Representation of micrometeorological and physiological parameters with numerical models influencing the vineyard ecosystem: the case of Piemonte (Italy)

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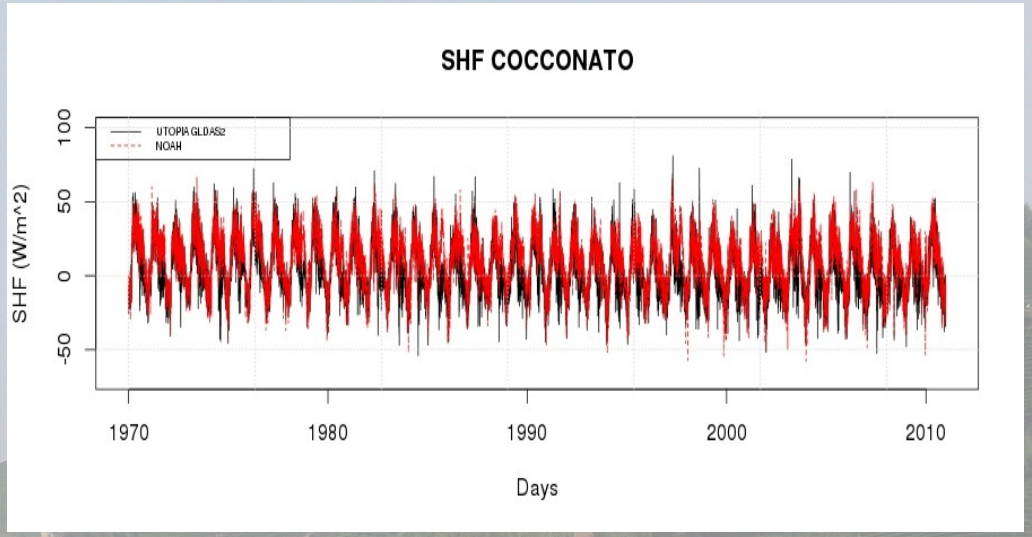
Aims of the project

- To simulate micro-meteorological conditions within vineyards using a numerical model (land surface SVAT scheme UTOPIA)
- To simulate physiological vineyard conditions using a numerical model (VINEYARD crop model)
- To infer micro-meteorological and physiological variables in the past and present climate
- To analyze which micro-climatic conditions could improve grape quality
- To analyze the chance of employ numerical model to evaluate agronomic variables trends by means of gridded databases

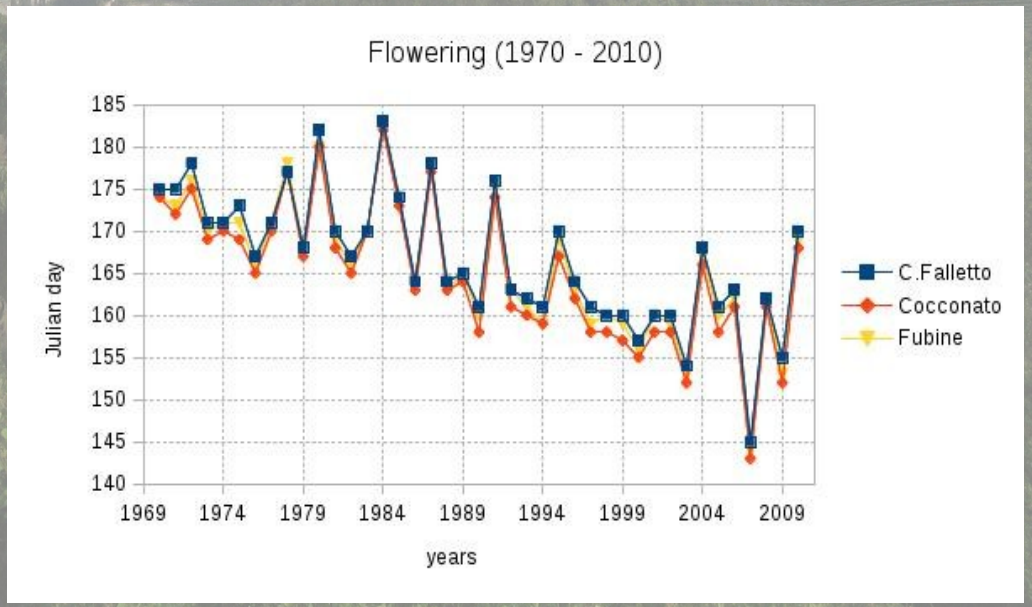
Long term simulations

- Selected time period: January 1970 – December 2010

- Intercomparison of UTOPIA and NOAH land surface models driven by the global dataset GLDAS2.0

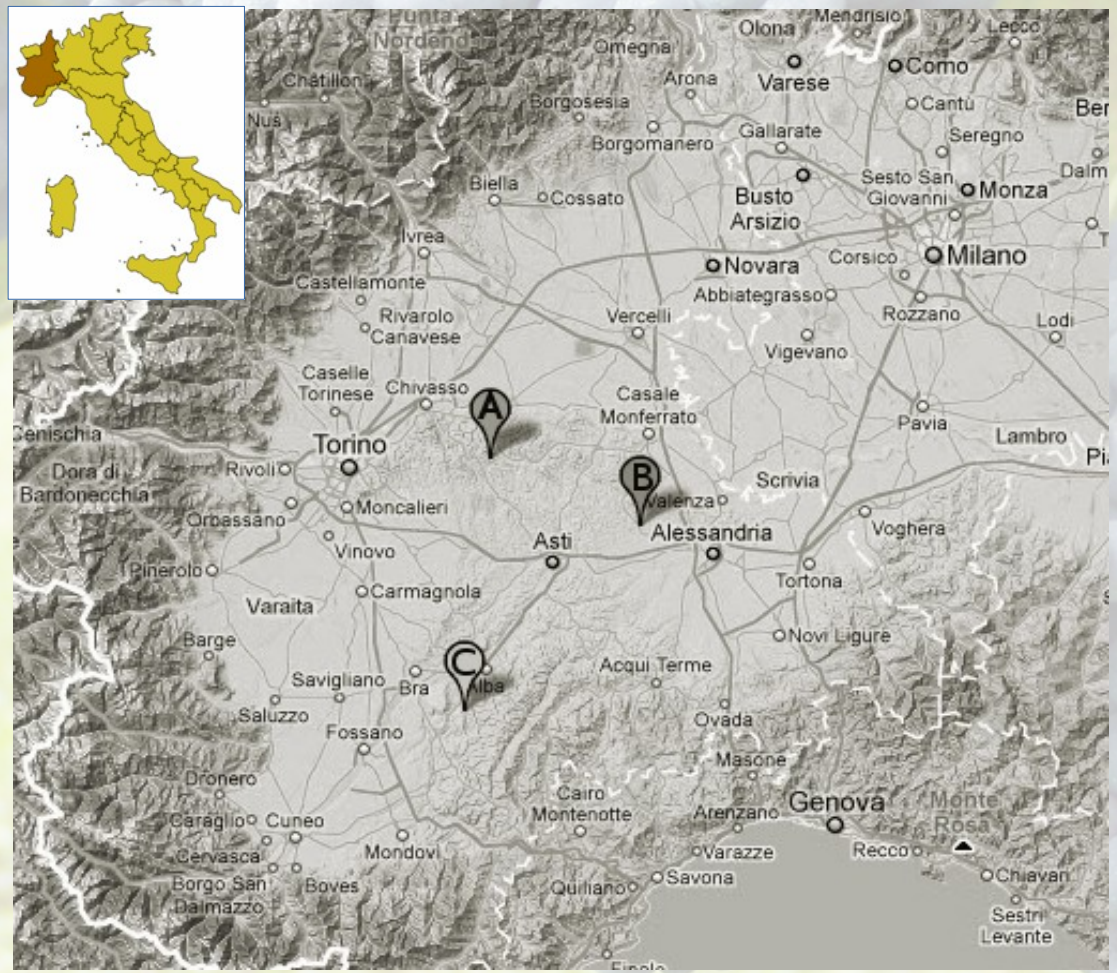


- Preliminary simulations performed by the VINEYARDS crop model driven by UTOPIA output data and by GLDAS2.0 dataset



Supplementary slides

The Piemonte region and selected sites



- Piedmontese sites:

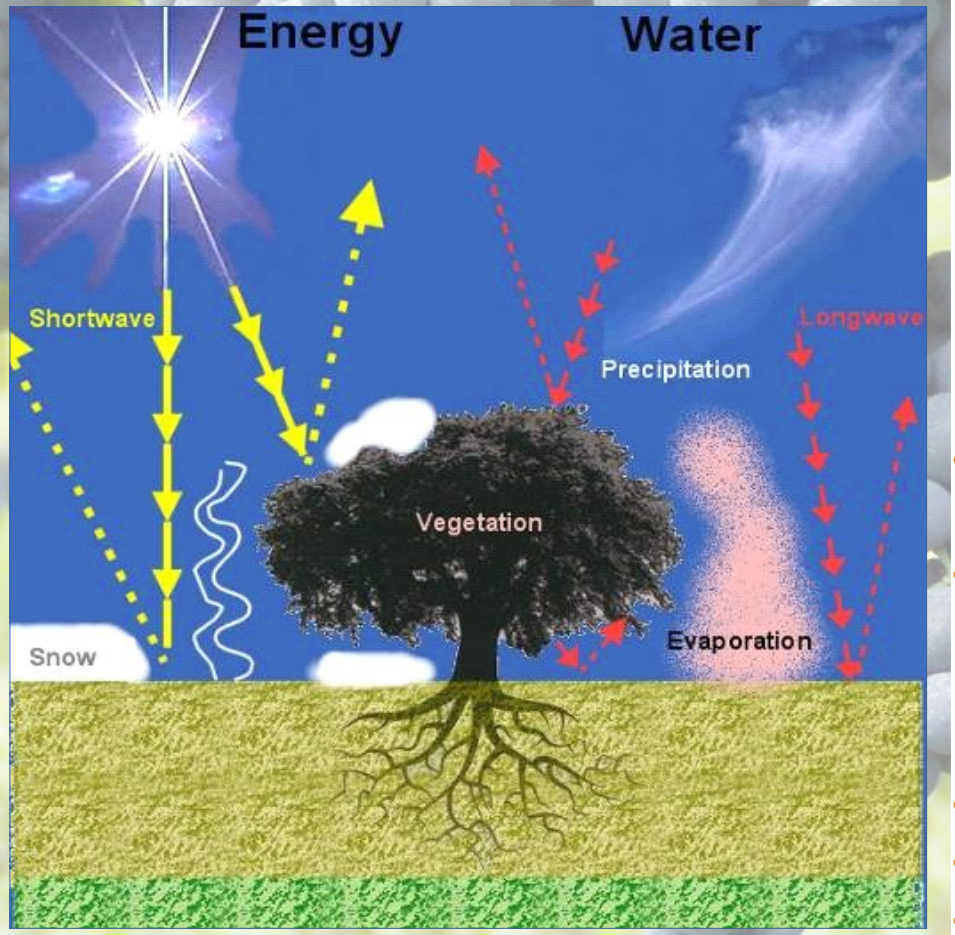
A = Cocconato (AT)
B = Fubine (AL)
C = Castiglione Falletto (CN)

- Vineyards characterized by the same climate but by different microclimatic conditions

- Different site characteristics

- Selected cultivar: Nebbiolo

UTOPIA model



University of TOrino model of land Process Interaction with Atmosphere

(Cassardo, 2016)

Diagnostic 1-D model

Vegetation– 1 layer "BIG LEAF" – optimized for vineyards

Physical processes:

- Partition of heat fluxes among air, vegetation and soil
- Soil and canopy energy balance and temperatures

Hydrological processes

- Hydrological balance components
- Soil moisture
- Vegetation wetness

Carbon assimilation rate and photosynthesis

The UTOPIA model simulations

- The long term simulations were carried out using gridded datasets as input from 1970 to 2010

- Selected gridded database: GLDAS2.0 (**G**lobal **L**and **D**ata **A**ssimilation **S**ystem)

- Selection of the grid point (0.25°) nearest to the site

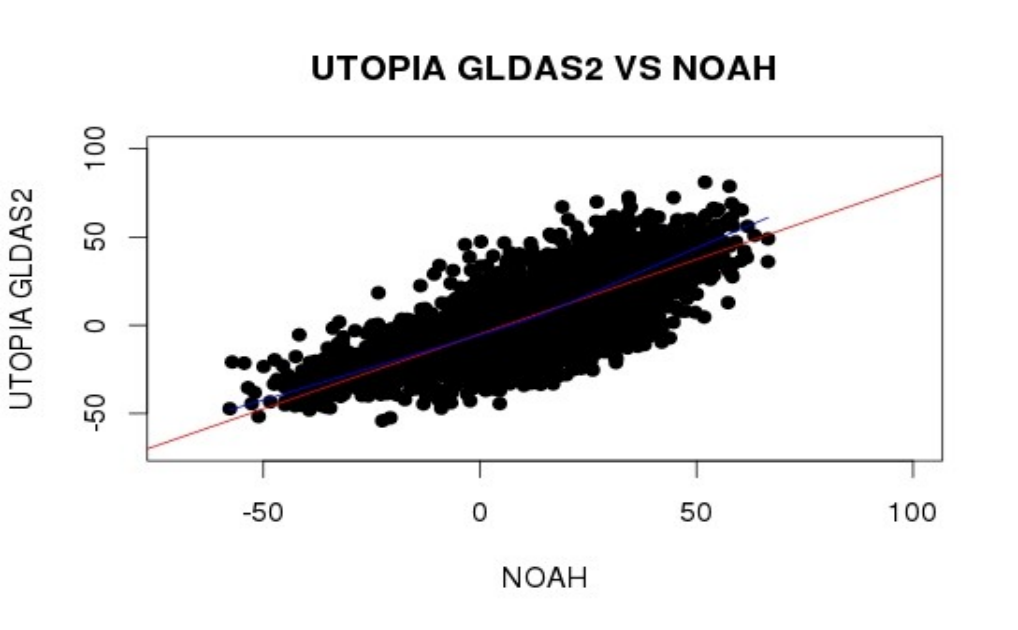
- Check on input data quality

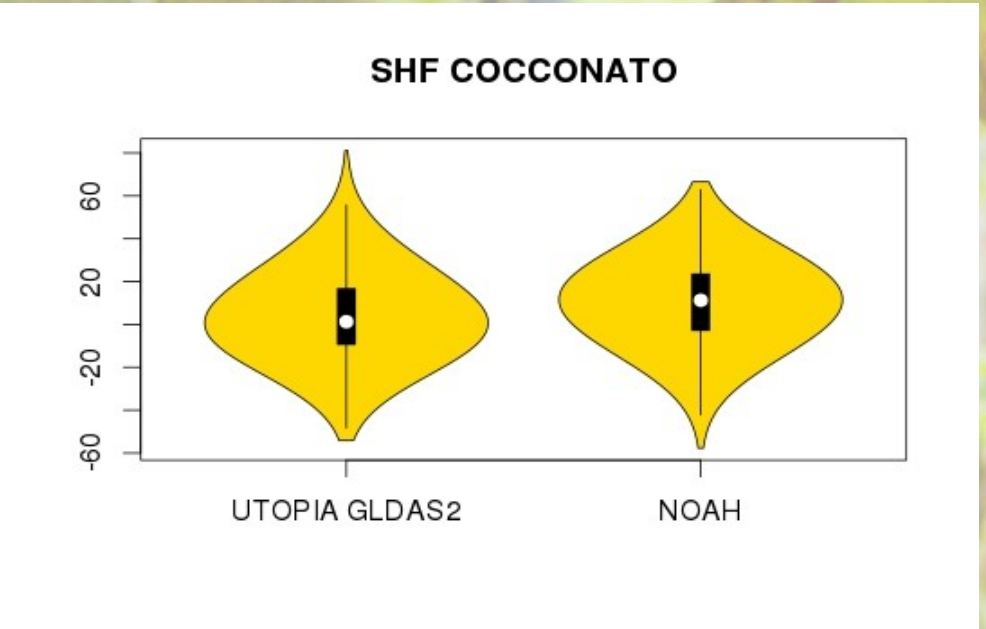
- Possibility of intercomparison UTOPIA vs NOAH

