Definition of the required satellite revisit frequency to fulfill farmer information needs - Use of GNSS in precision agriculture

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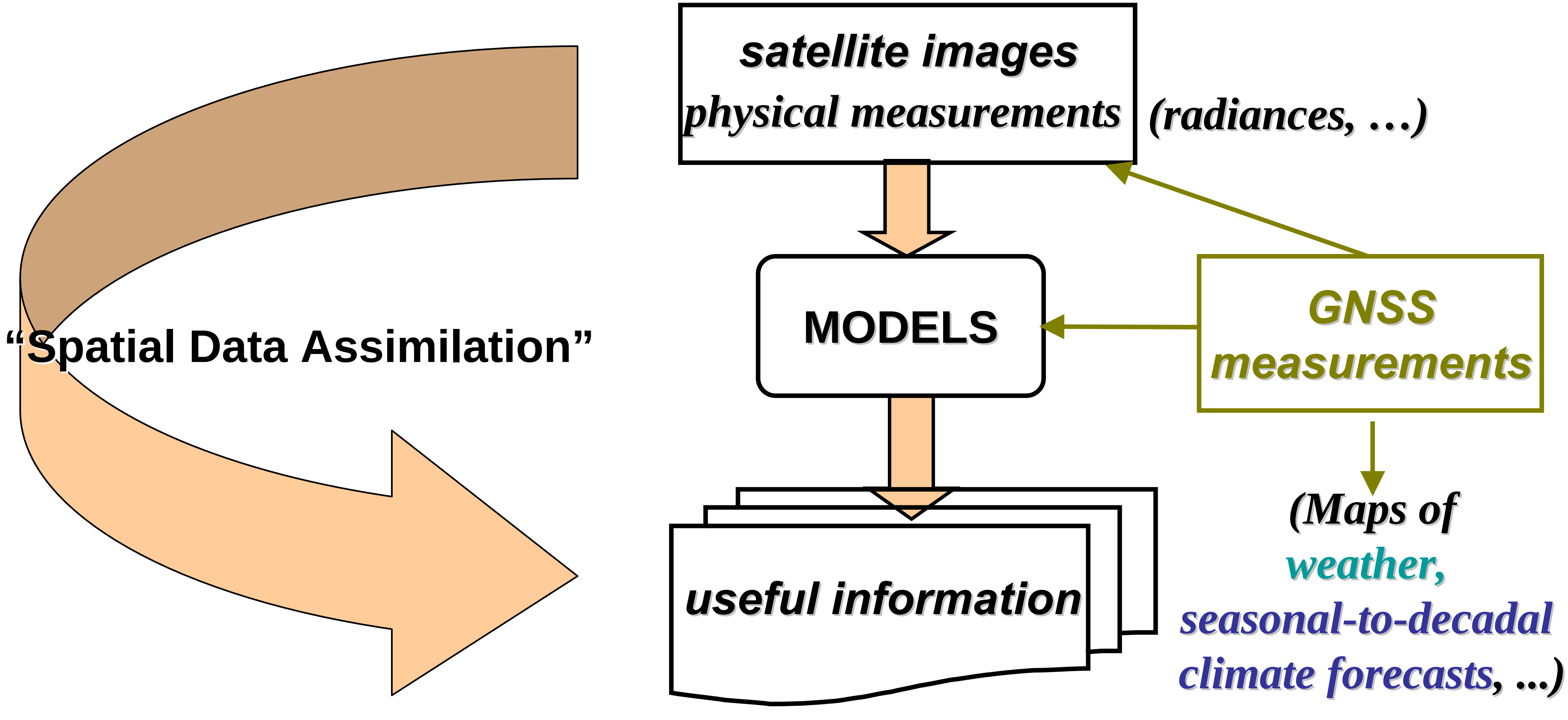
At present, the leading domains of Earth Observation applications are Meteorology and Oceanography, where satellite images are integrated in operational systems



As compared to the operational systems

used in Meteorology and Oceanography,

Agriculture is one step behind

However, in accordance with a French Feasability Study (2000)

- ***about 500,000 farmers are potentially interested by near-real time agronomic information (Lat: 30° - 50°N & 30°- 40° S)***
- ***the affordable price of information: 7-8 Euro/year/ha***

Evaluating the data assimilation technique

in Agriculture to fulfill farmer information needs

was the objective of the the "ADAM" Project:

"Assimilation of spatial Data by AgroModeling"

Participants

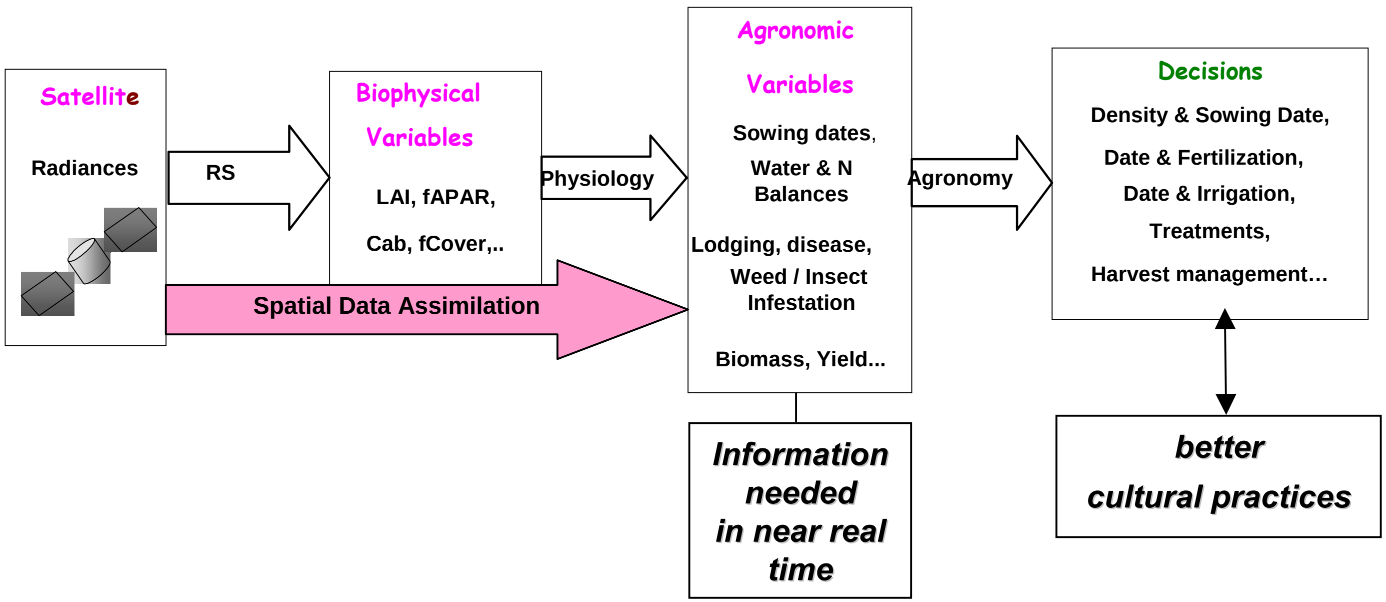
France:

