Land surface albedo at high spatial resolution from a merging of Sentinel-2 and Landsat-8 data; analysis of times series at landscape scale and validation

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Overview

Objectives

HR Surface Albedo (SA) product at 10m/20m/30m meters from S2-A -B + Landsat-8.

Justification

Existing SA products of moderate resolution (MODIS, VIRSS, PROBA-V, S3) have too coarse resolution to satisfy users requirements in matter of energy budget (C, H20) for domains like agriculture, forestry, urban, etc

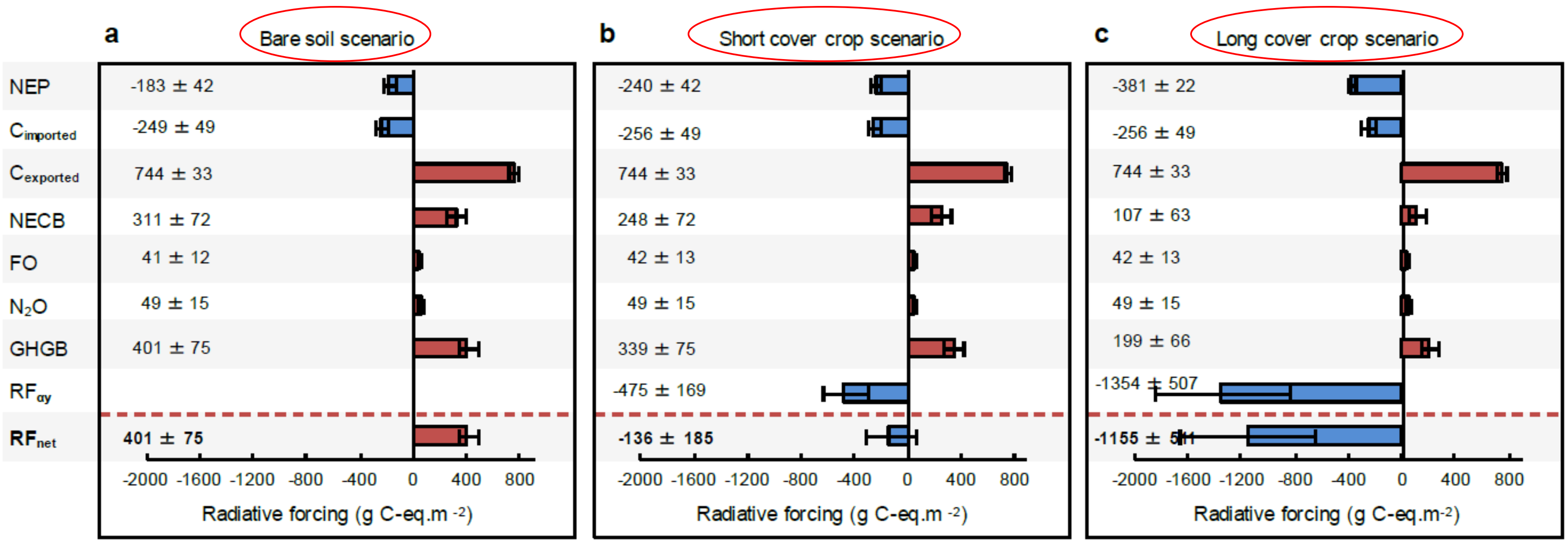
Management and decisions (irrigation, etc) are taken at plot scale.

Challenge !

To make agriculture practices to be more compliant with climate mitigation.

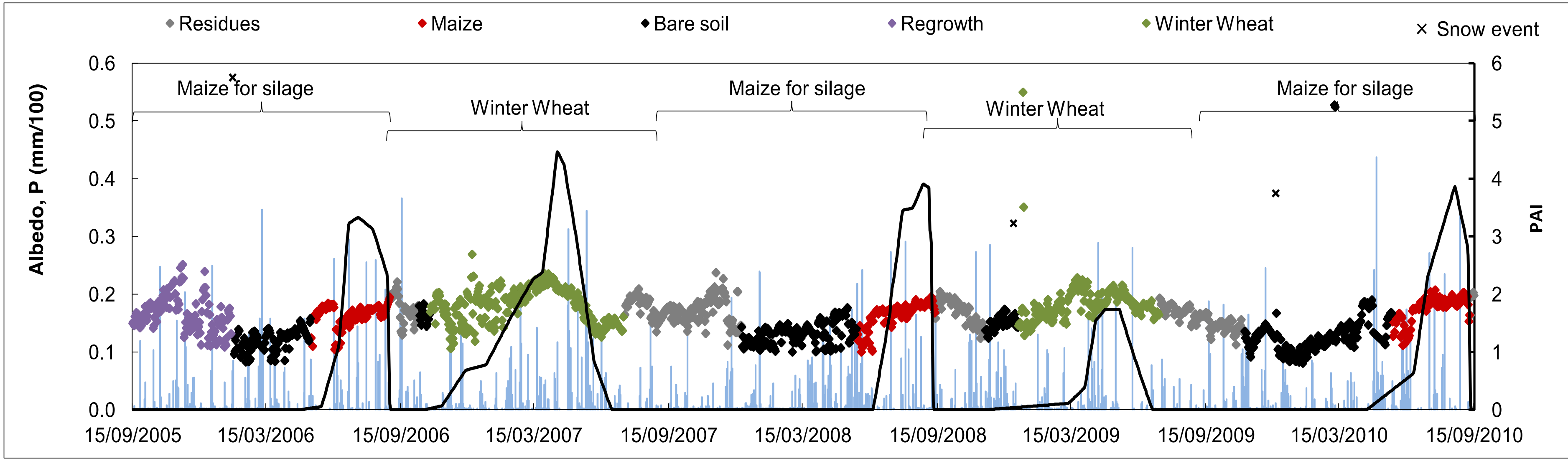
Abatement of GHG effects and intermediate crops (IC)

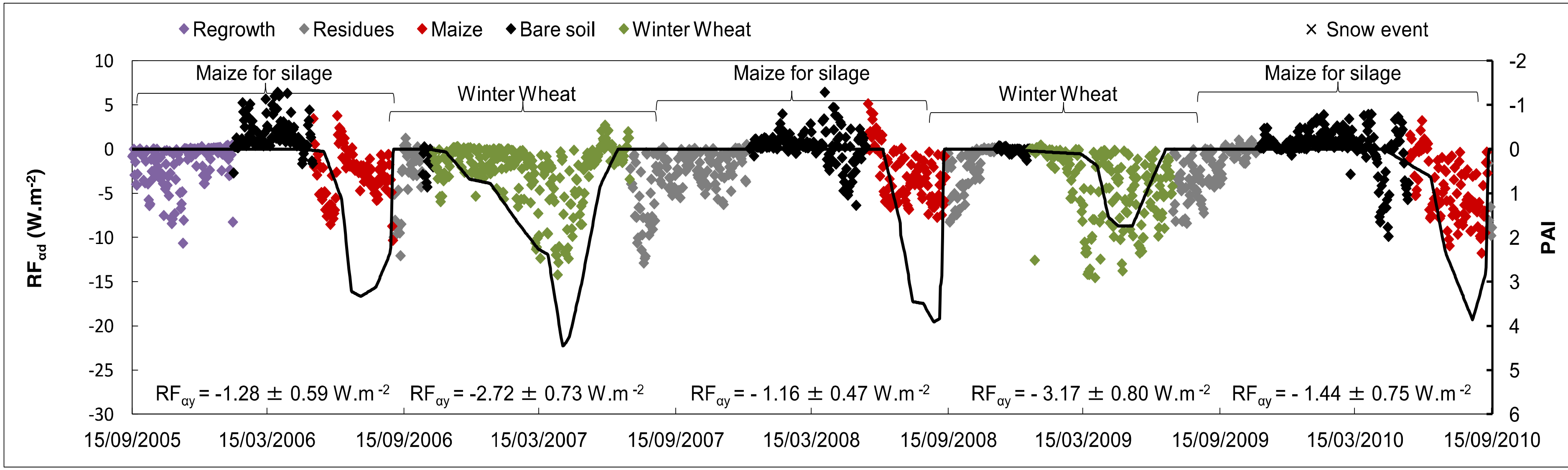
Effects of introducing short & long cycles for IC compared to bare soil prior growth start for a maïze crop *(Ferlicoq & Ceschia 2015)*



- Reduction on soil C storage by 20% to 65 %
- Reduction GHG emissions by 15% to 51 %
- **Increase of albedo infers a strong cooling effect (~7 times the C storage)**
- **Albedo + C storage** => with IC, major switch from global warming to cooling (acting as an equivalent C sink) : **90 % of this effect is due to surface albedo**

Dynamic of surface albedo and radiative forcing for an ICOS station





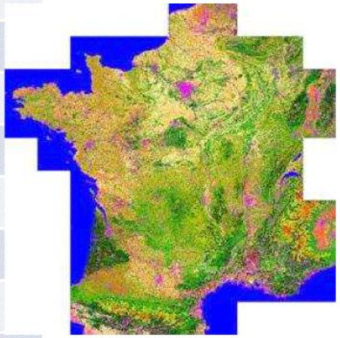
ICOS station of Lamasquère (near Toulouse)