GLDAS database	
Latitude extent	-60° to 90°
Longitude extent	-180° to 180°
Spatial resolution	1.0°, 0.25°
Temporal resolution	3-hourly and monthly
Temporal coverage	GLDAS-2.0: 3Z January 1, 1948 – 21Z December 31, 2010
	GLDAS-2.1: 0Z March 1, 2001 - present for the 1.0° data 0Z February 24, 2000 – present for the 0.25° data
Dimension	360 (lon) x 150 (lat) for the 1.0° data 1440 (lon) x 600 (lat) for the 0.25° data
Origin (1st grid center)	(179.5W, 59.5S) for the 1.0° data (179.875W, 59.875S) for the 0.25° data
Land surface models	NOAH 3.3, GLDAS/NOAH

Output data: UTOPIA vs NOAH

Daily sensible heat flux SHF (W/m^2)
Time period: 1970 - 2010



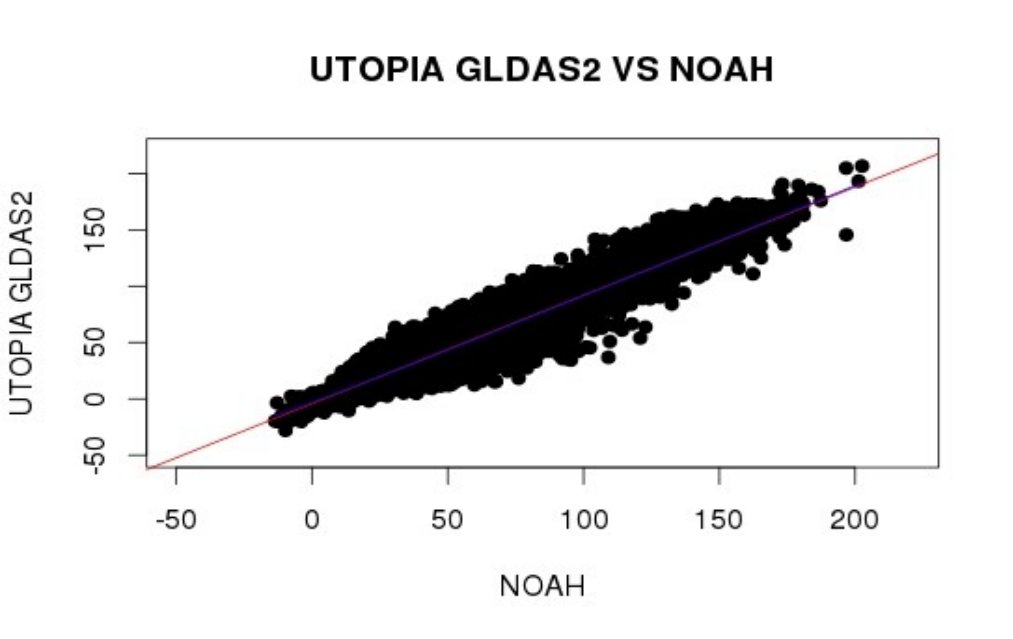


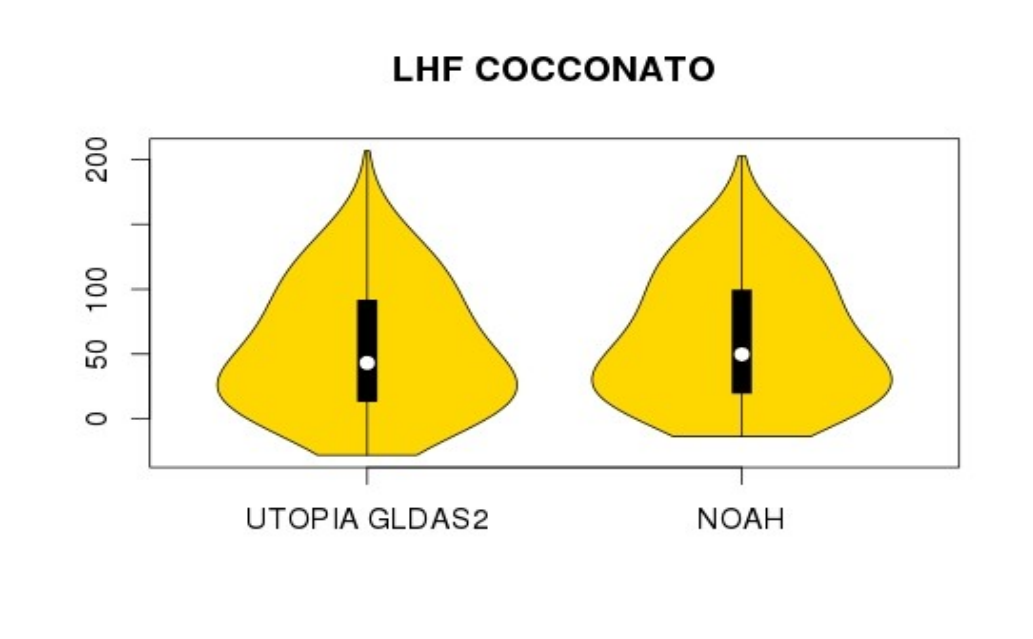
	mean	Standard deviation	median	min	max	Range	skew	kurtosis	Standard error
UTOPIA	3.8	17.9	1.3	-54.1	81.1	135.2	0.4	-0.2	0.2
NOAH	10.4	17.9	11.2	-57.4	66.5	124.3	-0.2	-0.4	0.2

R = 0.85

Output data: UTOPIA vs NOAH

Daily latent heat flux LHF (W/m^2)
Time period: 1970 - 2010



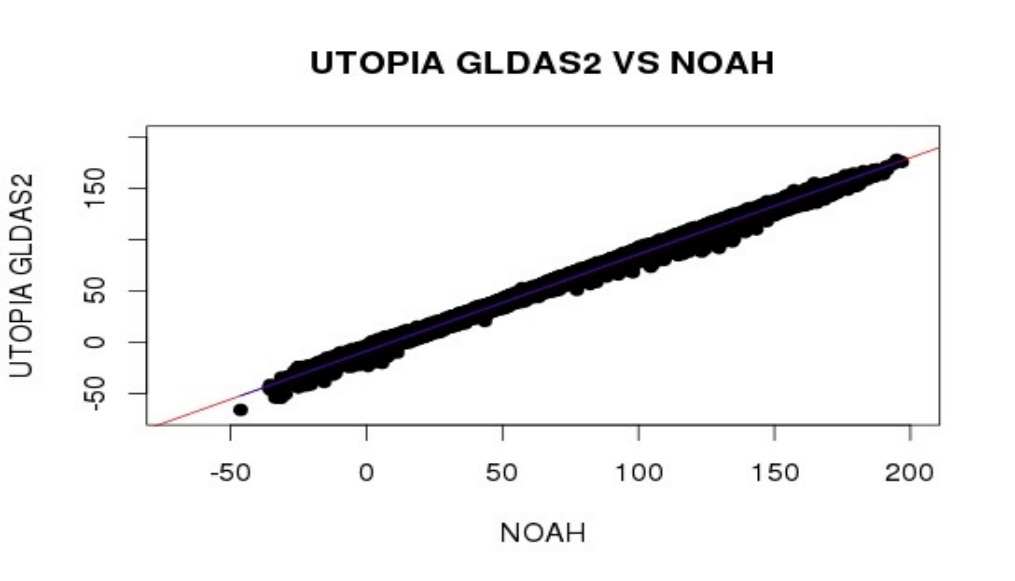


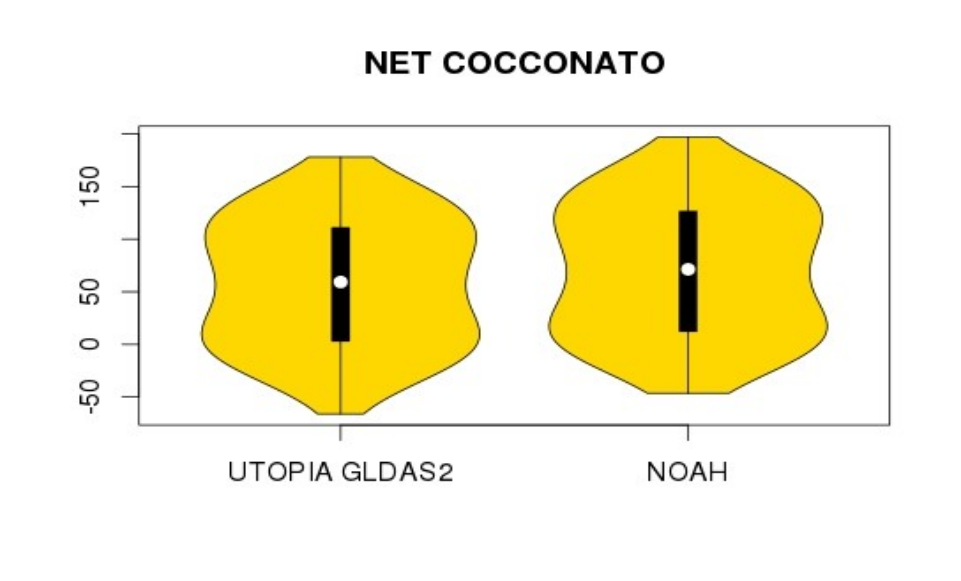
	mean	sd	median	min	max	Range	skew	kurtosis	se
UTOPIA	54.1	44.9	43.1	-28.0	206.5	234.6	0.6	-0.9	0.4
NOAH	60.7	45.7	49.8	-13.5	202.5	216.1	0.5	-1.0	0.4

R = 0.98

Output data: UTOPIA vs NOAH

Daily net radiation NET (W/m^2)
Time period: 1970 - 2010



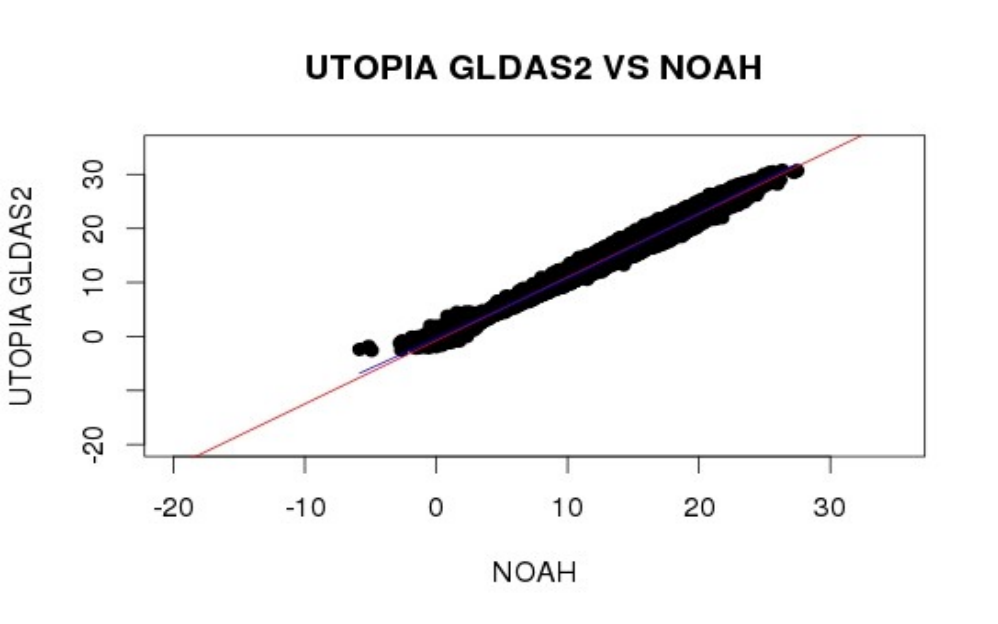


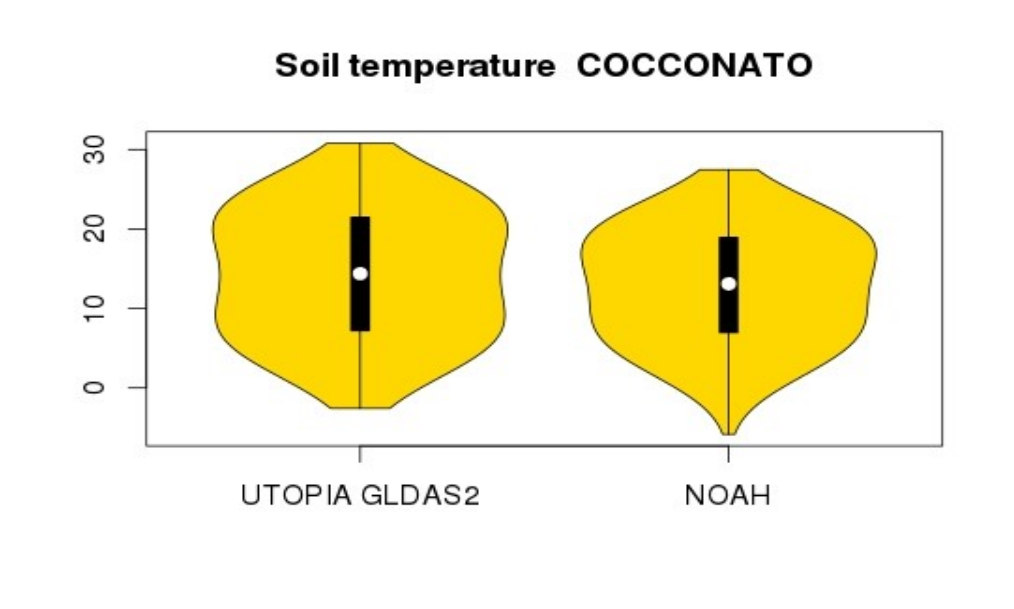
	mean	sd	median	min	max	Range	skew	kurtosis	se
UTOPIA	58.4	56.4	59.2	-66.1	178.0	244.1	0.04	-1.4	0.5
NOAH	71.0	59.7	71.3	-46.3	196.8	243.1	0.05	-1.4	0.5

