Predicting vineyard's evolution with the crop model IVINE driven by meteorological model forecasts: preliminary results

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Aims of the project

In the frame of MACSUR (Modelling European Agriculture with Climate Change for Food Security) and DAMOVIP (DAti e MOdelli previsionali per la VIticoltura di Precisione) projects, our group has focused on crop modelling applied to vineyards. In particular:

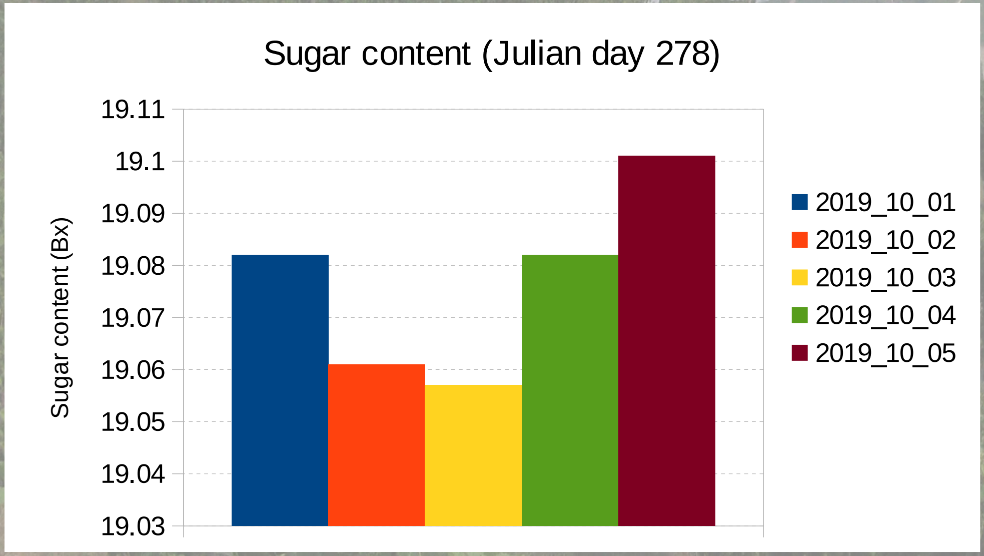
- To simulate physiological and phenological conditions in a Nebbiolo vineyard using the numerical model IVINE (Italian Vineyard Integrated Numerical model for Estimating physiological values)
- To check the ability of the crop modelling in representing microscale processes within the vineyard
- To analyze the effects of micro-meteorological conditions on vine growth and grape quality
- To develop an advanced tool able to:

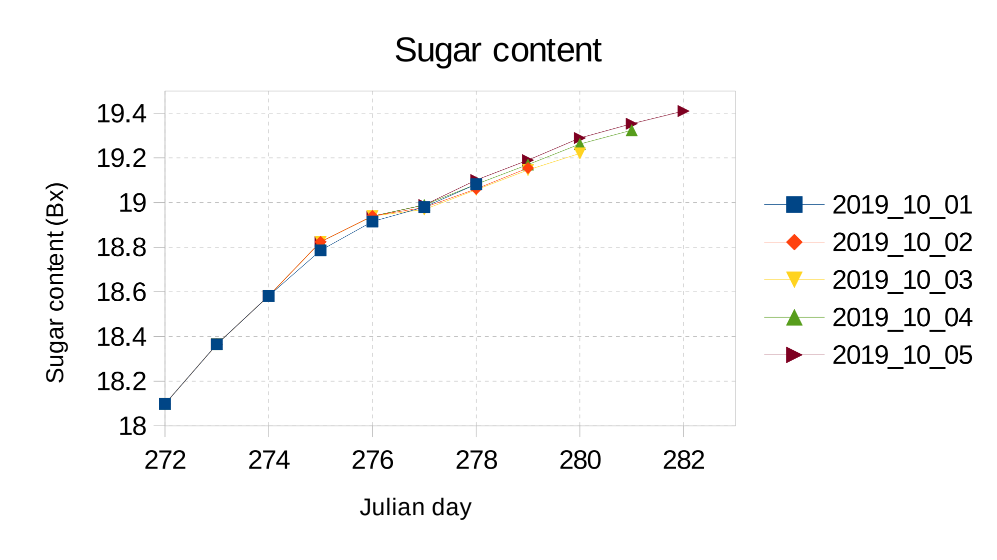
  monitoring in real time the vine growth

  <u>predicting vineyard's short-term evolution</u>

The short-term simulations

The simulations were performed for the whole 2019 year over 156 WRF grid points distributed in the Langhe, Roero and Monferrato wine areas of Piedmont.
Here some pheno-physiological variables in vineyards are analyzed, relative to some significant points and events, and the main results are discussed.





Supplementary slides

The selected area

- Selected area: 156 WRF grid points distributed in the Langhe, Roero and Monferrato wine areas of Piedmont.
- Latitude: from 44.503° to 44.908°
- Longitude: from 7.855° to 8.298°
- Time period: 2019 season

The simulations

In order to use the model for forecasting purposes, the set of input data required by IVINE must be retrieved by the simulation's outputs of a mesoscale model, in turn driven by a Global Circulation Model simulation.

For this task four daily 5-days simulations are performed over Piedmont Italian region with WRF mesoscale model driven by the GFS (Global Forecast System).

- Two chained simulations carried out:

First one: WRF (Weather Research and Forecasting)

Second one: IVINE

- The IVINE input dataset is updated every six hours using the values coming by the new simulation, while considering past values acquired

The WRF (Weather Research and Forecasting)

WRF (Weather Research and Forecasting): it is an open source and free meteorological model that is developed thanks to a collaboration between several international meteorological centers (including NCAR, NOAA, NCEP) and with the participation of numerous researchers.

