EO_Regions_Science

Basic Research in support of EO_Regions!

A STEREO III Shared-Cost Project

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Outline

- Introduction
  - Context: EO_Regions!
  - Objectives & Partnership
- Corner Reflector Design
- Change Detection Toolbox
- Structuring Services and Ontologies
- Methodology for User Needs and In-situ Data
- Data Assimilation to AquaCrop Model
- Conclusion

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Context

EO_Regions! : A RW project lead by SPACEBEL:

Development of innovating EO services based on Sentinel data

⇒ Deployment of a digital platform

- available to users and data providers of earth observation domain at regional scale (Wallonia)
- exportable as a tool-box to other European regions and emergent countries (show case: Senegal)

EO_Regions! proposes a marketplace dedicated to the commercialization of Earth observation services

- Based on Sentinel data
- A clear understanding of the user needs
- Integrated infrastructure: big data storage
- Sharing of data and services
- Combination/re-use of geospatial data over a territory

- Dynamical monitoring of territories
- Services targeted to users not expert but interested in the added value of EO information
- Correct use of the information
- Easy & flexible access
- Increased added value of local existing data

EO_Regions_Science

Objectives

EO_Regions_Science:

Basic Research in support of EO_Regions!

an ensemble of bricks to build the foundation of EO_Regions!

- build up the necessary scientific knowledge in order to achieve EO_Regions! objectives linked to thematic EO services:
  - change detection and monitoring methodologies,
  - ontologies,
  - crop modelling,
  - user needs definition

Integration of Sentinel data into the AquaCrop model (FAO)

Support in situ acquisitions & provide case study data

Structuring services by semantic web language and ontologies

Change Detection toolbox

Corner Reflector definition → Applications in ground displacements monitoring

- facilitate the operationalization of these services
- generate original results interesting Belgian remote sensing community outside the EO_Regions! context.

T1 - Corner Reflector Design

Corner Reflector definition → Applications/Service in ground displacements monitoring

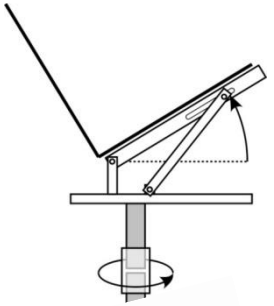
Measuring ground displacements: by differential SAR interferometry (DInSAR)
BUT requires phase stability « islands » generally referred to as Persistent Scatterers

⇒ Proposed alternative in natural areas: use **Corner Reflectors (CR's)** as artificial permanent scatterers.

- passive devices used to reflect the incoming radar signal back to its source
- stable and strong response to the SAR signal over a long period of time

Exemples of possible services in EO_Regions!	Description
Monitoring of old mineshafts	Measurement of ground movements and subsidence in the old mine shafts
Regional subsidence follow-up	Measurement of ground motion during geothermal drilling, extraction of shale gas ; evolution of groundwater

Corner Reflector Design



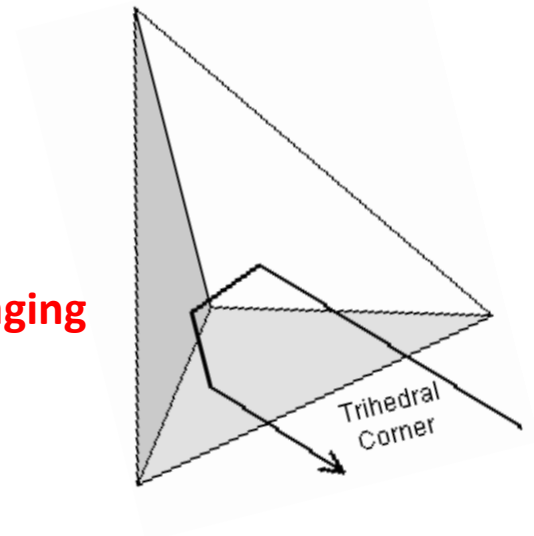
Principe:

- **1 CR** on system/area to be monitored.
- Additional **CR's** as **fixed reference** in the zone of interest and to subtract atmosphere and orbital residuals.

  - ❖ CR specification w.r.t. EO_Regions! requirements
  - ❖ Design and manufacturing
  - ❖ Testing and evaluation

- + Initial **topographic reference by GPS** measurements

Baseline: S1 imaging



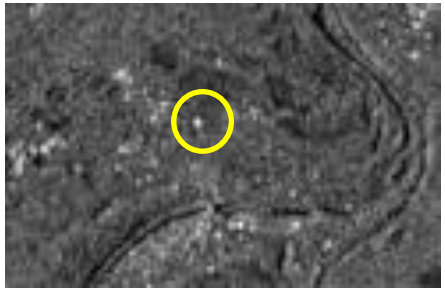
CSL Corner Reflector

2 Corner Reflectors built for EO_Regions!:
- 1m
- 1.5m

CSL Corner Reflectors

Use of CR for Sentinel-1

Excerpts from the CR time series



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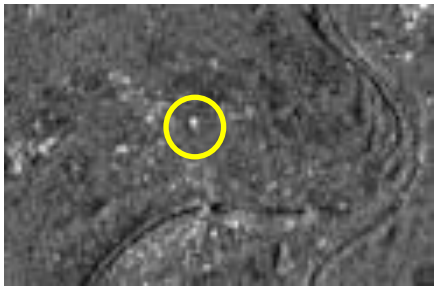

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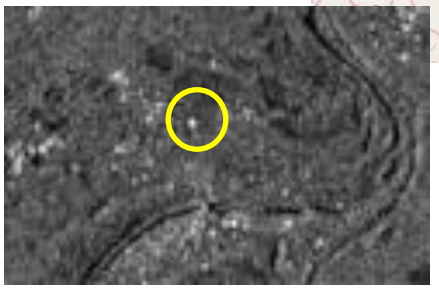

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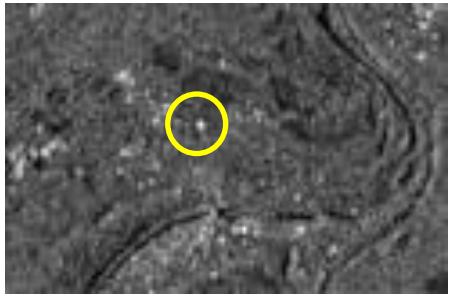

