WINE AND A CHANGING CLIMATE:

WILL THE TERROIR MODEL OF TODAY SURVIVE?

PRESENTED BY
ROGER C BOHMRICH MW

SOCIETY OF WINE EDUCATORS VIRTUAL CONFERENCE
AUGUST 14 , 2020

"Climate change is a wave you must ride or be swept away by."

Dr. Elizabeth Wolkovich
University of British Columbia & Harvard University

Quoted in: Brooks, L, Climatologists Say Cabernet's Days as King in Napa are Numbered, Wine Business Monthly, Jan 2019

"Many people in the wine world still don't understand the urgency of climate change."

Miguel A. Torres
Familia Torres, Catalonia, Spain
Co-founder, International Wineries for Climate Action
iwcawine.org

Quoted in: Joy, R, Wine world needs more urgency on climate change, says Torres, decanter.com, April 12, 2019

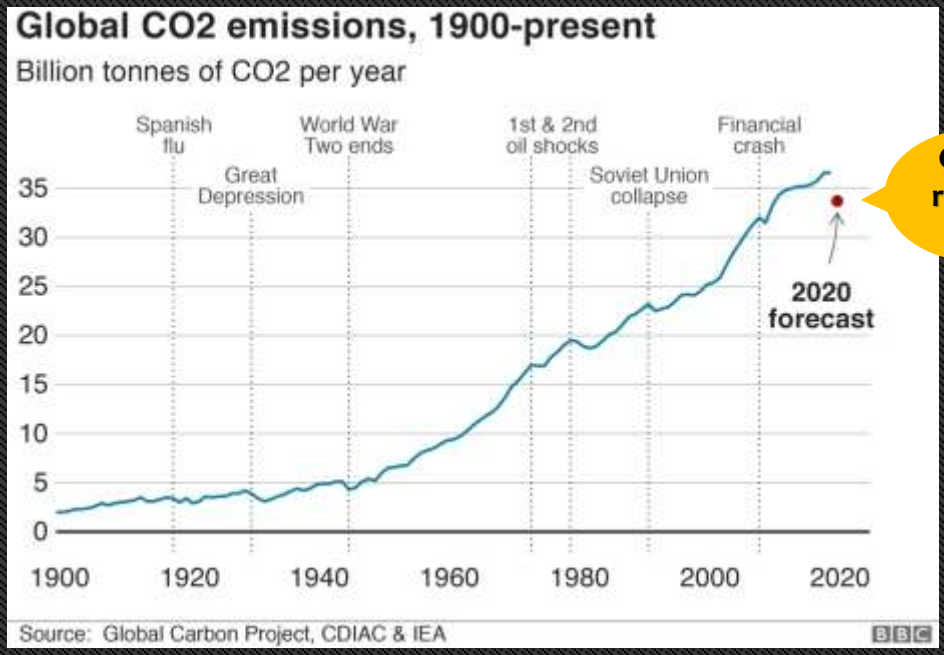
WINE AND A CHANGING CLIMATE – *KEYWORDS*

CONCEPTS

Anthropogenic
Global "weirding"
Bioclimatic index
GST
Climate/Maturity Grouping
Evapotranspiration
Asynchrony
Intraspecific diversity
High altitude
High latitude

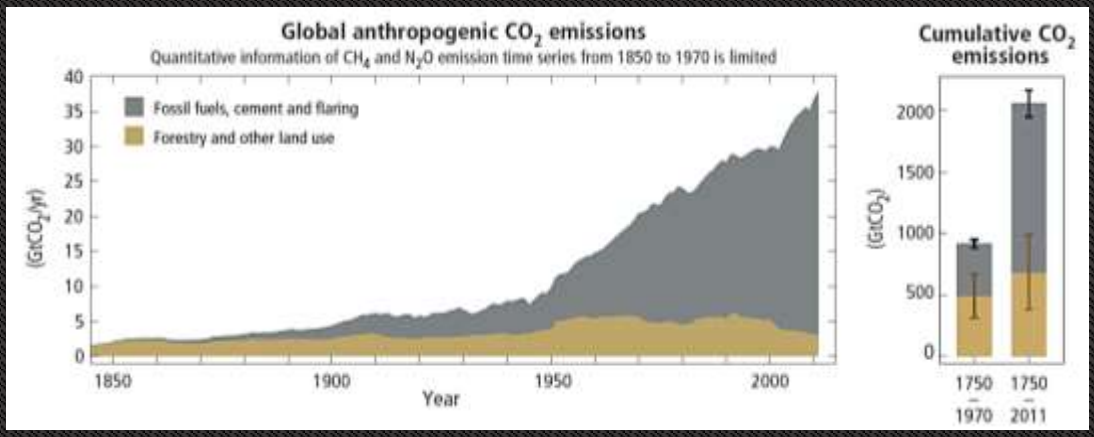
PLACES & NAMES

Hautes-Côtes
Vallais
Lake County
New England Australia
Elqui
Calchaqui
La Quebrada de Humahuaca
Otronio
Chile Chico
Kojder
Hällåkra
Slinde



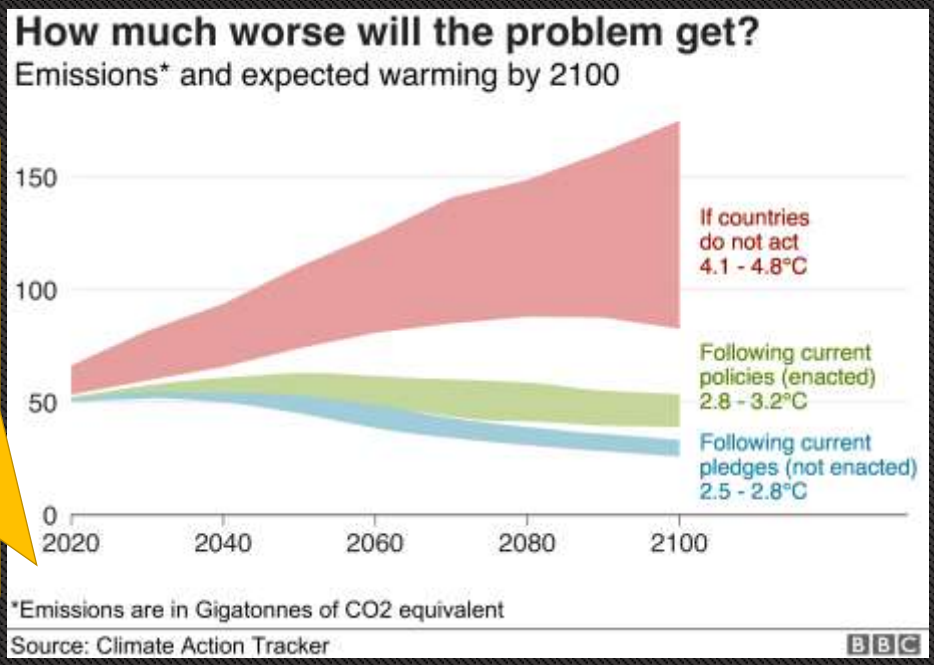
McGrath M, Climate change and coronavirus: Five charts about the biggest carbon crash, www.bbc.com, 6 May 2020

"Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems." IPCC, 2014



IPCC, *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

"We have reduced our CO_2 emissions per bottle by 30% from 2008 to 2019… By 2030, we are committed to reaching a 55% reduction." Familia Torres, Spain

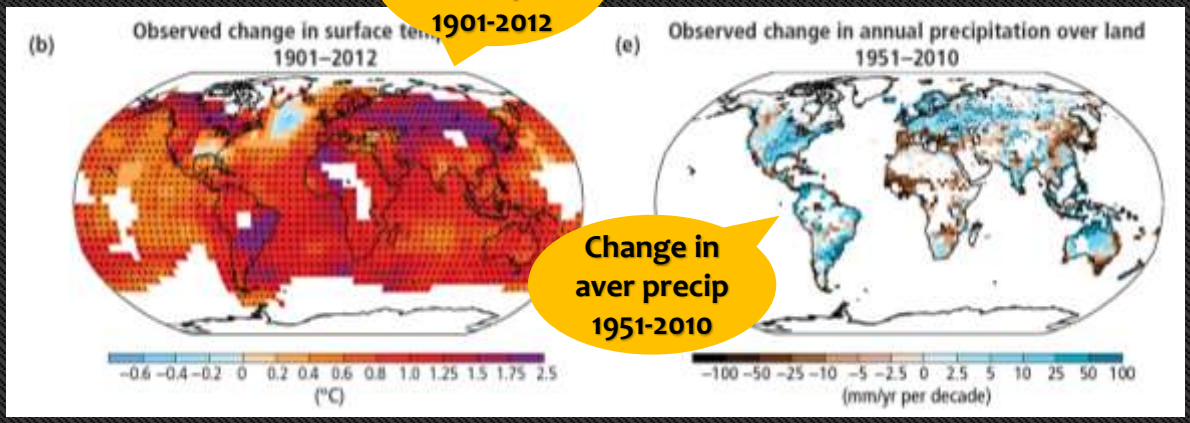


Matt McGrath, Climate change and coronavirus: Five charts about the biggest carbon crash, www.bbc.com, 6 May 2020