R = 0.99

Output data: UTOPIA vs NOAH

Daily soil temperature (°C)
Time period: 1970 - 2010



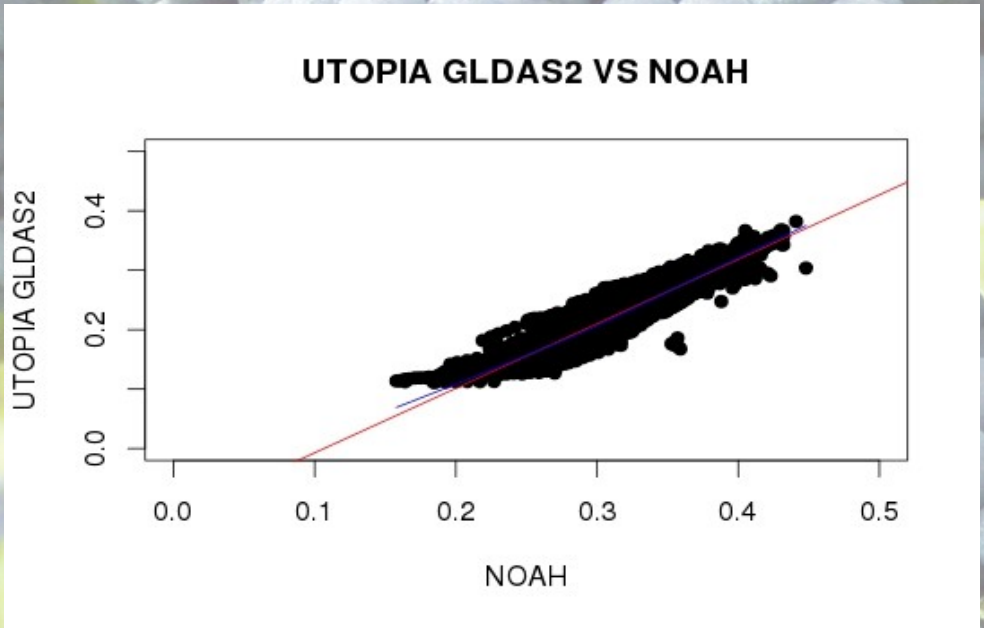


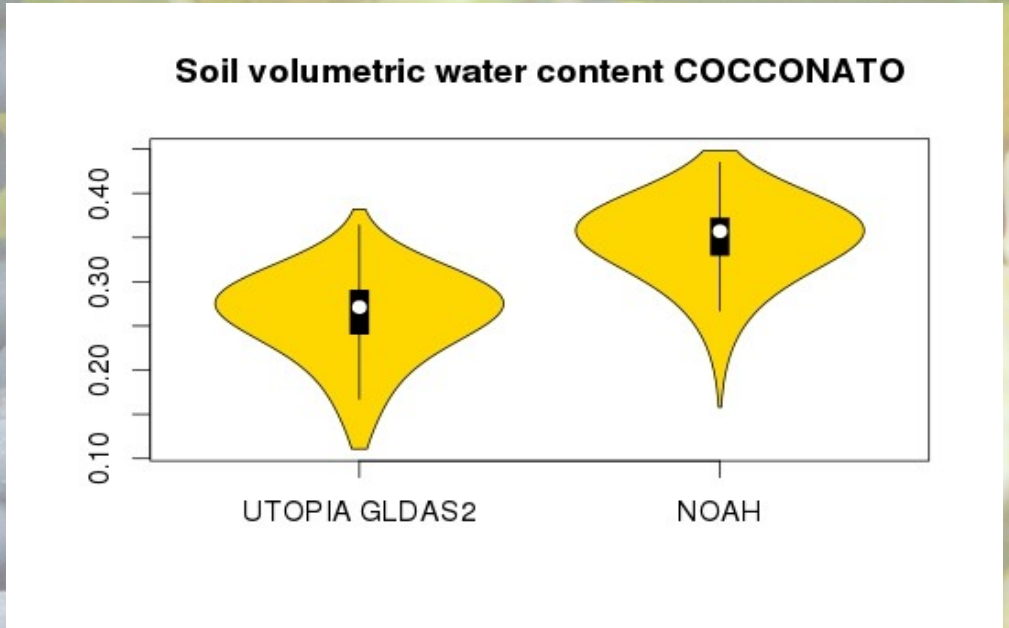
	mean	sd	median	min	max	Range	skew	kurtosis	se
UTOPIA	14.4	7.7	14.4	-2.6	30.8	33.4	-0.03	-1.3	0.06
NOAH	12.9	6.6	13.1	-5.8	27.8	33.3	-0.10	-1.3	0.05

R = 0.99

Output data: UTOPIA vs NOAH

Daily soil volumetric water content (m^3/m^3)
Time period: 1970 - 2010



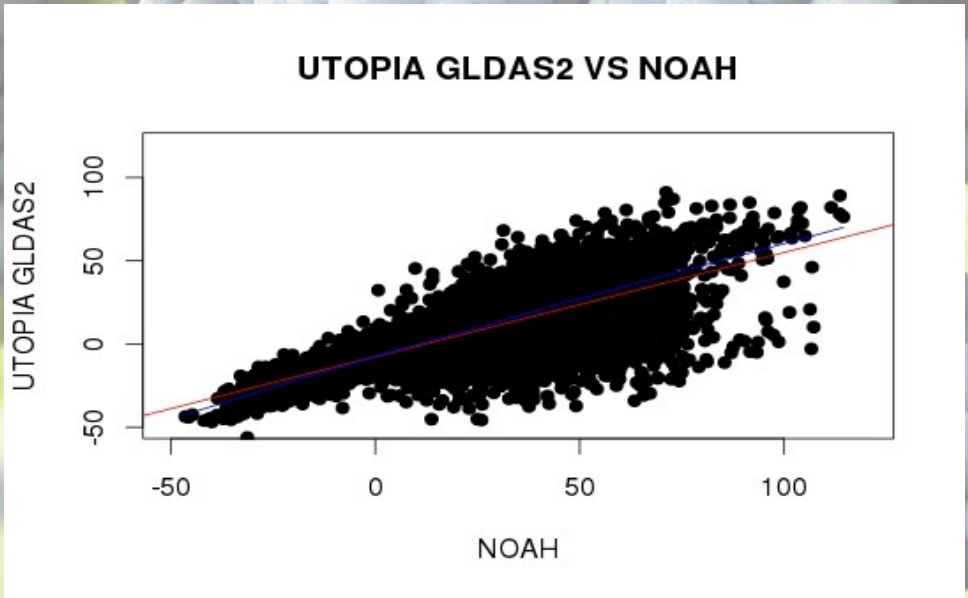


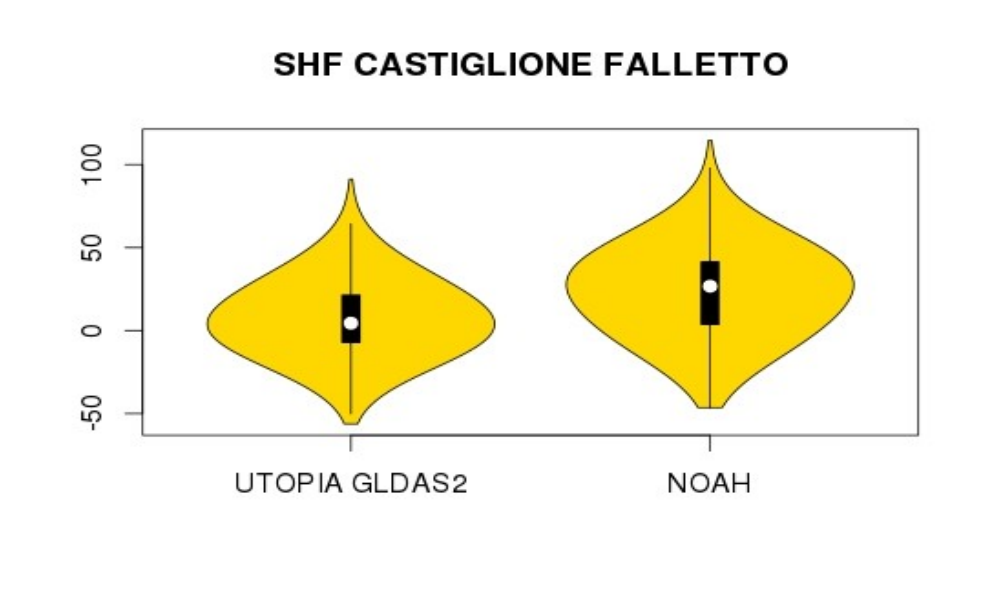
	mean	sd	median	min	max	Range	skew	kurtosis	se
UTOPIA	0.26	0.04	0.27	0.14	0.37	0.23	-0.91	0.28	0.0
NOAH	0.35	0.04	0.36	0.16	0.45	0.29	-1.23	1.72	0.0

R = 0.94

Output data: UTOPIA vs NOAH

Daily sensible heat flux SHF (W/m^2)
Time period: 1970 - 2010



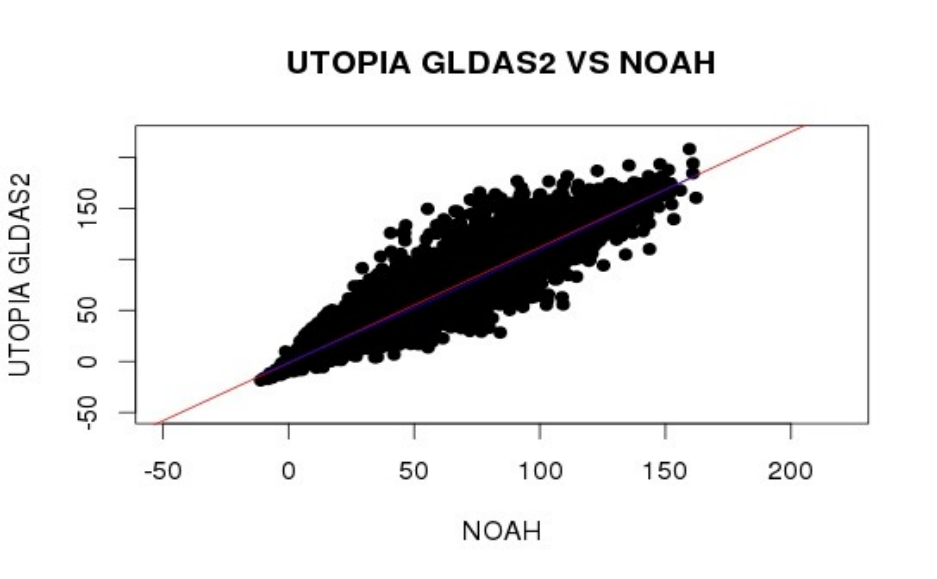


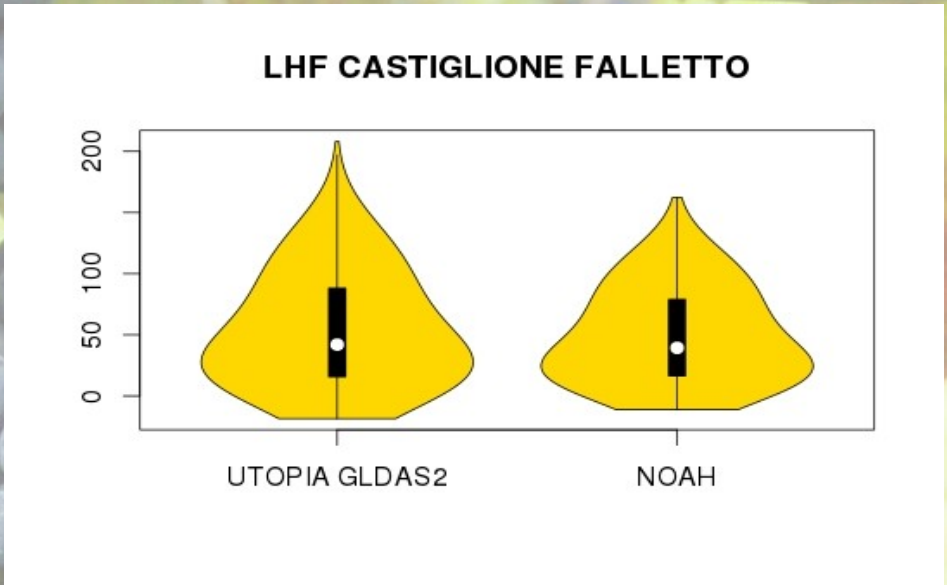
	mean	sd	median	min	max	Range	skew	kurtosis	se
UTOPIA	7.3	19.4	4.4	-56.2	91.2	147.4	0.4	-0.1	0.2
NOAH	23.7	23.6	26.7	-46.4	114.5	160.9	-0.1	-0.5	0.2

R = 0.76

Output data: UTOPIA vs NOAH

Daily latent heat flux LHF (W/m^2)
Time period: 1970 - 2010



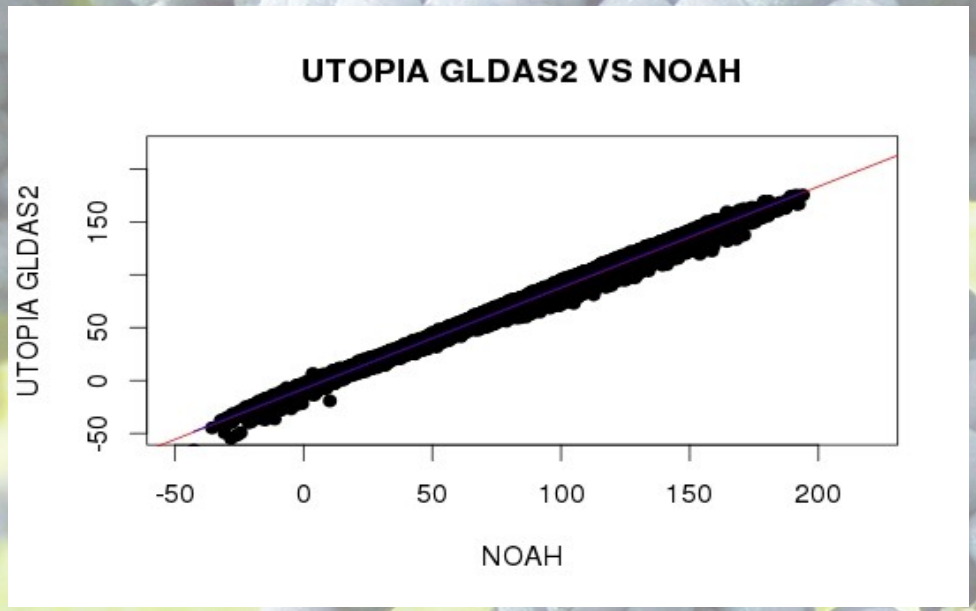


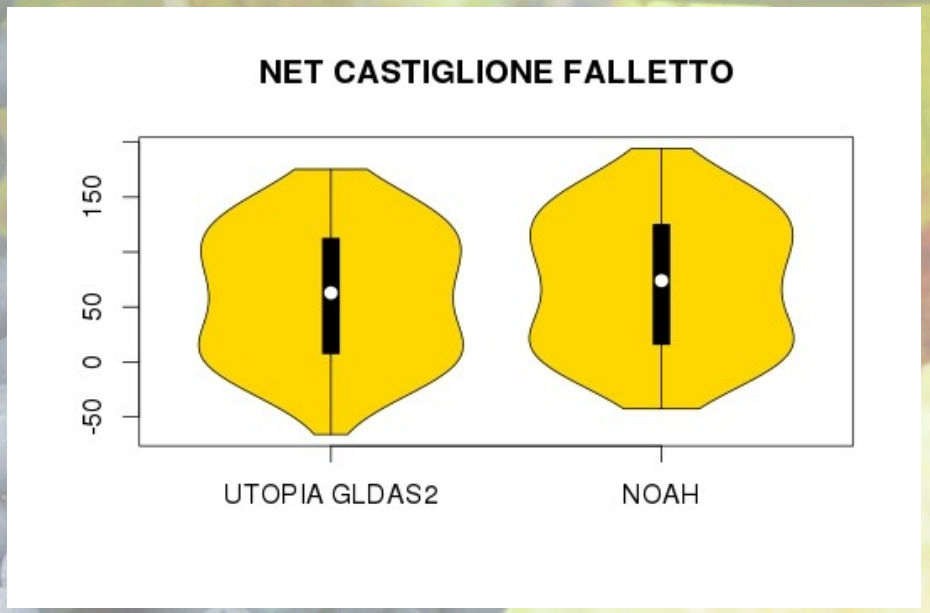
	mean	sd	median	min	max	Range	skew	kurtosis	se
UTOPIA	53.9	43.4	42.0	-18.5	208.0	226.5	0.6	-0.8	0.4
NOAH	48.9	36.8	39.3	-11.0	162.2	173.2	0.6	-0.9	0.3