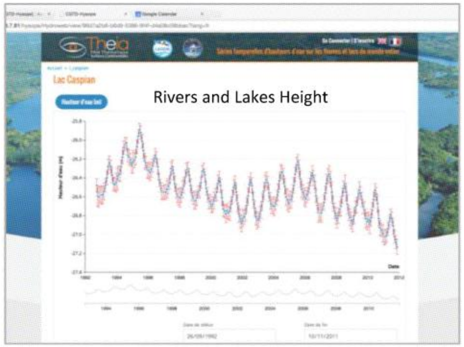
Theia Land Data Centre

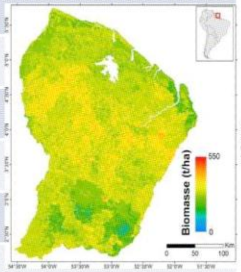
Product portfolio

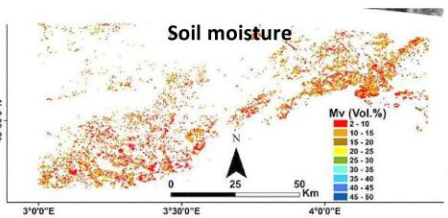
Added Value Products from Science Expertise Centres (~ 25 CES)

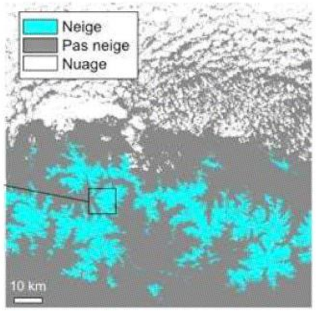
Added Value Products	Status
Surface reflectance	In production
Land Cover & Land Use	In production
Snow Coverage	In production
Soil moisture	In production
Lakes & Rivers height	In production
Decametric vegetal variables	Prototype being developed
Continental water quality	Prototype being developed
Epidemiology	
Irrigated surfaces	
Evapotranspiration	
Soil sealing-urban sprawl	
Forest biomass	
Soil mapping	
Albedo	
High frequency changes	
...	











Atmospheric correction

(Olivier Hagolle et al.)

MAJA's methods

Use the time dimension !

- MAJA combines multi-spectral and multi-temporal criteria
  - to detect cloud, shadows, water and snow
  - to estimate Aerosol Optical Thickness (AOT) and water vapour (WV)
    - The aerosol type is a parameter (until version 3.1)
- MAJA corrects for atmospheric effects (absorption and scattering), including :
  - adjacency effect (blurring effects from atmosphere)
  - terrain effect
- Cloud detection works at 240m resolution
  - could be reduced to 120m: doubles computing time

Documentation on methods

- search for "MAJA ATBD"(https://doi.org/10.5281/zenodo.1209633)

Who is developing MAJA ?

- methods : CESBIO, CNES, DLR
- processor : CS-SI
- validation support from CAP GEMINI
- funded by CNES from the beginning (and CNRS 2011-2015, ESA in 2017)

Merging satellite information (1/2)

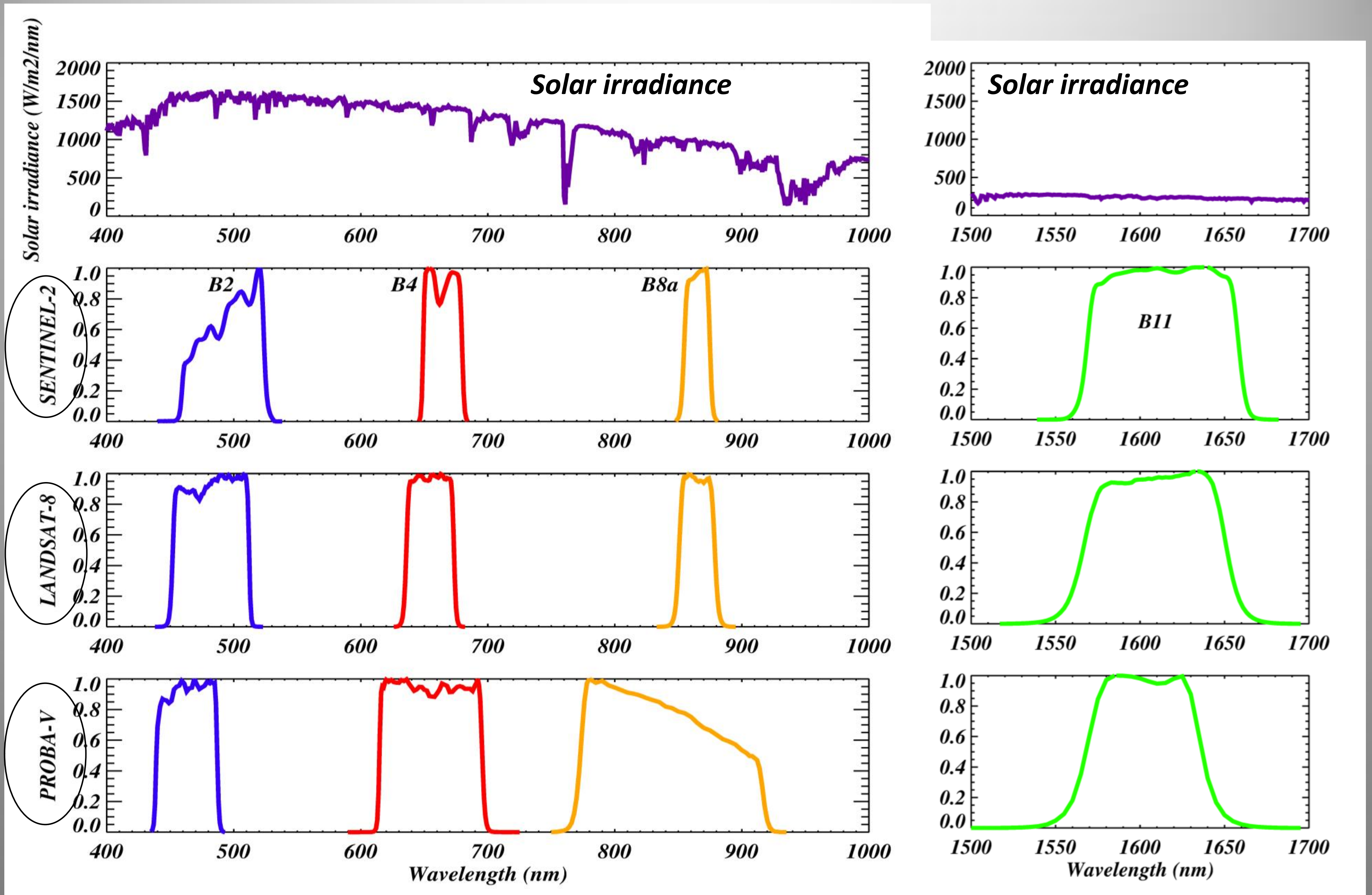
	😀	😬	☹️
SPATIAL RESOLUTION	S2	L8	PV
SPECTRAL RESOLUTION	S2	L8	PV
TEMPORAL RESOLUTION	PV	S2	L8
DIRECTIONAL RESOLUTION	PV	S2	L8

S2 : Sentinel-2 (10m & 20m)

L8 : Landsat-8 (30m)

PV : PROBA-V (300m) *[follow-on of SPOT/VEGETATION]*

Merging satellite information (2/2)



Narrow to Broadband conversion of HR SA (1/2)

6075 simulations using RT code PROSAIL_5B

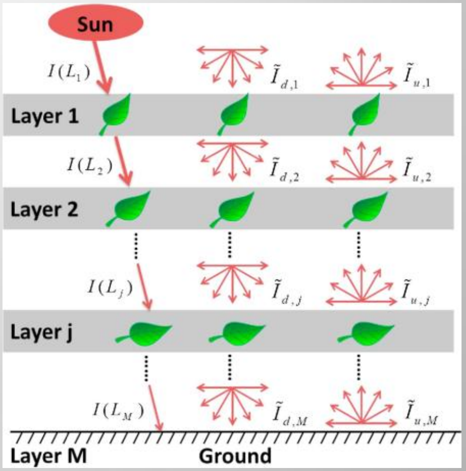
+ solar radiation [/solar/spectra/am1.5/astmg173/astmg173.html]

+ spectral bands S2: B2, B3, B4, B5, B6, B7, B8a, and B11

Model	Variable	Physical meaning	Unit	Range of values
PROSPECT	Cab	chlorophyll content	µg.cm-2	10, 50, 90
	Car	carotenoid content	µg.cm-2	12.0
	Cbrown	brown pigment content	arbitrary units	0.5
	Cw	Equivalent Water Thickness	cm	0.015
	Cm	Dry Matter Content	g.cm-2	0.1
	N	Leaf mesophyll	dimensionless	1.
SAIL	LAI	leaf area index	m^2/m^2	0.5, 1, 2, 3, 4
	LIDF	average leaf angle	degree	Spherical
	Rsoil	soil reflectance (dry, wet)	dimensionless	0.23 @400nm (wet) 0.32 @400nm (dry)
	Psoil	Proportion between dry and wet	dimensionless	0.20, 0.50, 0.80
	Skyl	diffuse/direct radiation	dimensionless	0.20, 0.50, 0.80
	Hspot	hot spot factor	dimensionless	0.2
	Tts	solar zenith angle	degree	0, 30, 60
	Tto	observer zenith angle	degree	0, 30, 60
	Psi	relative azimuth angle	degree	0, 45, 90, 135, 180

