A follow-up for Sentinel-2: Sentinel for Global Agriculture Requirements

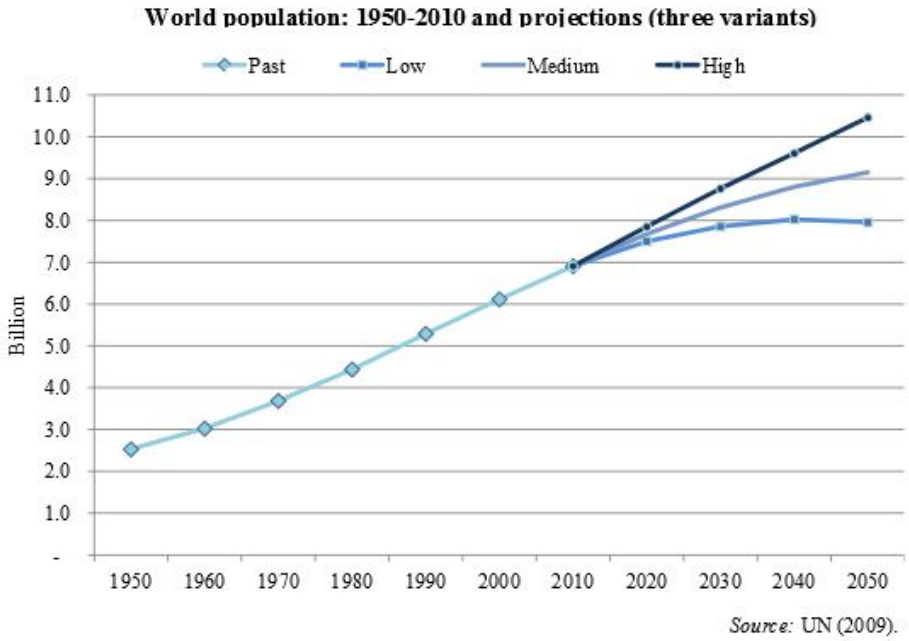
Gérard DEDIEU and Olivier HAGOLLE
CESBIO/CNES

Jean-Claude SOUYRIS
CNES

Toulouse, France

gerard.dedieu@cesbio.cnes.fr

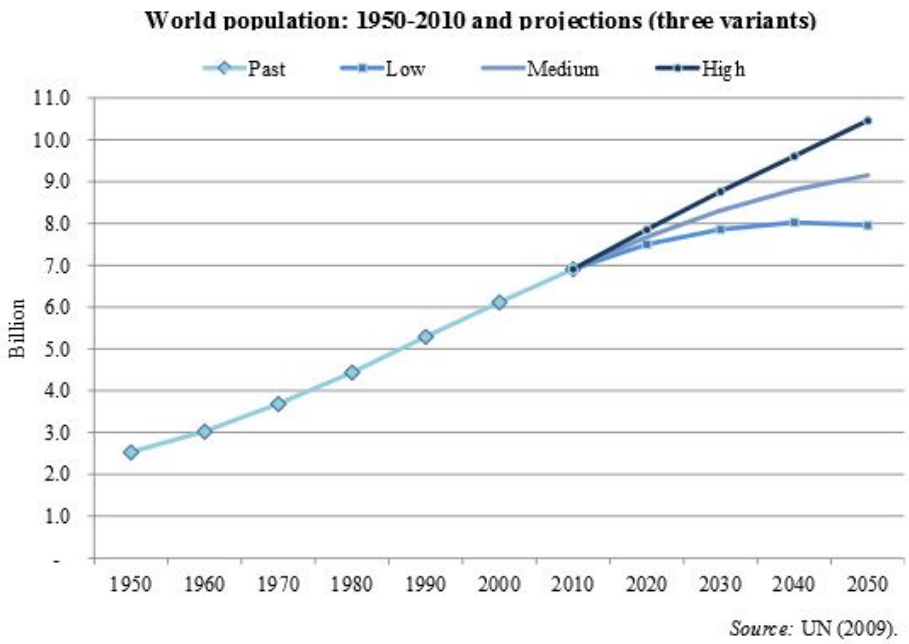
Agriculture and Food production : prospect

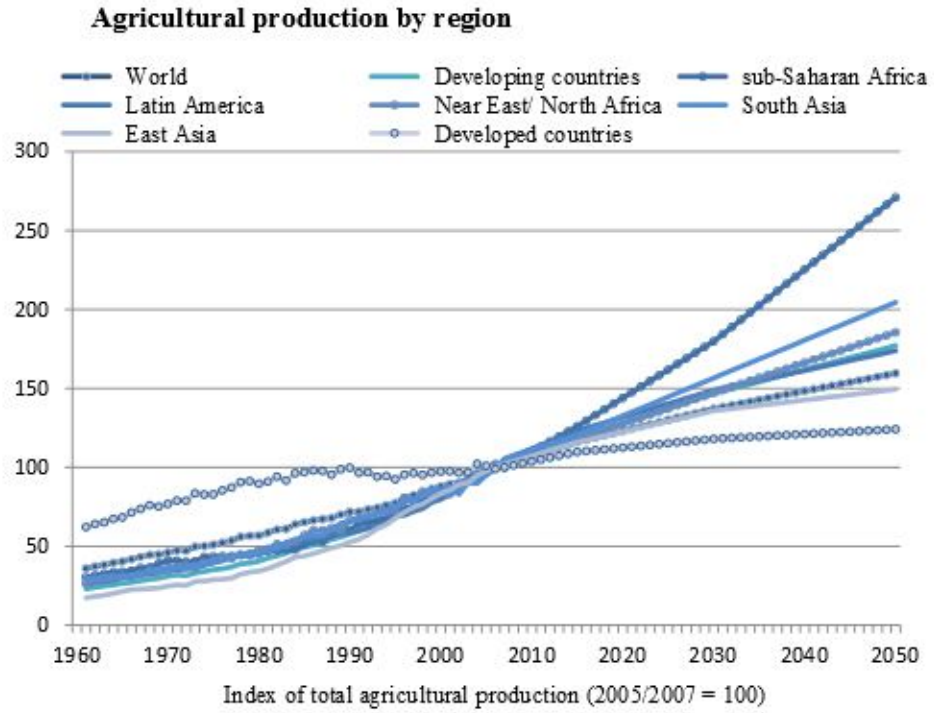


World population

- 6.9 billion in 2010 (827 million undernourished)
- 9.15 billion in 2050

Agriculture and Food production : prospect





World population

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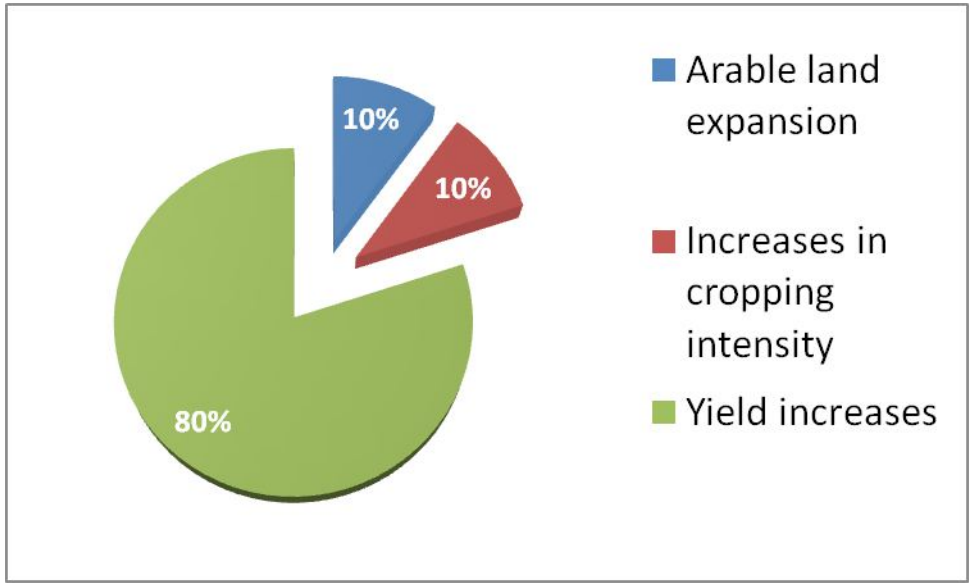
- 9.15 billion in 2050

annual world agricultural production would need to increase by some 60 %from 2005/2007 to 2050
77 % in developing countries
+ 24 percent increase in developed countries (+15% per capita)