"Warming of the climate system is unequivocal… the atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen." IPCC, 2014

Change in surface temp 1901-2012

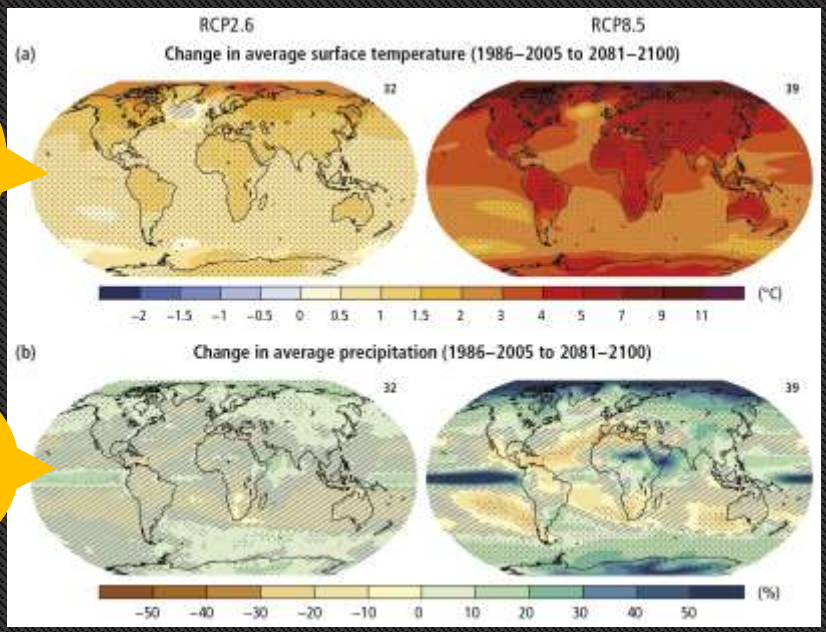
Change in aver precip 1951-2010



IPCC, *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Change in aver surface temp 1986-2005 to 2081-2100

Change in aver precip 1986-2005 to 2081-2100



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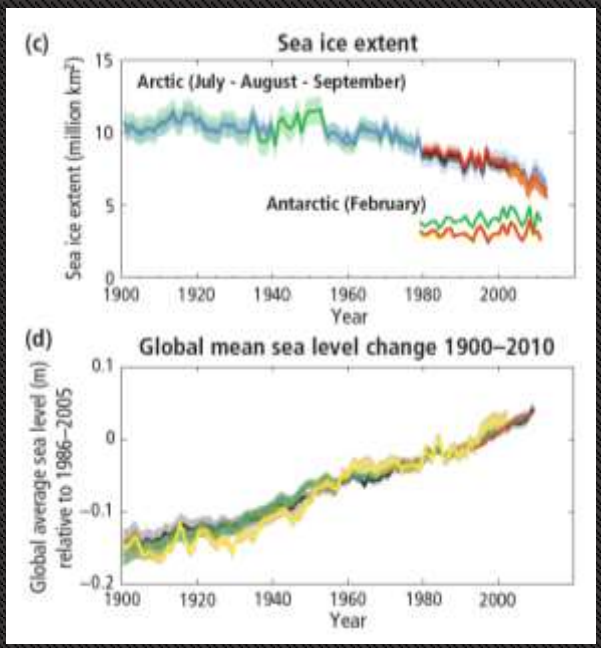


MELTING ICE, RISING SEAS

"Over the period 1901–2010, global mean sea level rose by 0.19 [0.17 to 0.21] m. The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia (*high confidence*)."

IPCC, 2014

IPCC, *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

A WARMING CLIMATE – *ITS IMPACT ON THE VINE*

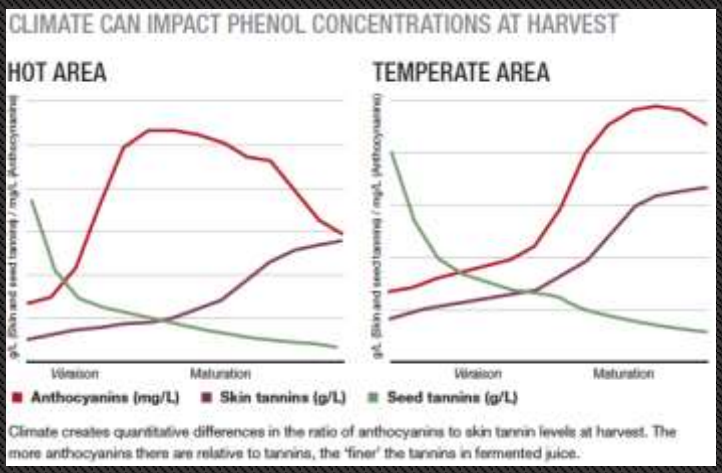
"a 1° F [0.56° C] increase in average temperature would shorten the season from budbreak to harvest by between five and 15 days."

Gregory Jones
Director of Evenstad Center
Linfield College, Oregon

KEY OUTCOME:
shift of ripening phase to hotter part of summer = changes composition of fruit

Quoted in: Greenspan M, The Climate is Changing, Whether We Like it or Not, Wine Business Monthly, April 2020

A WARMING GROWING SEASON – *IMPLICATIONS FOR WINE*



"We can expect asynchrony among primary (such as Brix) and secondary metabolites (aroma, flavor and phenols) will likely increase."

Dr. Bruce Zoecklein
How Climate Change Affects Winegrowing
Wines & Vines, Feb 2018

TRANSLATION: Higher temperatures can boost sugars and diminish desirable aromas and flavors, disrupting the balance of a wine… and lowering the quality. [*if that trend intensifies*]

CASE IN POINT: ALTERED PHENOLOGY – *ALSACE (RIESLING)*

Start of harvest

50% veraison

50% flowering

50% budbreak

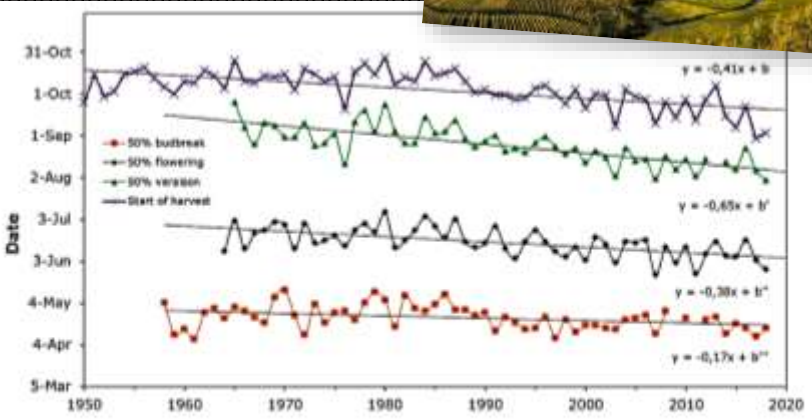
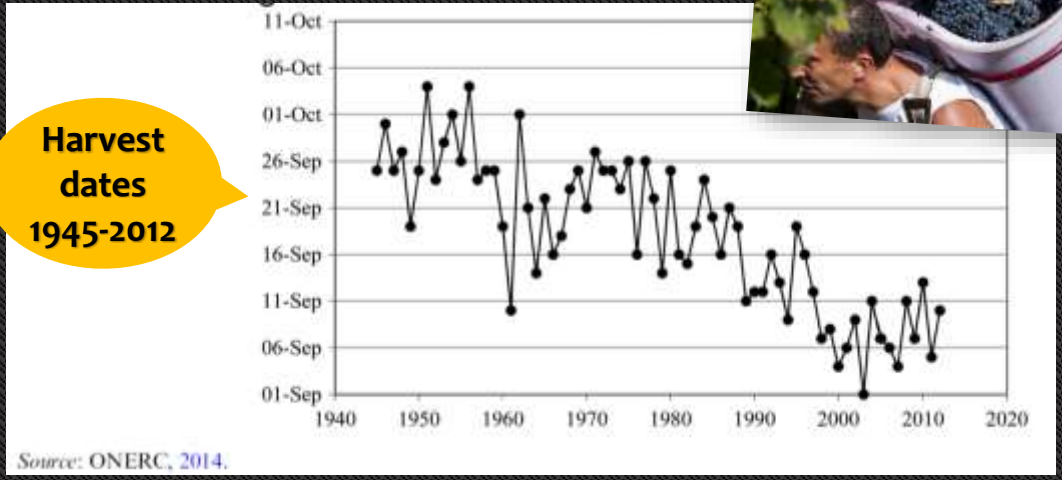


Figure 2. Long-term evolution of vine phenology for Riesling in Alsace. Data source: budbreak, flowering and veraison adapted from [48]; harvest dates from Conseil Interprofessionnel des Vins d'Alsace (CIVA).

