IVINE: a crop model for simulating pheno-physiological processes on vineyards, also from a climatic point of view

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Summary

- Introduction to IVINE model
- Methods
  - Use of IVINE model – required observations in input and to check output
    - GLDAS (plus UTOPIA)
    - Search for long term series of observed data in specific locations
- Experimental results and discussions:
  - Variation of thermal thresholds with the altitude
  - Calibration/validation of IVINE with some vine varieties
  - Trend of the phenological phases from 1986 to 2014

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IVINE (Italian Vineyard Integrated Numerical model for Estimating pheno-physiological values)

INPUT DATA

- Soil characteristics (thickness and number of soil layers, soil texture)
- Geografic coordinates
- Hydrological soil parameters
- Plant density
- Treatament of vineyards
- **Varietal characteristics**

BOUNDARY CONDITIONS

- **Meteorological hourly data**
- **Soil temperature**
- **Soil water potential**

IVINE
(Andreoli et al., 2019)

$$GDH = \sum_{h} T_r(h,n)$$

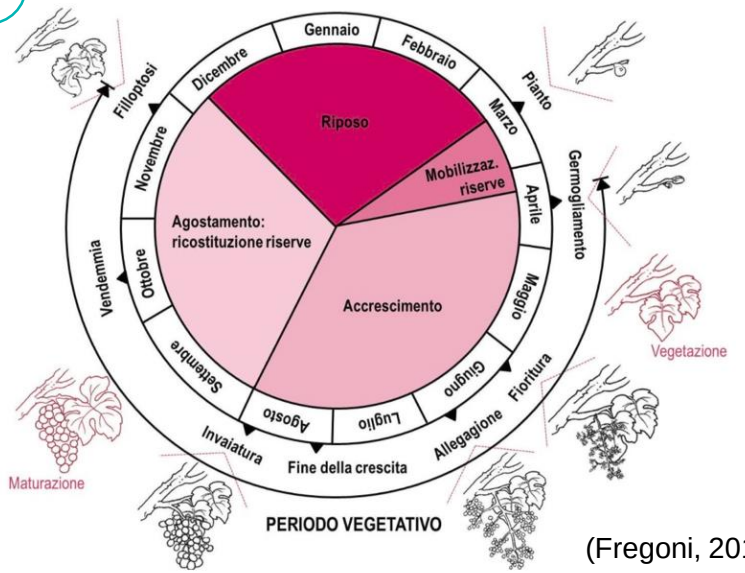
$$GDD_n = \sum_{n} \left(T_{av}(n) - T_{base}(n)\right)$$

OUTPUT DATA → daily data

- Yield and sugar concentration in the berries
- Leaf development (LAI)
- **phenological stages (Julian days)**

(BBCH scale: Biologische Bundesanstalt, Bundessortenamt and CHemical industry)

Dormancy exit (BBCH 1)
Bud burst (BBCH 7)
Flowering (BBCH 65)
Fruit set (BBCH 71)
Beginning of ripening (BBCH 81)
Veraison (BBCH 83)
Harvesting (BBCH 89)



(Fregoni, 2013)

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UTOPIA (University of TOrino model of land Process Interaction with Atmosphere)

INITIAL CONDITIONS

- Coordinates (Lon, Lat, altitude)
- Soil characteristics
- **Vegetation code: 26 (vineyards)**

UTOPIA:

third generation Land Surface Model, bigleaf 1-D. Evaluates the mass, momentum and water vapor exchanges between the atmosphere and the earth's surface (bio-geo-hydrosphere) (Cassardo et al. 2015).

OUTPUT DATA (every 30 minutes):

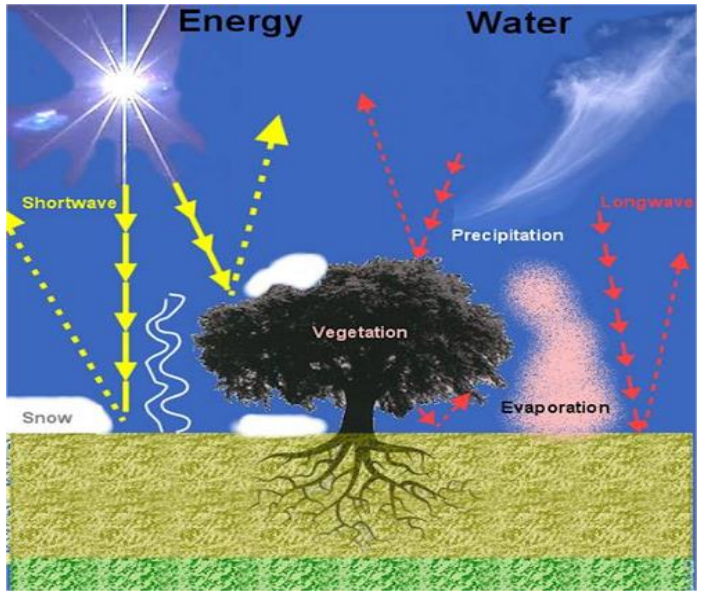
- Soil temperature (° C)
- Volumetric soil water content (m^3 m^{-3})
- Soil water potential (m or kPa)
- PAR (W m^{-2})

BOUNDARY METEOROLOGICAL CONDITIONS:

From GLDAS 2.0 (Rodell et al., 2004 - **(Global Land Data Assimilation System)**

Availability: 1948-2014. Resolution: 3-hours, 0.25° lon/lat.