Agriculture and Food production : prospect

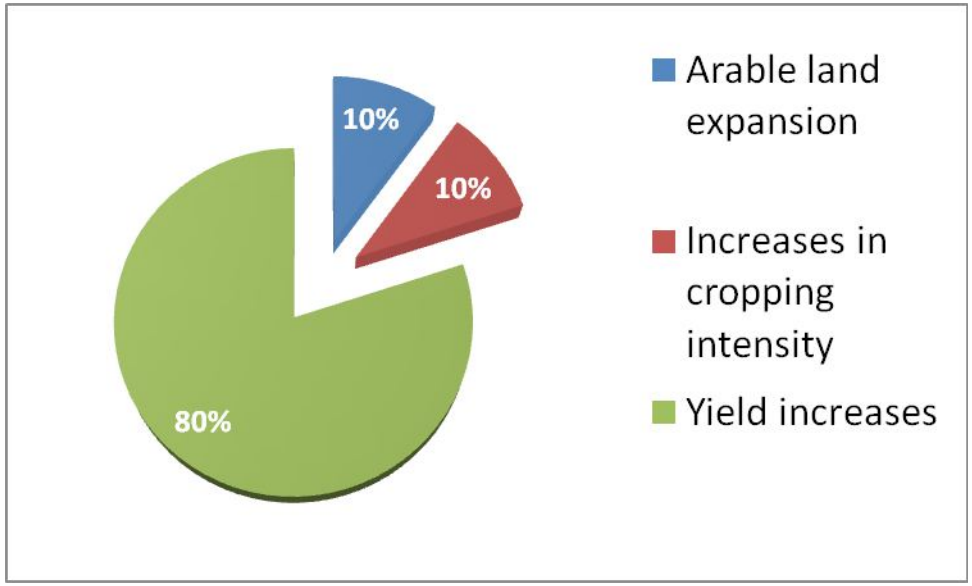
Sources of growth in crop production (percent)

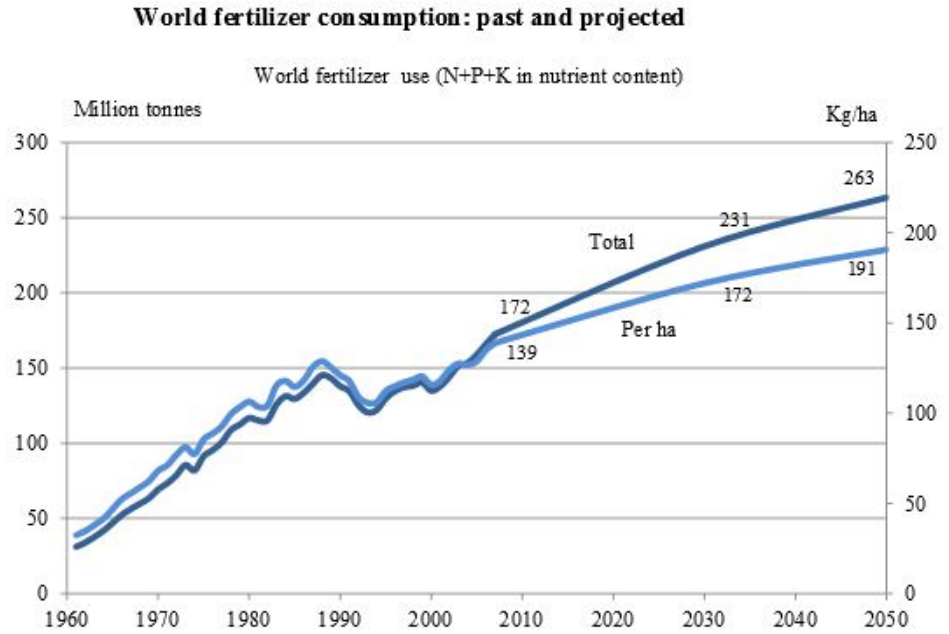


(cropping intensity: the ratio of harvested area to arable land)

Agriculture and Food production : the challenge

Sources of growth in crop production (percent)





Agriculture and Food production : the challenge

- Increase of food production (and reduction of waste and loss)
- Adaptation to climate change (and contribution to mitigation)
- Reduction of environmental impacts
  - Fertilizer pollution, soil degradation, unsustainable water use, biodiversity erosion, …
- Reduction of the volatility of commodity prices
- Improvement of food « quality » (traceability, organic products, …)

Agriculture and Food production : the challenge for EO

Which Earth Observation system could contribute to address the agri-food challenge ?

For now :

- **Medium resolution sensors (MODIS, VEGETATION, Proba-V, …)**
- **+ Landsat, SPOT, RapidEye, Deimos 1, ….**

In the near future

- **Sentinel 1, 2,**

⇒operational service mainly oriented towards global commodities market and crisis management :

Ex: FAS (USA), CropWatch (China), MARS (Europe), GIEWS (FAO), …

http://bookshop.europa.eu/fr/global-agriculture-monitoring-pbLB3010456/
http://earthobservations.org/cop_ag_gams.shtml

Agriculture and Food production : the challenge

- Increase of food production (and reduction of waste and loss)
- Adaptation to climate change (and contribution to mitigation)
- Reduction of environmental impacts
- Reduction of the volatility of commodity prices
- Improvement of food « quality » (traceability, organic products, …)
- Reduction of the volatility of **commodity prices**

Concepts to cope with these challenges

Sustainable agriculture which exploit ecosystem functionalities

- Doubly green revolution (Griffo, 1996, Conway, 1997)
- Agroecology (Gliessman, 1998)
- Ecologically intensive agriculture (Griffon 2010)
- …

Technical answers

- e.g. genetically modified organism (GMO)

Agriculture and Food production : the challenge for EO

Are the current and planed missions sufficient to address the agri-food challenge ?

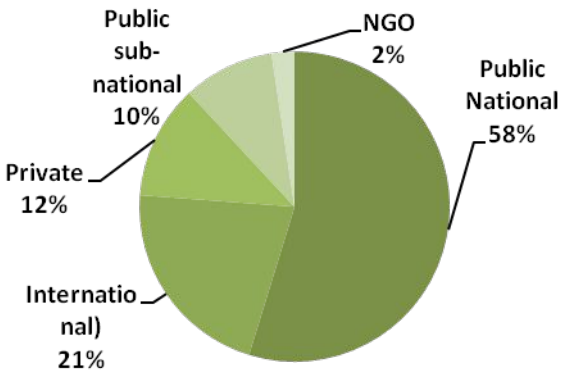
For which users ?

- **Markets and crisis management : Traders, GEOGLAM, WFP**
- **Tactical management : precision farming, water management**
- **Strategic management : new cropping systems, soil restoration, pest control, water resources, …**
- **Research : from fundamental processess to operational models**

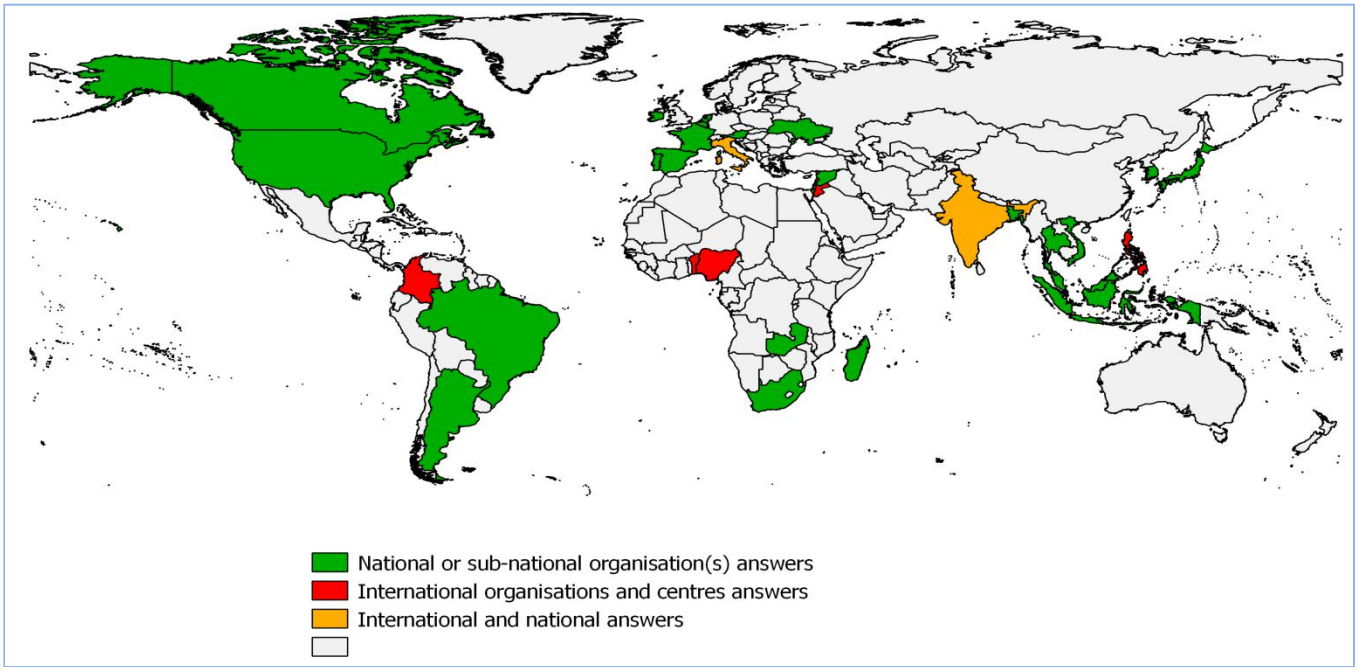
sentinel-2

→ AGRICULTURE

User requirement survey



On May 18th, 2014, the questionnaire was filed up by 42 people



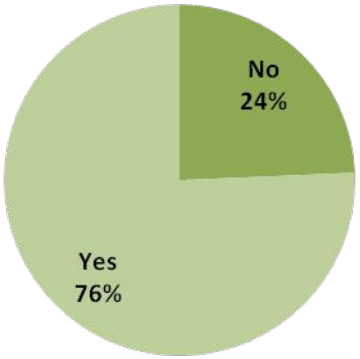
Geographic distribution of the answers to the questionnaire (for some countries, several answers were received)