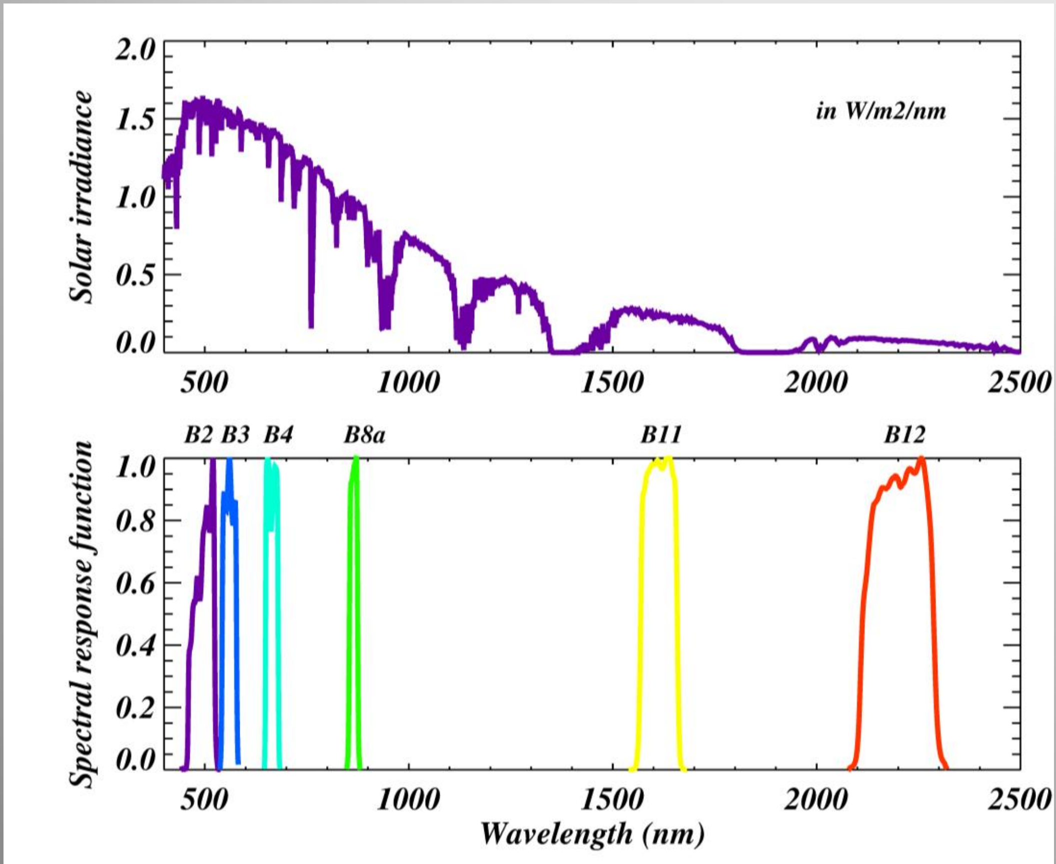
Narrow to Broadband conversion of HR SA (2/2)

6075 simulations from PROSAIL_5B model

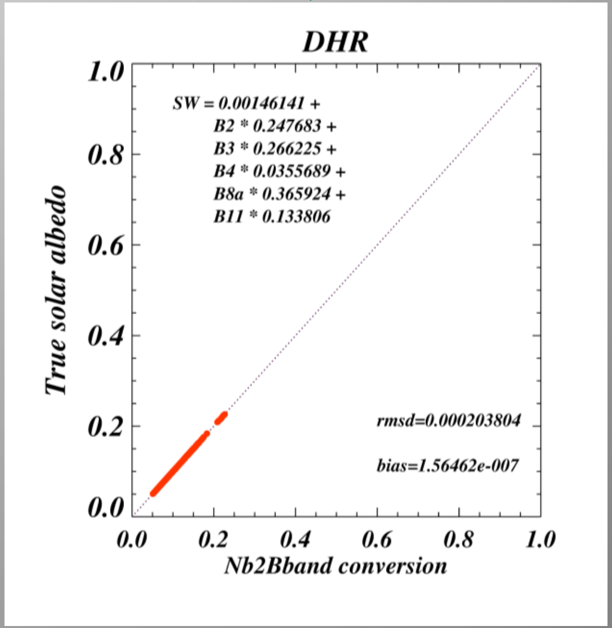


simulations

Solar spectrum



Sentinel-2 bands

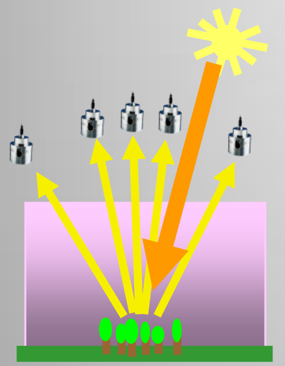


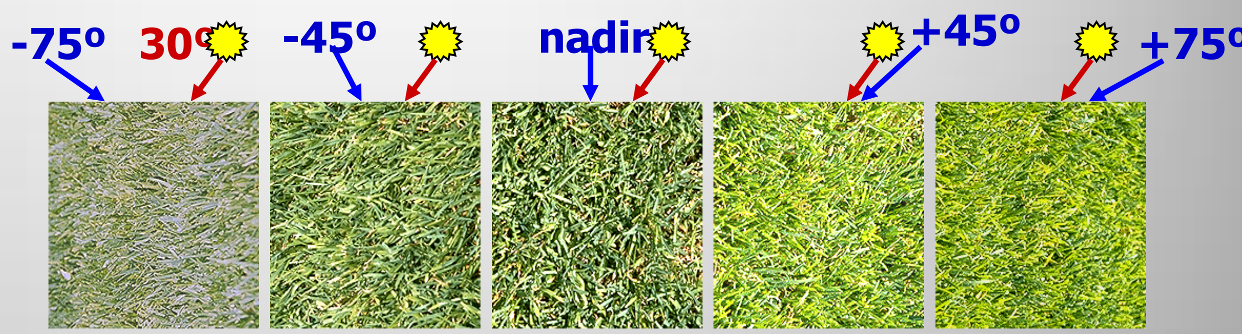
$$(S2\_like)_{\lambda} = a * X_{\lambda} + b$$

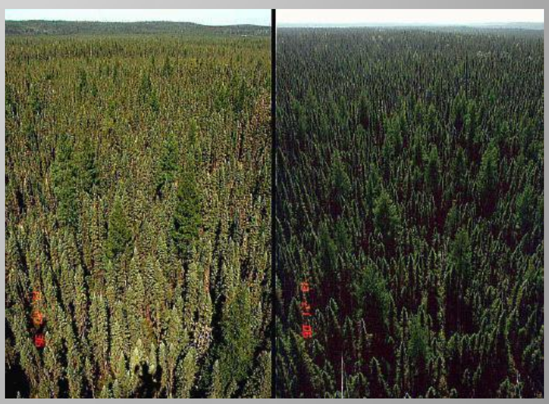
X_{λ} : channels Landsat-8 or Proba-V

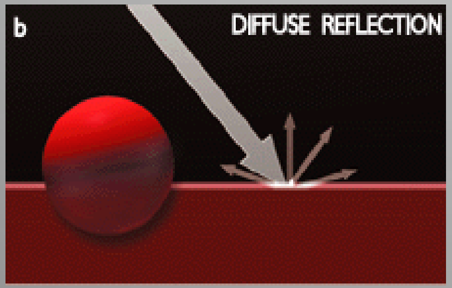
S2 channels	*conversion coefficients Landsat-8*	*conversion coefficients Proba-V*
Blue B2	**a = 1.02927** **b = 0.0000866074**	**a = 1.05524** **b = -0.000574786**
Red B4	**a = 1.00118** **b = 0.0000351332**	**a = 0.997323** **b = -0.000156254**
NIR B8a	**a = 0.999699** **b = 0.0000495315**	**a = 0.999686** **b = 0.0000699461**
SWIR B11	**a = 1.00122** **b = 0.000369154**	**a = 1.00241** **b = 0.00103424**

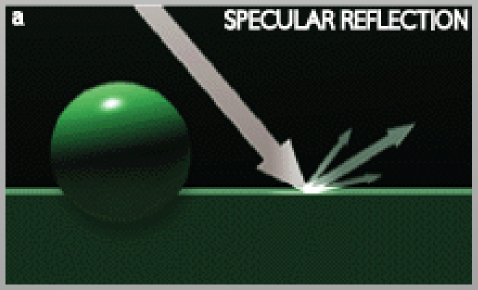
Bidirectional Reflectance Distribution Function (BRDF)