- **Air temperature(° C), relative humidity (%), pressure (hPa)**
- **Global solar radiation (W m^{-2})**
- **Wind speed and direction (m/s)**
- **Precipitation (mm)**



Scheme of a SVAT (Soil-Vegetation-Atmosphere Transfer) model (Cassardo et al. 2015)

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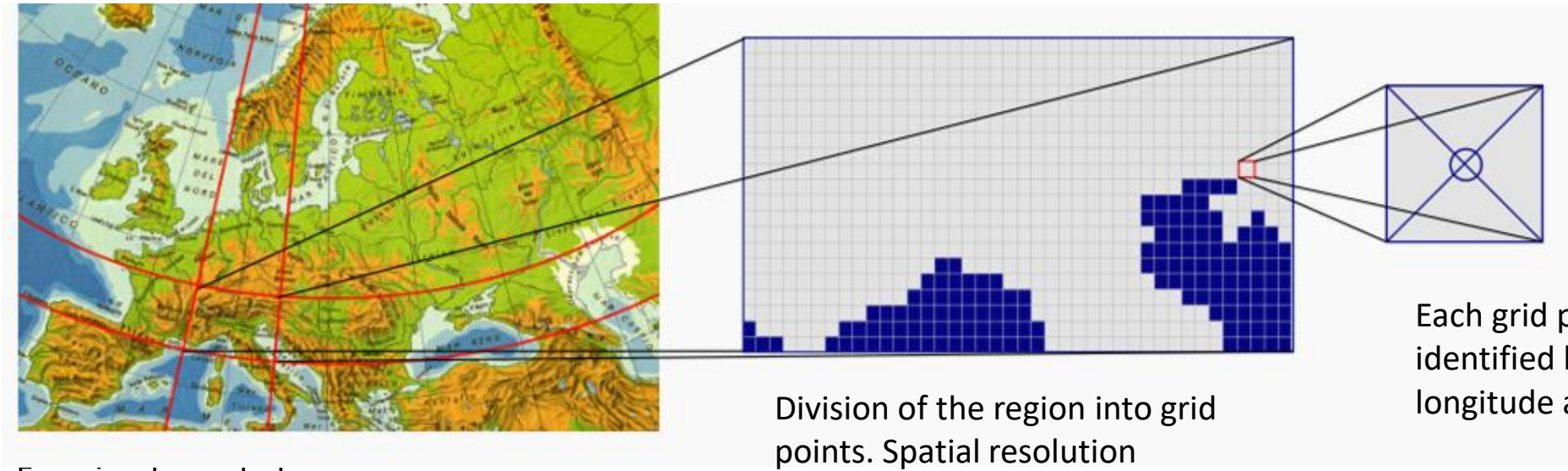
Climatic studies using global databases (GLDAS), ERA5, …)



Division of the region into grid points. Spatial resolution (longitude and latitude): 0.25°

Each grid point is identified by latitude, longitude and elevation

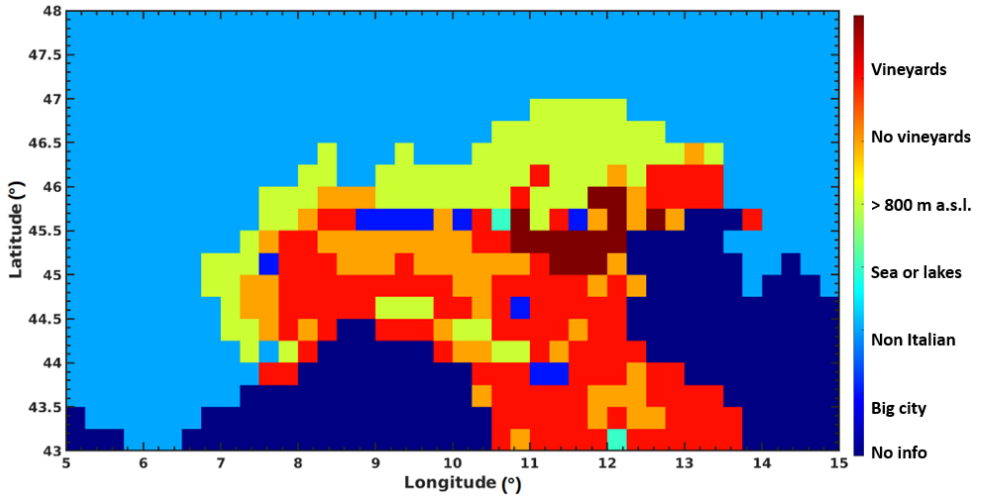
Examined area between:

- meridians between 5 ° E and 15 ° E
- parallels between 43 ° N and 48 ° N

➢ 657 grid points in the area considered:

- 178 grid points with crops but not vineyards
- 125 grid points with vineyards producing DOC and DOCG wines (in red)

Source: Del Canuto et al., 2010



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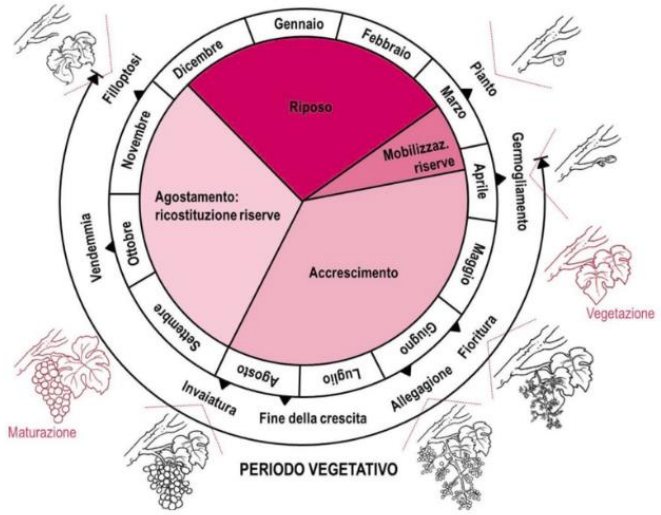
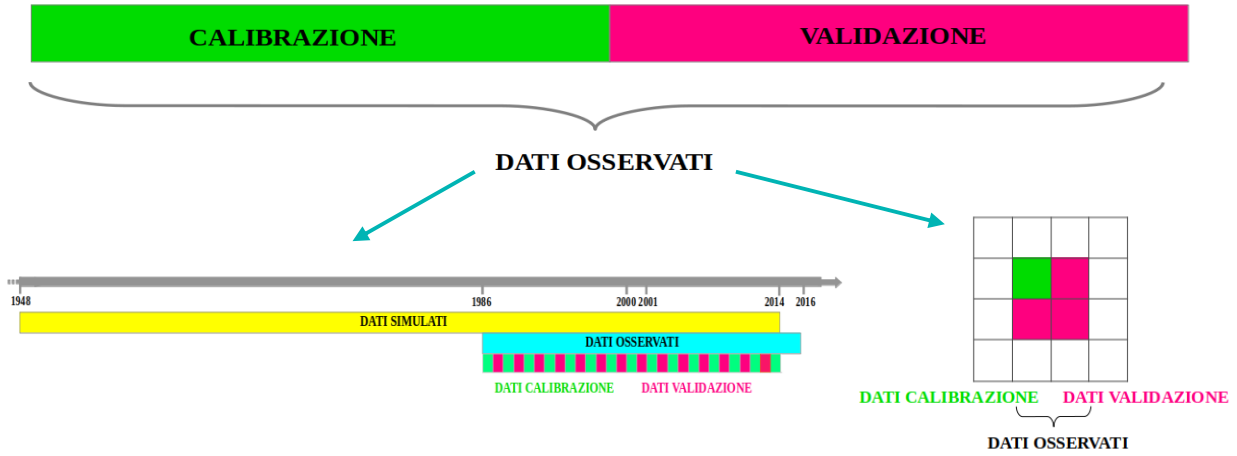
Calibration and validation of the IVINE model

1. The different Italian areas characterized by different varieties → need to have specific parameters for each variety of *Vitis Vinifera*
2. Research of field observations of phenological phases and parameters of different grape varieties
3. Identification of specific varieties for each grid point, if characterized by viticulture
4. Optimization of the model for the main grape varieties present in the territory considered
5. The outputs of the model must be good representations of reality