Cornelis van Leeuwen and Philippe Darriet, The Impact of Climate Change on Viticulture and Wine Quality, Journal of Wine Economics, Volume 11, Number 1, 2016

CASE IN POINT: EARLIER HARVESTS – *CHÂTEAUNEUF-DU-PAPE*

Harvest dates 1945-2012



Source: ONERC, 2014.

Cornelis van Leeuwen and Philippe Darriet, The Impact of Climate Change on Viticulture and Wine Quality, Journal of Wine Economics, Volume 11, Number 1, 2016

CASE IN POINT:
EVOLVING GRAPE COMPOSITION – *LANGUEDOC*

Cornelis van Leeuwen and Philippe Darriet, The Impact of Climate Change on Viticulture and Wine Quality, Journal of Wine Economics, Volume 11, Number 1, 2016

CASE IN POINT:
RISING TEMPERATURES, ALTERED PROFILES – *LOIRE*

SNAPSHOT: *CABERNET FRANC*

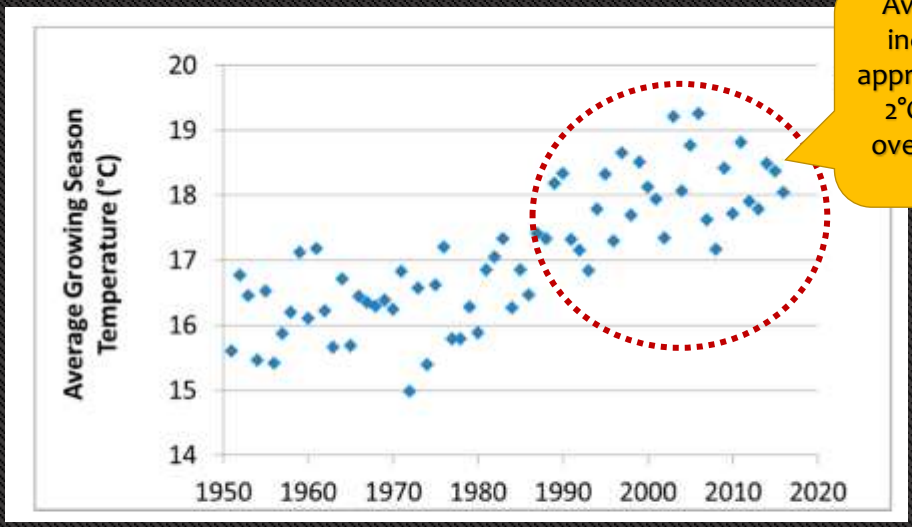
	SUGAR (MEAN G/L)	INCREASE G/L	TITRATABLE ACIDITY (MEAN G/L)	DECREASE (G/L)
ANJOU (1981-2010)	184.3	+46.6	6.0	-2.2
SAUMUROIS (1981-2010)	186.9	+54.4	5.7	-2.0
BOURGUEIL (1970-2010)	185.7	+41.0	5.5	-2.8
CHINON (1970-2010)	187.4	+51.8	5.4	-2.7

"Fifteen years ago, people wanted more ripeness. Because of climate change, ripe is easy now."
Jacky Blot, Domaine de la Taille aux Loups, Montlouis

Quoted in Vinous, Loire Chenin Underrated No More-July 23, 2020

Data from: Neethling E, et al., Change in climate and berry composition for grapevine varieties cultivated in the Loire Valley, Climate Research, Vol. 53: 89–101, 2012, doi: 10.3354/cr01094, June 2019.

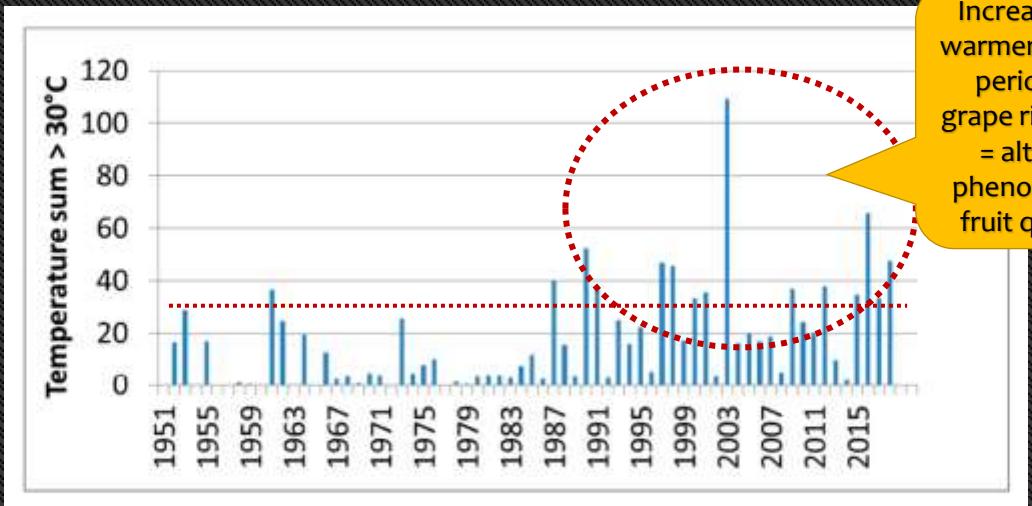
CLIMATE DATA FOR BORDEAUX, 1951 – 2018:
AVERAGE GROWING SEASON TEMPERATURE



AvGST has increased approximately 2°C (3.6°F) over past 70 years

Van Leeuwen, C. et al., An Update on the Impact of Climate Change in Viticulture and Potential Adaptations, www.mdpi.com/journal/agronomy, 5 Sep 2019.

CLIMATE DATA FOR BORDEAUX, 1951 – 2018:
TEMPERATURE SUM >30 C (86 F) 45 DAYS BEFORE HARVEST



Increasingly warmer during period of grape ripening = altered phenology & fruit quality

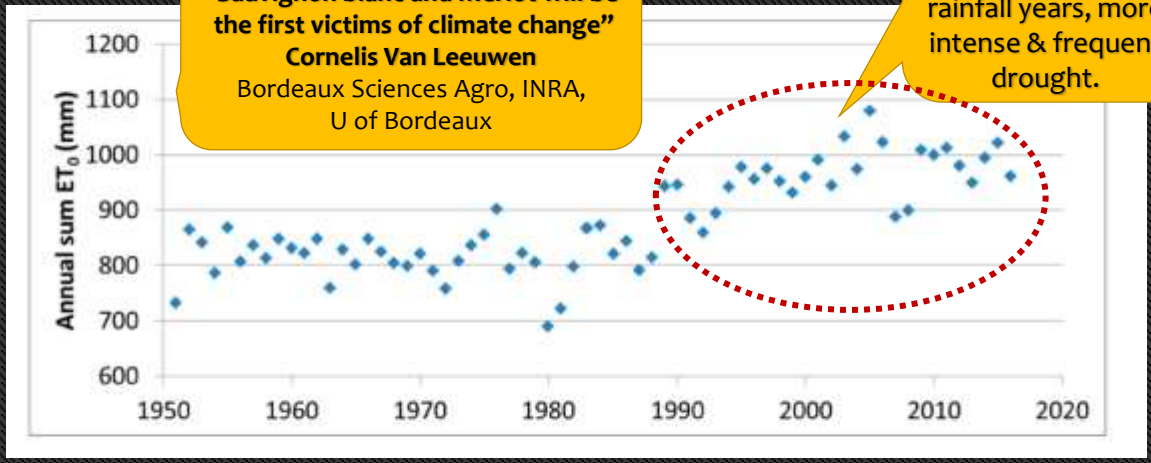
Van Leeuwen, C. et al., An Update on the Impact of Climate Change in Viticulture and Potential Adaptations, www.mdpi.com/journal/agronomy, 5 Sep 2019.

