



# Mesure de l'humidité des sols et suivi de l'irrigation par télédétection



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## ➤ Avant

- Images payantes,
- Temps de revisite faible,
- Résolution spatiale peu adaptée,
- Pré-traitements à faire soi même (calibration/corrections) ...

## ➤ Aujourd'hui

- Données gratuites ou accès privilégié à certaines données payantes,
  - Un temps de revisite élevé,
  - Images mieux résolues, en particulier avec les constellations Européennes Copernicus radar et optique,
  - Images pré-traitées
- ➔ Encourage le développement de méthodes opérationnelles pour la cartographie de nombreuses variables / phénomènes / activités (Humidité, Irrigation ...)

## ➤ Images radar

- Données tout temps
- Forte sensibilité à l'humidité du sol
- ...

## ➤ Images optiques

- Suivi de l'activité chlorophyllienne en milieux agricoles
  - ...
- Capteurs européens Sentinel-1/2: pixel de 10 m x 10 m ➔ adapté pour une cartographie à l'échelle de la parcelle
- Temps de revisite ~ 6 images par mois pour S2 et près de 15 images par mois pour S1 (2 capteurs)
- ➔ Adaptés au suivi de l'humidité et à la cartographie des surfaces irriguées

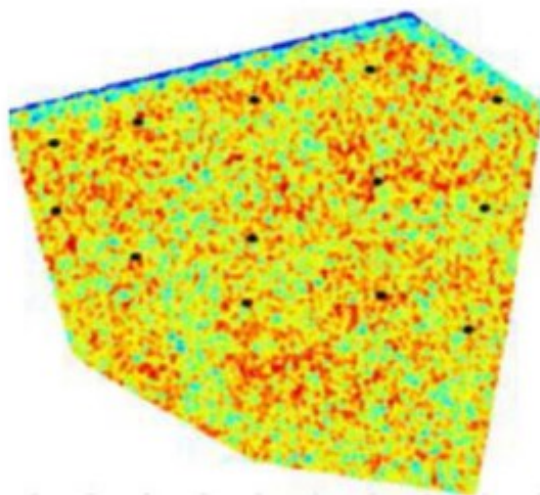


# Produits existants d'humidité du sol

- Currently, several satellite missions provide surface soil moisture estimations at different spatial resolutions (low to medium spatial resolutions):
  - SMAP: 36 km x 36 km, 9 km x 9 km, 1 km x 1 km
  - ASCAT: 25 km x 25 km, 12.5 km x 12.5 km, 1 km x 1 km
  - SMOS: 25 km x 25 km
  - Copernicus Land distributes the first soil moisture estimations over the European continent at 1-km using S1 data: algorithm based on the University of Technology Wien Change Detection Model

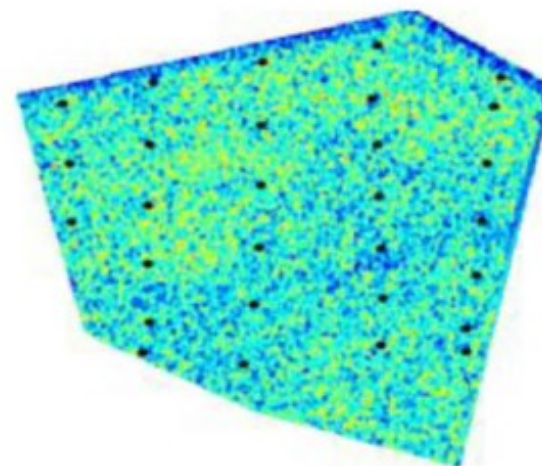
- Augmentation de l'humidité du sol → Augmentation du signal radar
- Irrigation → Augmentation de l'humidité du sol