R = 0.96

Output data: UTOPIA vs NOAH

Daily net radiation NET (W/m^2)
Time period: 1970 - 2010



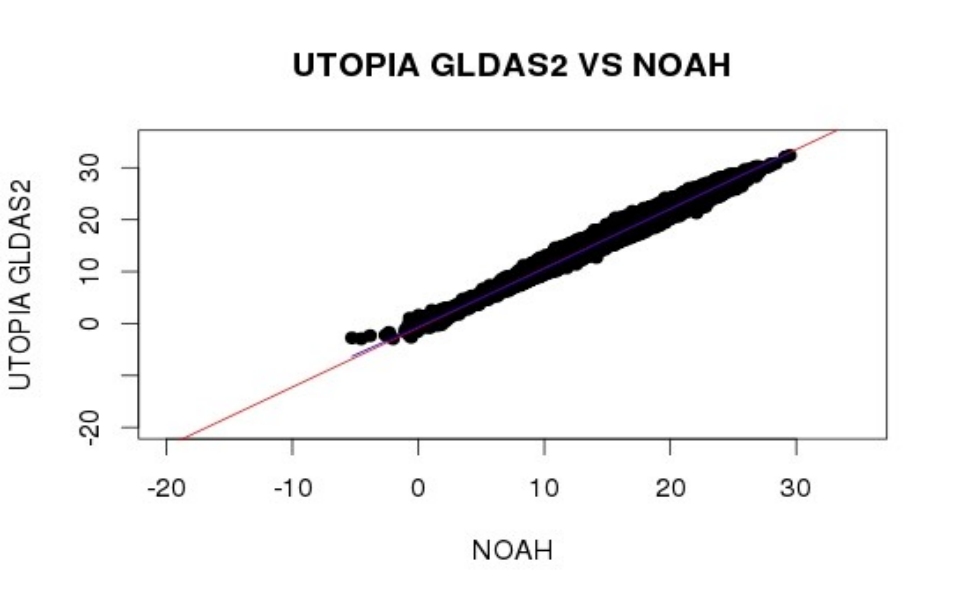


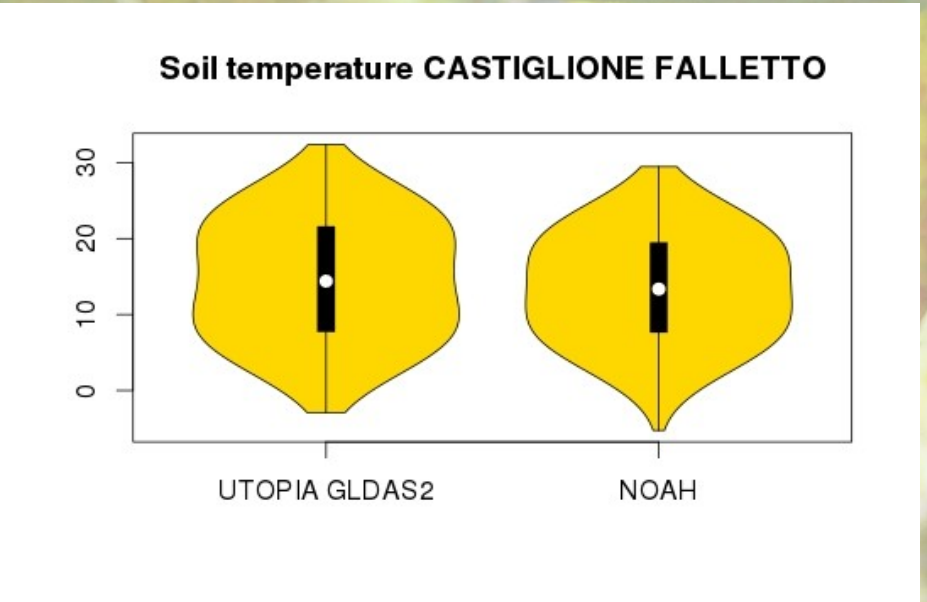
	mean	sd	median	min	max	Range	skew	kurtosis	se
UTOPIA	61.6	55.2	62.9	-65.9	175.3	241.3	0.04	-1.4	0.5
NOAH	72.7	57.7	73.9	-42.6	194.0	236.6	0.04	-1.4	0.5

R = 0.99

Output data: UTOPIA vs NOAH

Daily soil temperature (°C)
Time period: 1970 - 2010



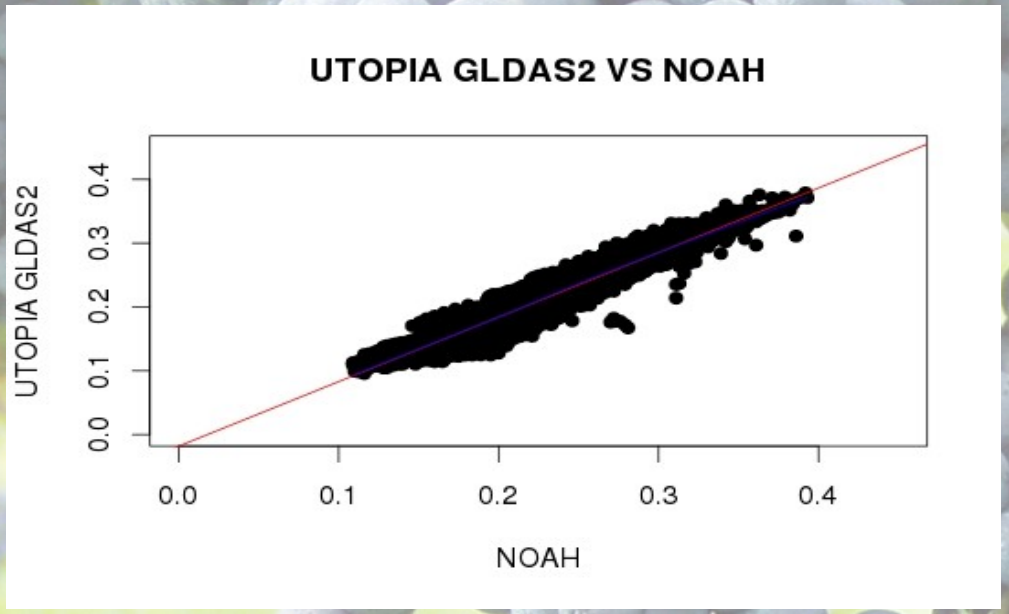


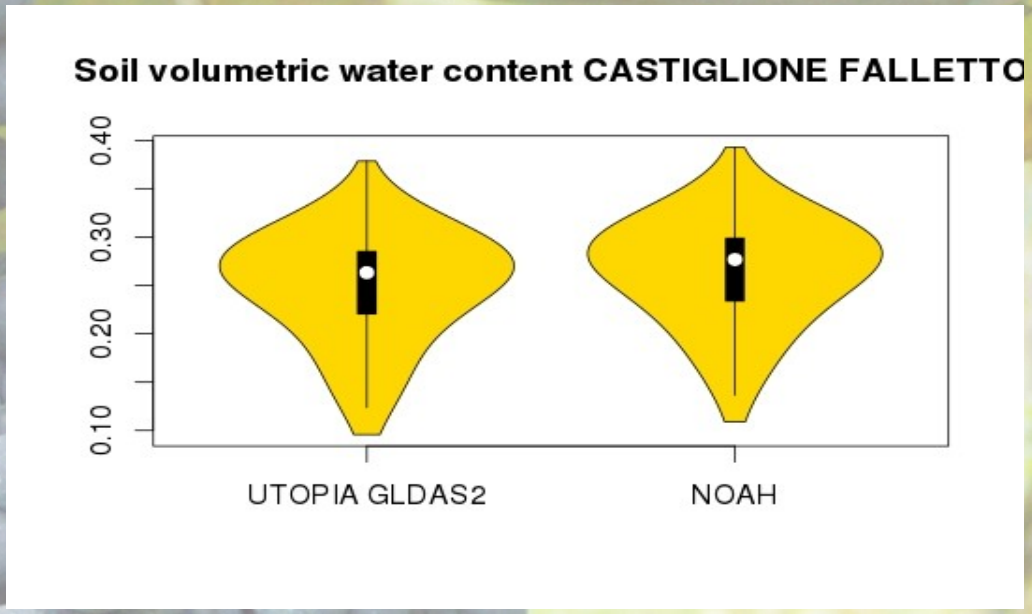
	mean	sd	median	min	max	Range	skew	kurtosis	se
UTOPIA	14.6	7.5	14.4	-2.9	32.4	35.3	0.02	-1.3	0.1
NOAH	13.5	6.5	13.4	-5.3	29.5	34.8	0.00	-1.2	0.1

R = 0.99

Output data: UTOPIA vs NOAH

Daily soil volumetric water content (m^3/m^3)
Time period: 1970 - 2010



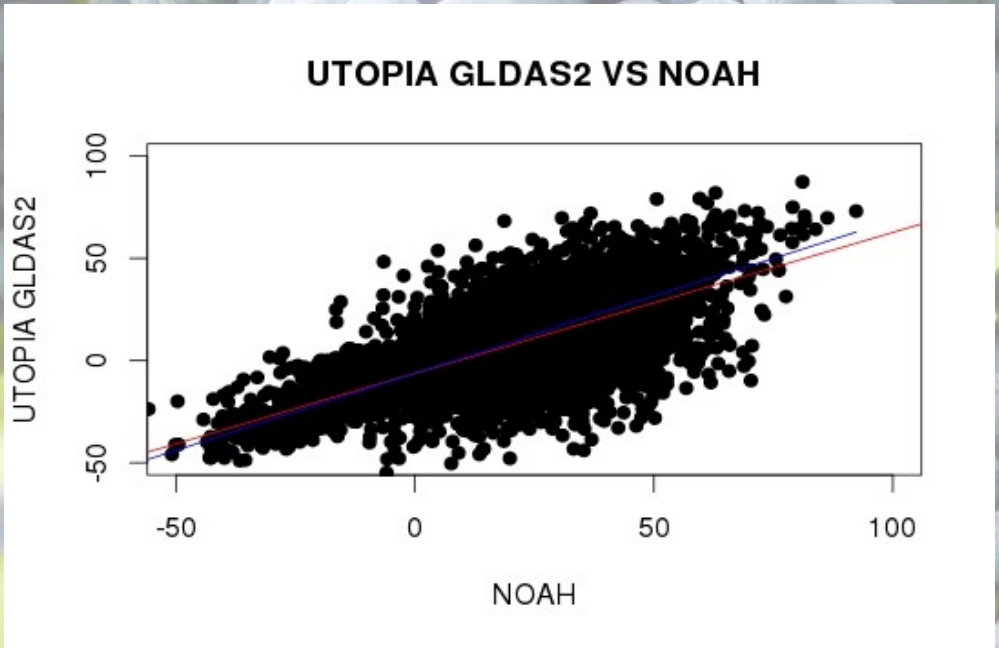


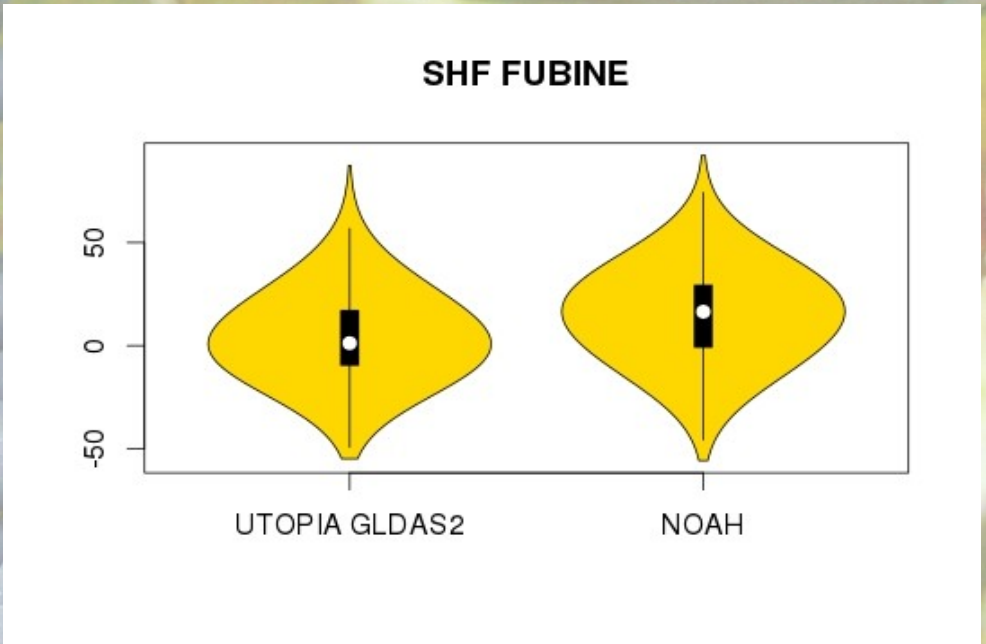
	mean	sd	median	min	max	Range	skew	kurtosis	se
UTOPIA	0.25	0.05	0.26	0.10	0.38	0.28	-0.85	-0.05	0.00
NOAH	0.26	0.05	0.28	0.11	0.39	0.28	-0.79	0.07	0.00

R = 0.98

Output data: UTOPIA vs NOAH

Daily sensible heat flux SHF (W/m^2)
Time period: 1970 - 2010



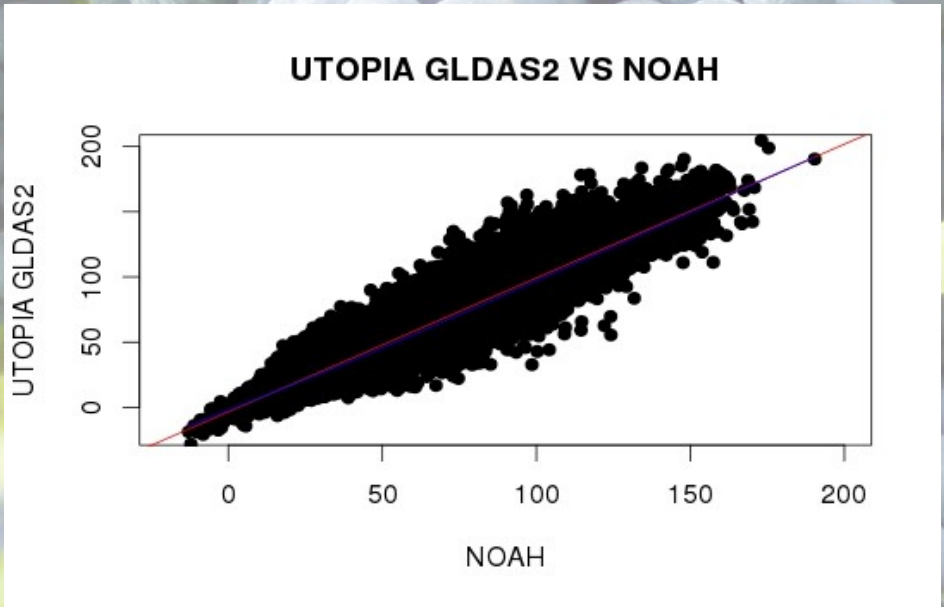


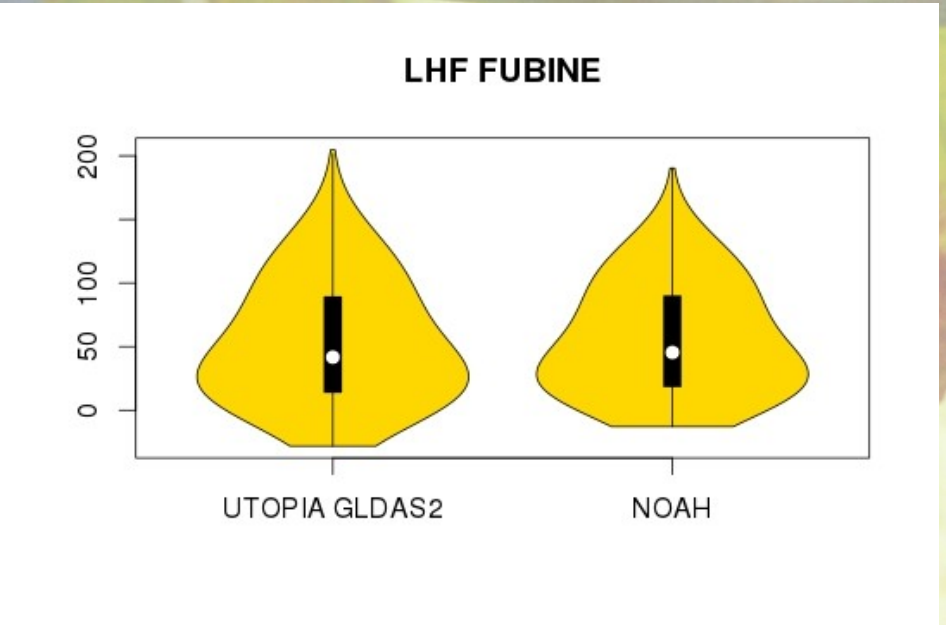
	mean	sd	median	min	max	Range	skew	kurtosis	se
UTOPIA	4.0	18.3	1.2	-54.9	87.4	142.3	0.5	0.03	0.2
NOAH	14.8	19.6	16.5	-55.8	92.3	148.1	-0.1	-0.4	0.2

