Pacific GIS and Remote Sensing Council

**Conference 27 Nov. - 1 Dec. 2023, FIJI**

*Improving Resilience in the Pacific Islands Through GIS and Remote Sensing*

# An Operational Vegetation Drought Processing Chain based on Google Earth Engine satellite imagery and meteorological products

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*Remote sensing and Geomatics company*

IRD
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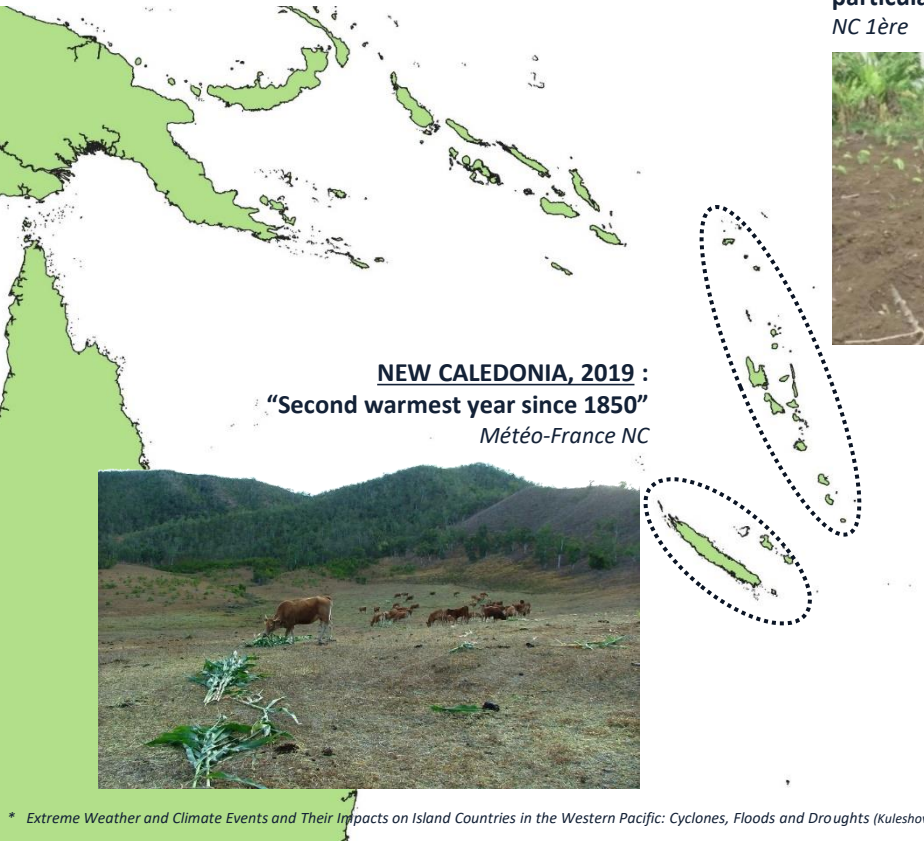
OEIL
*Environment Observatory in New Caledonia*

METEO FRANCE

* *Research Engineer*
*INSIGHT/IRD, Noumea, NEW CALEDONIA*

# CONTEXT and OBJECTIVES

# Drought in the Pacific Islands



**VANUATU, 2015 : "Tanna Island particularly affected by drought"**
*NC 1ère*

**FRENCH POLYNESIA, 2021 : "Polynesia undergoes an extreme drought"**
*Météo-France*

**NEW CALEDONIA, 2019 : "Second warmest year since 1850"**
*Météo-France NC*



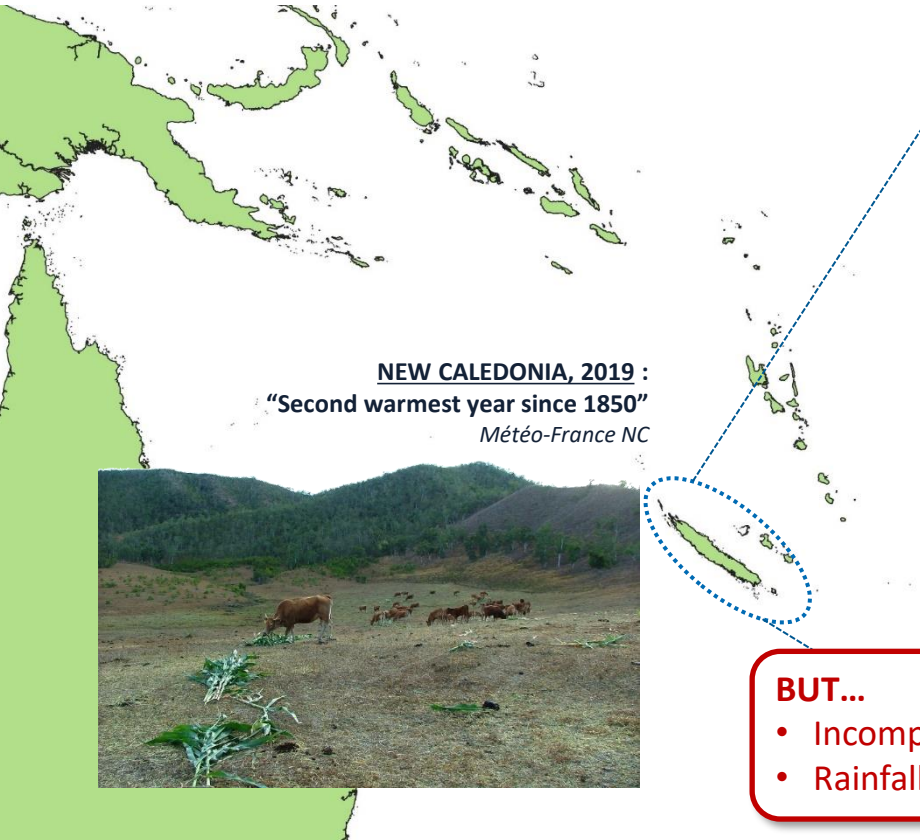
**FIJI, 2010 : "Meteorological drought affected Fiji"***

**WALLIS-et-FUTUNA, 2016 : "Warmest and driest January in both Wallis and Futuna since the first weather records in 1971."**

**Impacts on :**
Biodiversity
Agricultural crops
Water ressource

* *Extreme Weather and Climate Events and Their Impacts on Island Countries in the Western Pacific: Cyclones, Floods and Droughts (Kuleshov, 2014)*

# Drought in the Pacific Islands



**NEW CALEDONIA, 2019 :**
**"Second warmest year since 1850"**
*Météo-France NC*



**The Rural Agency** and **Meteo France** facing the Drought Hazard :

- **Detection** of meteorological drought
- **Purchase of drought food** for farmers
- **Compensation** for producers

Agence rurale

*Compensation for producers*

*Standardized Precipitation Index (SPI)*

METEO FRANCE

**BUT…**

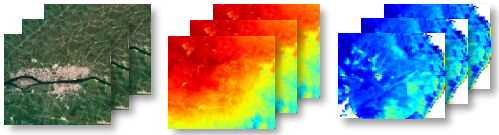
- Incomplete spatial coverage
- Rainfall deficit ≠ Plant water stress