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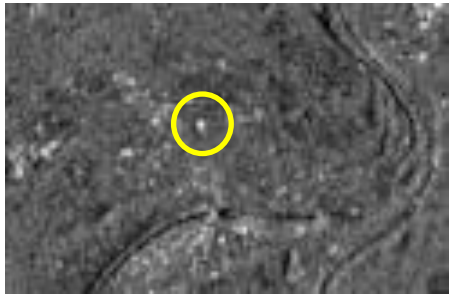

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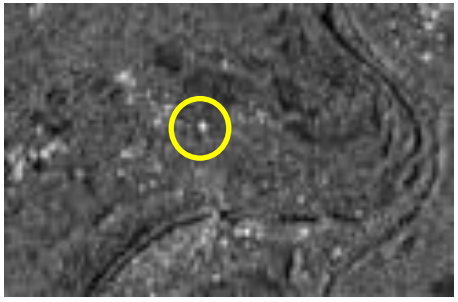

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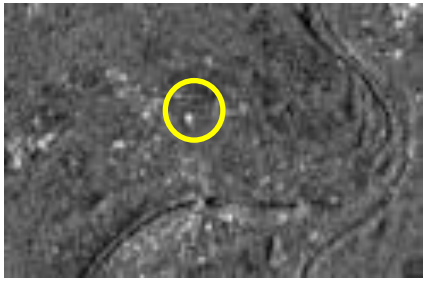
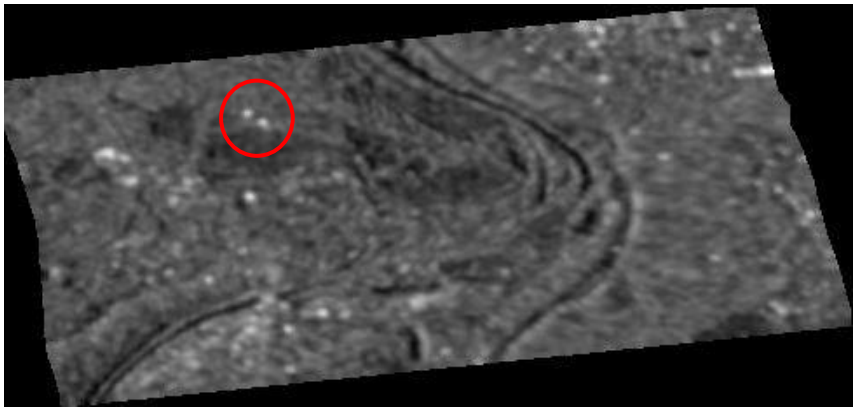
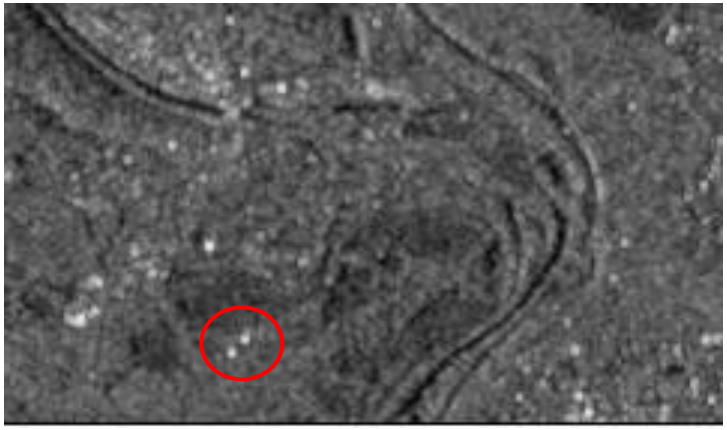


S1B_VV_23_01_2018

CSL Corner Reflectors

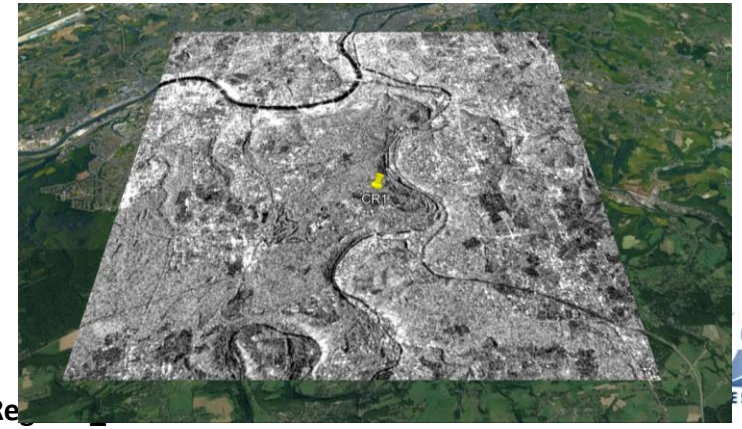
Geoprojected result





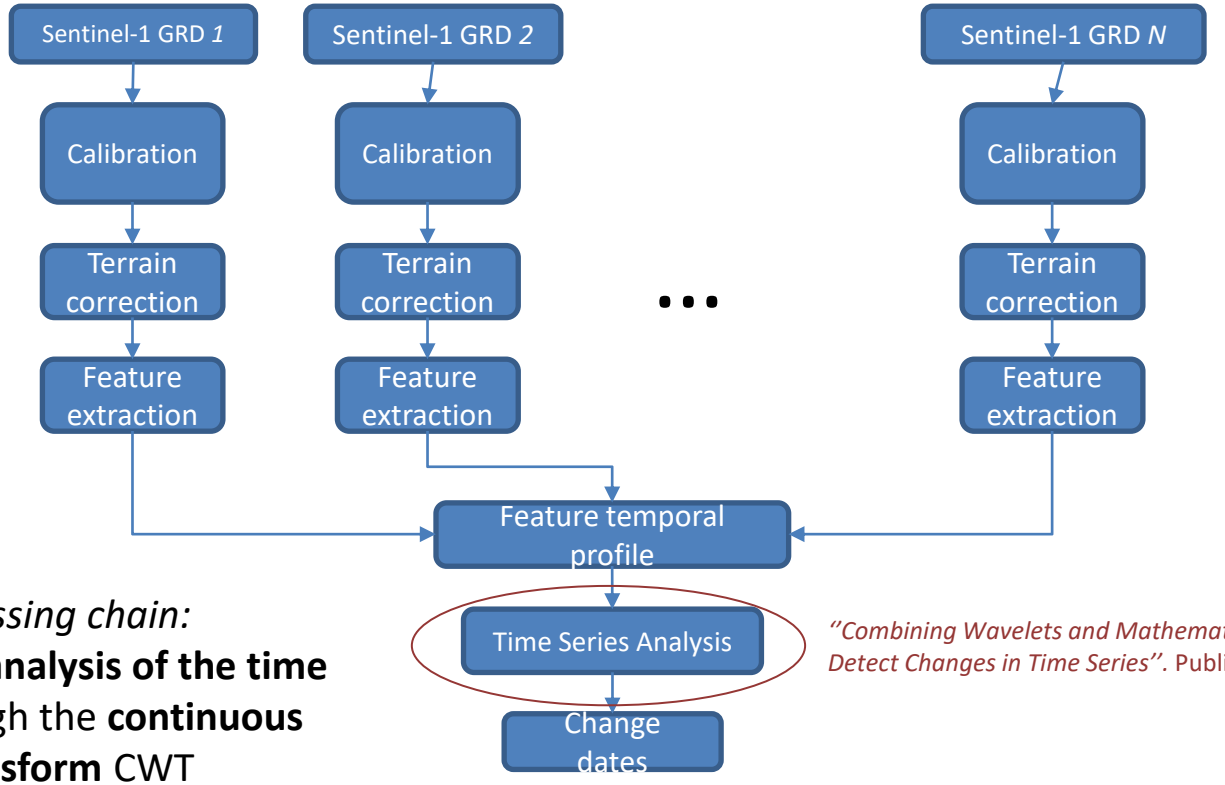
sigma_0 (CSL InSAR processor)