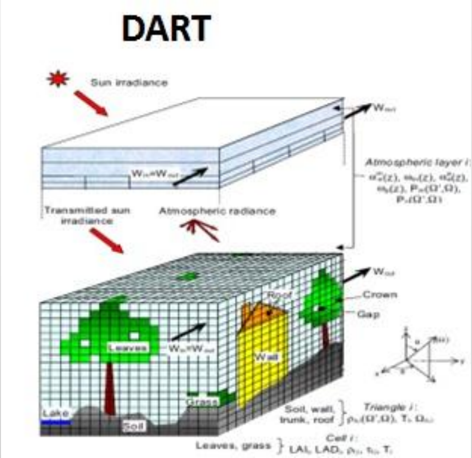


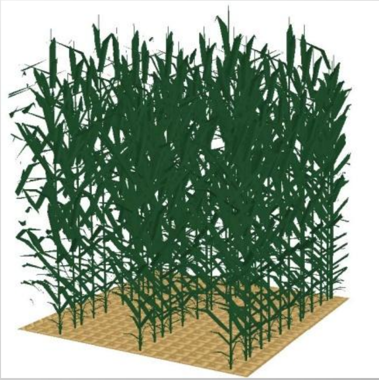


Three categories of RT models for measuring BRDF/albedo

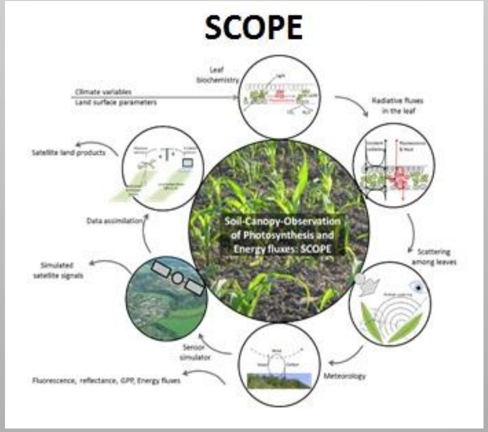
LESS Complex
+
MORE operational

3D





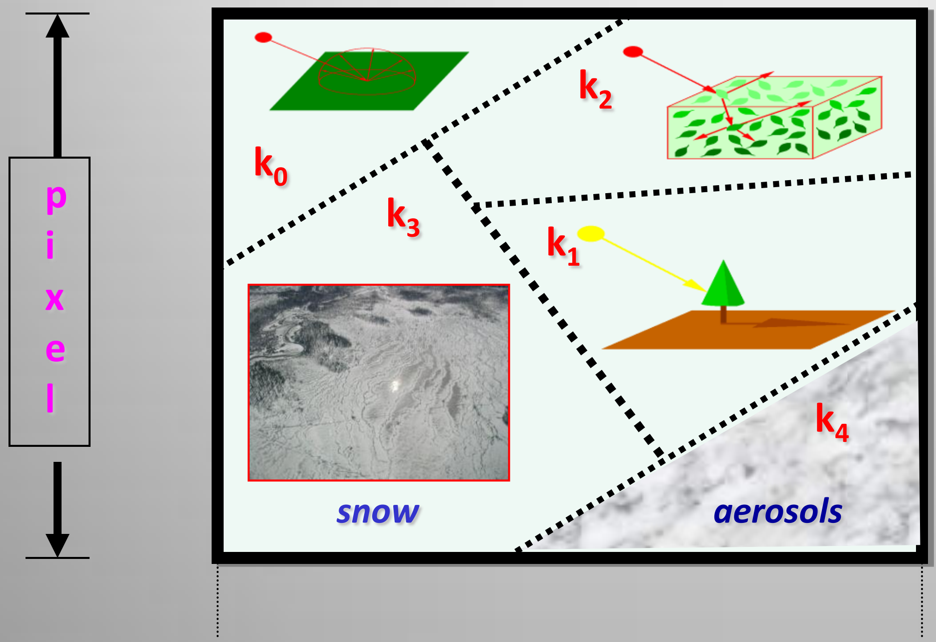
1D



Kernel-Driven

Kernel-Driven approach

Bi-directional Reflectance Distribution Function (BRDF)



$$FDRB = \sum_{0}^{4} k_i f_i$$

k_0 : coeff. Isotropy

k_1 : coeff. Roughness

k_2 : coeff. Volume scattering

k_3 : coeff. Specular

k_4 : coeff. Aerosol diffusion

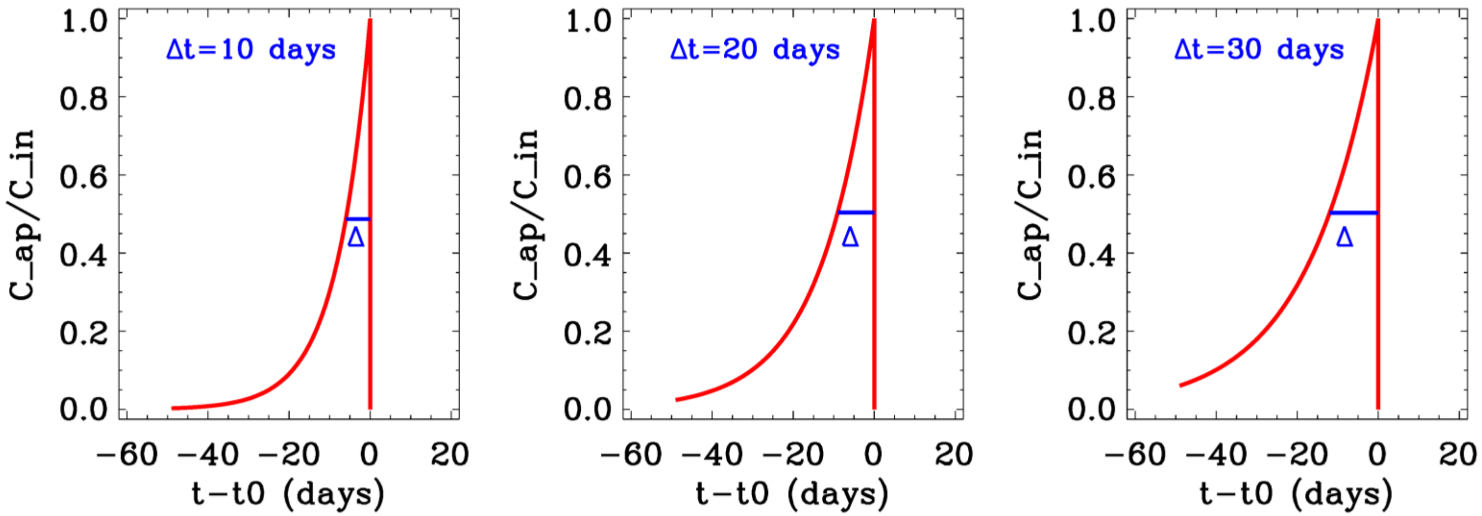
f_i = f(angles)

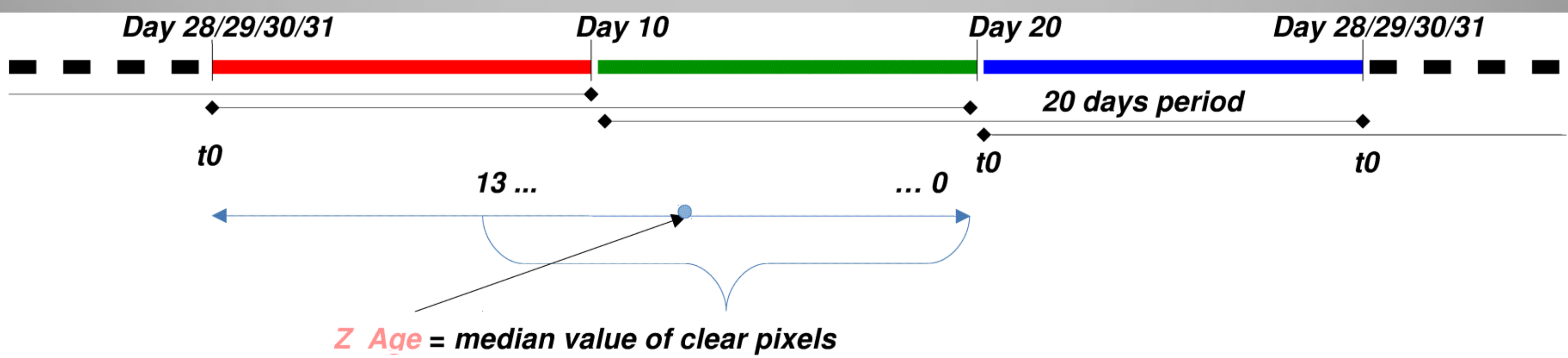
$$K_{ap}^{J} = MK^{J-1}$$

- Recursive procedure for state variable K

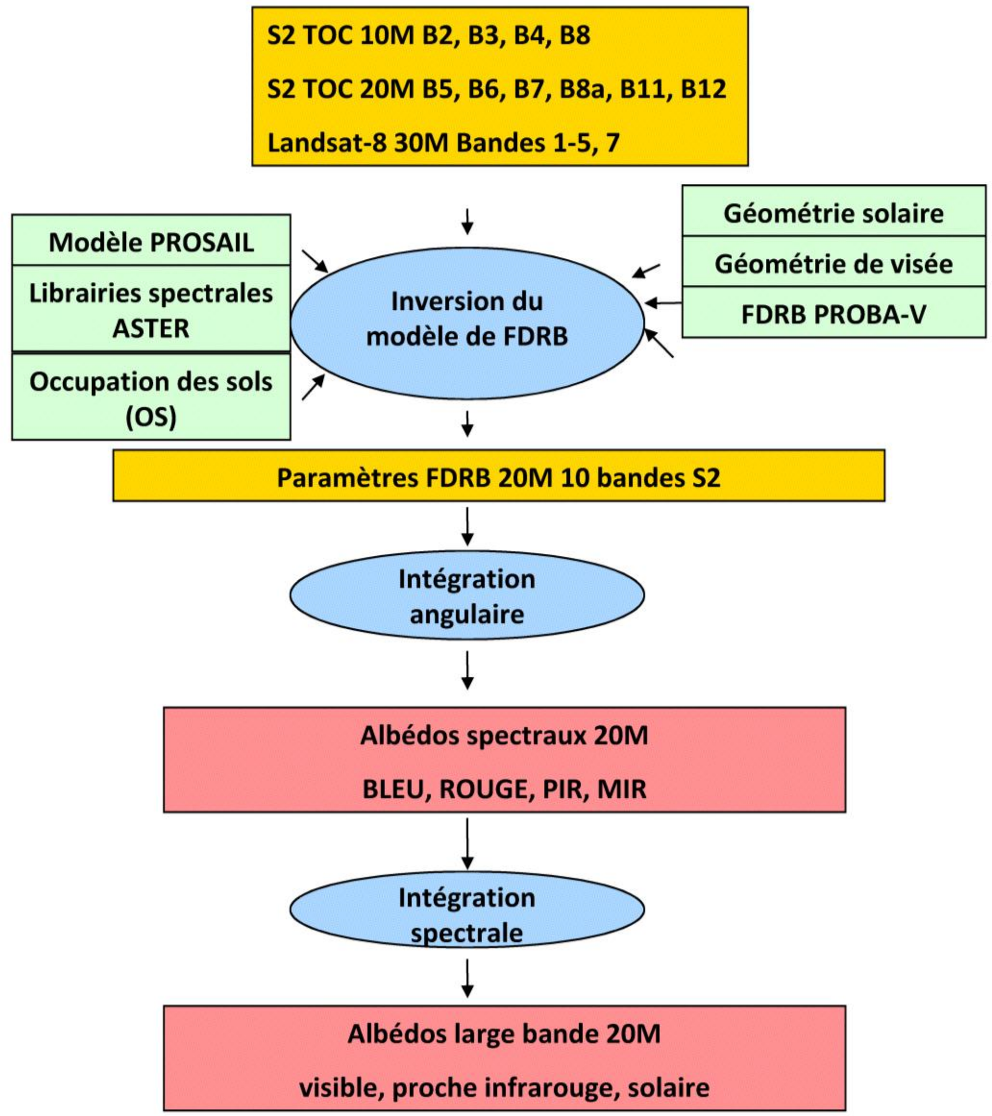
-- Linear state-transition model (operator M)