sentinel-2

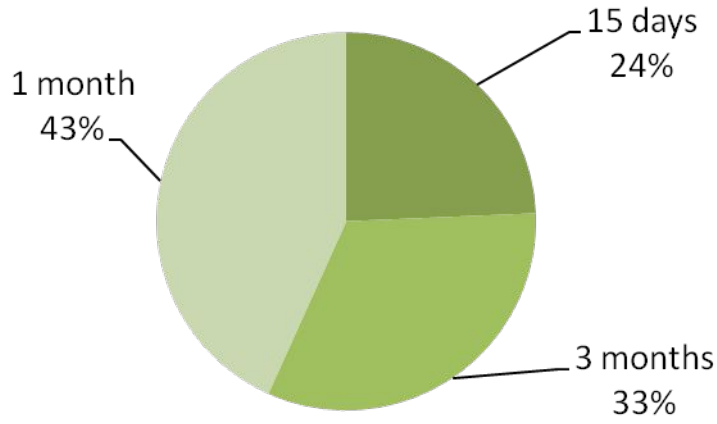
→ AGRICULTURE

Crop type map

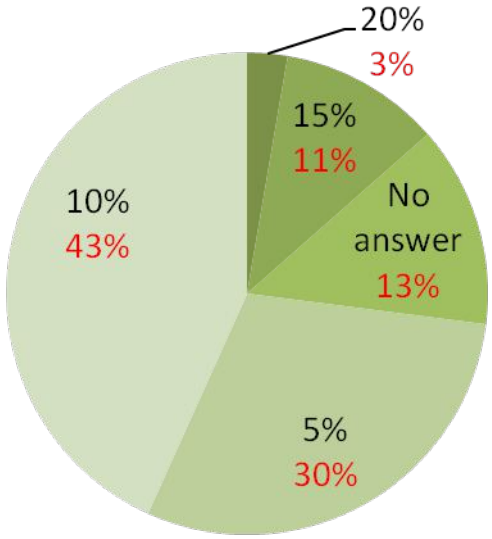
Suitability of a yearly delivery at the end of the season



Best update frequency



Thematic accuracy : maximum acceptable error on the crop type area (in red, the percentage of answers for each proposed accurac y level: 5%, 10%, 15%, 20%)

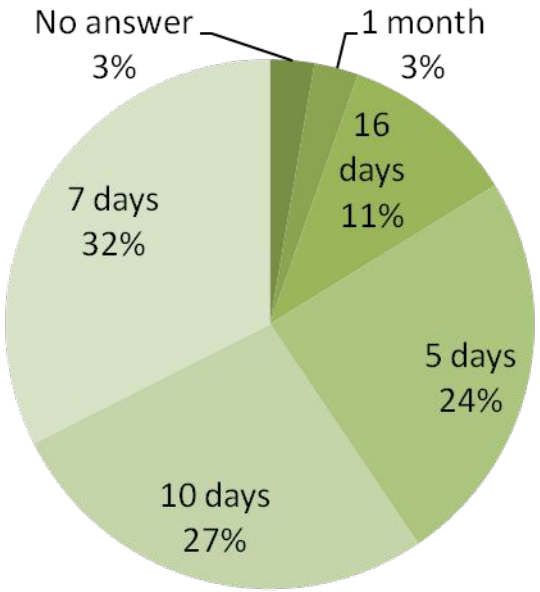


sentinel-2

→ AGRICULTURE

Vegetation status (NDVI, LAI, fAPAR, phenology, …)

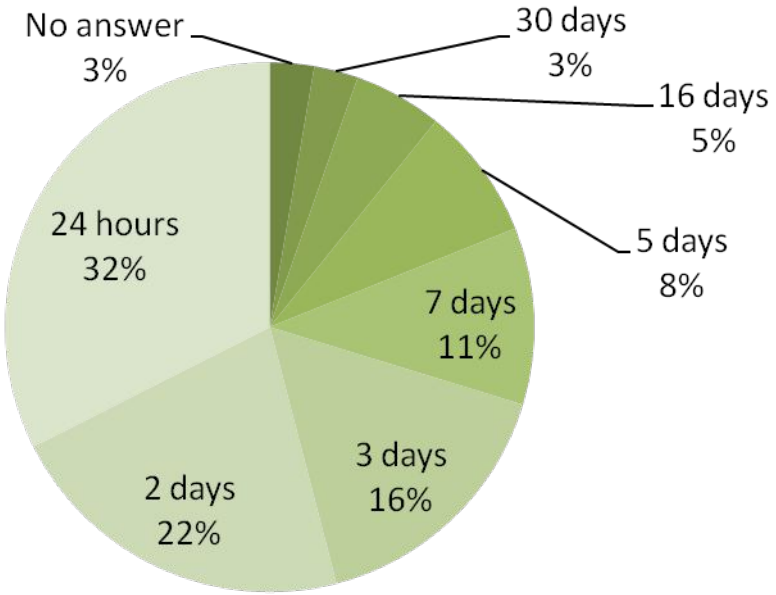
Temporal resolution



10 days or better : 84%

16 days or better 16 days: 95%

Delivery time

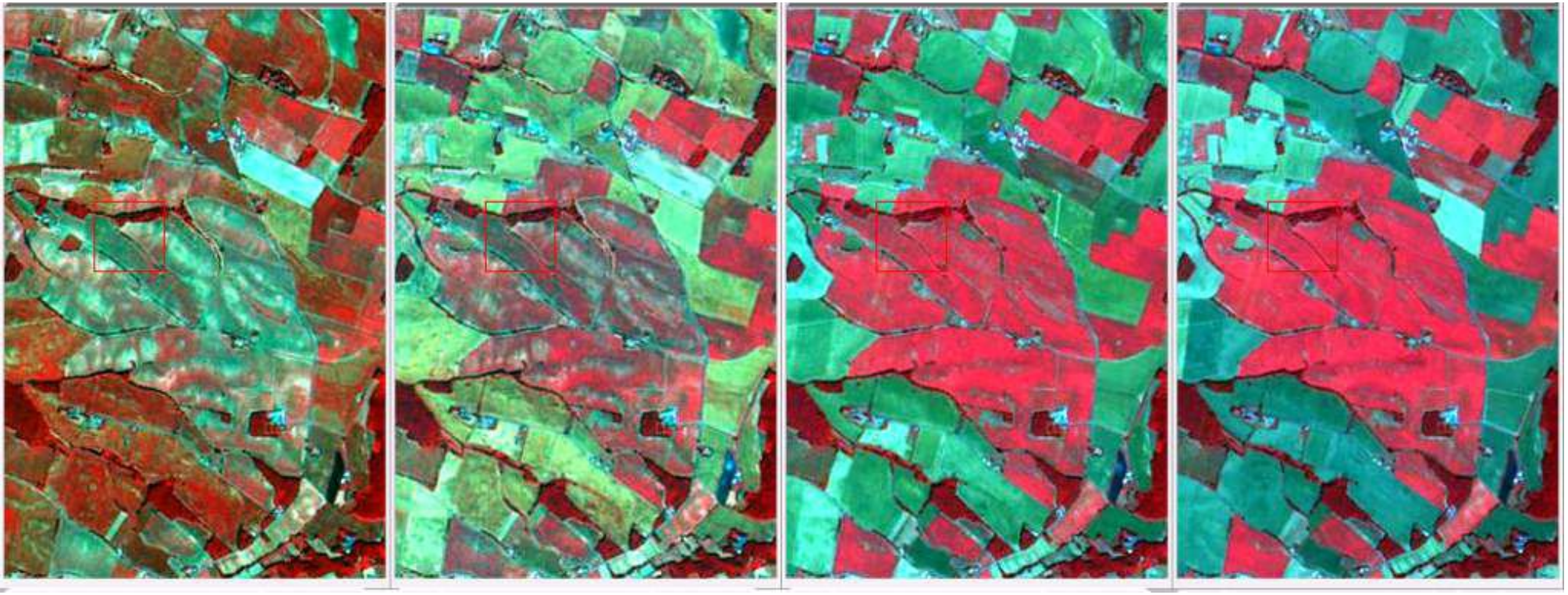


3 days or better : 70%

EO observation requirements for agriculture: shortwaves (SW)