R = 0.74

Output data: UTOPIA vs NOAH

Daily latent heat flux LHF (W/m^2)
Time period: 1970 - 2010



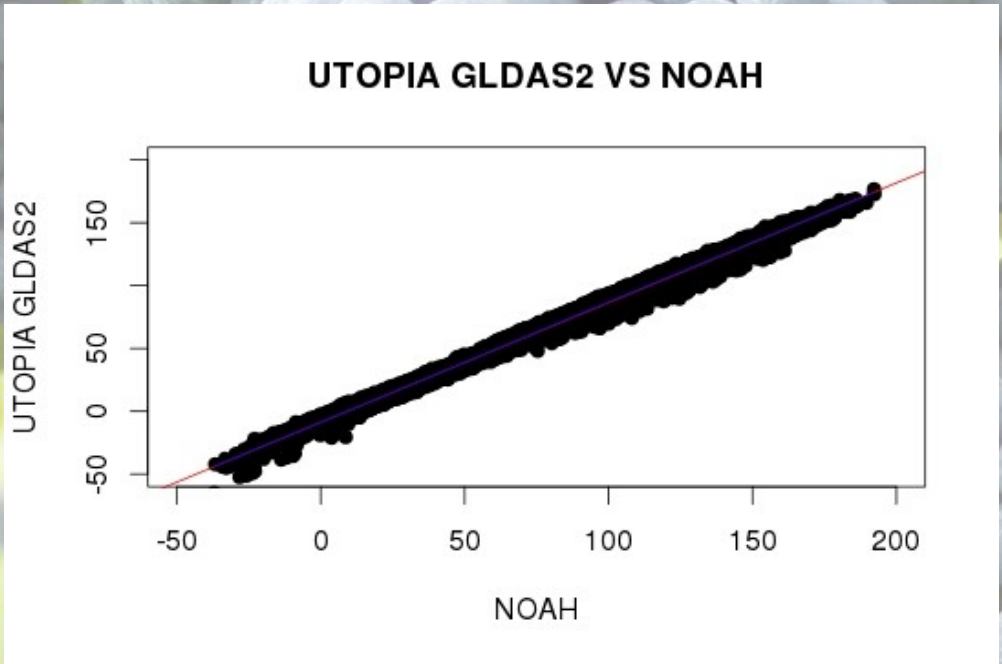


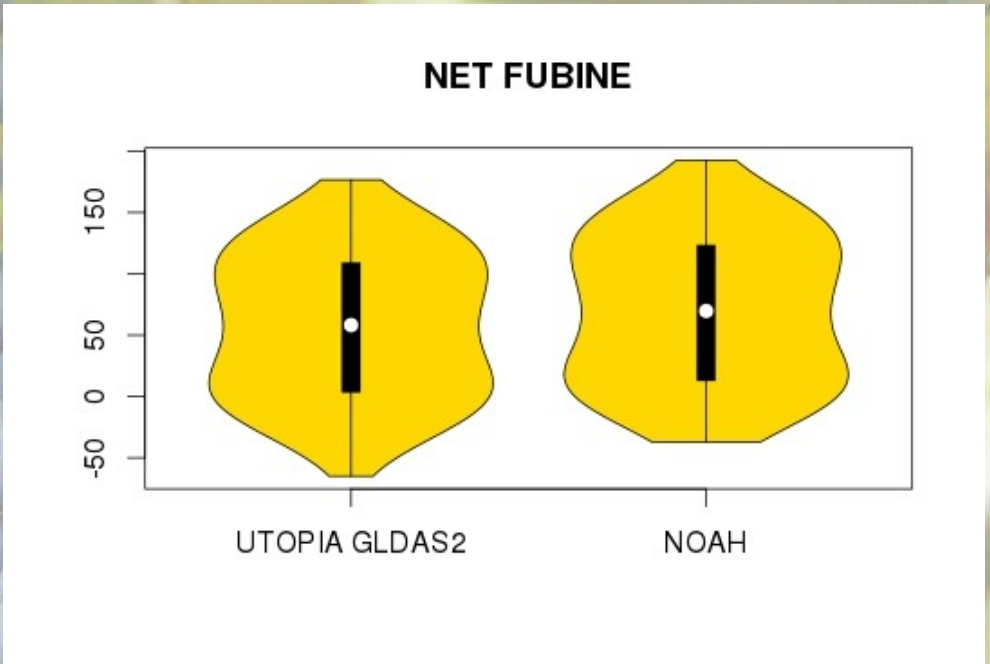
	mean	sd	median	min	max	Range	skew	kurtosis	se
UTOPIA	53.3	44.0	41.8	-28.2	204.7	232.8	0.6	-0.8	0.4
NOAH	55.2	41.1	45.5	-12.9	190.4	203.2	0.5	-1.0	0.3

R = 0.96

Output data: UTOPIA vs NOAH

Daily net radiation NET (W/m^2)
Time period: 1970 - 2010



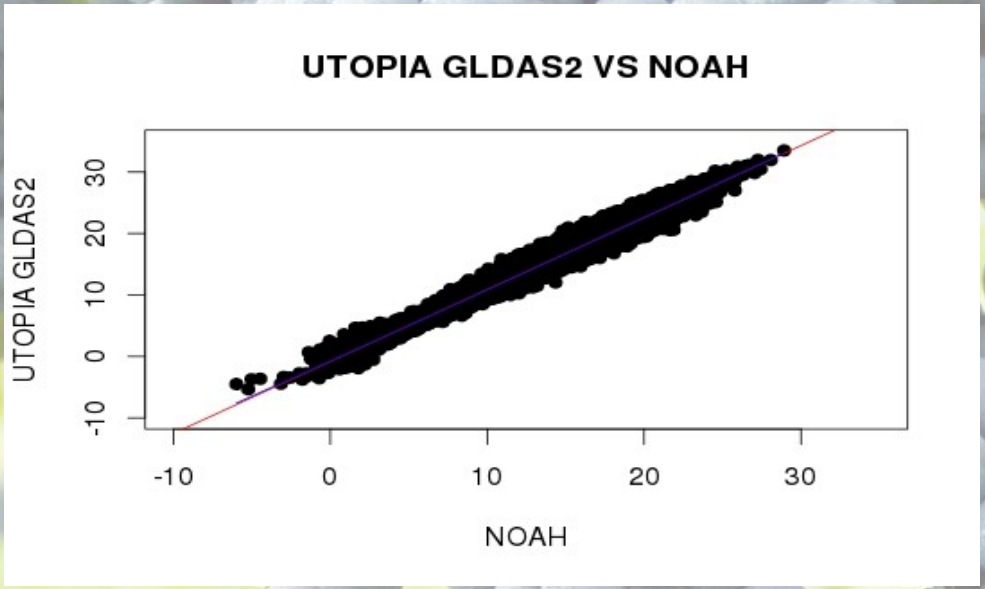


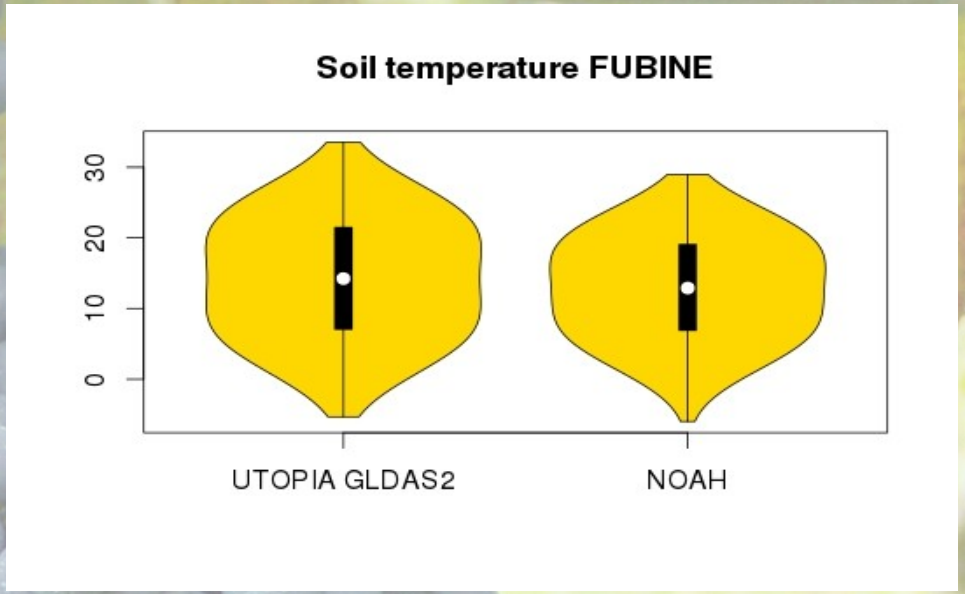
	mean	sd	median	min	max	Range	skew	kurtosis	se
UTOPIA	57.7	55.1	58.2	-65.0	176.7	241.7	0.1	-1.4	0.5
NOAH	69.8	57.8	69.7	-37.0	192.3	229.3	0.1	-1.4	0.5

R = 0.99

Output data: UTOPIA vs NOAH

Daily soil temperature (°C)
Time period: 1970 - 2010



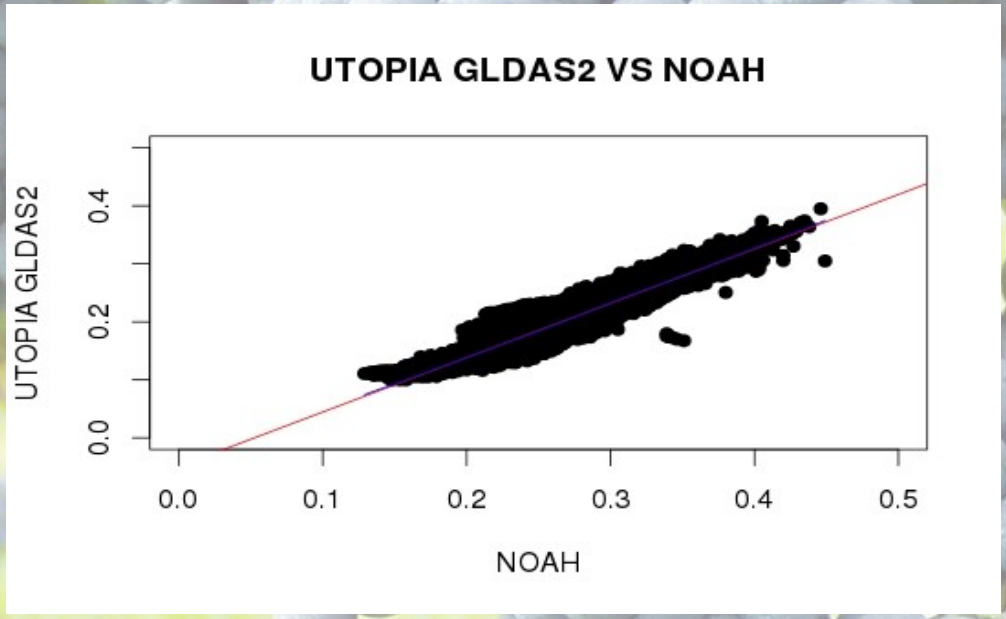


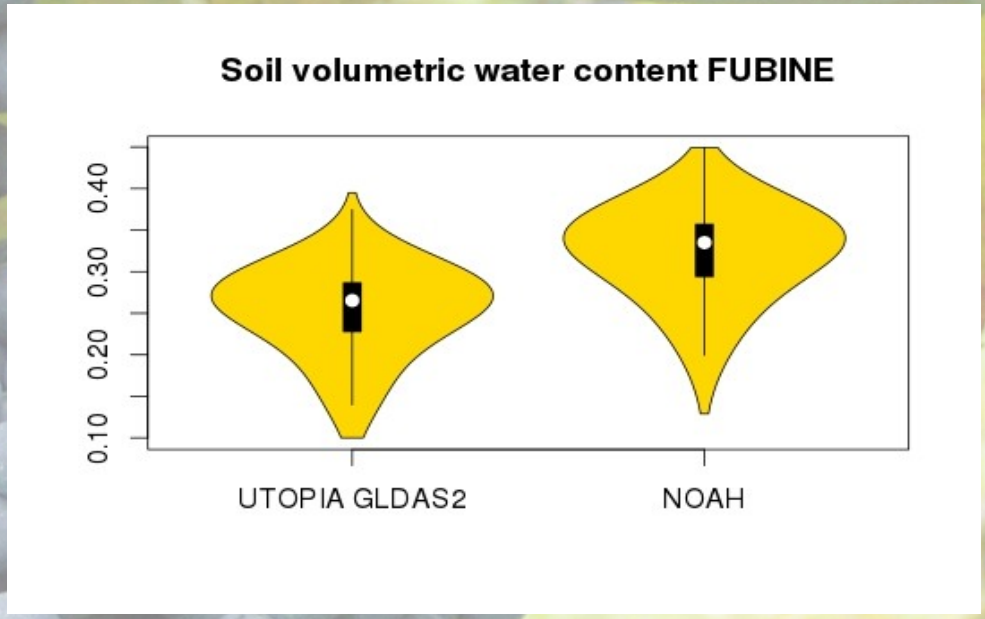
	mean	sd	median	min	max	Range	skew	kurtosis	se
UTOPIA	14.3	7.9	14.2	-5.3	33.5	38.8	-0.02	-1.3	0.1
NOAH	12.9	6.7	12.9	-6.0	28.9	34.9	-0.1	-1.2	0.1

