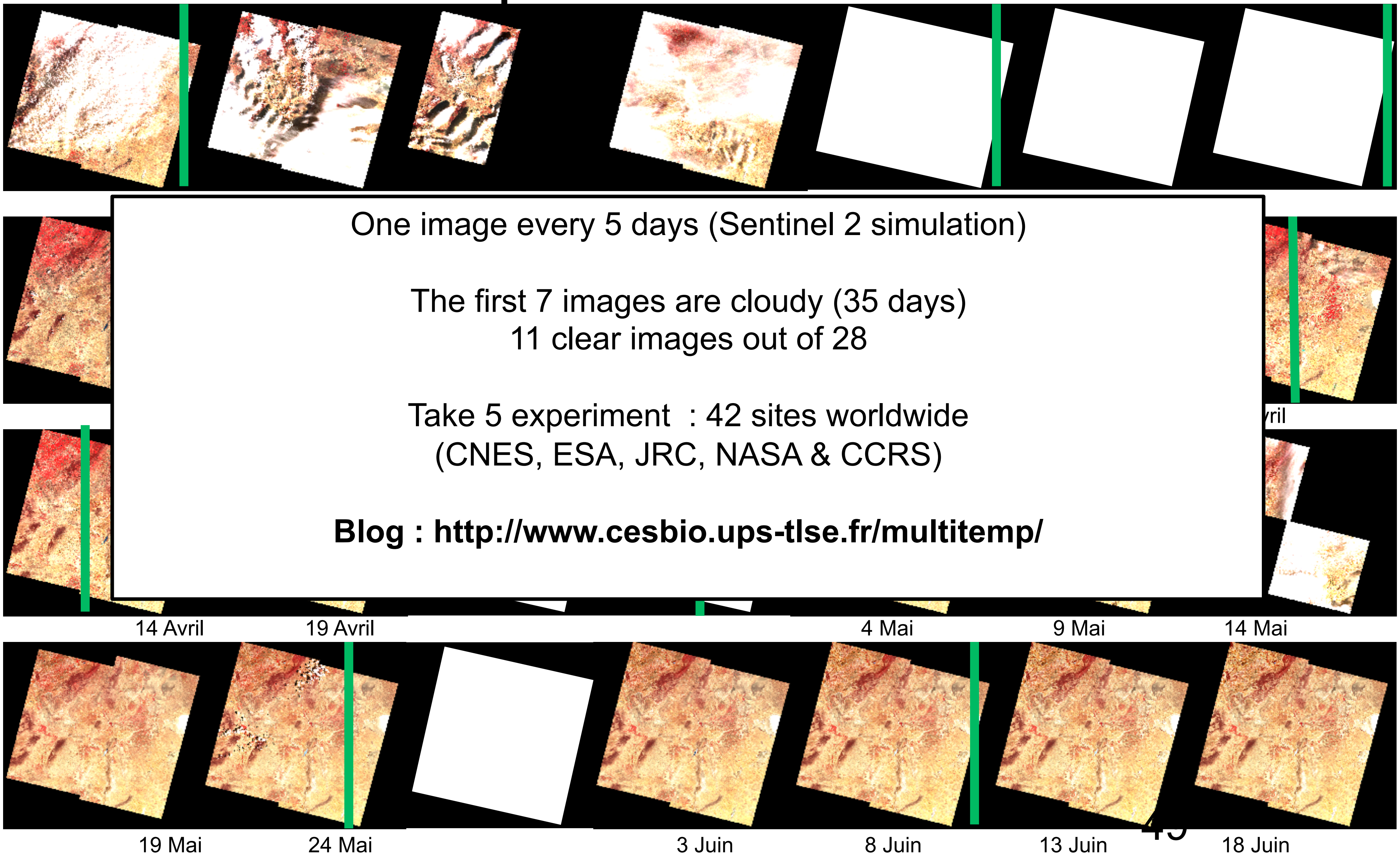
SPOT 5 = Green bars



SPOT4 (Take Five experiment) and clear SPOT5 acquisitions

Lepage et al., 2013

SPOT 5 = Green bars



One image every 5 days (Sentinel 2 simulation)

The first 7 images are cloudy (35 days)
11 clear images out of 28

Take 5 experiment : 42 sites worldwide
(CNES, ESA, JRC, NASA & CCRS)

Blog : http://www.cesbio.ups-tlse.fr/multitemp/

Sentinel 2: challenges

- **1st challenge**
  - **Develop algorithms and methods able to exploit Sentinel 2 (and other as needed) for producing reliable results at local, regional, country and global scales**