- French Space Agency (initiative)
- Institute for Agronomic Research
- College of Agriculture Purpan

Romania:

- Romanian Space Agency
- Institute for Soil and Agrochem. Research
- Institute for Cereals Research
- InterGIS srl (GNSS measurements provider)

Concept of Spatial Data Assimilation in Agriculture



"ADAM" aimed to define the specifications of a spatial mission
"AGRICULTURE"
adapted to the assimilation data technique

Specifications of a spatial mission “AGRICULTURE”

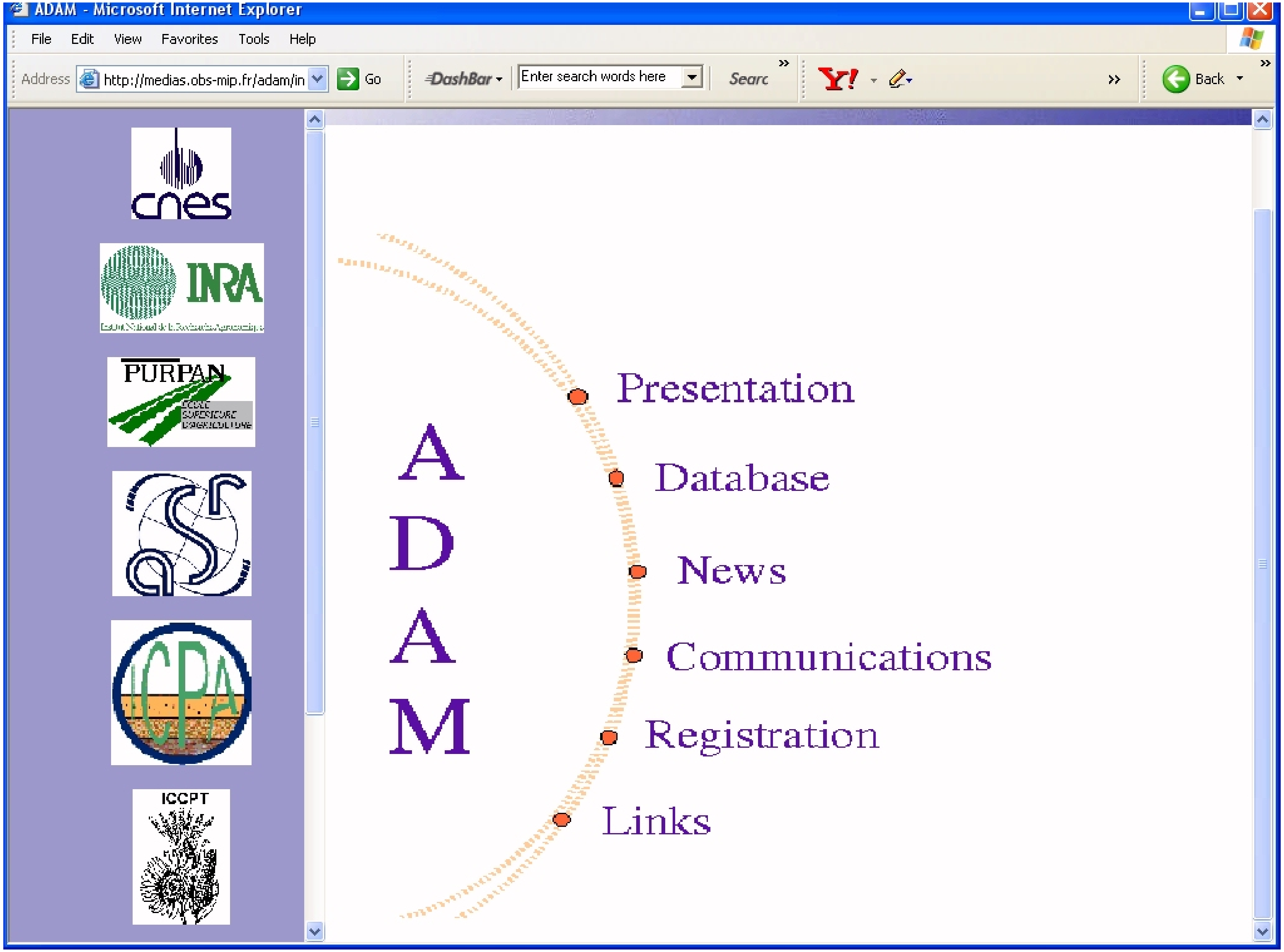
• satellite revisit frequency ?

• spatial resolution ?

• spectral bands ?

to fulfill farmer information needs, at an affordable price

ADAM web page: http://medias.obs-mip.fr/adam/



ADAM Data Base

- **Meteo - Atmosph.**
  - 2000/2001 campaign
  - 2001/2002 campaign
  - *******
    - meteo
    - PAR
- **Soil**
  - 2000/2001 campaign
  - 2001/2002 campaign
  - *******
- **Vegetation**
  - 2000/2001 campaign
  - 2001/2002 campaign
  - *******
    - Biomass
    - Chlorophyll
    - LAI-2000
    - Cropping techniques
    - Yield - quality
- **Maps**
  - Permanent maps
  - 2000/2001 campaign
  - 2001/2002 campaign
  - *******
    - DEM
    - GCP
    - Geology
    - Soil
- **Satellite images**
  - SPOT (TOA, TOC, aux.data, ext., QL)
  - ERS (intensity, aux. data, ext., QL)
  - RADARSAT (intensity, aux.data, ext., QL)
  - Reference image
- **Meetings**
  - Steering Committees
  - Technical Meetings
- **Temp**
- **Export**