WRF can be used for applications at different scales: from microscales phenomena (breeze, fog, etc.) to synoptic ones.

It is highly configurable: through appropriate files called namelists it is possible to choose many dynamics and physical parameters (e.g. Surface and soil Layers, Planetary Boundary Layer, Radiation schemes, Clouds Microphysics, Cumulus parameterization, damping and diffusion options, etc.)

Non-hydrostatic fluid dynamic model.

Arakawa C-grid horizontal grid (scalar variables defined in the center of the grid, vector variables in the corners).

Vertical coordinates of the Eta-Level type, i.e. function of pressure.

The WRF (Weather Research and Forecasting)

Input data from global model GFS (Global Forecast System) every 6 h.

- Preprocessing trough WPS (Wrf Preprocessing System): 3 programs (Geogrid, Ungrib, Metgrid) that prepare global model data on the model layers and grid points inserting static terrestrial fields (topography, land use, soil type, etc.) for the selected domain.

- Processing consists of 2 steps:
- - computation of boundary and vertical layer conditions;
- - execution of the equation solver (usually about 2 hours of machine time)

- Output of many variables (surface, soil layers and atmosphere layer) in each grid points of the simulation domain.

Simulation domain

The crop growth model IVINE

(Italian Vineyard Integrated Numerical model for Estimating physiological values)

Input data (meteorological)

· Air temperature,
· Air relative humidity,
· Solar global radiation,
· Photosynthetically active radiation,
· Soil temperature,
· Soil water content,
· Wind speed and direction,
· Rainfall,
· Leaf wetness

Input data (others)

- Geography (latitude, longitude, slope, height)
- Soil hydrology,
- Plant density (plants/ha),
- Variety characteristics (clusters/plants, berries/cluster, °Brix maximum value, thermal tresholds),
- Vineyard management (trimming, severity of trimming).

IVINE MODEL

Output data

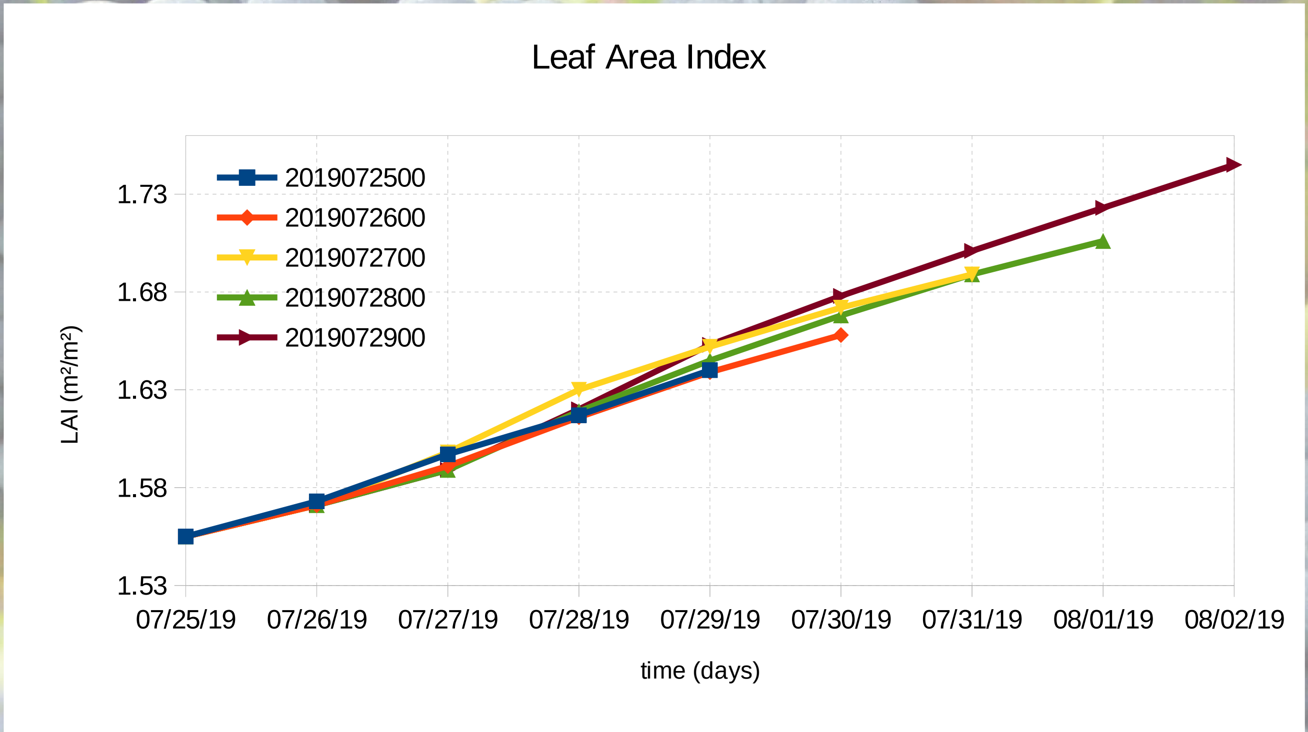
·Predawn leaf water potential,
·Timing of the main phenological phases (dormancy break, budburst, flowering, fruit-set, beginning of ripening, veraison, harvest),
·Leaf development,
·Yield,
·Sugar concentration .