R = 0.99

Output data: UTOPIA vs NOAH

Daily soil volumetric water content (m^3/m^3)
Time period: 1970 - 2010



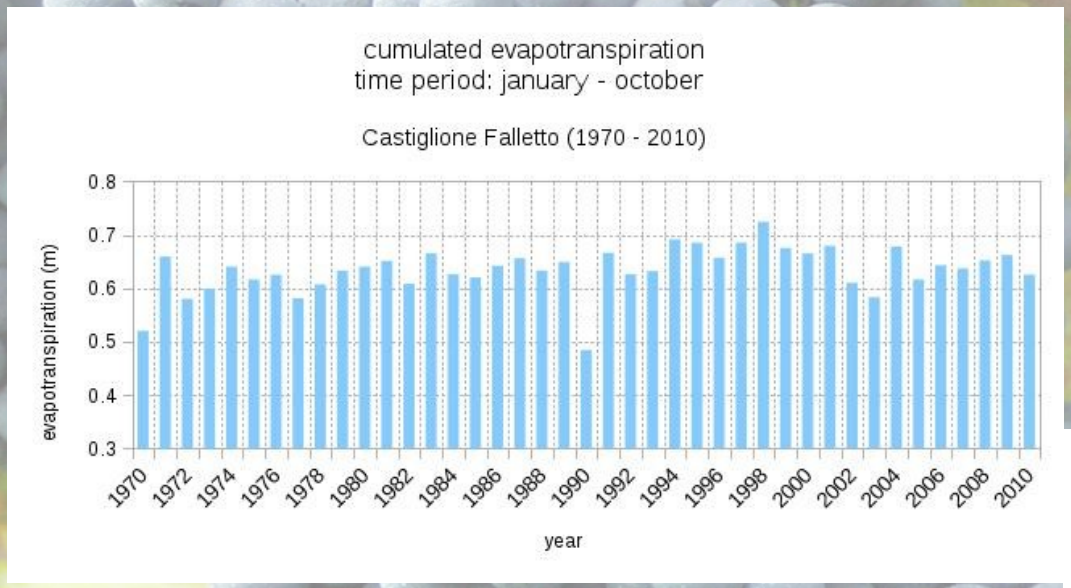


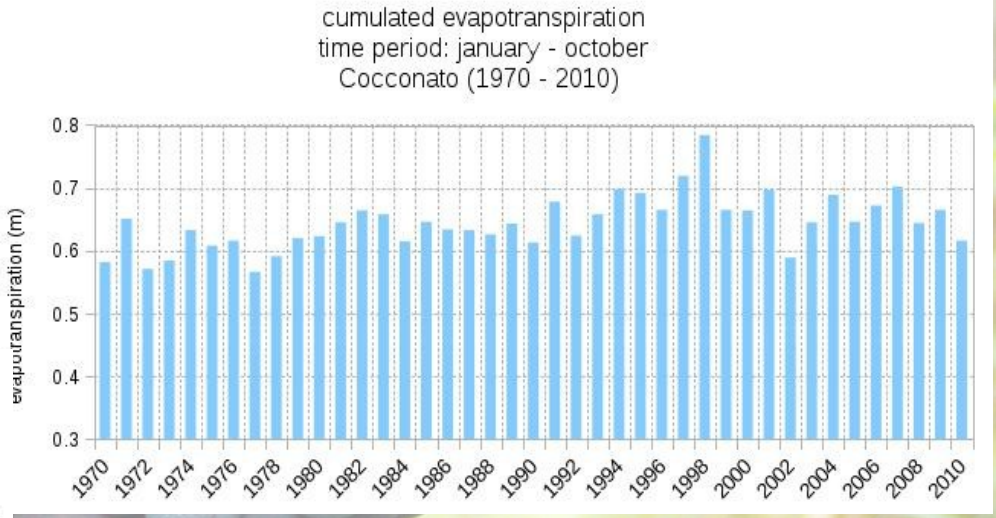
	mean	sd	median	min	max	Range	skew	kurtosis	se
UTOPIA	0.25	0.05	0.27	0.10	0.40	0.30	-0.91	0.23	0.00
NOAH	0.32	0.05	0.34	0.13	0.45	0.32	-0.95	0.47	0.00

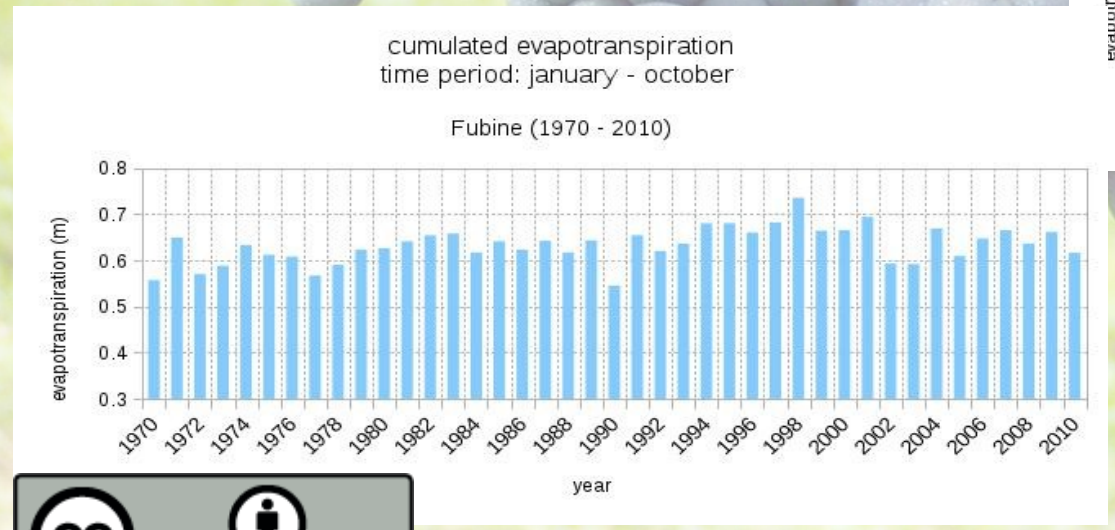
R = 0.97

Output data: UTOPIA

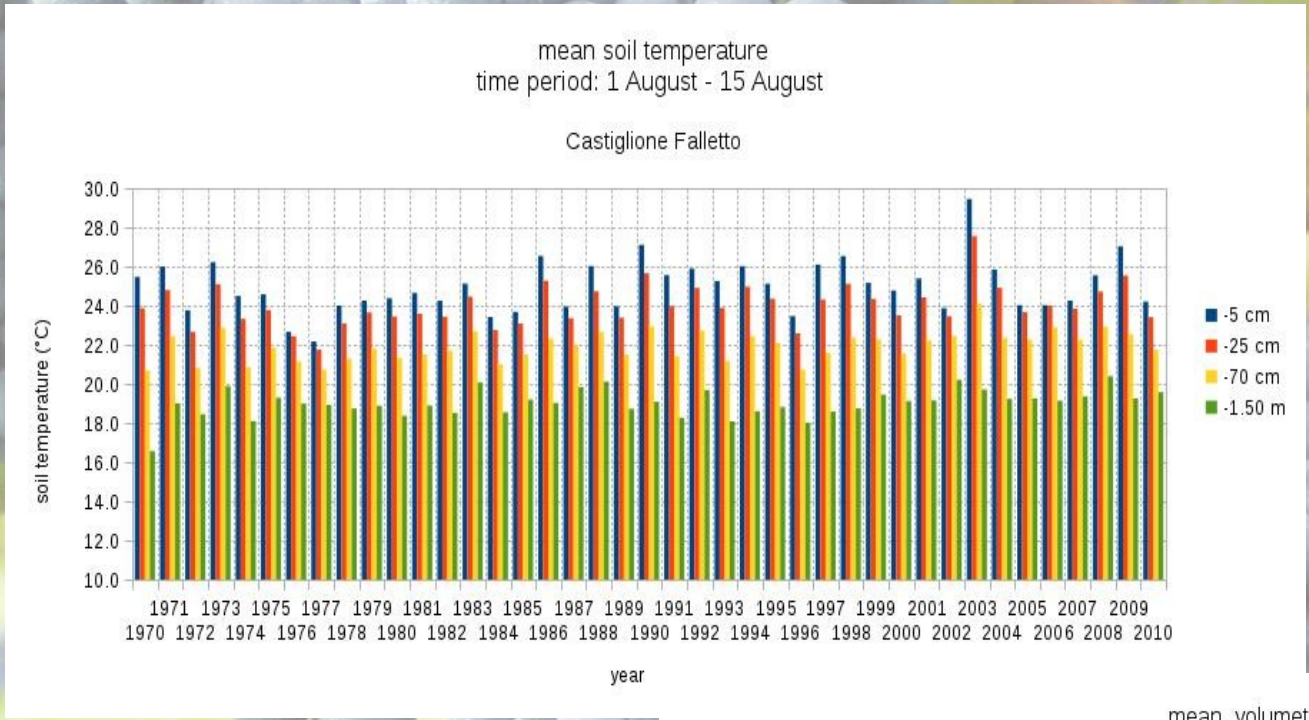
Simulation of variables of agronomic interest: the <u>evapotranspiration</u>







Output data: UTOPIA

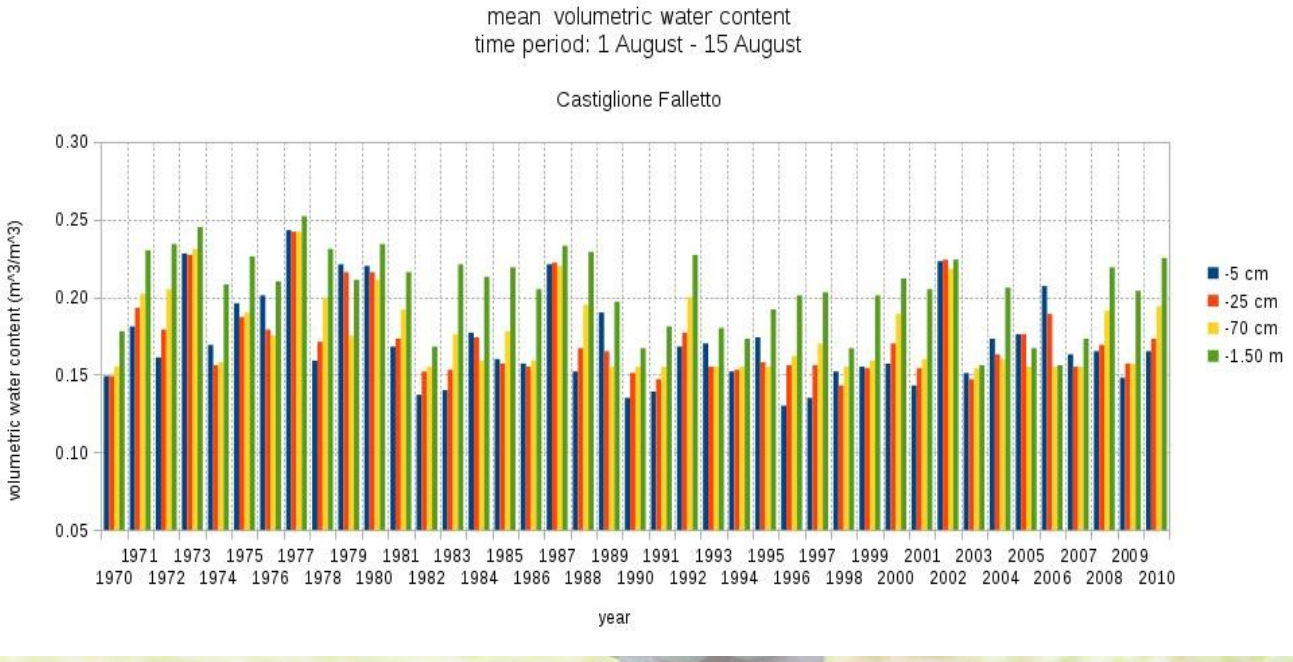


Castiglione Falletto
Simulation of variables of agronomic interest: soil temperature and volumetric water content

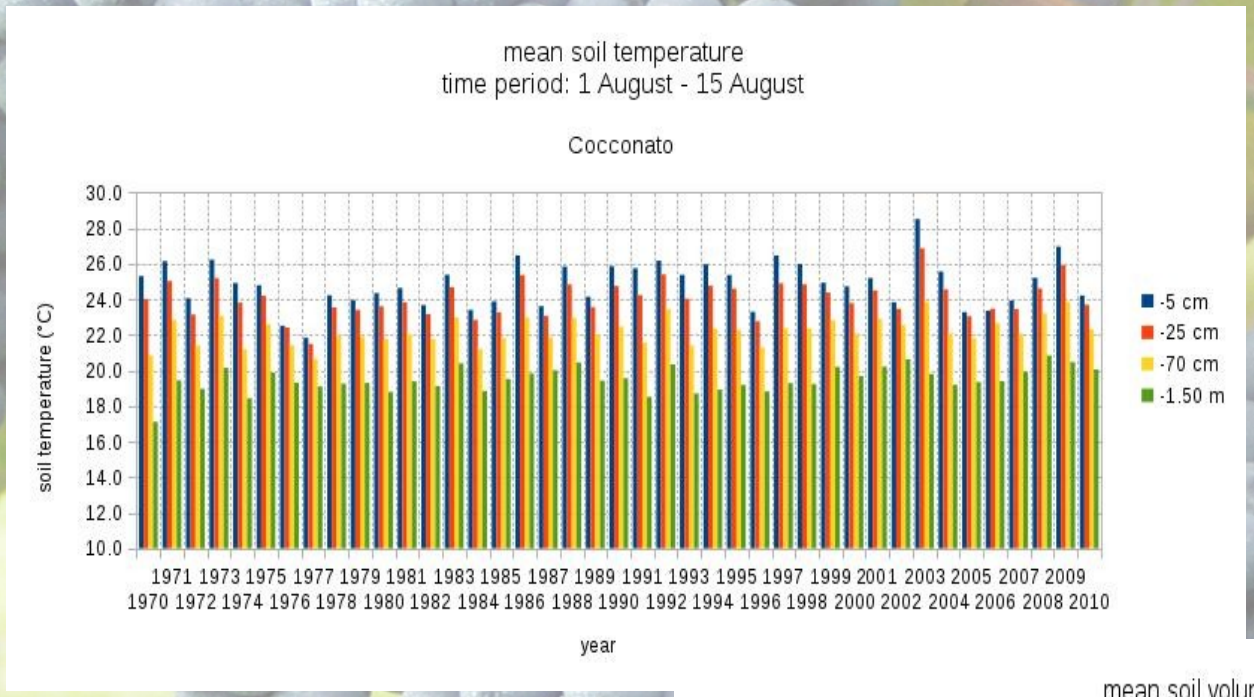
Soil category: loam

Volumetric water content at field capacity: 0.313 (m^3/m^3)

Volumetric water content at wilting point: 0.155 (m^3/m^3)