CLIMATE DATA FOR BORDEAUX, 1951 – 2018:
ANNUAL SUM OF (REAL) EVAPOTRANSPIRATION

"Sauvignon blanc and Merlot will be the first victims of climate change"
Cornelis Van Leeuwen
Bordeaux Sciences Agro, INRA,
U of Bordeaux

Higher evapotranspiration

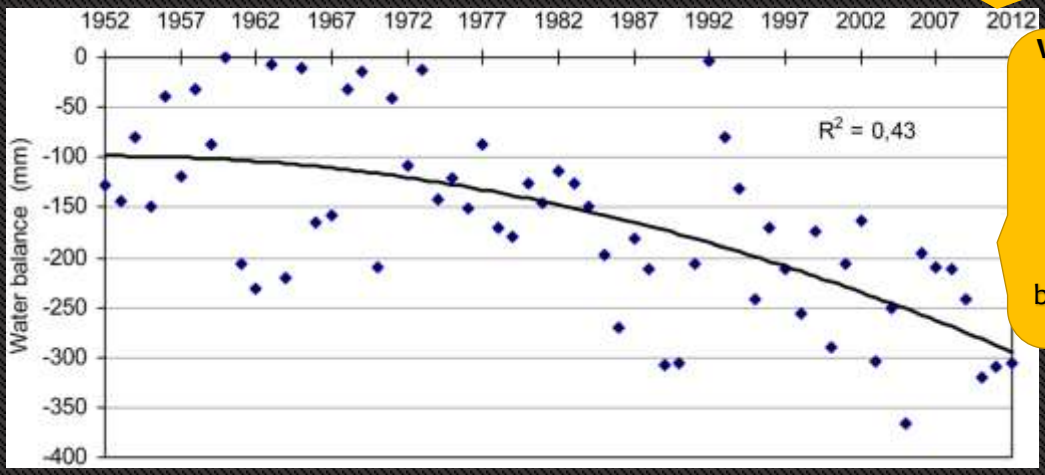
More frequent low rainfall years, more intense & frequent drought.



Van Leeuwen, C. et al., An Update on the Impact of Climate Change in Viticulture and Potential Adaptations, www.mdpi.com/journal/agronomy, 5 Sep 2019.

CLIMATE DATA FOR BORDEAUX, 1952 – 2012:
EVOLUTION OF WATER BALANCE IN SAINT-ÉMILION

Water Balance = difference between precipitation & Real Evapotranspiration



Water deficits *(at specific stages)* improve red wine quality: reduce berry size + boost phenolic compounds

Cornelis van Leeuwen and Philippe Darriet, The Impact of Climate Change on Viticulture and Wine Quality, Journal of Wine Economics, Volume 11, Number 1, 2016

SHORT-TERM GAIN, LONG-TERM PAIN?

"The *best vintages in Bordeaux* (where vines are not irrigated) *are dry vintages*. The frequency of dry vintages has increased over the past three decades and this resulted in better vintage ratings in recent years."

Cornelis van Leeuwen et al.,
An Update on the Impact of Climate Change in Viticulture and Potential Adaptations

Van Leeuwen C. et al., An Update on the Impact of Climate Change in Viticulture and Potential Adaptations, www.mdpi.com/journal/agronomy, 5 Sep 2019.

GLOBAL "WEIRDING" *A TURBULENT, UNSTABLE CLIMATE*

- ✓ Severe storms
- ✓ Extreme cold
- ✓ Heatwaves
- ✓ Drought
- ✓ Wildfires
- ✓ Floods
- ✓ Hurricanes?

Drought in Australia

Photo The Drinks Business

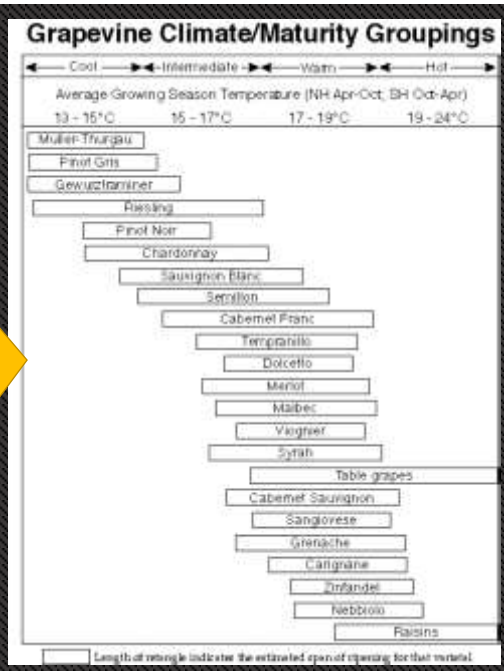
Hail in Chablis

Photo Decanter Jean-Baptiste Lemoyne, copyright JBLemoyne

Wildfires

Photo Napa Valley Register/Tim Carl Photography

"it is very difficult to establish precise upper limits by variety for growing high-quality wines"
Cornelis van Leeuwen
University of Bordeaux



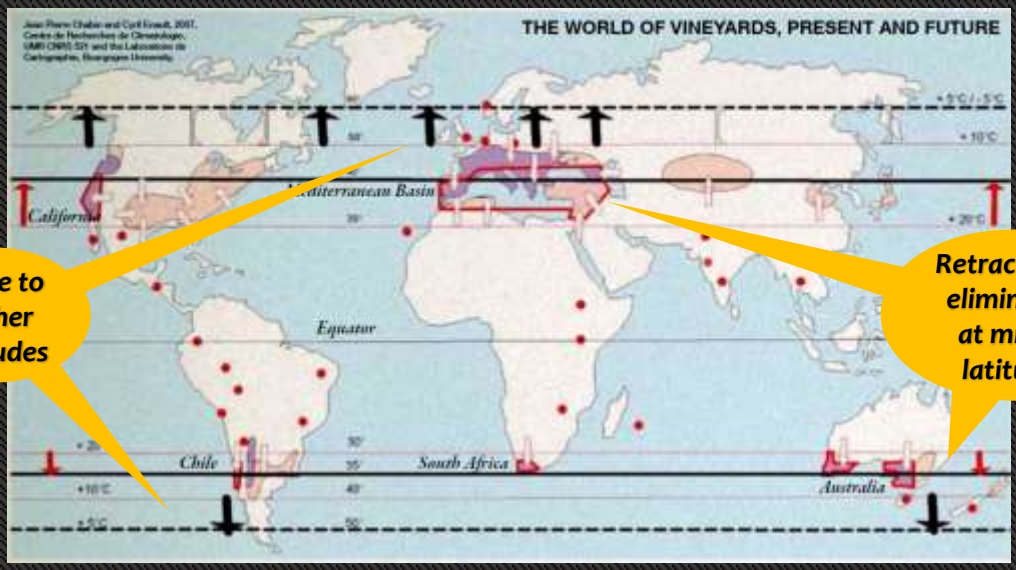
Van Leeuwen Cet al., Why climate change will not dramatically decrease viticultural suitability in main wine-producing areas by 2050, www.pnas.org/cgi/doi/10.1073/pnas.1307927110.

"The risk is that our current climate models are under-projecting future change..."
Dr. Gregory Jones,
Evenstad Center, Oregon

Quoted in
Climate change: time to act
Decanter, July 2019

Jones G , Climate and terroir: Impacts of climate variability and change on wine. Fine Wine and Terroir—The Geoscience Perspective. Geoscience Canada, eds Macqueen RW, Meinert LD (Geological Association of Canada, St John's, Newfoundland), pp 1–14, 2006.

IS THIS THE FUTURE OF THE WORLD'S VINEYARDS?



Move to higher latitudes

Retraction or elimination at middle latitudes

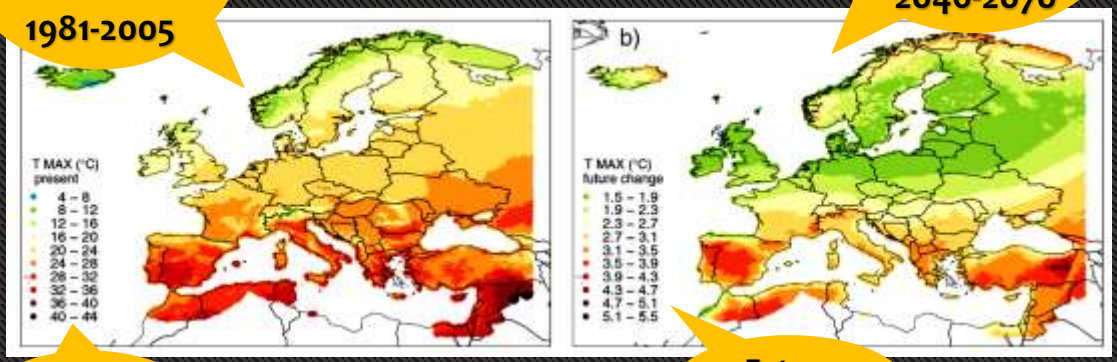
Jean Pierre Chabin and Cyril Enault, 2007, Centre de Recherches de Climatologie, UMR CNRS 521 and the Laboratoire de Cartographie, Bourgogne University.

