Future effects of climate change on the suitability of agricultural crop production over Europe

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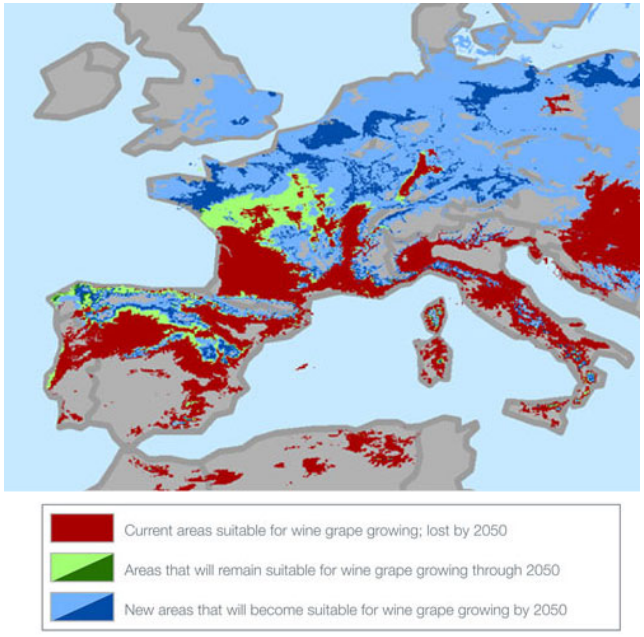
1. Motivations

- **Europe** is one of the world's largest and most productive suppliers of food and fiber (Easterling et al., 2007).
- **Agriculture** covers about 35% of the total land area of western Europe (Rounsevell et al., 2006).

According to the **IPCC** (Chapter 23, 2013):

*Changes in mean temperature and precipitation will likely affect **agricultural crop** and livestock production*



From Conservation International

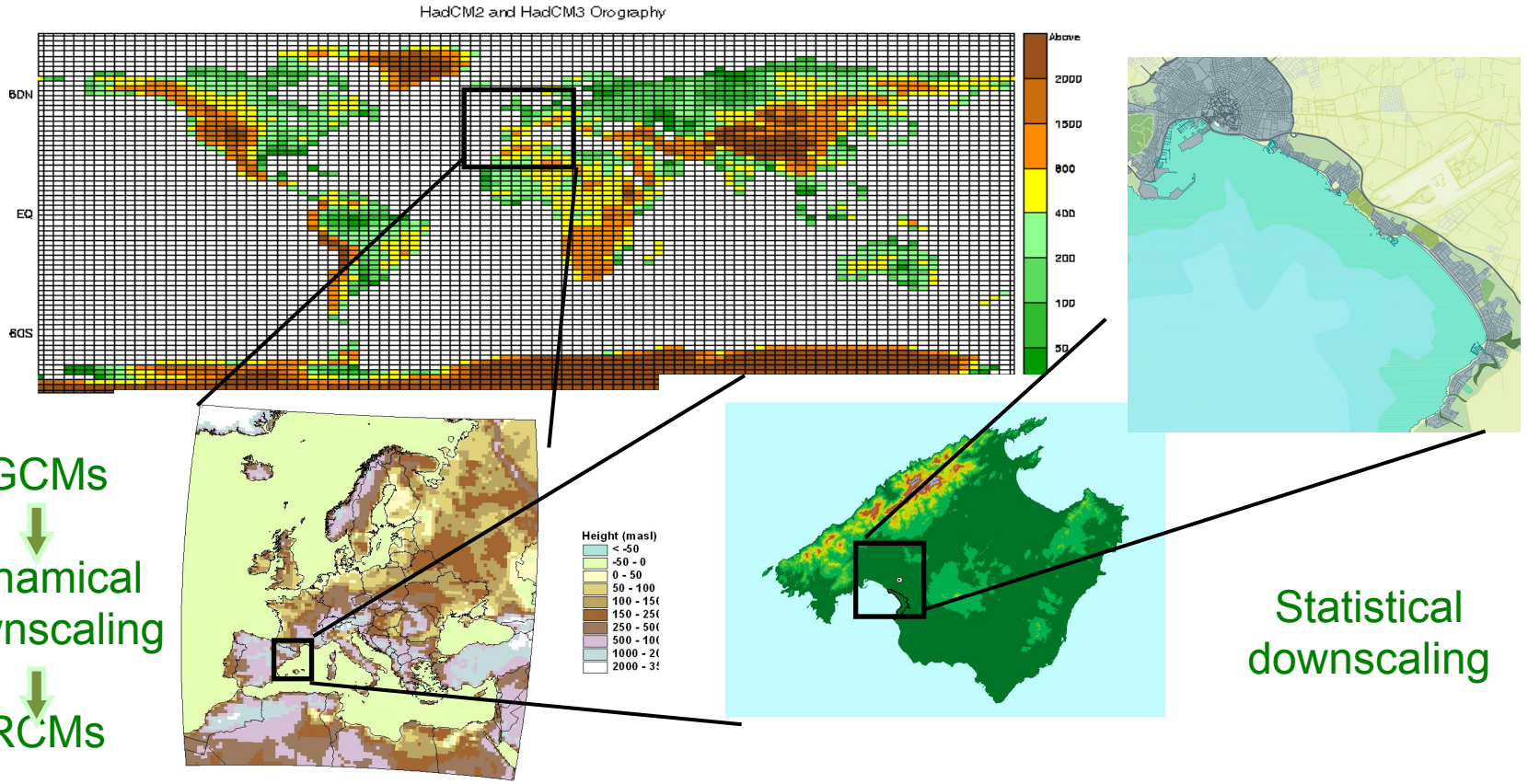
Different effects depending on the crop (grapevine, chickpeas, tomato, almonds..)

Most scenario studies suggest that agricultural land areas in Europe will continue to decrease in the future (Busch et. al 2006)

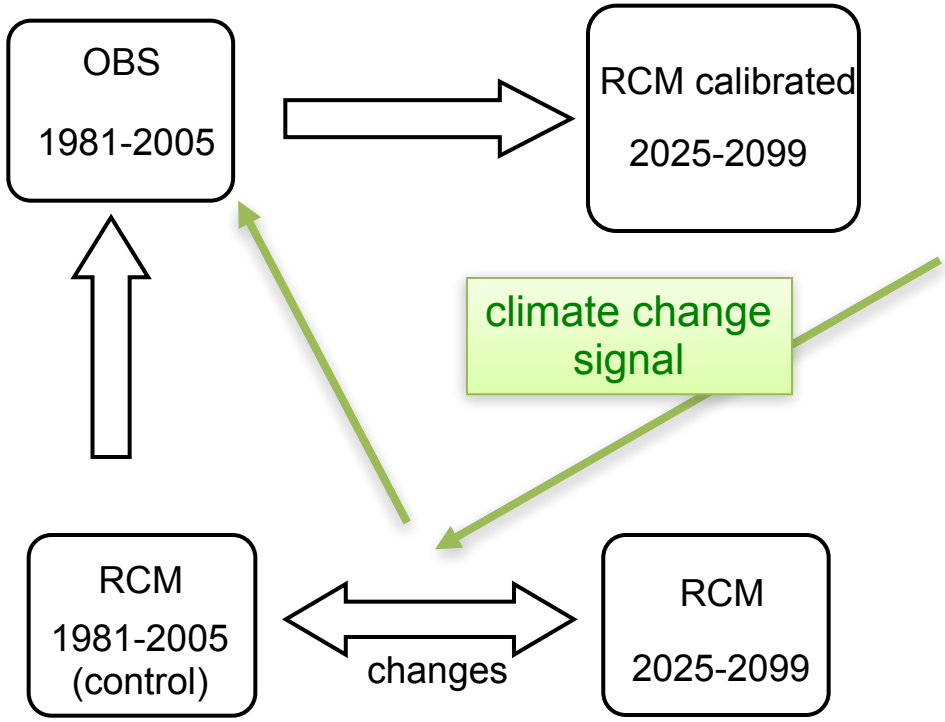
Tools for exploring climate change impacts