All ground data were located by GNSS measurements

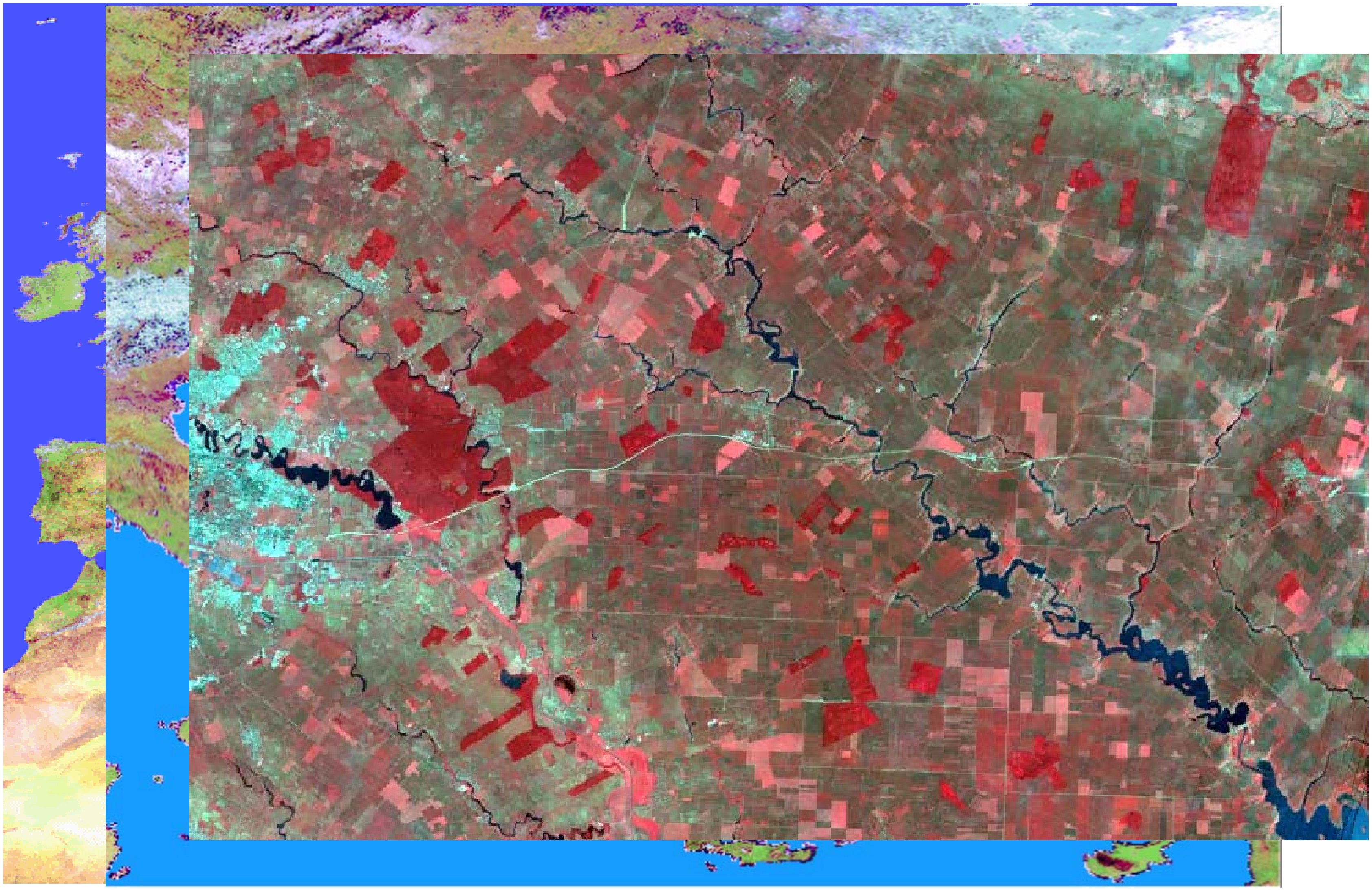
Yield maps produced by YMS

The reference satellite images were registrated using ground control points located by GNSS measurements

Measurements in differential mode

"ADAM" Site (40 x 60 km²)

Localization: Romania, Fundulea, 35 km East of Bucharest



In this topic we are dealing with

the most important biophysical variable

retrievable from radiometric data:

the Leaf Area Index (LAI)

LAI is required for decision making with:

- ***a weekly update of the values***
- ***a given accuracy (to be defined)***

What is the required satellite revisit frequency

to produce pertinent agronomic information,

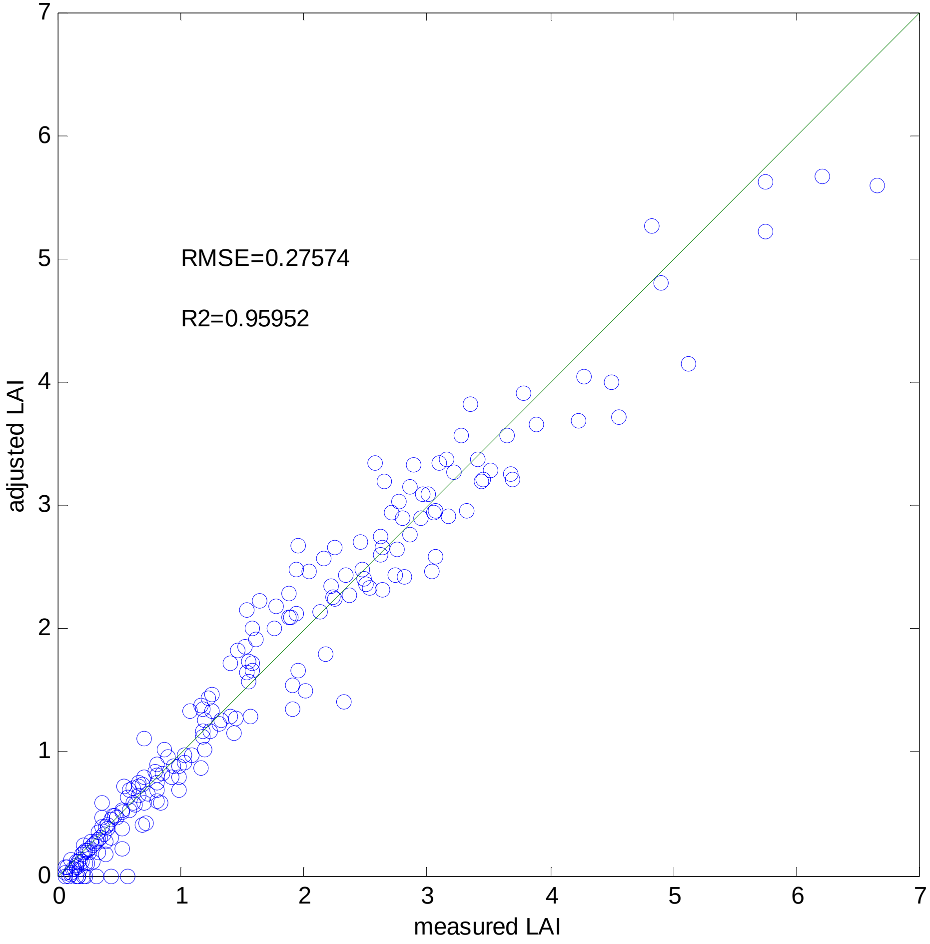
that can be derived by LAI data assimilation ?