- **Crop growth indicators : every 5 to 10 days**

June 5th 2006 | June 14th 2006 | June 23th 2006 | June 29th 2006

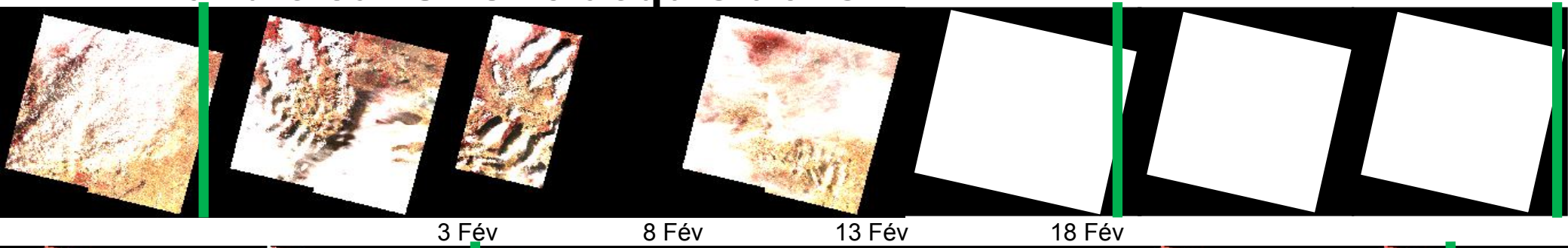


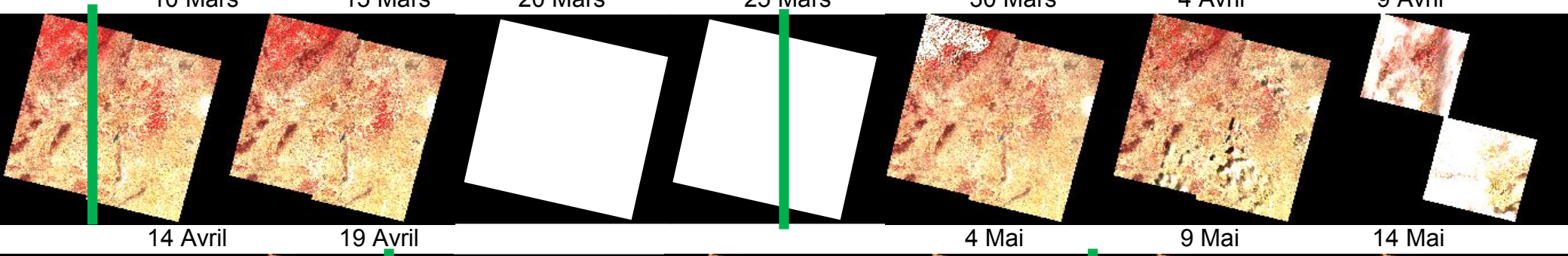
Formosat-2 images, 8m resolution : green, red, near infrared colour composite

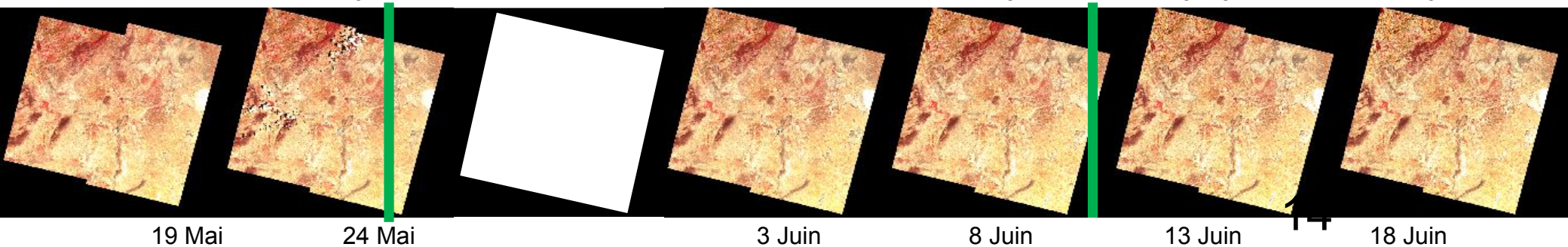
TUNISIA : SPOT4 (Take Five experiment) and clear SPOT5 acquisitions

Lepage et al., 2013

SPOT 5 = Green bars







SPOT4 (Take Five experiment) and clear SPOT5 acquisitions

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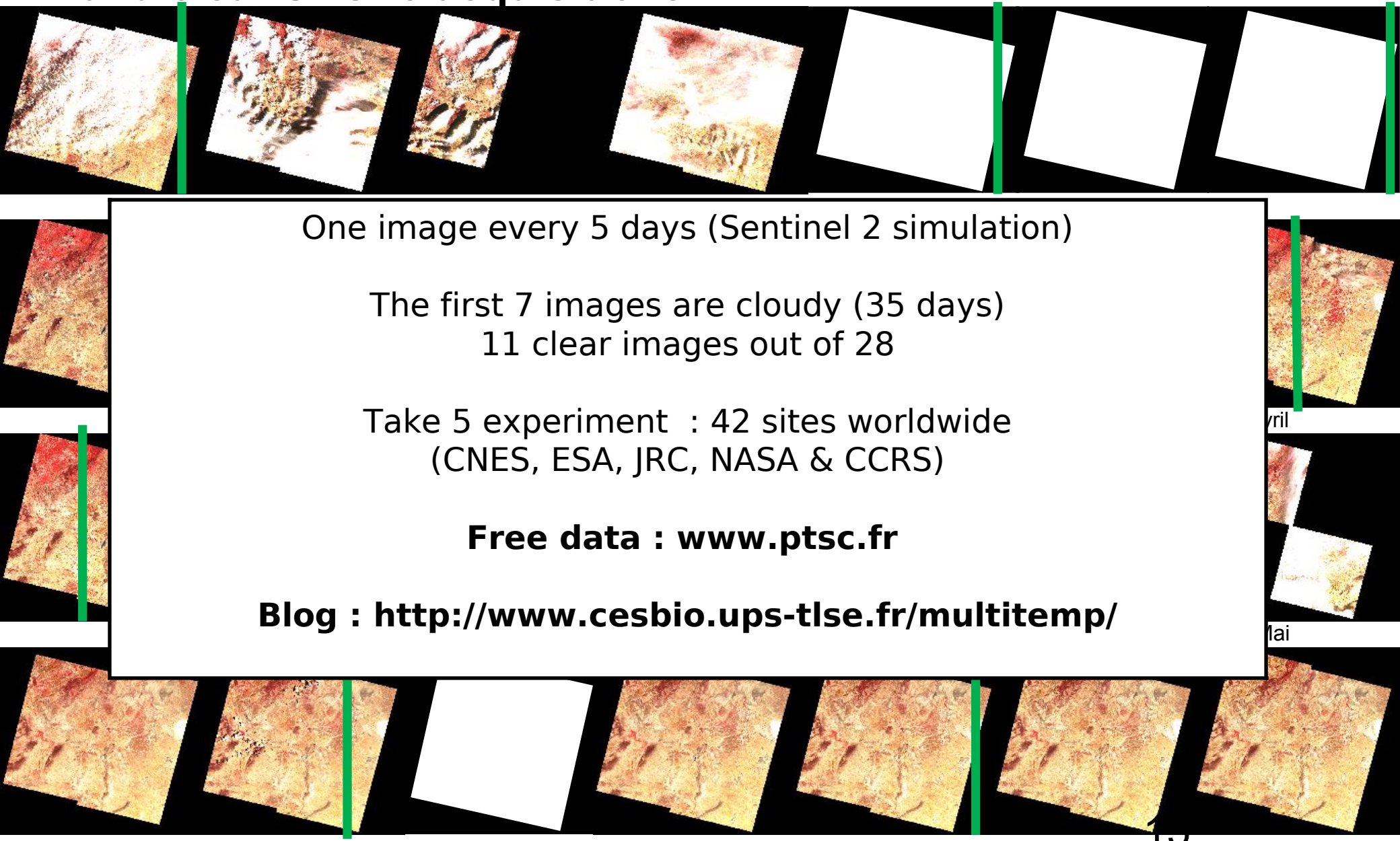


One image every 5 days (Sentinel 2 simulation)

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)