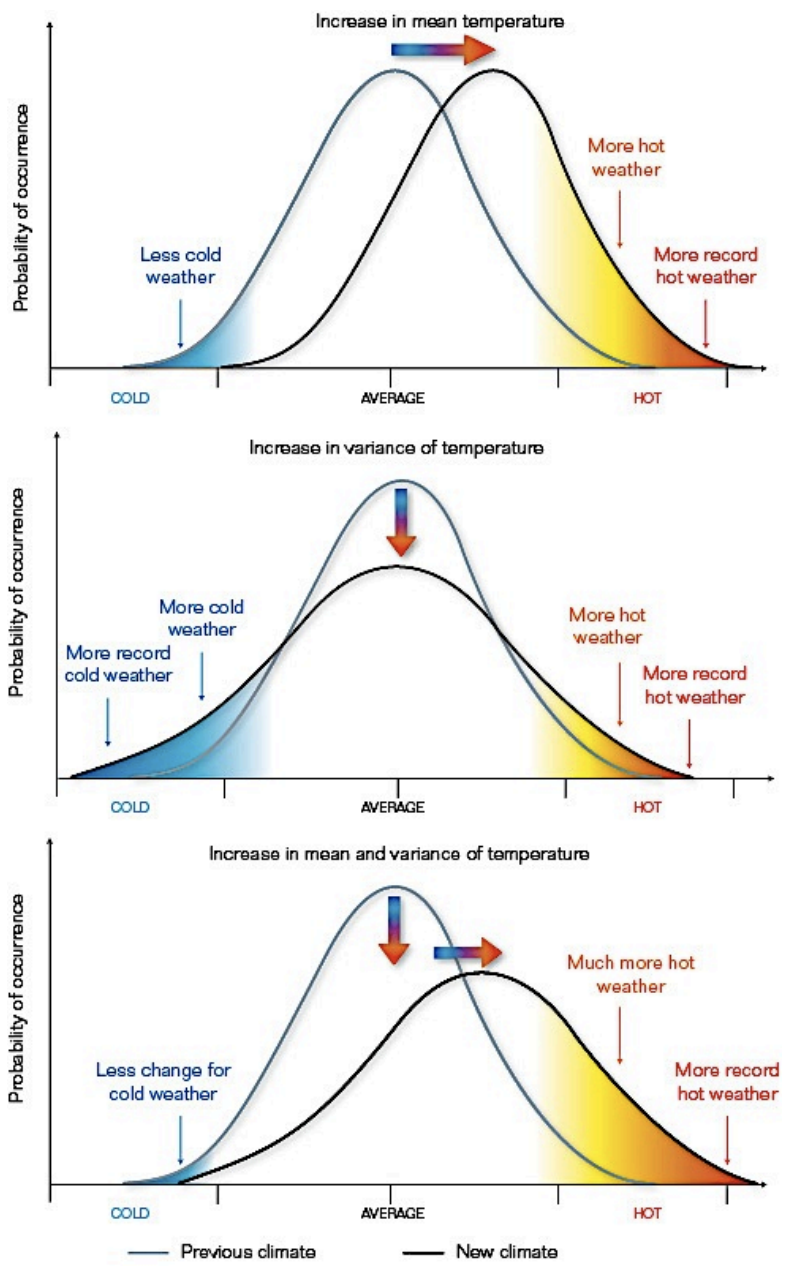
- GCMs → RCMs

  - Regional scales: Dynamical downscaling. Regional Climate Model (RCMs)
  - Local scales: Statistical downscaling and model calibration from RCMs



Statistical downscaling of RCM outputs

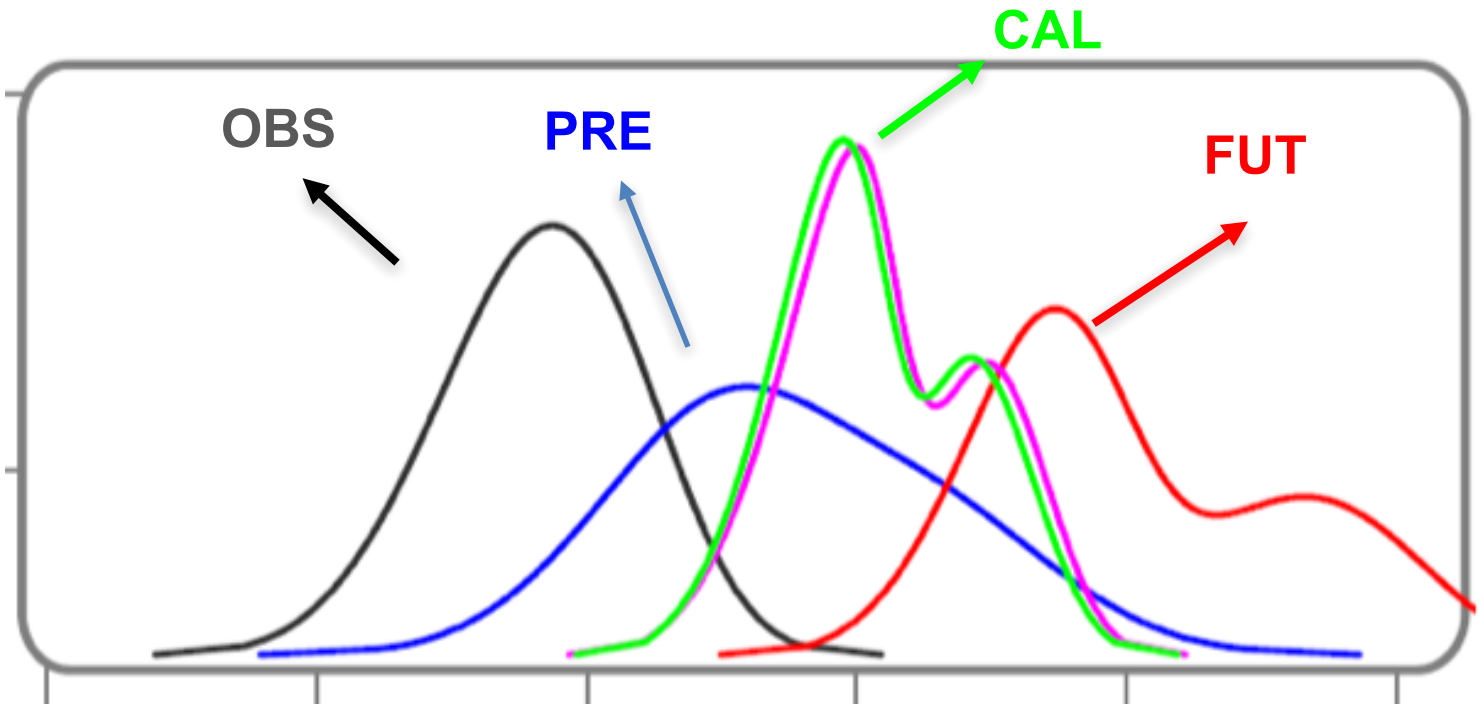




Quantile-Quantile adjustment

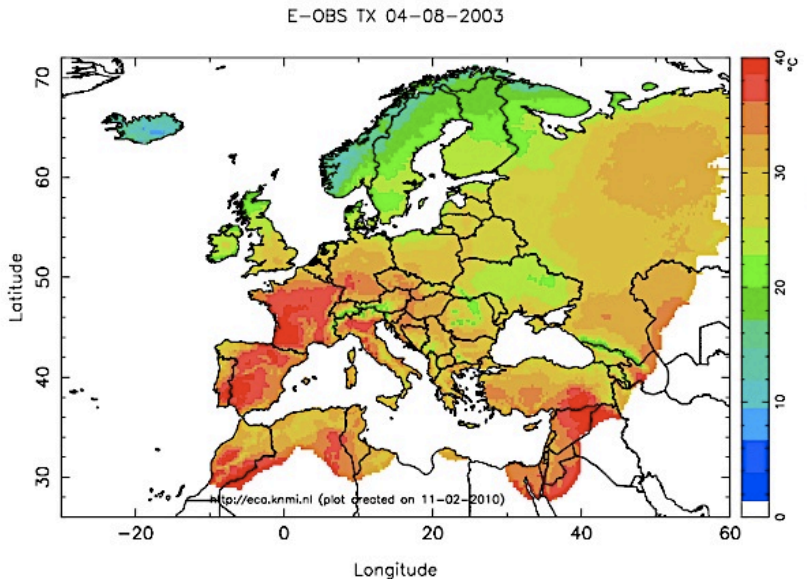
(Cardell et al. 2019a)