Synthesis and temporal composition





‘Flowchart’


S2 TOC 10M B2, B3, B4, B8
S2 TOC 20M B5, B6, B7, B8a, B11, B12
Landsat-8 30M Bandes 1-5, 7
Modèle PROSAIL
Librairies spectrales ASTER
Occupation des sols (OS)
Inversion du modèle de FDRB
Géométrie solaire
Géométrie de visée
FDRB PROBA-V
Paramètres FDRB 20M 10 bandes S2
Intégration angulaire
Albédos spectraux 20M
BLEU, ROUGE, PIR, MIR
Intégration spectrale
Albédos large bande 20M
visible, proche infrarouge, solaire

Directional-hemispherical (DHR or Black Sky Albedo)

[Angular reference : local solar noon (max of energy)]

Bi-hemispherical albedo (BHR or White Sky Albedo)

Spectral albedo (Sensor Bands)

Broadband albedo :

solar [0.3µm, 4.0µm]
VIS [0.4µm, 0.7µm]
NIR [0.7µm, 4.0µm]

Blue-sky albedo (BSA)

BSA = DHR * (1 – diffuse) + BHR * diffuse

PRODUCT	DEFINITION	FREQUENCY	RESOLUTION	REQUIRED MEASUREMENT UNCERTAINTY	STABILITY	STANDARDS/ REFERENCES
Maps of directional hemispherical reflectance (DHR) albedo for adaptation	Albedo without diffuse irradiance component.	Daily	50m	max(5%; 0.0025)	max(1%; 0.001)	
Maps of bi-hemispherical reflectance (BHR) albedo for adaptation	Albedo with isotropic illumination only (white-sky)		50m	max(5%; 0.0025)	max(1%; 0.001)	
Maps of DHR albedo for modelling	Albedo without diffuse irradiance component.	Daily	200/500m	max(5%; 0.0025)	max(1%; 0.001)	
Maps of BHR albedo for modelling	Albedo with isotropic illumination only (white-sky)		200/500m	max(5%; 0.0025)	max(1%; 0.001)	

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ELSEVIER

Surface albedo and toc-r 300 m products from PROBA-V instrument in the framework of Copernicus Global Land Service

Check for updates

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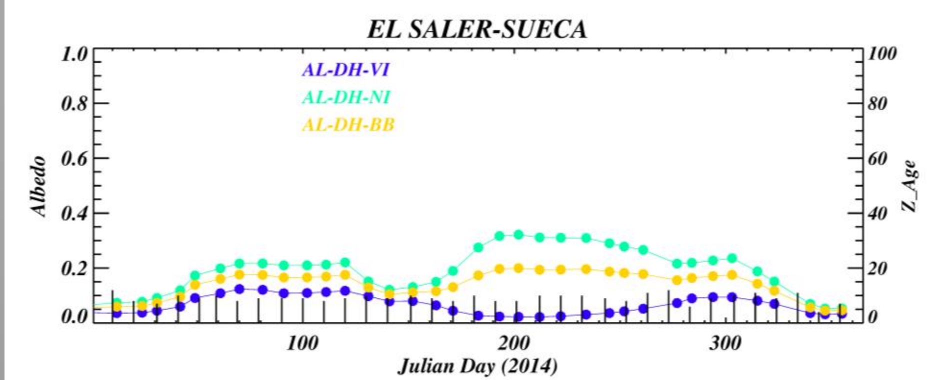
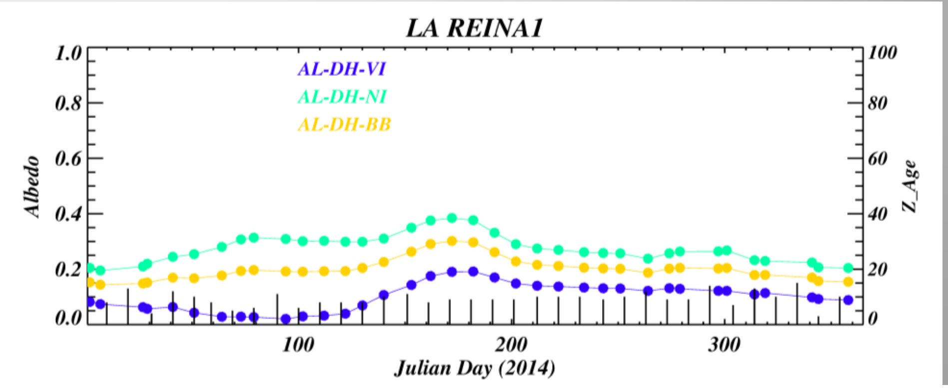
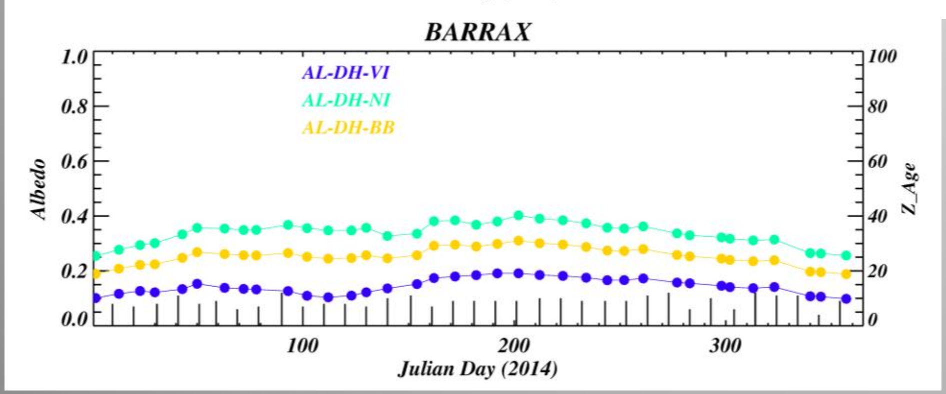
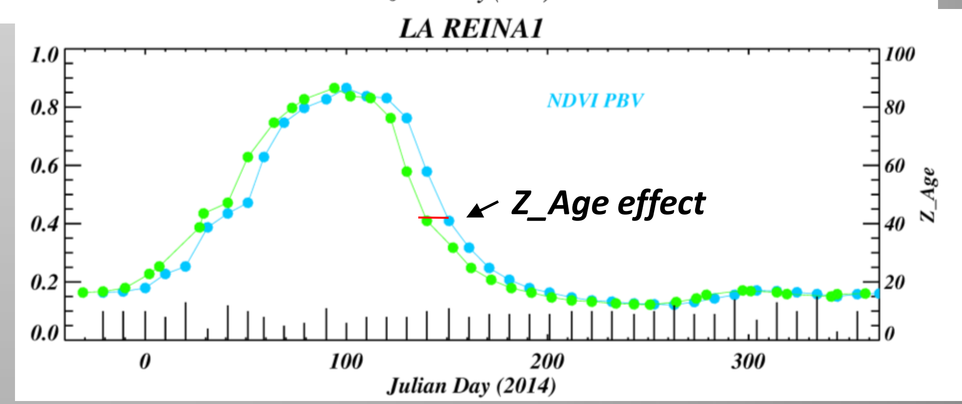
PROBA-V albedo: time series over agricultural areas in Spain