Free data : www.ptsc.fr

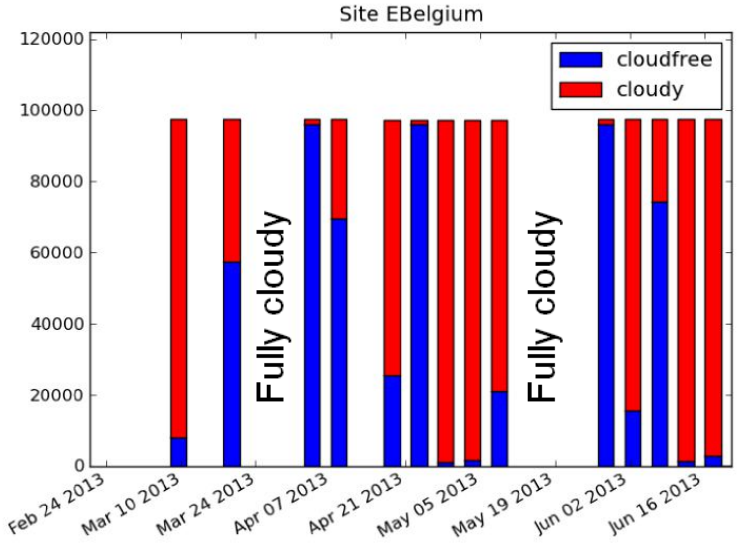
Blog : http://www.cesbio.ups-tlse.fr/multitemp/

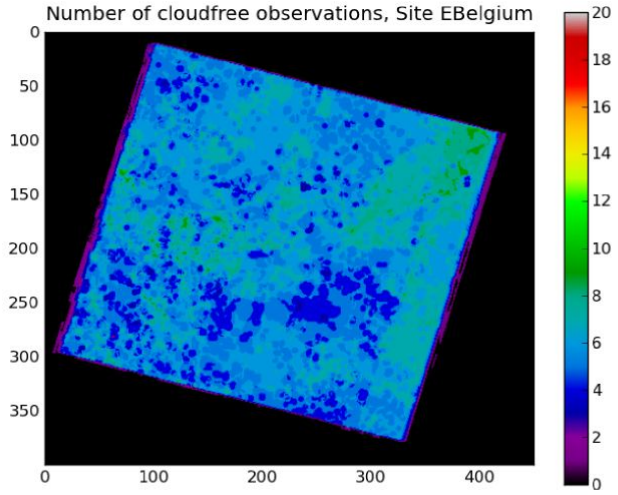
19 Mai 24 Mai 3 Juin 8 Juin 13 Juin 18 Juin

EO observation requirements for agriculture

- **Sentinel 2 A&B, together, will provide a 5 day revisit cycle**
  - **Should be sufficient for (dynamic) crop type mapping**
  - **Insufficient for building a robust and global crop growth monitoring system at high resolution**

Observed cloudiness during the SPOT-4 Take 5 experiment (1 image every 5 days)
1 february to 21 june 2013. Belgium site





EO observation requirements for agriculture: shortwaves (SW)

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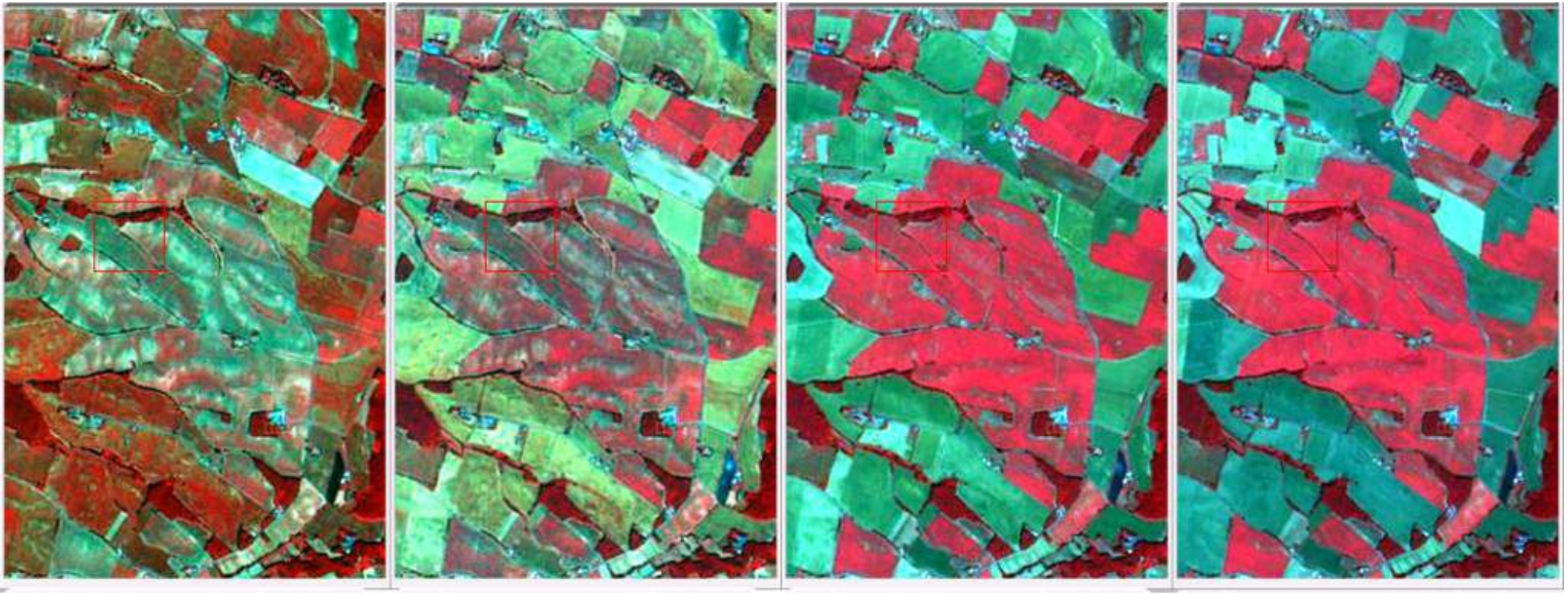


Formosat-2 images, 8m resolution : green, red, near infrared colour composite

EO observation requirements for agriculture

Main mission requirements

- Ground resolution should allow to monitor individual fields and provide information for precision farming practices and agronomic decisions
- Revisit time should allow to monitor vegetation growth : one “clear” image every 5 to 10 days.
- Information shall be delivered all the time, in time
- The issue is global : global coverage of land
- Near Real Time data delivery required for tactical management
- Long term commitment (>20 years) : to justify/motivate user investments (money, people, …)
- Long term archive
- Increase of food production mainly expected in developing countries : free or low cost data

EO observation requirements for agriculture

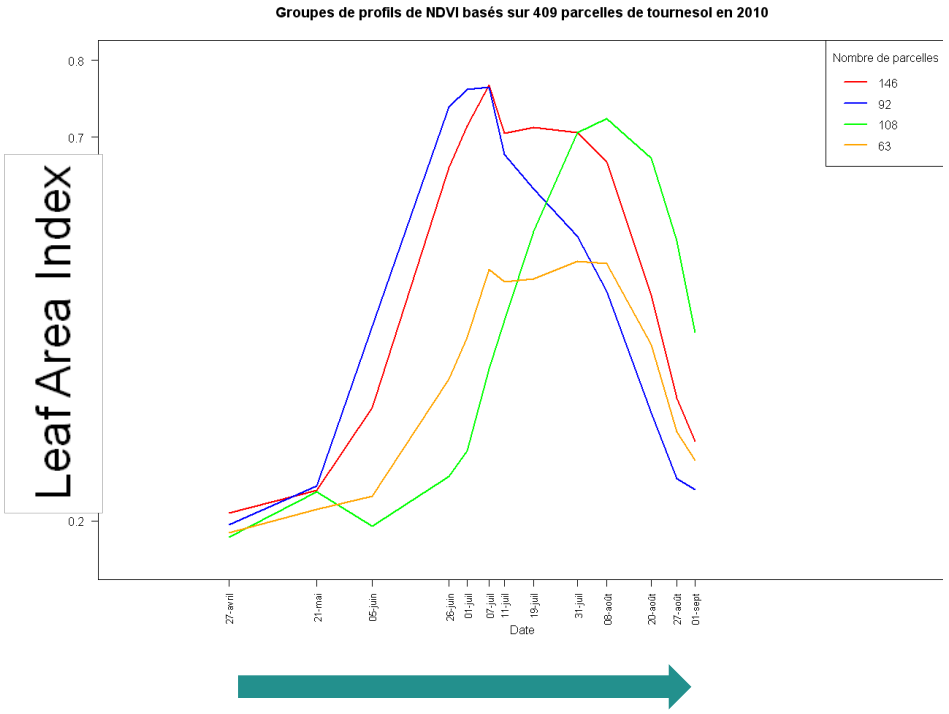
- **Main specifications (very preliminary) : spectral domains**
  - **Optical instruments (solar spectrum and thermal infrared)**
    - **Solar channels**
      - Blue, red and near-infrared as a minimum
      - Improved instrument : spectral channels similar to the ones of Sentinel-2 + possibly new ones (e.g. fluorescence)
      - Ground resolution : 5 to 30 m, objective 10m
      - SNR : 70 (TBC)