$$p_i = o_i + g\overline{\Delta} + f\Delta'_i,$$

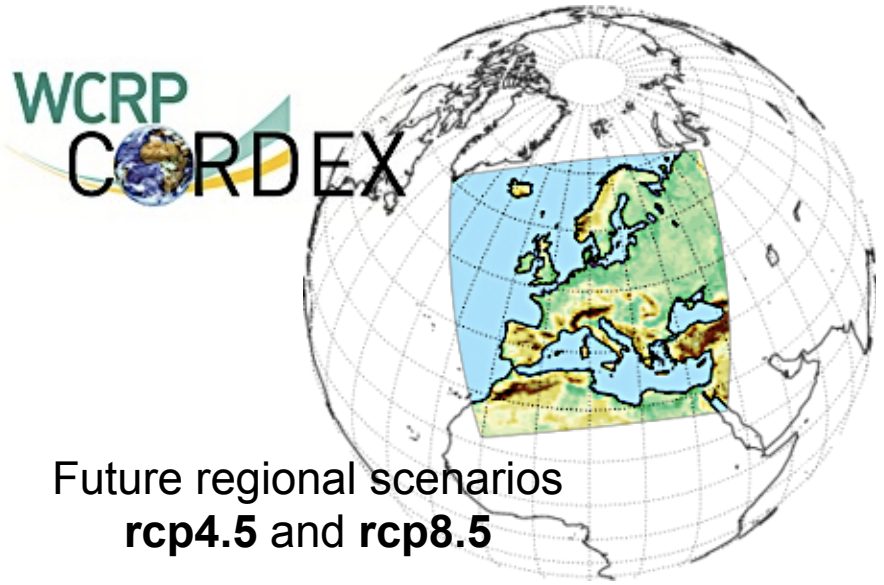


2. Database and methodology

E-OBS gridded dataset (25 km)



EURO-CORDEX (12,5 km)



Future regional scenarios
rcp4.5 and **rcp8.5**

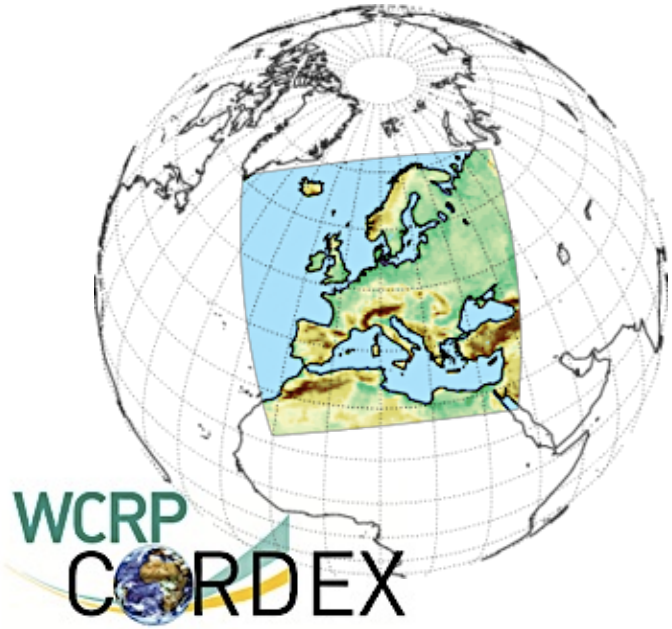
Daily series of:

- 2-m **minimum** and **maximum temperatures**
- **Accumulated precipitation**

Climate change projections

Compute changes in calibrated CDFs between a 25-year past (i.e. control/ observed; 1981-2005) and successive 25-year RCM time-slices (2021-2045; **2046-2070**; 2071-2095)

Future regional scenario
rcp4.5 and **rcp8.5**



Driving GCM	RCM	Institute
CNRM-CM5-LR	CCLM4-8-17	CLMcom
EC-EARTH	CCLM4-8-17	CLMcom
HadGEM2-ES	CCLM4-8-17	CLMcom
MPI-ESM-LR	CCLM4-8-17	CLMcom
EC-EARTH	RACMO22E	KNMI
HadGEM2-ES	RACMO22E	KNMI
EC-EARTH	HIRHAM5	DMI
NorESM1-M	HIRHAM5	DMI
CNRM-CM5	ALADIN53	CNRM
CNRM-CM5	RCA4	SMHI
EC-EARTH	RCA4	SMHI
HadGEM2-ES	RCA4	SMHI
MPI-ESM-LR	RCA4	SMHI
IPSL-CM5A-MR	RCA4	SMHI

Grapevine is a genus of 79 accepted species of vining plants (family Vitaceae) predominantly from the **Northern hemisphere**.