Geoprojected result superimposed on goggle-Earth



T2 - Change Detection

RMA **Development of a Change Detection toolbox**



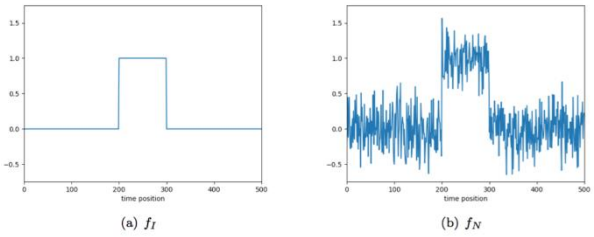
First step of processing chain:

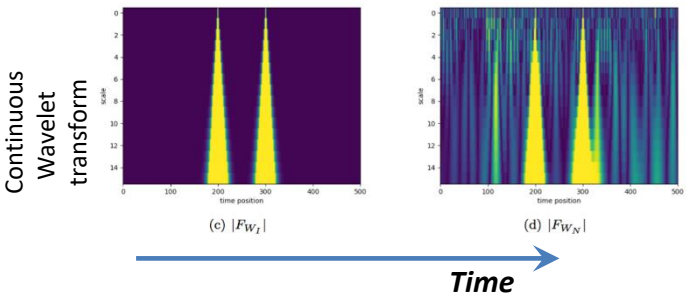
multi-scale analysis of the time series through the **continuous wavelet transform** CWT

"Combining Wavelets and Mathematical Morphology to Detect Changes in Time Series". Published on PIERS 2017.

Change detection – Processing steps

1. **Finding at which positions** U = {u_1, u_2, . . . , u_N } the modulus of its Continuous Wavelet Transform (**CWT**) features **local maxima**.