    ⇨ monitoring of crop canopy development and senescence (NDVI, LAI)

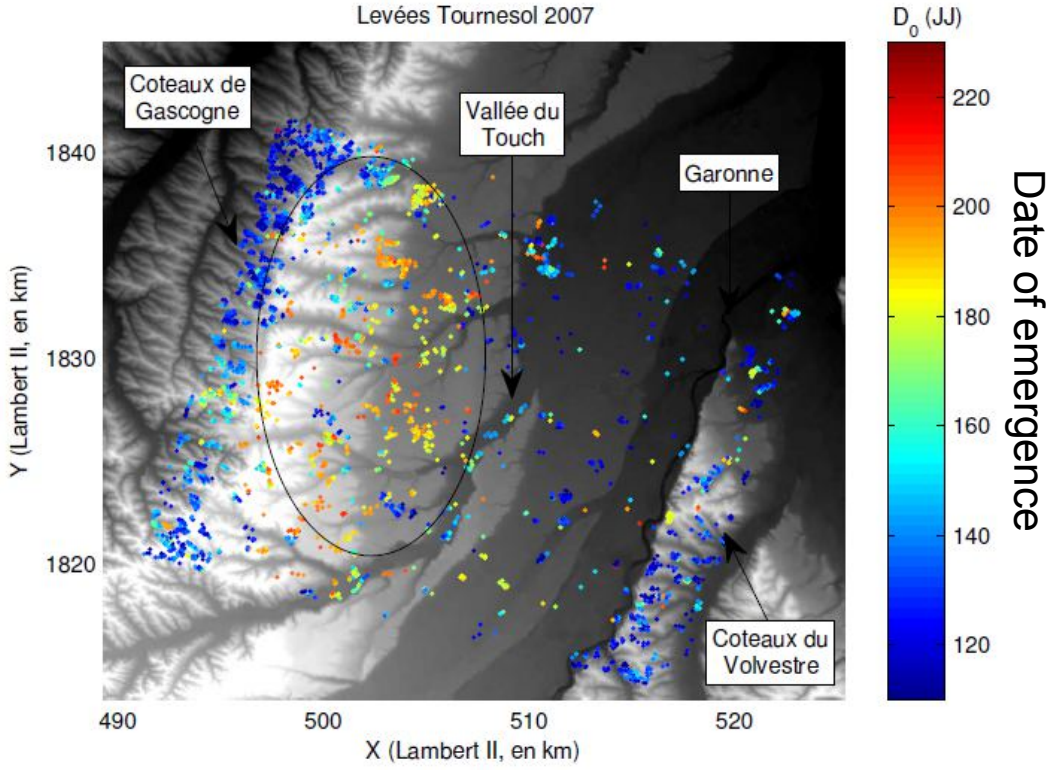
EO observation requirements for agriculture: shortwaves (SW)

- **Crop growth indicators : every 5 to 10 days**
  Vegetation index, Leaf area index, Biomass, …

Sunflower : different phenology groups corresponding to different soil types



Time



Claverie et al., 2012, Remote Sensing of Environment 124: 844-857

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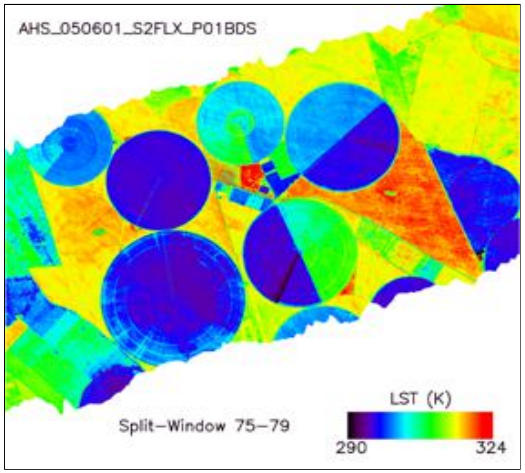
    ⇨ cropmapping & monitoring of canopy development and senescence (NDVI, LAI)

    - **Thermal infrared channels**
      - 10.3 µm and 11.5 µm as a minimum
      - Improved instrument : 8.6, 9.1, 10.3, 11.5 µm
      - Ground resolution : ~50 m
      - NedT 0.3K @290K , absolute accuracy : 1 K

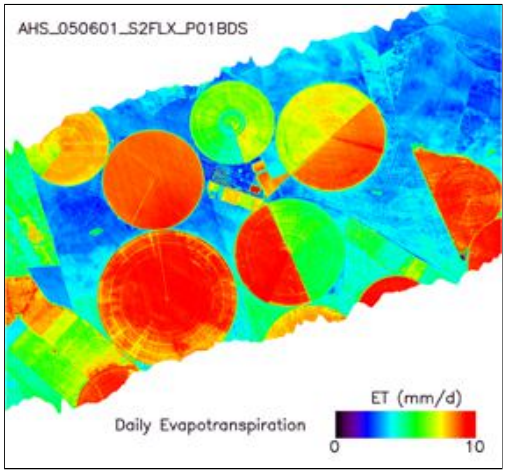
    ⇨ Temperature as a result of energy balance => water balance.

EO observation requirements for agriculture: Thermal Infrared (TIR)

- **Coupling EO data and models : driving, assimilation, validation: use of thermal infrared channels**

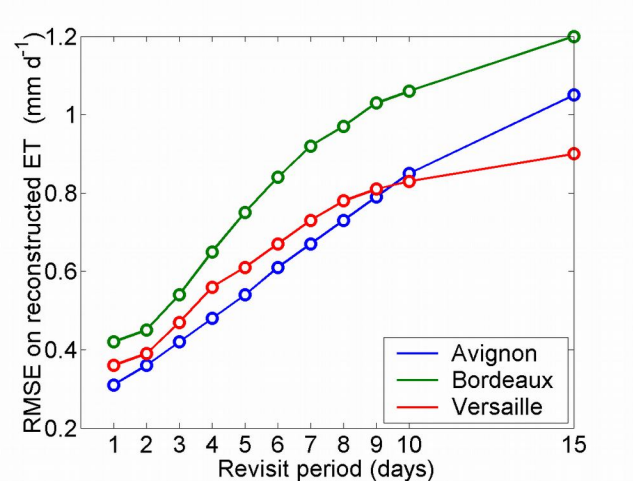


Surface temperature



Daily evapotranspiration

Actual evapotranspiration map (c) derived from surface temperature (b) over Barrax area (southern Spain, a)



Analysis of the impact of the revisit on the accuracy of daily AET retrievals

Surface temperature witnesses water stress earlier than NDVI

Lagouarde et al.: The MISTIGRI thermal infrared project: scientific objectives and mission specifications, International Journal of Remote Sensing,, 2012

EO observation requirements for agriculture

Main specifications (very preliminary) : spectral domains

Optical instruments (solar spectrum and thermal infrared)

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Radar

- **C band (TBC)**: crop LAI/biomass monitoring, superficial soil moisture
- 20 m, 3 looks, polarimetry

EO observation requirements for agriculture: Microwaves (SAR)