Sauvignon Blanc

Riesling

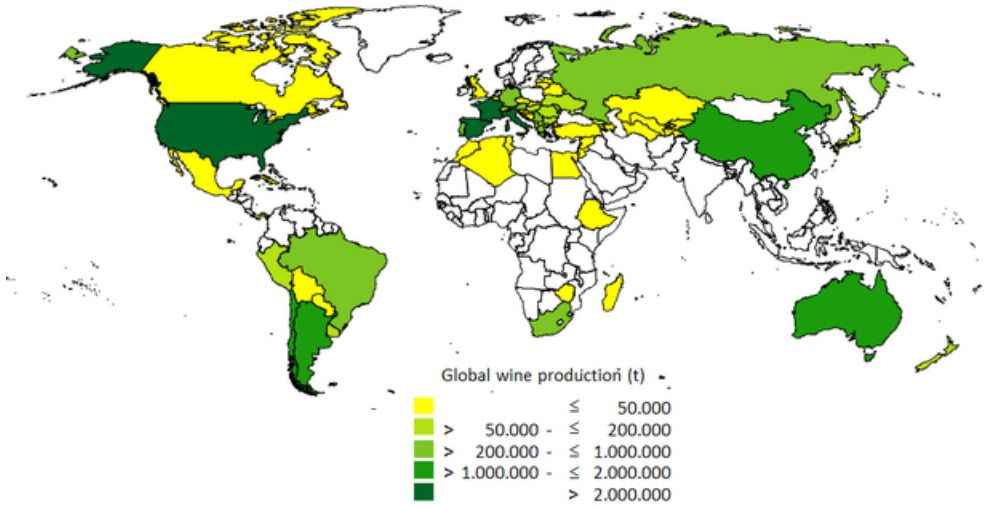
Chardonnay

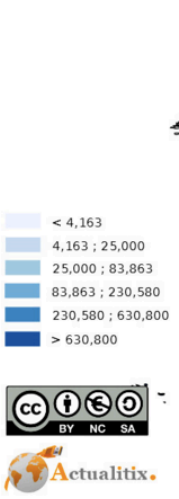
Pinot Noir

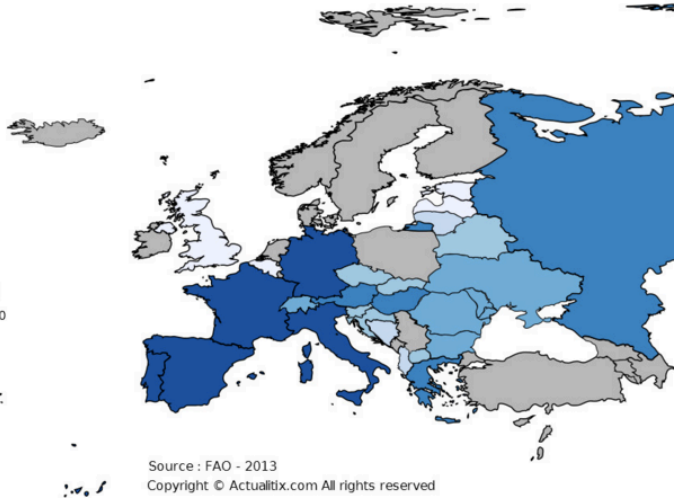
Cabernet Sauvignon

Merlot

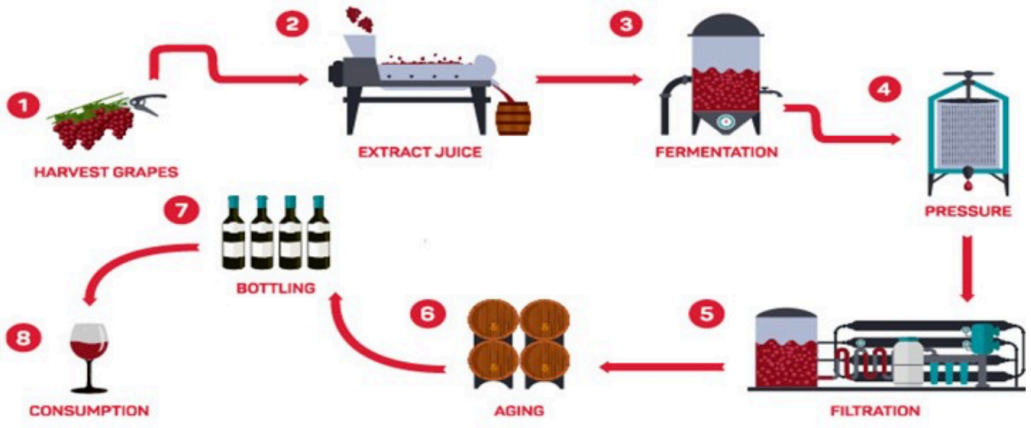
Wine - Production (Tons)







The cultivation of grapes for **wine production** → one of the agricultural sectors with more **economic importance**



One of the most **sensitive to climate modifications**

Temperature

1. Mean summer maximum temperature
2. Mean temperature April-October
3. Winkler Index
4. Huglin warmth index

Precipitation

1. Real evapotranspiration and water balance

3. Results

Temperature

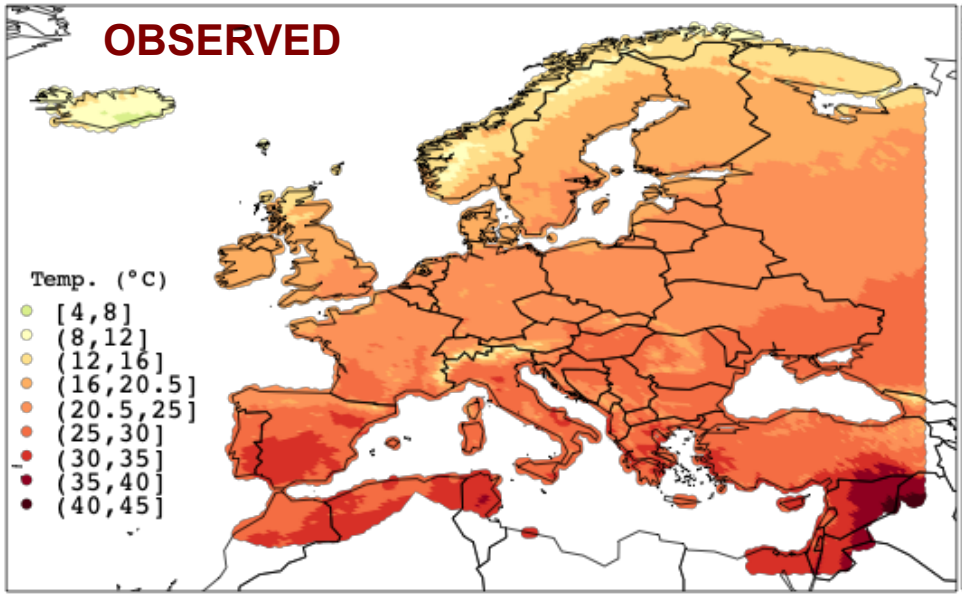
1. Ripening season of grapevines (mid-summer and early autumn)
2. Optimum maximum temperature in summer: 25ºC
3. Optimum temperature for the development of the fruit: 20-30ºC

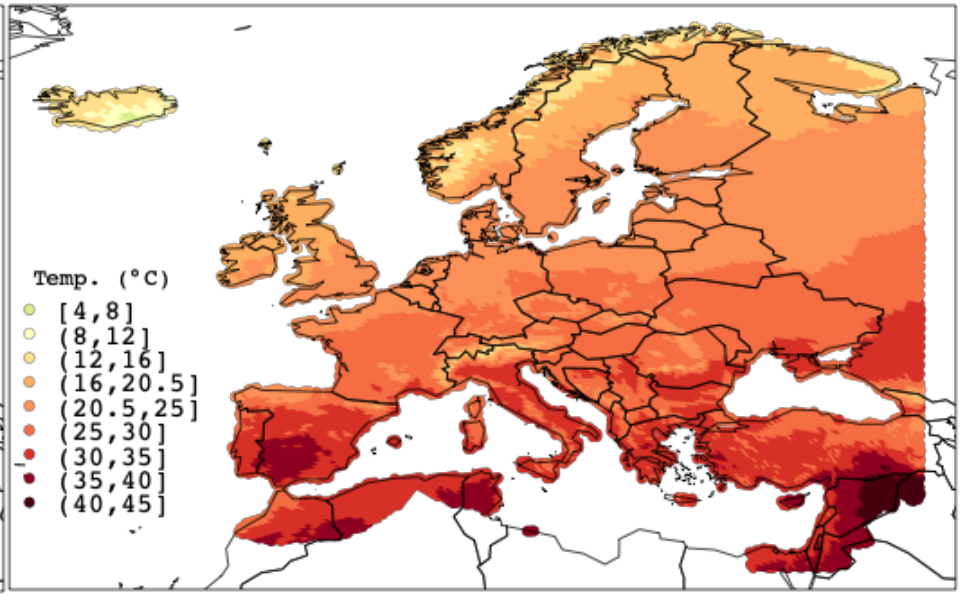
Severe thermal stress conditions

- A reduction in production (Moutinho-Pereir et al., 2004).
- Fast growth and early harvest.
- Fruit with less aromas and loss of pigments (Collins et al., 2006).
- Negative effects over organic components & quality wine (Yamane et al., 2006).