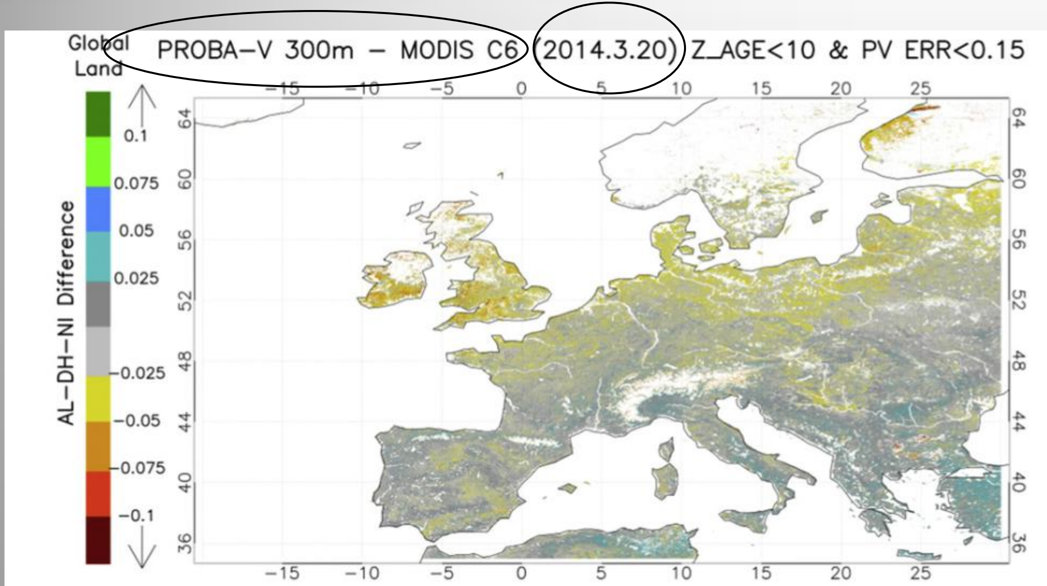


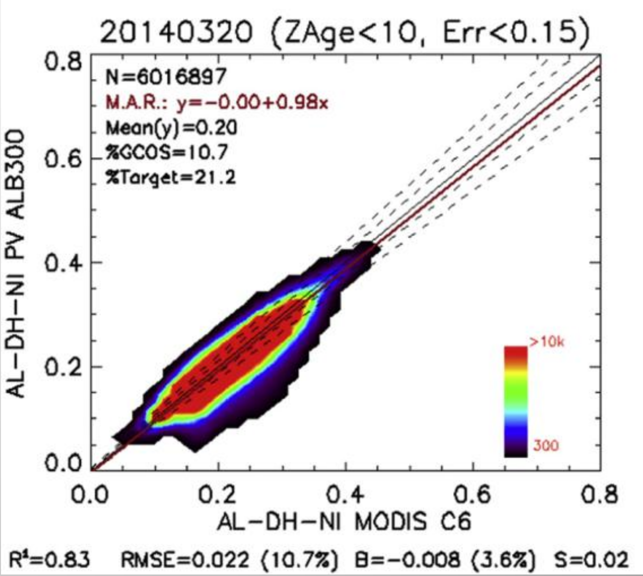


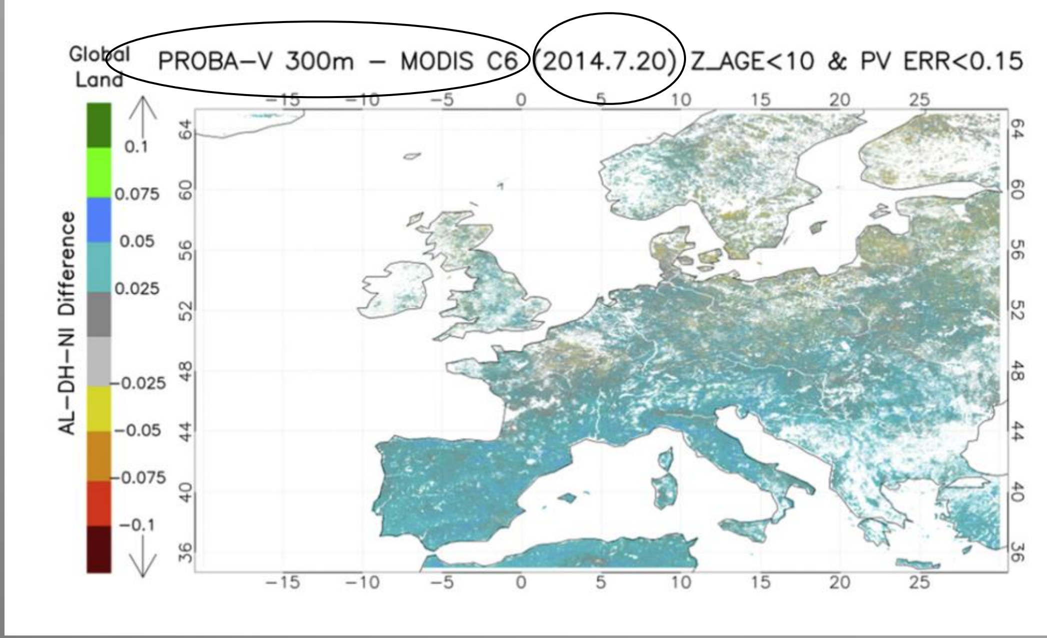


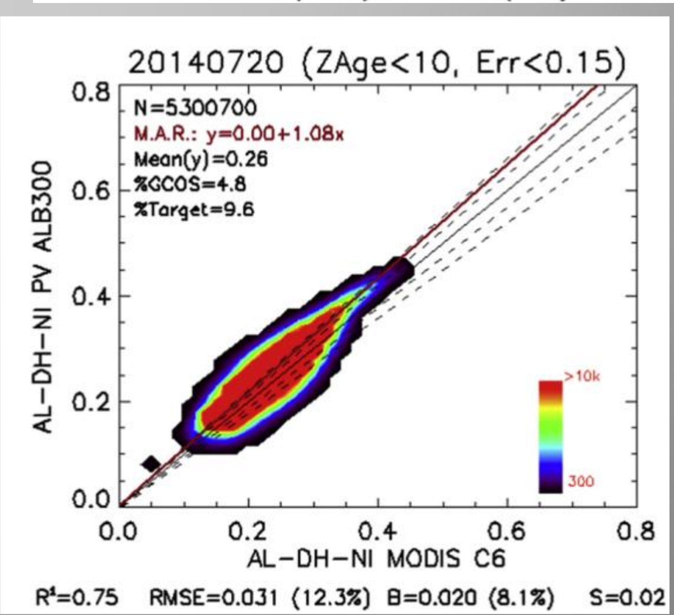


PROBA-V albedo: comparison with MODIS



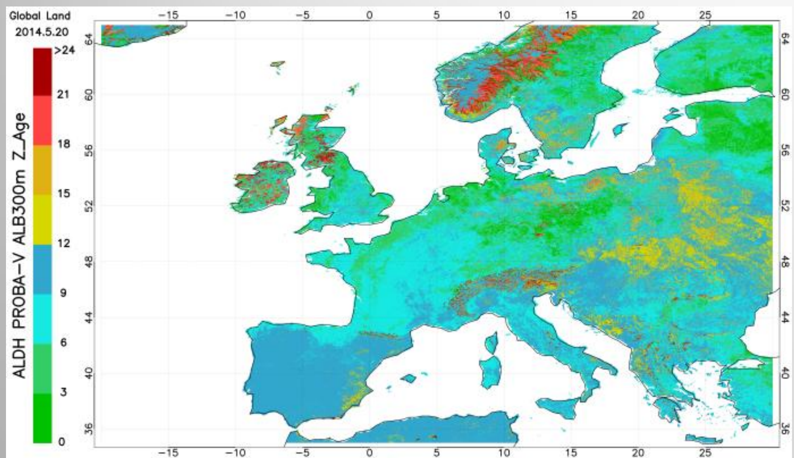






Age of albedo at different times

2014.05.20



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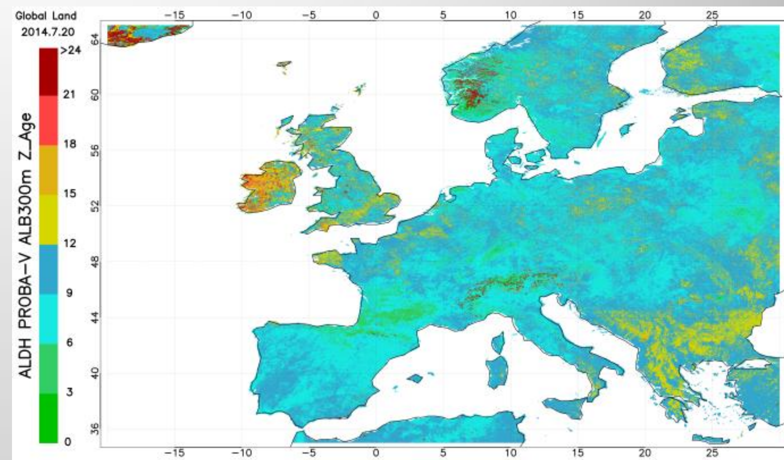