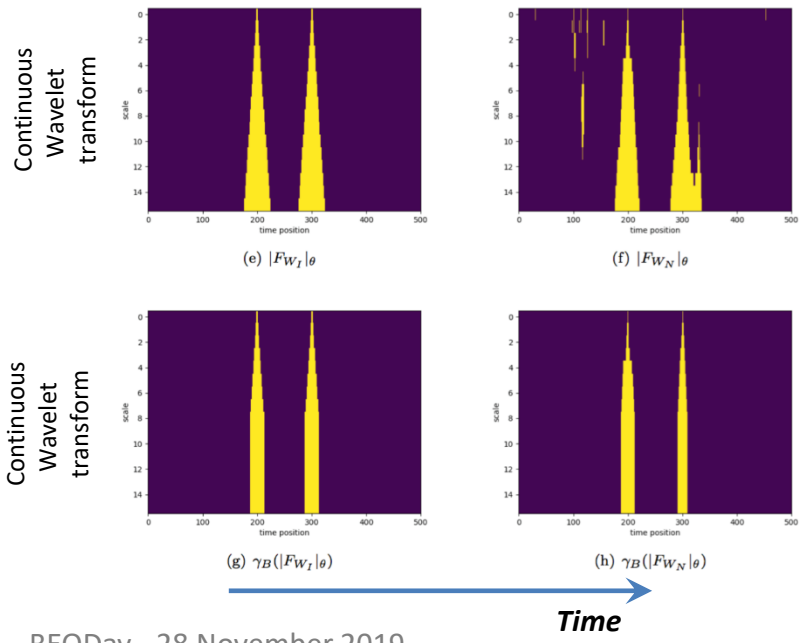




Issue: noise in the CWT coefficients

2. **Thresholding CWT coefficients**

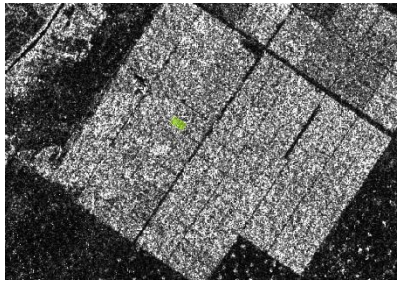
3. **Mathematical morphology**



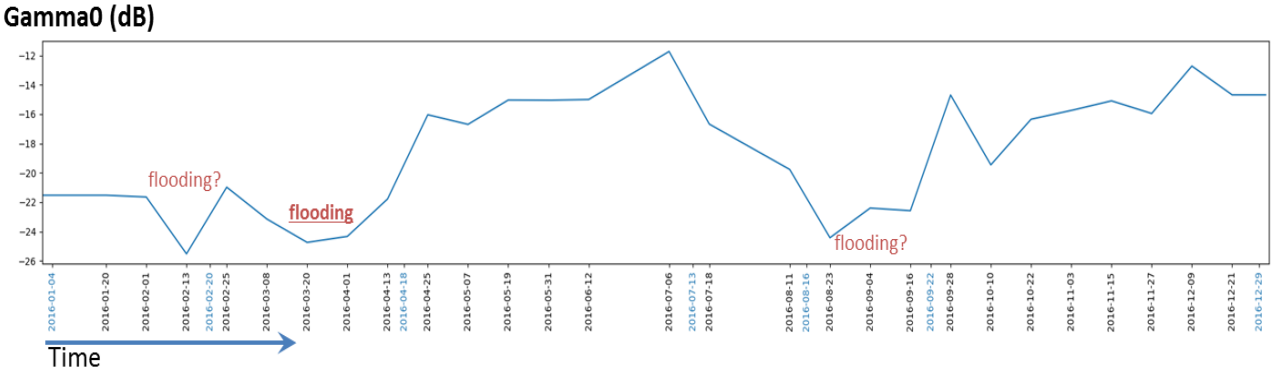
Change detection – Time Series Analysis

Results

Sentinel-1 temporal profile of a rice field, Senegal



S1 data



Detection of planting and harvest dates - Sugar cane, Senegal

	Planting Date	Harvest Date
Correct	602	682
Wrong	119	39
Accuracy	83%	94%

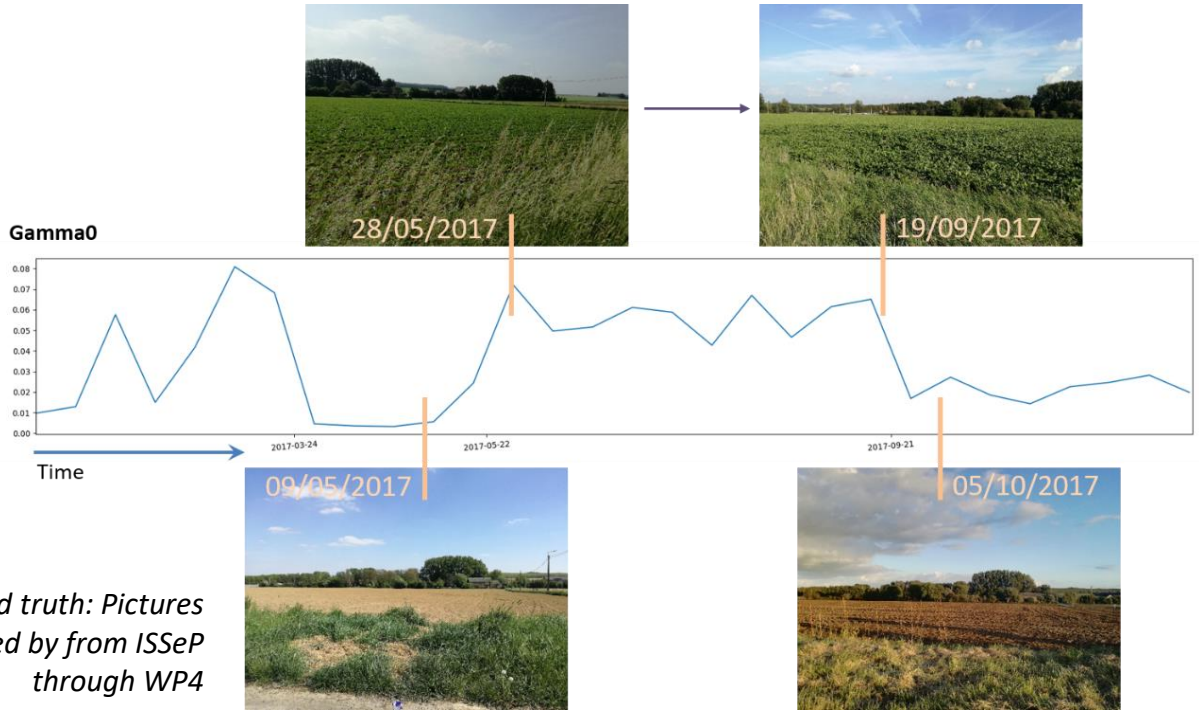
721 sugarcane fields,
Ground truth + Sentinel1 data

Detection accuracy of planting and harvest dates for sugarcane fields

Change detection – Time Series Analysis

Results

Sentinel-1 temporal profile of a pea field, Belgium



Ground truth: Pictures provided by from ISSeP through WP4

T3 - Ontologies

Development of a Search Engine based on semantic queries using graph databases and ontologies for services retrieval

Structuring services by semantic web language and ontologies

- Multiplicity of available processes
- Huge quantities of data provided by recent satellites,

➔ Risk of incoherence in users' requests understanding

Semantic Web
Artificial Intelligence
Natural Language Processing

Development of two ontologies related to:
- the processing that can be performed on available information (EORegions)
- user's natural language queries (EORegions_Science)

➔ ensure coherence between user's requests and treatments

➔ provide the most valuable service to the user

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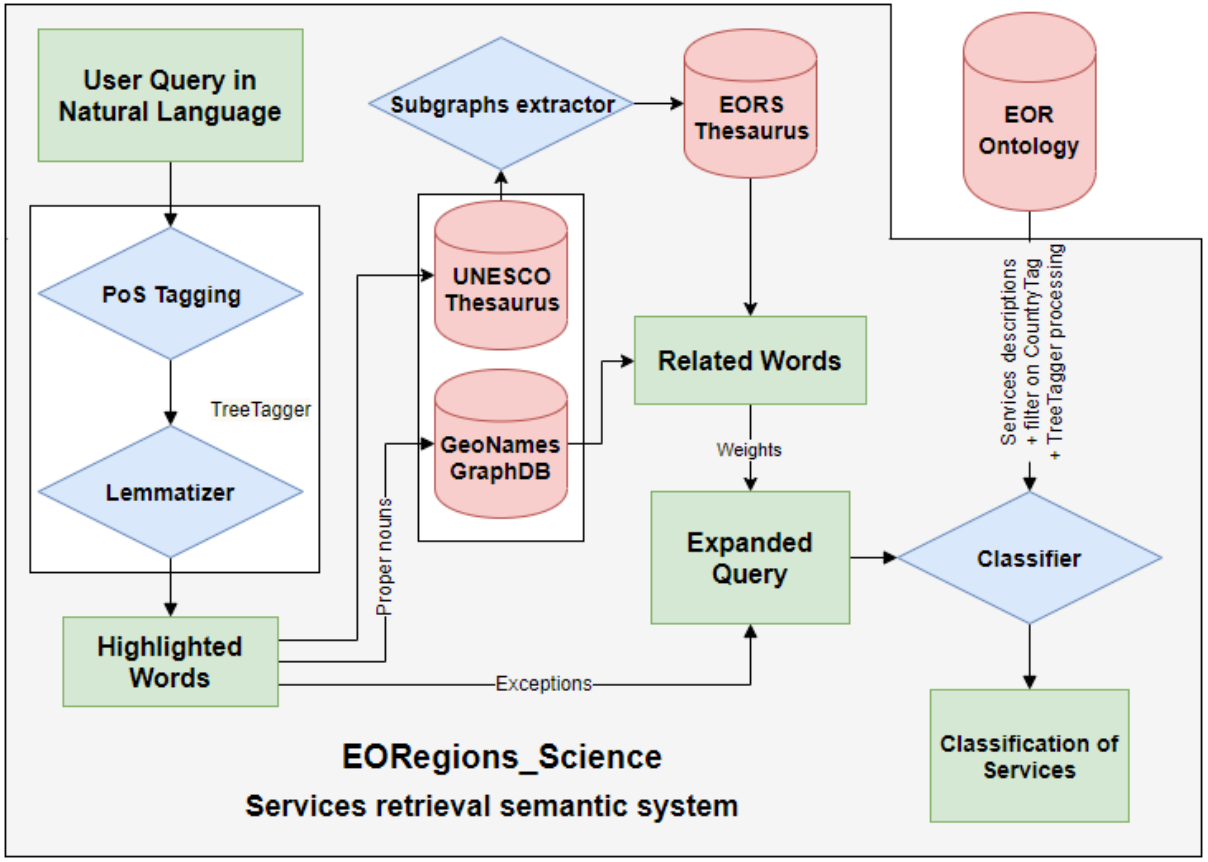
Ontologies