# Space Climate Observatory, New-Caledonia

*(April 2021 – July 2022)*

## Complementary Earth Observation data

SPATIALIZED = localization



**Vegetation** *(Optical)*

**Surface Temperature** *(Thermal)*

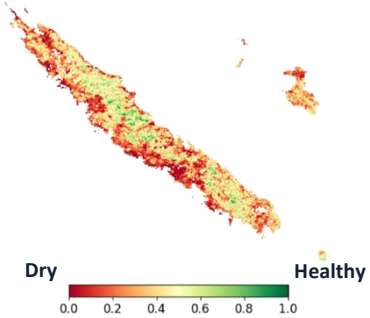
**Soil Moisture** *(Microwaves)*

HISTORICAL = quantification

**Expert meteorological data: precipitations, evapotranspiration**

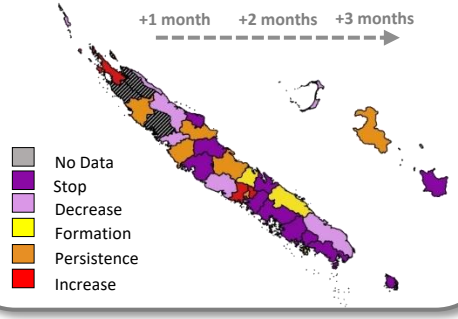
## Current Indicator

*Anomalies of surface indices*




## Forecast Indicator

*Long-range probabilistic forecast system*



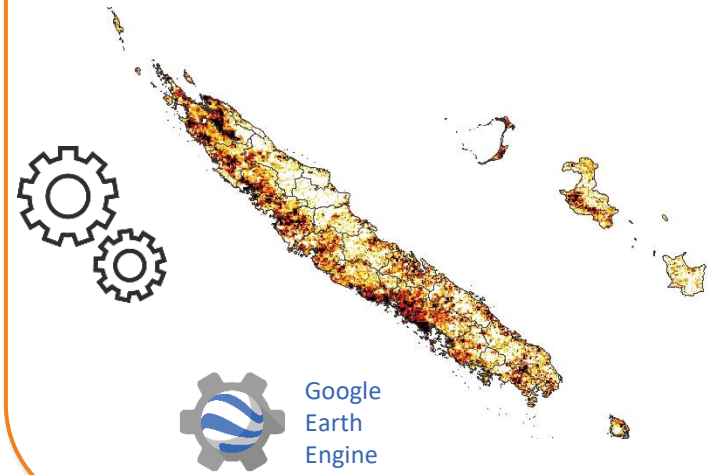

## User platform


## Development of Vegetation Drought indicators :

- ✓ Spatialization and forecast
- ✓ Evaluated from operational meteorological drought products (SPI)
- ✓ Demonstrated relevance of products

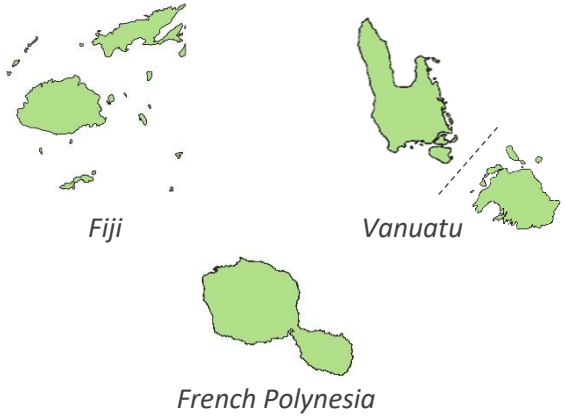
# French Pacific Fund *(ongoing project…)*

## Industrialization
*New-Caledonia*



Google Earth Engine

## Regionalization
*Other Pacific Island Territories*




FONDS PACIFIQUE

**Industrialization and Regionalization :**

- Operational implementation and production on New-Caledonia
- Adaptation to other territories with new products

**OEIL**
*Environment Observatory in New Caledonia*

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IRD
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# INDICATORS DEVELOPMENT and EVALUATION

# Methodology at GLOBAL SCALE

**GLOBAL DROUGHT INDICATOR**

- Drought information at global scale *(entire territory)*
- Combined drought products *(SPI, SPEI, MAI, VHI)*
- Agro-meteorological drought model *(Sepulcre-Canto et al., 2012))*

**PRECIPITATION DEFICIT** → **SOIL MOISTURE DEFICIT** → **VEGETATION STRESS**

METEO FRANCE

In-situ precipitation
SPI 3-months
40 stations
1981 - today




ASCAT (MetOp)




**STANDARDIZED WATER BALANCE**

METEO FRANCE

**SPEI 3-months**
**SPEI = f(P - ET) ***
32 stations
1991 - today

** **P** = precipitations*
*__ET__ = evapotranspiration*
*(Thornthwaite, 1948)*

MODIS (Aqua, Terra)
Vegetation Health Index
*Combined anomalies of NDWI, LST*
500 m
2000 - today

# Methodology at GLOBAL SCALE

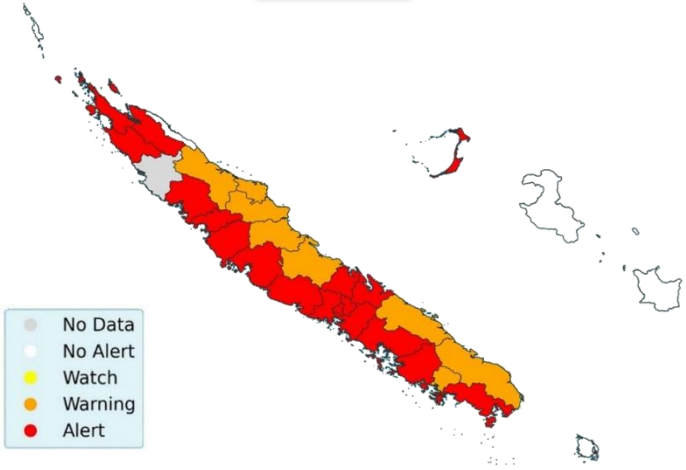
**GLOBAL DROUGHT INDICATOR**

- Drought information at global scale *(entire territory)*
- Combined drought products *(SPI, SPEI, MAI, VHI)*
- Agricultural drought cause-effect relationship *(Sepulcre-Canto et al., 2012))*

PRECIPITATION DEFICIT → SOIL MOISTURE DEFICIT → VEGETATION STRESS

**Watch** **Warning** **Alert**

**Drought Alerts :**



# Methodology at LOCAL SCALE

**LOCAL DROUGHT INDICATOR**

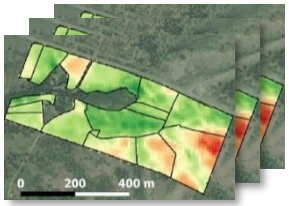
- Drought information at local scale *(10 m)*
- Updated every 10 days
- Focus on vegetation stress

