



**AGENZIA REGIONALE PER LA PROTEZIONE DELL'AMBIENTE DELLA SARDEGNA**  
**ARPAS**

**ARPAS**  
**Environmental Protection Agency of Sardinia**

Andrea Motroni

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- ❖ **Climate and weather monitoring**
  - ❖ **Agrometeorology**
    - ❖ **Drought and desertification**
      - ❖ **Climate change impacts**
        - ❖ **Phenology and invasive species monitoring**
          - ❖ **Aerobiology and human and animal wellbeing**



## MeteoClimatological Department

Arpas 5 District Departments

2 Regional Specialistic Departments

MeteoClimatology ←-----→ Geology



Medioitalia

## Arpas

5 District Departments

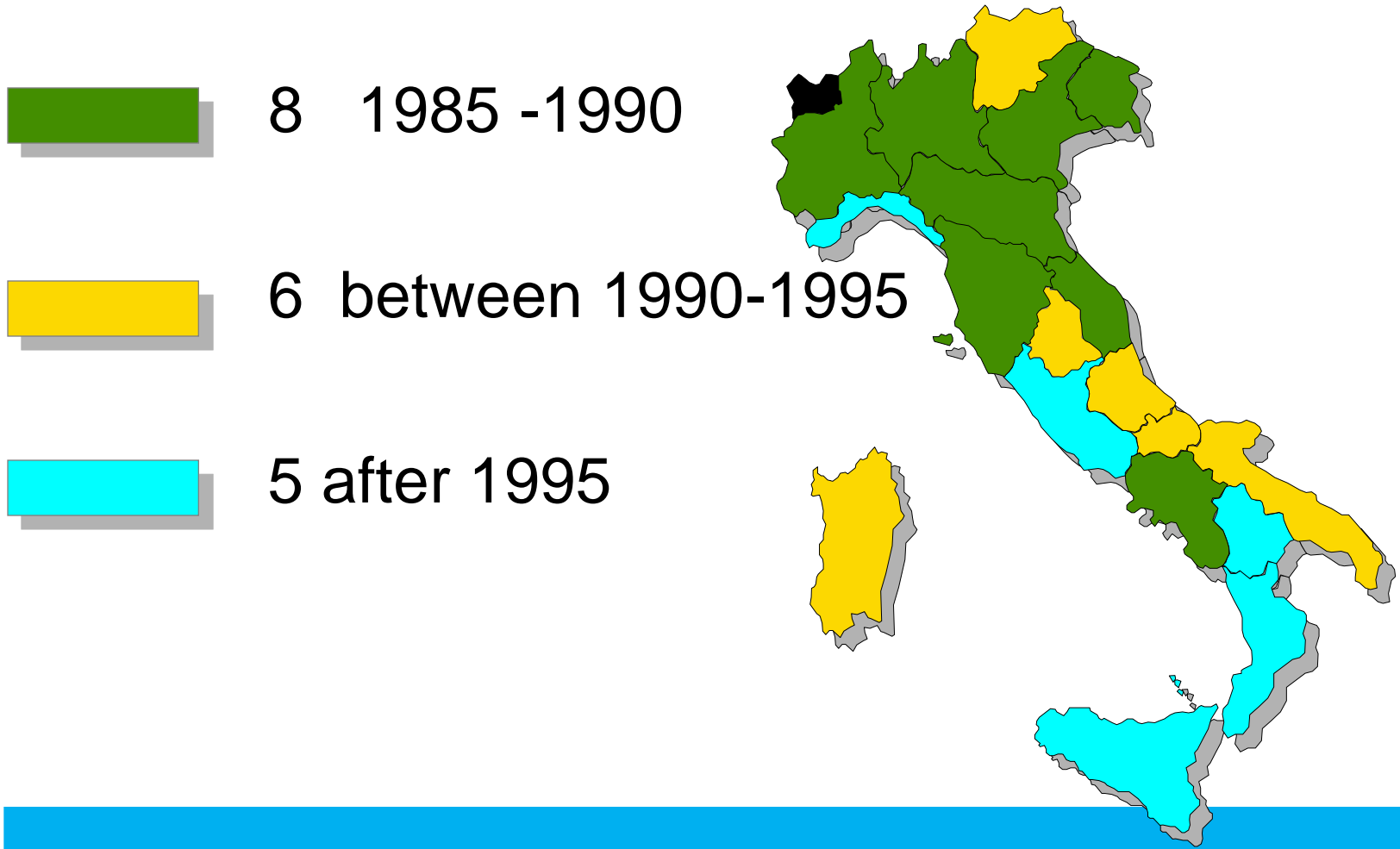
2 Specialistic Departments



MeteoClimatology ←-----→ Geology



# Period of starting



# Meteorological Services network



- Available on line meteorological and agrometeorological data from more than 1700 automatic weather stations

## OBJECTIVES

- WEATHER FORECAST AND ALERT CIVIL DEFENCE ABOUT METEOROLOGICAL THREATENING EVENTS
- TO MONITORATE THE CLIMATE OF SARDINIA
- TO GIVE METEOROLOGICAL INFORMATION AT LOCAL AND EVEN MORE DETAILED SCALE
- TO GIVE OPERATIVE INFORMATION FOR AGRICULTURAL PLANNING: SEEDING, IRRIGATION, WEEDING, TREATMENTS, TILLAGE, HARVESTING
- CLIMATE CHANGE ADAPTATION STRATEGIES AND PLANS
- DESERTIFICATION MONITORING

# USERS



AGENZIA REGIONALE PER LA PROTEZIONE  
DELL'AMBIENTE DELLA SARDEGNA - ARPAS

**AGRICULTURAL EXTENSION SERVICE  
TECHNICIANS**

**CROP DEFENCE AND LAND RECLAMATION  
CONSORTIA**



**AGENCIES OF SARDINIA  
REGIONAL GOVERNMENT**

**MEDIA (TV, RADIO, NEWSPAPERS)**

**PRIVATE USERS (FREE LENSE  
ENGINEERS and LAWYERS)**

**TURISTIC OPERATORS**





# MC Department Technologies

**ATMOSPHERIC GENERAL CIRCULATION MODELS FORECASTING DATA OF E.C.M.W.F. (READING, UK) AND LIMITED AREA MODEL (BOLAM) OF REGIONAL METEOROLOGICAL SERVICE OF EMILIA ROMAGNA**



**NETWORK of about 200 METEOROLOGICAL AND AGROMETEOROLOGICAL AUTOMATIC STATIONS**

**METEOROLOGICAL RADAR**

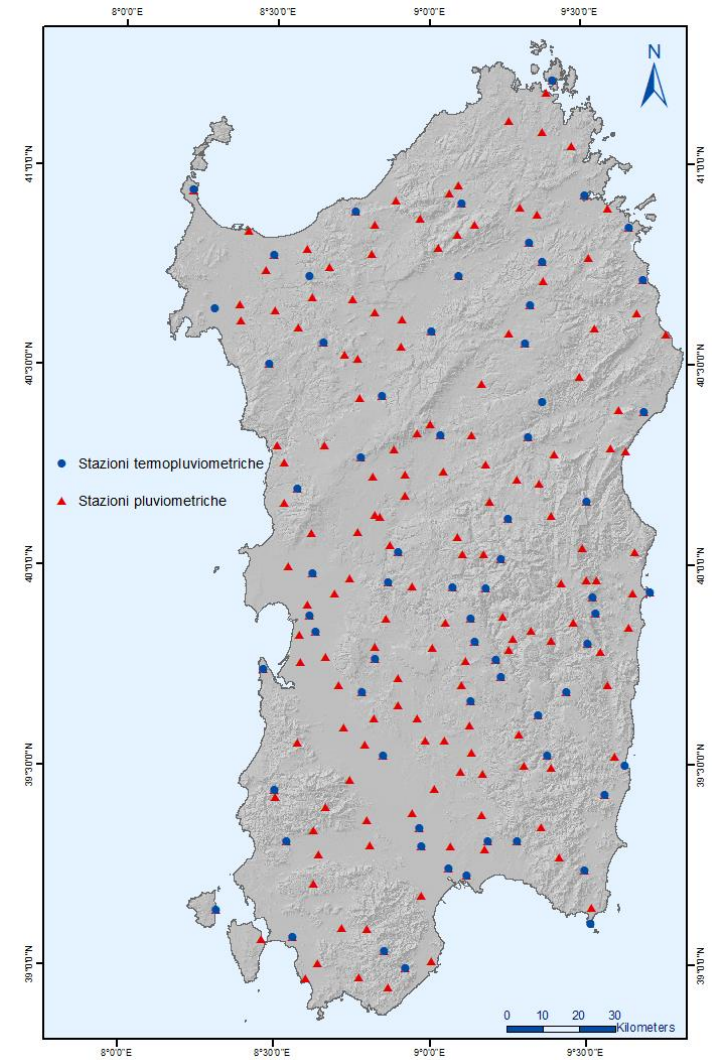
**MULTIPLATFORM INFORMATIC SYSTEM**

**RELATIONAL DATABASES : CLIMATOLOGICAL  
AGROPHENOLOGICAL AND METEOROLOGICAL DB**



## - Weather stations network of MC

MC in control of  
200 weather  
stations all over  
the Sardinian  
territory.



## Sensors:

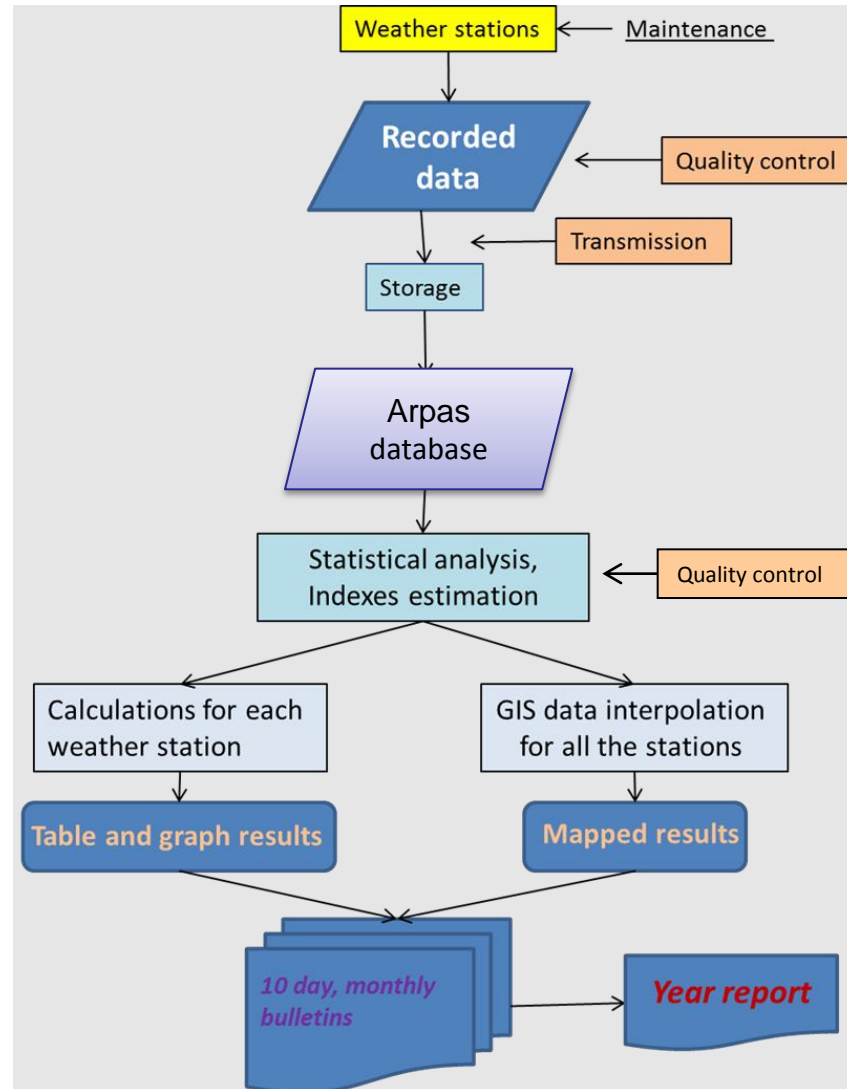
- air temperature
- soil surface temperature
- soil temperature  
at -10 cm and -50 cm
- rainfall
- relative humidity
- 2 m & 10 m wind speed
- 10 m wind direction
- global radiation
- scattered radiation
- leaf wetness
- pressure and sun insolation



All the stations have to respect WMO standards

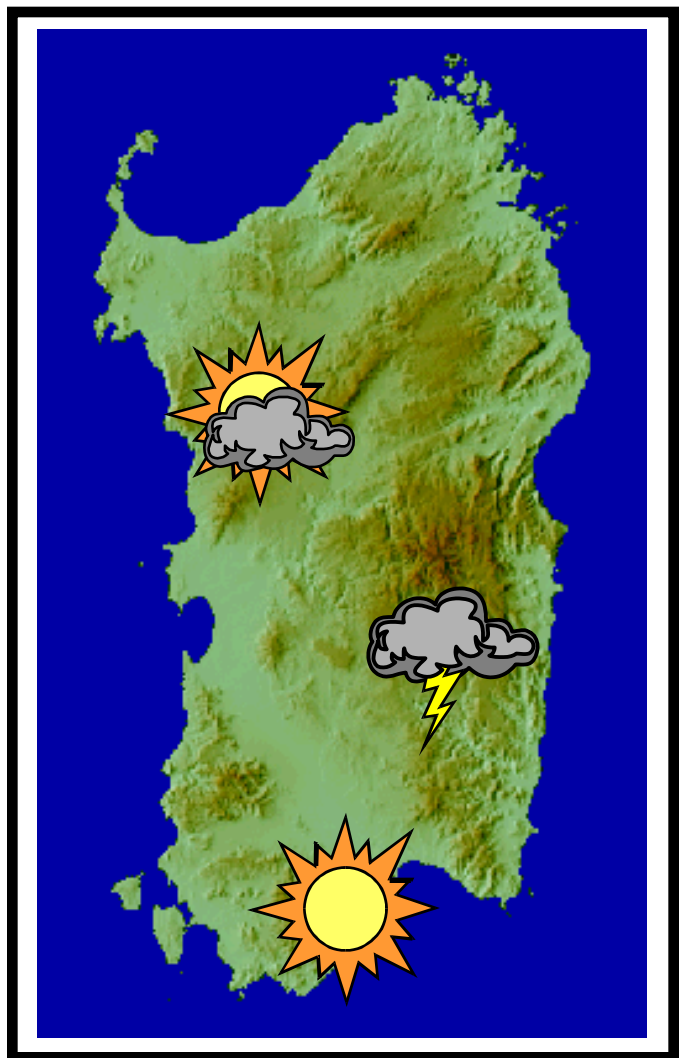


# Agrometeorological Data flow





# OUTPUTS



**DAILY WEATHER FORECAST BULLETIN**

**CIVIL DEFENCE ALERT (daily and hourly)**

**WF**

**DAILY AGROMETEOROLOGICAL BULLETINS**

**METEOROLOGICAL AND AGROMETEOROLOGICAL  
DECADAL AND MONTHLY REPORTS**

**METEOROLOGICAL AND AGROMETEOROLOGICAL  
YEARLY RESUMES**

**CLIMATE AND CLIMATE CHANGE**

**RESEARCH PROJECTS ON METEOROLOGICAL,  
AGROMETEOROLOGICAL AND ENVIRONMENTAL  
ISSUES**

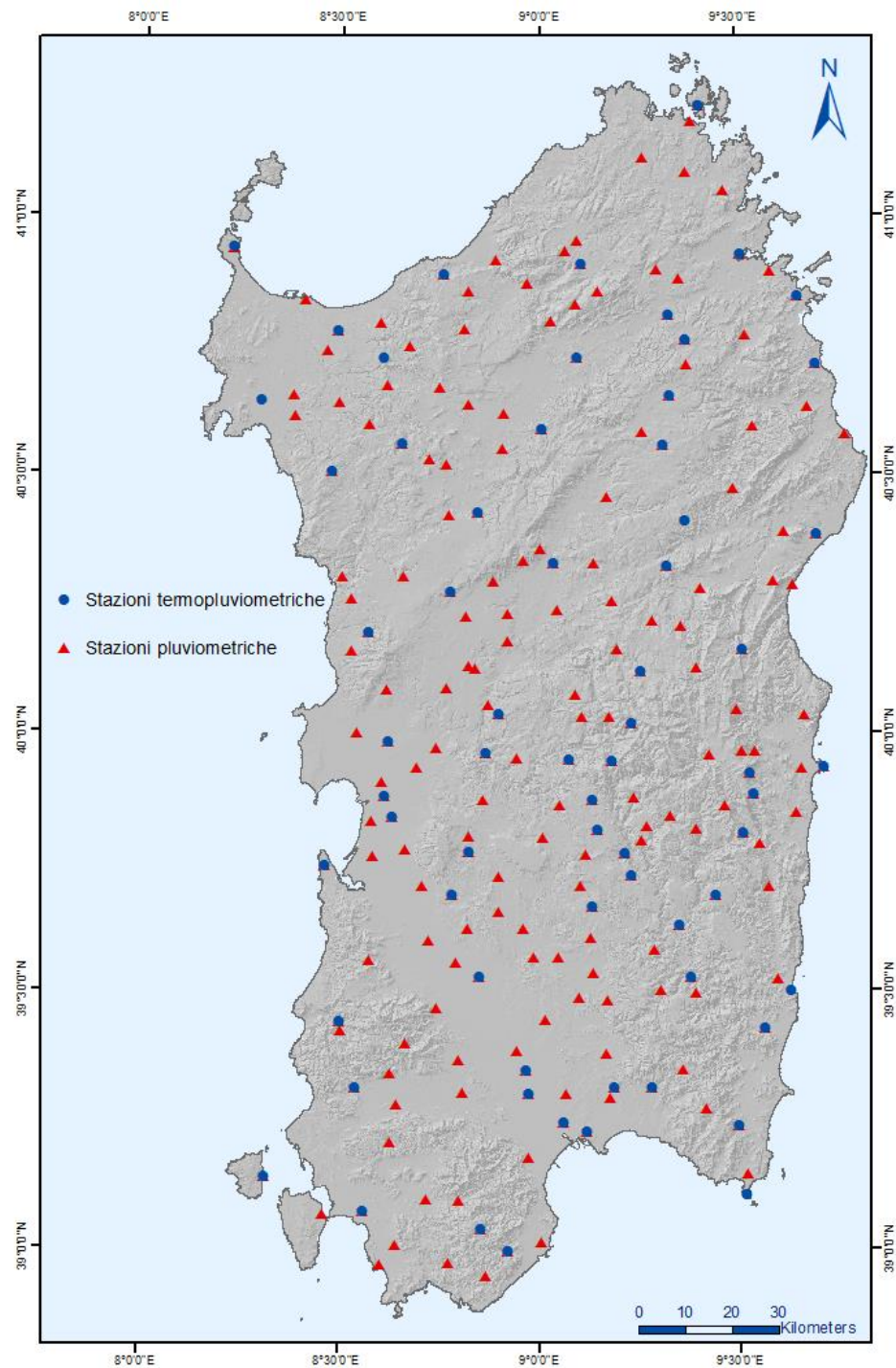
# Data interpolation

Location of the pluviometric and thermo-pluviometric stations

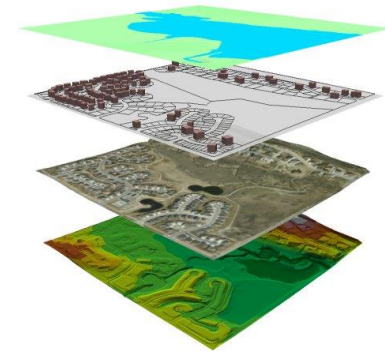


- Rather homogeneous distribution
- Lack of long time series in some areas
- Different variables can be interpolated separately