Andreoli, V.; Cassardo, C.; La Iacona, T.; Spanna, F., 2019: Description and Preliminary Simulations with the Italian Vineyard Integrated Numerical Model for Estimating Physiological Values (IVINE), Agronomy, 9, 94; doi:10.3390/agronomy9020094

Simulation results

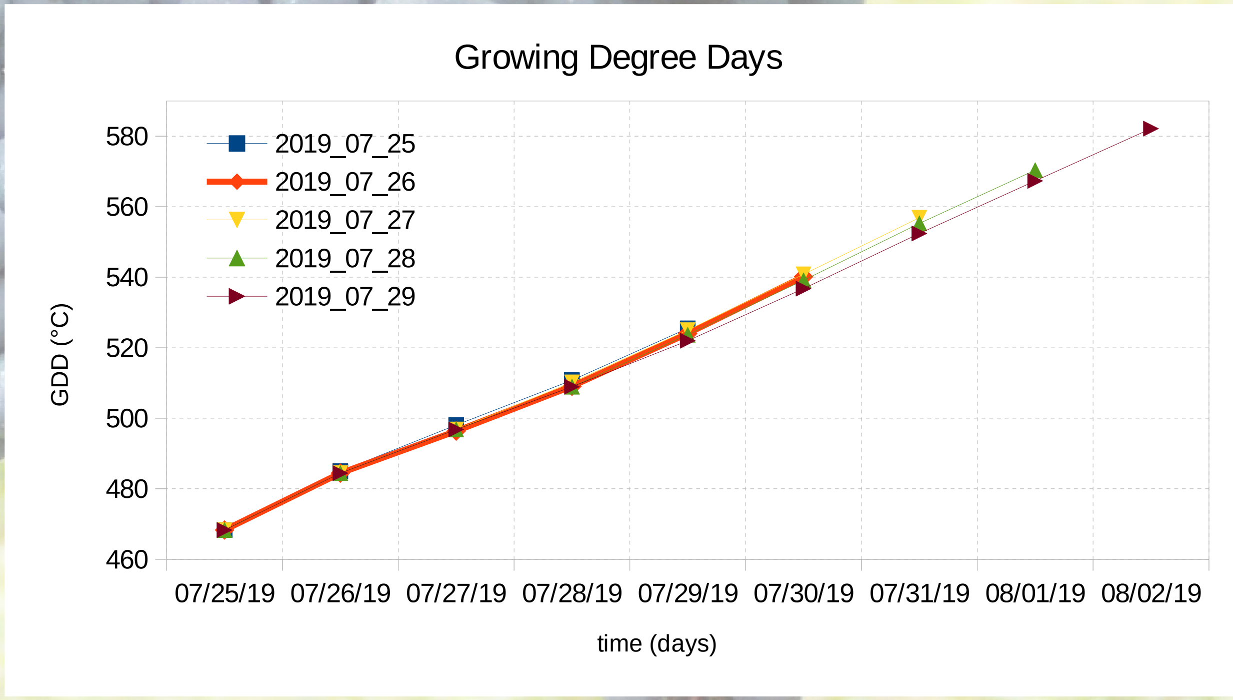
- The following slides show some examples of short-range forecast on pheno-physiological variables.
- WRF grid point:
  latitude: 44.7982°, longitude: 8.0033°, altitude:242.74 m
- Five WRF runs have been used to drive IVINE model. This kind of simulation allow a check on forecast stability.

Leaf Area Index

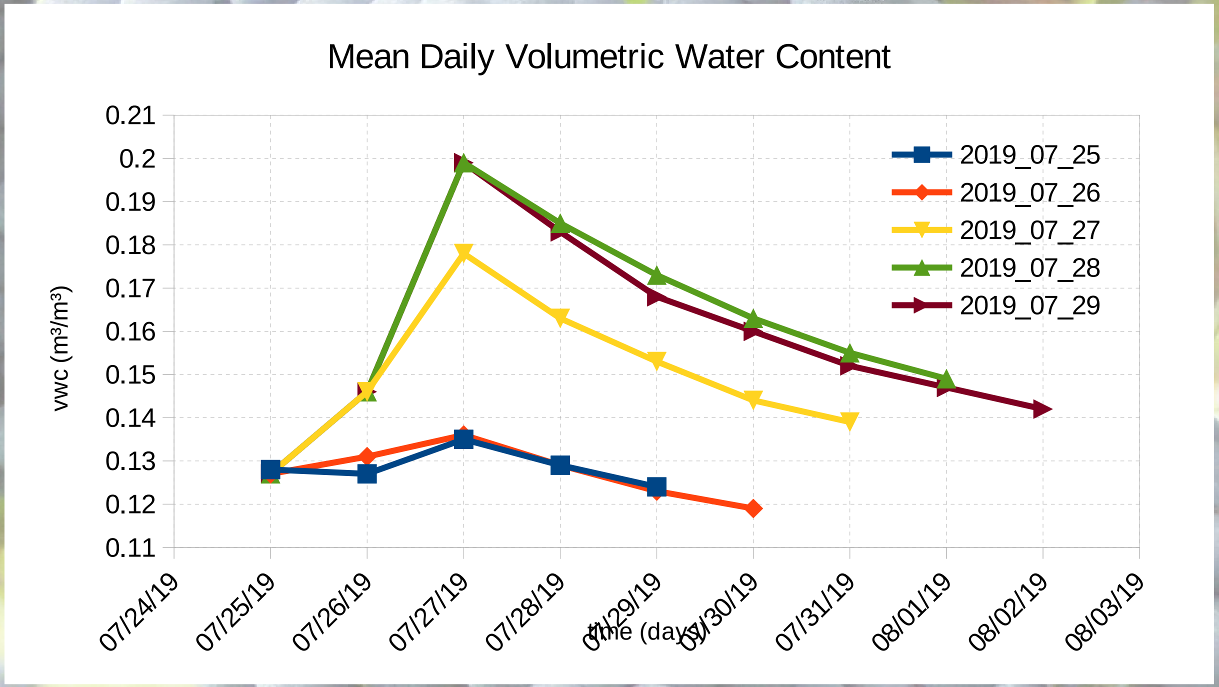


LAI values dispersion is about 0.02 – 0.03 m^2/m^2 between different runs on the last (5th) day of simulation. Simulation of LAI depends on air temperature (growing degree days) and soil water content.