Map taken from: Impact of climate change on wine in France, Greenpeace International, Sep 2009

EUROPE: IS THIS THE FUTURE?
Mean Max Summer Temp

Mean maximum temp in summer 1981-2005

Mean maximum temp in summer 2046-2070



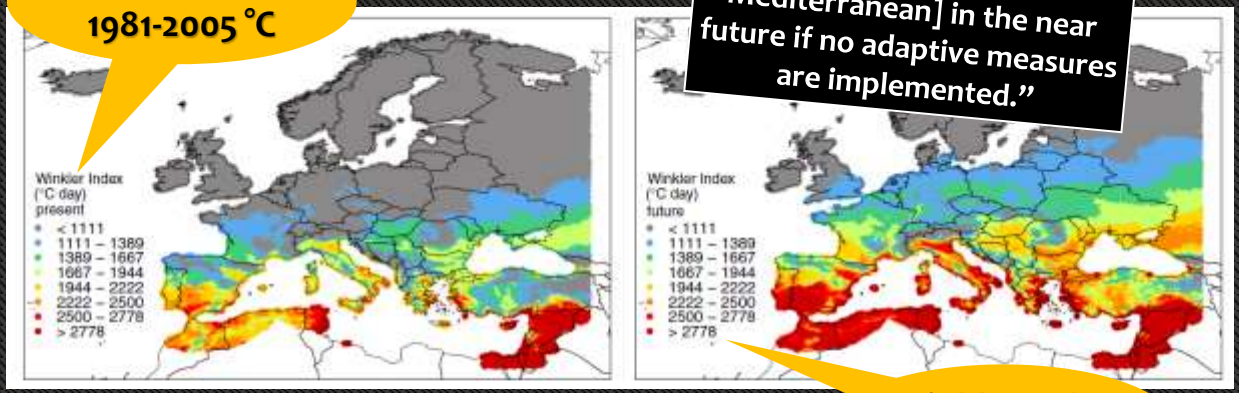
Present Max Temp °C

Future increase °C

EUROPE: IS THIS THE FUTURE?
Winkler Index

"the vine may cease to be viable in some regions of SEM [Southern Europe & Mediterranean] in the near future if no adaptive measures are implemented."

Winkler Index 1981-2005 °C



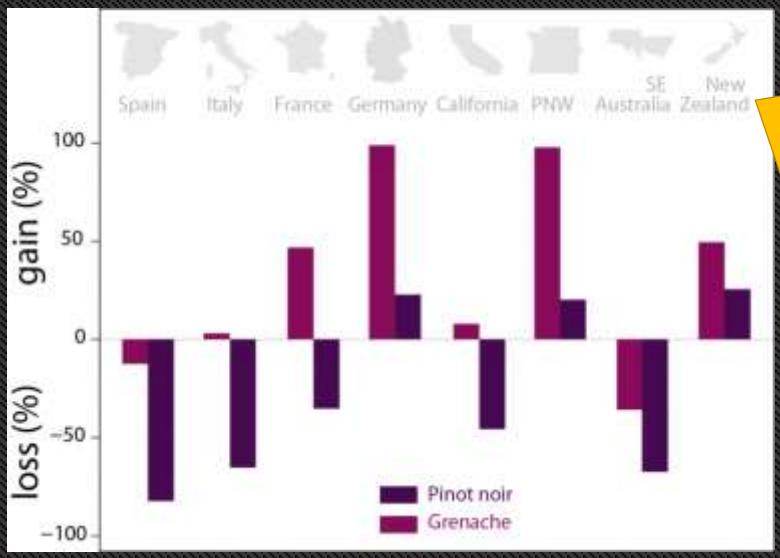
Winkler Index 2046-2070 °C

SWAPPING VARIETIES TO ADAPT – "*INTRASPECIFIC DIVERSITY*"

2°C warming: Swapping varieties reduced vineyard loss from **56% to 24%**

4° warming: from **85% to 58%**

***** PNAS 2020 study

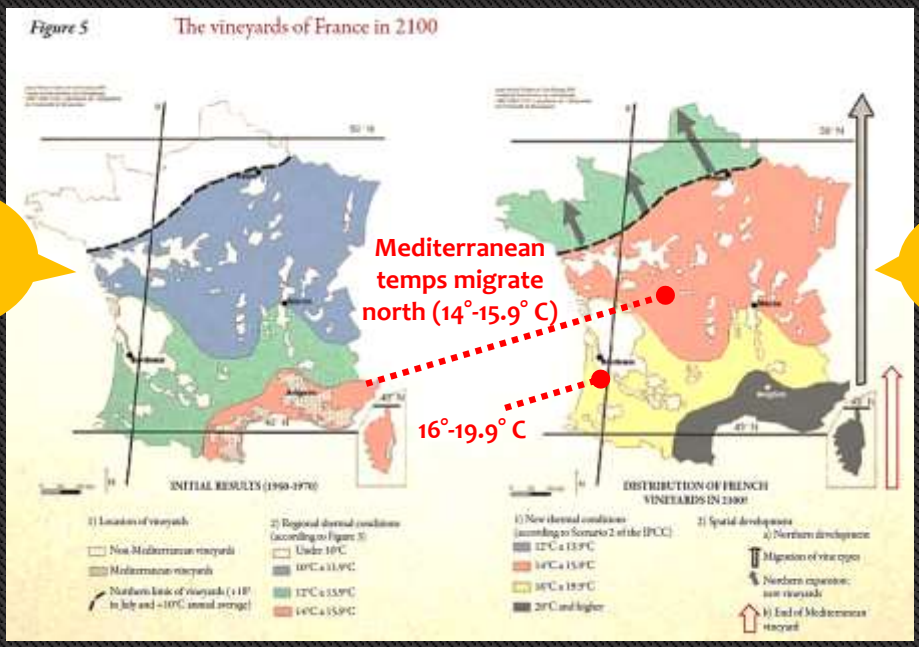


2°C warming may produce winners & losers

Take away: ***Already-hot regions have little flexibility***

*Original study: Morales-Castilla I et al., Diversity buffers winegrowing regions from climate change losses, PNAS February 11, 2020 / first published January 27, 2020.
Graph: Ignacio Morales-Castilla, reprinted in Sarah Fecht, Wine Regions Could Shrink Dramatically With Climate Change Unless Growers Swap Varieties, State of the Planet – Earth Institute | Columbia University, Jan 27, 2020.

France 1950-1970



France 2100?

Jean Pierre Chabin and Cyril Enault, 2007, Centre de Recherches de Climatologie, UMR CNRS 521 and the Laboratoire de Cartographie, Bourgogne University.

Impact of climate change on wine in France, Greenpeace International, Sep 2009

"There are ways of adapting,"
…but "the taste of Bordeaux is going to change."

Jean-Marc Touzard
Director, INRA

Quoted in :
Godin, M (May 22, 2020), 'The Taste of Bordeaux Is Going to Change.' Under Threat From Climate Change and Coronavirus, French Winemakers Try Experimenting, time.com.