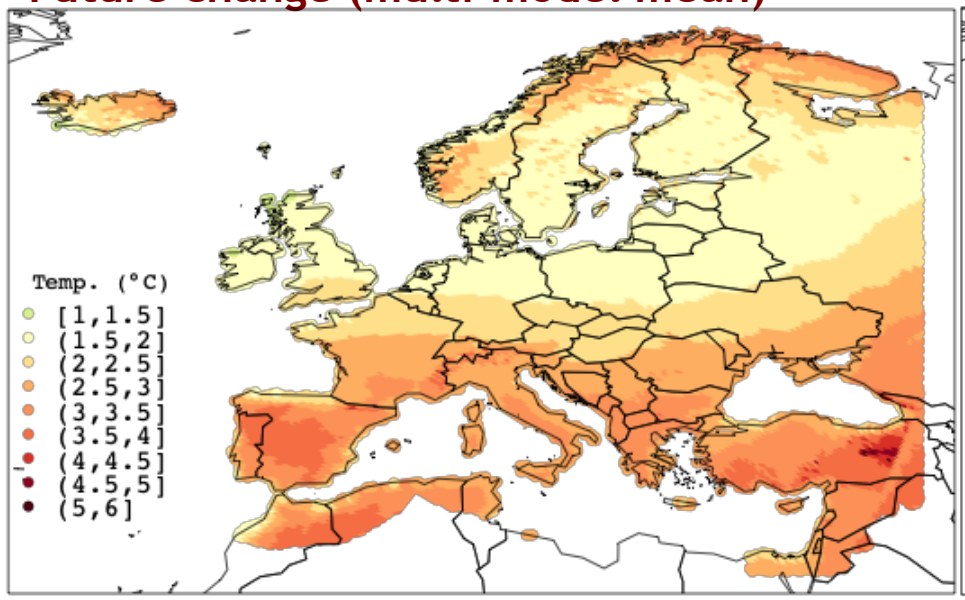
3.1 Mean summer maximum temperature

Future projected

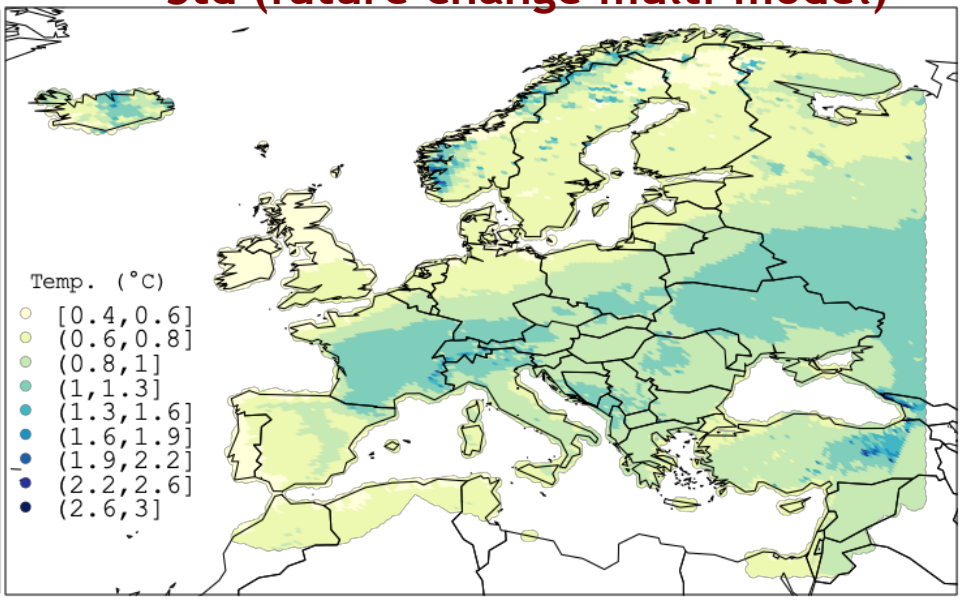




Future change (multi-model mean)

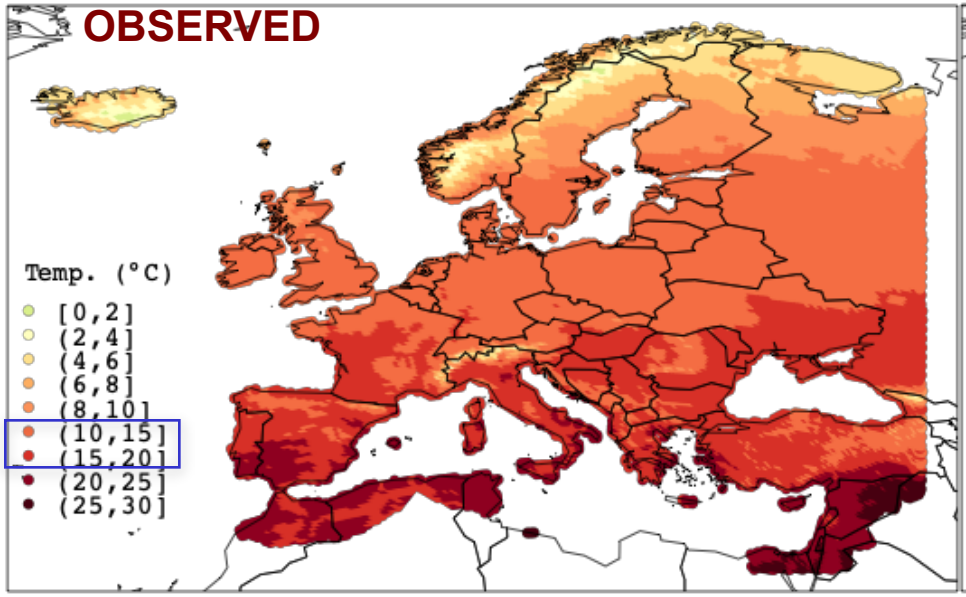


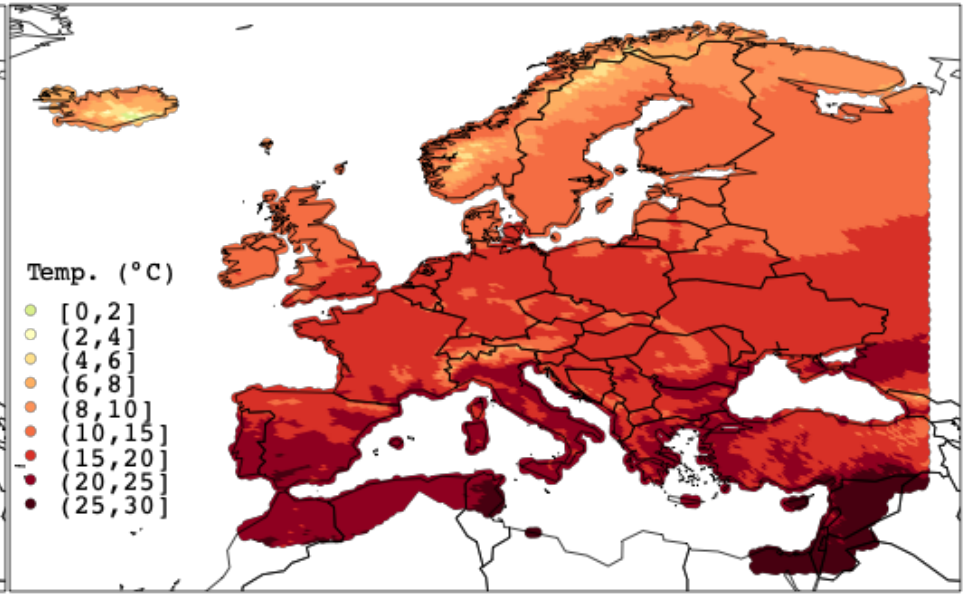
Std (future change multi-model)



3.2 Mean temperature April-October (ripening season)

Future projected





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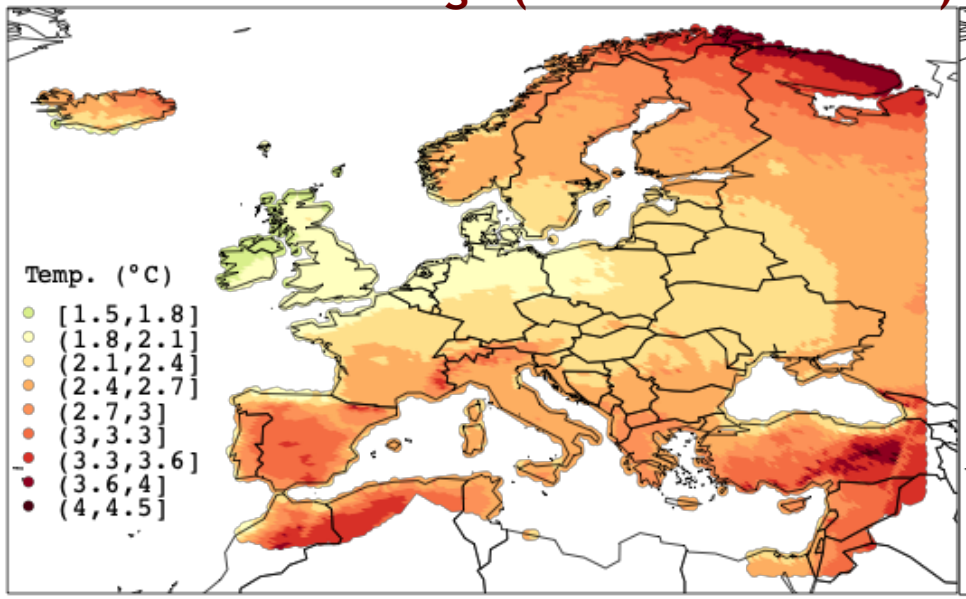
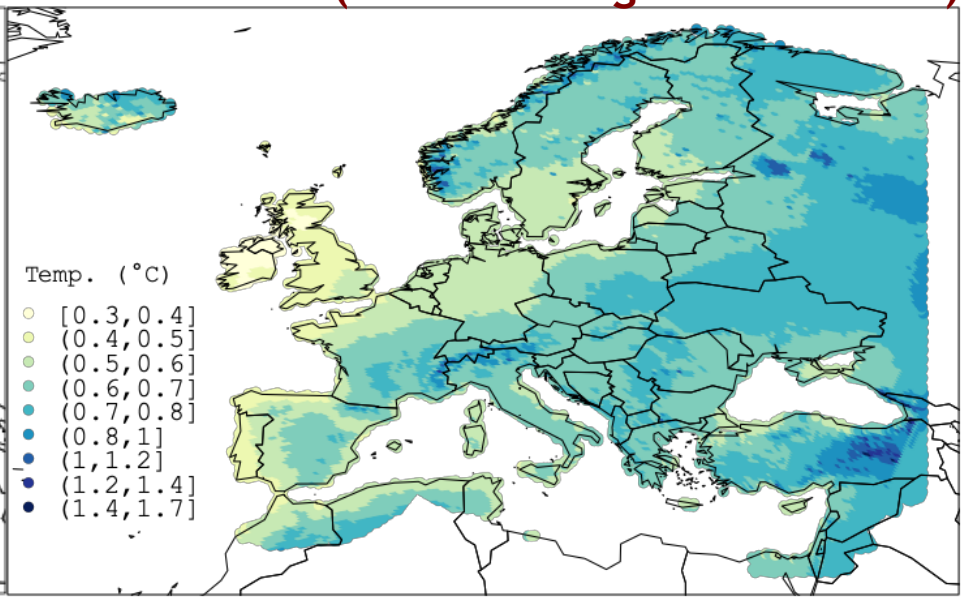