**Landsat** (L7, L8, L9)
**USGS Level 2 Reflectances**
30 m
2000 - today

**Sentinel-2** (2A, 2B)
**THEIA / ESA Level 2 Reflectances**
10 m
2016 - today

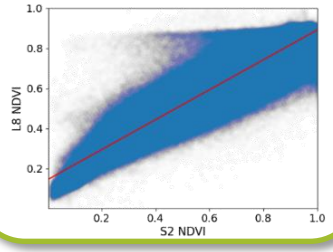
## PRE-PROCESSING

- Computing NDWI/NDVI time series
- Clouds filtering and reprojection



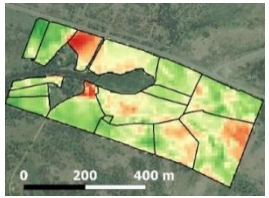

## COMPOSITING

- Radiometric calibration
- Decade (10-day) composition




## VEGETATION STRESS *

- Seasonal anomalies of NDWI (*Amri et al., 2011*)
- Seasonal = mean and std for each decade



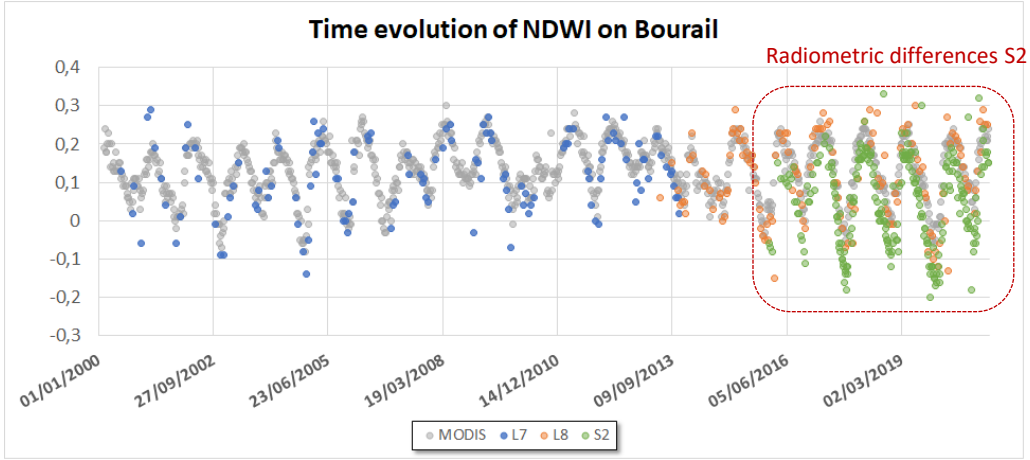

## POST-PROCESSING

- Filtering bare soil, dense vegetation
- From NDVI 10-day composites

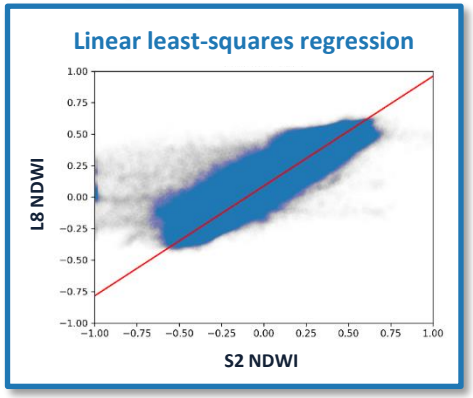

*** *Vegetation Anomaly Index* :**

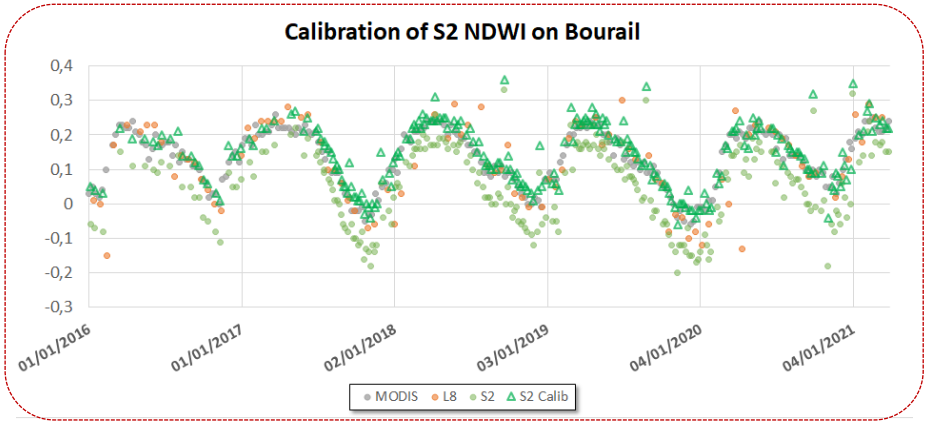
$$VAI_{D,M} = \frac{NDWI - NDWI_{mean}}{NDWI_{std}}$$

# Methodology at LOCAL SCALE




RADIOMETRIC CALIBRATION



# Some results at GLOBAL SCALE

*November 2019*

$$* VHI = \alpha \times VCI + (1 - \alpha) \times TCI$$

With $VCI = \frac{NDWI - NDWI_{min}}{NDWI_{max} - NDWI_{min}}$

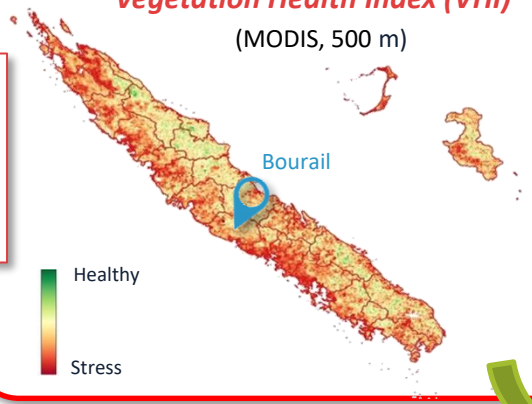
$TCI = \frac{LST - LST_{max}}{LST_{max} - LST_{min}}$

$\alpha = 0.5$

**GLOBAL INDICATOR**

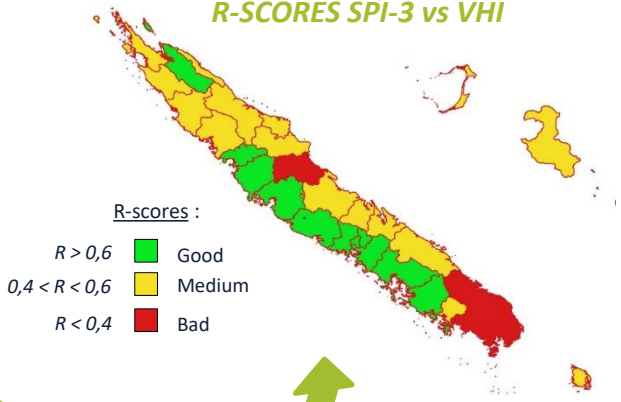
***Vegetation Health Index (VHI)****

(MODIS, 500 m)