**Time frame: 1971-2000**



## GIS implementation (Geographic Information System)



Statistic methods

Geo-statistic methods

Spatial interpolation of the climatic data



Overlay and spatial analysis



Map Algebra and  
Spatial overlay



# Data interpolation

**Analysis of the best spatial interpolation technique for:**  
Monthly average minimum and maximum temperatures and monthly average precipitation



Methodological basis: previous studies of ARPAS - Dip. Meteorologico

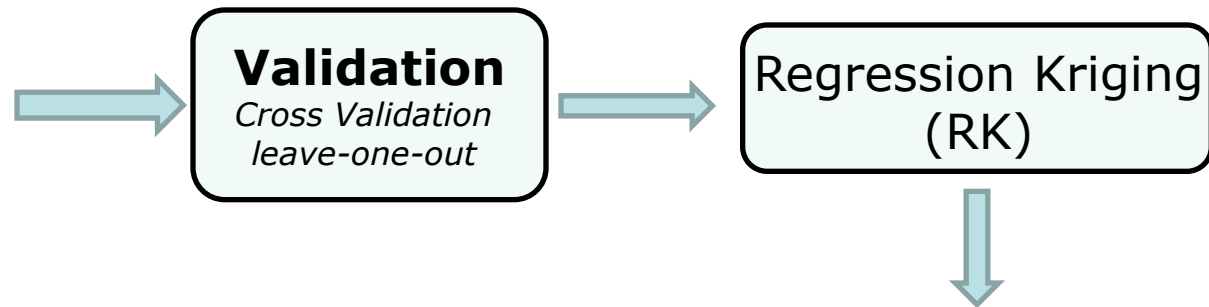
**We compare 3 methods  
of statistic and geo-statistic  
spatial interpolation**

Ordinary Kriging  
(OK)

Multiple Linear Regression  
(MLR)

Regression Kriging  
(RK)

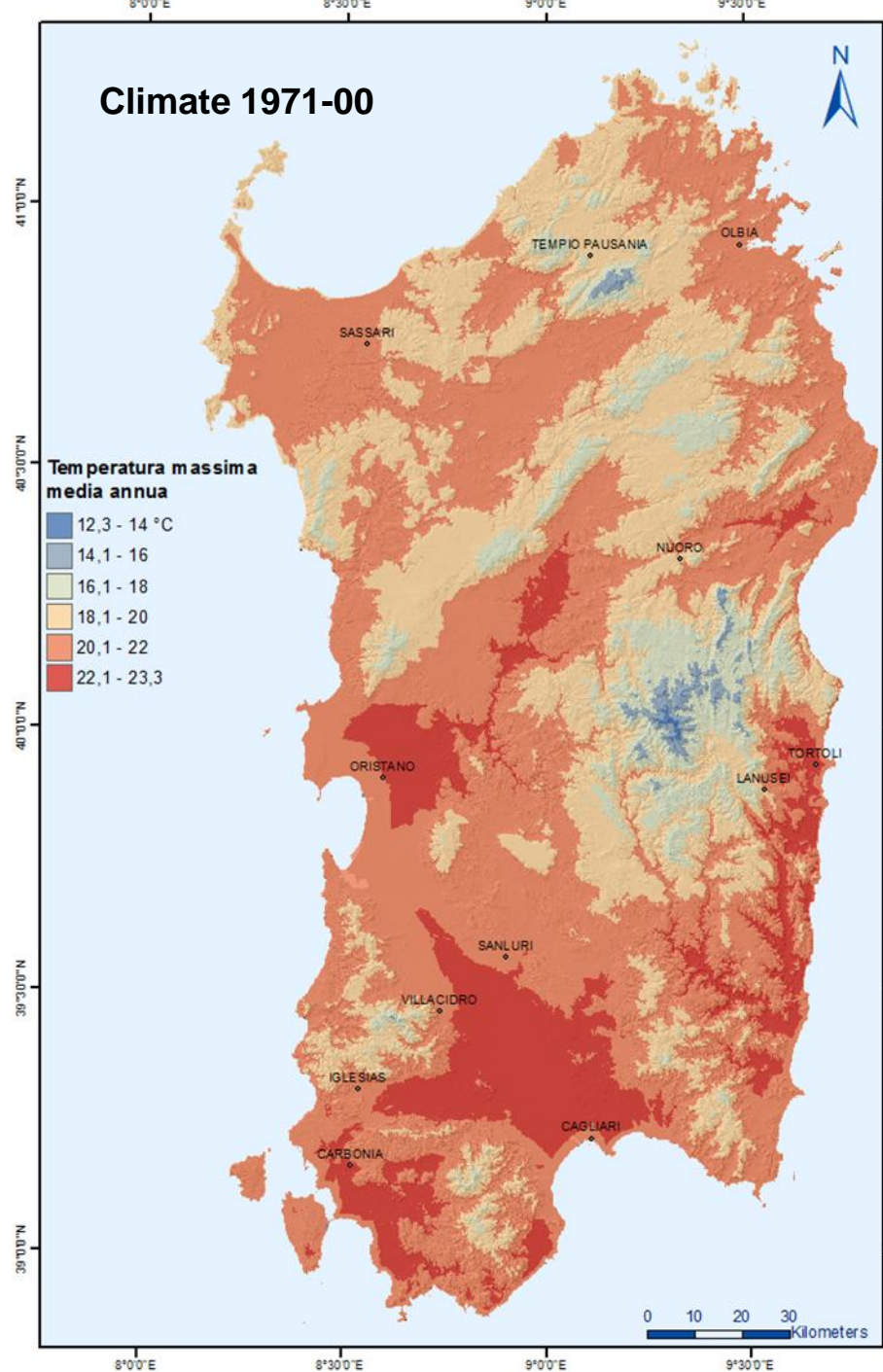
**Best method:**



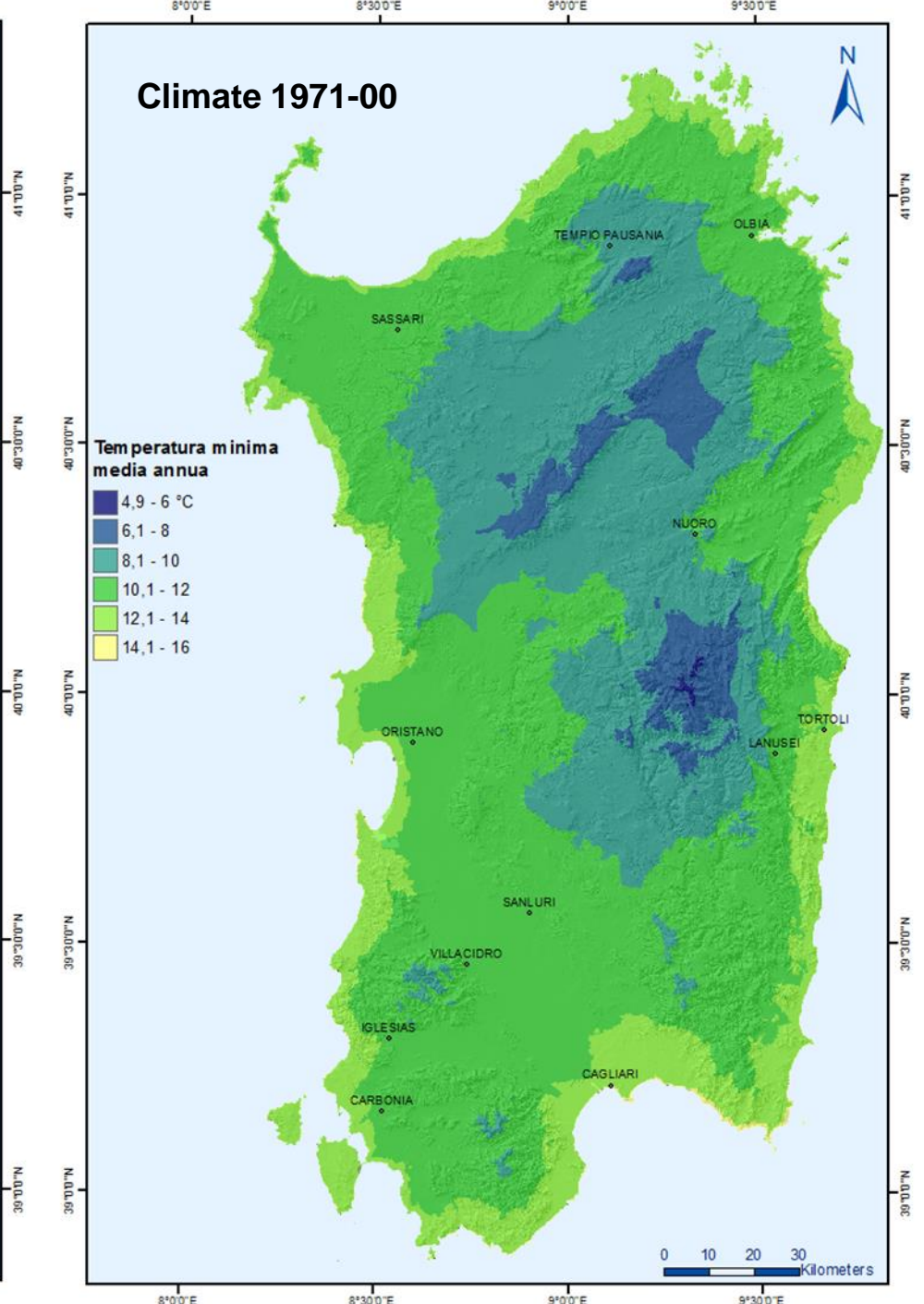
*Hybrid method for interpolation, where a portion of the variability is explained by a regression model and another portion by interpolating the residuals of the regression by Ordinary Kriging (Hengl, 2007).*



# Climate 1971-00



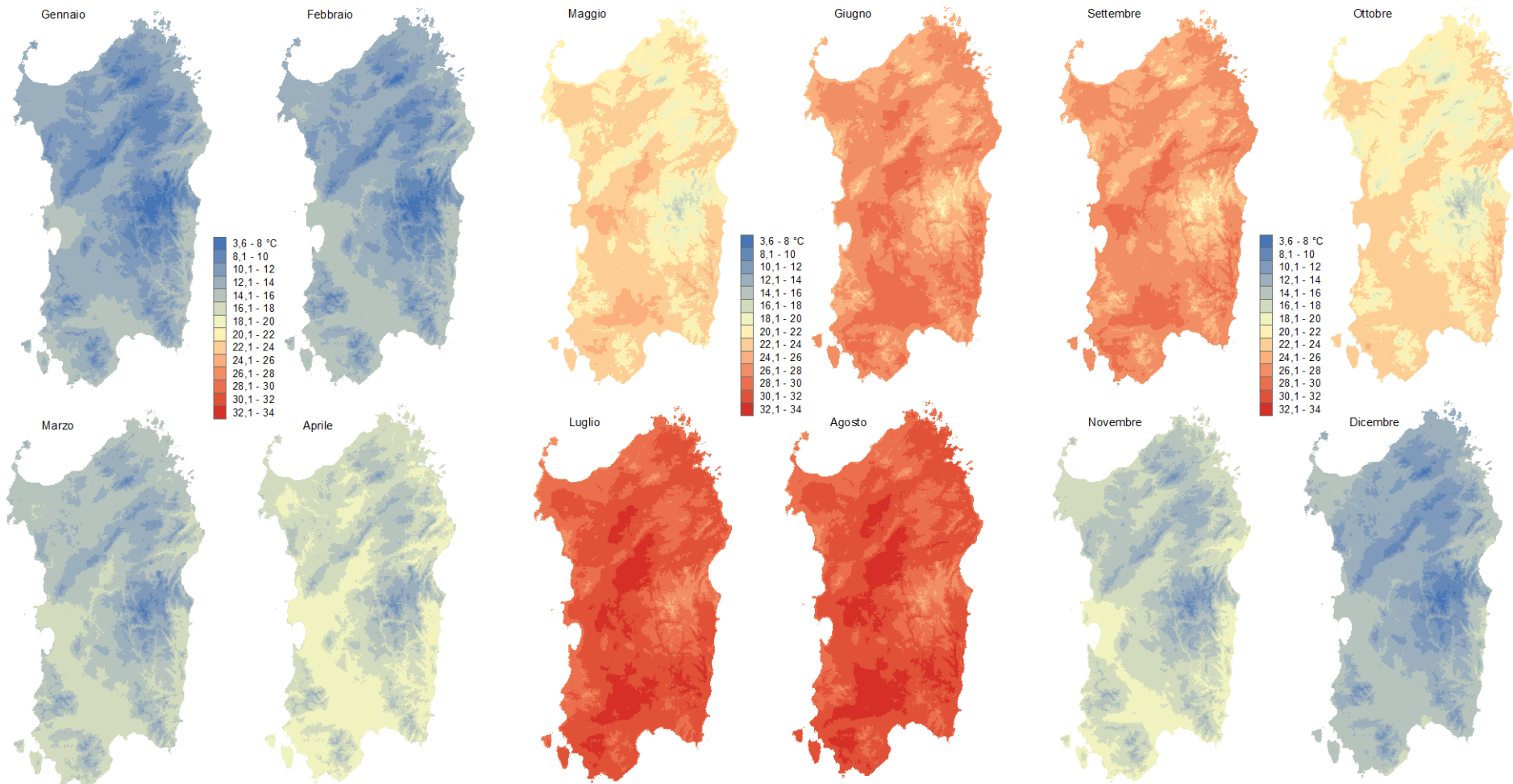
# Climate 1971-00

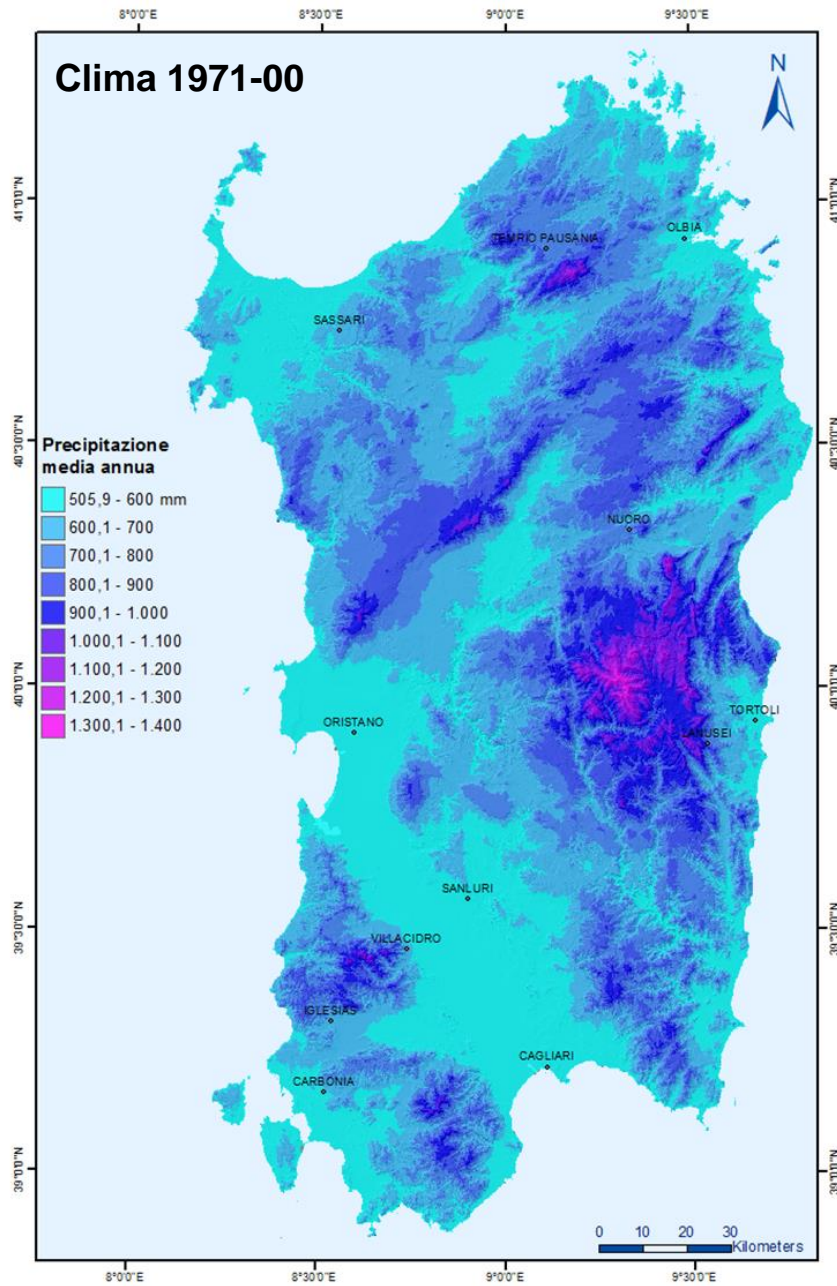


# Climatic mean of monthly maximum temperature 1971-00



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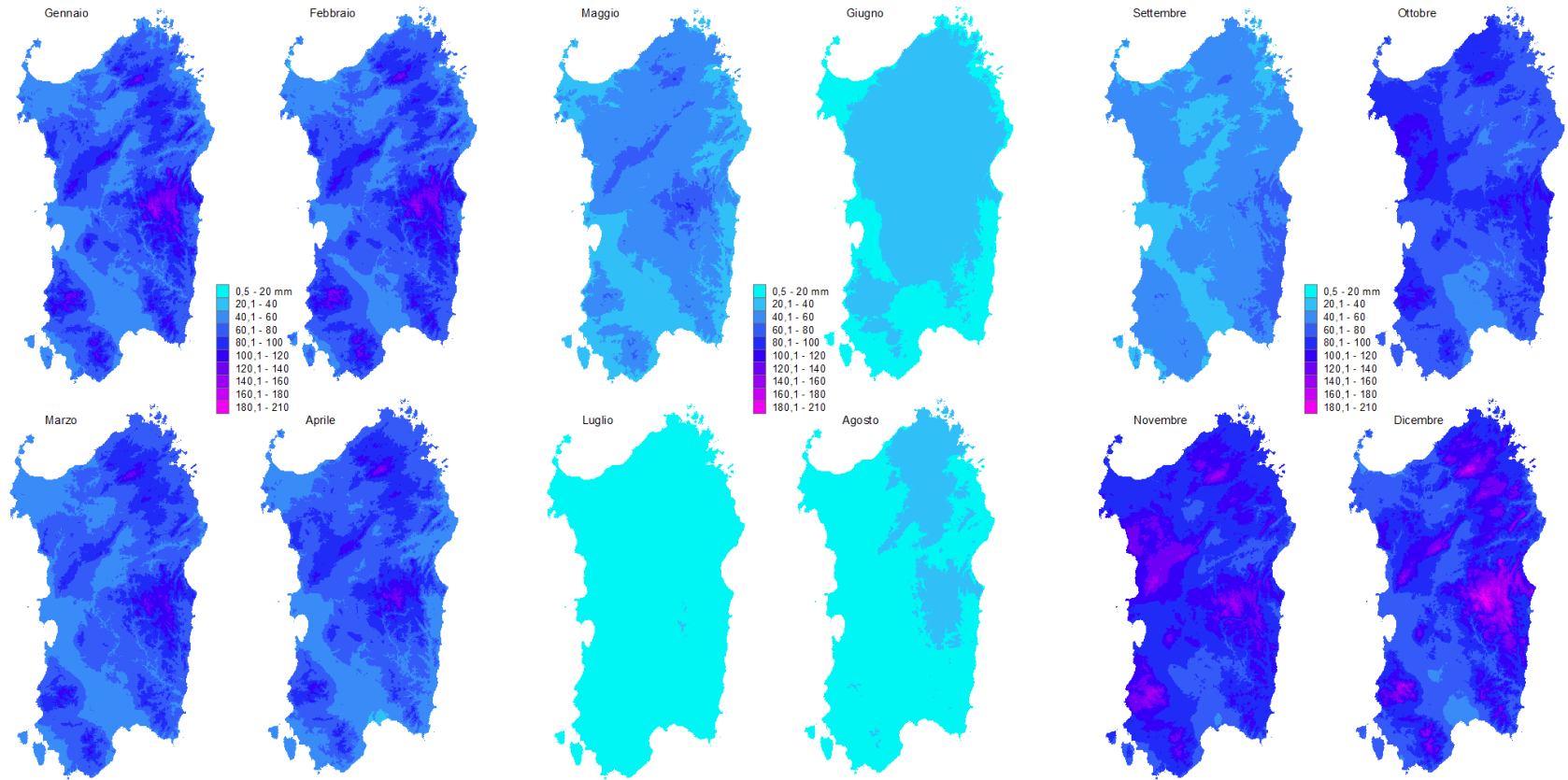