13/02/08

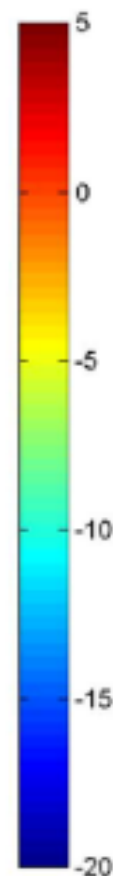


Forte humidité

13/05/08



Faible humidité



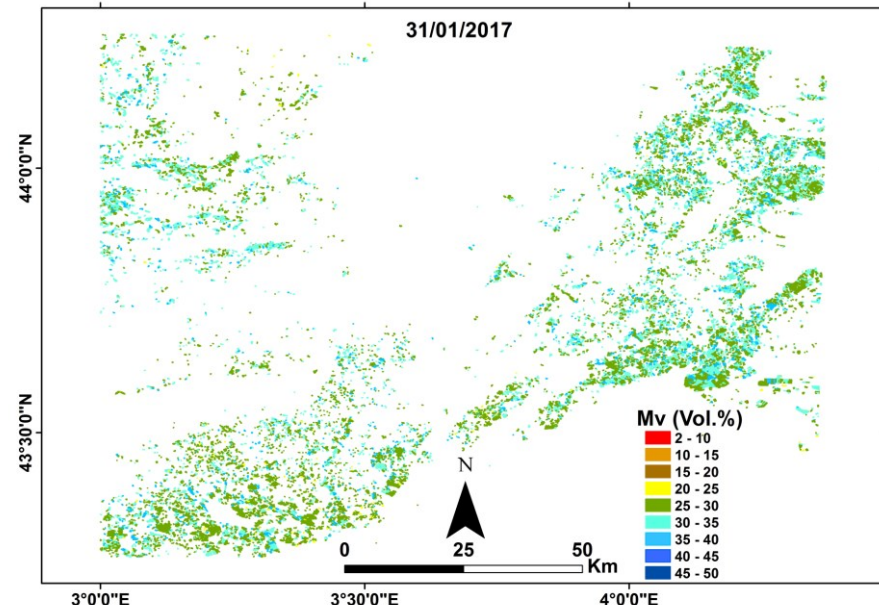
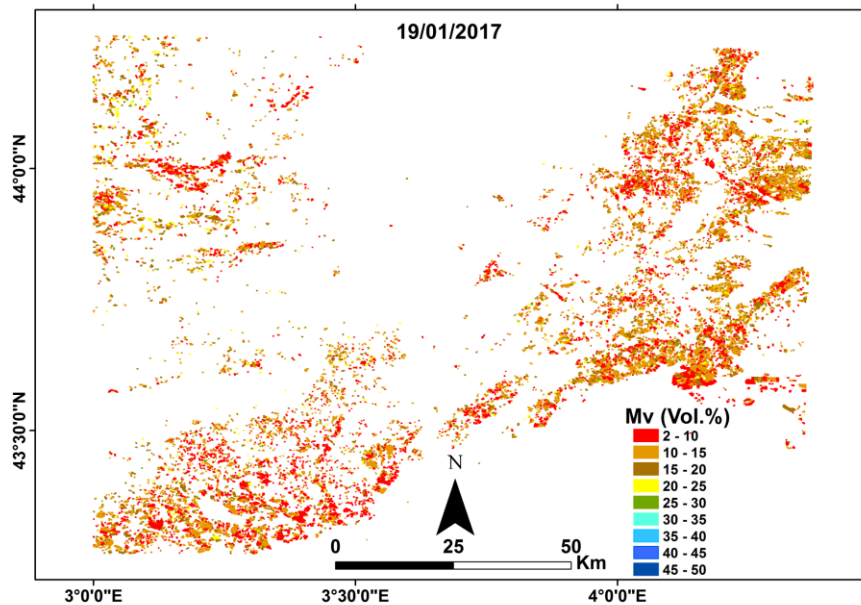
# Estimation de l'humidité du sol

- Un algorithm appelé S<sup>2</sup>MP (Sentinel-1/Sentinel-2 derived soil Moisture at Plot scale) a été développé à l'UMR TETIS
- Il modélise le signal radar en utilisant des modèles physiques (Water Cloud Model et Integral Equation Model)
- Calibration des modèles sur des parcelles de grandes cultures + prairies
- Inversion basée sur les réseaux de neurons
- Un code simplifié peut être téléchargé à cette reference:

El Hajj M., Baghdadi N., Zribi M., 2018. Estimation de l'humidité du sol par couplage d'images radar et optique. Chapitre book: Baghdadi N., Mallet C., et Zribi M. (eds), QGIS et applications en agriculture et forêt, vol. 2, p. 15-58, 2018, ISTE Editions, 374 pp.



# S<sup>2</sup>MP: soil moisture maps



- ✓ Estimations only for agricultural areas and grasslands except vineyards and orchards
- ✓ RMSE ~ 6 vol.%
- ✓ Degradation when NDVI is high (mature crops)
- ✓ For some crops, moisture estimation on agricultural plots is no longer possible when vegetation is well developed (NDVI < 0.7): wheat for example

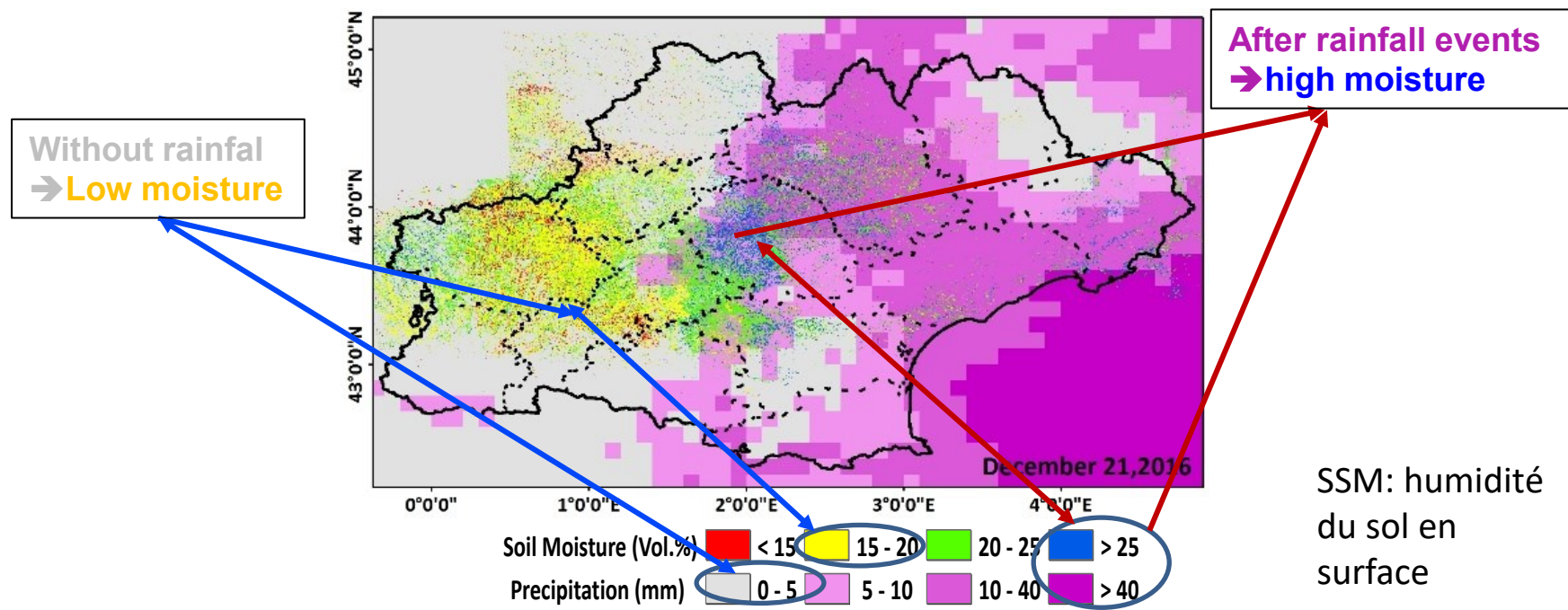
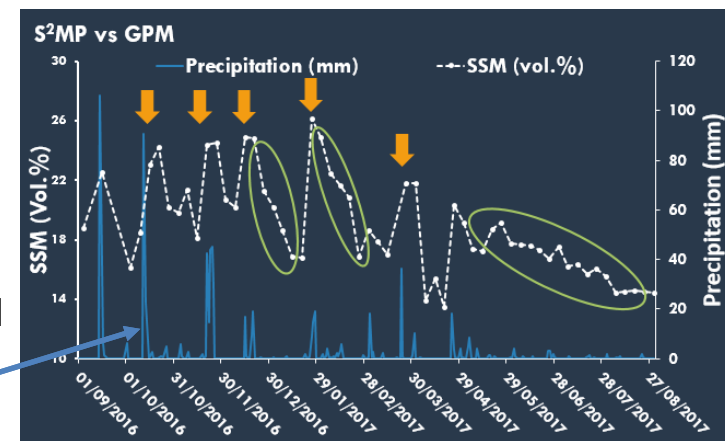
# S<sup>2</sup>MP: soil moisture maps