***<u>STEP I:</u>* DERIVING LAI FROM "ADAM" SATELLITE TIME SERIES**

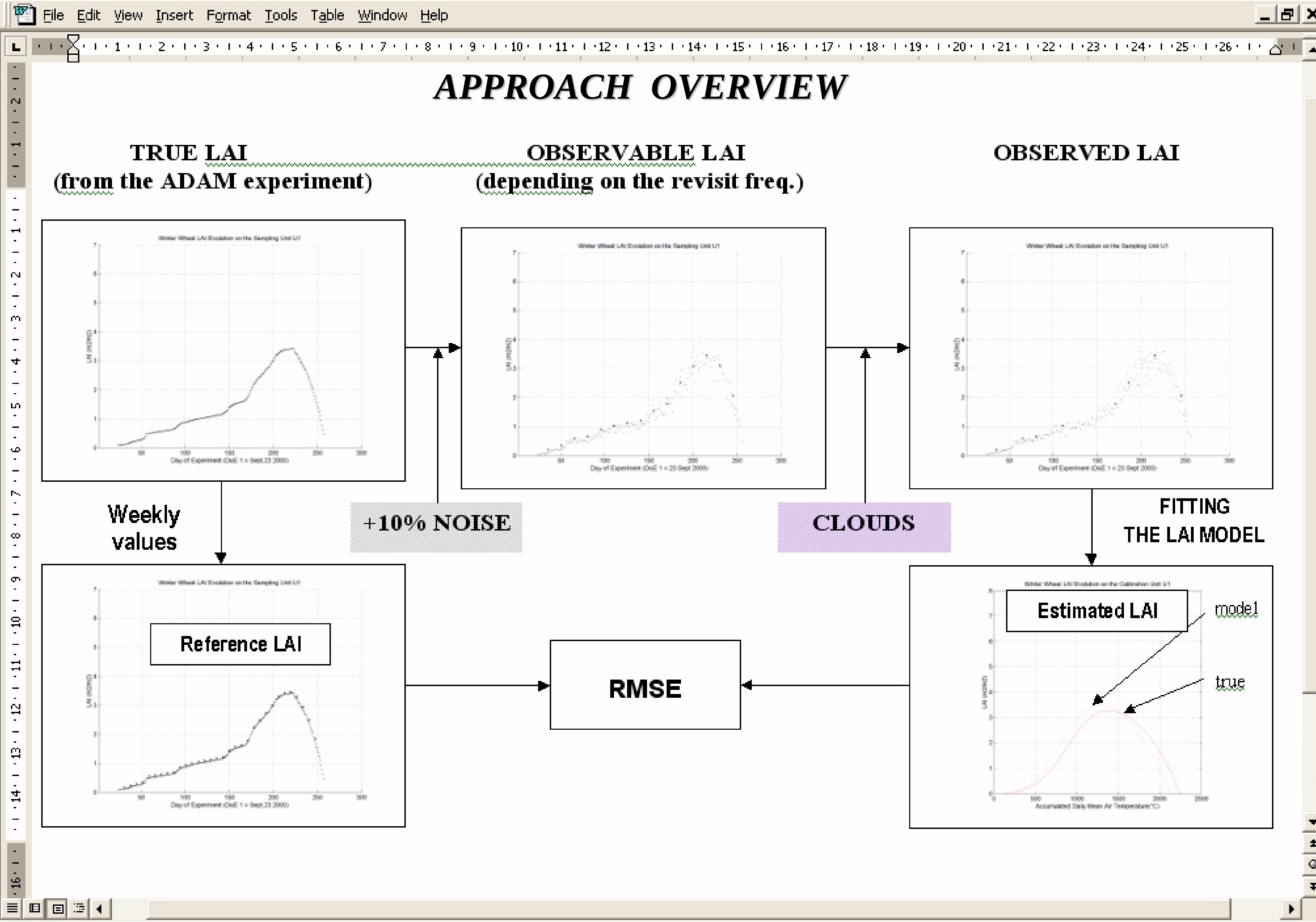
Input data and algorithm

- ***33 SPOT XS images from the ADAM campaign 2000-2001***
- ***Green, Red and Near Infrared Bands ("top of canopy" reflectance)***
- ***30 classes of radiometric evolution found by k-means algorithm***
- ***LAI evolution model parameters found by minimisation of distances among measured and simulated data***

Comparison between the measured and simulated LAI values



STEP II: Definition of the satellite revisit frequency



Assumptions used

(1) Simulations are enough realistic

- ***variability of situations, as observed over the ADAM experiment***
- ***uncertainities levels on LAI estimates from RS observations: 10%, 20% and 25%***

(2) Consideration of 6 revisit frequency scenarios:

1-day, 2-days, 3-days, 7-days, 15-days and 30-days

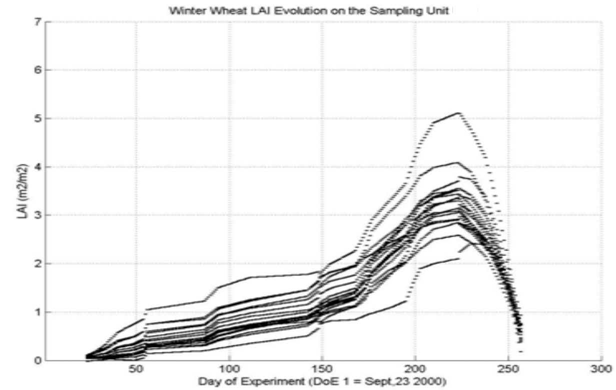
(3) Probability levels to have clouds: 0.5 and 0.6, independent with time

(4) Phasing of the orbit cycle variable (start day randomly drawn)

(5) Reference case made of the "true" LAI observed weekly (fixed dates)

(1) Generation

of the “true and reference” LAI data set



Empirical Transfer Functions

(previously obtained, see article IGARSS’03)

$LAI = \alpha_0 + \Sigma\alpha_i\rho_i$, i=1,3

→

For 40 Sampling Units:

$\widehat{LAI}$

at SPOT acquisition dates

(28 dates between 15 Oct 2000 – 6 June 2001)