Growing degree days dispersion is about 1.7 – 3.5 °C between different runs

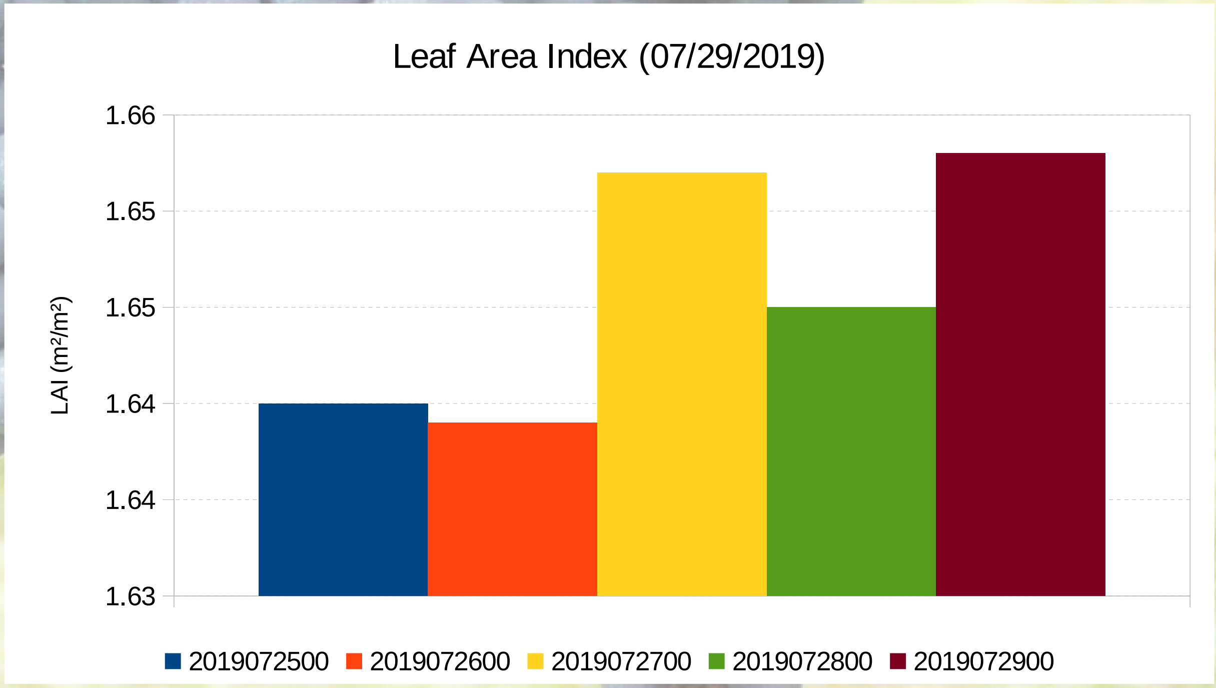


Leaf Area Index

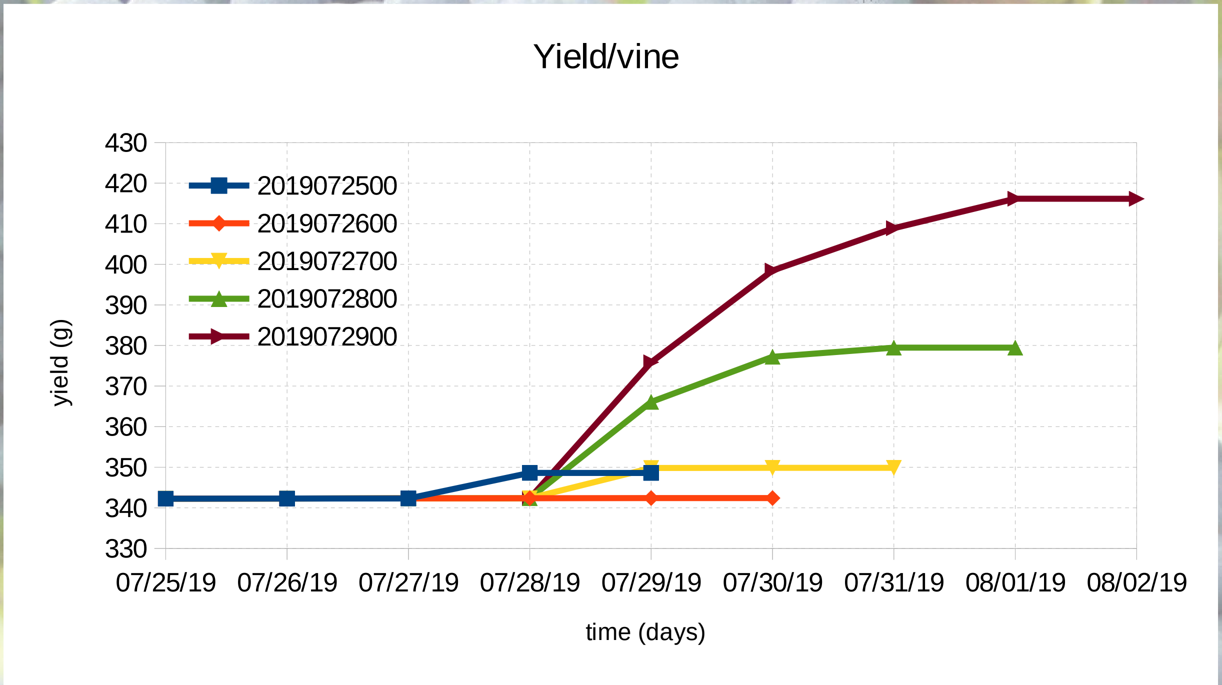


Volumetric water content dispersion is about 0.0 – 0.5 m³/m³ between different runs

Comparison of LAI on 5th day of simulation.