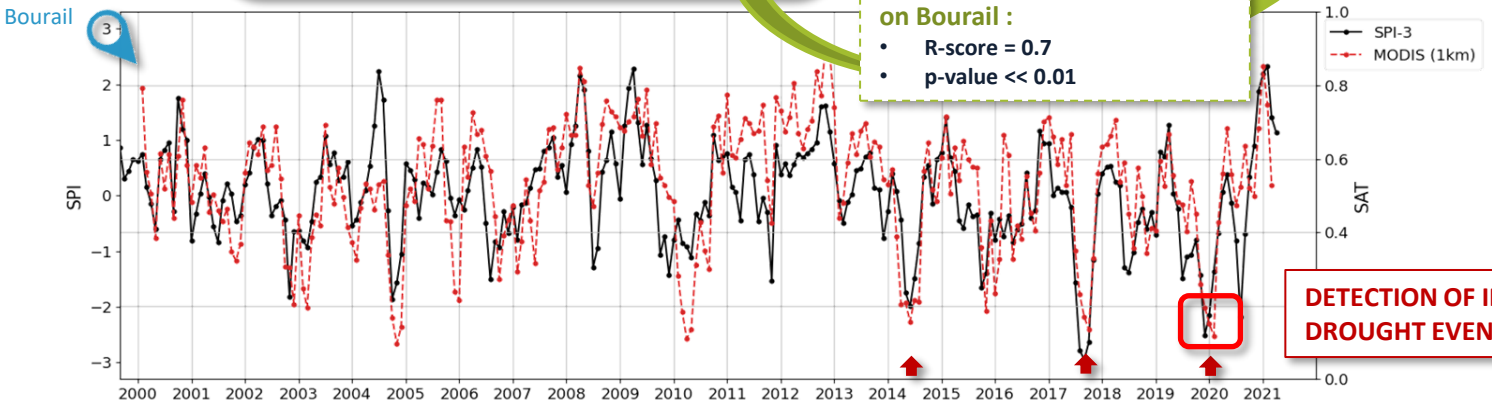

**CONFIDENCE INDEX**

***R-SCORES SPI-3 vs VHI***




**Good correlation SPI-3 vs VHI on Bourail :**

- **R-score = 0.7**
- **p-value << 0.01**




**DETECTION OF IMPORTANT DROUGHT EVENTS**

# Some results at GLOBAL SCALE

*November 2019*

$$* VHI = \alpha \times VCI + (1 - \alpha) \times TCI$$

With $VCI = \frac{NDWI - NDWI_{min}}{NDWI_{max} - NDWI_{min}}$

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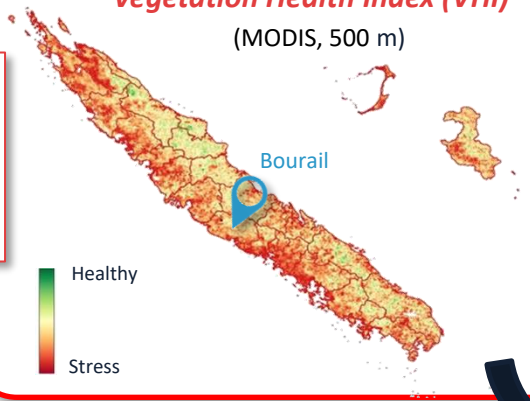
**GLOBAL INDICATOR**

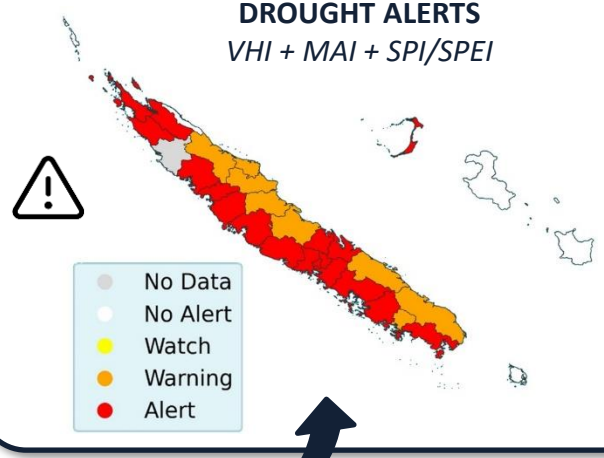
***Vegetation Health Index (VHI)****

(MODIS, 500 m)