RECASTING THE PARADIGM: BORDEAUX BLEND *(RED)*

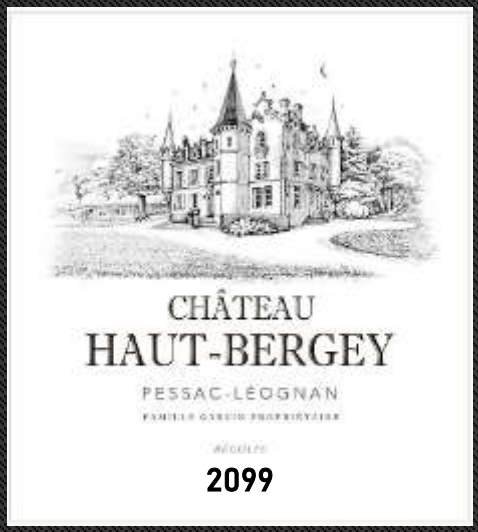
TODAY
65% Cabernet Sauvignon
25% Merlot
5% Cabernet Franc
5% Petit Verdot

TOMORROW?
30% Cot (Malbec)
20% Petit Verdot
20% Touriga Nacional*
15% Marselan*
(Grenache x Cab Sauv)
10% Castets*
(nearly extinct, see Liber Pater)
5% Arinarnoa*
(Tannat x Cab Sauv)

**** Newly authorized***

REINVENTING THE BORDEAUX BLEND (*WHITE*)

TODAY
80% Sauvignon Blanc
20% Semillon

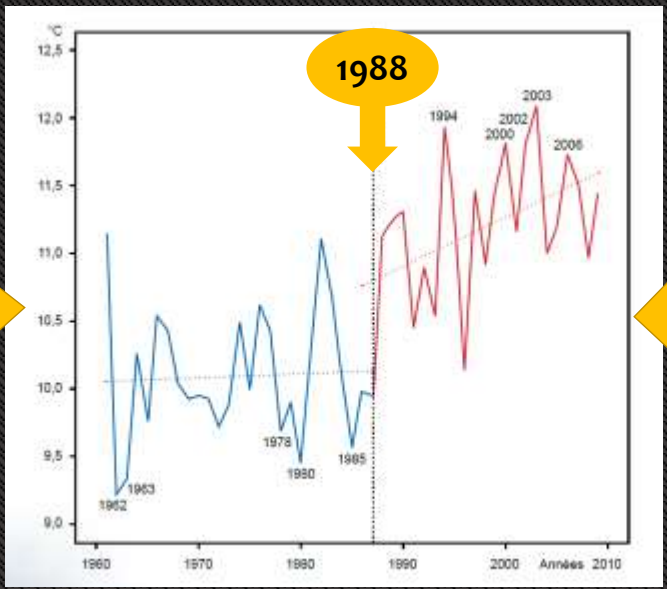


TOMORROW?
60% Alavarinho*
20% Petit Manseng*
10% Semillon
10% Liliorila*
(Chard x Baroque)

** Newly authorized*

BURGUNDY – 1961 to 2010
UNMISTAKEABLE WARMING TREND

Average annual temperature °C



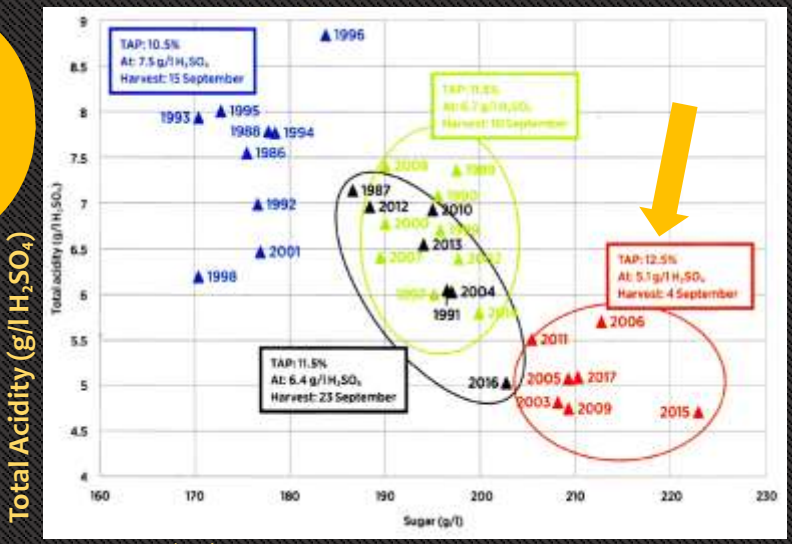
Coldest years in last 50 came before 1987. **Hottest** years in last 50 came after 1988.

LE CHANGEMENT CLIMATIQUE EN BOURGOGNE (1961-2040)
http://climatologie.u-bourgogne.fr
Yves RICHARD et Thierry CASTEL

BURGUNDY – 1986 to 2017

EARLIER HARVESTS, RISING POTENTIAL ALCOHOL & FALLING ACIDITY

TAP = Total Potential Alcohol
At = Total Acidity (sulfuric)



"I reckon we've got another decade to adapt before it's too late."
Diana Snowden-Seysses, Domaine Dujac, Morey-Saint-Denis

Quoted in Climate change in Burgundy: time to act Decanter, March 2020

Graph: BIVB/Atkin T, Climate Change in Burgundy: Time to Act, Decanter , March 2020

BURGUNDY –

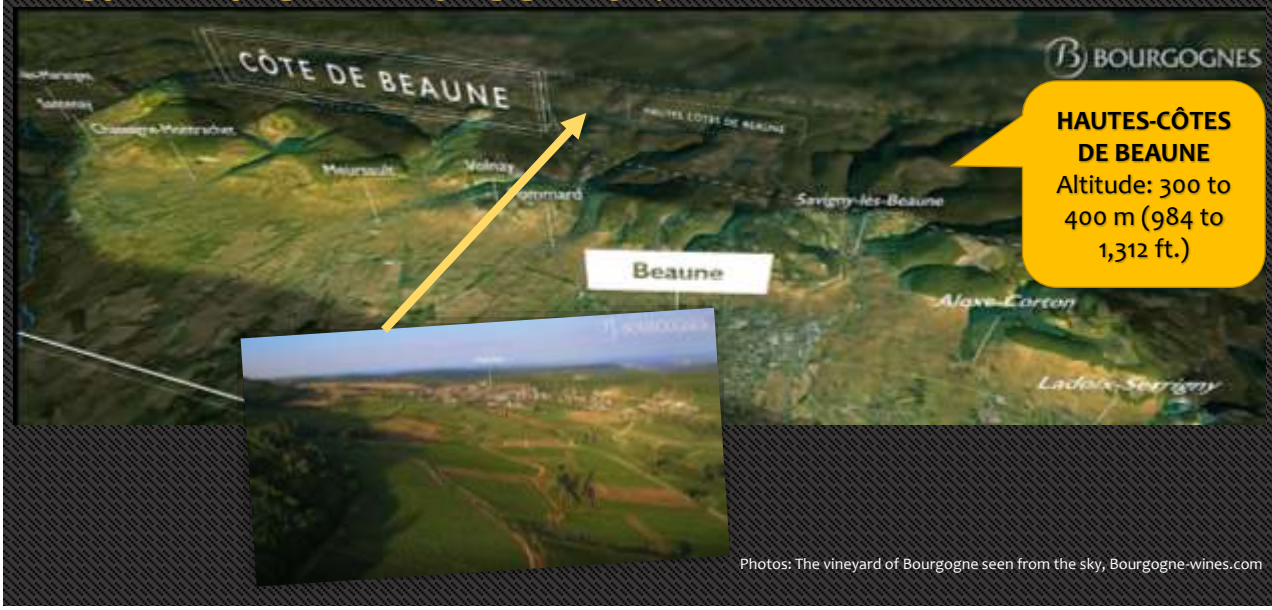
IS PINOT NOIR THE POLAR BEAR OF GRAPE VARIETIES?

Photo: Bourgogne Aujourd'hui

Photo: Polar Bears International

SHORT ANSWER:
NO, PINOT NOIR HAS MORE OPTIONS.

THE HAUTES-CÔTES – *WILL MORE ALTITUDE & COOLER CONDITIONS BE PINOT'S SAVIOR?*



Photos: The vineyard of Bourgogne seen from the sky, Bourgogne-wines.com

SWITZERLAND - *A MESSAGE FOR BURGUNDY?*

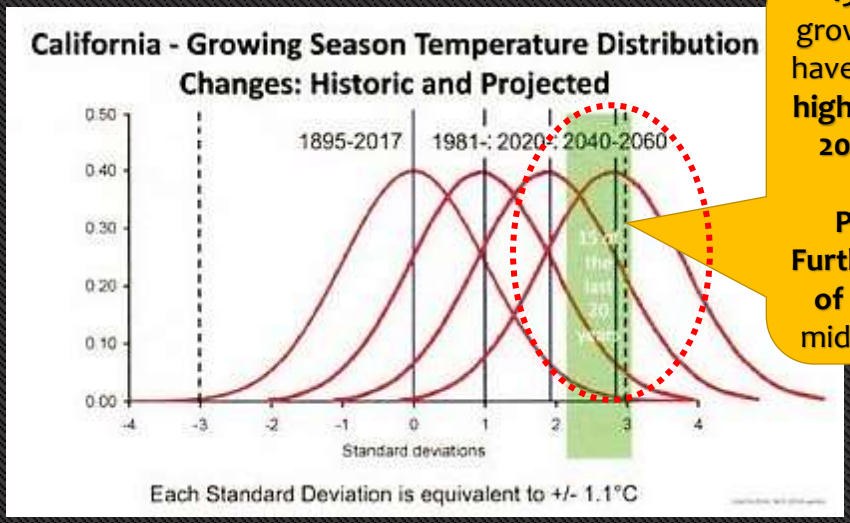
Vallais, Switzerland
Up to 1,100 m (3,600 ft.)