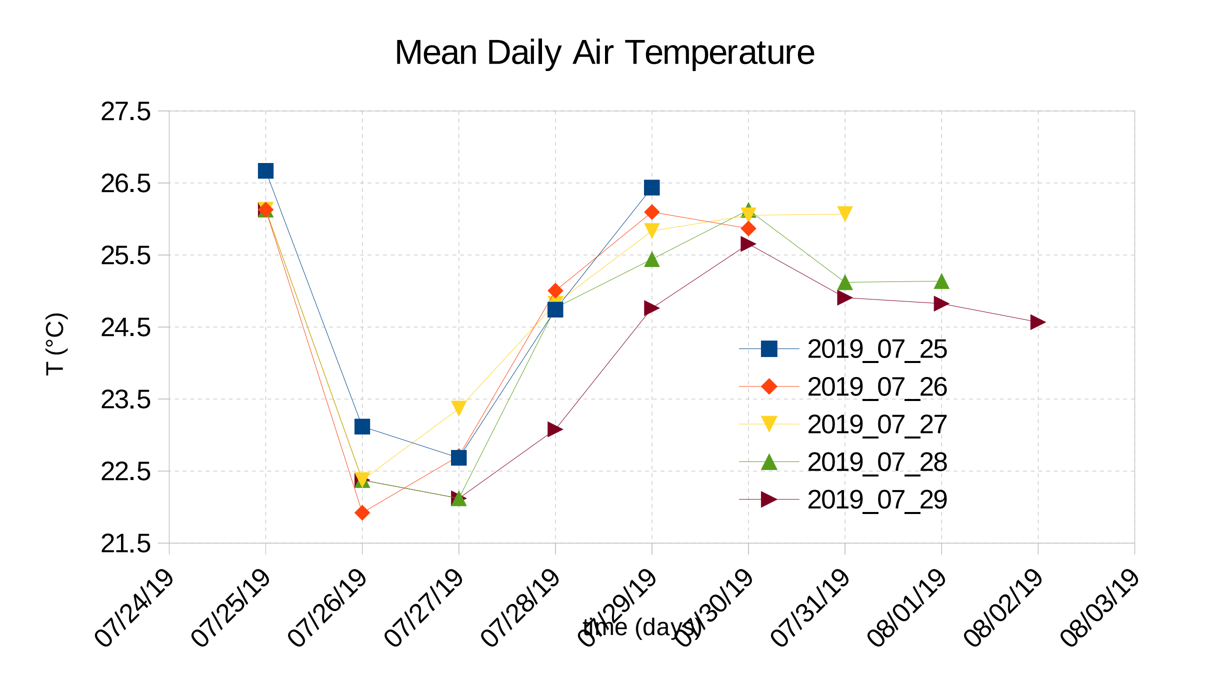


Yield

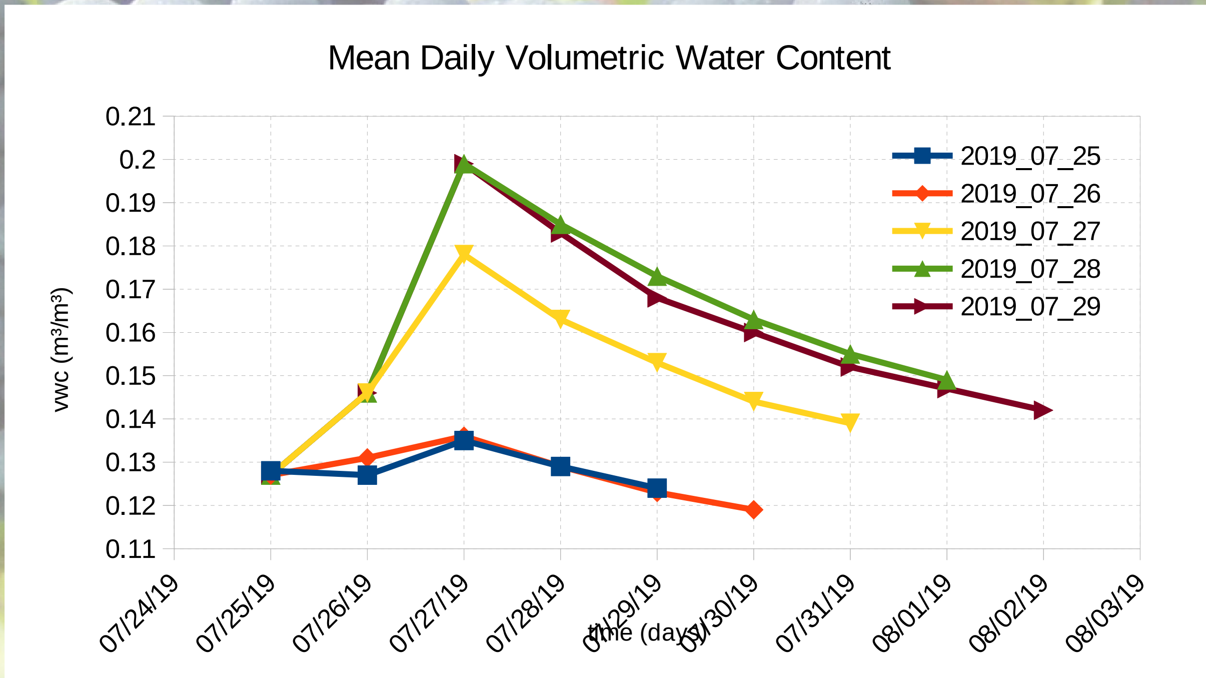


Yield values dispersion is about 10 – 60 g between different runs on the last (5th) day of simulation.
Simulation of yield depends on air temperature, soil water content, solar radiation and LAI.