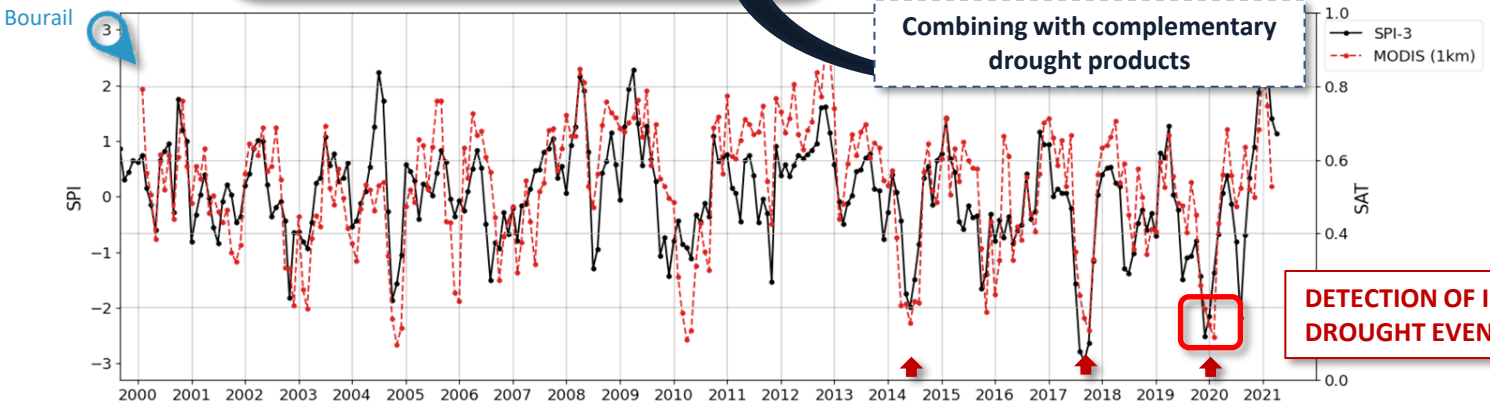



**DROUGHT ALERTS**

*VHI + MAI + SPI/SPEI*

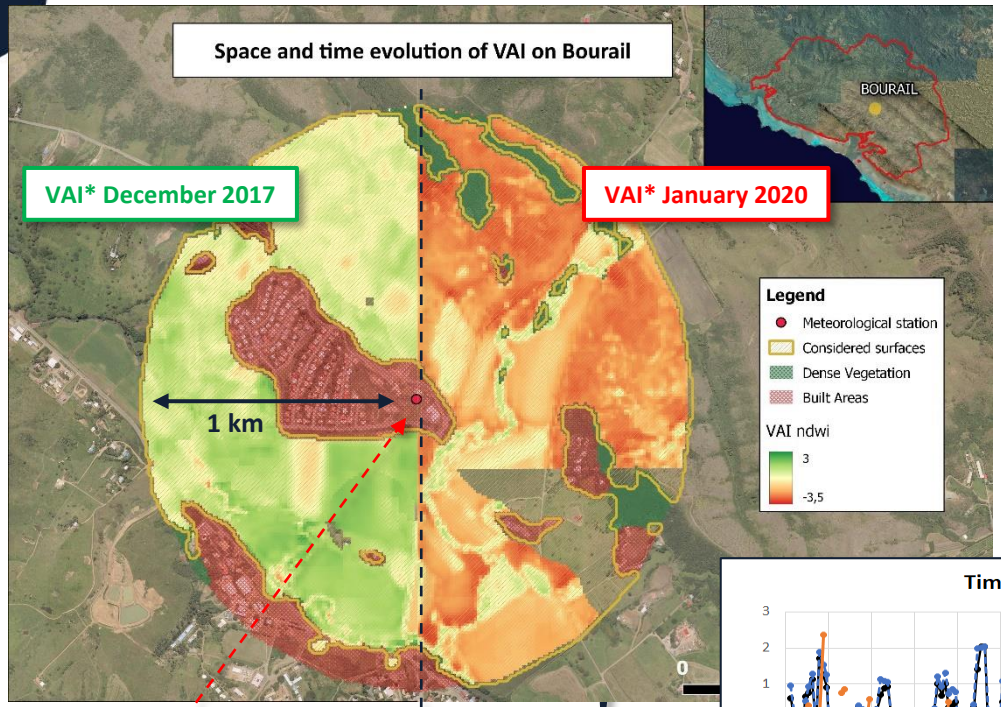



**Combining with complementary drought products**




**DETECTION OF IMPORTANT DROUGHT EVENTS**

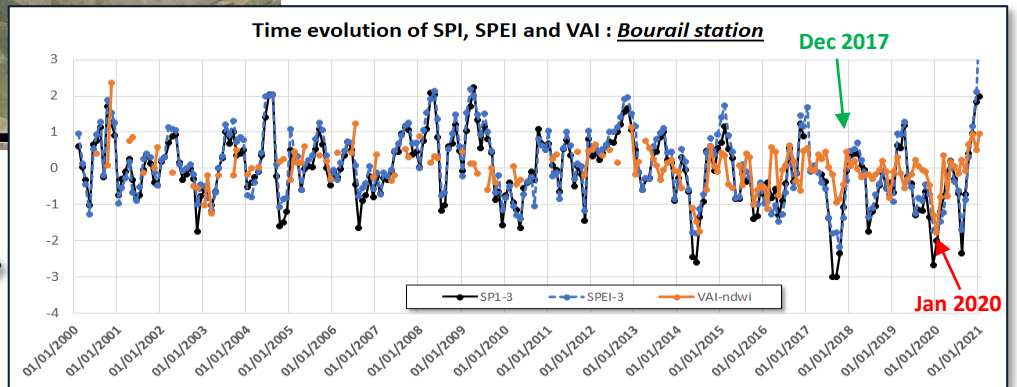
# Some results at LOCAL SCALE



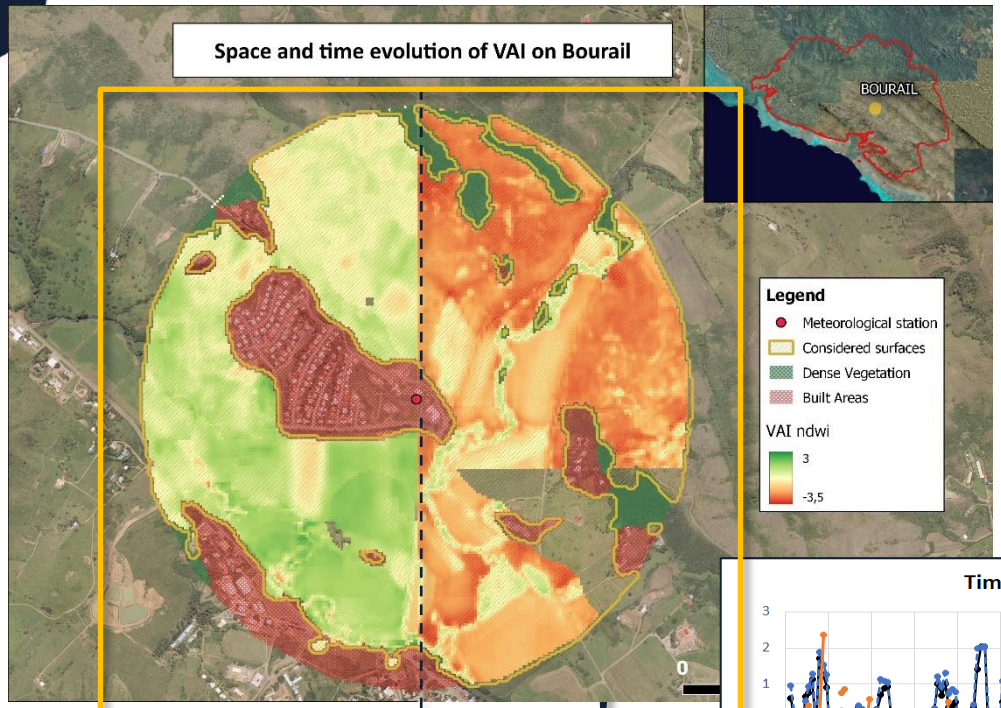

Meteo Station

* ***Vegetation Anomaly Index (10 m) :***

$$VAI_{D,M} = \frac{NDWI - NDWI_{mean}}{NDWI_{std}}$$

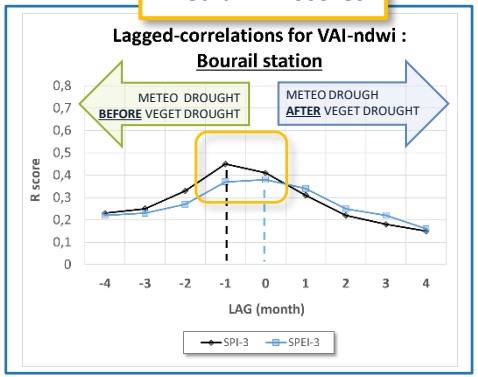


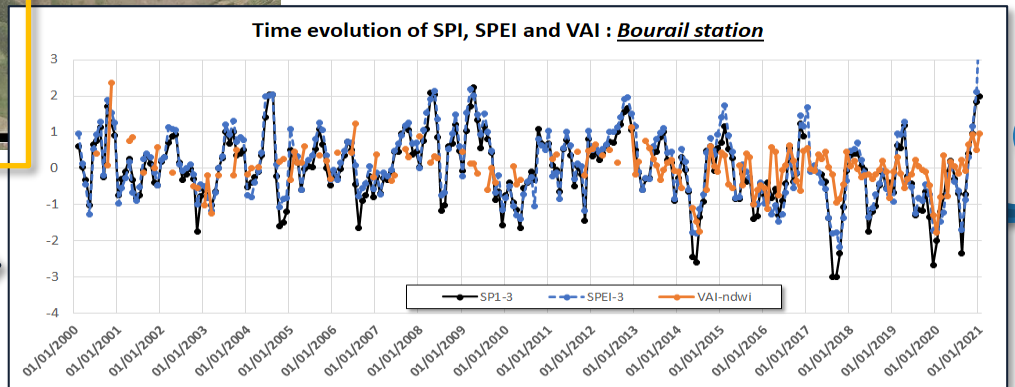
# Some results at LOCAL SCALE




**VEGETATION DROUGHT INDICATORS :**
**AFFECTED BY LOCAL FACTORS** *(human activity, soils…)*

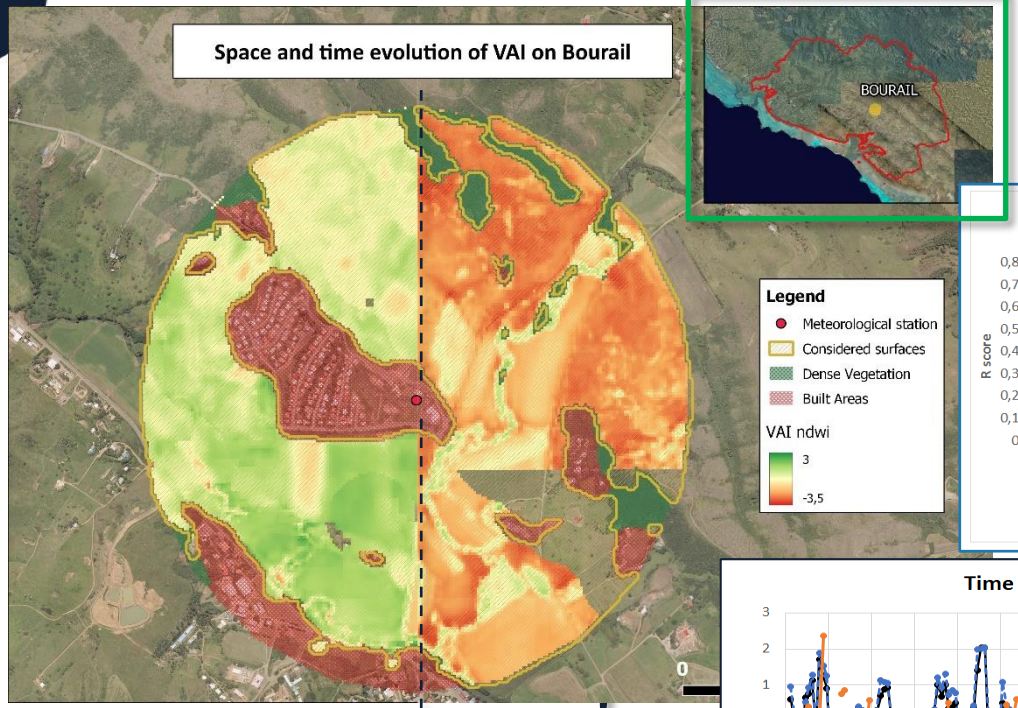
**LOCAL SCALE**
Medium R-scores



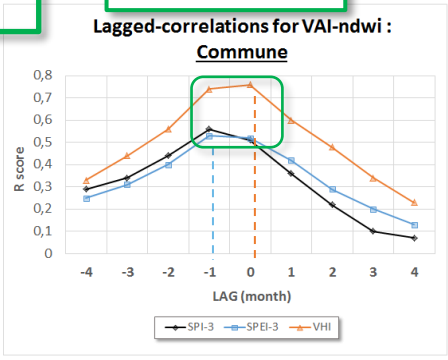