→

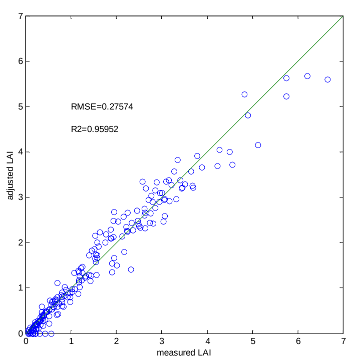
Linear interpolation

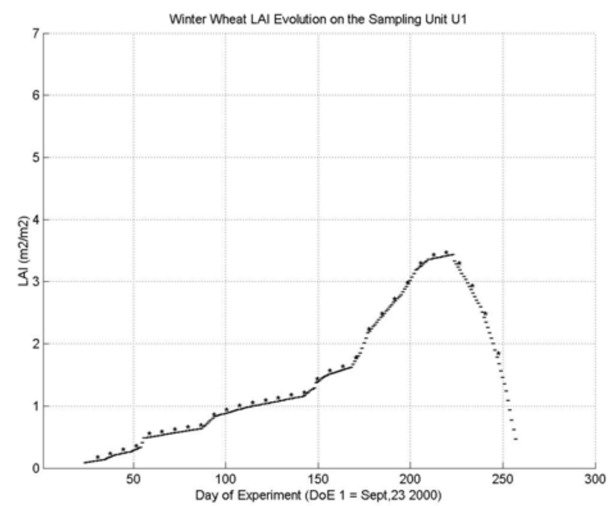
→

Daily $\widehat{LAI}$

↓

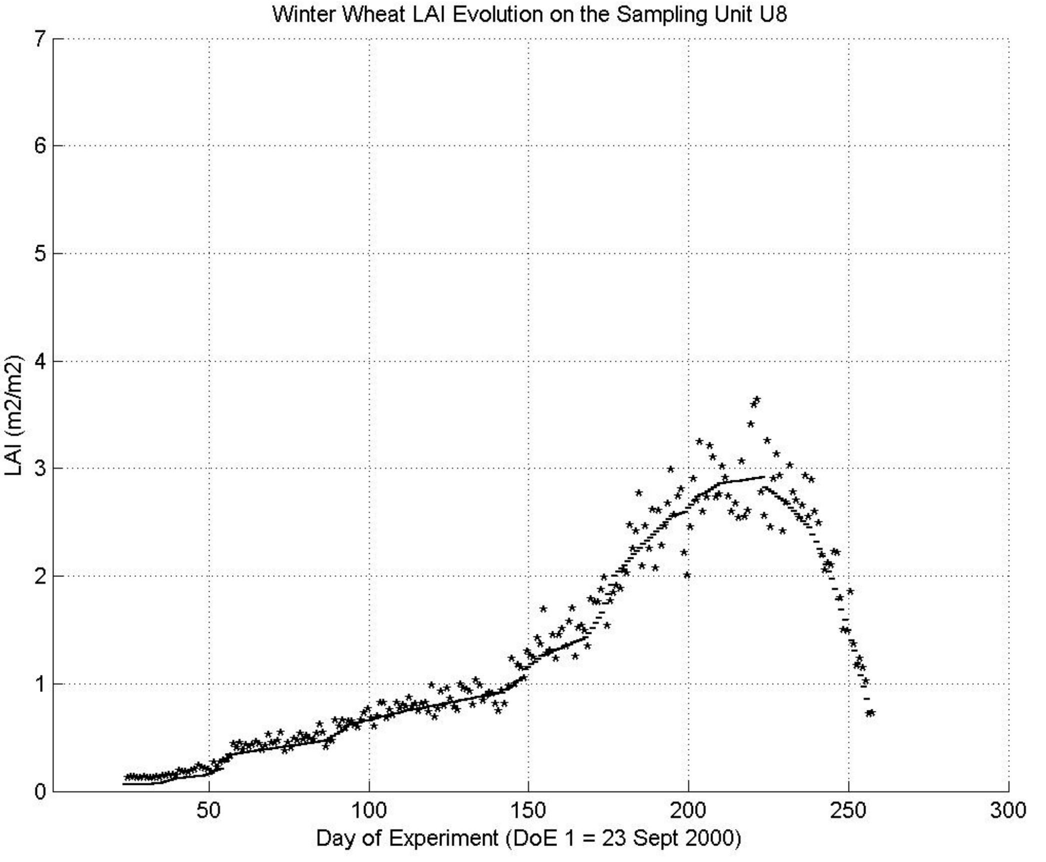
Weekly $\widehat{LAI}$





(2) Generation of an "observable" LAI dataset taking into account measurement and model uncertainities, in the form of an additive gaussian noise

Exemple



(3) Generation of time series of good images considering:

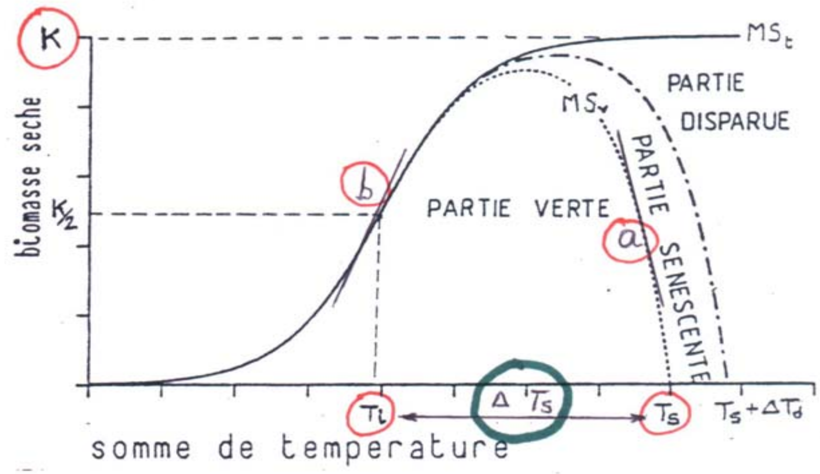
- *six scenarios of satellite revisit frequency*
- *two probability levels to have clouds (clear sky)*
- *different starting date for the acquisition cycle*

EXEMPLE

	A	B	C	D	E	F	G
1	1-day revisit	2-days revisit	3-days revisit	7-days revisit	15-days revisit	30-days revisit	Clear sky
2	1	0	0	0	0	0	1
3	1	1	1	0	0	0	0
4	1	0	0	0	0	0	1
5	1	1	0	0	1	0	0
6	1	0	1	1	0	0	1
7	1	1	0	0	0	0	1
8	1	0	0	0	0	0	0
9	1	1	1	0	0	0	0
10	1	0	0	0	0	0	1
11	1	1	0	0	0	0	0
12	1	0	1	0	0	0	1
13	1	1	0	1	0	0	1
14	1	0	0	0	0	0	1
15	1	1	1	0	0	0	1
16	1	0	0	0	0	0	0
17	1	1	0	0	0	0	0
18	1	0	1	0	0	1	1
19	1	1	0	0	0	0	1
20	1	0	0	1	1	0	0
21	1	1	1	0	0	0	1
22	1	0	0	0	0	0	0
23	1	1	0	0	0	0	0
24	1	0	1	0	0	0	1
25	1	1	0	0	0	0	0
26	1	0	0	0	0	0	0
27	1	1	1	1	0	0	0
28	1	0	0	0	0	0	0
29	1	1	0	0	0	0	1
30	1	0	1	0	0	0	0
31	1	1	0	0	0	0	0
32	1	0	0	0	0	0	0
33	1	1	1	0	0	0	1
34	1	0	0	1	0	0	0
35	1	1	0	0	1	0	1
36	1	0	1	0	0	0	0
37	1	1	0	0	0	0	0
38	1	0	0	0	0	0	1
39	1	1	1	0	0	0	1
40	1	0	0	0	0	0	0
41	1	1	0	1	0	0	1