Mean annual rainfall amount

# Climatic mean of monthly rainfall 1971-00



AGENZIA REGIONALE PER LA PROTEZIONE  
DELL'AMBIENTE DELLA SARDEGNA - ARPAS





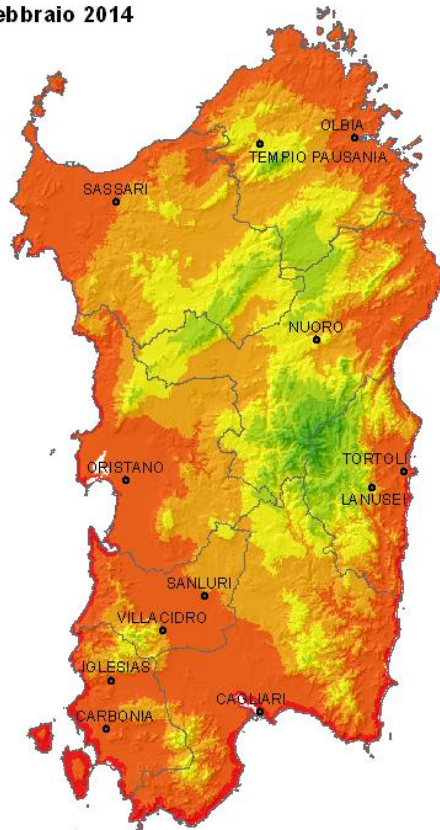
Growing degree days

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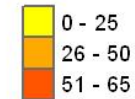
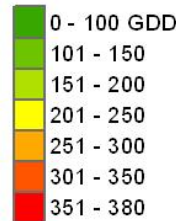
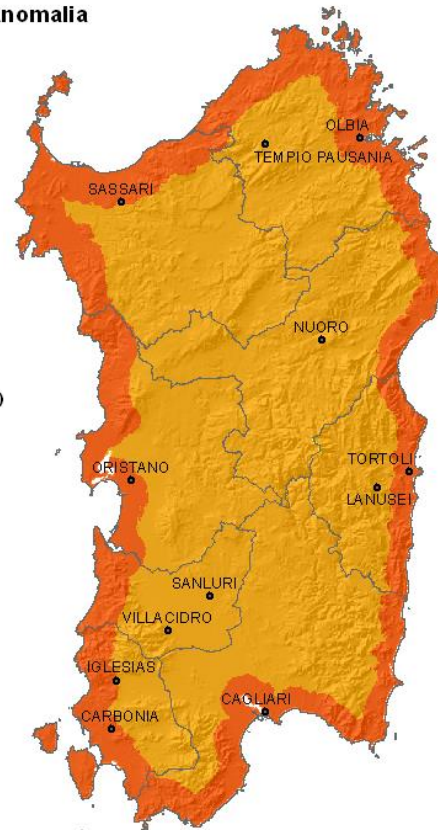
# Growing Degree Days

The summation of daily GDD units can be used for a variety of things: comparing one region to another, comparing one season to another, and predicting important stages in crops' development

Febbraio 2014



Anomalia

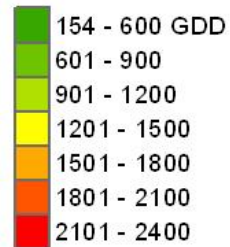
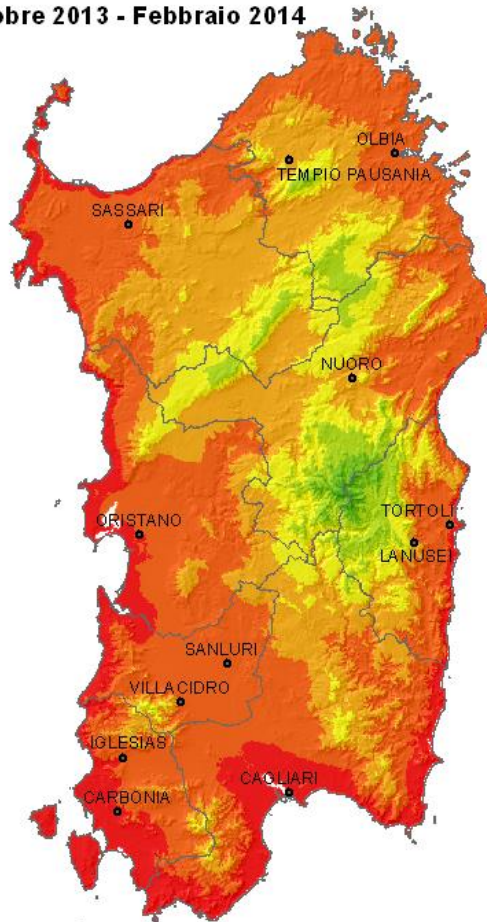


GDD calculated on 0°C base

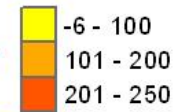
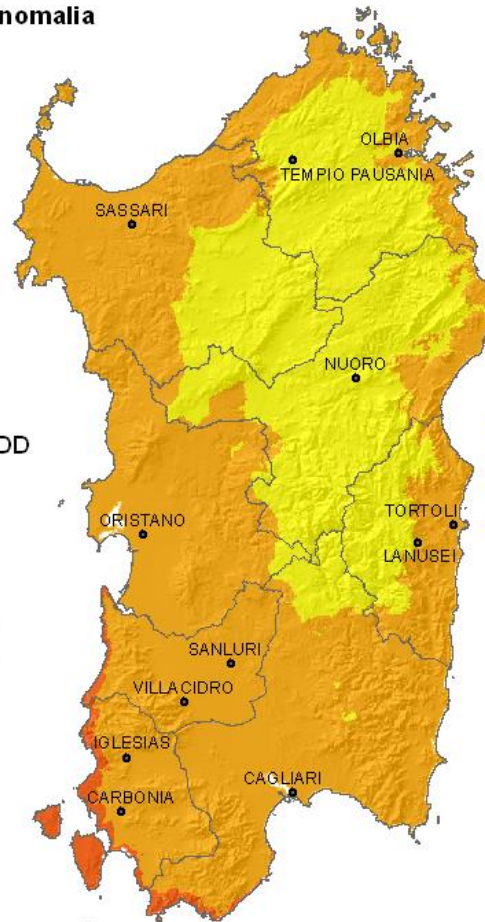
# Growing Degree Days



Ottobre 2013 - Febbraio 2014



Anomalia

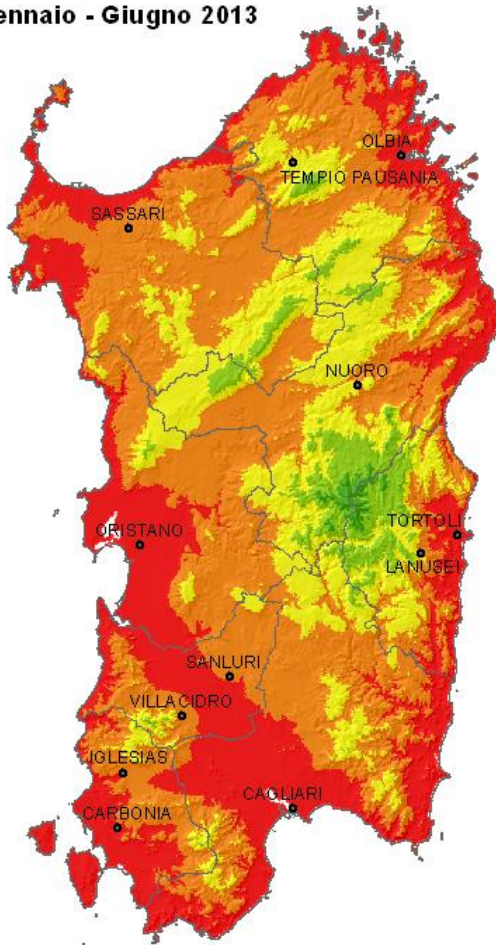


GDD calculated on 0°C base

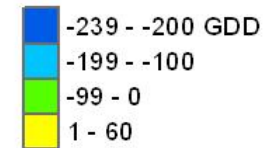
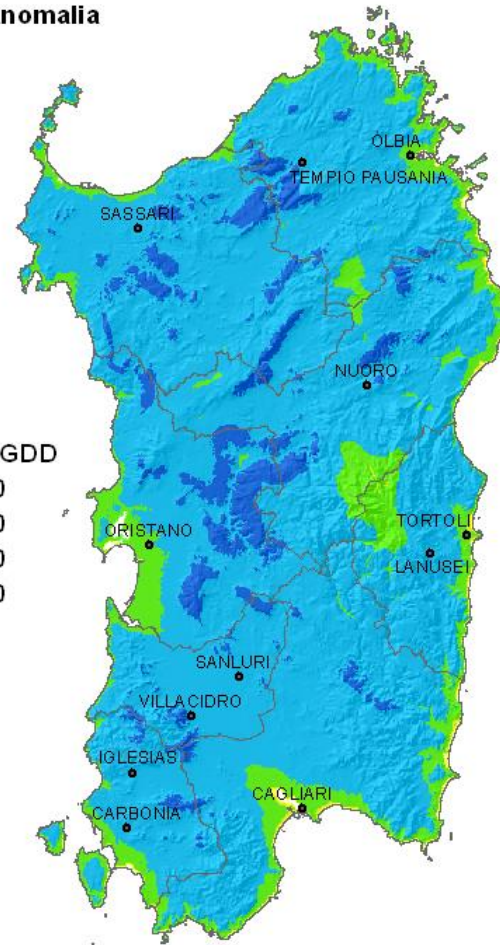
# Growing Degree Days



Gennaio - Giugno 2013



Anomalia



GDD calculated on 0°C base



## 10 day rainfall maps – Ultime 3 decadi

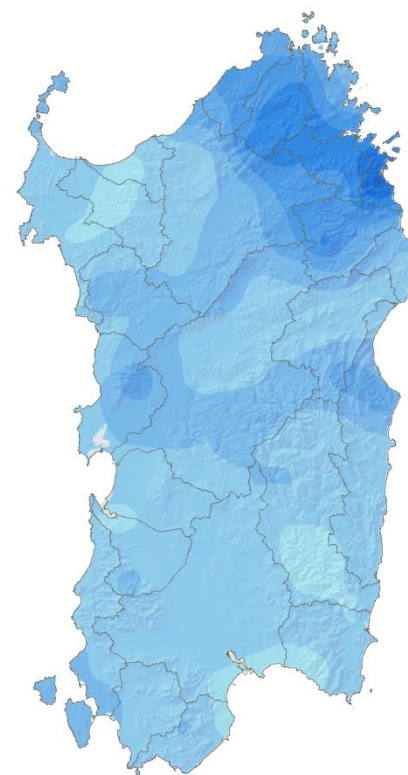
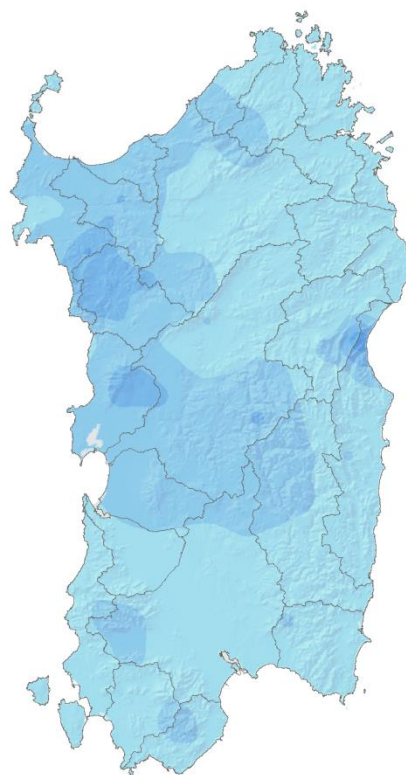
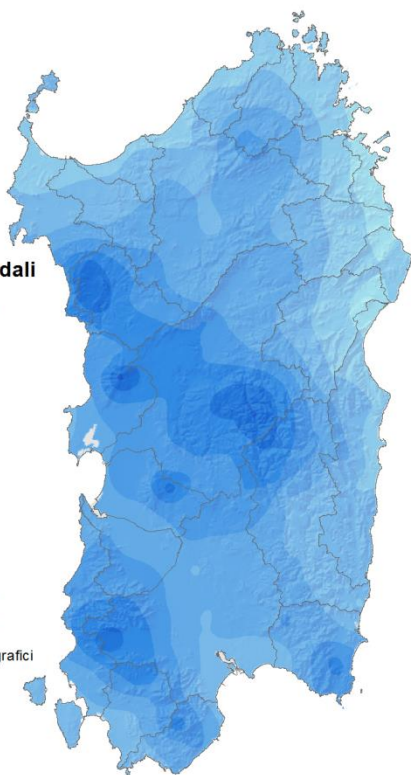
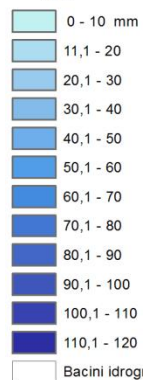
III dicembre