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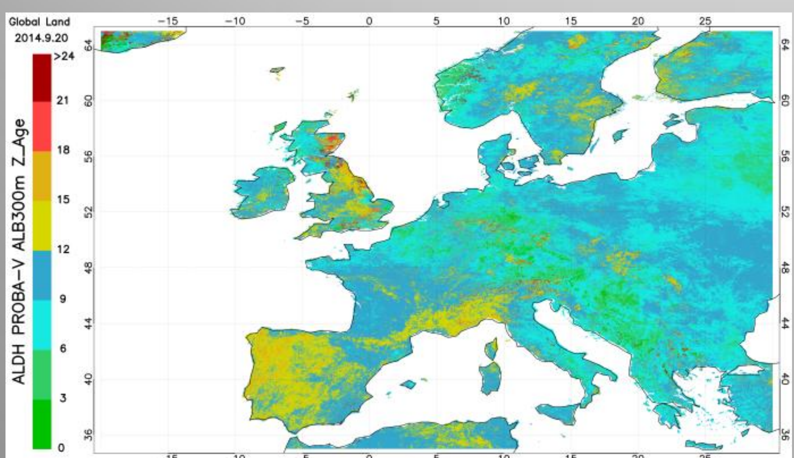
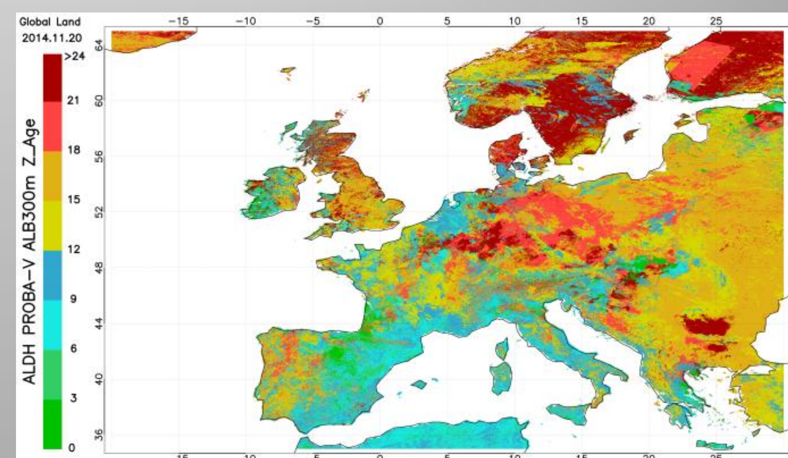
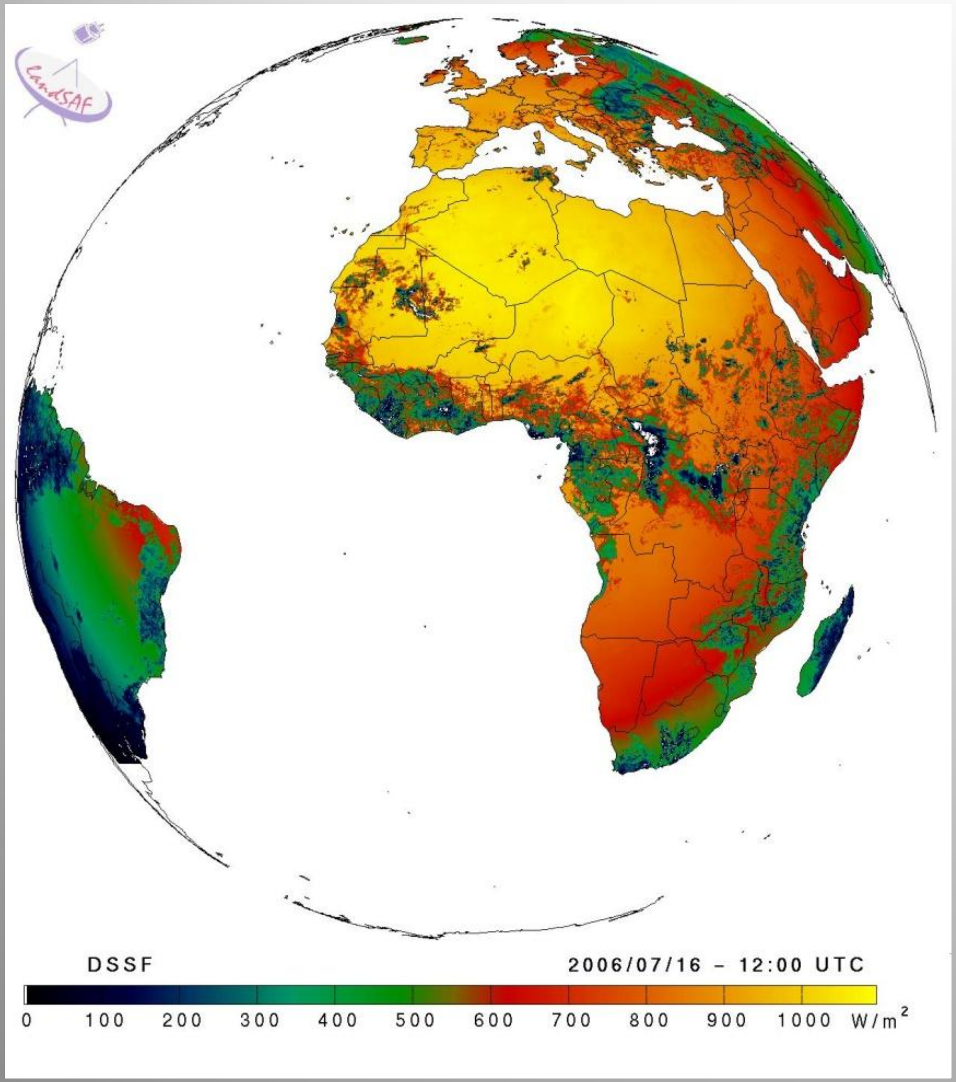


2014.11.20



Downward Short-wave (solar) Surface Radiation

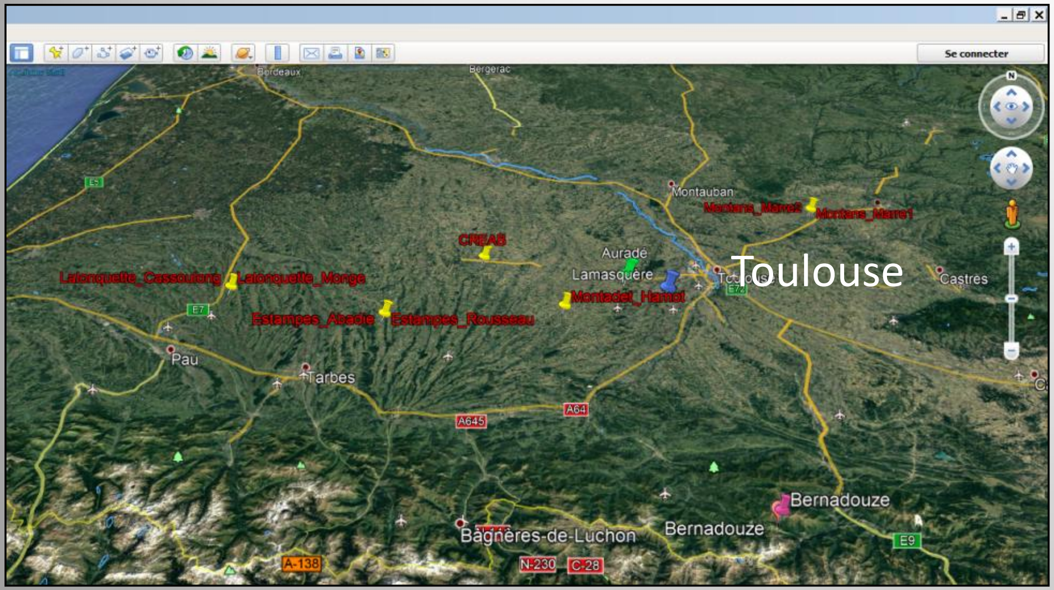


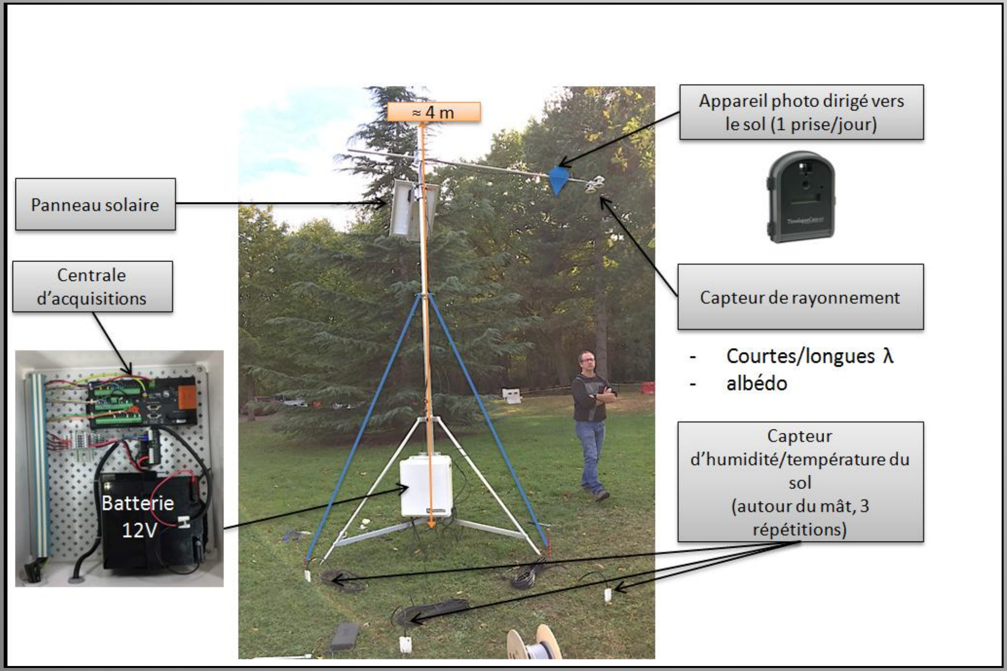
METEOSAT Second Generation (MSG) /SEVIRI

- ✓ 30-min and daily products
- ✓ 3 km at sub-satellite point
- ✓ NRT (EUMETCast)
- ✓ Off-line
- ✓ Available since 2005

https://landsaf.ipma.pt/en/

Validation phase





ICOS stations of Auradé & Lamasquère

+ 6 others

+ Bernadouze in Pyrénées

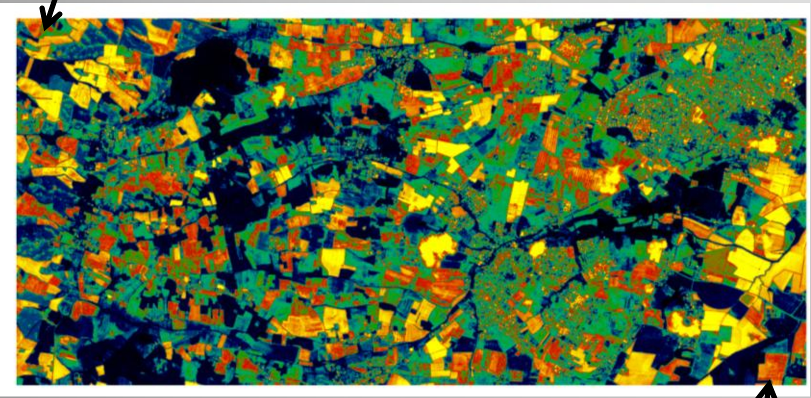
Started in 2017.