Air temperature dispersion is about 0.7 – 1.7 °C between different runs on the last (5th) day of simulation.

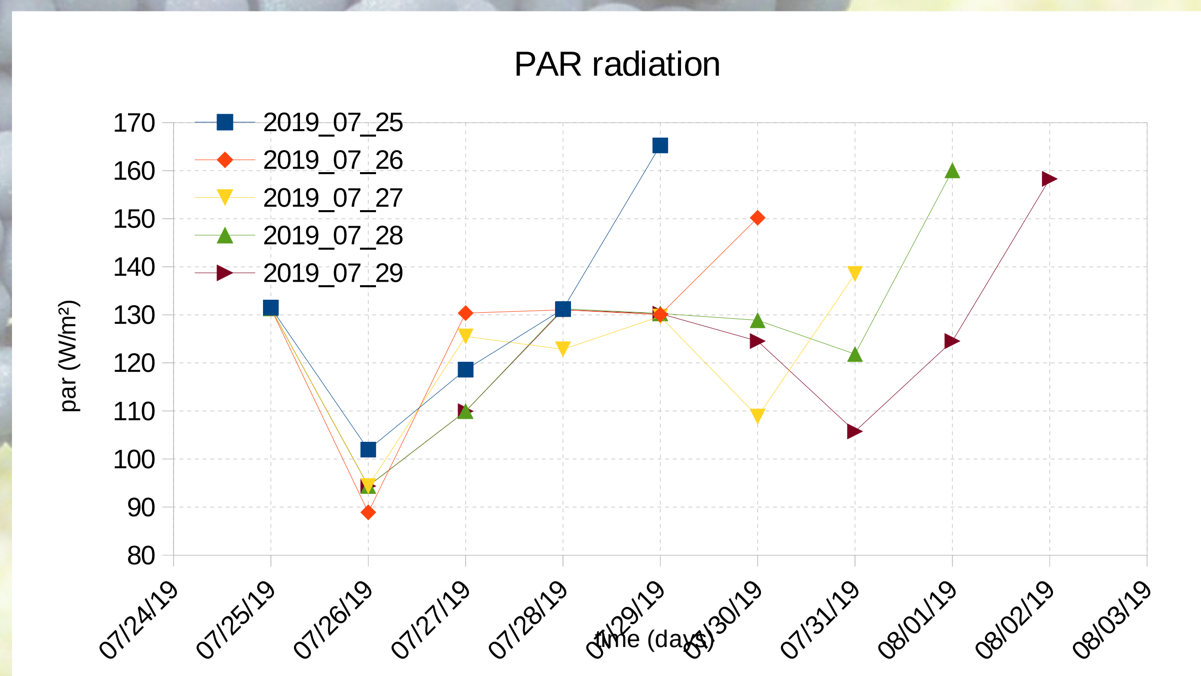


Yield

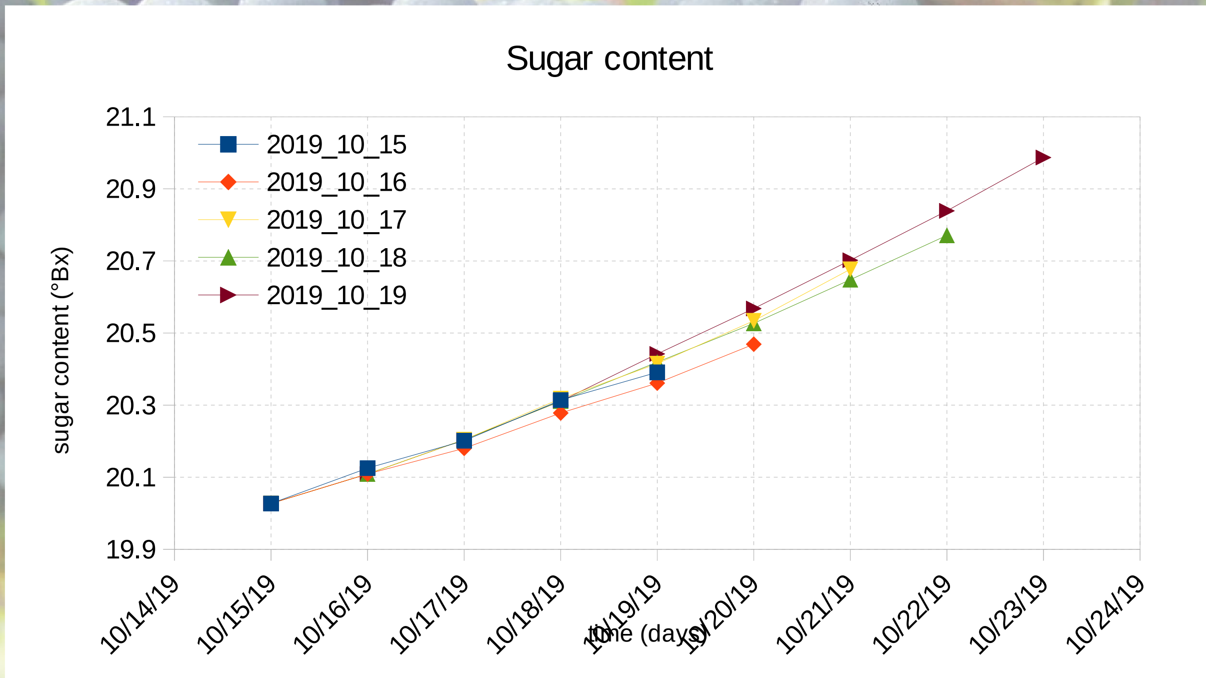


Volumetric water content dispersion is about 0.0 – 0.5 m³/m³ between different runs

PAR radiation dispersion is about 0 – 35 W/m² between different runs.