I gennaio

II gennaio



### Pioggie decadali



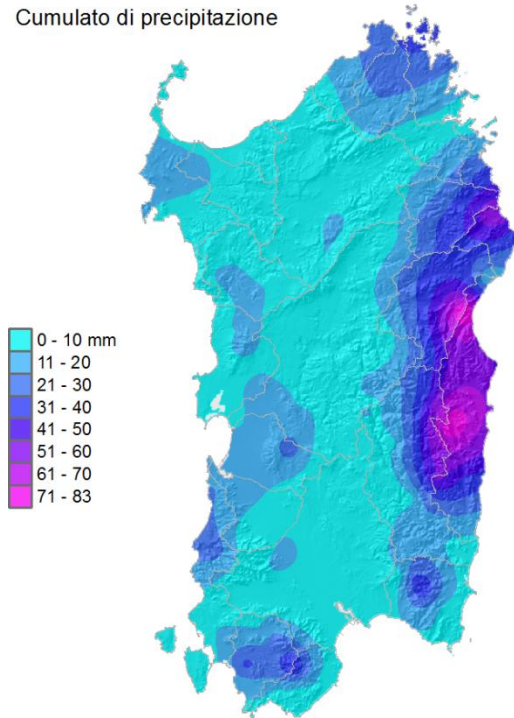
## Monthly rainfall maps

Ottobre 2017

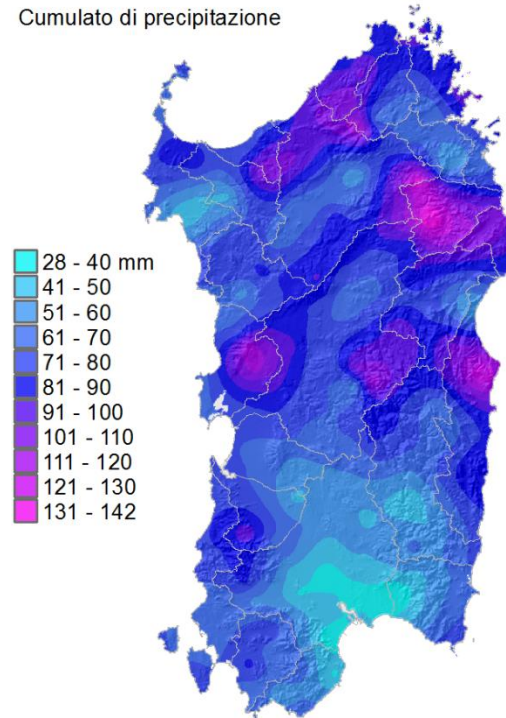
Novembre 2017

Dicembre 2017

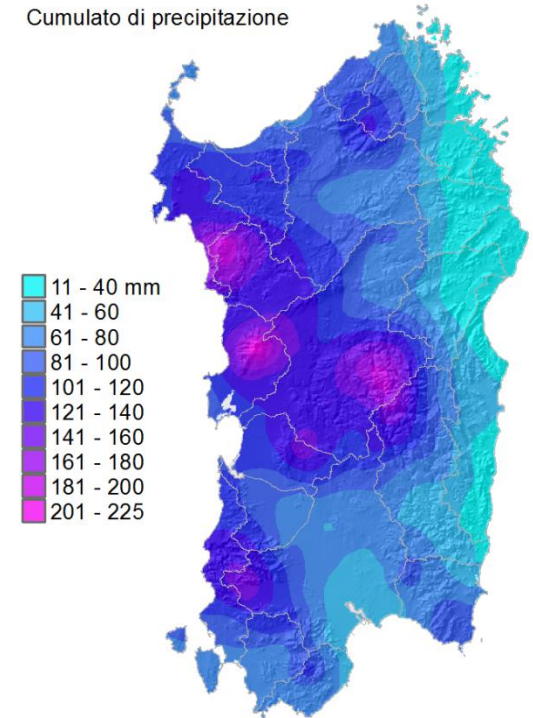
Cumulato di precipitazione



Cumulato di precipitazione

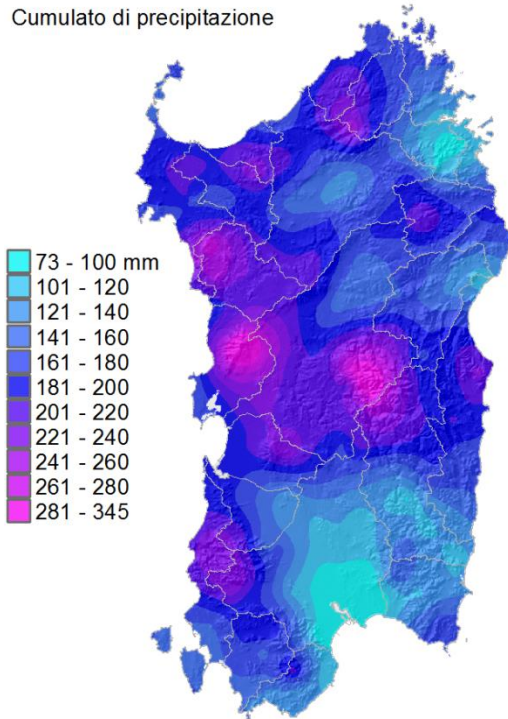


Cumulato di precipitazione

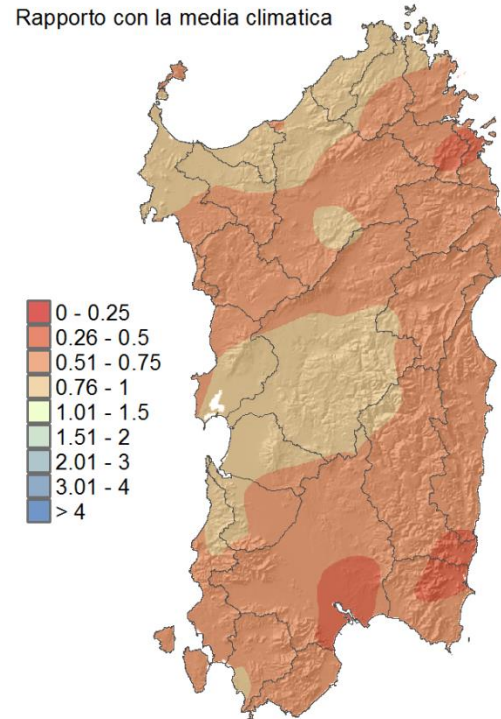


## Rainfall October – December 2017 – comparison with 1971-2000 climatic baseline

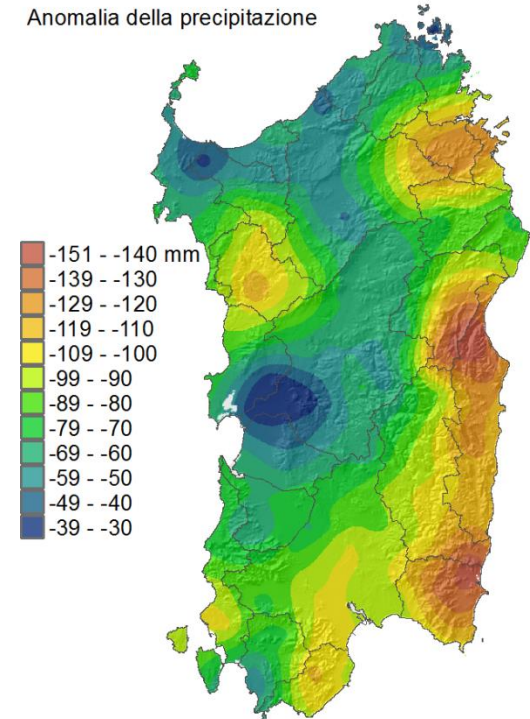
Cumulato di precipitazione



Rapporto con la media climatica



Anomalia della precipitazione



## Standardized Precipitation Index for December 2017 3, 6, 12 e 24 months

### Agricultural drought

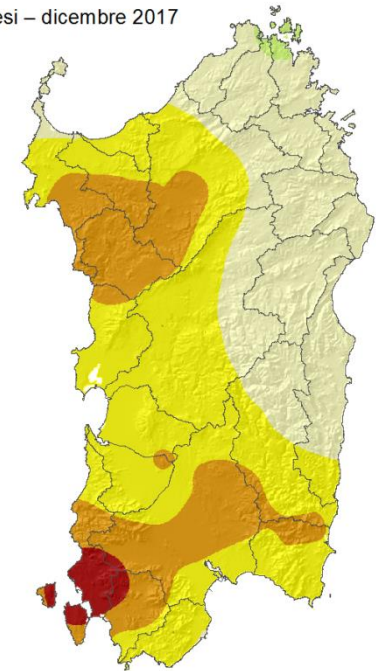
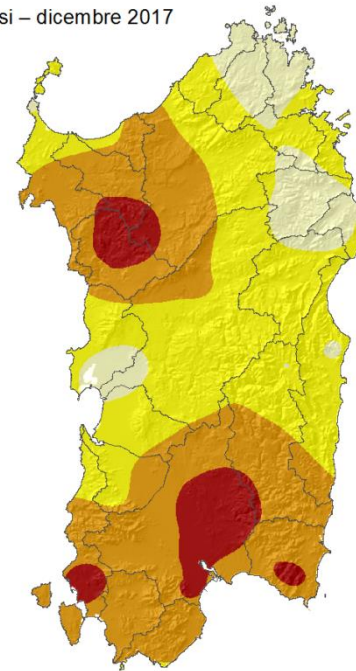
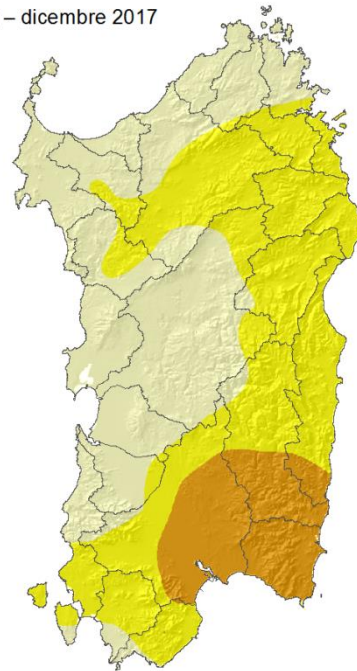
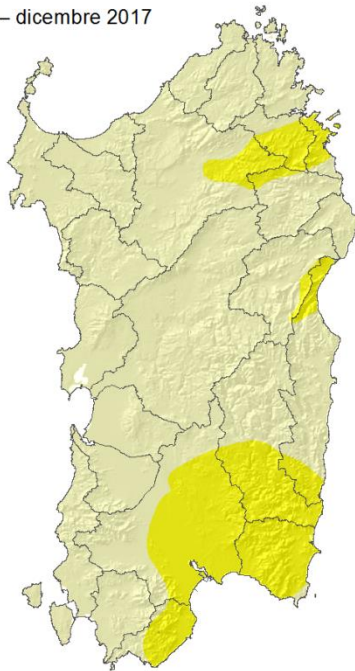
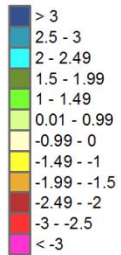
### Hydrological drought

SPI 3 mesi – dicembre 2017

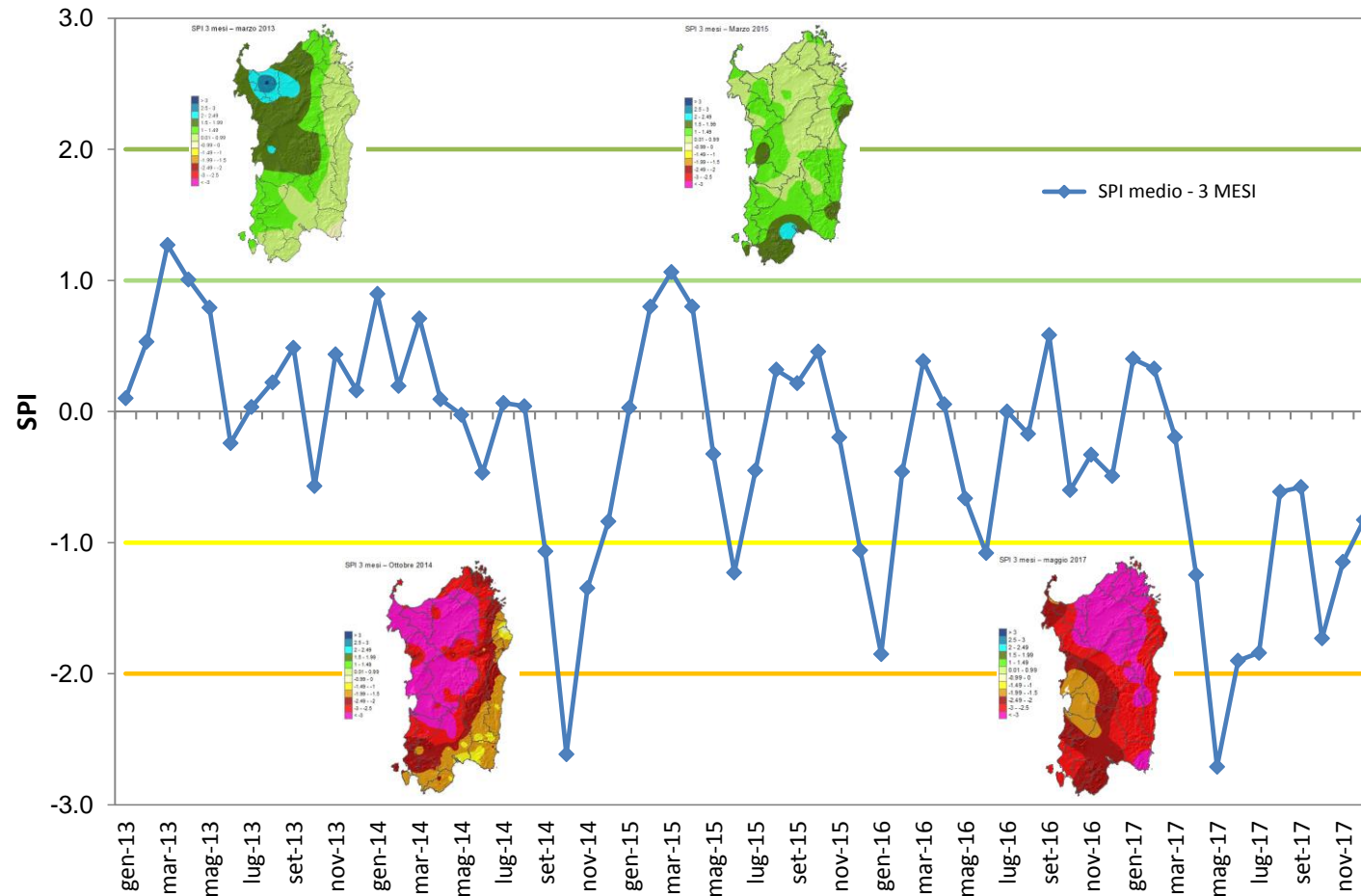
6 mesi – dicembre 2017

12 mesi – dicembre 2017

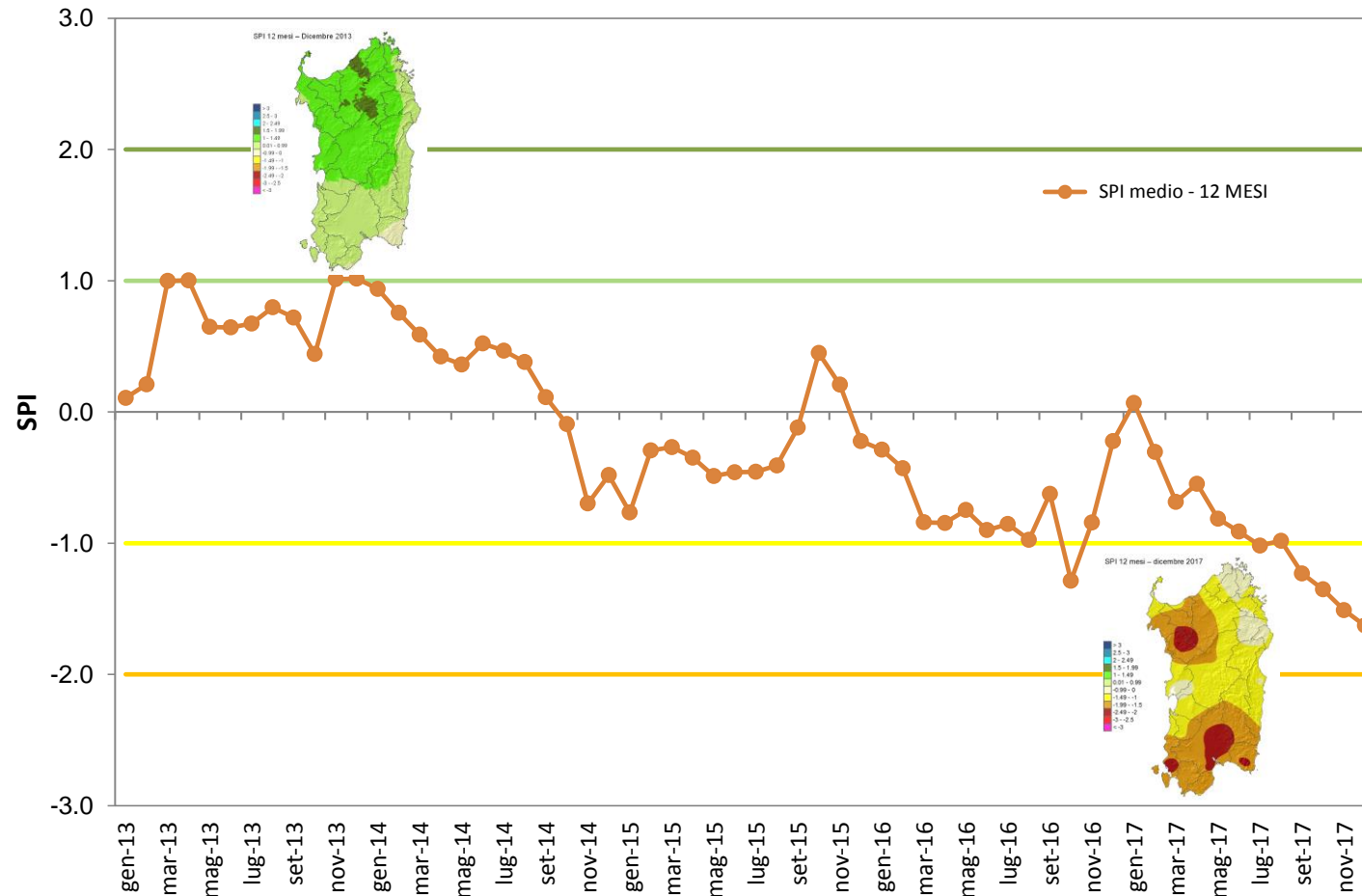
24 mesi – dicembre 2017



## SPI Index in the last 5 years based on 3 month-time-step. Agricultural drought



## SPI Index in the last 5 years based on 12 month-time-step. Hydrological drought





The Sardinian Agrometeorological Service has put together a climatic data bank of meteorological observations at ground level and aloft from

Period: starting 1922  
until now

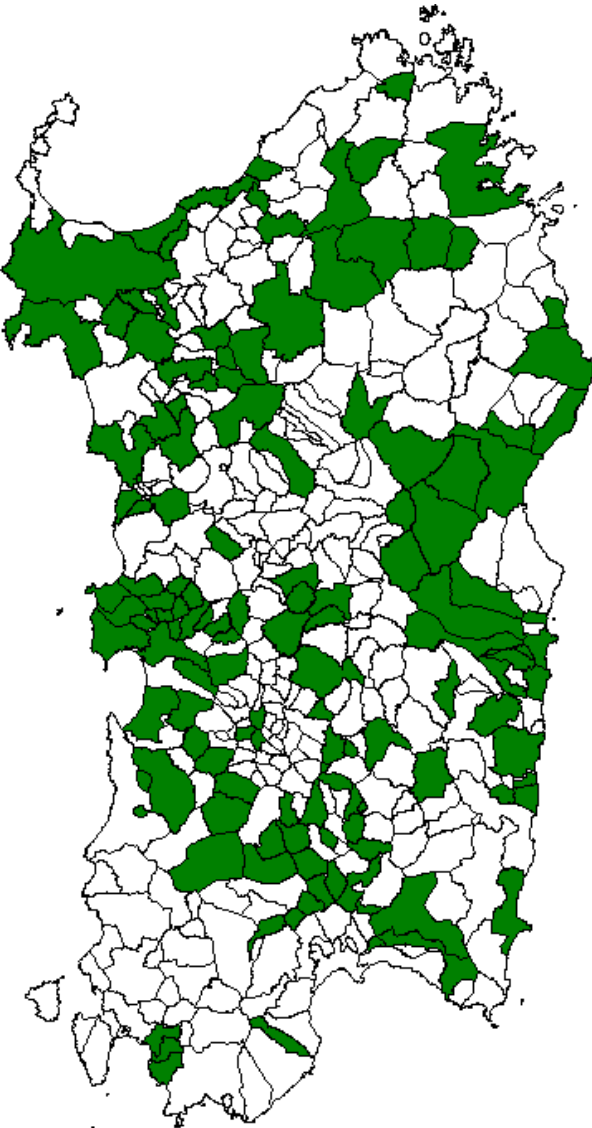
Monitoring the climate consists of:

- Collecting and checking the quality of the meteorological data.
- Climatological studies based on hourly, daily, monthly, and annual meteorological parameters and derived agrometeorological ones (ET<sub>o</sub>, Σ °C, etc) .
- Objective determination of the physical areas and time periods of rainfall and temperature in Sardinia and the meteorological conditions associated with them.
- Estimating the temperatures in areas without meteorological observation stations.
- Identifying the links between rainfall and atmospheric circulation.
- Statistical analysis of severe examples of heavy rainfall and high winds, their links to the meteorological situation, and their occurrence in the region.



## UNTIL 2007

### Agrophenological network



**S.A.R. manages a database with agronomic information (phenology, crop management, productivity) on 250 farms monitored by Advisor Service (ERSAT).**

**This map shows the distribution of farms monitored.**

**The directly monitored crops are Olive, Grape, Citrus, Tomato, Artichoke, Cereals.**



## SUPPORT TO IRRIGATION

HMC has developed specific activities to produce and disseminate data, plans and information both for farmers and for regional organisations which manage water

Calculations on the benchmarks of consumptive use and the potential and actual agricultural consumptive use. This is obtained by applying the appropriate agricultural coefficient for the particular crops and the various phenological phases.

Assessments of the effectiveness of the rainfall, using a radar meteorological system and a mathematical model to estimate the infiltration and the surface water flow.

Estimates of the water content of the soil using mathematical models of the **water balance** in order to calculate the volume of irrigation and the best moment to irrigate at farm level, using a model of the water balance in the soil. This service is called IRRINET and it is available on the Internet.

Development of specific software for planning and managing irrigation.