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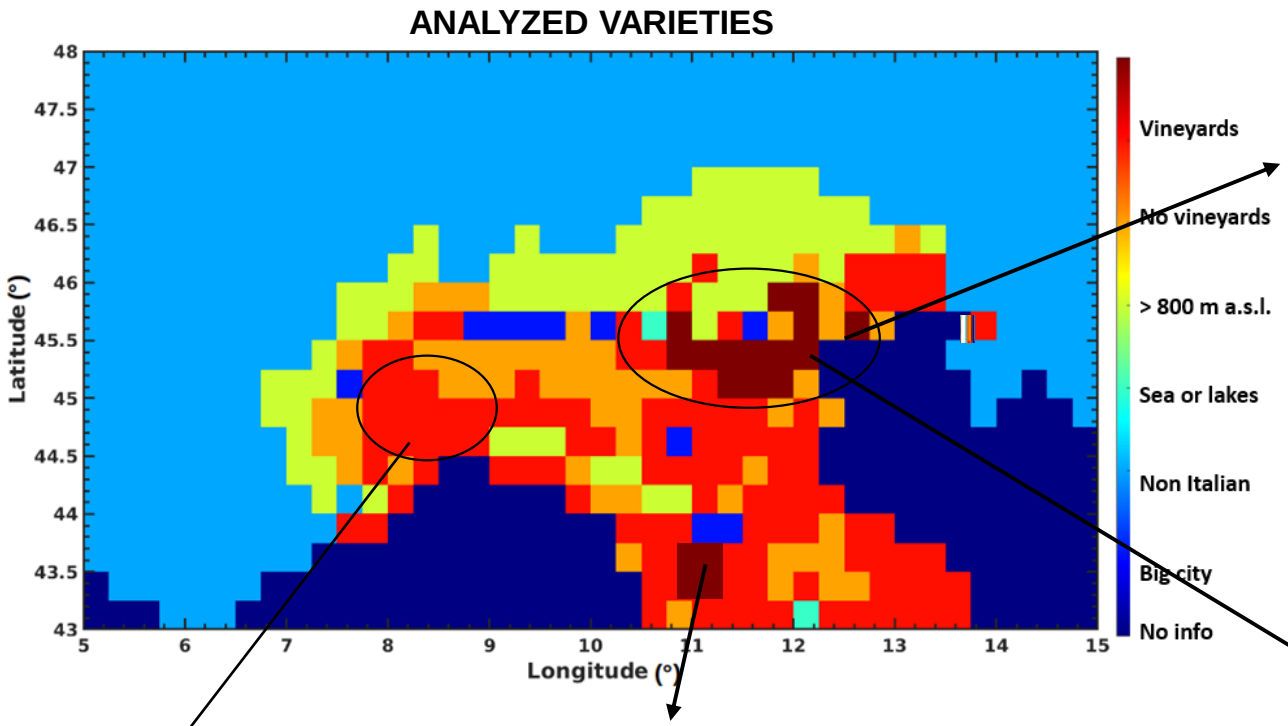
Optimized varieties in the IVINE model

(BioVenezia), (ExtendaVitis), (AgroAmbiente.info), (catalogoviti.politicheagricole.it)



- ***Vitis Vinifera cv* Chardonnay, Glera:**
  14 grid points identified
  Used 11 grid points, initially
  excluding elevations > 200 m a.s.l.

- ***Vitis Vinifera cv* Sangiovese:**
  Analysis in 4 different grid points (one used for calibration, three for validation)

- ***Vitis Vinifera cv* Merlot, Cabernet Sauvignon:**
  Detailed analysis on specific grid points

- ***Vitis Vinifera cv* Barbera and Nebbiolo:**
  Optimization carried out on several vineyards (Andreoli et al., 2019)

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IVINE empirical variables

- → Average number of bunches per plant before and after thinning
- Thinning day, if one (GG)
- → Average number of initial and potential berries/bunches
- → Maximum berry sugar content value of the variety(° Brix)
- → Maximum sugar content value for the beginning of ripening (° Brix)
- → Maximum sugar content value for the veraison (° Brix)
- Thermal threshold of the exit from dormancy (GDH)
- → Thermal threshold at the budding (GDH)
- → Thermal threshold at the flowering(GDD)
- → Thermal threshold at the fruit set(GDD)
- → Thermal threshold at the beginning of maturation(GDD)
- → Thermal threshold at the veraison (GDD)
- → Thermal threshold at the harvest (GDD)
- Maximum value of LAI (Leaf Area Index) (m^2_{leaves} m^{-2}_{plants})
- Thinning dates (1st , 2nd, 3rd) (GG)

→ : values found in literature (National Register of Vine Varieties).
→ : values determined during calibration.

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Parameters and thermal thresholds optimization

Parameters and thresholds	Chardonnay	Glera	Merlot	C. Sauvignon	Sangiovese
STUD	100	100	100	100	100
→ STG	$(5.5 \pm 0.3)10^3$	$(5.0 \pm 0.4)10^3$	5700	7300	5400
→ STF	$(2.19 \pm 0.13)10^2$	$(2.35 \pm 0.15)10^2$	230	235	250
→ STA	80	55	75	75	50
→ STIM	650	550	550	600	650
→ STIV	40	40	40	40	40
STR	400	400	400	400	400
→ GGR	1250	1350	1350	1300	1400
→ NGPp	25	21	20	25	11
→ NAGP	120	130	105	120	160
→ CZM	19	17	20.5	20	23
→ CZIM	6	6	6.5	7	11
→ CZI	7	8	9.5	9	12