- **How can we produce reliable results ?**
- **What makes results/services unreliable ?**
  - **Insufficient image quality : work on atmospheric corrections for instance**
  - **Insufficient temporal sampling due to cloudiness or to the intrinsic revisit of S2**
    - Addition of Landsat, SPOT, … data : probably not sufficient at country scale
    - Development of methods to combine Sentinel 2 and radar (Sentinel 1)
    - Combination of Sentinel 2 with Sentinel 3 (SUOMI NPP/VIIRS, ProbaV…)
    - Development of data assimilation within process models
      - Provides all the information we need and which cannot be observed from space (e.g. grain yield)
      - Provides information even if there is no satellite data available

Interest of radar

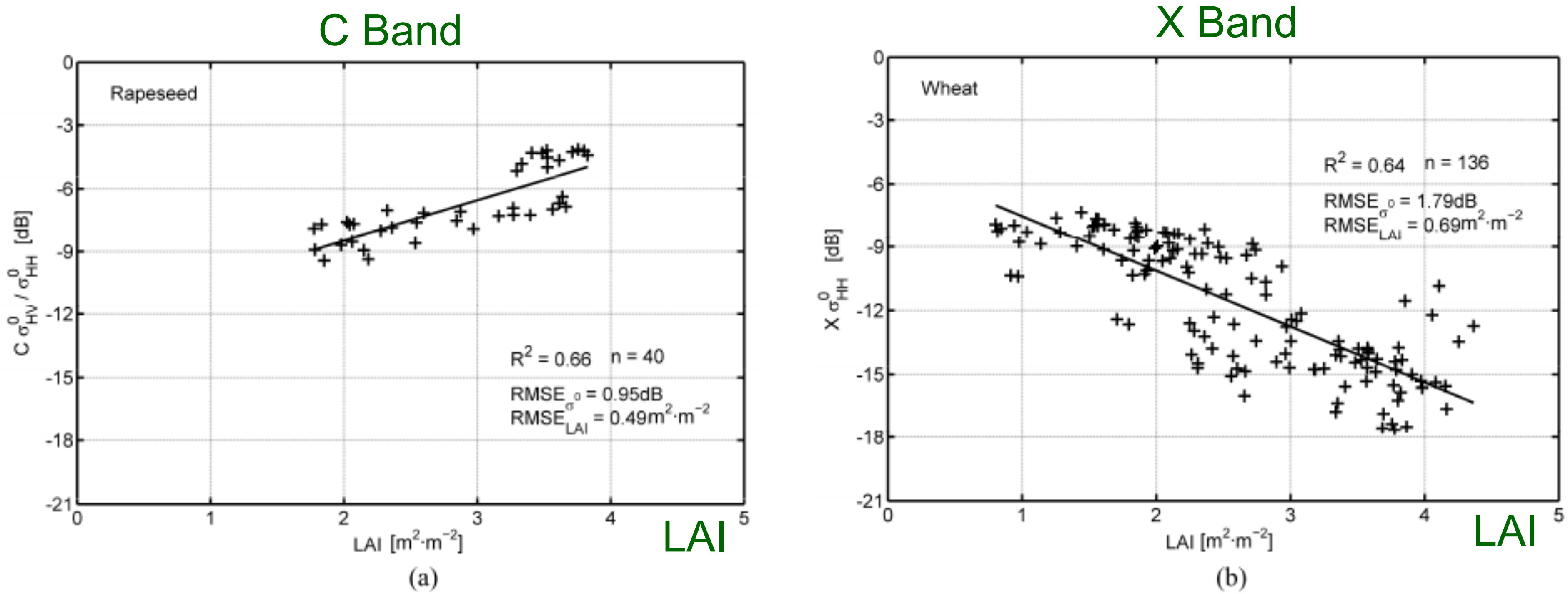
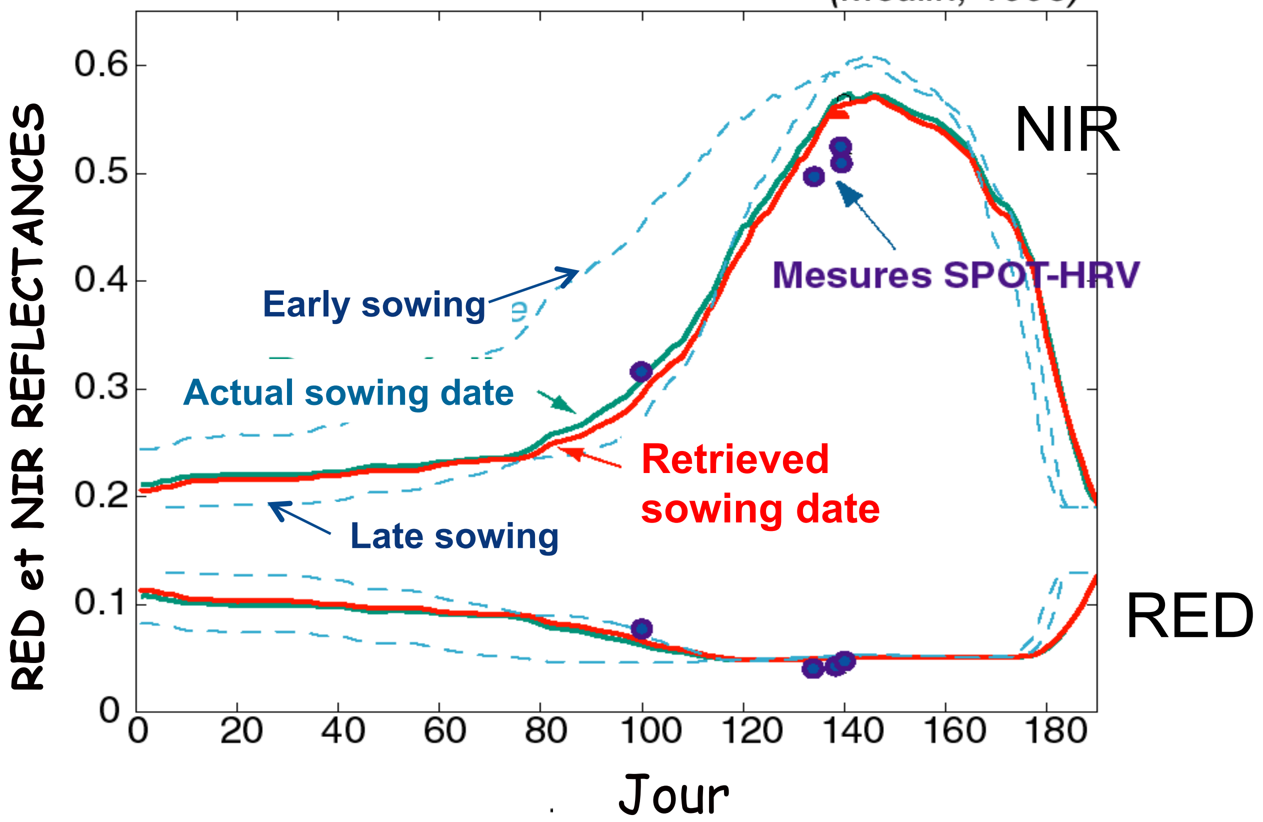