Std (future change multi-model)



3.3 Winkler Index

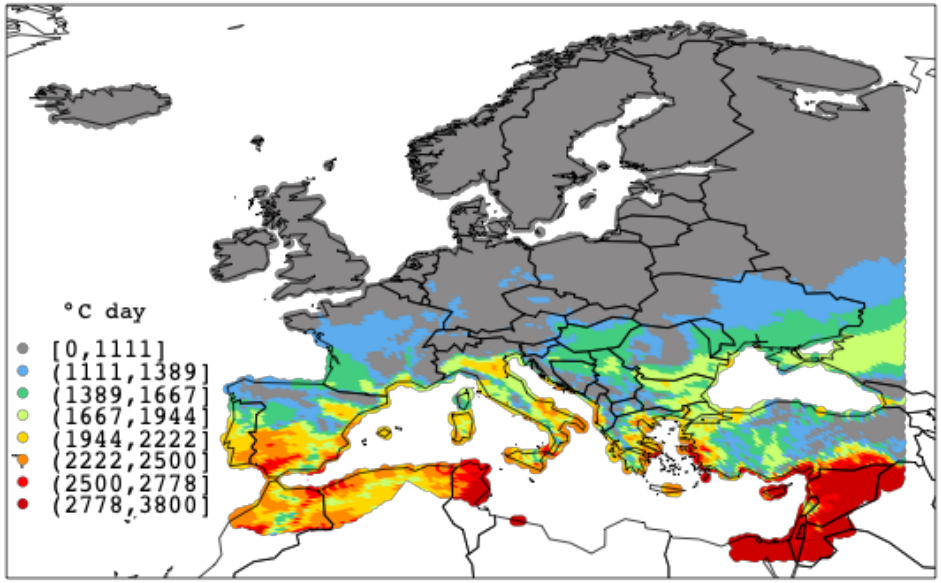
- Measures the heat accumulation or growing degree days above the vegetative zero (10 ºC), during the ripening season (Amerine and Winkler, 1944).

$$WI = \sum_{1abr}^{30oct} (T - 10)$$

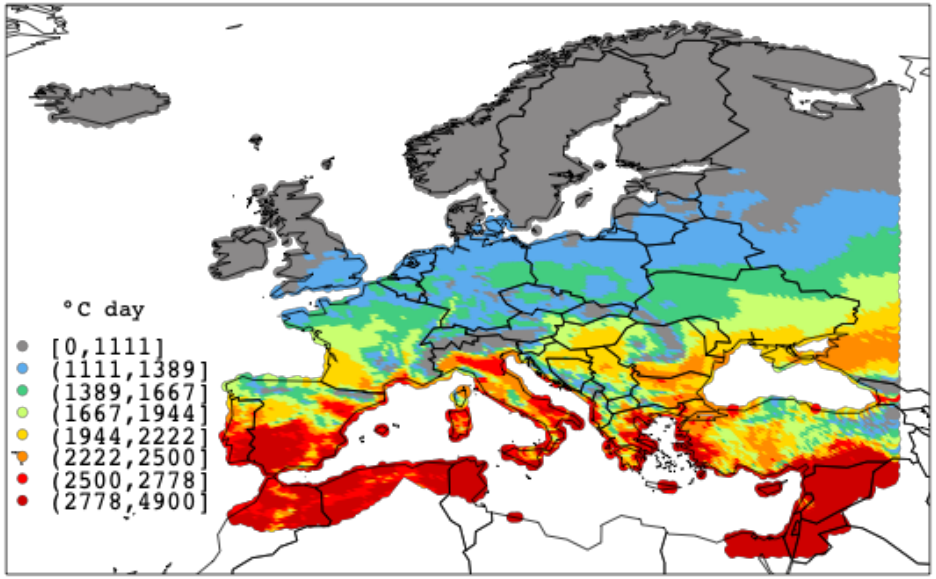
Region/class	ºC day	General ripening capability and wine style
Too cold	<1111	Only very early ripening varieties achieve high quality, mostly hybrid grape varieties and some V. vinifera
Region I	1111-1389	Only early ripening varieties achieve high quality, some hybrid grape varieties bust mostly V. vinifera
Region II	1389-1667	**Early and mid-season table wine varieties will produce good quality wines**
Region III	1668-1944	**Favourable for high production of standard to good quality table wines**
Region IV	1945-2222	**Favourable for high production, but acceptable table wine quality at best**
Region V	2222-2500	Typically only suitable for extremely high production, fair quality table wine or table grapes varieties destined for early season consumption are grown
Region VI	2501-2778	Only suitable for extremely high production
Too warm	>2778	No suitable for vitis production

3.3 Winkler Index

OBSERVED

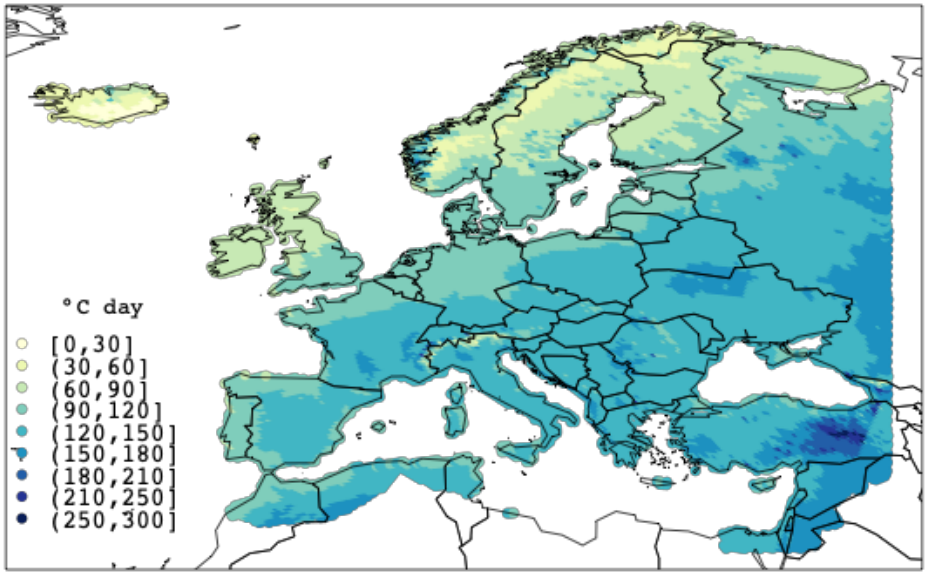


Future projected



- Too cold
- Region I : Chablis, Champagne
- Region II : Bordeaux, Alsace
- Region III : Rioja, Piemonte
- Region IV : Montpellier
- Region V : Greek islands, Sicily
- Region VI
- Too warm