Pinot Noir accounts for 30% of plantings… in hottest locales, some is now being replaced by Syrah

Photo Swisswine.ch/Wink Lorch, Wine at altitude, Wine-Business-International.com, Jun 3, 2015.

"Climatologists Say Cabernet's Days as King in Napa are Numbered"

Larry Brooks | Wine Business Monthly | Jan 2019



15 of last 20 growing seasons have been **3° to 5° higher than 1895-2017 average.**

Projection: Further increases of 4° to 5° F by mid-21st century.

Larry Brooks, Climatologists Say Cabernet's Days as King in Napa are Numbered, Wine Business Monthly, Jan 2019

COULD CLIMATE CHANGE MEAN AN END TO CABERNET IN NAPA VALLEY? THIS WINEMAKER THINKS SO

DANA REBMANN | SONOMA MAGAZINE | JANUARY 2020The

Dan Petroski,
winemaker at Larkmead Vineyards

Dedicating 3 acres out of their 110-acre estate to a 'viticultural research block' planted with Petite Sirah, Zinfandel, Aglianico, Tempranillo, Touriga Nacional, Charbono, Syrah & Chenin Blanc.

"My number one objective for these seven red grape varieties is that they have the ability to blend well with Cabernet, as a supporting actor until Cabernet can't be used anymore," says Petroski.

METAMORPHOSIS OF THE NAPA RED BLEND?

TODAY
55% Cabernet Sauvignon
28% Merlot
11% Cabernet Franc
5% Petit Verdot
1% Malbec

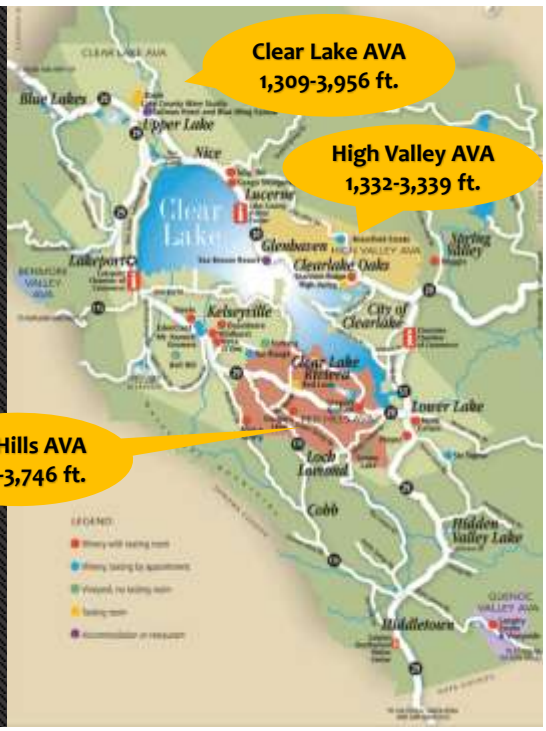
TOMORROW?
40% Syrah
25% Malbec
15% Saint-Macaire
10% Tempranillo
10% Petit Verdot

LAKE COUNTY – *THE NEW NAPA?*

"HIGHER, DRIER, SHORTER & COLDER"

Legendary grape grower betting Lake County will be the next Wine Country
Esther Mobley | San Francisco Chronicle | Jan 22, 2016

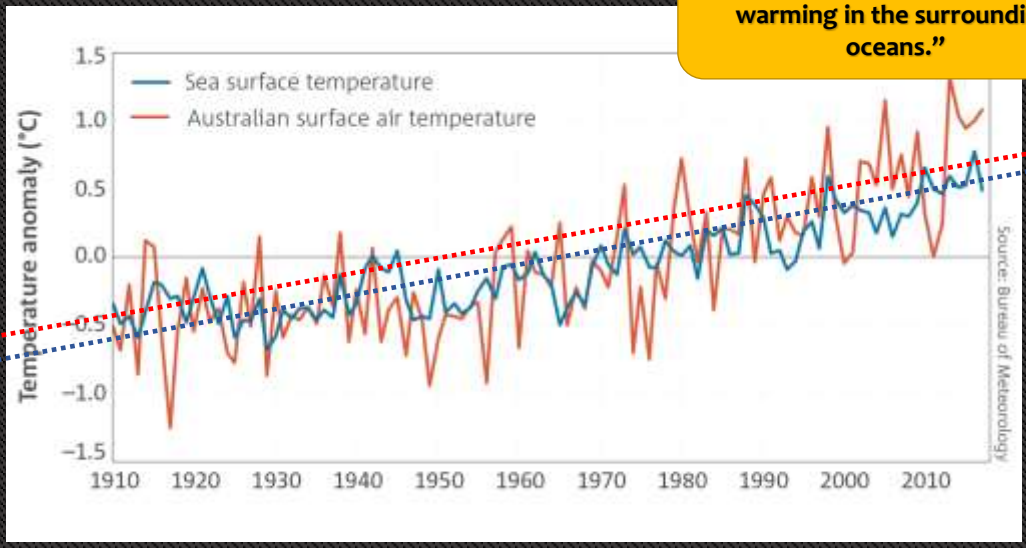
~ 3% of CA vineyards are above 1,000 ft.



Jones GV, Climate Characteristics for Winegrape Production in Lake County, California, 12/1/2014

AUSTRALIA – TEMPS ON THE RISE

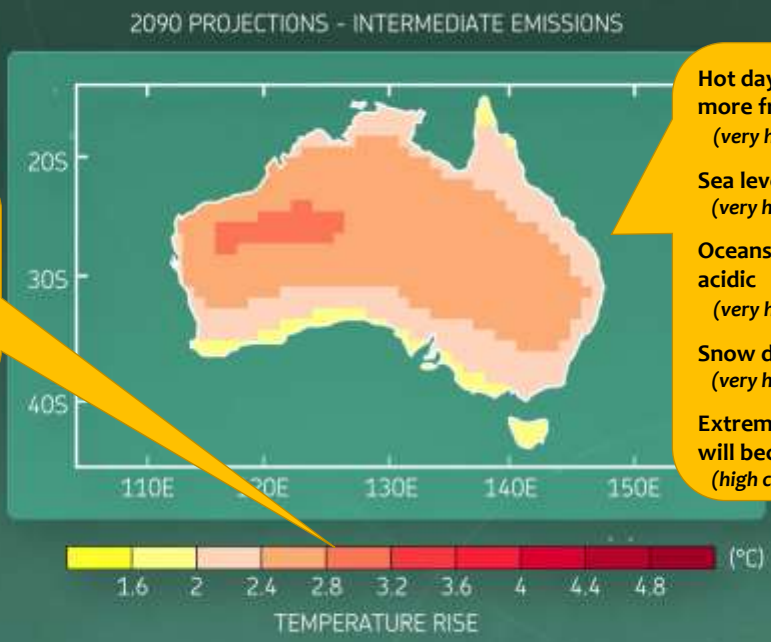
"Australia's climate has warmed since 1910. It is consistent with warming in the surrounding oceans."



State of the Climate, 2016. Bureau of Meteorology and CSIRO, climatechangeinaustralia.gov.au

AUSTRALIA

"Temperatures across all wine regions of Australia will increase by about 3° C by 2100."