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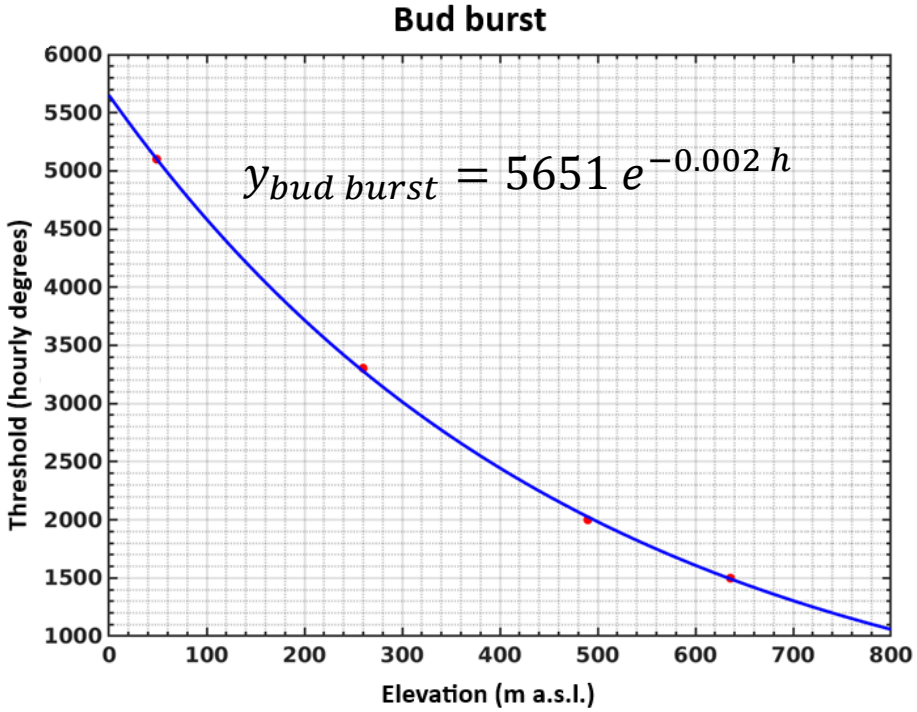
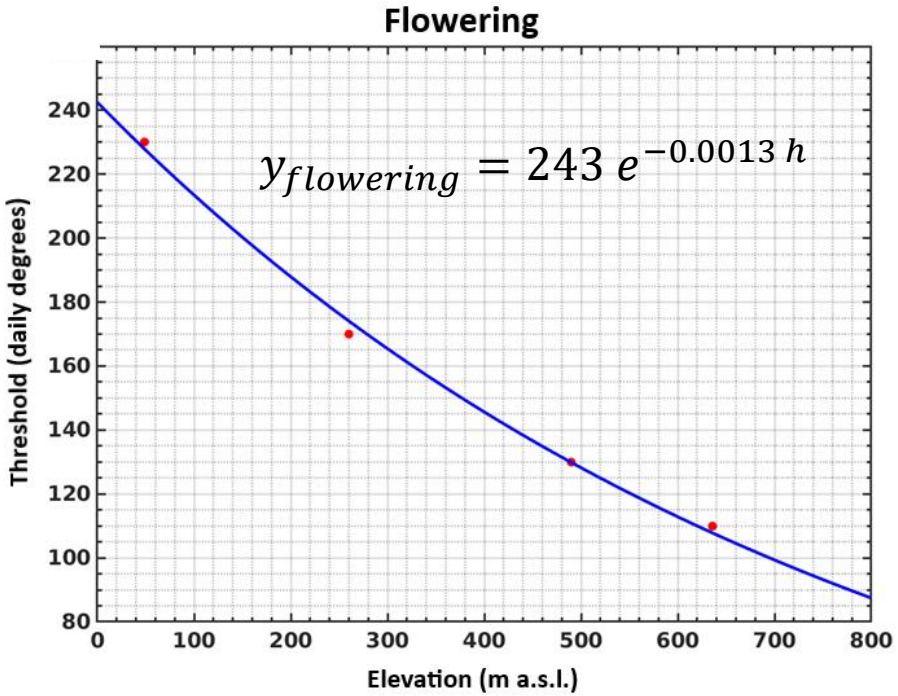
STUD (thermal threshold for exit from dormancy, in GDH); **STG** (thermal threshold for budding, in GDH); **STF** (thermal threshold for flowering, in GDD); **STA** (thermal threshold for fruit set, in GDD); **STIM** (thermal threshold for the beginning of ripening, in GDD); **STIV** (thermal threshold for veraison (GDD); **STR** (thermal threshold for harvest (GDD); **GGR** (degrees day on harvest day (GDD); **NGPp** (number of bunches per potential plant); **NAGP** (number of berries per potential bunch); **CZM** (maximum sugar content, in ° Brix);
CZIM (sugar content at the beginning of ripening, in ° Brix); **CZI** (maximum sugar content on veraison, in ° Brix)

Thermal thresholds vs elevation





Using the data observed at grid points located at different elevatins, the thermal thresholds decrease exponentially as the altitude increases. It happens for all phenological phases depending only on thermal thresholds