Std (future change multi-model)



3.4 Huglin Index

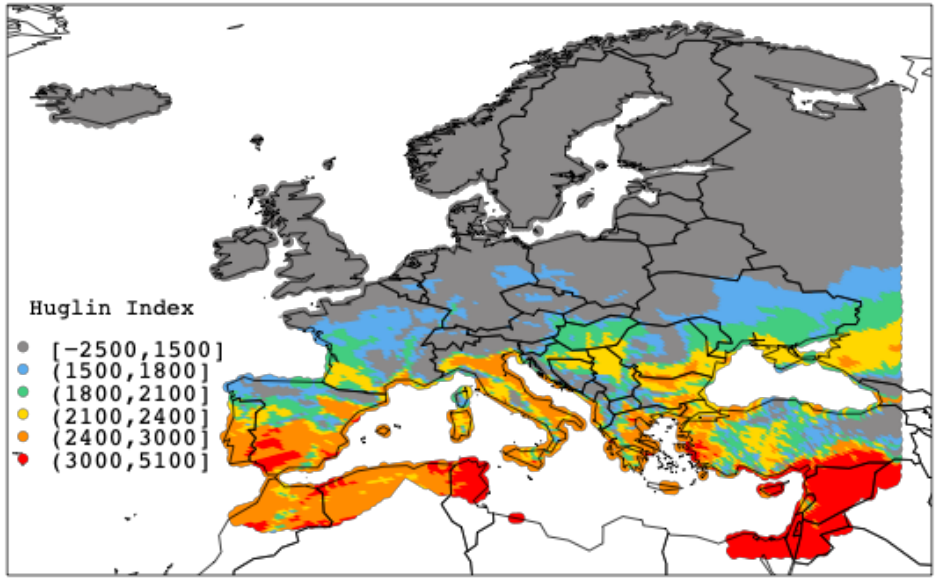
- Estimates the heliothermic potential of a specific climatic condition and is related to the thermal requirements of vine varieties and their potential sugar content.

$$HI = \frac{K}{2} \cdot \sum_{1abr}^{30oct} [(T - 10) \cdot (T_{max} - 10)]$$

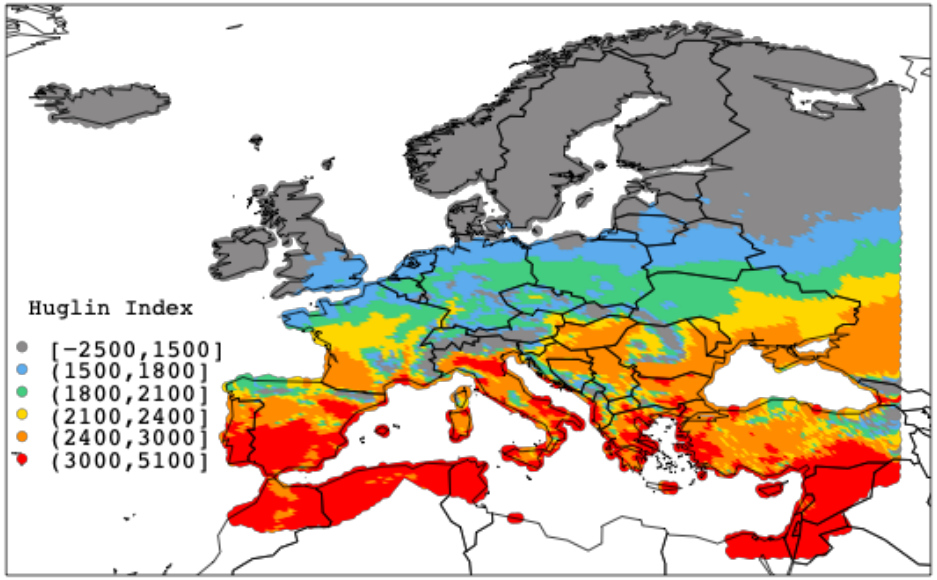
Region/class	HI	Grape Variety
Very cool	HI <= 1500	No suggestions
Cool	1500 < HI <= 1800	Blauer Portugieser, Pinot blanc, Pinot noir, Chardonnay.
Temper	1800 < HI <= 2100	Cabernet Franc, Chenin blanc, Merlot, Ugni blanc.
Warm Temper	2100 < HI <= 2400	Tempranillo, Grenache, Carignan, Aramon.
Warm	2400 < HI <= 3000	
Very warm	HI > 3000	No suggestions

3.5 Huglin Index

OBSERVED

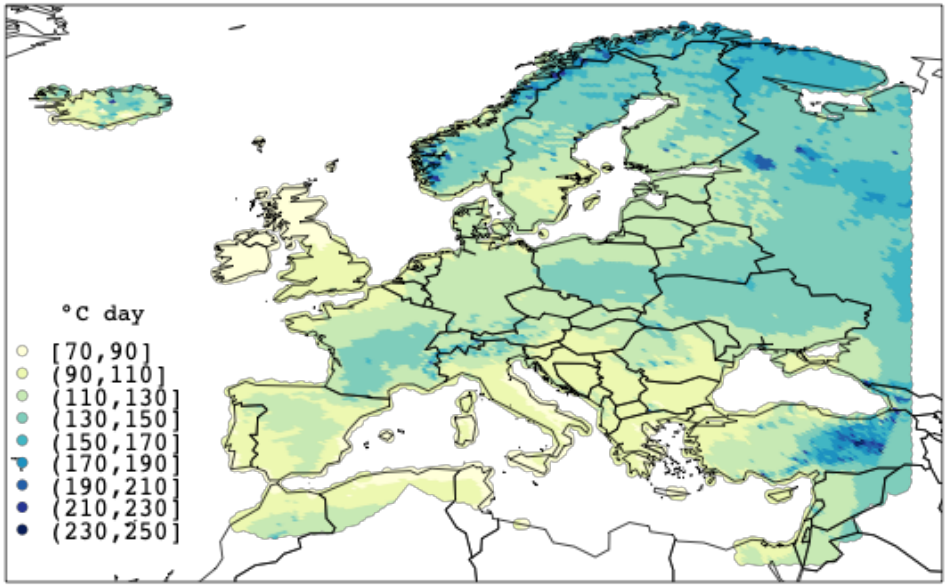


Future projected



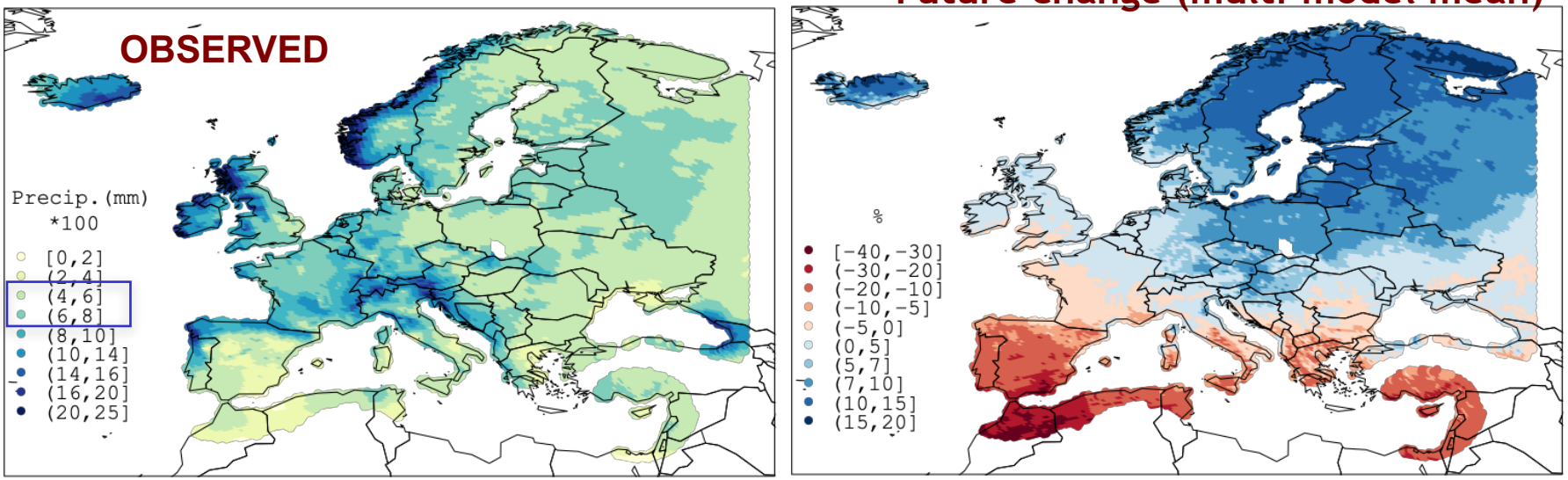
- Very cool
- Cool: Pinot blanc, Pinot noir
- Temper: Cabernet Franc, Merlot
- Warm temper: Tempranillo, Grenache
- Warm
- Very warm