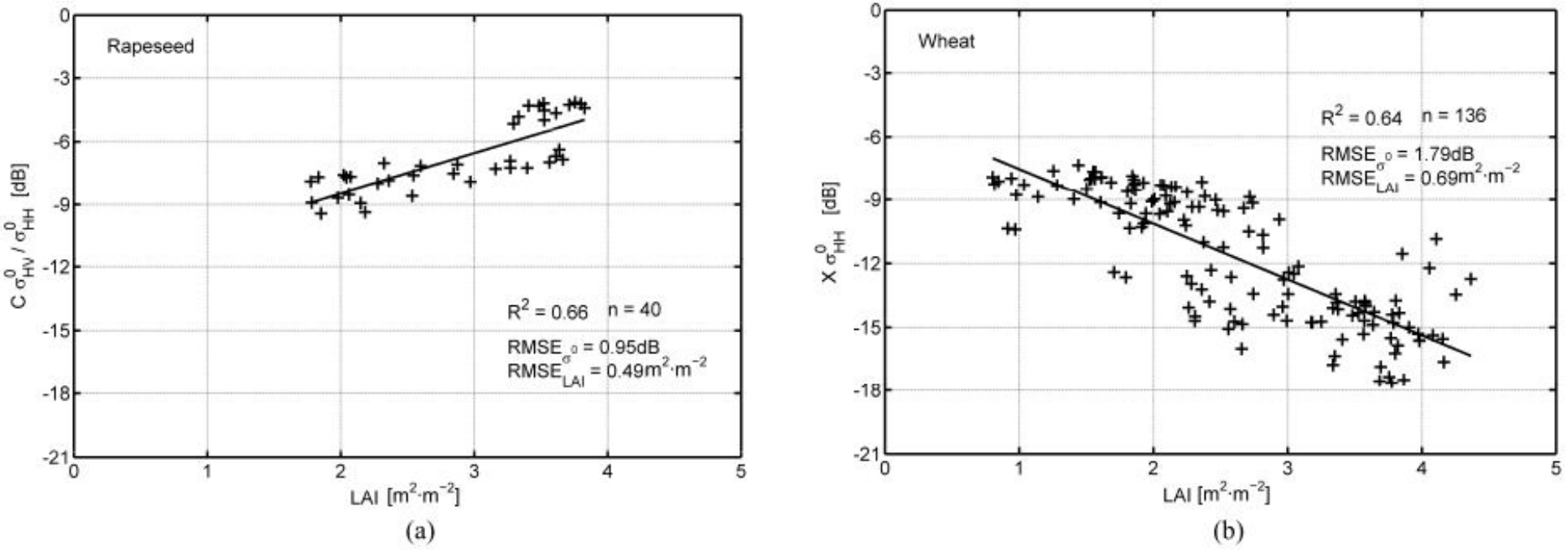

Figure 12. Examples of empirical relationships obtained during the growing period between the $\sigma^0_{C\text{-}HV/HH}$ and LAI of rapeseed (a) and between the $\sigma^0_{X\text{-}HH}$ and LAI of wheat (b).

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

EO observation requirements for agriculture

Main specifications (very preliminary) : spectral domains

Optical instruments (solar spectrum and thermal infrared)

- **Solar channels**
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  - Improved instrument : spectral channels similar to the ones of Sentinel-2 + possibly new ones (e.g. fluorescence)
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⇨ monitoring of crop canopy development and senescence (NDVI, LAI)

- **Thermal infrared channels**
  - 10.3 µm and 11.5 µm as a minimum
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⇨ Temperature as a result of energy balance => water balance.

Radar

- **C or L band** (further analysis needed) : crop biomass monitoring, superficial soil moisture
- 20 m, 3 looks, polarimetry

EO observation requirements for agriculture

- **Main specifications (very preliminary) : revisit**
  - **Optical instruments (solar and thermal infrared channels)**
    - 1 day revisit, sun-synchronous

EO observation requirements for agriculture

Main specifications (very preliminary) : revisit

Optical instruments (solar and thermal infrared channels)

- 1 day revisit, sun-synchronous
- Global coverage
- Constant view angle for a given location : reduced bi-directional effects, facilitates geometric and atmospheric correction

EO observation requirements for agriculture

Main specifications (very preliminary) : revisit

Optical instruments (solar and thermal infrared channels)

- 1 day revisit
- Constant view angle for a given location : reduced bi-directional effects, facilitates geometric and atmospheric correction

Radar

- ~10 day revisit (TBC)
- Global coverage
- Polarization HH VV VH

Combined use of optical and microwave instruments should be further studied in order to refine and optimize their respective revisit specifications

EO observation requirements for agriculture

Technical implementation (very preliminary) : revisit

Optical instruments (solar and thermal infrared channels)

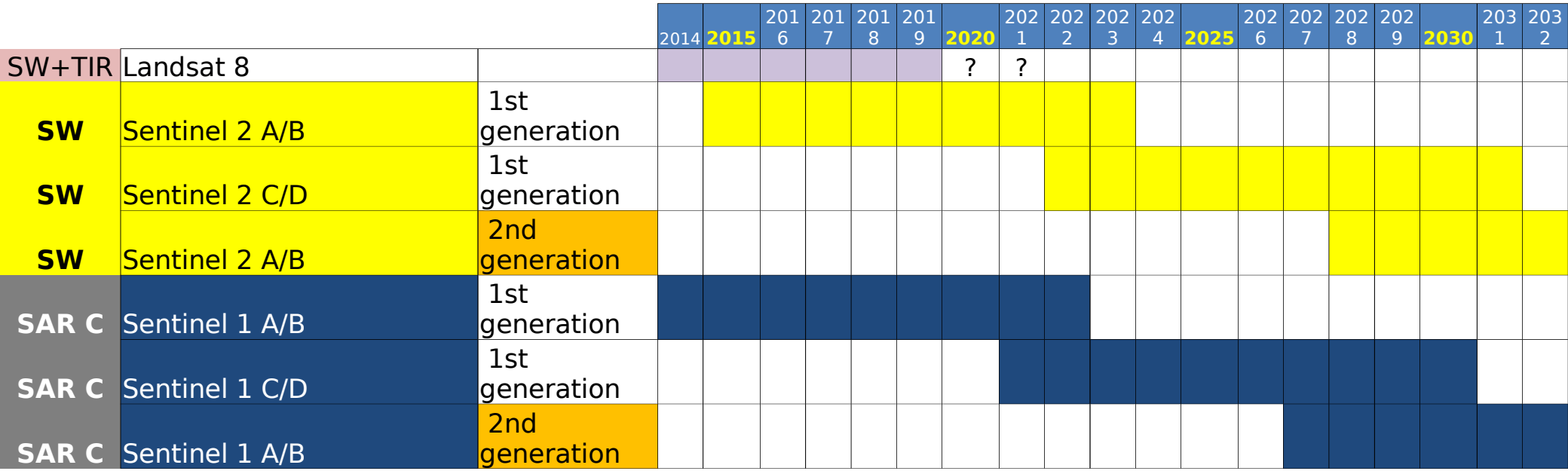
- Polar orbit, sun-synchronous, altitude 831 km
- 1 day revisit
- Field of view : 480 km.
- Scenario 1 : 6 satellites with solar and thermal instrument on the same platforme
- Scenario 2 : 6 satellites for solar, 6 satellites for thermal

Radar

- ~10 day revisit (TBC)
- Field of view : AD
- One to two satellites

No tasking : systematic acquistions

Current and planed Copernicus mission for Land



Current and planed Copernicus mission for Land
+ scenario

			2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
SW+TIR	Landsat 8								?	?											
SW	Sentinel 2 A/B	1st generation																			
SW	**Additional simple SW missions (B/R/NIR)=>daily revisit with S2**																				
TIR	**TIR Precursor 3 days revisit**																				
SW	Sentinel 2 C/D	1st generation																			
TIR	**TIR Precursor 3 days revisit**																				
SW+TIR	**Sentinel 2 A/B Daily revisit**	2nd generation																			
SAR C	Sentinel 1 A/B	1st generation																			
SAR C	Sentinel 1 C/D	1st generation																			
SAR C	**Sentinel 2 A/B Systematic Orbit and acquisitions**	2nd generation																			

Scenario (one amongst others)

Complementing as soon as possible Sentinel 2 with 4 to 8 microsatellites on a 10 day orbit, with simplified instruments (blue, red, near infrared) and 300 km field of view

Thermal infrared acquisitions on a different platform, with relaxed revisit frequency (e.g. 3 days)

Prepare the more ambitious mission for 2028

Secondary uses

Agriculture is very demanding in terms of revisit, spatial resolution, operationality, ..

- **Land**
  - **Land cover & Land use**
  - **Carbon cycle : Net primary productivity of the ecosystems, forest biomass (with L band)**
  - **Snow cover monitoring, snow melt modeling and contribution to stream flow**
  - **Catchment modeling (land cover, runoff, evapotranspiration)**
  - **Monitoring of ecosystems : deforestation, burned areas, …**
  - **Landscape ecology and biodiversity, green corridors**
  - **…**
- **Coastal Oceanography, estuaries**
  - **Sediments, phytoplancton, primary productivity, tidal zones**
  - **Submesoscale activity in coastal ocean**
- **Meteorology**
  - **Modeling of the surface-atmosphere interface, meso-scale modeling**
  - **Urban heat island**

Conclusion

- Agriculture and food production : a major challenge
- Sentinels 1 & 2 are well suited to address some of the issues
  - The community should work more on the combined use of optical and SAR data
- The second generation of S1 and S2 is expected to be launched by 2028
  - About 7 years to develop new satellites
  - 2 to 3 years to specifiy
  - 1 year to ∞ to convince policy makers and big bosses
- **=> the community has to start now to be ready in 2028**