Fitting the LAI evolution model (1/2)

$$LAI = K\left[\frac{1}{1+e^{-b(T-T_i)}} - e^{a(T_i+\Delta Ts)}\right]$$



where ***K*** ***is the amplitude of maximal leaf area,***

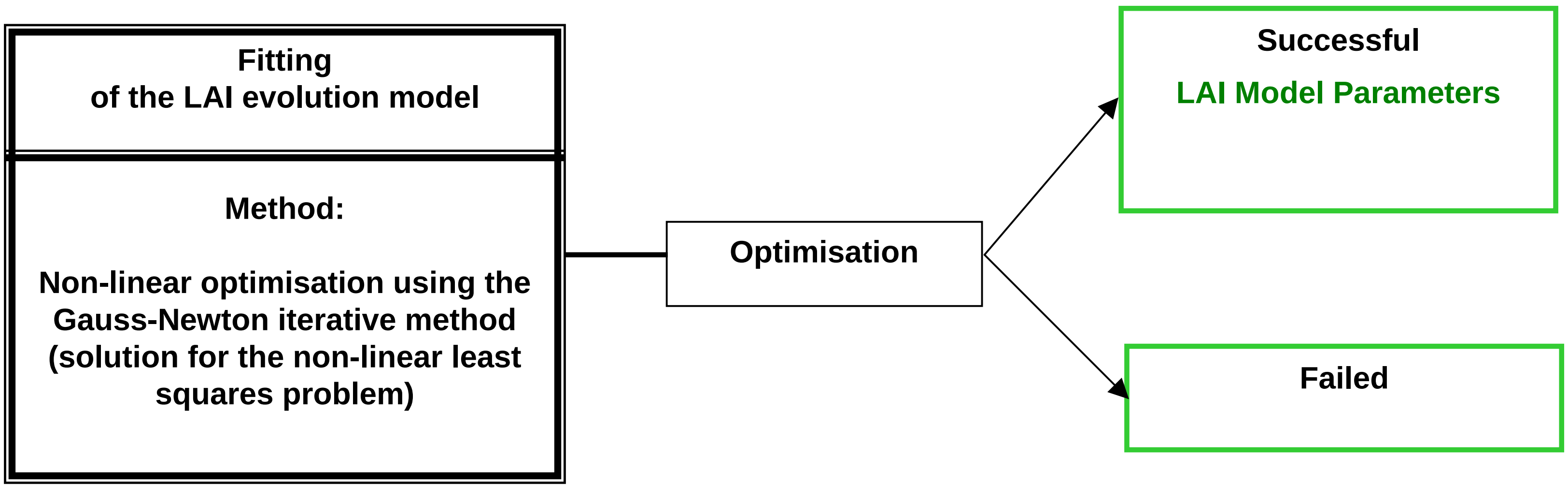
b ***is the relative growth rate at the first inflexion point, called Ti,***

a ***is the relative senescence rate,***

Ts ***is the disappearance time of green leaves***

T ***is the accumulated daily mean air temperature***

Fitting the LAI evolution model (2/2)