Std (future change multi-model)



Precipitation, real evapotranspiration and water balance

Despite the vine is resistant to drought because it has deep roots, **the water is a limiting factor for growth**



Real evapotranspitation (RET)

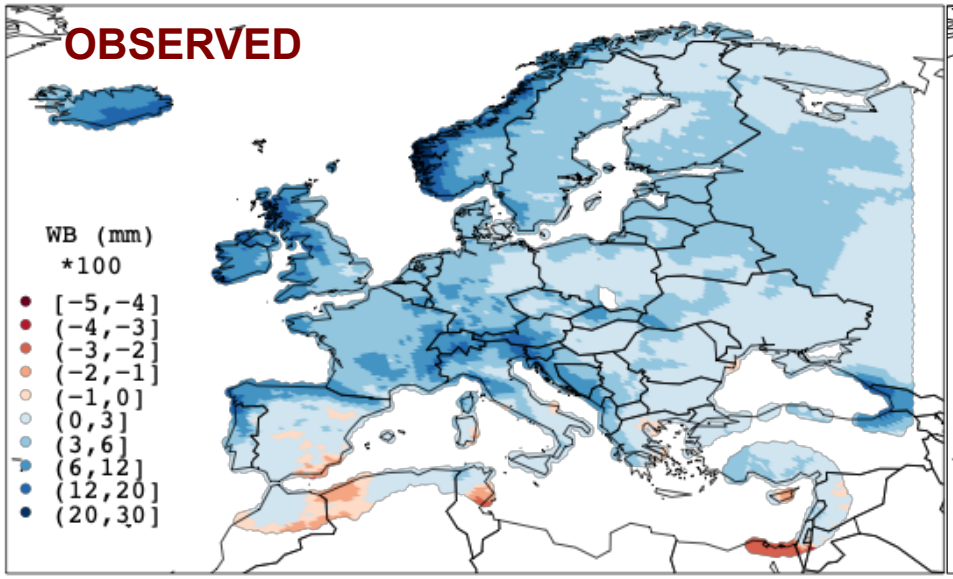
The loss of moisture from a surface by direct evaporation & the loss of water by transpiration of the vegetation

$$ETR = K_c \cdot ETP$$ *(Thornthwaite 1948)*

Water balance (WB)

WB= P - ETR

3.5 Water balance



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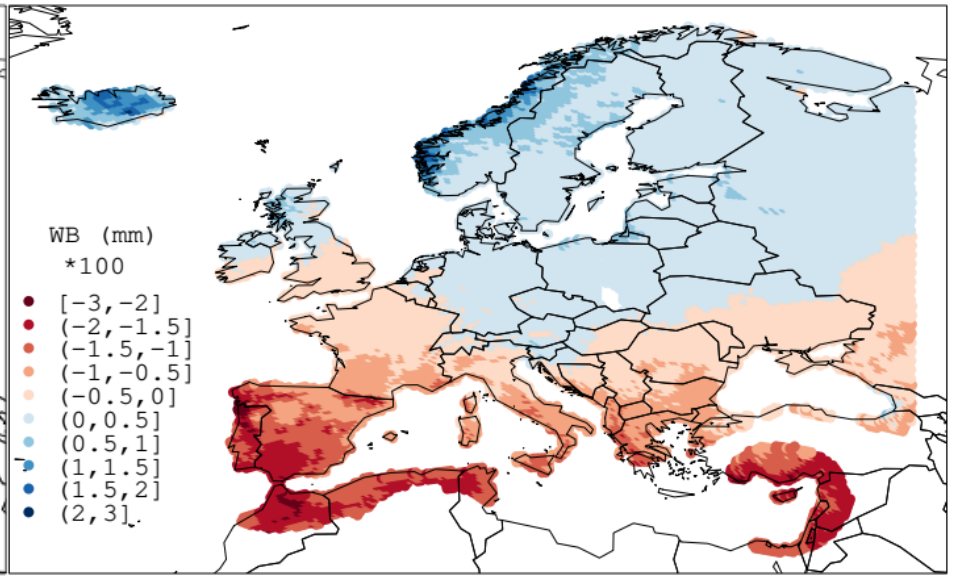

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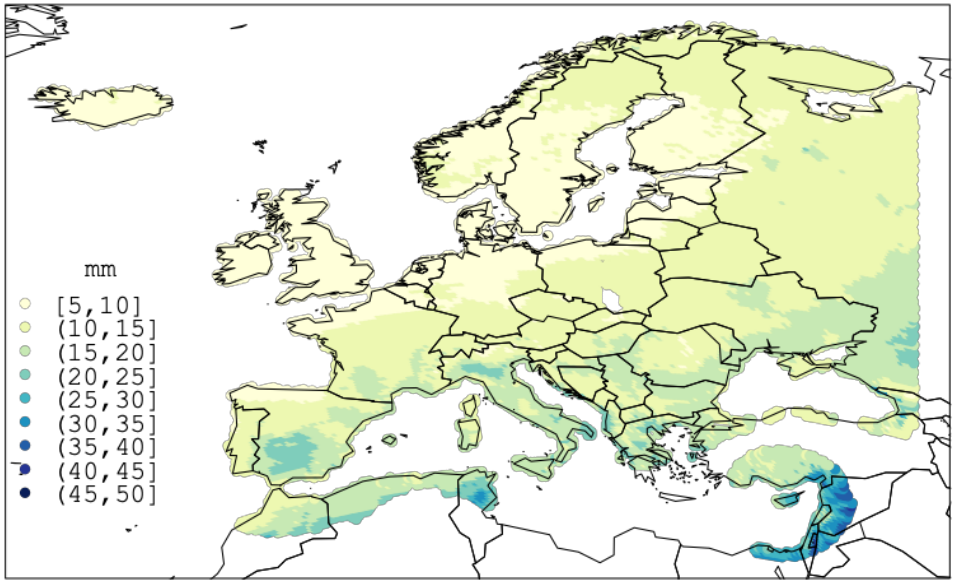

If water deficit increases, the rate of perspiration and therefore heat dissipation is also affected → **increase in leaf temperature** (Hsiao, 1973).

If the present trend continues … it will be necessary the adpotion of **new strategies and management practices** to mantain the quality and production targets of the wine sector in Europe






Factors which **also determine the actual growing conditions.**

They **could allow viable viticulture outside of the predicted suitability areas** (Mosedale et al. (2016); Sabir et al. (2018)).

4. Conclusions

- The grapevine will be exposed for longer to excessive temperatures for proper maturation by the mid 21st century.
- According to the evolution of the WI and HI, the suitability of southern European regions for growing grapavine will be progressively less adequate. However, the areas of northern Europe that were not suitable for the grapevine can be grown in the near future.
- A generalized decrease in the annual WB is expected in the Mediterranean due to the decrease in annual precipitation and the increase in the evaporative demand of the plant.
- The adoption of more efficient irrigation methods should be evaluated, due to the greater consumption of water by the crop and the reduction of rainfall.
- The vine may cease to be viable in some regions of the SEM in the near future if no adaptive measures are taken taking into consideration.

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