Output data: UTOPIA

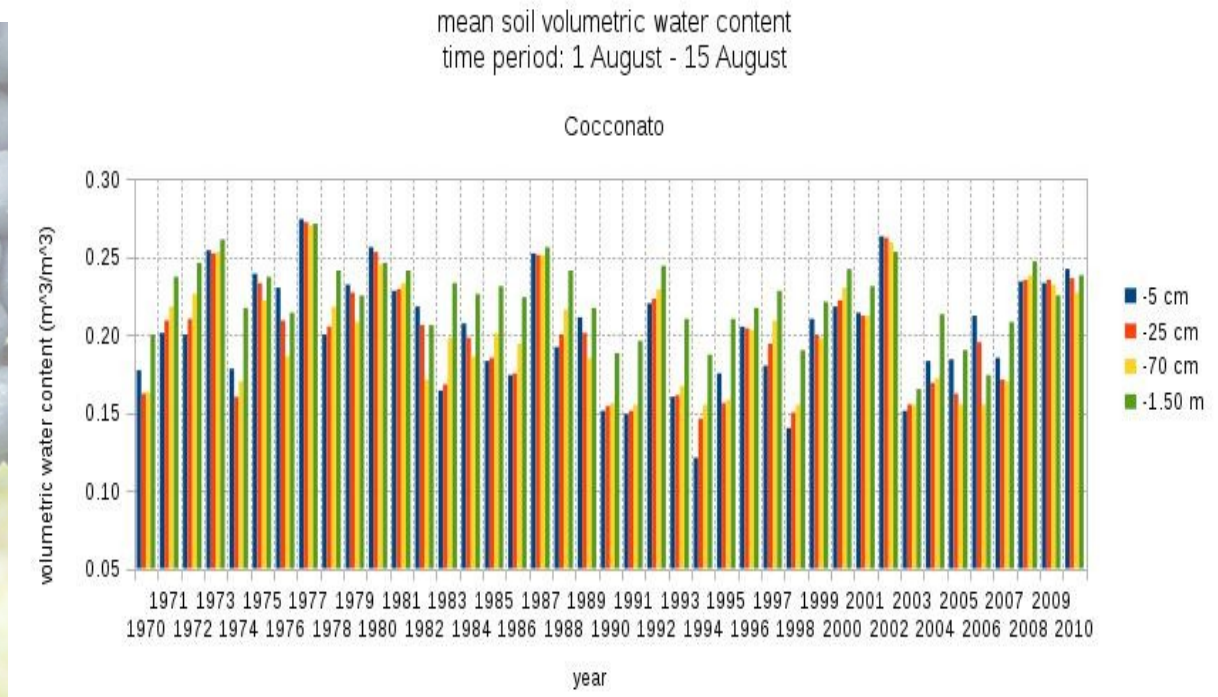


Cocconato
Simulation of variables of agronomic interest: the soil temperature and the volumetric water content

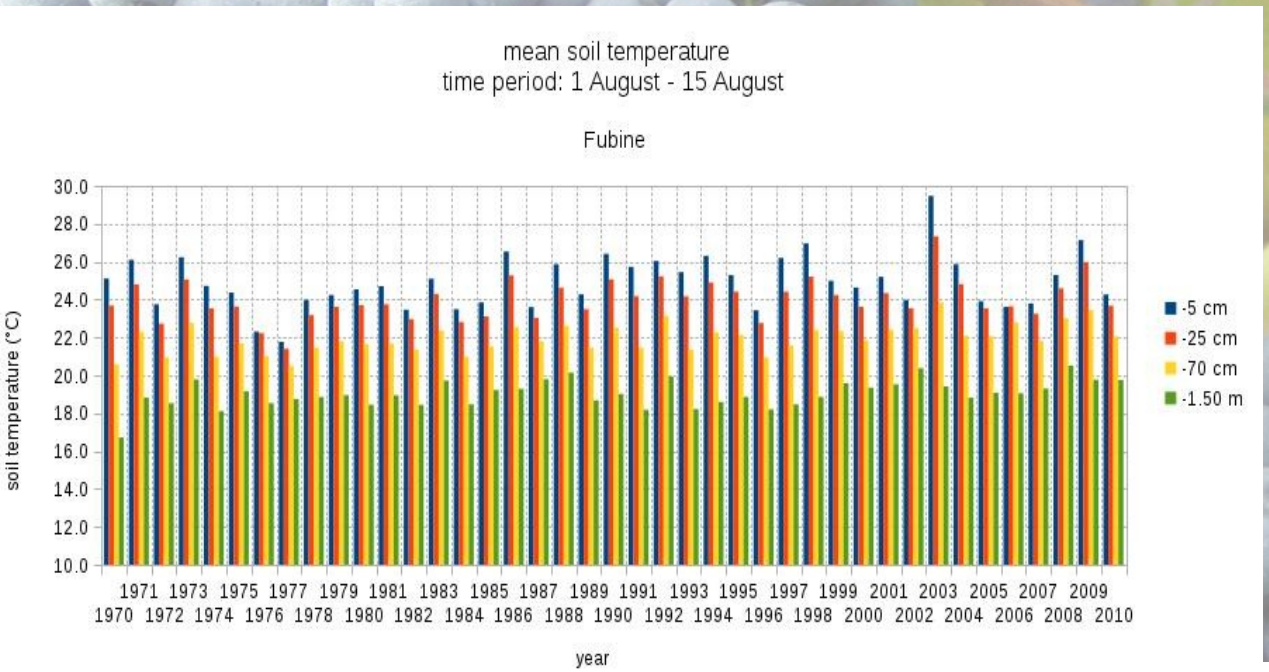
Soil category: loam

Volumetric water content at field capacity: 0.313 (m^3/m^3)

Volumetric water content at wilting point: 0.155 (m^3/m^3)



Output data: UTOPIA

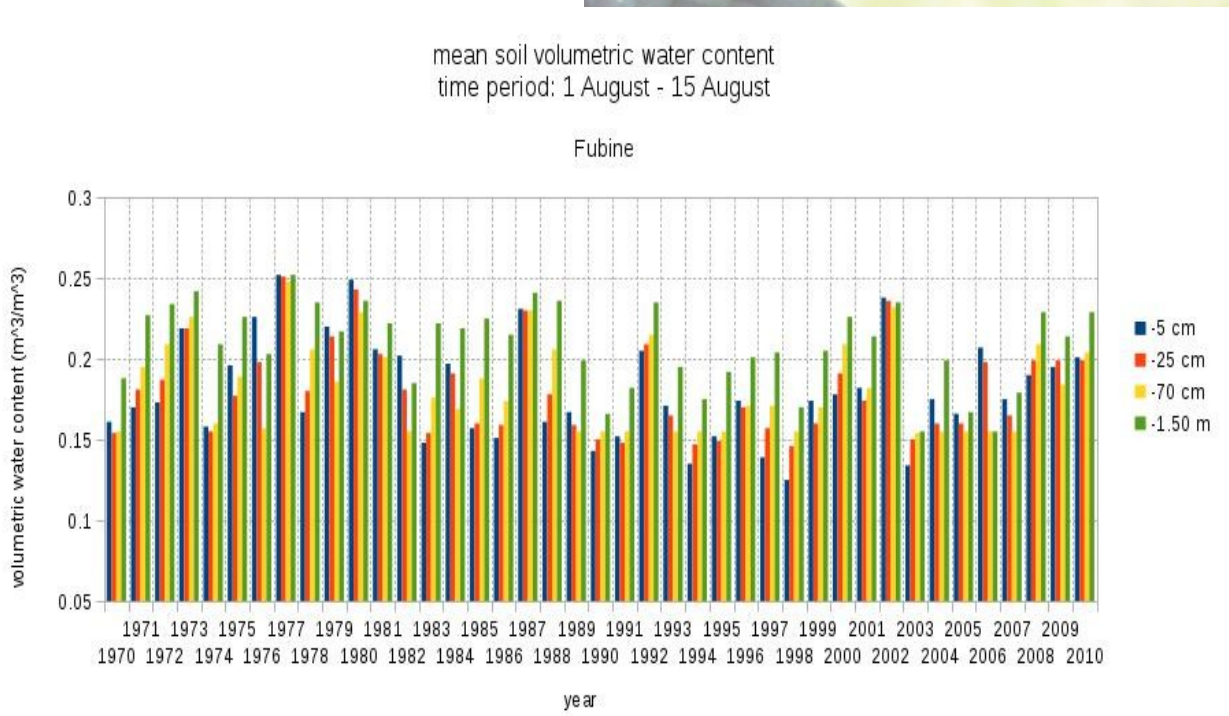


Fubine
Simulation of variables of agronomic interest: the soil temperature and the volumetric water content

Soil category: loam

Volumetric water content at field capacity: 0.313 (m^3/m^3)

Volumetric water content at wilting point: 0.155 (m^3/m^3)



VINEYARD CROP model

(Andreoli V., Cassardo C., 2016)

Measured data

- Air temperature(a),
- Air relative humidity(b),
- Solar global radiation(c),
- Photosynthetically active radiation(d),
- Soil temperature(e),
- Soil water content(f),
- Wind speed and direction(g),
- Rainfall(h),
- Leaf wetness(i)

Vineyard and soil characteristics

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

VINEYARD CROP MODEL

Main model outputs

- Predawn leaf water potential(f,h),
- Timing of the main phenological phases (dormancy break, budburst...)(a,b,c,e,f,g),
- Leaf development(a,f),
- Yield(a,d,f),
- Sugar concentration(a,b,c,e,f,g).

-I.Cortazar Atauri et al., Asynchromous dynamics of grapevine (VITIS VINIFERA) maturation: experimental study for a modelling approach. *J. Int. Sci. Vigne Vin*, 2009, 43, n.2, 83-97
-G.Cola et al.,Description and testing of a weather-based model for predicting phenology, canopy development and source-sink balance in Vitis Vinifera L. cv. Barbera. *Agricultural and Forest Meteorology* 184 (2014) 117-136
-A.Singels et al.,Refinement and validation of the PUTU wheat crop growth model 2.leaf area expansion. *S.Afr.J.Plant Soil* 1991, 8(2)

The CROP model simulations

The long term simulations were carried out using as input data:

UTOPIA long term output:

- soil temperature
- soil water content
- air relative humidity
- leaf wetness

and GLDAS2.0 data:

- air temperature
- solar global radiation
- photosyntetically active radiation
- wind speed and direction
- rainfall
- atmospheric pressure

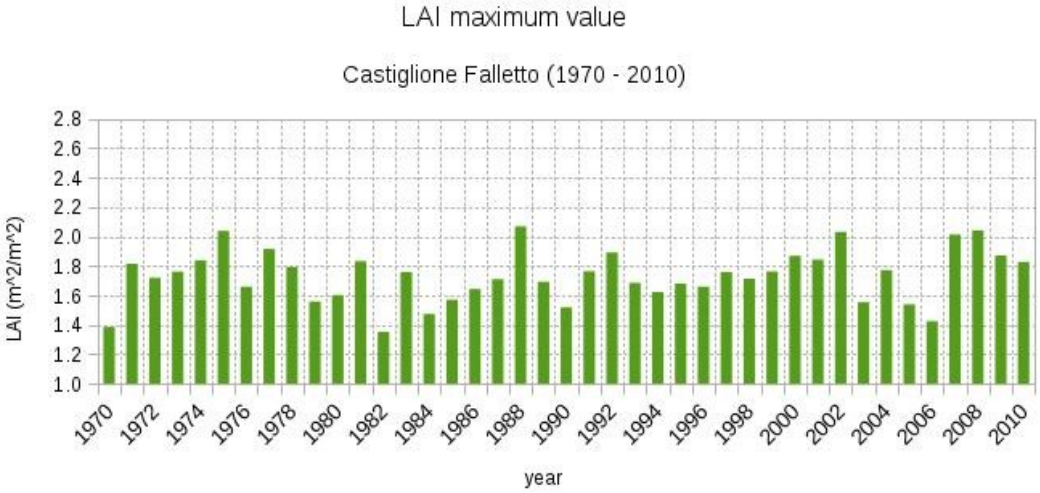
Time period: 1970 - 2010

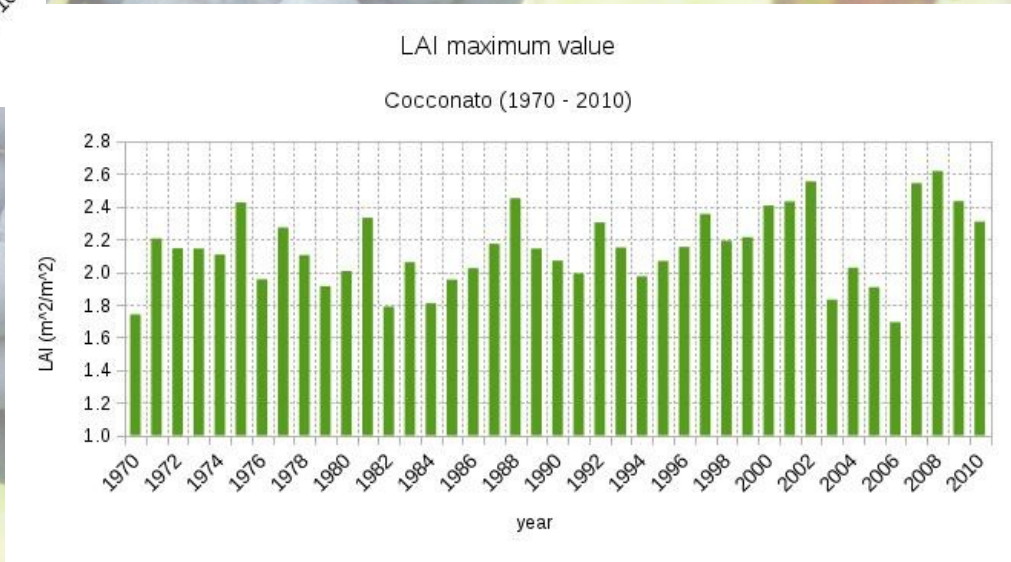
Selected sites: Cocconato, Fubine and Castiglione Falletto

Output data: VINEYARD CROP model

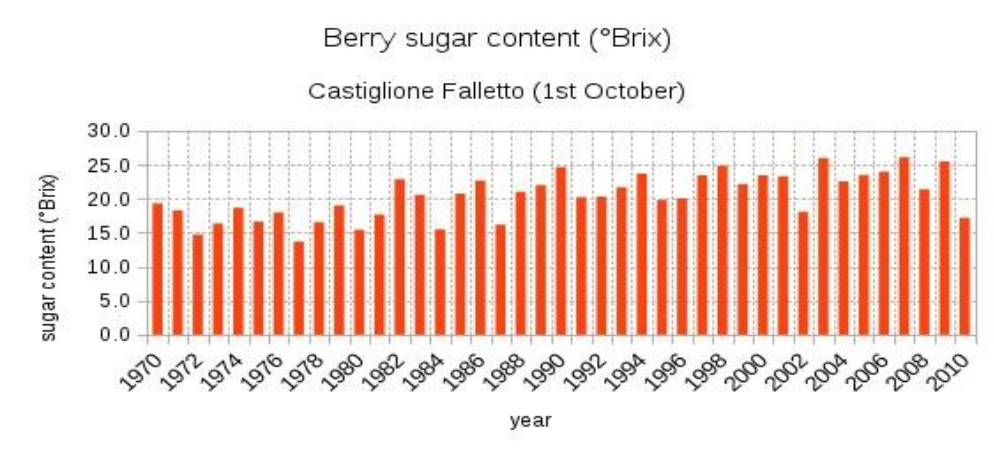
Simulation of Leaf Area Index maximum value

The high LAI value of Cocconato site can be mainly associated with the higher soil moisture value