- A good coherence was observed between the temporal evolution of the soil moisture and the precipitation records derived from the GPM data (Global Precipitation Measurement)

💧 **High SSM-Rainfall correlation**

💧 **High SSM estimations following rainfall events**

💧 **Decreases in estimated SSM due to absence of rainfall**



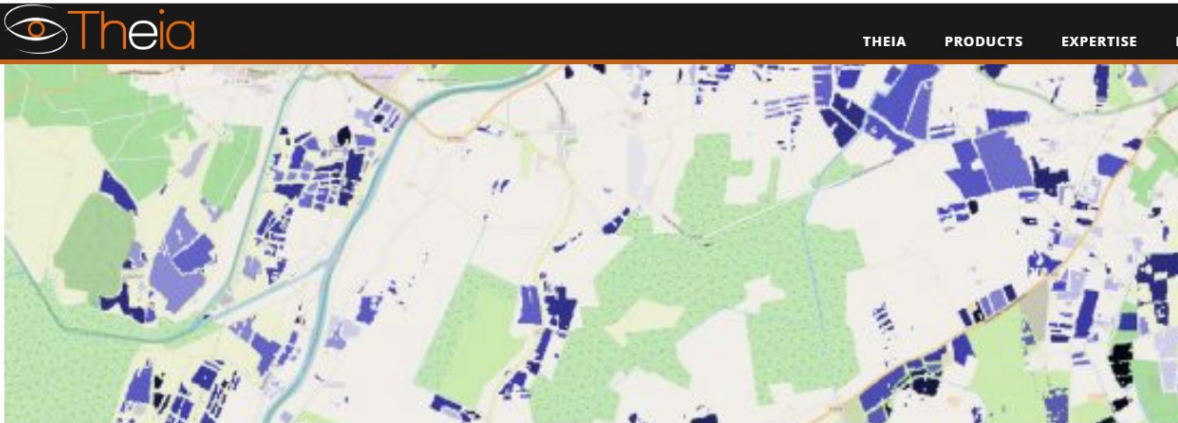


# Soil moisture maps on the Theia website

French Land Data Center Theia : <https://www.theia-land.fr/en/product/soil-moisture-with-very-high-spatial-resolution/>

**Fin de la production depuis fin 2022**

theia-land.fr/en/product/soil-moisture-with-very-high-spatial-resolution/



SOIL MOISTURE AT VERY HIGH SPATIAL RESOLUTION

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  - A Python script to download entire collections
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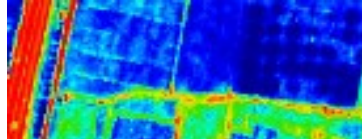
Data access

Download VHSR Soil Moisture Data on catalogue.theia-land.fr

Download VHSR Soil Moisture Data on Thisme

Read-Me Soil Moisture (Dec. 19) [Download](#)

A Python Script to download entire collections



## BACKGROUND

At global level the water withdrawal ratios are:

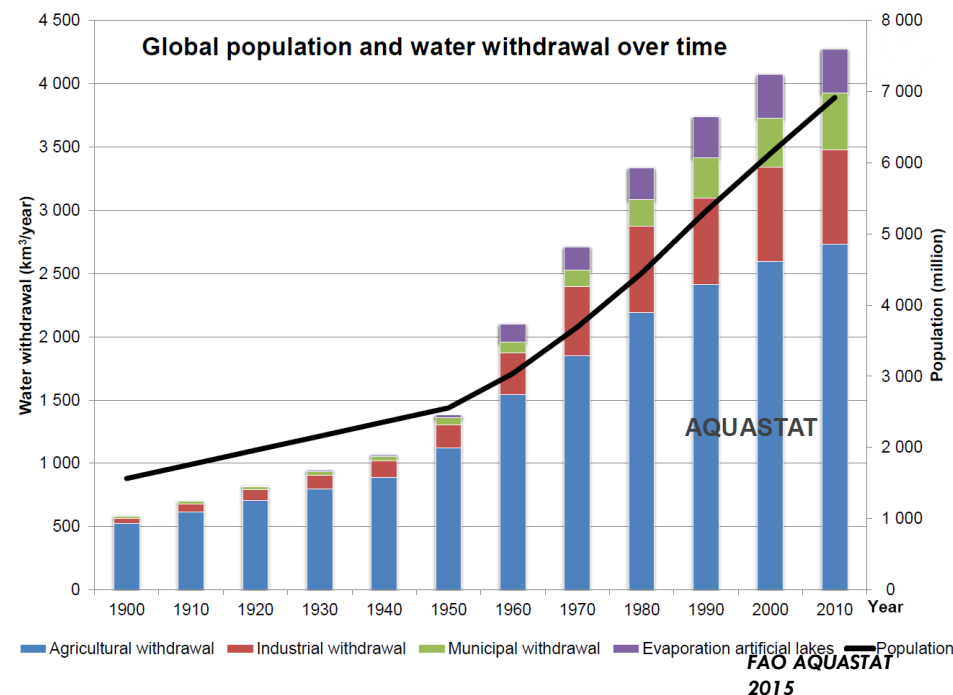
- 69% agricultural sector
- 19% industrial sector
- 12% municipal sector

Increase in population

→ Increase in food demand

→ Intensification using irrigation

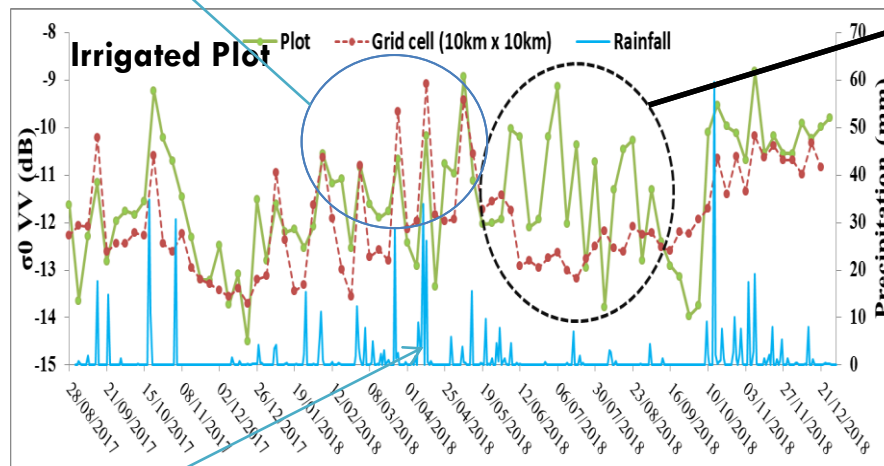
The irrigated agriculture accounts to more than 40% of the global food production



# Cartographie de l'irrigation

**Pluie** → Signal de la parcelle augmente (vert) mais  
aussi le signal moyen de toute la zone (rouge)

**Sans pluie:** Changement fréquent du signal mais  
une stabilité au niveau de toute la zone

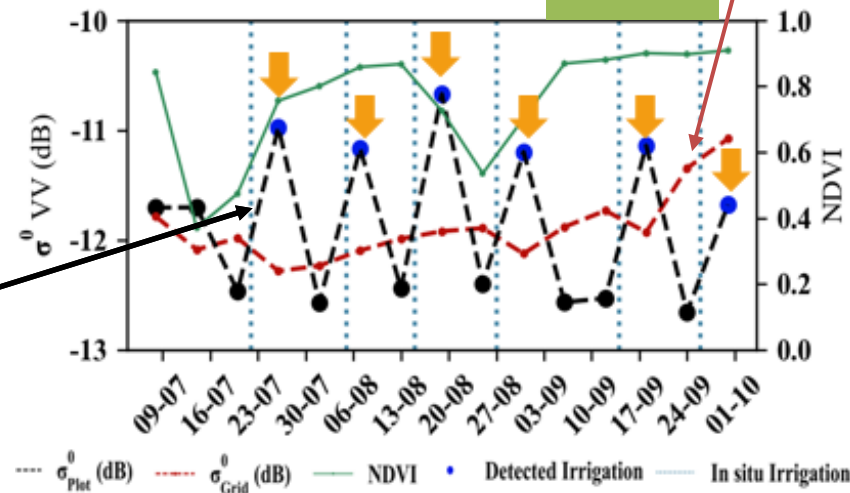


Pluie

Toute la zone

Prairies

Parcelle





## ➤ Supervised classifiers

- Use terrain data
- With supervised classifiers, it is difficult to generalize the same classifier on other years and other regions
- No in situ data ➔ No Irrigation map

➔ We propose an operational mapping of irrigated plots using S1 and S2 time series: without depending on in situ data

- Generate a reference dataset (irrigated / no-irrigated plots) before using supervised classification models
  - ✓ Irrigated plots must have several irrigation events
  - ✓ Irrigated plots must have high maximum NDVI value during the crop growth cycle
- Use this reference dataset in the construction of the supervised classification model



## METHOD

### MAIN ASSUMPTIONS

Rainfall and irrigation have the same effect on the soil moisture (SSM) values → Same effect on S1 signals