At higher altitudes, the phenological phases anticipate

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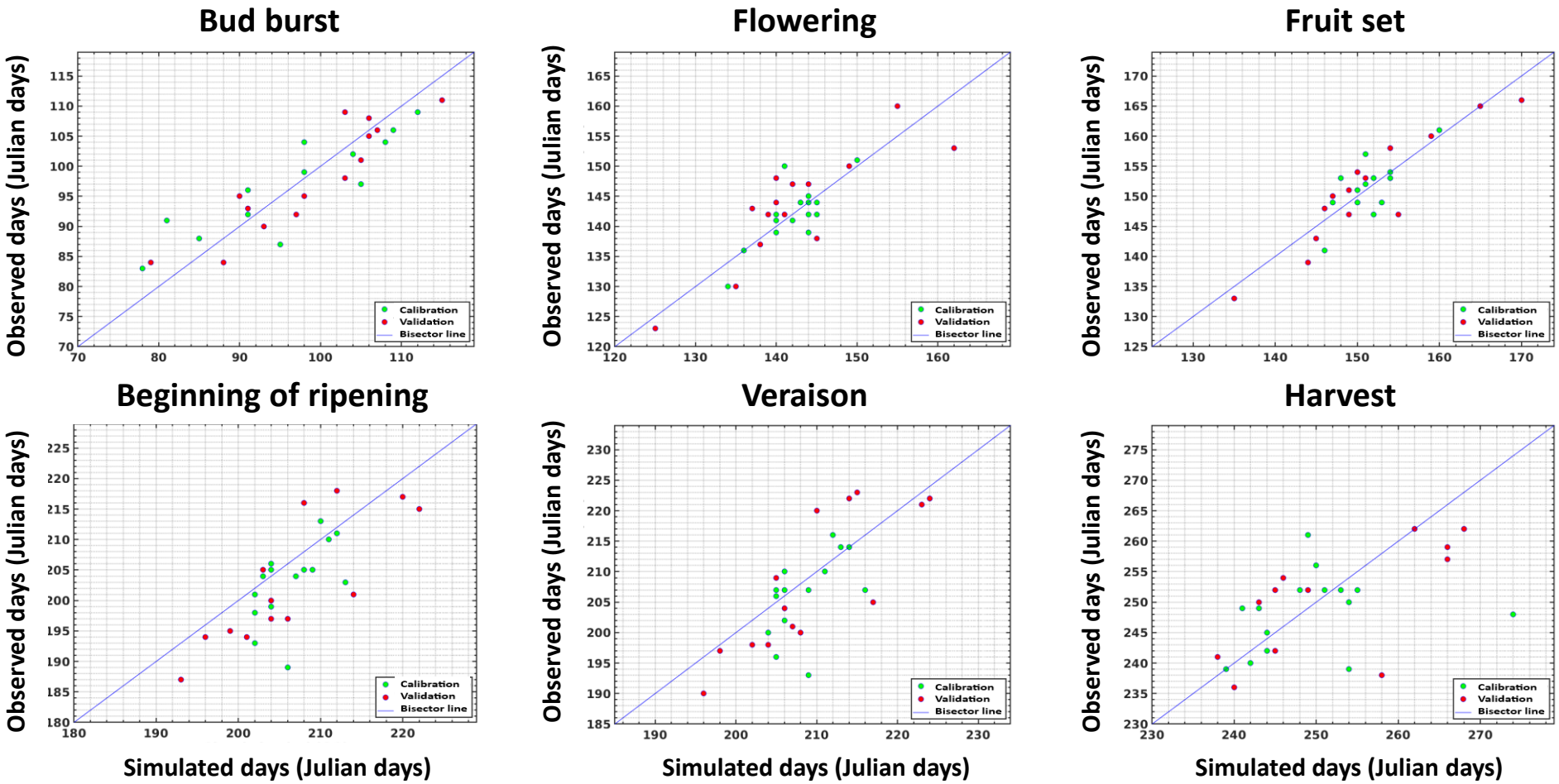
Correlation between phases observed and simulated by IVINE

Chardonnay



Multiple phenological phases analyzed

Uniform distribution around the bisector line, homogeneous distribution of observed and simulated data