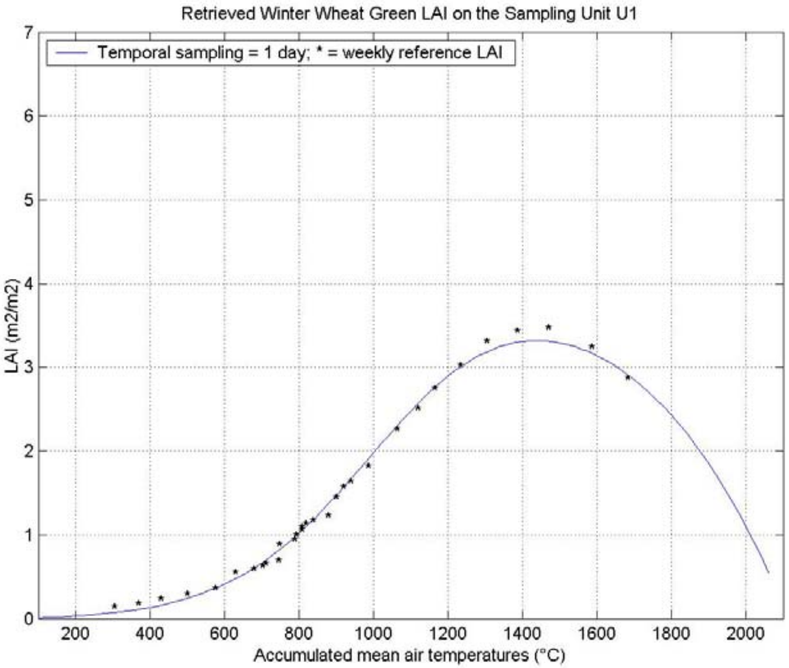
RELEVANT RESULTS

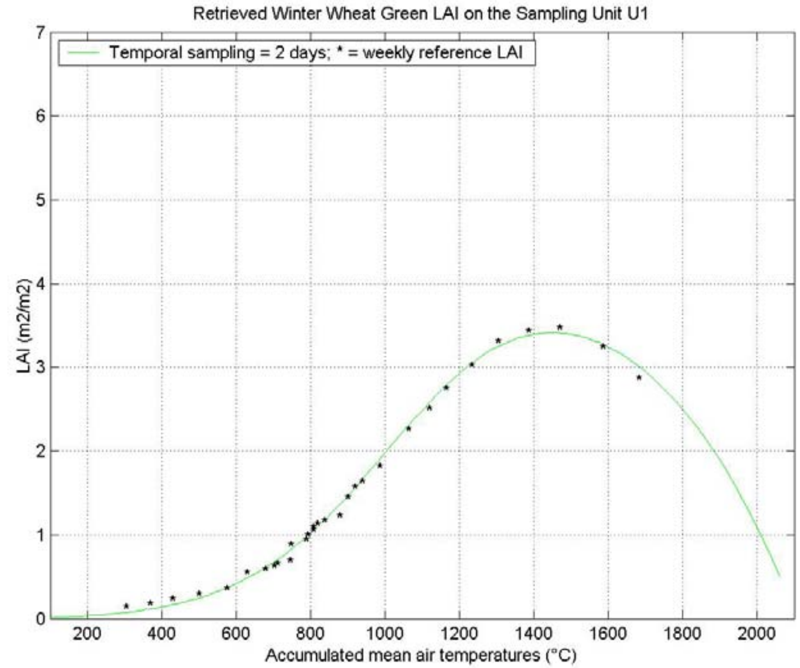
(I) Example of retrieved LAI dynamics

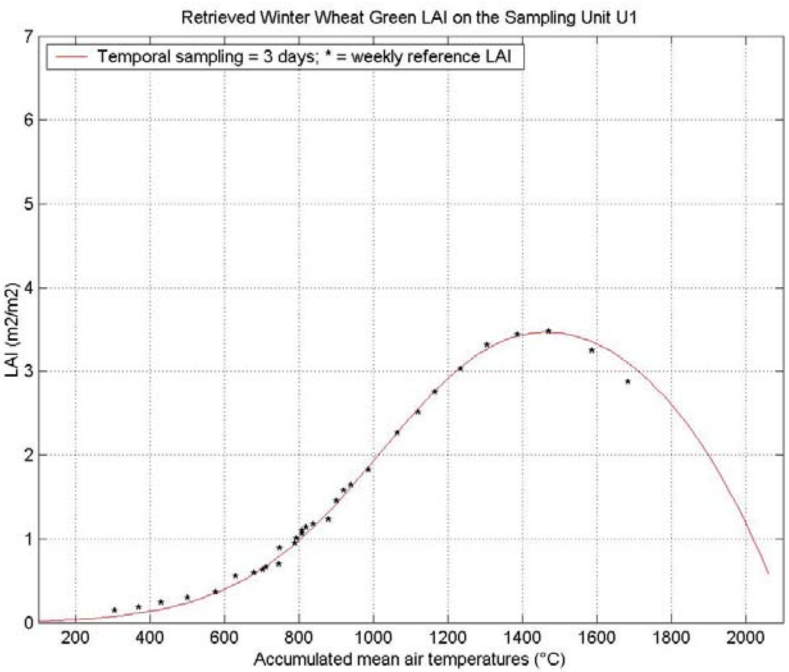
as compared with the weekly reference LAI dataset

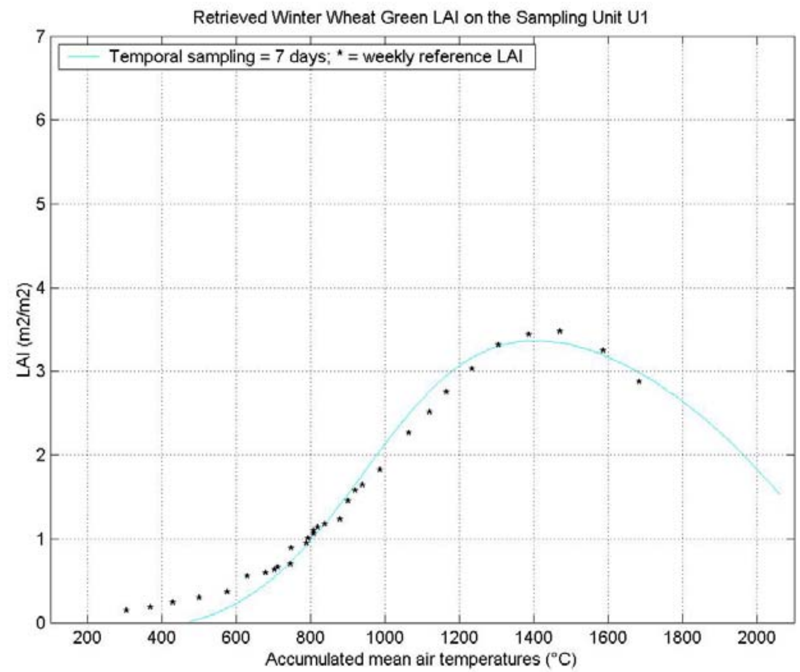
for

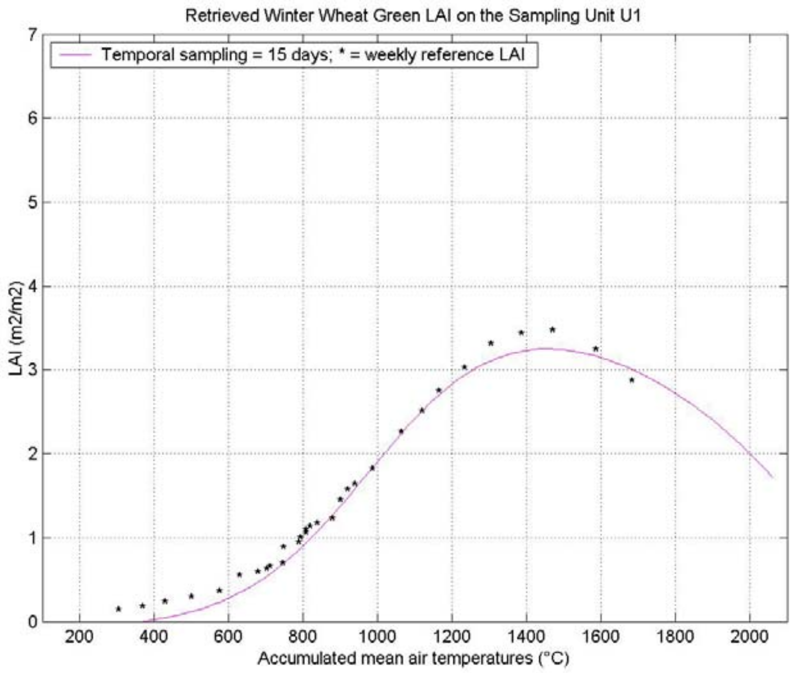
- ***one sampling unit***
- ***six revisit scenarios***
- ***one replicate***

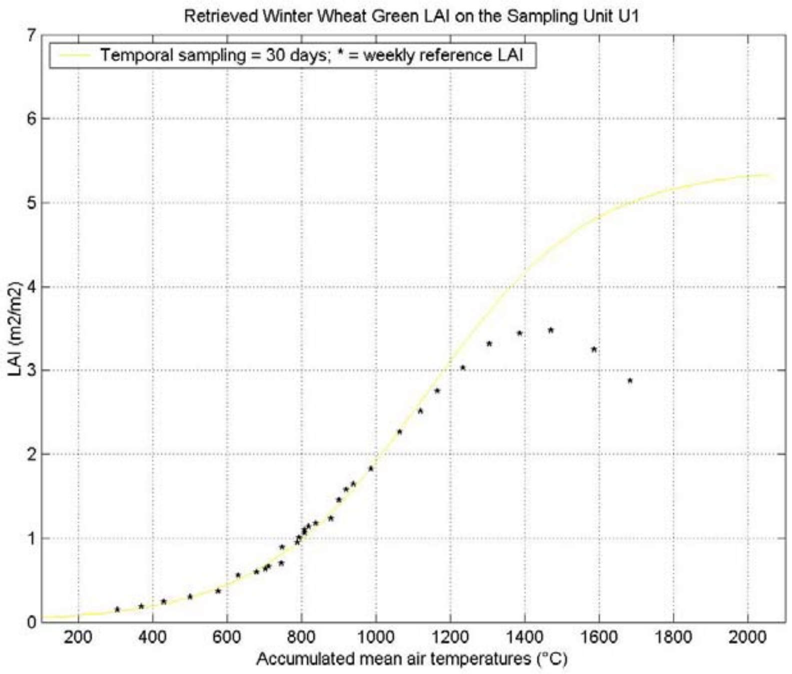

Retrieved Winter Wheat Green LAI on the Sampling Unit U1
Temporal sampling = 1 day; * = weekly reference LAI
LAI (m2/m2)
Accumulated mean air temperatures (°C)