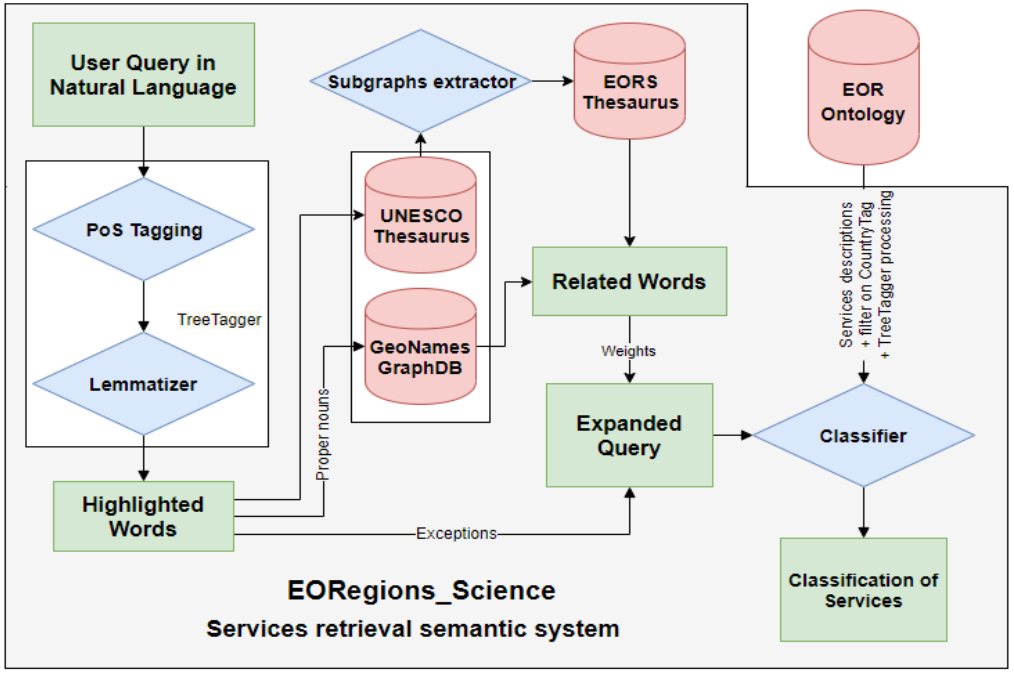


- **Red silos**: graphs databases (thesaurus, ontologies …).
- **Green rectangles**: main data that are results exchanged between algorithms within the project (usually Lists of Literals).
- **Blue diamonds**: main algorithms created within the scope of the project
  - **Part of Speech (PoS) Tagging**: marks up a word based on its definition and context in a sentence as corresponding to a particular part of speech
  - **Lemmatizer**: simplifies a word, removing influence of conjugation, inflectional endings, gender, number …

⇨ **Highlighted words**

EO_Regions_Science

Ontologies



Thesaurus reconstruction

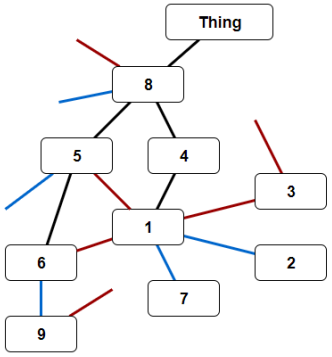
Data training influenced by terms used in users' queries

⇨ get the more used and accurate terms

Query Thesaurus

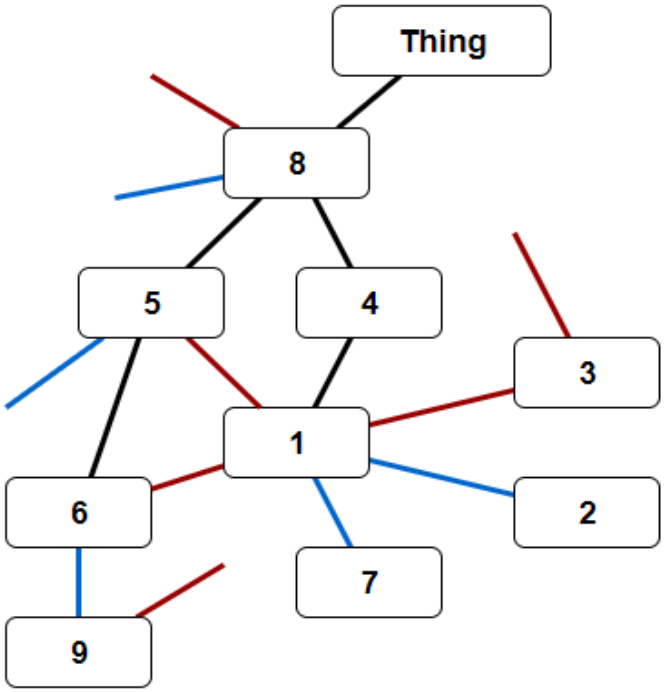
based on the highlighted words following the PoS Tagging and Lemmatisation

Extract subgraph



Ontologies

Extract subgraph



Black connexion : broader relation of the concept.
Red connexion : related relation of the concept.
Blue connexion : narrower relation of the concept

A processing chain = made of collections of class Operations and class Data

Shared use of Operations
Stored services descriptions

⇨ the chain constitutes a graph

Starting from concept [1] , connections with neighbours lead to extract the tree graph (in black) from broader connections, to [Thing] : the hyperclass of the concepts.