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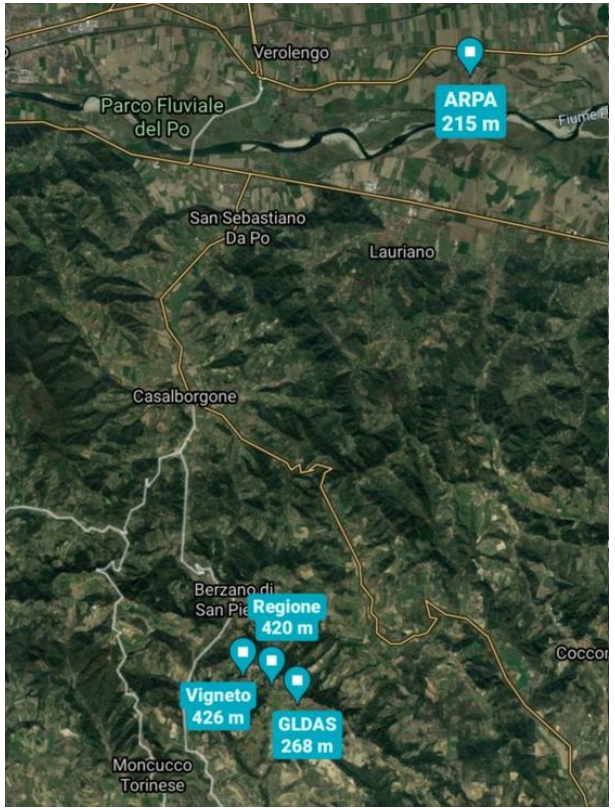
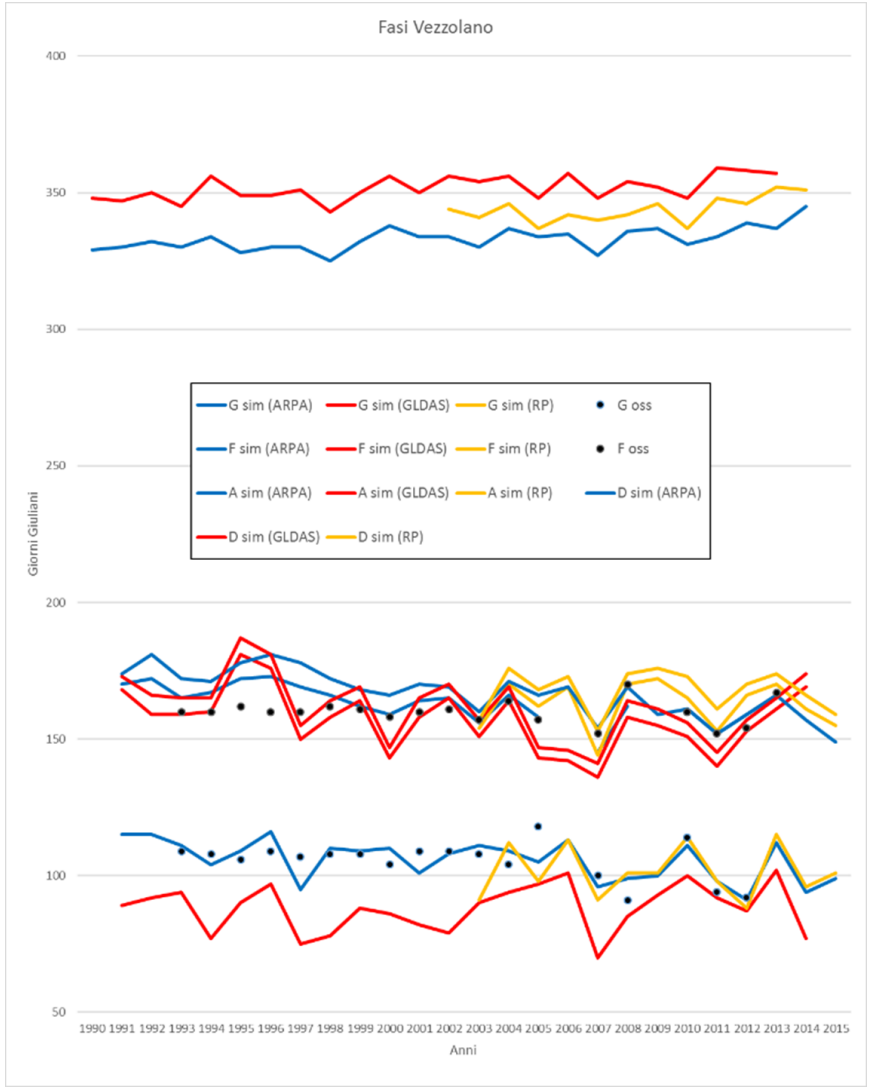
Phenological phases calibration/validation

Vezzolano - barbera





Exit from dormancy (no observations): large difference probably caused by thermal inversion