Remove ambiguity between rainfall and irrigation in SAR temporal series

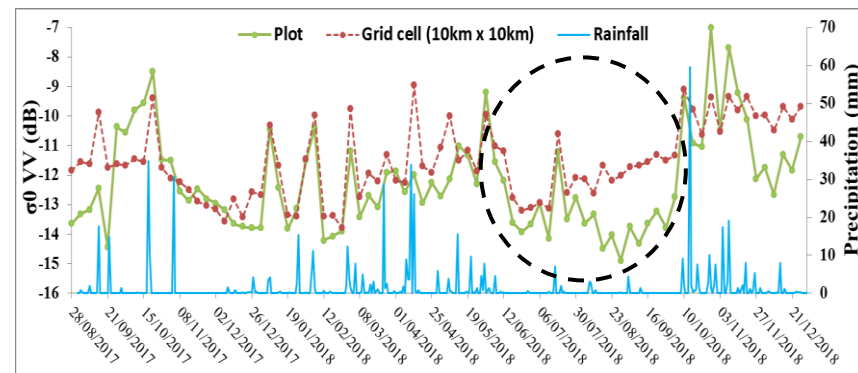
Additional rainfall information is required

Radar signal at 10 km scale represents rainfall events

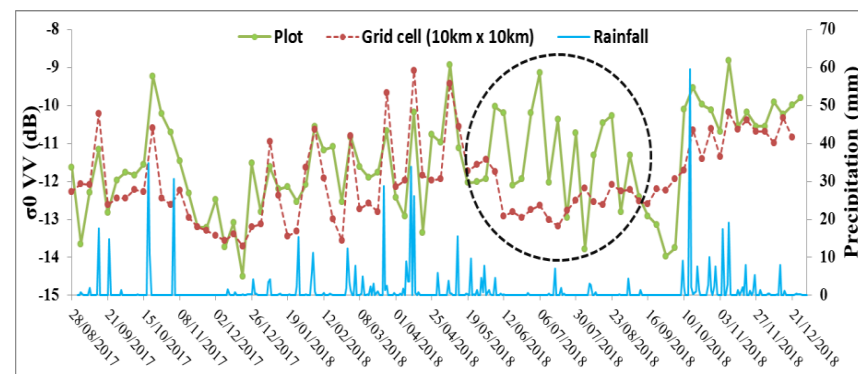
Compare the SAR signal obtained at plot scale and the SAR signal obtained at 10 km grid scale

### Non Irrigated Plot

Coherence between plot and grid SAR data

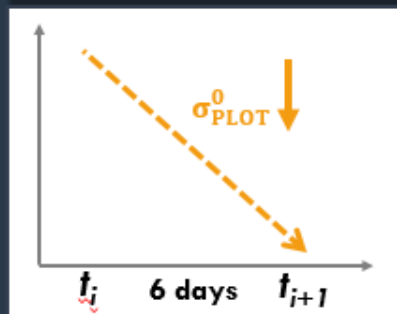


### Irrigated Plot

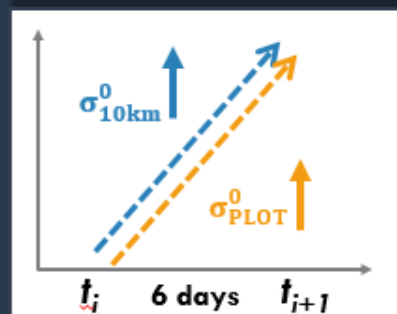


## Main Assumptions for detecting Irrigation Events:

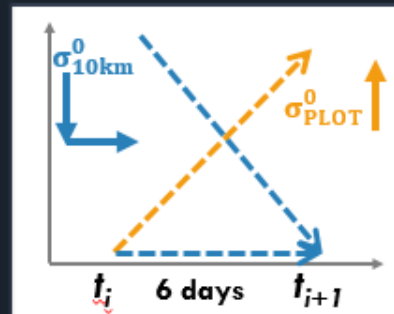
- 💧 Increase in  $\sigma_{\text{PLOT}}^0$  is mainly related to increase in SSM
- 💧 With rainfall both  $\sigma_{\text{PLOT}}^0$  and  $\sigma_{10\text{KM}}^0$  increase
- 💧 With Irrigation  $\sigma_{\text{PLOT}}^0$  increases with stability or decrease of  $\sigma_{10\text{KM}}^0$