T4 - In-situ data & EO Promotion

Supporting in situ acquisitions & providing case study data

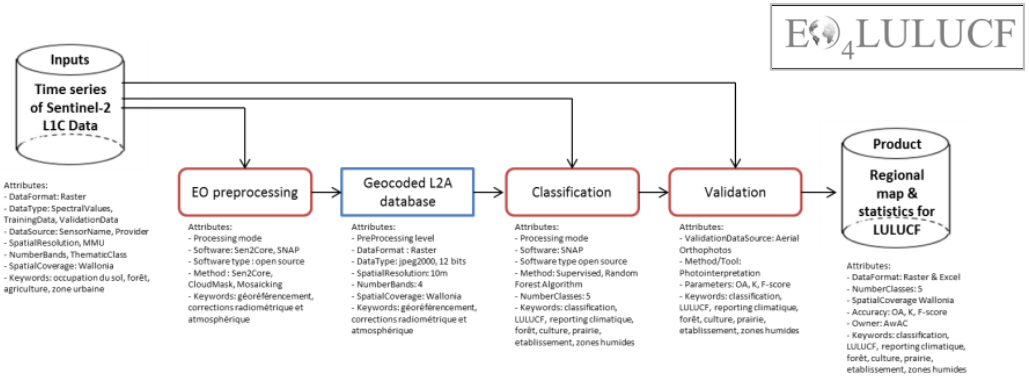
1. Support in-situ acquisition protocols

Field campaigns and research activities of WP 2,3,5

Example: Field monitoring at 10 dates for validating change detection methods from WP 3 (in Eghezée)

2. Test cases of ISSeP potential EO services

Example: LULUCF reporting flow chart to support ontologies (WP2)



In-situ data & EO Promotion

3. Earth Observation Promotion:

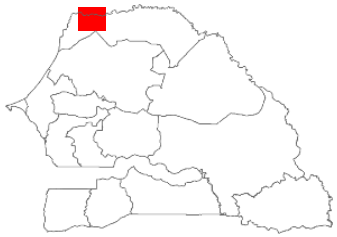
⇨ ***Use of Sentinel data & Copernicus services***

EO_Regions! platform

within EO working groups

- GTEO with Skywin *-> see all presentations on www.issep.be/gteo*
- GT-COWAL [SPW])
- Training sessions
- Public events
- …

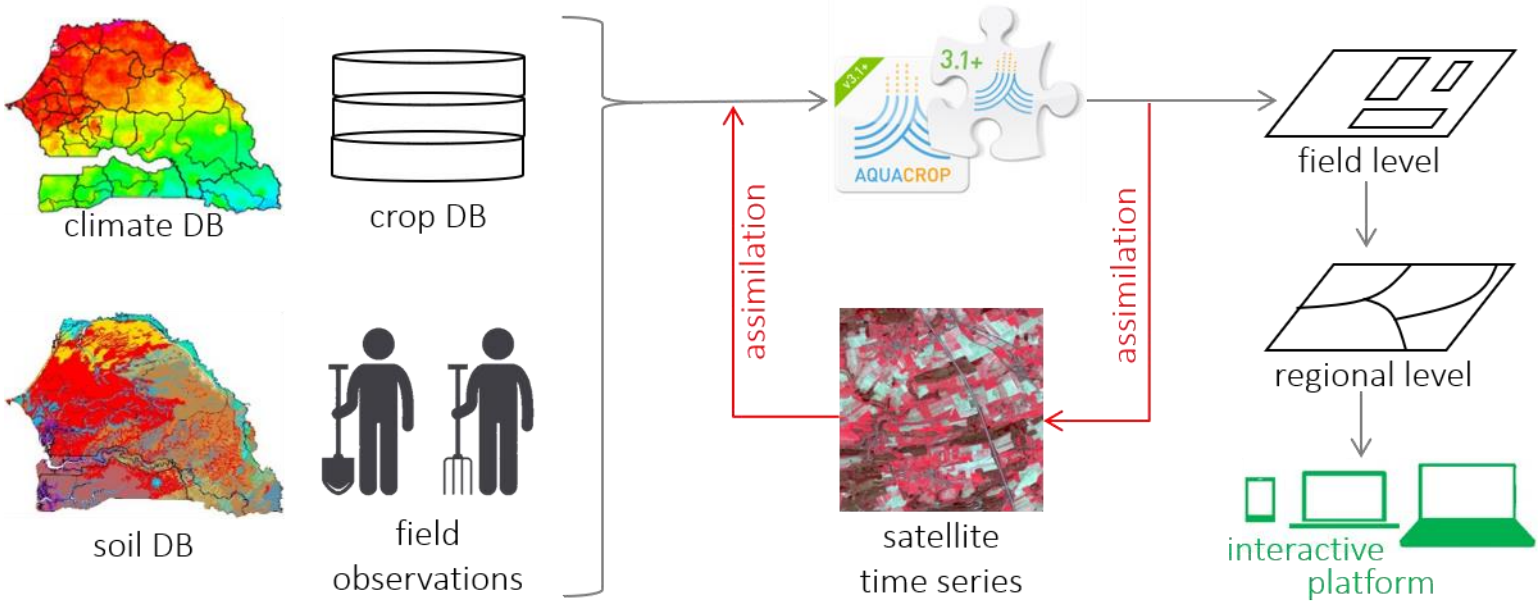
T5 – AquaCrop (FAO)



Broaden the yield forecasting technique to a different region, out of Belgium: in particular sugar cane in Senegal

Improve the yield forecasting technique at field level by assimilating: Sentinel-2 & Sentinel-1 derived products