Bud burst: in average good, but with larger interannual variability

Flowering: the lowest differences between simulations and observations

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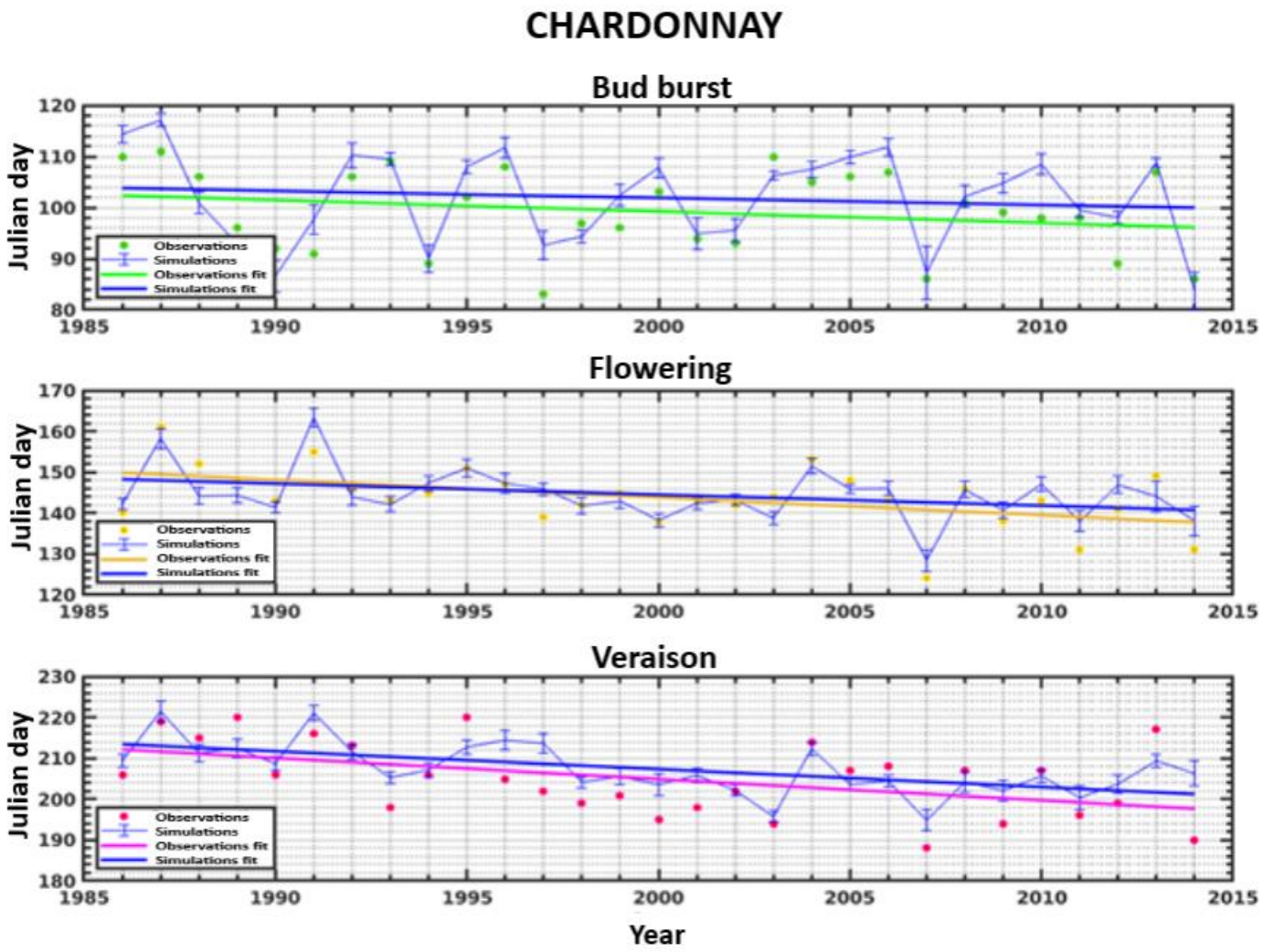
Time trend of the phenological phases from 1986 to 2014



$$y_{obs} = -0.20\ t + 544$$
$$y_{sim} = -0.14\ t + 375$$

$$y_{obs} = -0.40\ t + 1008$$
$$y_{sim} = -0.30\ t + 680$$

$$y_{obs} = -0.50\ t + 1239$$
$$y_{sim} = -0.40\ t + 1079$$

In 29 years:

-4-6 days

-9-12 days

-12-15 days

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On the difference between observed and simulated data

Stages	Chardonnay	Glera	Merlot	C. Sauvignon	Sangiovese
Bud burst	(6±3) days	(3±4) days	(5±3) days	(5±4) days	-
Flowering	(5±4) days	(3±5) days	(3±3) days	(3±2) days	(3±3) days
Fruit set	(3±2) days	(2±2) days	(3±2) days	(3±2) days	(7±4) days
Beginning of ripening	(5±4) days	(4±3) days	(4±4) days	(5±4) days	(10±6) days
Veraison	(5±4) days	(5±4) days	(3±4) days	(5±4) days	-
Harvest	(6±6) days	(4±2) days	(9±7) days	(9±7) days	-

- The largest error occurs for harvest phase (real date could vary according to vinery choices)
- Larger errors for Sangiovese than for other varieties

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Conclusions

ACTIVITY CARRIED OUT:

1. Search of observations of phenological phases and pheno-physiological characteristics of different vine varieties.
2. Verification of the dependence between meteorological data and phenological phases
3. Analysis of the occurrence of phenological phases for each variety. Calibration of parameters for each variety. Validation of IVINE using observations.
4. Analysis of long-term time trend of phenological phases simulated by IVINE

RESULTS:

1. The IVINE crop model was optimized for the Vitis Vinifera cv following varieties: Chardonnay, Glera, Merlot, Cabernet Sauvignon and Sangiovese
2. The phenological stages of bud-burst and flowering are particularly temperature-dependent. The veraison phase depends also on soil temperature and moisture
3. A new set of parameters needed by IVINE was set for all above-mentioned varieties
4. The days in which a phenological phase occurs, simulated by the IVINE model, are increasingly anticipated over the years. Such variations are often statistically significant

TO DO

1. More physical parameterizations for phenological phases (soil moisture?)
2. Calibration also for other varieties

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