## PLANT PROTECTION ACTIVITIES

in collaboration with prestigious scientific institutions such as the University of Parma and the University of Sassari, develops modelling simulation instruments to help those working in the phyto-health protection and technical assistance to agriculture fields.

At present, the following models are available:

UNTIL 2007

E.P.I., which checks for evidence of downy mildew in grape vines (*Plasmopara viticola* - Berl. et De Toni). It is able to evaluate the possibility of outbreaks of serious epidemics and gives precise data on when anti-cyrtogamic actions should be taken.

A phenological model which simulates the flight of the grapevine tignoletta (*Lobesia botrana* - Den. Et Schiff). This can predict the peak hatching periods for the butterflies and allows to plan in advance protection programs.

A phenological model which simulates the flight of the olive moth (*Prays oleae* - Bern.). This can predict the peak hatching periods for the anthophagous generations of the moths and thus it helps to plan in advance protection programs.

A dynamic model of the olive fly population (*Bactrocera oleae* - Gmelin). At present this is the most important instrument developed by S.A.R.. It simulates the infestation of olive phytophagous. It can evaluate the olive fly population in the field and thus provides useful information for planning protection programs.





# - EPI *Plasmopara* model helpful to grapevine protection

UNTIL 2007

Bollettino di ausilio alla lotta contro  
*Plasmopara viticola* (Berl. et De Toni)

Calcolo dell'indice EPI (Strizyk, 1983)

Bollettino del 13 agosto 2001

Si segnala il superamento della soglia di intervento in alcune stazioni.  
Si consiglia di intervenire compatibilmente con gli interventi già effettuati.

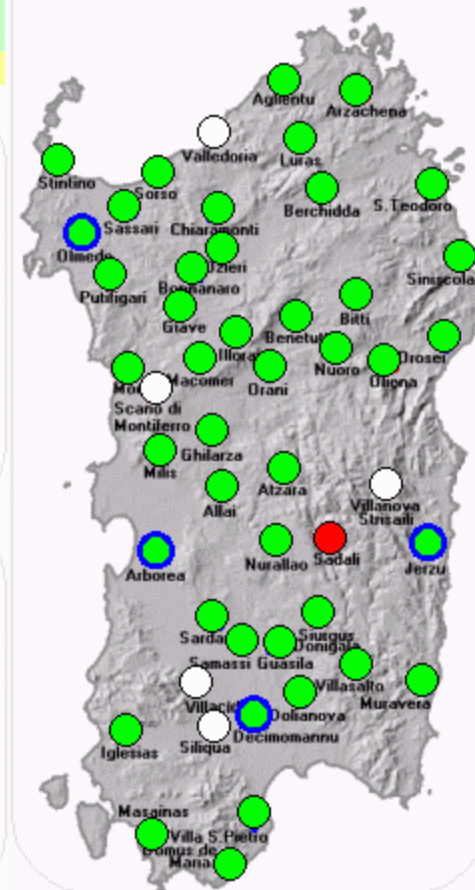
#### Note

I trattamenti sono vincolati al superamento della fase di grappoli visibili. Sono da evitare formulati sistemici (per evitare fenomeni di resistenza), mentre si consigliano prodotti ad assorbimento traslaminare quali CYMOXANIL in miscela con MANCOZEB o, dopo l'allegagione, con RAME (Nalli, 1990). I cerchi bordati di blu (◉) indicano le stazioni per le quali è stato possibile calcolare una climatologia su 30 anni. In queste località le simulazioni risultano essere più attendibili; nelle altre stazioni la climatologia viene calcolata su 5 anni.

Legenda sulla situazione di pericolo

● si ● no ○ dati non disponibili

Situazione al 12 agosto 2001



S.A.R. has validated the E.P.I. model (Strizyk, 1983) in Sardinia with interesting results. A daily bulletin for ERSAT and major farms, with warnings for *Plasmopara* protection, are outputs of simulation. The bulletin is available on the S.A.R. website.

## **DROUGHT AND DESERTIFICATION RESEARCH ACTIVITIES**

**MC collaborates with University of Sassari Desertification Research Center and NRC-IBIMET in environmental research.**

Climatic and geophysical data, together with vegetation and land use digital information, are monitored and stored in GIS in order to provide useful tools for land planners and decision makers.

### **Main fields of interest:**

**Climate change, climate risk assessment, desertification and other issues related to environmental problems and water management in a semi-arid territories**

**Geographic Information System and Remote Sensing technology are used to study, monitor and map the effects of drought on natural and agricultural ecosystems and to find out the best strategies to mitigate this phenomenon.**

## DROUGHT AND DESERTIFICATION RESEARCH ACTIVITIES

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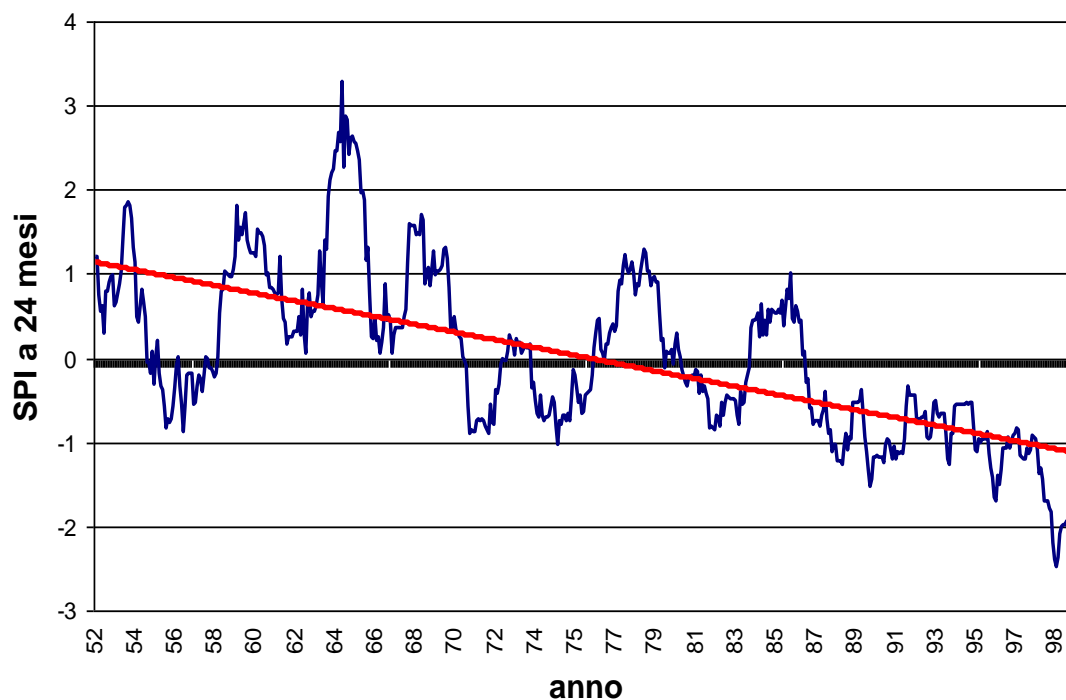
**Geographic Information System and Remote Sensing technology are used to study, monitor and map the effects of drought on natural and agricultural ecosystems and to find out the best strategies to mitigate this phenomenon.**



## Precipitation trends SPI 1951-00

Standardized Precipitation Index a 24 mesi

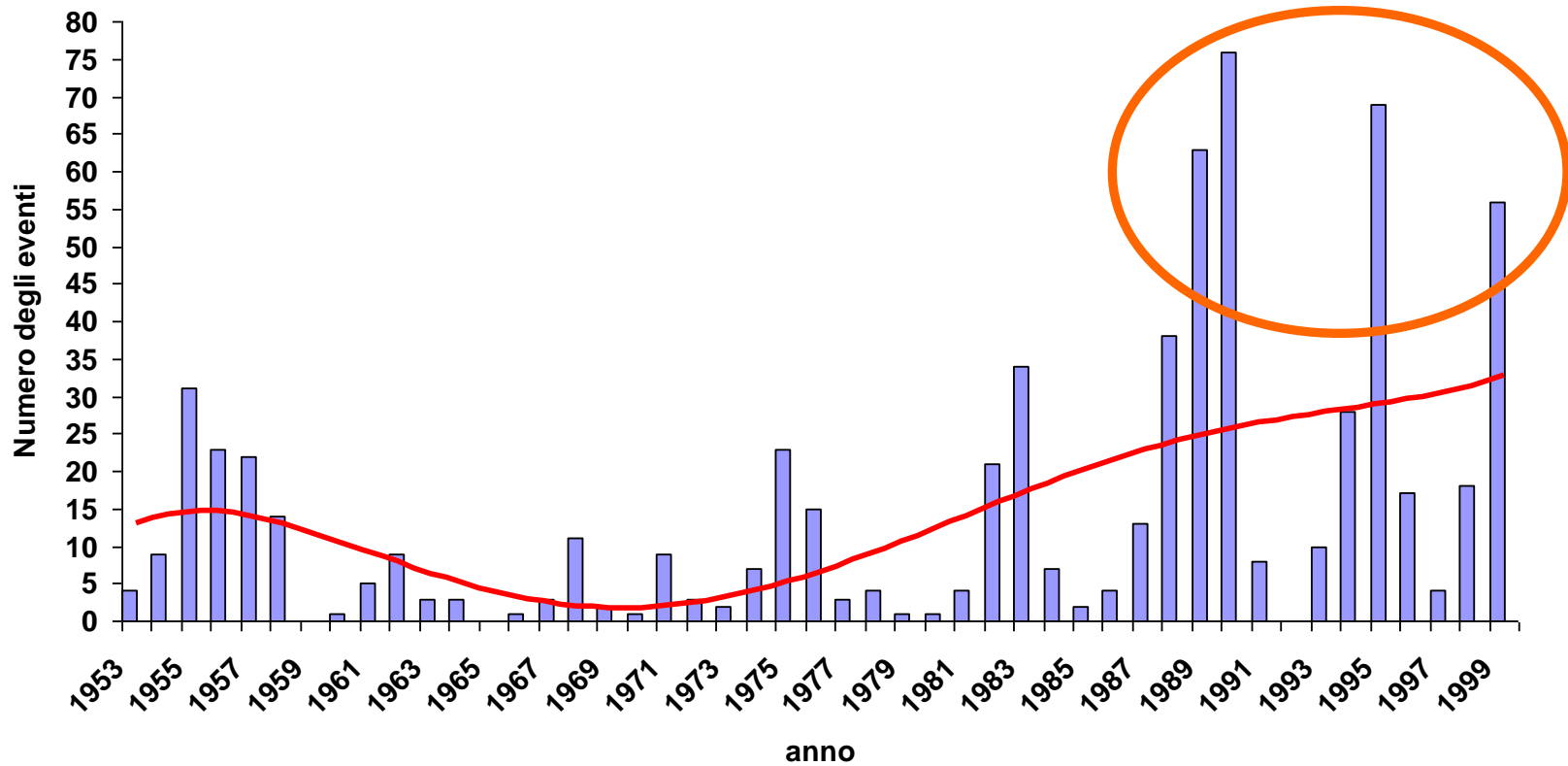
$$y = -0.004x + 1.1424$$



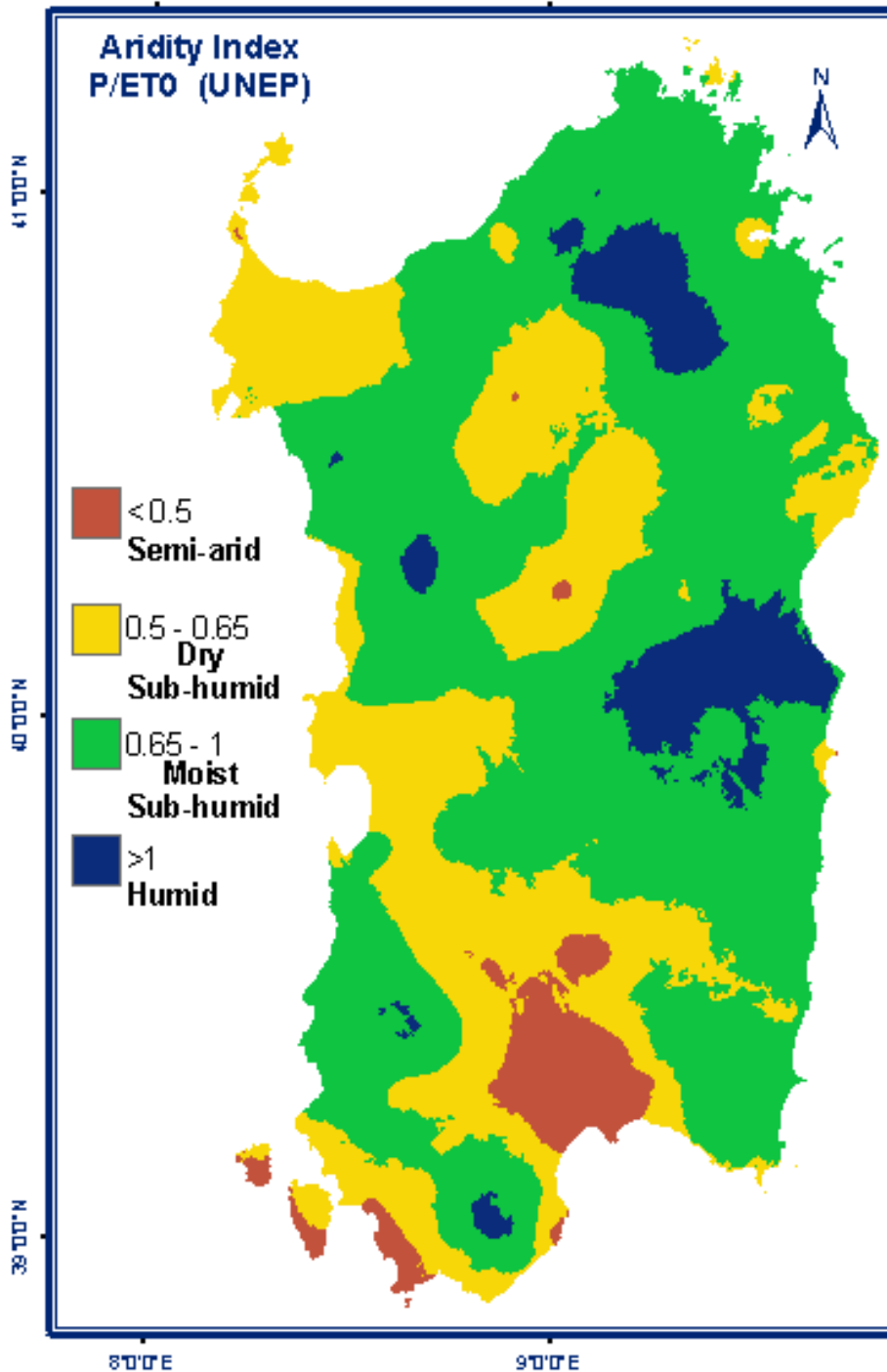


## Drought extreme events

### Sardegna - Numero degli eventi con $SPI < -1$







1951-00

Aridity Index= $P/ET_0$

4,6% semi-arid

29,8% dry sub-humid

58,1% sub-humid

7,5% humid

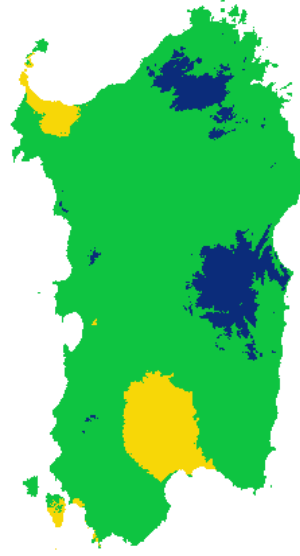
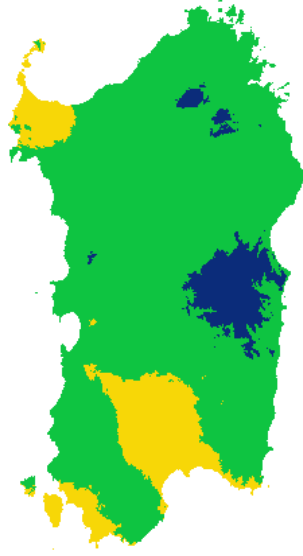
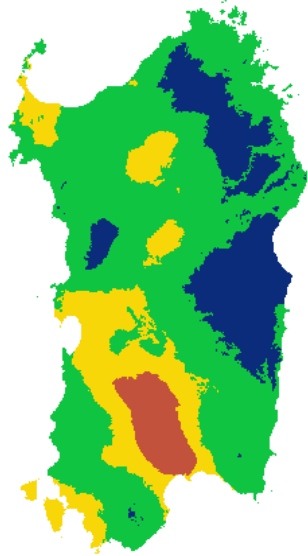
# Aridity index FAO-UNEP (P/ET<sub>o</sub>)



Decennio 1951-60

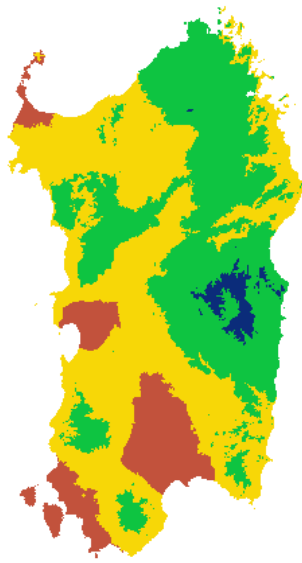
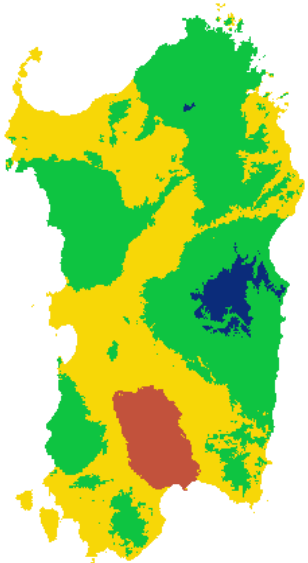
Decennio 1961-70