Figure 12. Examples of empirical relationships obtained during the growing period between the $\sigma^0_{C\text{-}HV/HH}$ and LAI of rapeseed (a) and between the $\sigma^0_{X\text{-}HH}$ and LAI of wheat (b).

(Fieuzal et al., Advances in Remote Sensing, 2013, 2, 162-180)

Retrieval of the sowing date of wheat by assimilation of SPOT data in a wheat growth model

(Moulin, 1995)



Conclusion

- **Sentinel 2 : a number of opportunities for science and application**
  - Land cover mapping : large area, improved accuracy, frequent updates are now possible
  - Modeling of land surface processes, e.g. for water management

- **But still a number of challenging issues (fortunately for scientists)**
  - Preprocessing algorithms need to be assessed and improved : cloud/shadow/ snow identification, atmospheric effects correction, BRDF
  - Combined use of optical (Sentinel-2, S3) and radar (Sentinel-1) to get more robust results/services
  - Assimilation within process models

Conclusion

- Sentinel 2 fulfil one of the Recommendations of the "Workshop on Developing a Strategy for Global Agricultural Monitoring in the framework of Group on Earth Observations (GEO), 16-18 July 2007, FAO, Rome" :

  - Within the next 5 to 10 years, the space agencies should develop and implement the next generation of operational moderate resolution sensing systems, working in concert to provide **a truly integrated system, acquiring and providing global coverage of 60-10m cloud free imagery every 5-10 days**

- Still some work ahead us :

  - The international space agencies should give increased attention to demonstrating and exploiting the capability of fine resolution data from **thermal** and ***microwave*** sensors for agricultural monitoring and their **combination** with data from optical sensors.

http://www.earthobservations.org/documents/cop/ag_gams/200707_01/20070716_geo_igol_ag_workshop_report.pdf

Sentinel 2: conclusion

What, as scientists, shall we do to get the best of these data ?

Why should we get the best of these data ?

Sentinel 2: conclusion

What, as scientists, shall we do to get the best of these data ?

Why should we get the best of these data ?

=> To save humanity

Sentinel 2: conclusion

What, as scientists, shall we do to get the best of these data ?

Why should we get the best of these data ?

⇒ To save humanity

⇒ and to be allowed to keep playing with our marvelous toys and to get new ones


Thank you for your attention