R-SCORES

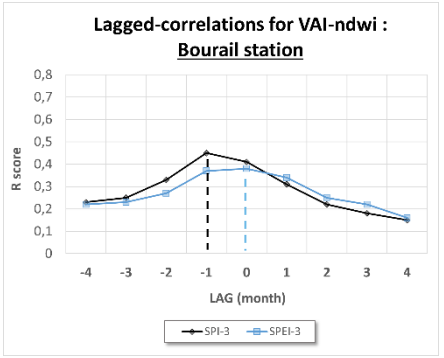
# Some results at LOCAL SCALE

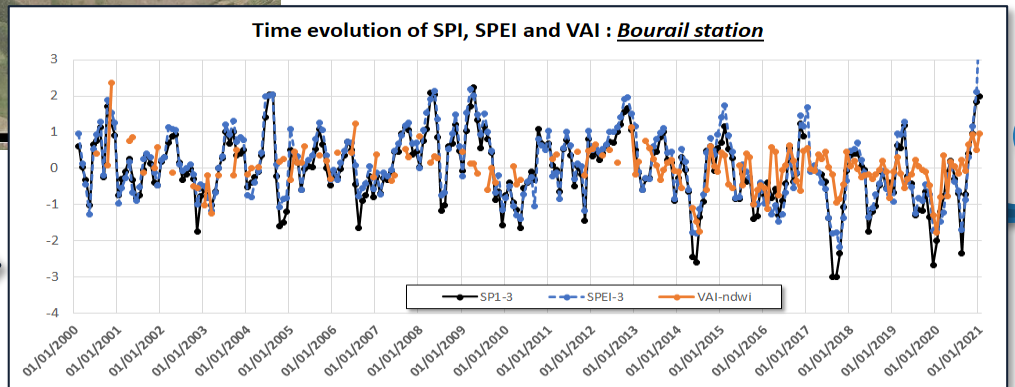



## VEGETATION DROUGHT INDICATORS : WELL-RELATED TO METEOROLOGICAL DROUGHT

**REGIONAL SCALE**
Good R-scores



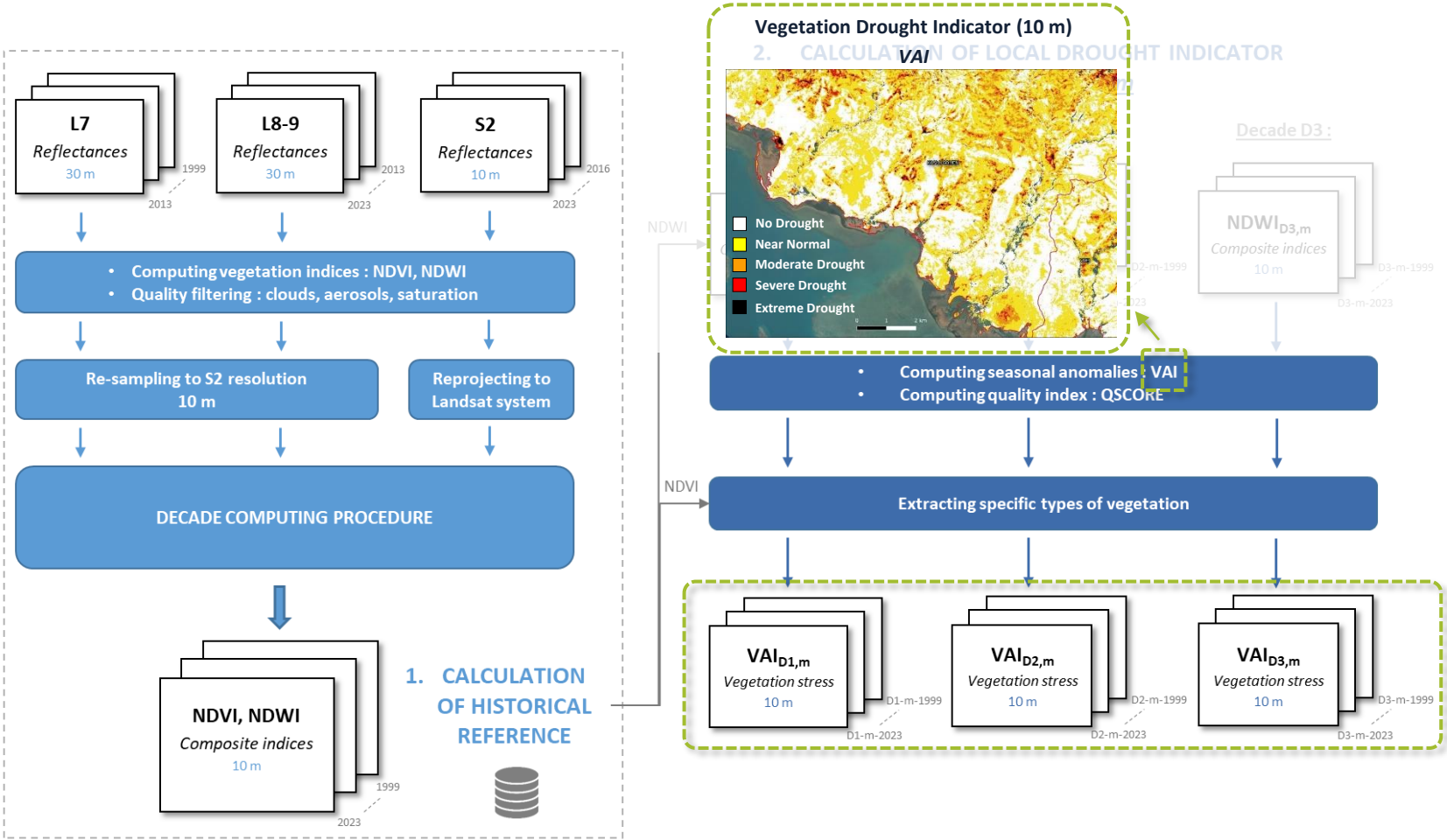



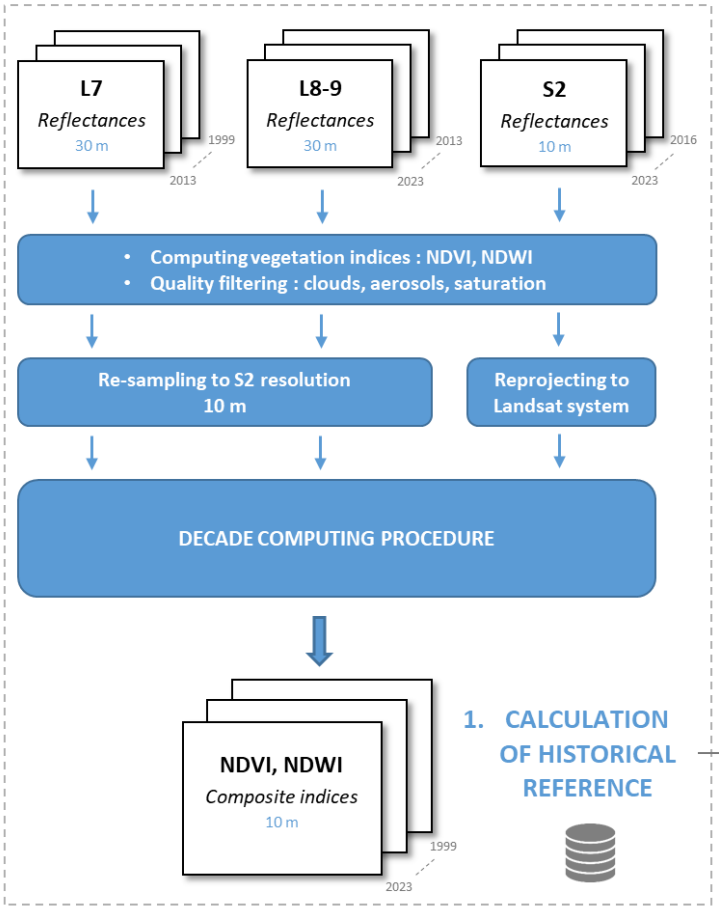

R-SCORES

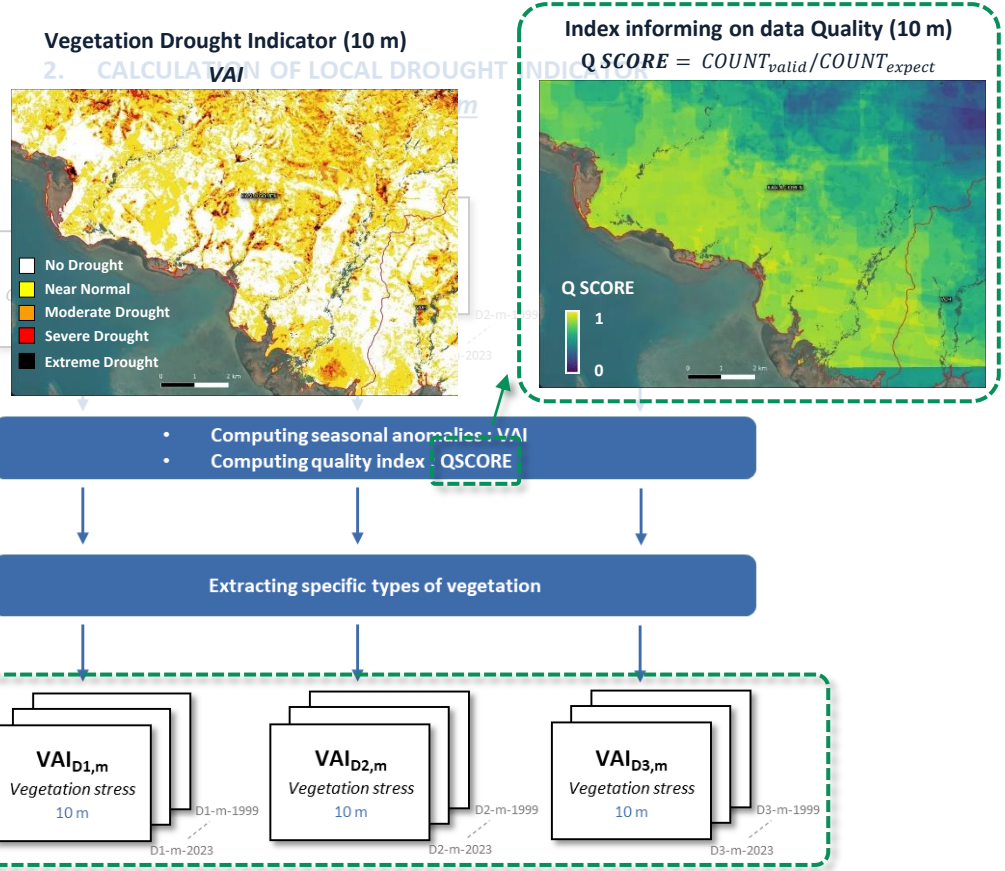
# DROUGHT PROCESSING CHAINS

# Local processing chain

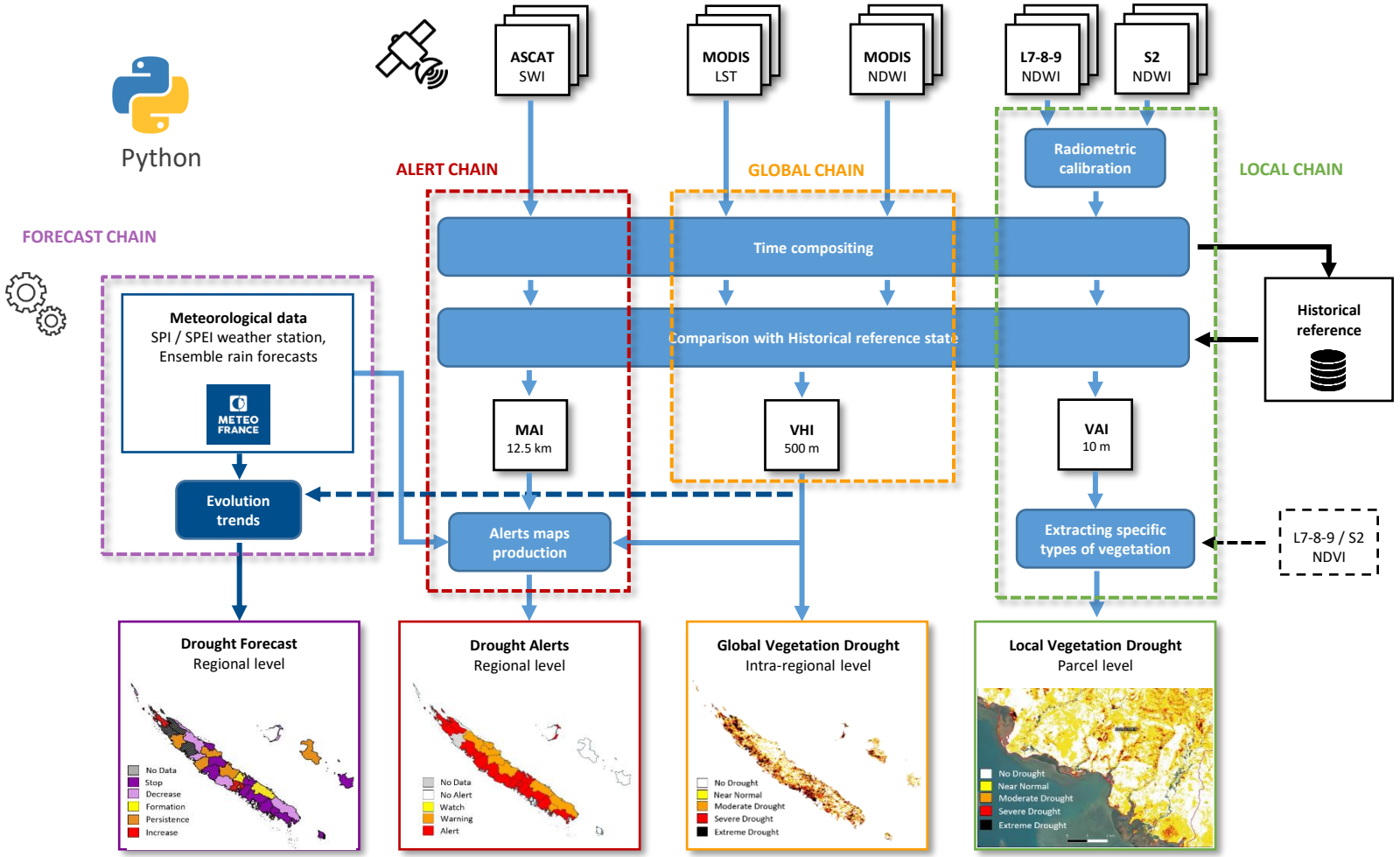


# Local processing chain



# Overview of all chains



# Overview of all chains

Python

ASCAT SWI

MODIS LST

MODIS NDWI

L7-8-9 NDWI

S2 NDWI

Radiometric calibration

Google Earth Engine

- **Satellite imagery access**
- **Online pre-processing**

Time compositing