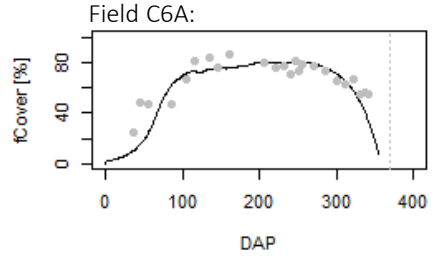
AquaCrop – Processing chain

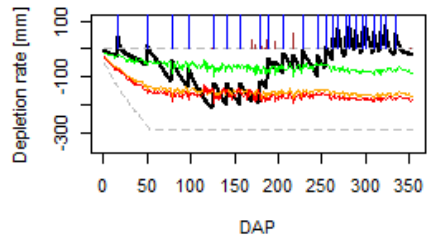


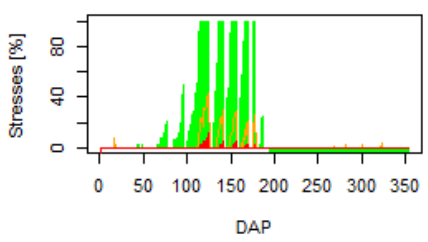
EO_Regions_Science

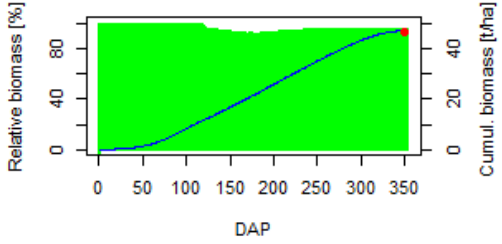
AquaCrop – Dashboard

Field C6A:

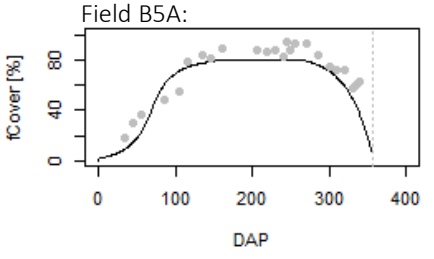


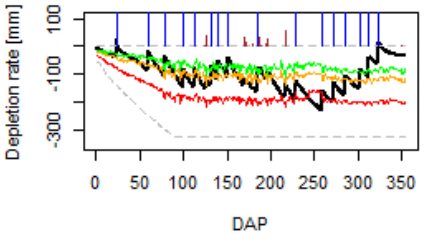


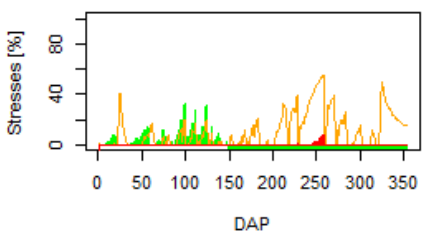


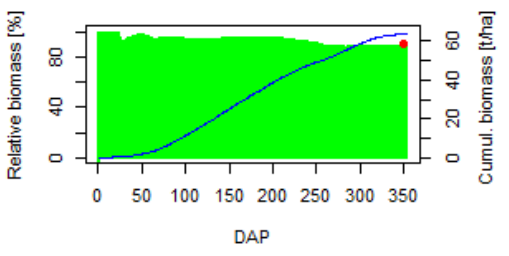


Field B5A:

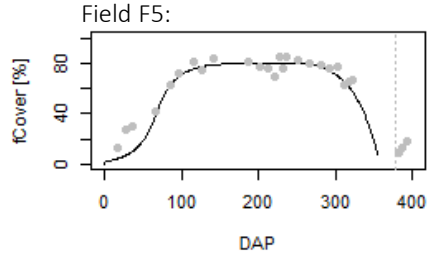


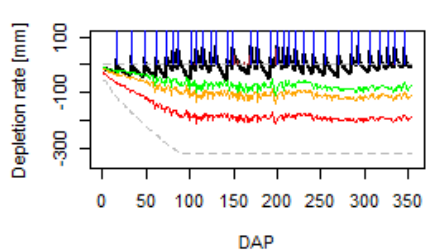


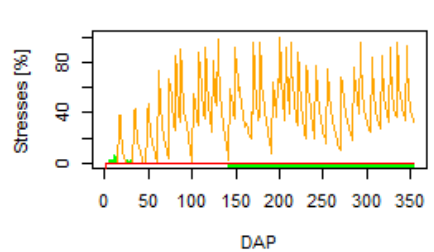


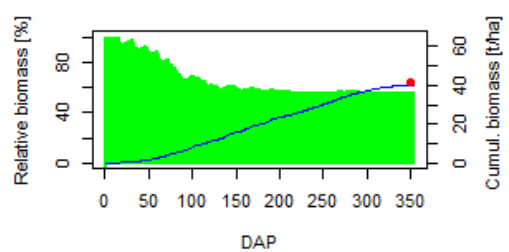


Field F5:









↑ Sim vs obs fCover

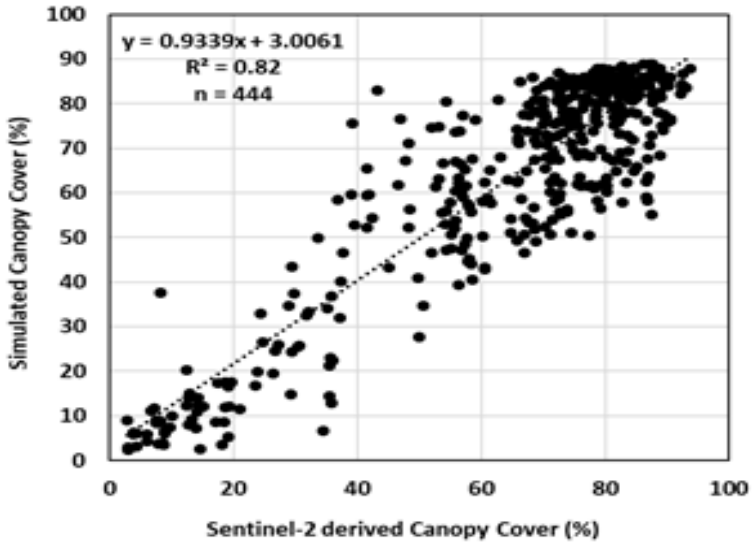
↑ Parcel water balance

↑ Stresses

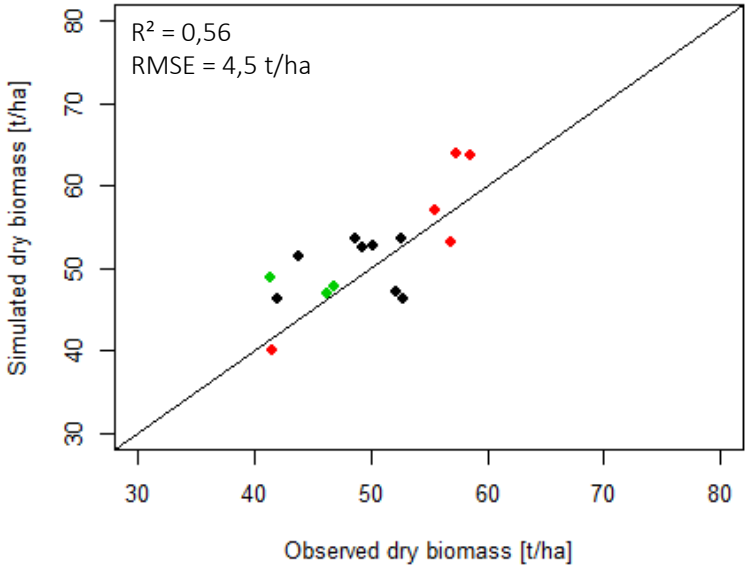
↑ Biomass production

AquaCrop – Results

Observed vs simulated fCover for the ensemble of monitored fields



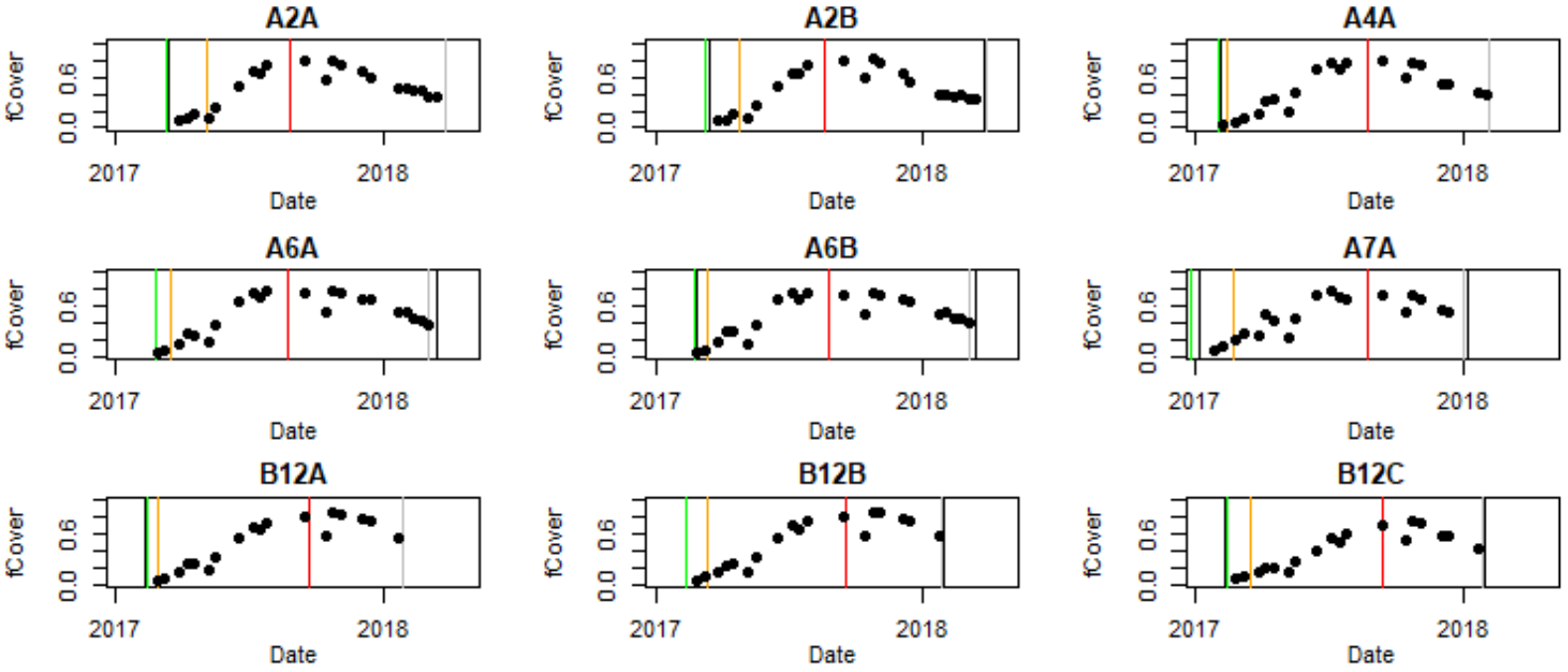
Observed vs simulated biomass for the ensemble of monitored fields



⇨ AquaCrop able to simulate canopy cover and biomass development accurately after assimilation of Sentinel-2 data

AquaCrop – Perspectives

Generic Sentinel-1 change indicators toolbox (developed by RMA):



- black dots: fCover Sentinel-2 values
- black and grey lines: observed planting and harvest date
- green lines: SAR detected planting date
- orange lines: SAR detected emergence date
- red lines: SAR detected maximum canopy cover date

Conclusion

Consistent and coordinated set of basic research activities done in support to EO_Regions!:

- **End-users needs were consolidated** regarding to the integration of the downstream EO services targeted by EO_Regions! by **identifying the potential users**

- An **ontology** was built that creates connections between the users queries and the performed treatments, ensuring **good coherence between users' requests**, expressed in their own language, and the **description of each service**

- A **change detection toolbox** able to detect significant variations in time series has been developed that could be used as **processing block** for the Sentinel-1 based services implemented within the EO_Regions! project.

- The use of **corner reflectors** as permanent scatterers has been considered, leading to specify and design the CR's built in the framework of EO_Regions!

- **Sentinel-2** data have been **integrated into the AquaCrop model** for broadening the forecasting technique to sugar cane in Senegal, which is one of the emergent countries targeted by EO_Regions! to export its toolbox and operate its platform.

Thank you for your attention

Structuring services by semantic web language and ontologies

Integration of Sentinel data into the AquaCrop model (FAO)

Supporting in situ acquisitions & providing case study data

Development of a Change Detection toolbox

Corner Reflector definition → Applications/Service in ground displacements monitoring