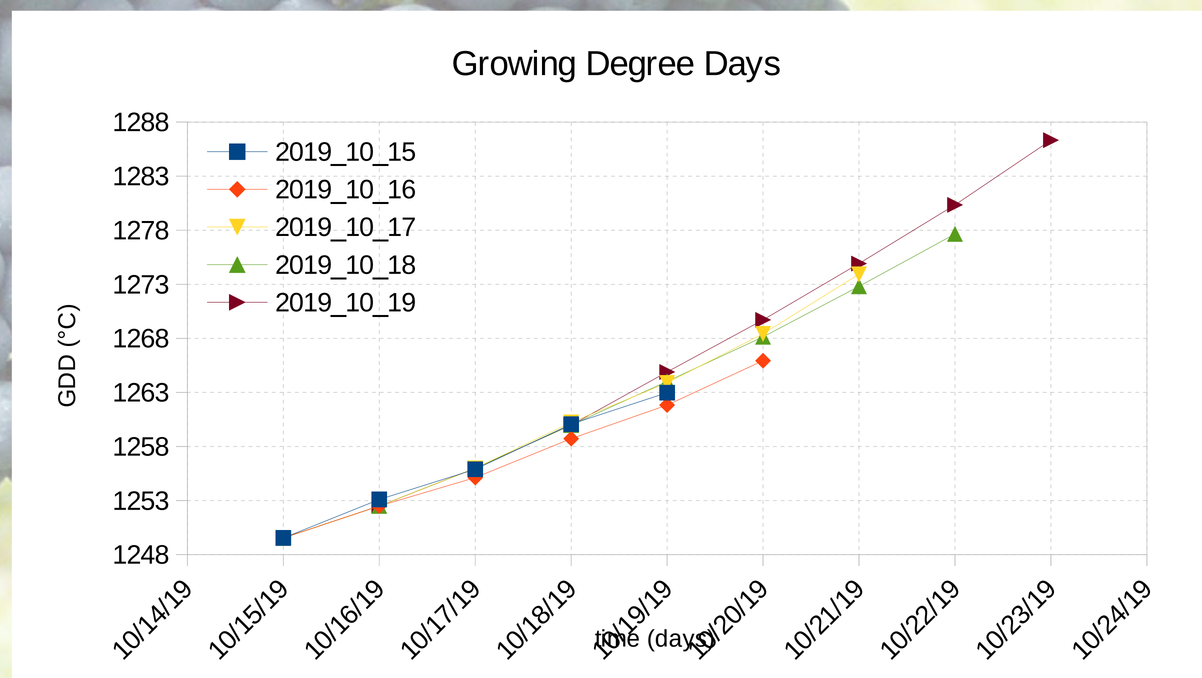


Sugar content

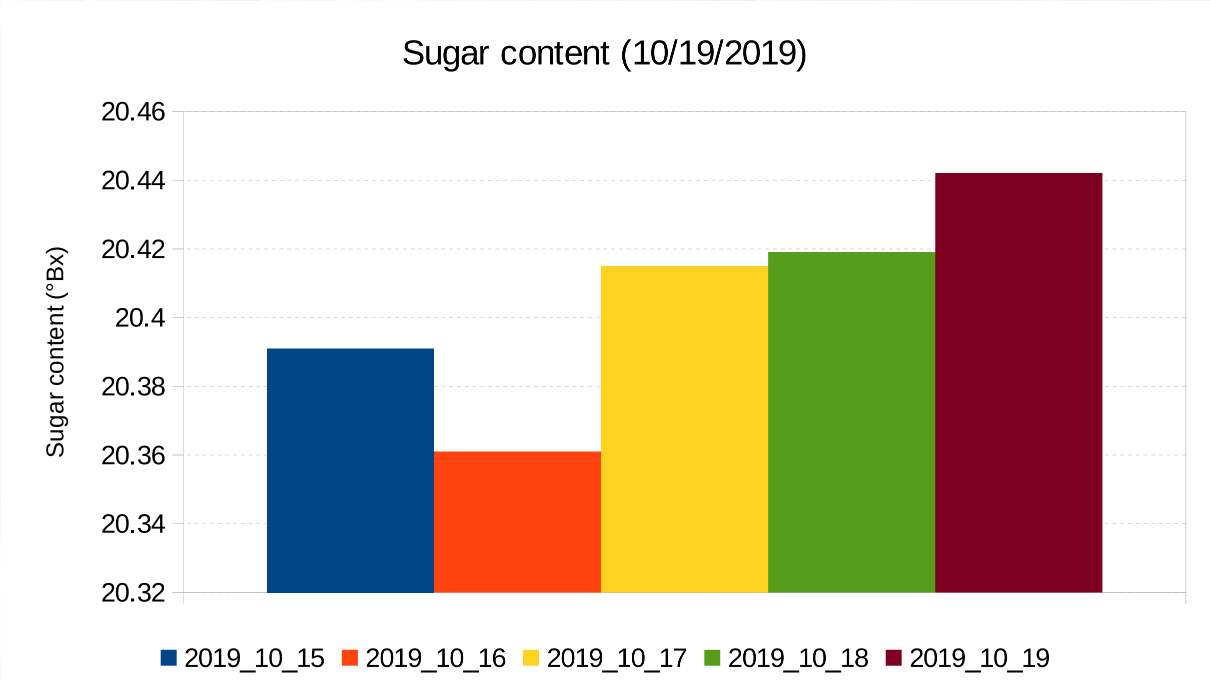


Sugar content dispersion is about 0.03 - 0.08 °Bx between different runs on the last (5th) day of simulation.
Simulation of sugar content depends on air temperature (growing degree days).