Historical

Meteorological data
SPI / SPEI weather station,
Ensemble rain forecasts

Comparison with Historical reference

MAI
12.5 km

VHI
500 m

Evolution trends

Alerts maps production

Drought Forecast
Regional level

Drought Alerts
Regional level

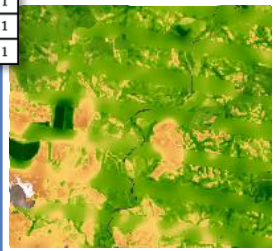
Global Vegetation Drought
Intra-regional level

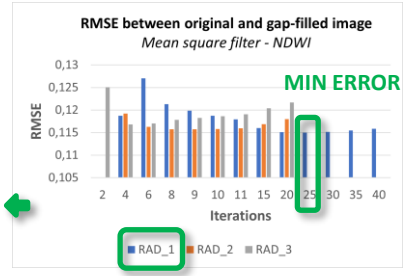
## ✓ Gap-filling of Historical Landsat indices (L7)

- Failure of the system's Scan Line Corrector (SLC)
- Corrected by application of morphological filter *(Ali et al., 2013 ; Yin et al., 2017)*
- Estimation of filter parameters by error minimization

FILTER

| | | |
|---|---|---|
| 1 | 1 | 1 |
| 1 | 1 | 1 |
| 1 | 1 | 1 |



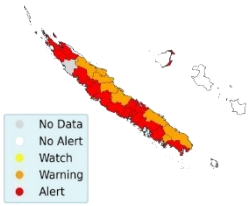