Decennio 1971-80

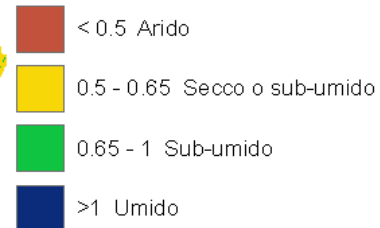


Decennio 1981-90

Decennio 1991-00



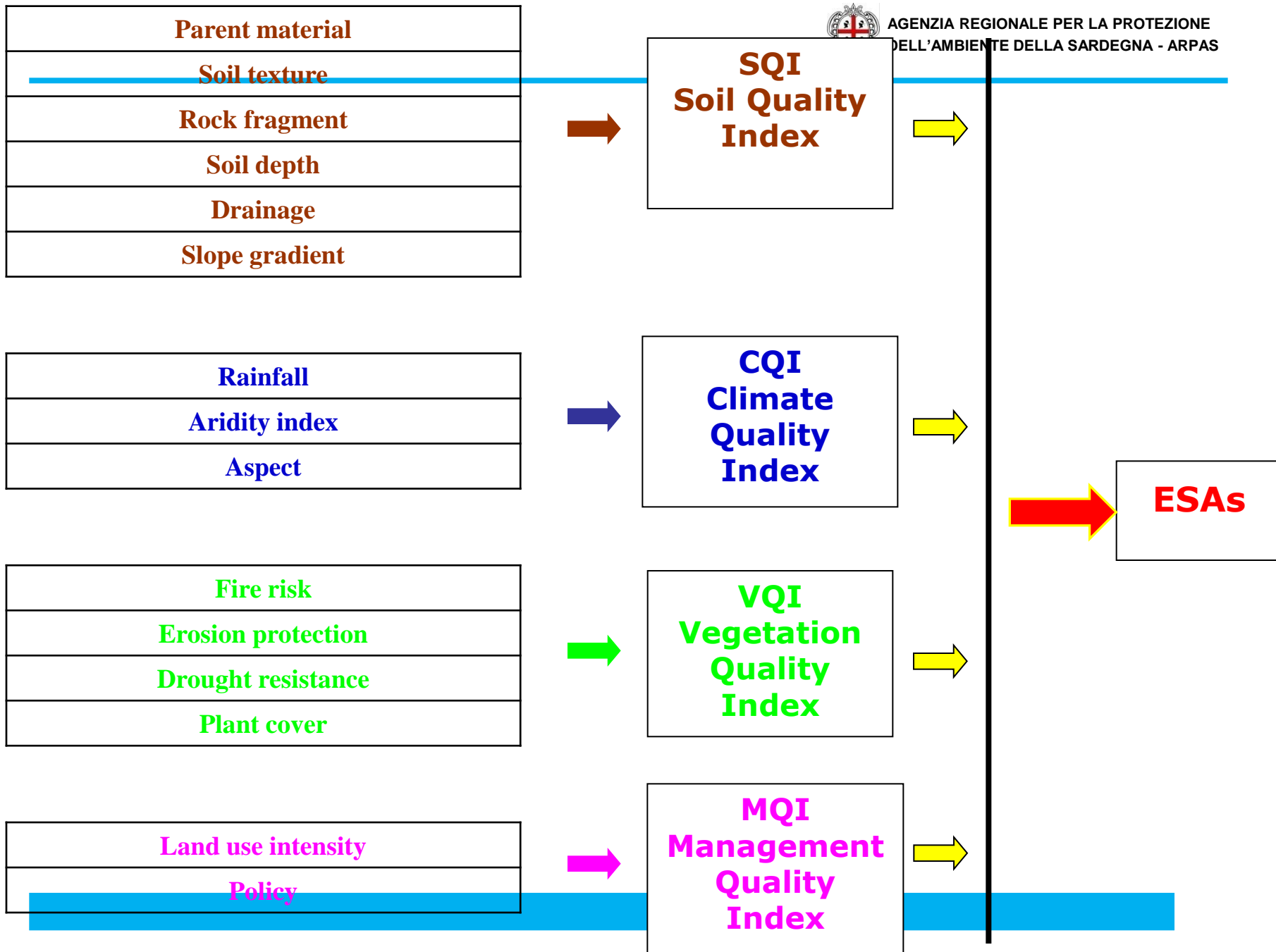
## Legenda



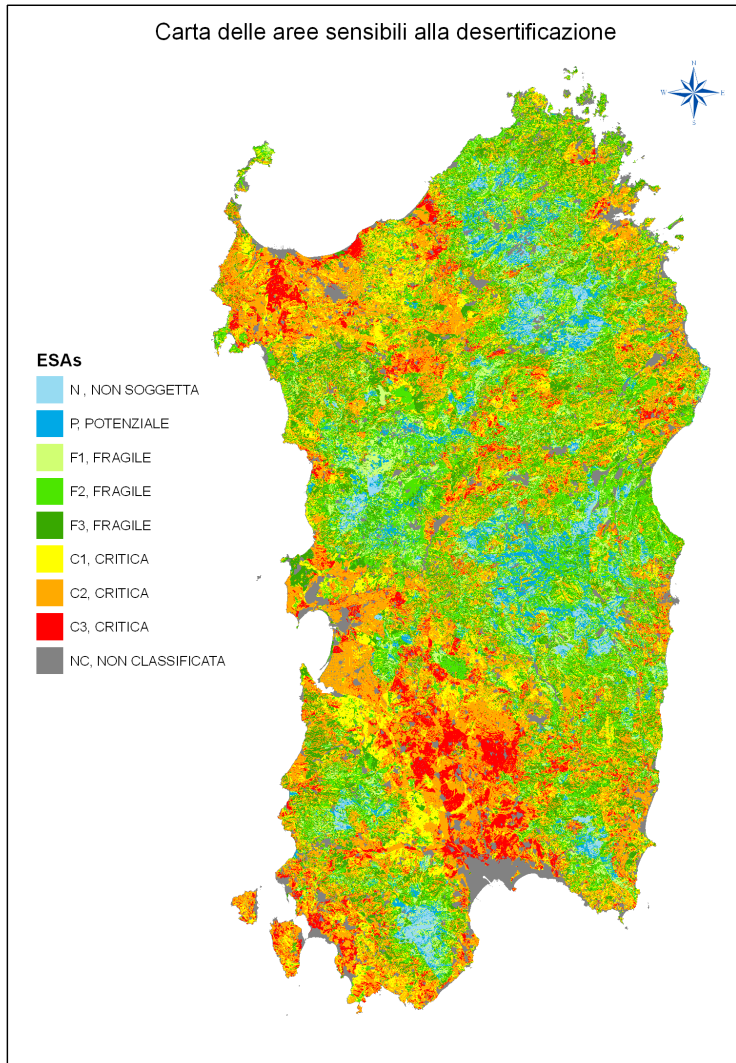
There is a trend

•but...

- 1997-2003
- 2004
- 2009

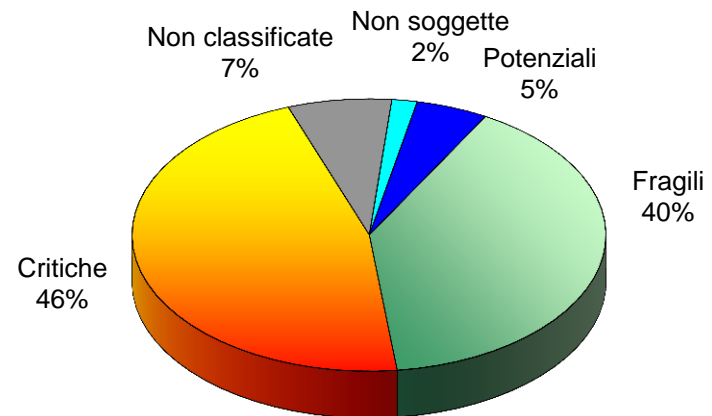


Carta delle aree sensibili alla desertificazione



## Sensitive areas to desertification ESAS

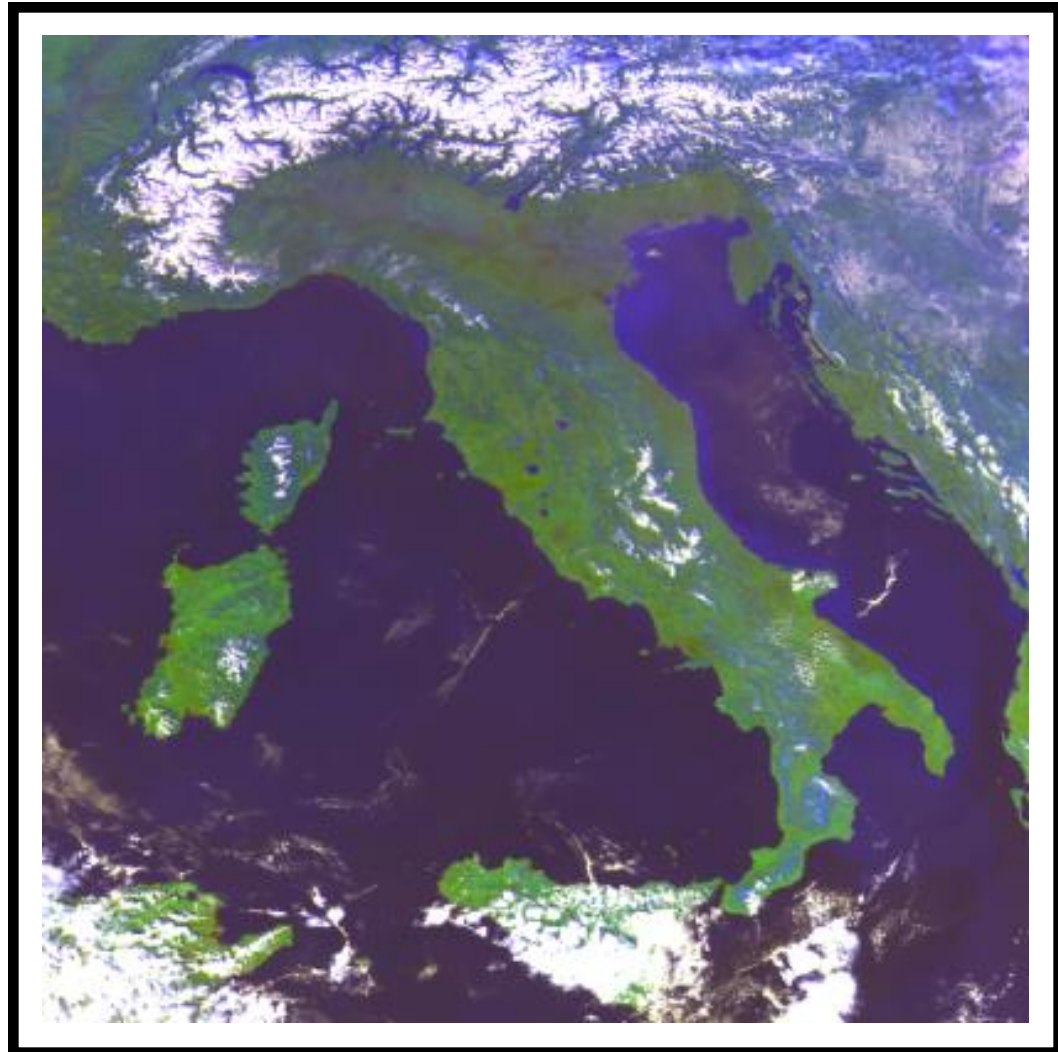
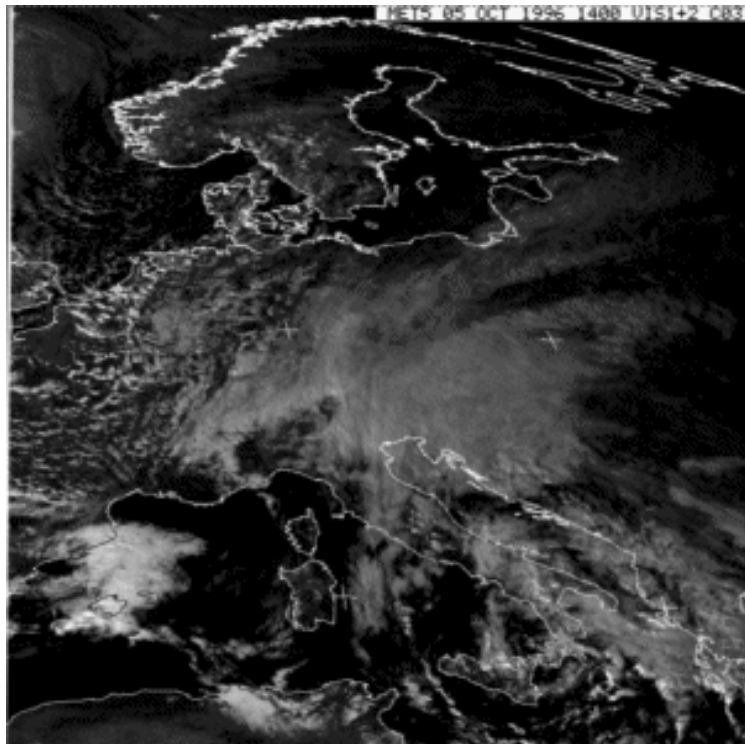
### Sardinia





## HMC TECHNOLOGIES

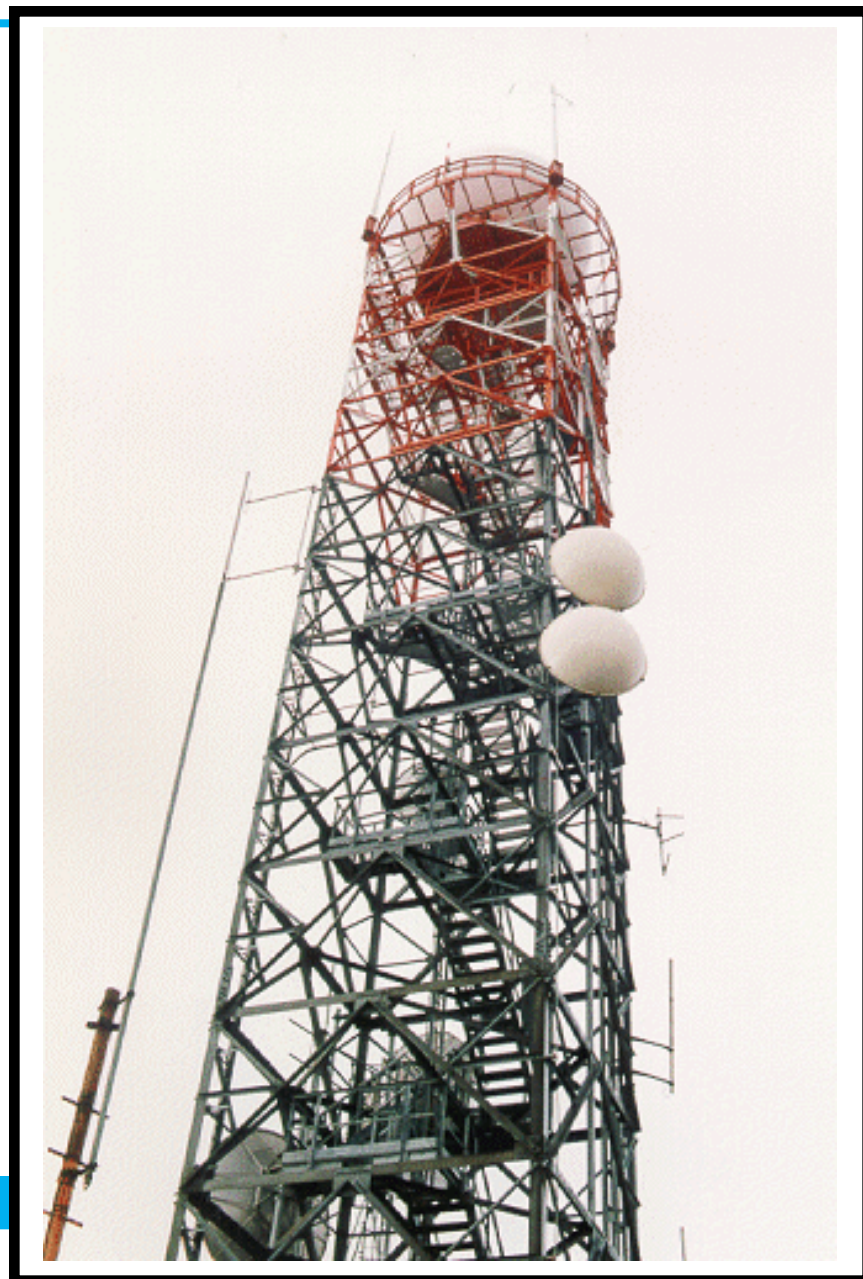
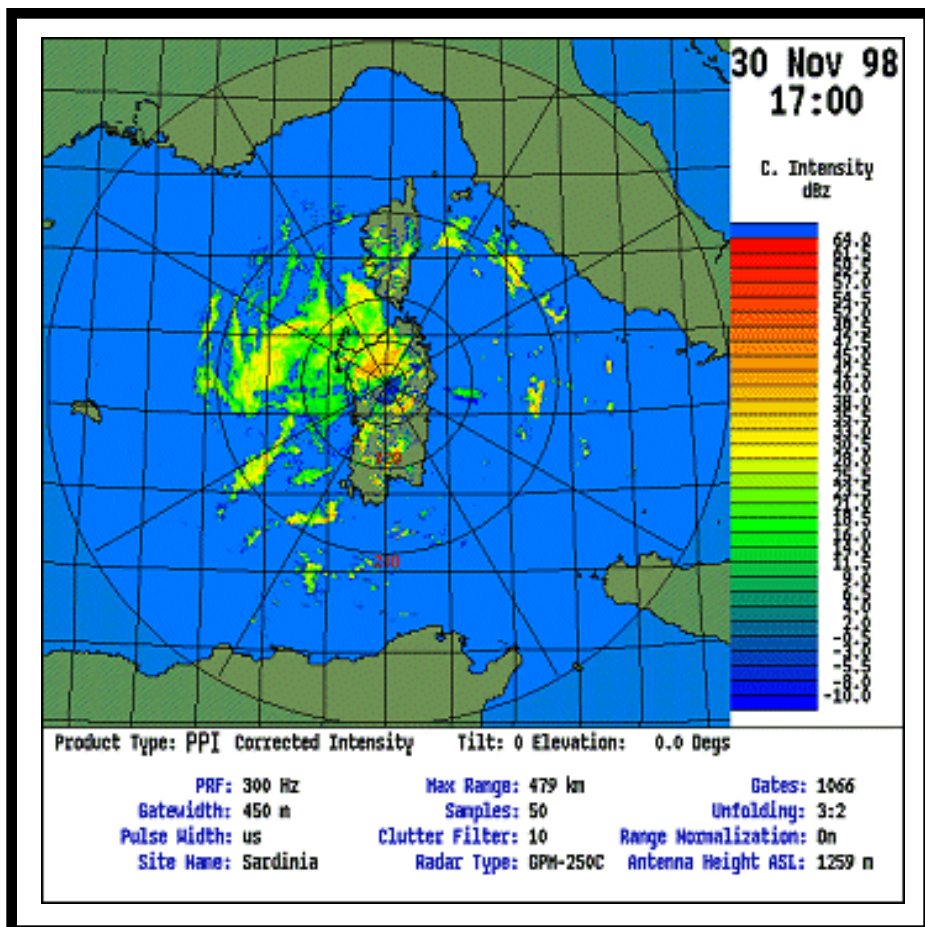
### METEOSAT