No detected Irrigation



No detected Irrigation



Possible Irrigation

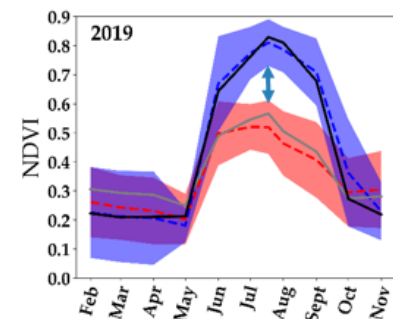
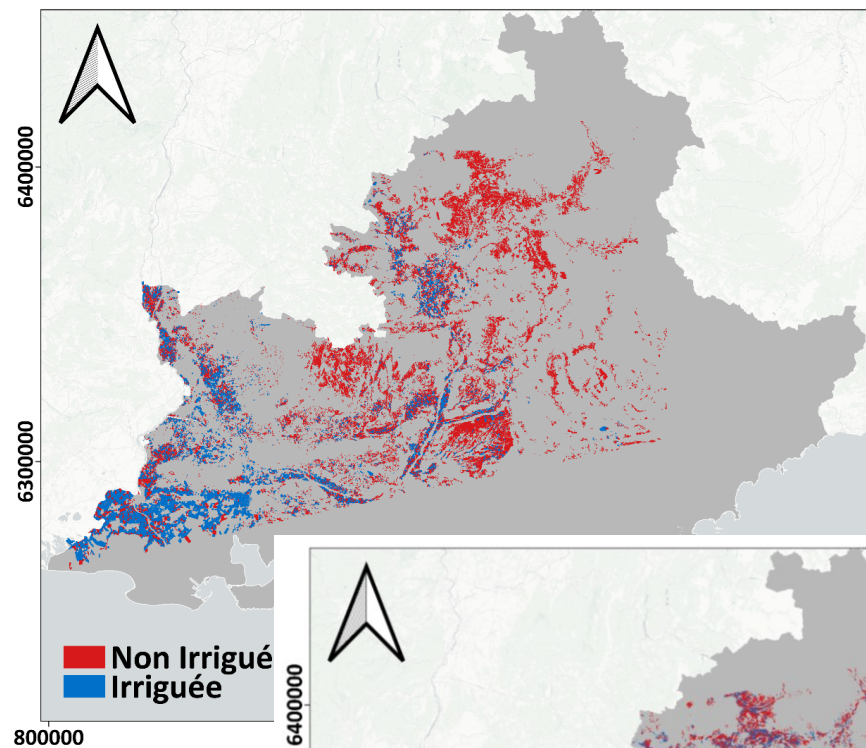
High possibility  
 $\Delta\sigma_{\text{PLOT}}^0 \geq 1\text{dB}$

Medium possibility  
 $0.5 \leq \Delta\sigma_{\text{PLOT}}^0 \leq 1\text{dB}$

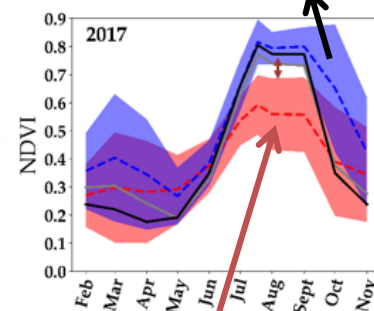
Low possibility  
 $-0.5 \leq \Delta\sigma_{\text{PLOT}}^0 \leq 0.5\text{dB}$