Retrieved Winter Wheat Green LAI on the Sampling Unit U1
Temporal sampling = 2 days; * = weekly reference LAI
LAI (m2/m2)
Accumulated mean air temperatures (°C)


Retrieved Winter Wheat Green LAI on the Sampling Unit U1
Temporal sampling = 3 days; * = weekly reference LAI
LAI (m2/m2)
Accumulated mean air temperatures (°C)

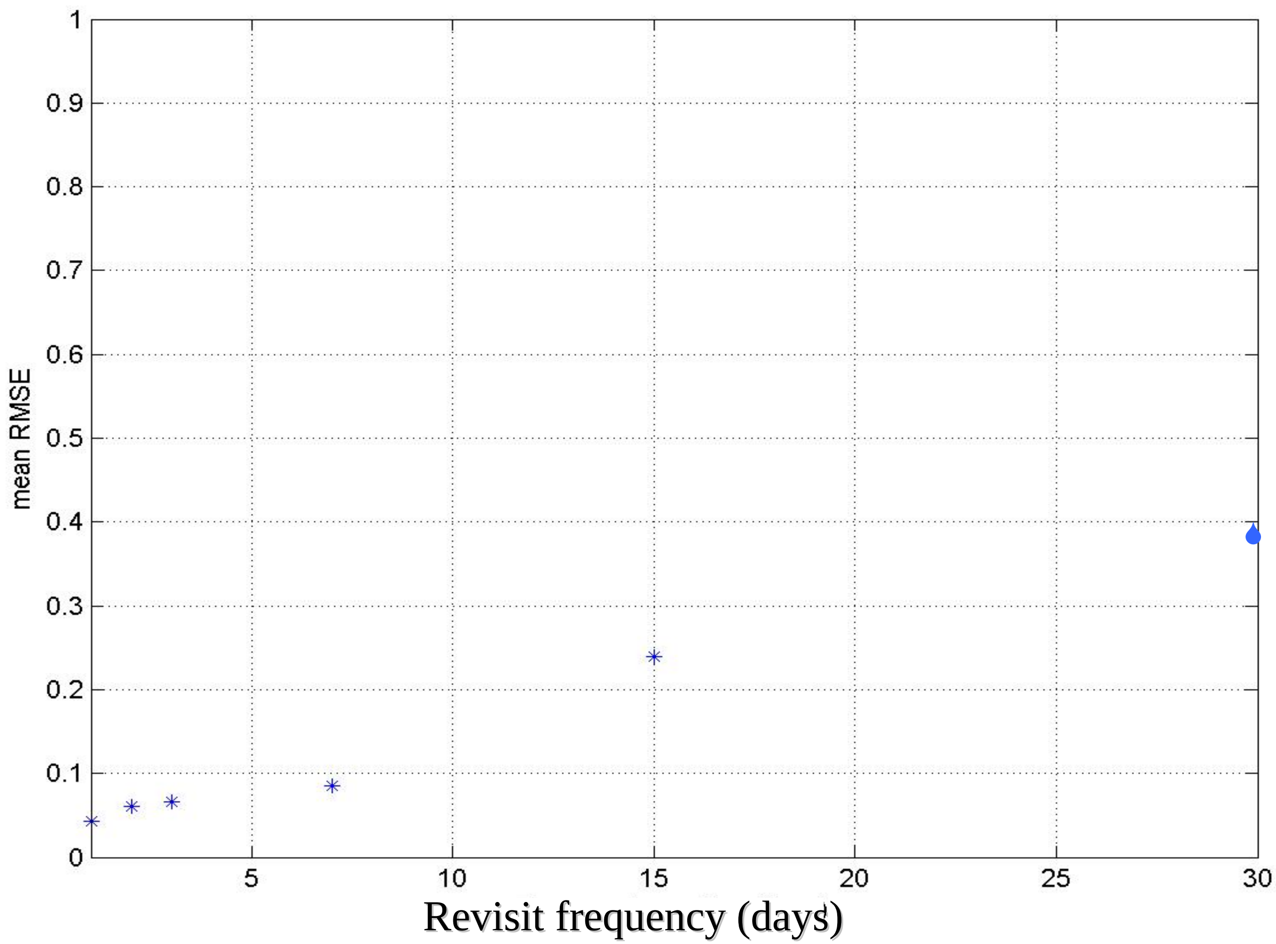

Retrieved Winter Wheat Green LAI on the Sampling Unit U1
Temporal sampling = 7 days; * = weekly reference LAI
LAI (m2/m2)
Accumulated mean air temperatures (°C)


Retrieved Winter Wheat Green LAI on the Sampling Unit U1
Temporal sampling = 15 days; * = weekly reference LAI
LAI (m2/m2)
Accumulated mean air temperatures (°C)
0
1
2
3
4
5
6
7
200
400
600
800
1000
1200
1400
1600
1800
2000


Retrieved Winter Wheat Green LAI on the Sampling Unit U1
Temporal sampling = 30 days; * = weekly reference LAI
LAI (m2/m2)
Accumulated mean air temperatures (°C)
0
1
2
3
4
5
6
7
200
400
600
800
1000
1200
1400
1600
1800
2000

(II) Overall results over:

- ***40 sampling units***
- ***6 revisit frequency scenarios***
- ***30 replicates (clouds occurrence scenarios)***



CONCLUSION

The results indicate that a 3 days to 1 week revisit frequency could be enough to generate enough accurate LAI values to produce information needed by farmers.

At present, the propagation of LAI uncertainities on yield estimation and on other higher level products is investigated, by running data assimilation techniques.

Remark:

On-going studies performed within "ADAM" (Claire Lauvernet) show that the revisit frequency could be dropped to 15 days, if information on spatial structures is added.

Follow-up the ADAM web page !


Thank you for your attention !