# EXTERNALITIES FOR VALORISATION

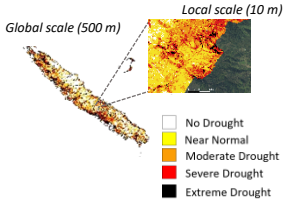
# *Monitoring and anticipating Vegetation Drought in the Pacific Island Countries and Territories*

## Development of Drought indicators

### Drought Alerts

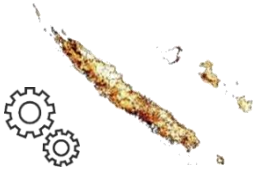



### Vegetation Drought

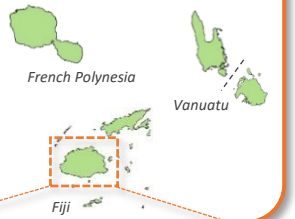


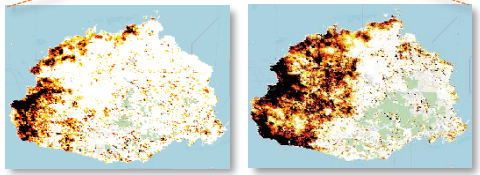

## Industrialization and Pacific

### Industrialization
*New-Caledonia*



### Regionalization
*Pacific Island Territories*

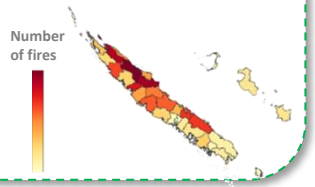



## Thematic valorizations

### Agriculture
*Crops water management*

### Fires
*Anticipating bush fires in the Pacific*




**CURRENT PROJECT**

April 2021 — July 2022 — Sept 2022

# THANK YOU FOR YOUR ATTENTION

*Vinaka Vaka Levu*