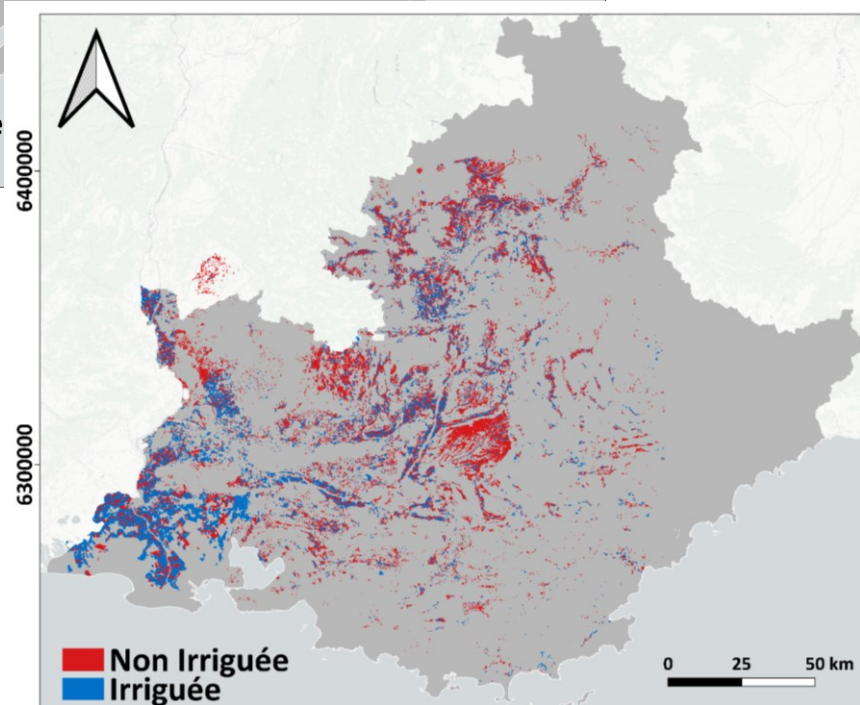
# Cartographie de l'irrigation



Irrigated

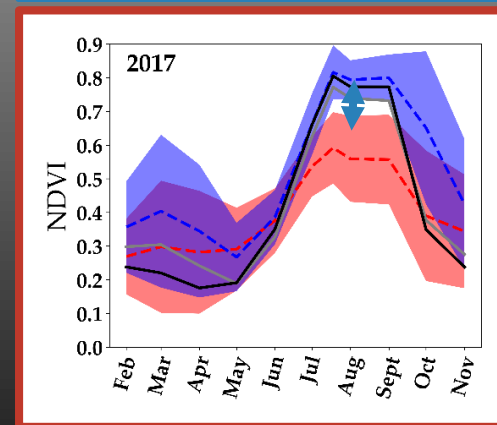
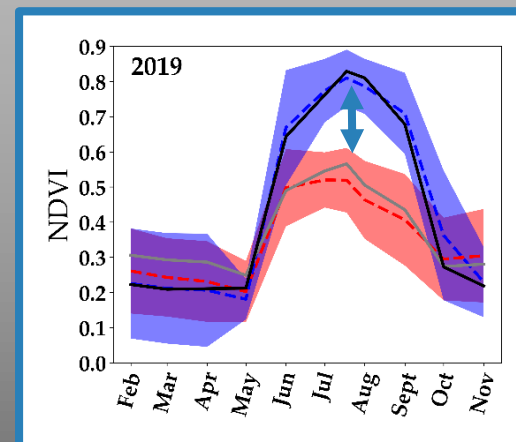
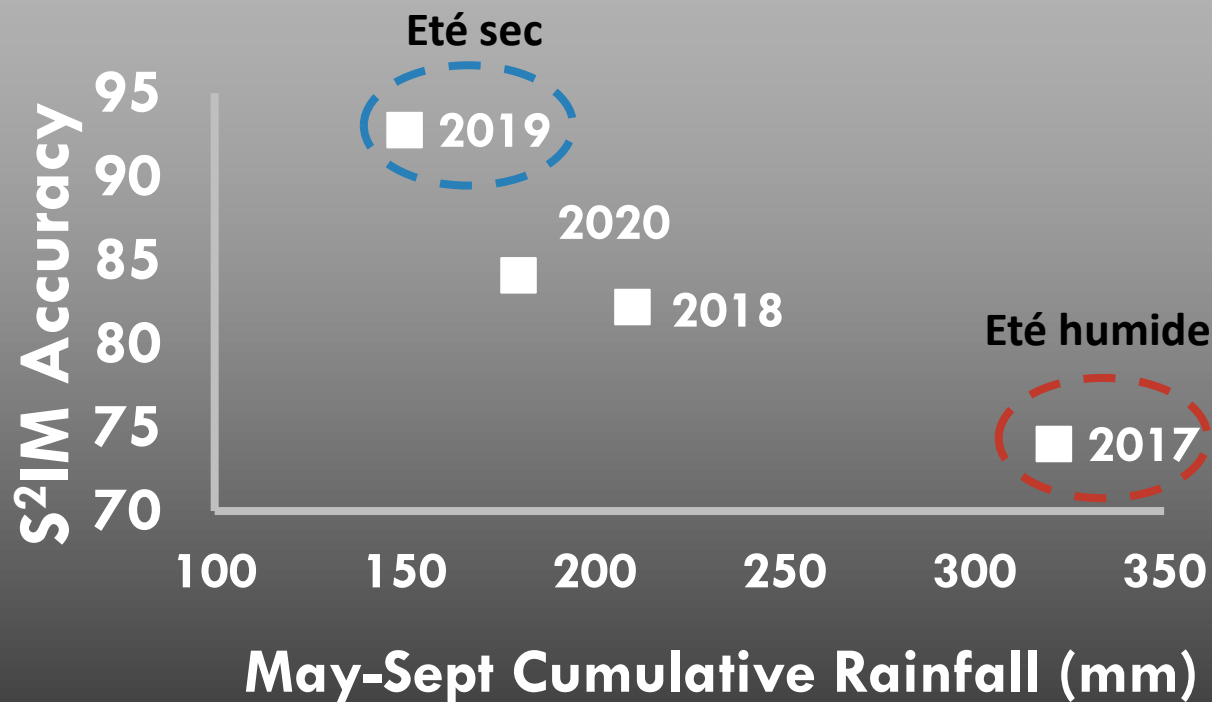


Non irrigated





## Climatic conditions of the studied regions



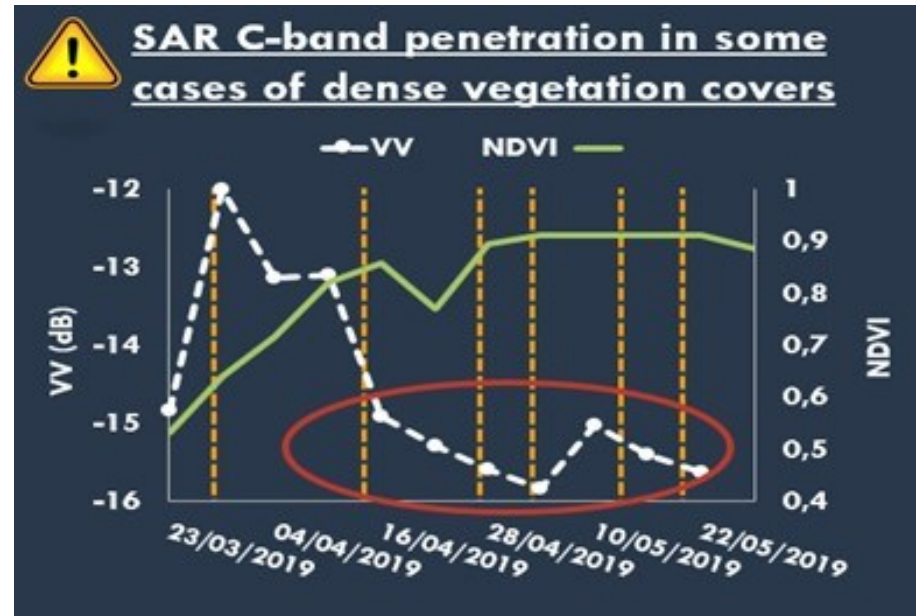
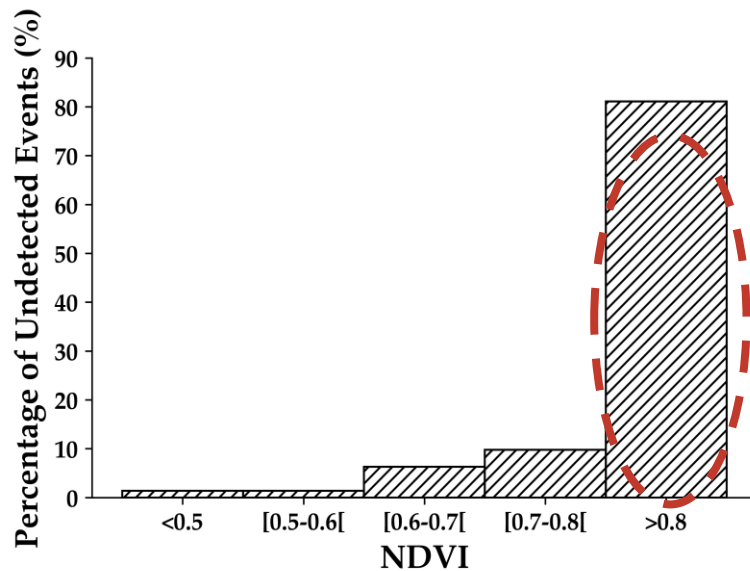
--- Selected Non-Irrigated    — In situ Non-Irrigated  
 --- Selected Irrigated        — In situ Irrigated