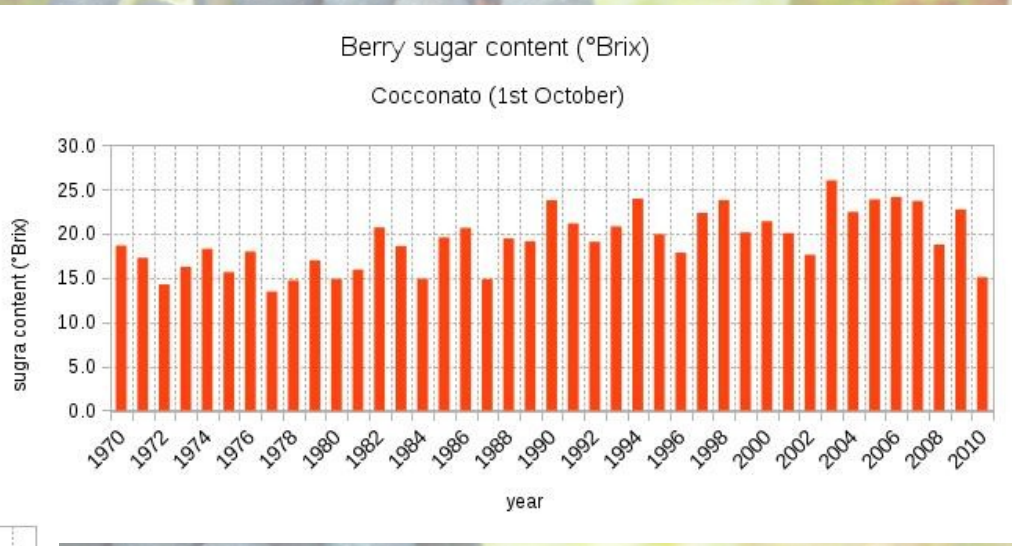


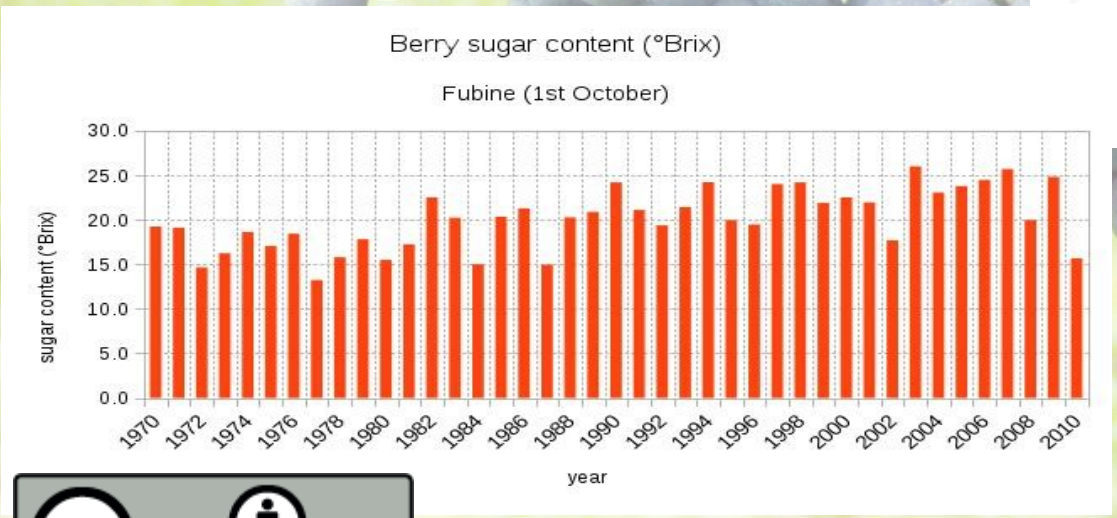
Output data: VINEYARD CROP model



Simulation of berry sugar content (October 1st)

Increasing trend of berry sugar content due to the higher air temperature value

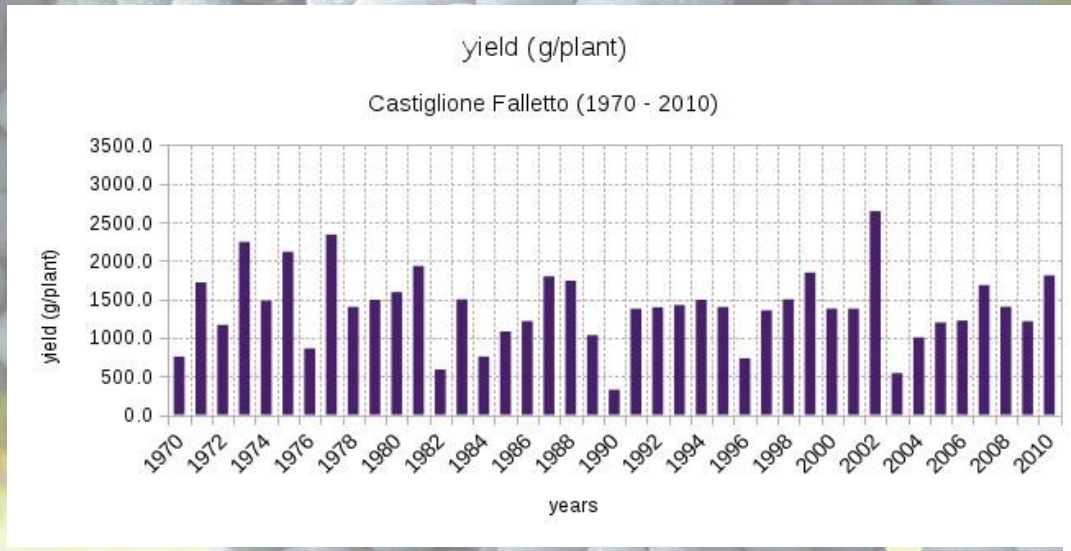


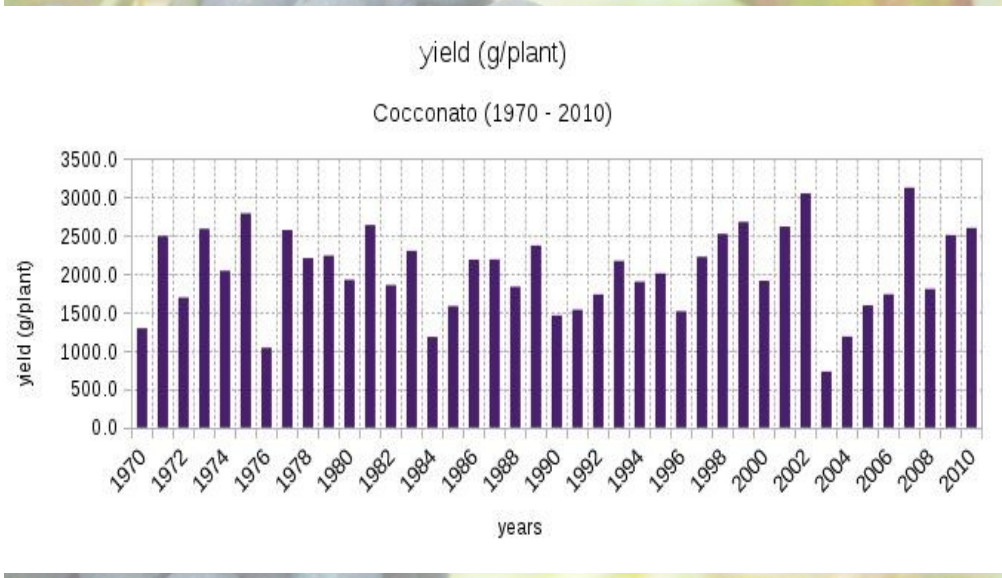


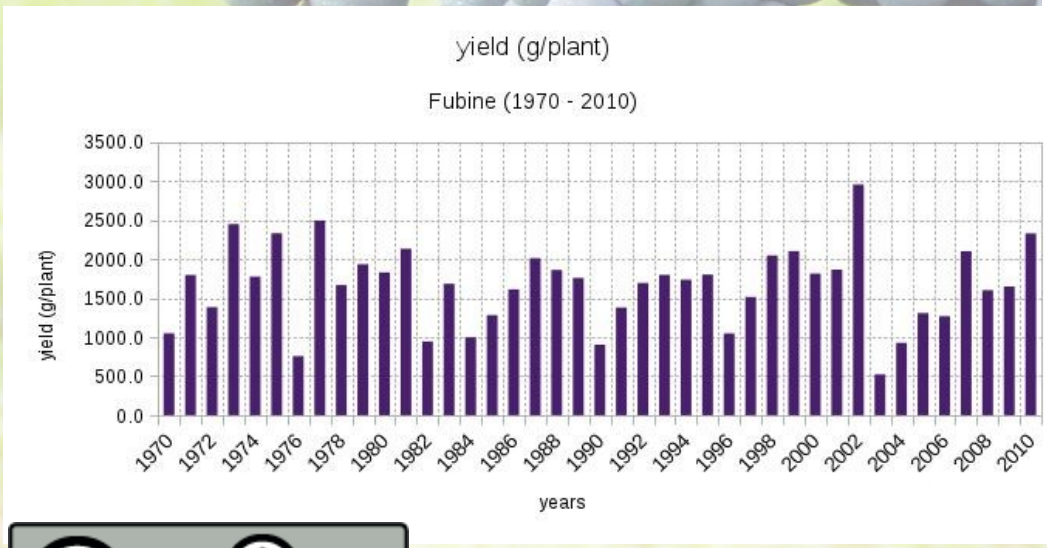
The low sugar content value of Cocconato site can be mainly associated with the higher soil moisture

Output data: VINEYARD CROP model

Simulation of yield/vine





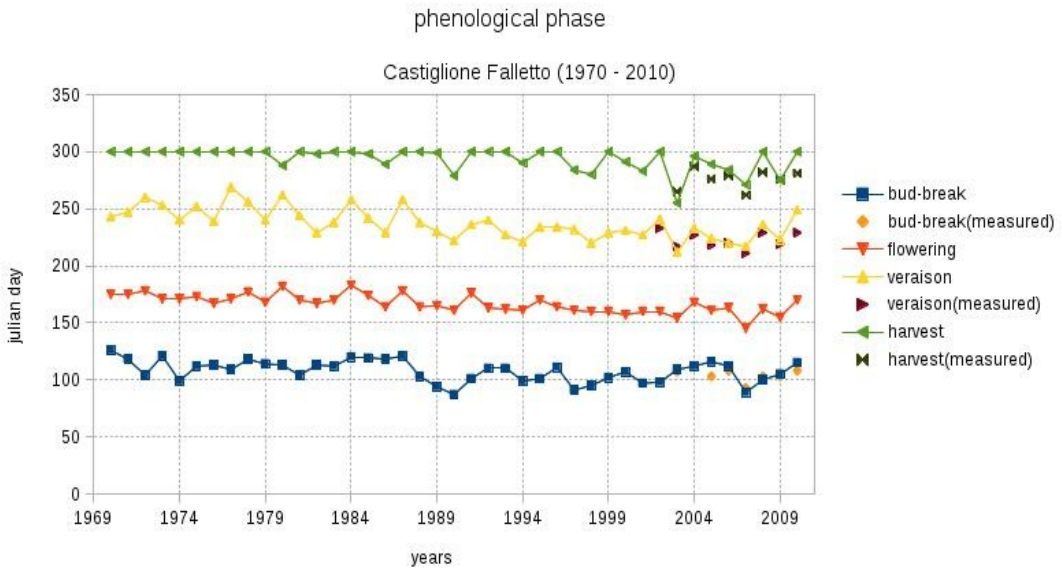


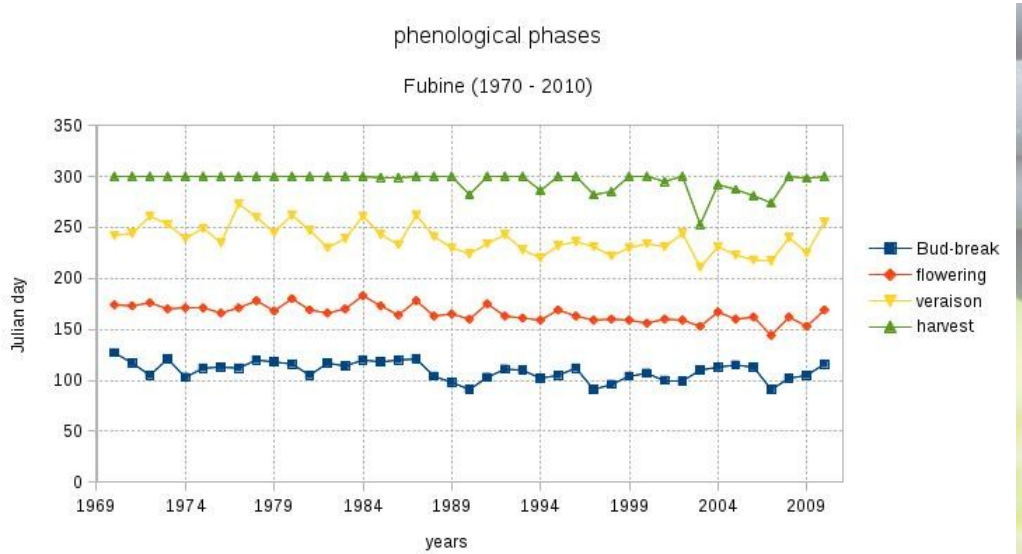
The high value of yield in Cocconato can be mainly associated with the higher LAI and soil moisture value

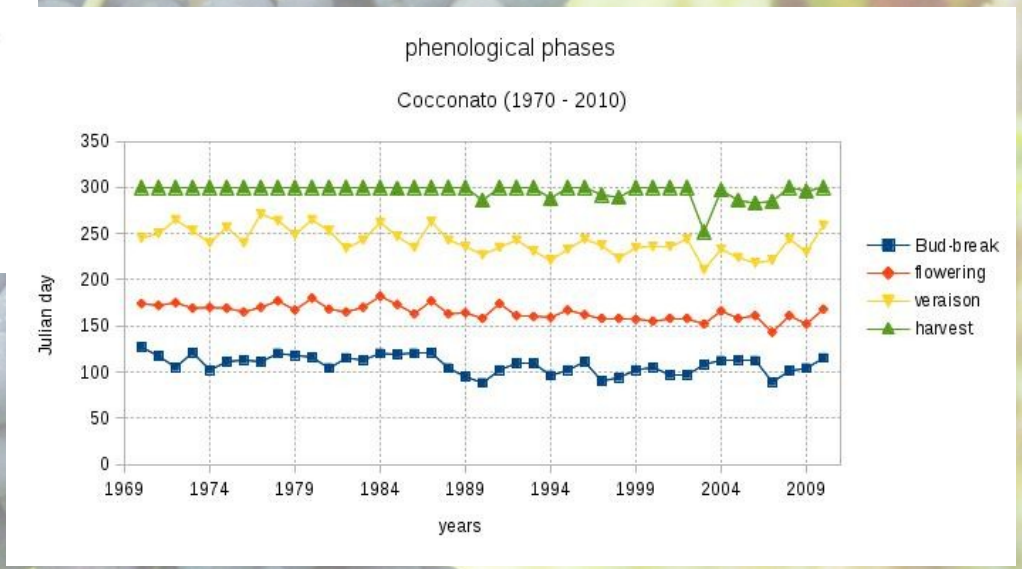
Output data: VINEYARD CROP model

Simulation of main phenological phases

The decreasing phenological timing trends is due to the increase of value of air temperature







Conclusions....

- We have simulated 40 years of data (1970-2010) using GLDAS2.0 dataset as input for driving the land surface model UTOPIA, and compared some output with those of NOAH land surface scheme, already stored in GLDAS2.0.
- The simulations show that the two models give reasonably close output, but with some differences, which change according with the variable considered.
- We have implemented a phenological model able to infer micro-meteorological and physiological variables, and we have applied it to the same 40-years period in order to have a long time trend relative to the past climate and allow us to make a sort of climatology of such variables
- The analysis of the output of two models (UTOPIA and VINEYARD CROP models) is ongoing. We present here the first interpretations on the main data.

...and future perspectives

- to simulate different cultivars
- to parameterize other variables as: acids, alcohol content.....

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