All stations fully operational from 2018.

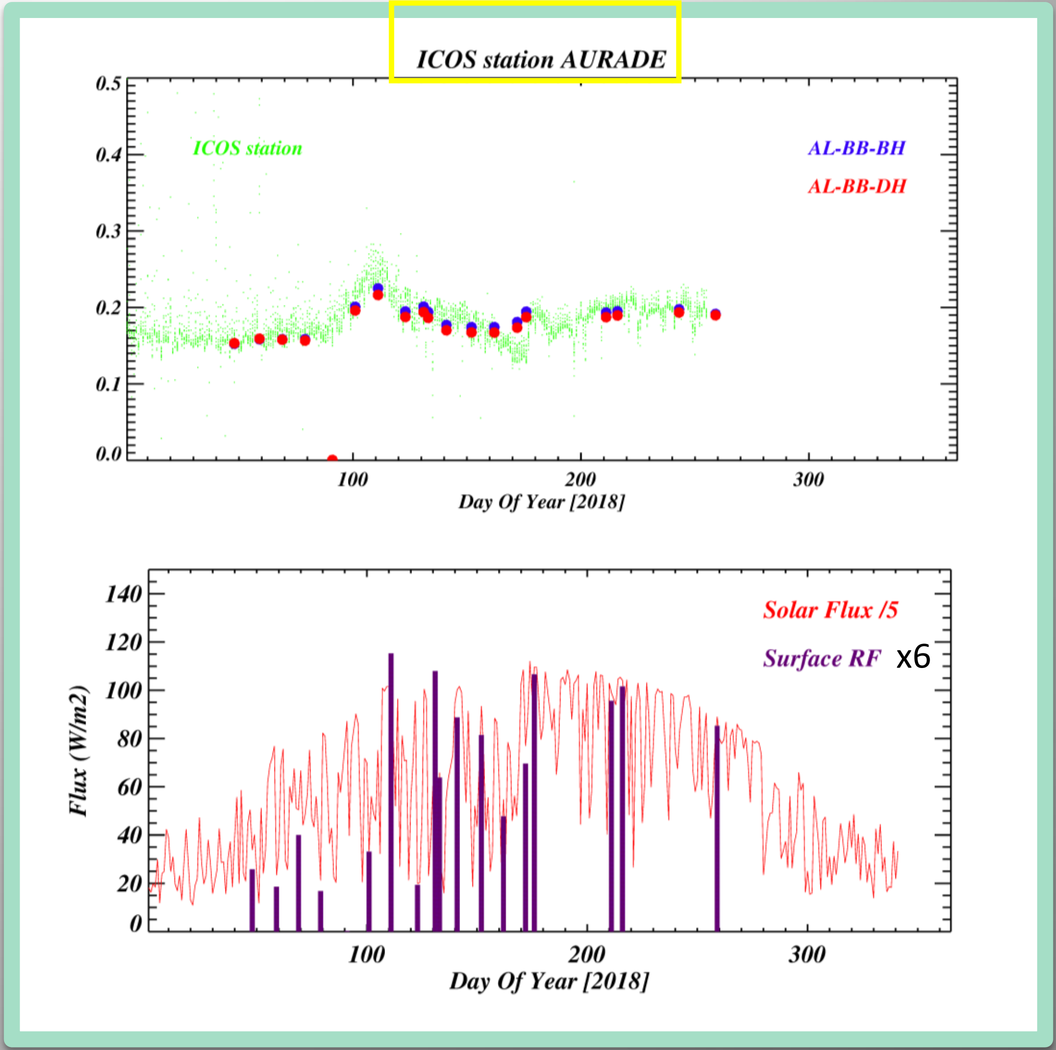
RESULTS USING SENTINEL-2

ICOS INTEGRATED CARBON OBSERVATION SYSTEM

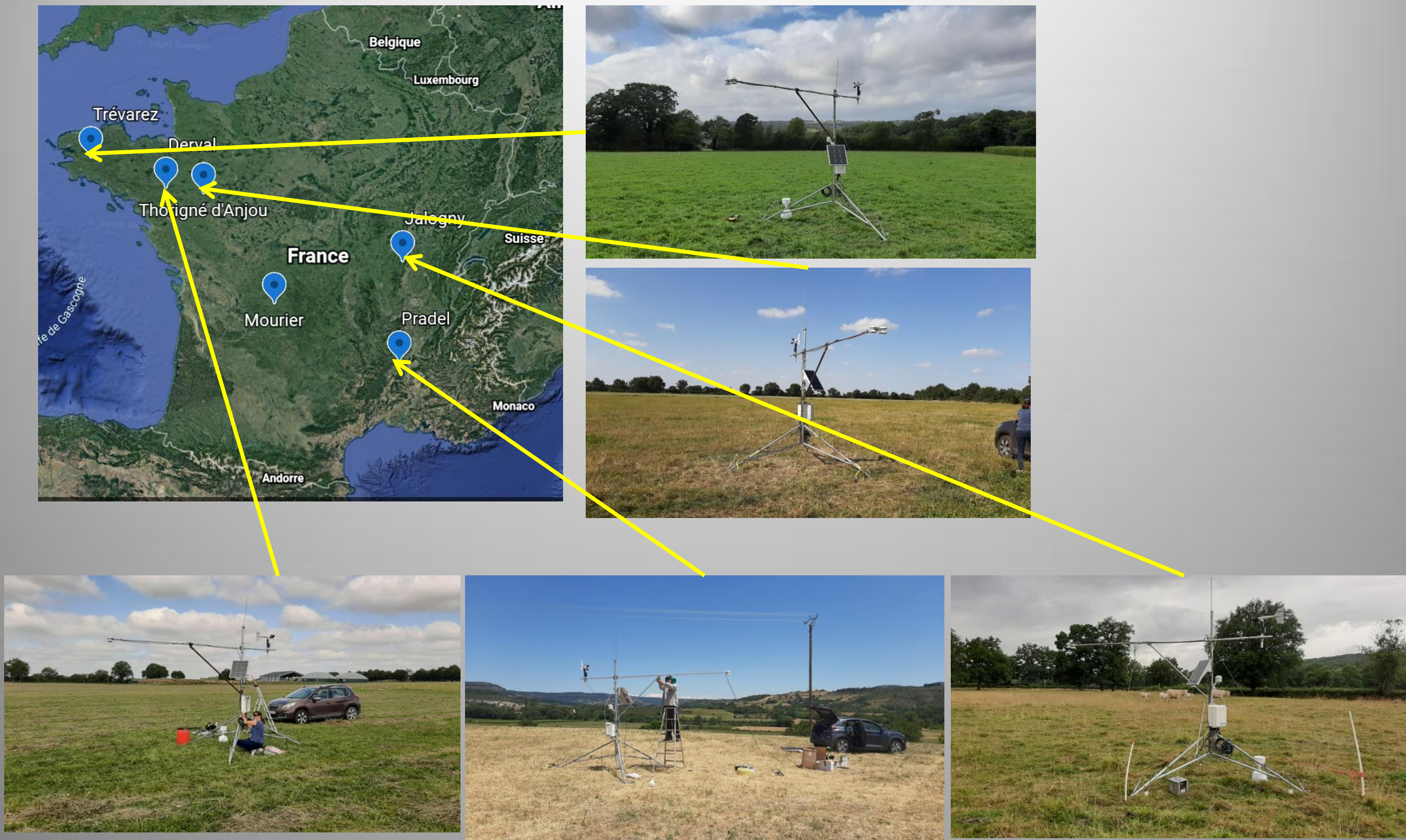
AURADE



LAMASQUERE



Project ALBEDO-prairies



Conclusion and perspectives

- *Possibility now to derive a surface albedo compatible with agricultural scale*
- *Ideally, vegetation and soil albedo products (separately)*

- *Interest of having a vegetation throughout the year (depending on water availability)*

1. It increases albedo over dark/medium bright soils (radiative effect)

2. It fixes soil nitrogen (biochemical effect)

- *Merge Sentinel-2, Landsat-8 and Sentinel-3 (ITT ESA)*
- *Start continental production (project SENAMAC /FPA-Copernicus User uPtake)*