  Refinement of the specification based on models, data, use cases, …

Conclusion

- 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**

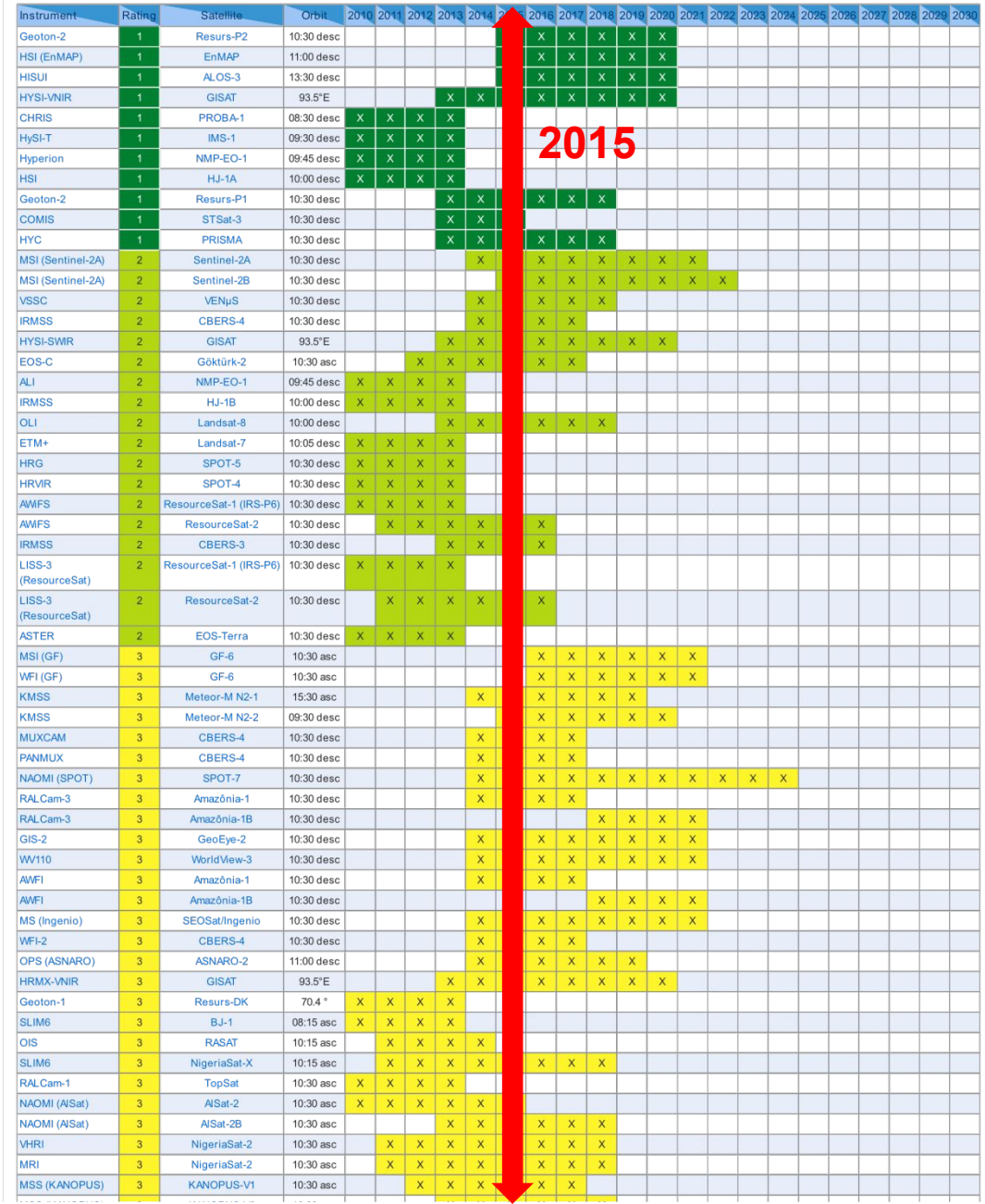
  - The international space agencies should give increased attention to **demonstrating and exploiting the capability of fine resolution data from thermal and microwave sensors for agricultural monitoring and their combination with data from optical sensors.**

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

Money for that mission ?

Money for that mission ?

It is there



Instrument	Rating	Satellite	Orbit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Geoton-2	1	Resurs-P2	10:30 desc							X	X	X	X	X										
HSI (EnMAP)	1	EnMAP	11:00 desc							X	X	X	X	X										
HISUI	1	ALOS-3	13:30 desc							X	X	X	X	X										
HYSI-VNIR	1	GISAT	93.5°E				X	X		X	X	X	X	X										
CHRIS	1	PROBA-1	08:30 desc	X	X	X	X																	
HySI-T	1	IMS-1	09:30 desc	X	X	X	X																	
Hyperion	1	NMP-EO-1	09:45 desc	X	X	X	X																	
HSI	1	HJ-1A	10:00 desc	X	X	X	X																	
Geoton-2	1	Resurs-P1	10:30 desc				X	X		X	X	X												
COMIS	1	STSat-3	10:30 desc				X	X																
HYC	1	PRISMA	10:30 desc				X	X		X	X	X												
MSI (Sentinel-2A)	2	Sentinel-2A	10:30 desc					X		X	X	X	X	X	X									
MSI (Sentinel-2A)	2	Sentinel-2B	10:30 desc							X	X	X	X	X	X	X								
VSSC	2	VENμS	10:30 desc					X		X	X	X												
IRMSS	2	CBERS-4	10:30 desc					X		X	X													
HYSI-SWIR	2	GISAT	93.5°E				X	X		X	X	X	X	X										
EOS-C	2	Göktürk-2	10:30 asc			X	X	X		X	X													
ALI	2	NMP-EO-1	09:45 desc	X	X	X	X																	
IRMSS	2	HJ-1B	10:00 desc	X	X	X	X																	
OLI	2	Landsat-8	10:00 desc				X	X		X	X	X												
ETM+	2	Landsat-7	10:05 desc	X	X	X	X																	
HRG	2	SPOT-5	10:30 desc	X	X	X	X																	
HRVIR	2	SPOT-4	10:30 desc	X	X	X	X																	
AWIFS	2	ResourceSat-1 (IRS-P6)	10:30 desc	X	X	X	X																	
AWIFS	2	ResourceSat-2	10:30 desc		X	X	X	X		X														
IRMSS	2	CBERS-3	10:30 desc				X	X		X														
LISS-3 (ResourceSat)	2	ResourceSat-1 (IRS-P6)	10:30 desc	X	X	X	X																	
LISS-3 (ResourceSat)	2	ResourceSat-2	10:30 desc		X	X	X	X		X														
ASTER	2	EOS-Terra	10:30 desc	X	X	X	X																	
MSI (GF)	3	GF-6	10:30 asc							X	X	X	X	X	X									
WFI (GF)	3	GF-6	10:30 asc							X	X	X	X	X	X									
KMSS	3	Meteor-M N2-1	15:30 asc					X		X	X	X	X											
KMSS	3	Meteor-M N2-2	09:30 desc							X	X	X	X	X										
MUXCAM	3	CBERS-4	10:30 desc					X		X	X													
PANMUX	3	CBERS-4	10:30 desc					X		X	X													
NAOMI (SPOT)	3	SPOT-7	10:30 desc					X		X	X	X	X	X	X	X	X	X						
RALCam-3	3	Amazônia-1	10:30 desc					X		X	X													
RALCam-3	3	Amazônia-1B	10:30 desc									X	X	X	X									
GIS-2	3	GeoEye-2	10:30 desc					X		X	X	X	X	X	X									
WV110	3	WorldView-3	10:30 desc					X		X	X	X	X	X	X									
AWFI	3	Amazônia-1	10:30 desc					X		X	X													
AWFI	3	Amazônia-1B	10:30 desc									X	X	X	X									
MS (Ingenio)	3	SEOSat/Ingenio	10:30 desc					X		X	X	X	X	X	X									
WFI-2	3	CBERS-4	10:30 desc					X		X	X													
OPS (ASNARO)	3	ASNARO-2	11:00 desc					X		X	X	X	X											
HRMX-VNIR	3	GISAT	93.5°E				X	X		X	X	X	X	X										
Geoton-1	3	Resurs-DK	70.4 °	X	X	X	X																	
SLIM6	3	BJ-1	08:15 asc	X	X	X	X																	
OIS	3	RASAT	10:15 asc		X	X	X	X																
SLIM6	3	NigeriaSat-X	10:15 asc		X	X	X	X		X	X	X												
RALCam-1	3	TopSat	10:30 asc	X	X	X	X																	
NAOMI (AISat)	3	AISat-2	10:30 asc	X	X	X	X	X																
NAOMI (AISat)	3	AISat-2B	10:30 asc				X	X		X	X	X												
VHRI	3	NigeriaSat-2	10:30 asc		X	X	X	X		X	X	X												
MRI	3	NigeriaSat-2	10:30 asc		X	X	X	X		X	X	X												
MSS (KANOPUS)	3	KANOPUS-V1	10:30 asc			X	X	X		X	X													

WMO-OSCAR
High resolution imagery for land observation

2010-2030

www.wmo.int/oscar

Interested to work on the concept ?

Join us :

gerard.dedieu@cesbio.cnes.fr
olivier.hagolle@cesbio.cnes.fr
jean-claude.souyris@cnes.fr

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Thank you for your attention

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