NOAA

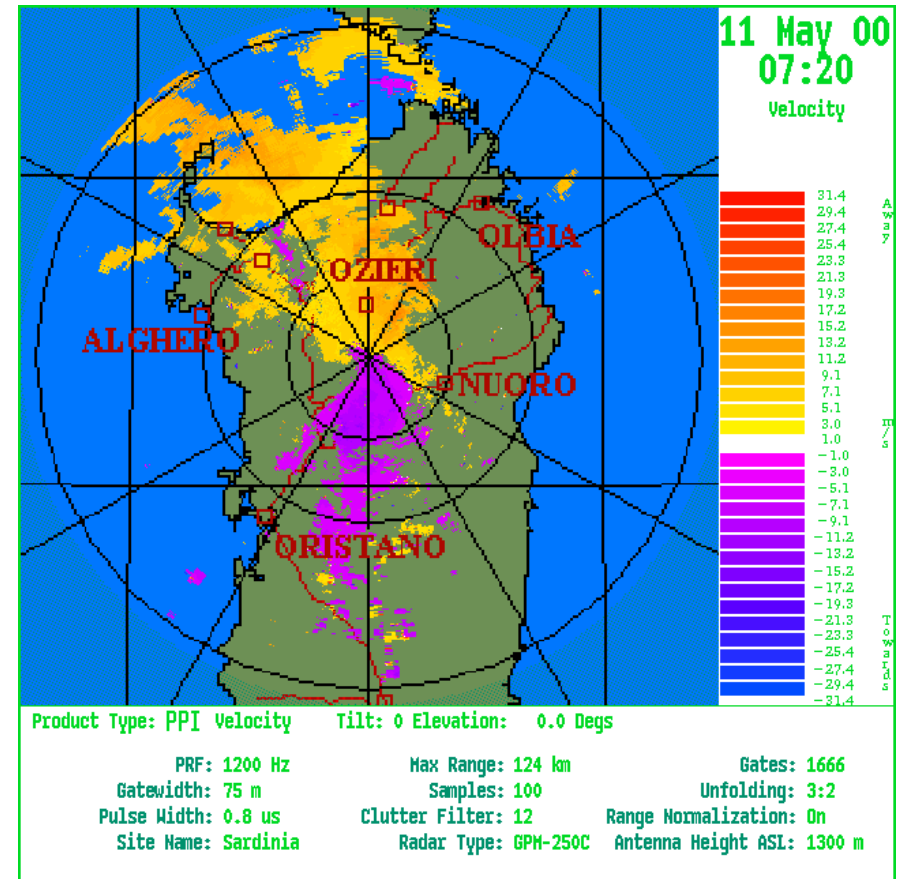
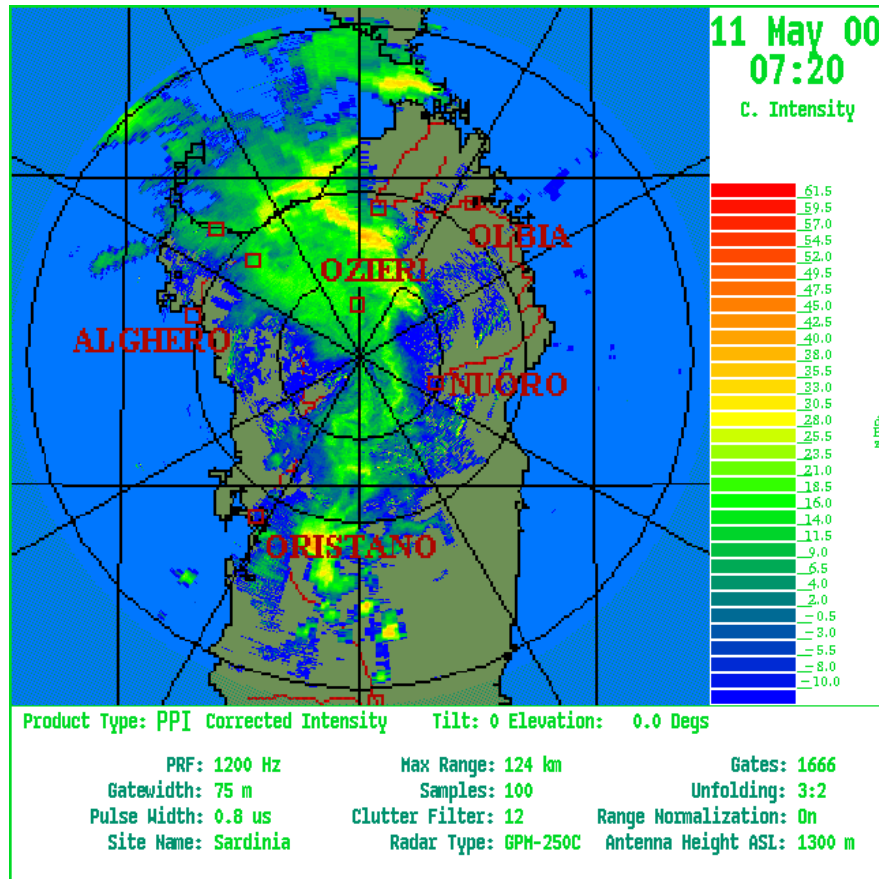


## HMC TECHNOLOGIES



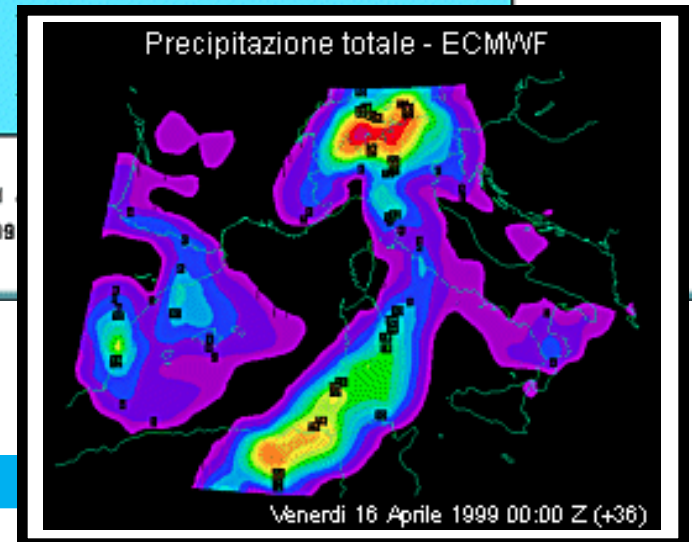
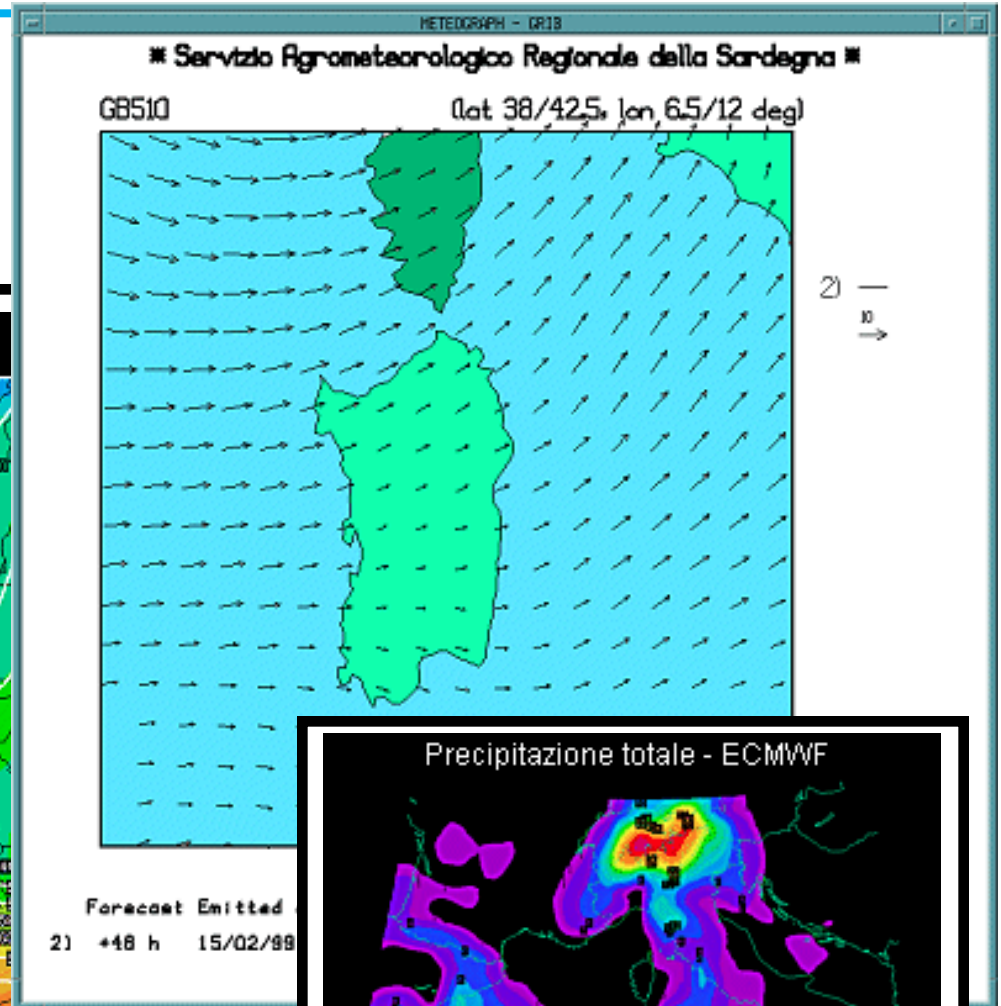
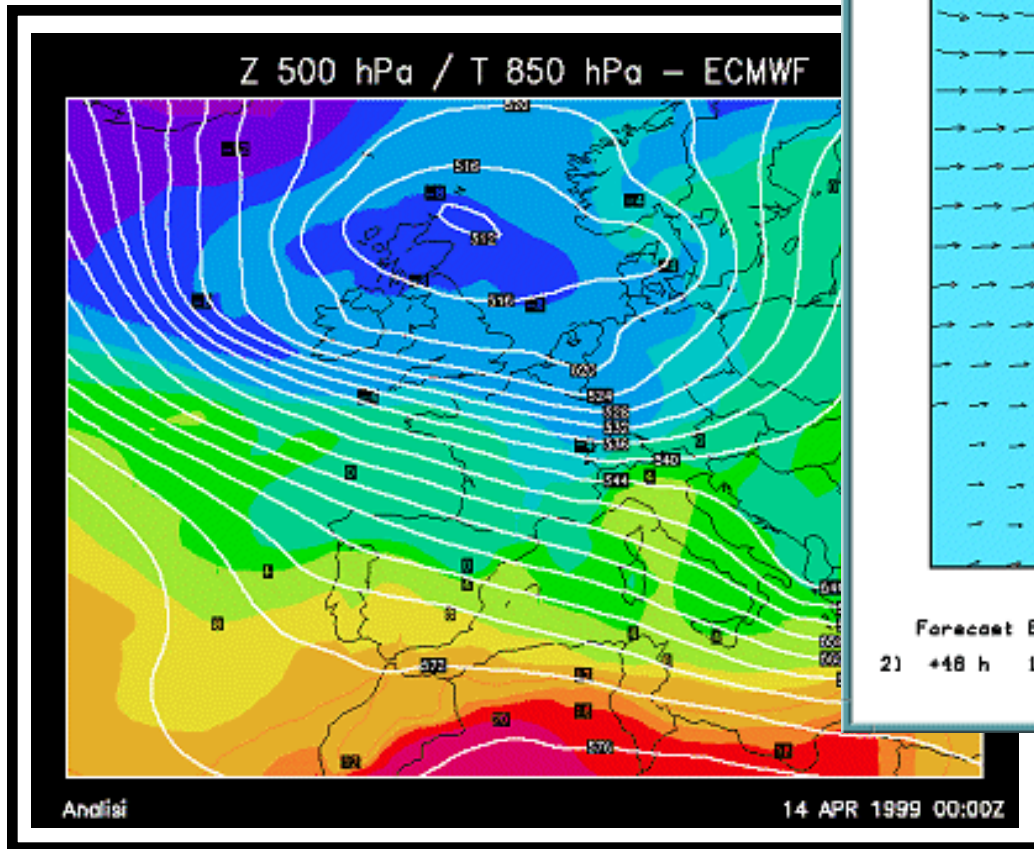


# HMC TECHNOLOGIES





# HMC TECHNOLOGIES

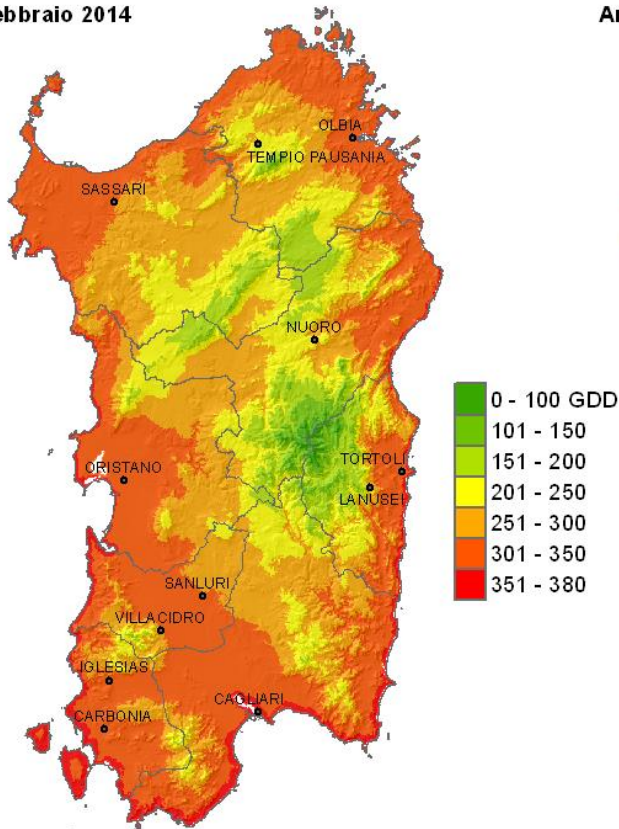




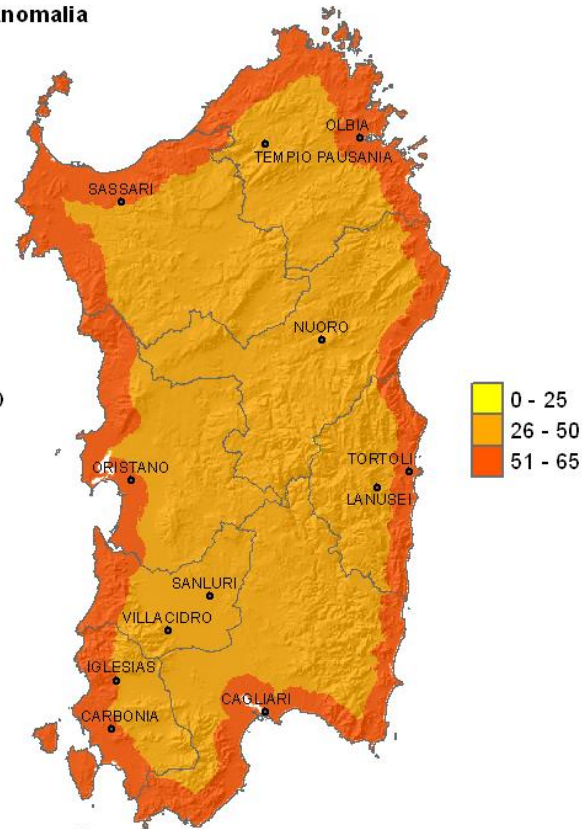


The summation of daily GDD units can be used for a variety of things: comparing one region to another, comparing one season to another, and predicting important stages in crops' development

Febbraio 2014

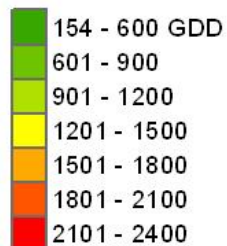
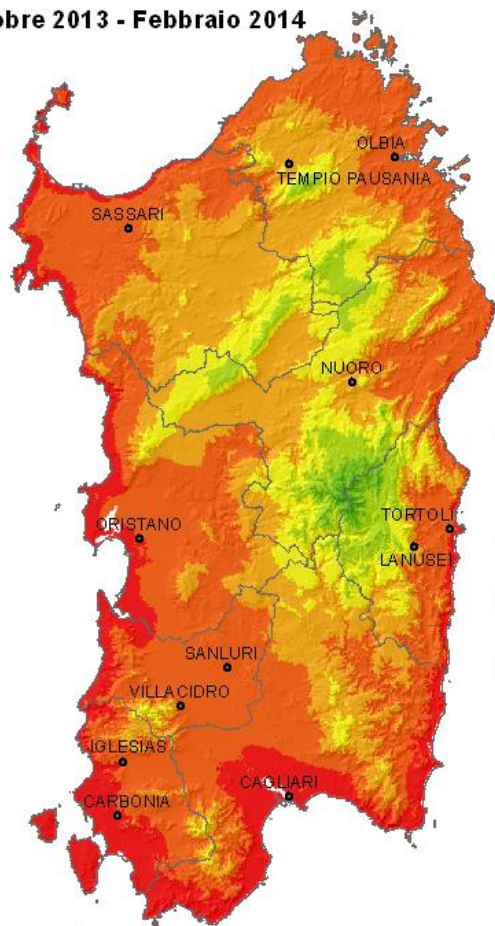