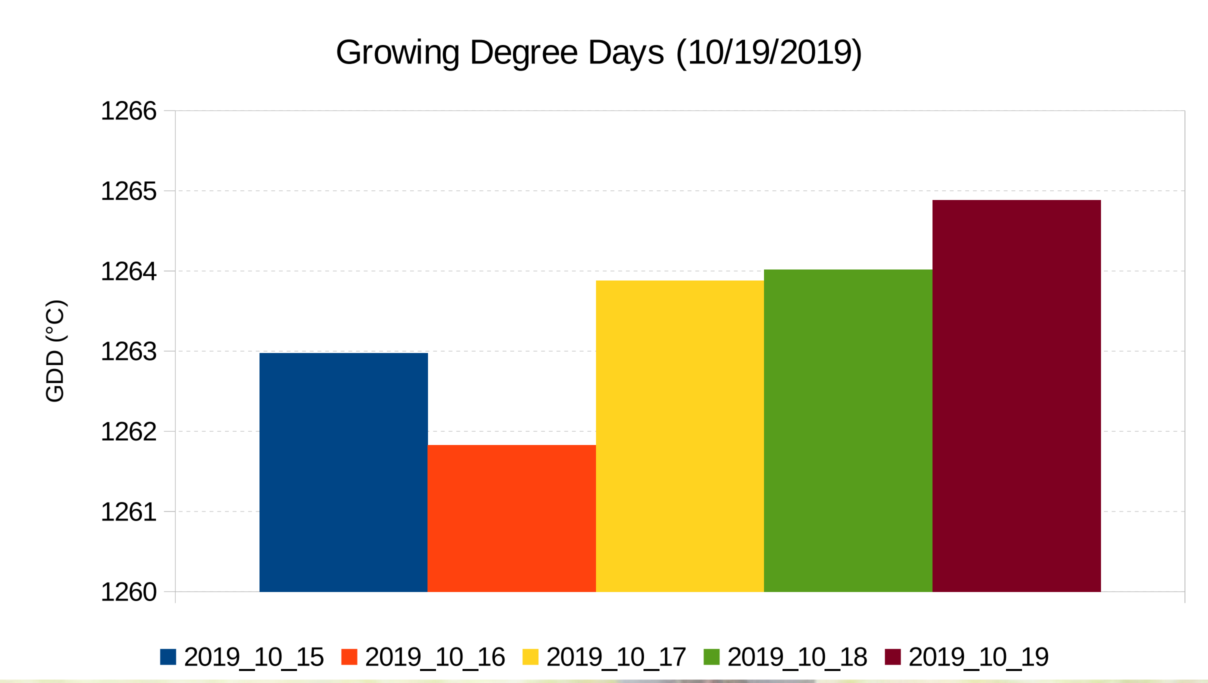
Growing degree days dispersion is about 1.1 – 3.0 °C between different runs



Sugar content



Comparison of sugar content on 5th day of simulation.



Comparison of growing degree days on 5th day of simulation.

Phenology

	2019_04.08	2019_04_09	2019_04_10	2019_04_11	2019_04_12
Bud-break	102	102	102	102	102

	2019_06_19	2019_06_20	2019_06_21	2019_06_22	2019_06_23
Flowering	174	174	174	174	174

	2019_09_03	2019_09_04	2019_09_05	2019_09_06	2019_09_07
Veraison		249	250	250	250

The julian days obtained by the five simulations are: 102 for bud-break and 174 for flowering.
The julian days obtained for veraison are: 249 and 250.
➔ The short-term forecast of main phenological stages results to be stable.

Conclusions...

- The crop growth model IVINE was developed to simulate grapevine phenological and physiological processes related to the environmental conditions.

- The developed model requires a set of meteorological and soil data as boundary conditions.

- The use of WRF outputs to drive IVINE allows to predict future values and their stability in time.

- The short-term forecast of pheno-physiological variables results to be stable on the last day (5th) of simulation for all considered processes.

The <u>main projects</u>:

- **MASGRAPE** (Multidisciplinary Approach to Study the GRAPEvine agroecosystem: analysis of biotic and abiotic factors able to influence yield and quality) – Regione Piemonte (2008-2010)
- **MACSUR (Modelling European Agriculture with Climate Change on Food Security)** phase 1 – Progetto Europeo JPI-FACCE (2013-2015)
- **MACSUR (Modelling European Agriculture with Climate Change on Food Security)** phase 2 – Progetto Europeo JPI-FACCE (2016-2018)
- **Progetto LAGRANGE** (Micro meteorological and vegetative assessments and advanced modelling for precision viticulture) (2015)
- **Progetto LAGRANGE** (Micro meteorological and vegetative assessments and advanced modelling for precision viticulture. Improvement and advances) (2016)
- **Progetto CRT - DAMOVIP** (DAti e MOdelli previsionali per la VIticoltura di Precisione) (2018-2019)
- Projects between privates and academy (2015-2019)