## LIMITATIONS



### SAR C-band penetration in some cases of dense vegetation covers



💧 80% of the undetected events have  $NDVI > 0.8$

💧 Undetected events → Very low penetration of the C-band SAR signal

💧 Irrigation events could be hardly detected on well-developed canopy

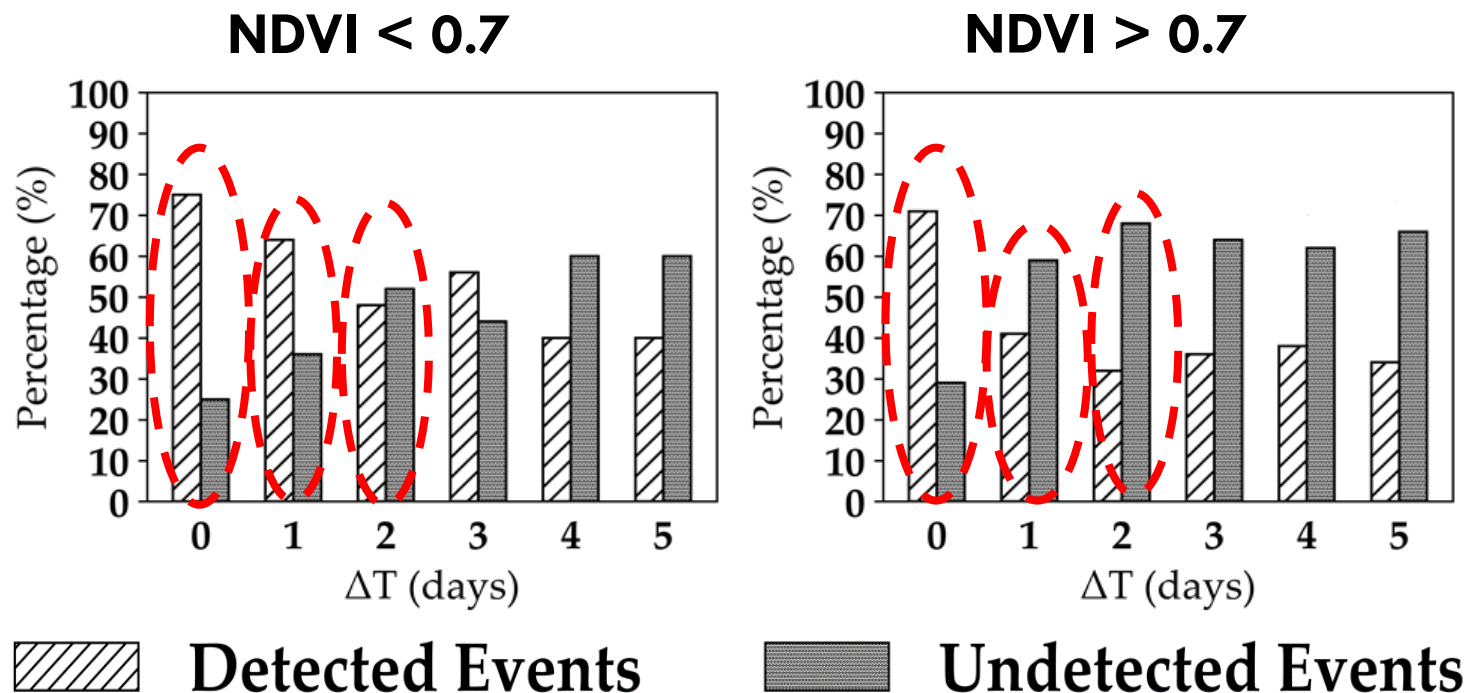




## LIMITATIONS



**Frequency of the SAR images:** Irrigation detection using SAR data could be limited to the time laps between the irrigation date and the SAR image date





- Moins bons résultats sur des années pluvieuses et sur des zones géographiques humides: confusion entre pluie et irrigation
- Pour certaines cultures et à partir d'un certain stade de croissance (**fort développement de la végétation**), **le radar ne peut plus pénétrer** le couvert et donc il n'atteint pas le sol pour nous renseigner sur son humidité.
- Impossible de cartographier les zones avec l'irrigation gouttes à gouttes car l'humidité est localisée sur des petites surfaces : résolution des capteurs actuels non adaptée.
- Si l'irrigation a eu lieu il y a plus que  $\sim 3$  jours, difficile de la détecter par les capteurs actuels qui ont un temps de revisite de 6 jours