Anomalia

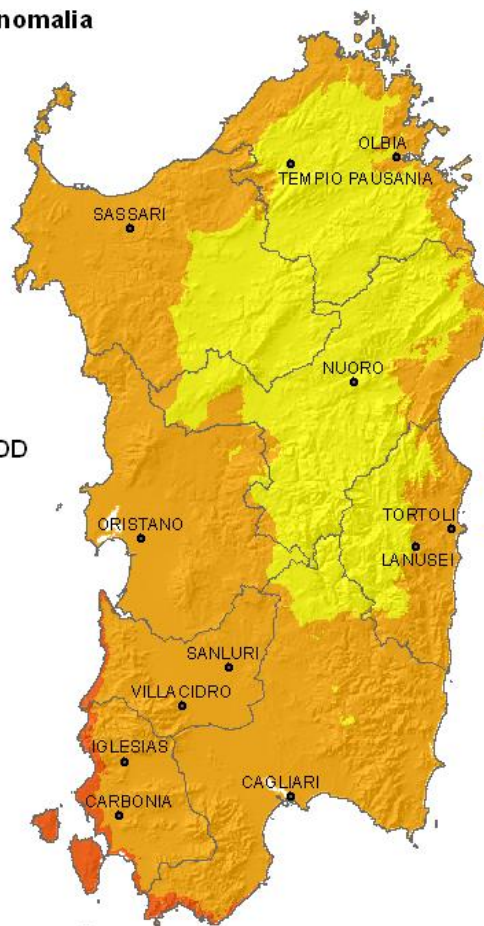


GDD calculated on 0°C base

**Ottobre 2013 - Febbraio 2014**

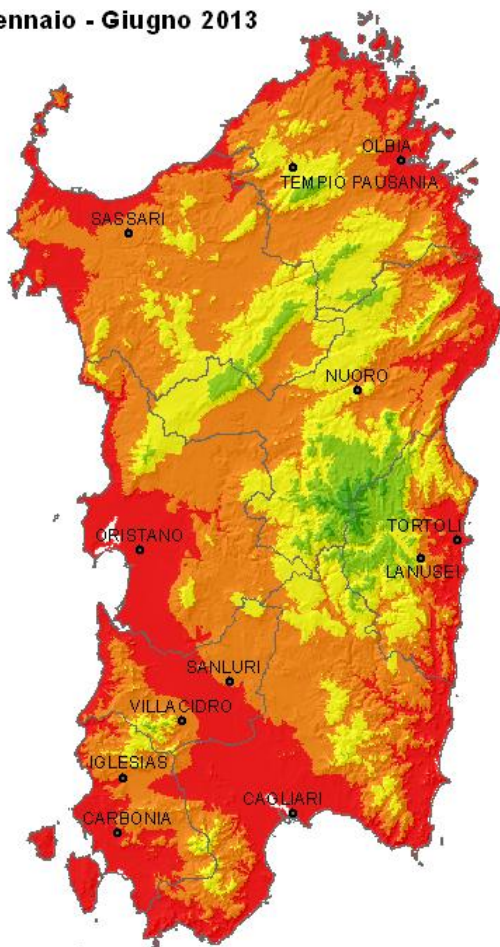


**Anomalia**

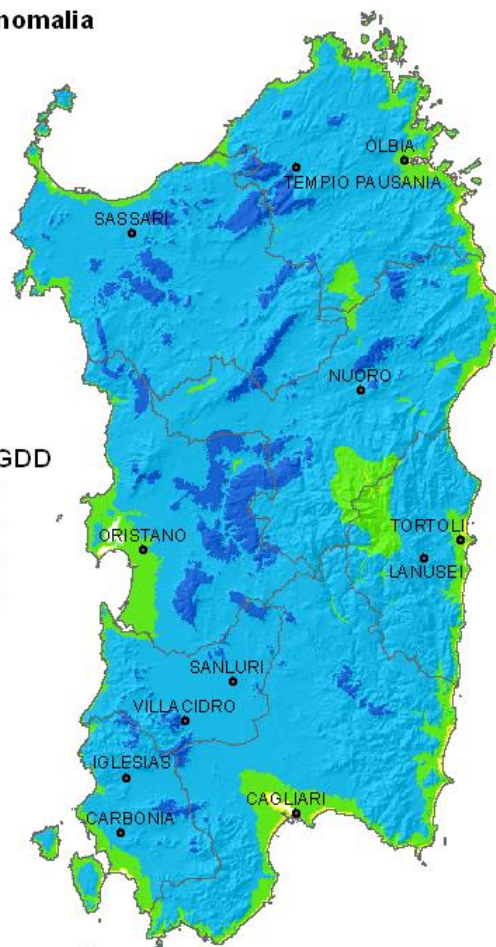


**GDD calculated on 0°C base**

**Gennaio - Giugno 2013**

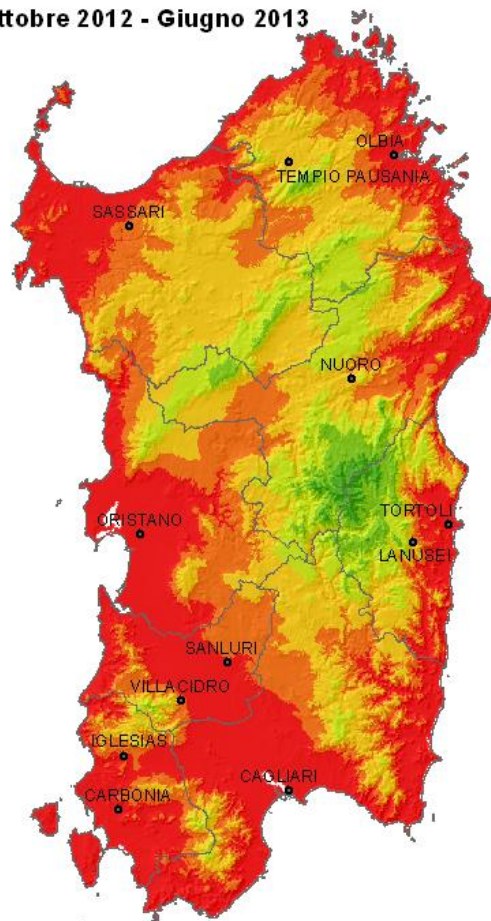


**Anomalia**

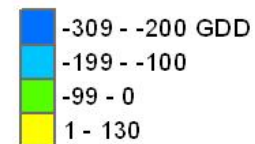
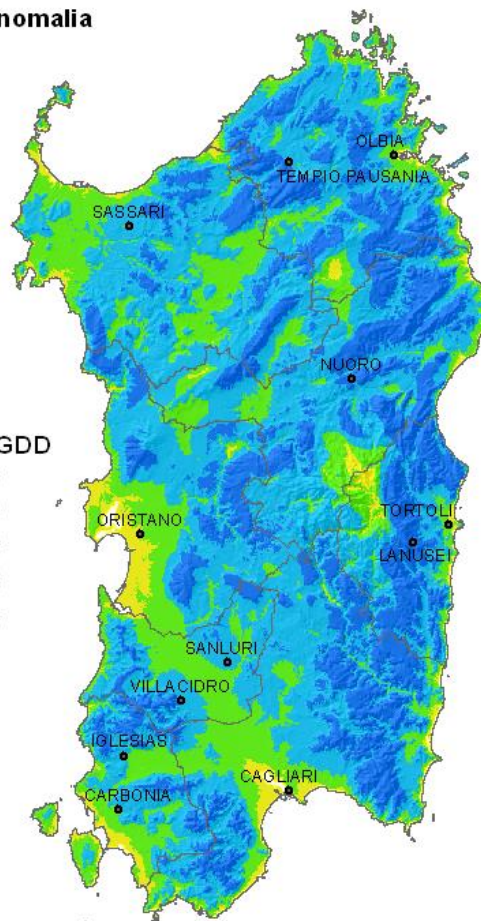


**GDD calculated on 0°C base**

Ottobre 2012 - Giugno 2013



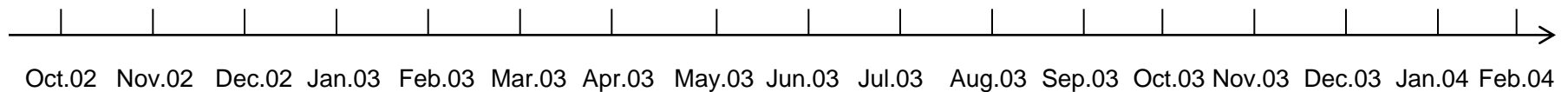
Anomalia



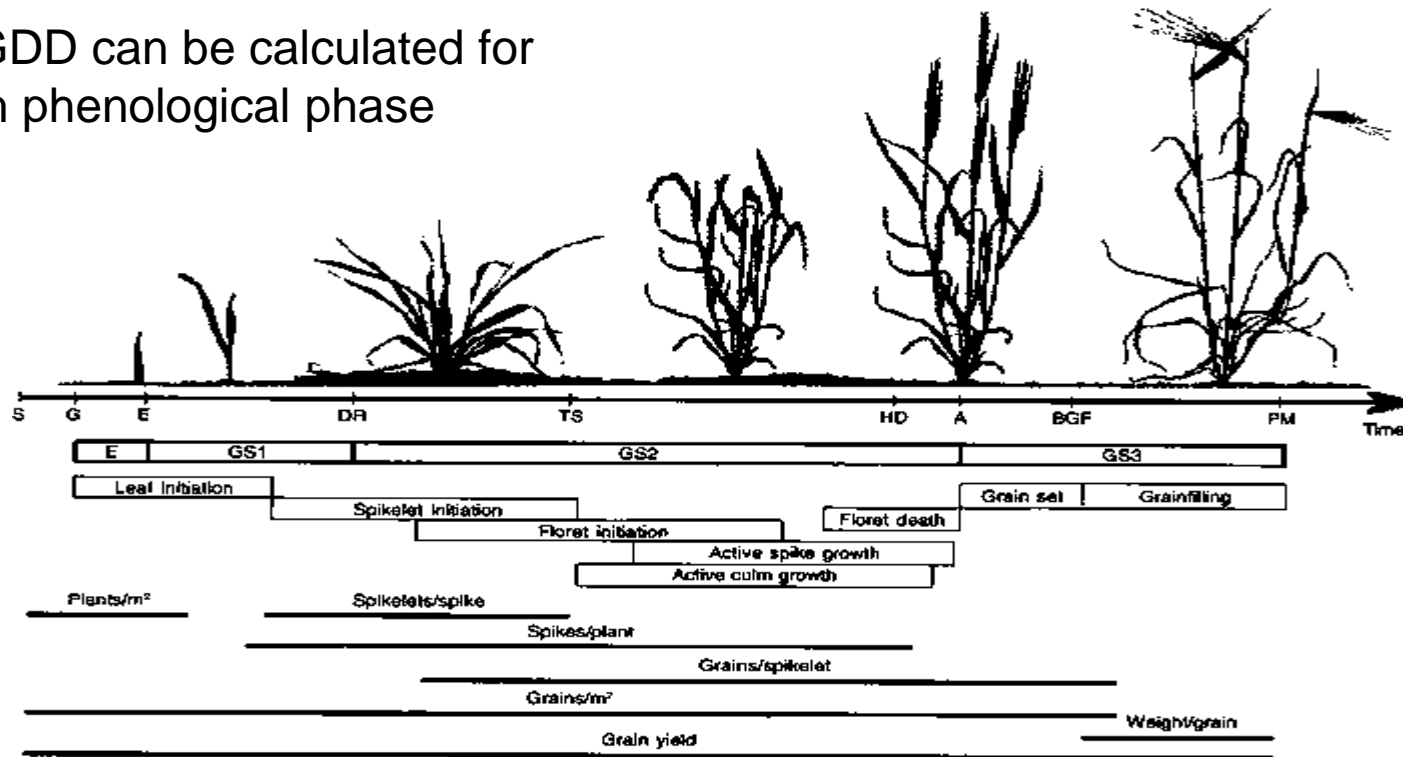
GDD calculated on 0°C base

## Why we use GDD?

- to know if there is anticipation or posticipation in the growing and phenological phases of different crops
- *pour savoir si il ya anticipation ou posticipation dans la culture et la phases phénologiques des cultures différentes*
  - on a monthly base compared to climatic mean conditions (anomaly)
  - on two months, semester, since the beginning of the season or the year



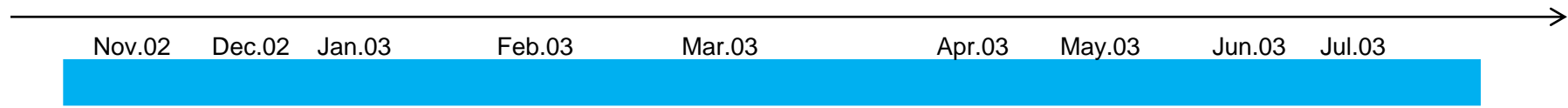
Or GDD can be calculated for each phenological phase



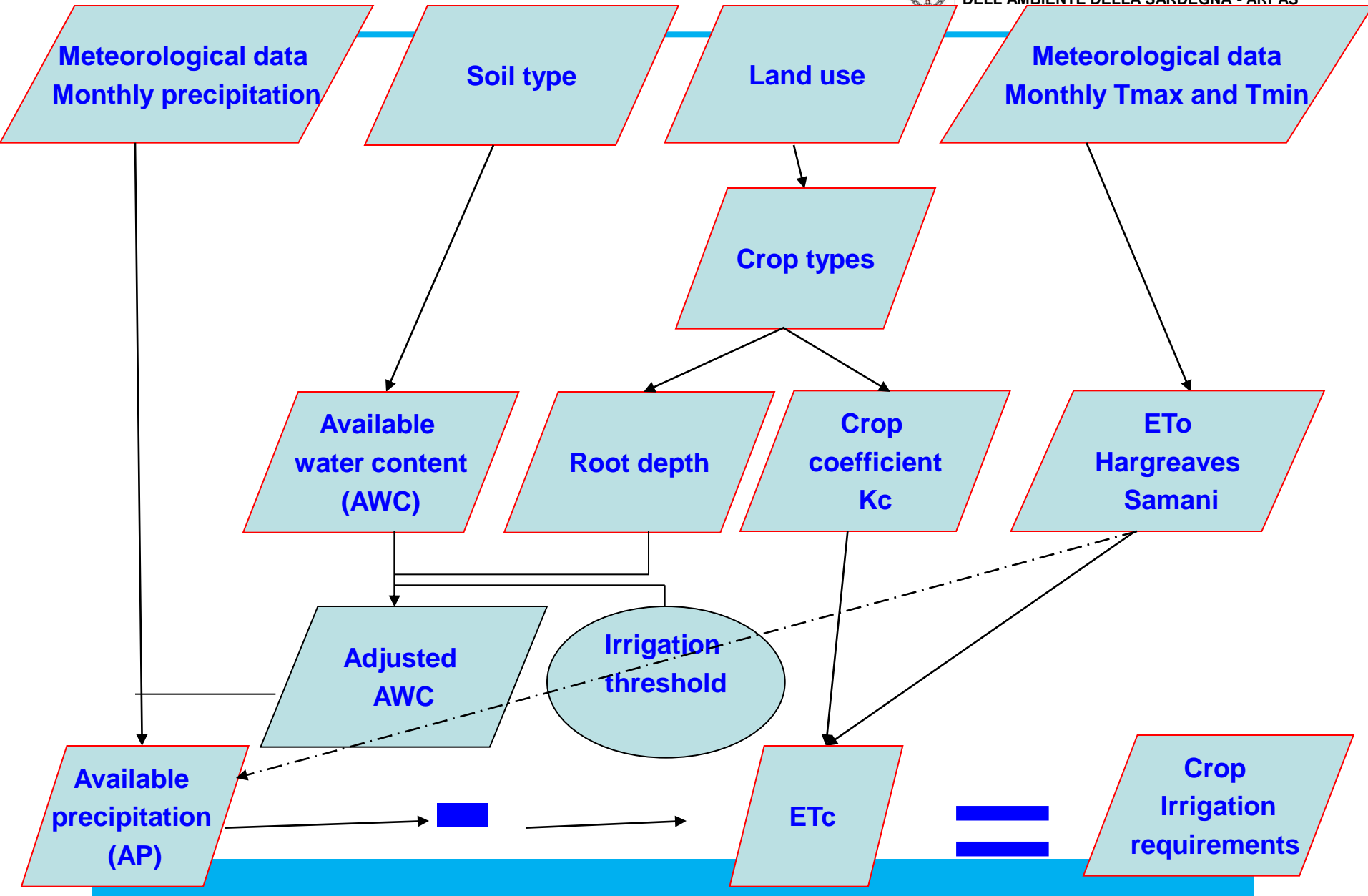
*from sowing to heading*

*from sowing to spike growth*

*from sowing to harvest maturity*

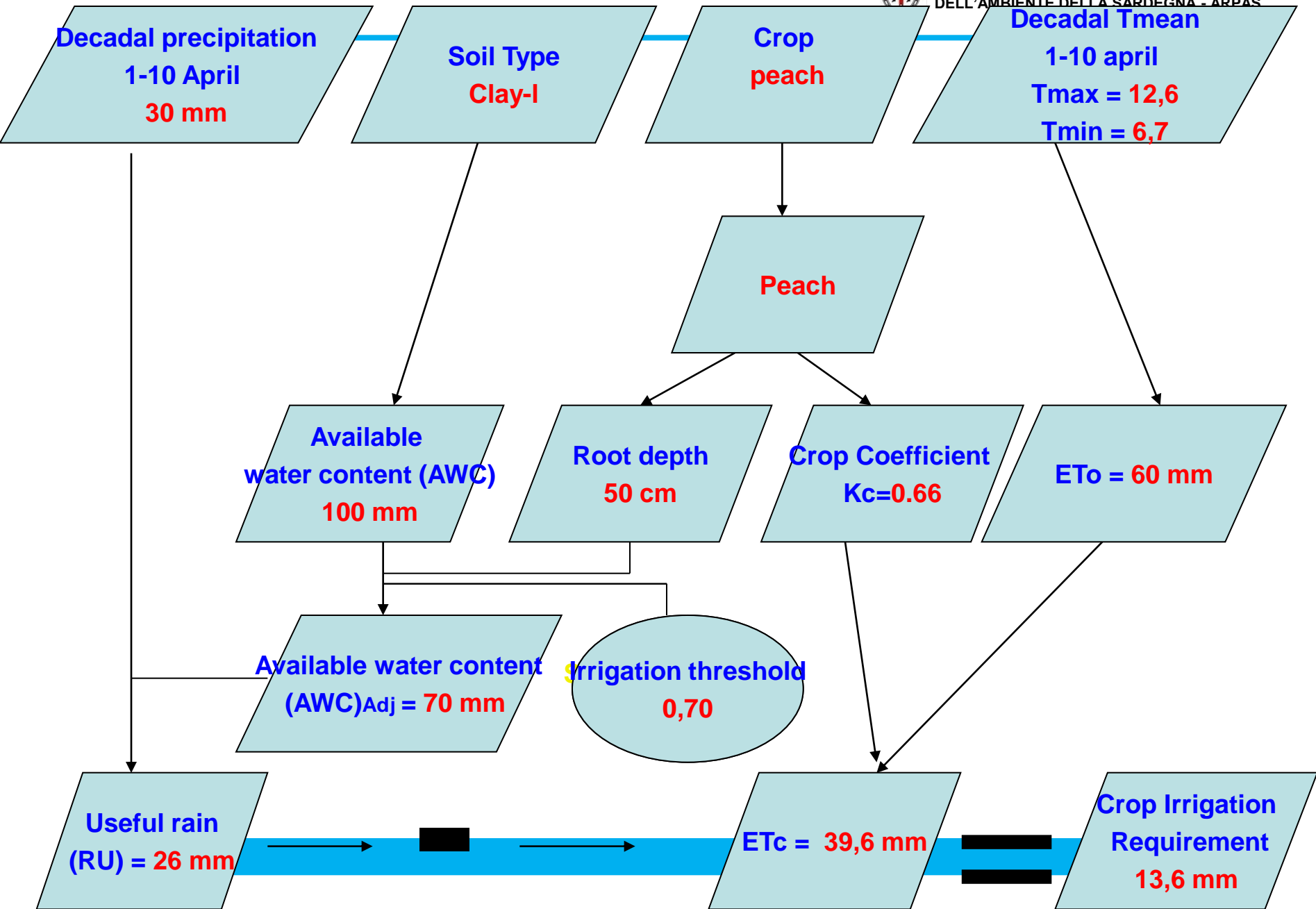


# Crop Irrigation requirements scheme





# Example: I decade of April - peach



# Example: first 10 days in April



Decadal precipitation  
1-10 April

Soil Type

Crop

Root depth

Crop Coefficient

ETo 1-10 April

Available water content  
(AWC)adj

Useful  
rain (Pu)

ETc

Water decadal  
requirement  
1-10 April

- GIS constructin with all crops
- Layers in raster format
  - all the crops
  - all the agricultural area

- **The general meteorological conditions for the next 2 days and the forecast for the following days.**
  - **The daytime and night-time temperatures for the next 5 days.**
  - **The risk of freezing for the next 4 days.**
  - **The probability of rain in the next 5 days.**
  - **Wind fields at 6 hourly intervals over the island and the surrounding seas for the next 4 days.**
  - **The sea status surrounding the Island every 12 hours for the next 5 days.**
-