Hot days will become more frequent and hotter *(very high confidence)*

Sea levels will rise *(very high confidence)*

Oceans will become more acidic *(very high confidence)*

Snow depths will decline *(very high confidence)*

Extreme rainfall events will become more intense *(high confidence)*

Projecting Future Climate Change (video), CSIRO, csiro.au

AUSTRALIA – *IS THERE A HIGH-ALTITUDE SOLUTION?*

1,306m (4,285 ft.) ASL

CLIMATE
New England Australia GI
+Rain mainly from late summer to early autumn
+Summer max temp rarely higher than 30° C (86° F)
+Severe thunderstorms, hail
+Severe frosts from June to Nov, snow

Climate: WineAustralia.com/Jilly Wines, jillywines.com.au

Black Mountain Vineyard, New England Australia GI Clunes, New South Wales
Planted with Pinot Noir in 2000
Managed by Jilly Wines

Sorrel Moseley-Williams, High-Altitude Vineyards that are Changing Wine, winemag.com, April 5, 2018

ALTITUDE – *ANTIDOTE FOR CLIMATE CHANGE? (AND OTHER BENEFITS…)*

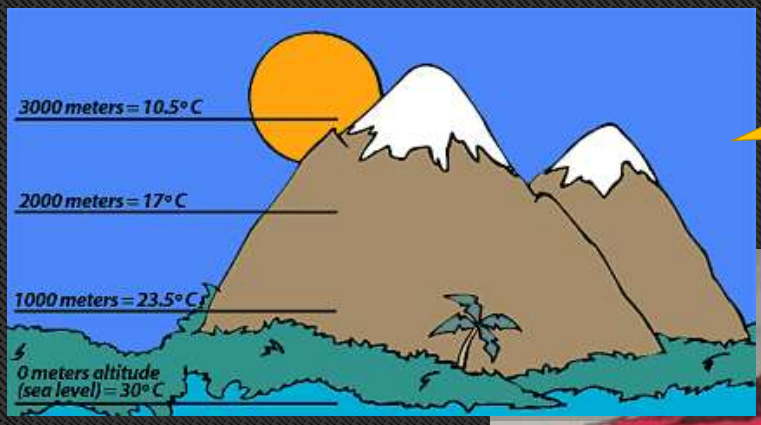


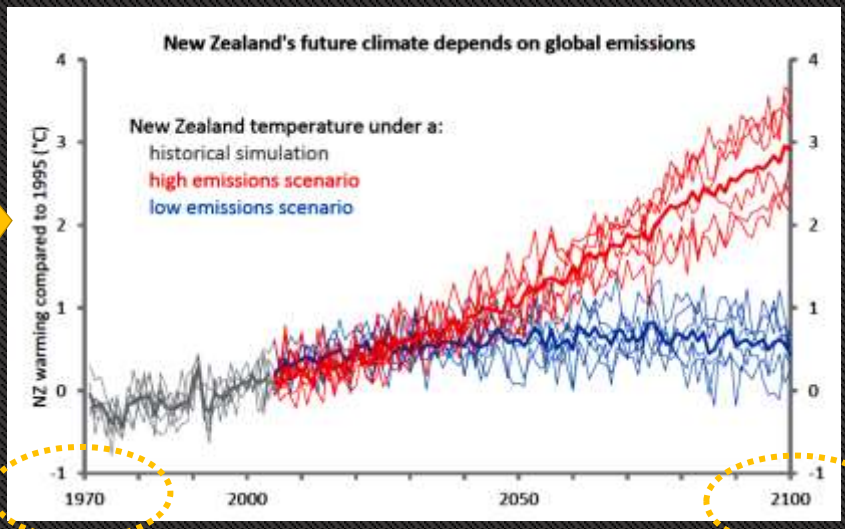
Image & data: UCAR Center for Science Education, scied.ucar.edu

Formula
6.5 ° C
per 1,000 meters
3.6 ° F
per 1,000 feet

Image: Ramón Bilbao, Rosé Trends, IMW Webinar Series, 9 July 2020

NEW ZEALAND – *MAY ESCAPE THE WORST*

Projected warming compared to 1995 (° C)



Climate Projections for New Zealand, Snapshot June 2016, Info 765, New Zealand Government, Ministry for the Environment.

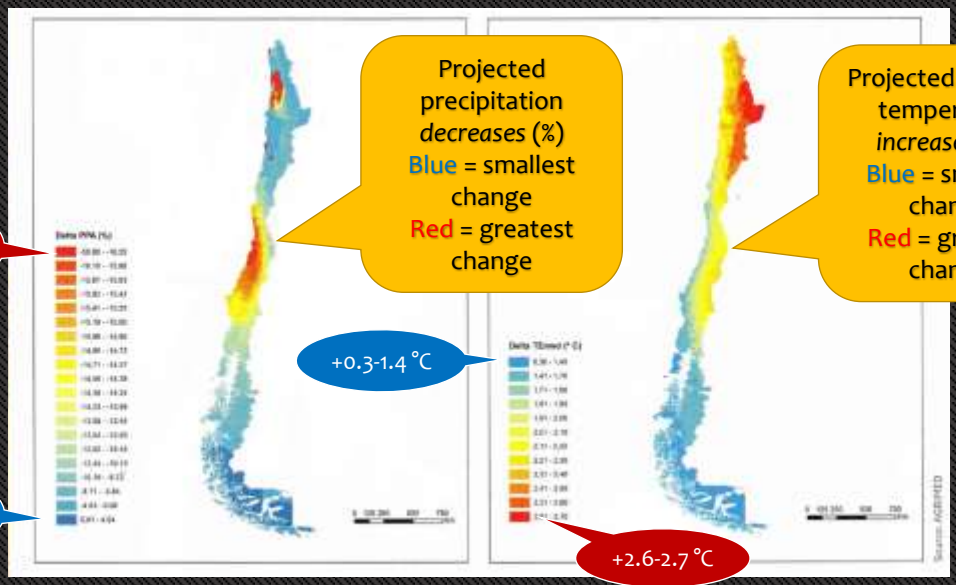
NEW ZEALAND – *MARLBOROUGH & OTAGO*

Otago
Projections by 2090
(high emissions)
up to 2.8°C warmer
25 extra days per year > 25° C
Summer rain: + 4% to 5%
Droughts: greater frequency

Marlborough
Projections by 2090
(high emissions)
up to 3.0°C warmer
38 extra days per year > 25° C
Summer rain: + 9%
Droughts: greater frequency & intensity

Maps & data: Climate change projections, Ministry for the Environment, mfe.govt.nz/climate-change

CHILE – *LESS RAIN, MORE HEAT BY 2050*



Agrimed/University of Chile, in Amanda Barnes, Climate change: the next frontier, Decanter July 2017.

CHILE – *THE QUEST FOR ALTITUDE*

Viñedos de Alcohuaz
Elqui Valley
1,650 to 2,206 m
(5,412 to 7,216 ft.)

Syrah, Garnacha, Malbec, Petite Syrah, Petit Verdot, Cariñena, Touriga Nacional, Roussanne, Marsanne

Chile's highest commercial vineyard

30° S

RHU 2015 is a blend of Syrah (80%) Grenache (5%) and Petite Sirah (15%). The wine is stored in 2,500 liter wooden foudres for 35 months. Fermentation is spontaneous with indigenous yeast in rock wine presses [lagar], built on the property.

Vdalcohuaz.cl

CHILE – *THE LURE OF LATITUDE*

46° S

Undurraga Chile Chico Vineyard *(experimental)*

World's most southerly vineyard?

ARGENTINA – *EXTREME ALTITUDE*

24.8° S

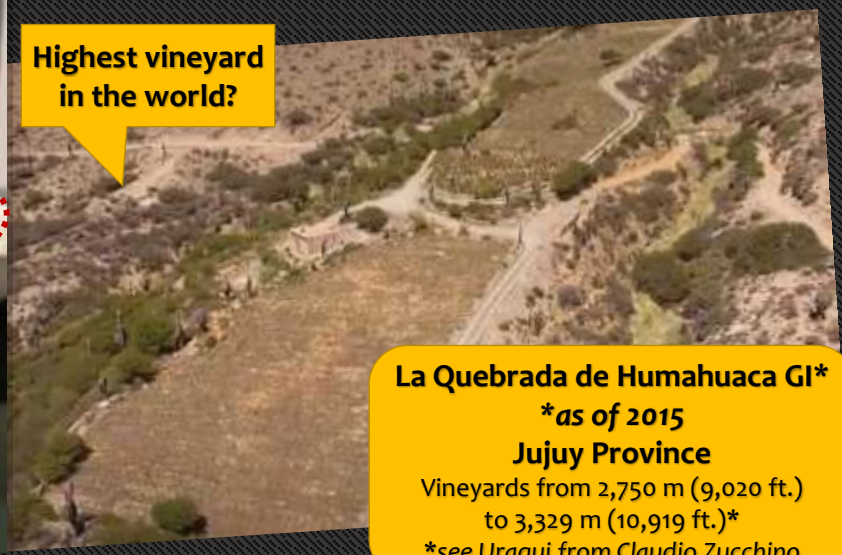
Bodega Colomé
Calchaqui Valley, Salta
Vineyards from 2,300 m (7,544 ft.) to 3,111 m (10,204 ft.)

'Altura Máxima'

2nd highest vineyard in the world?

Photo/image bodegacolome.com

ARGENTINA – *ULTRA-EXTREME ALTITUDE!*



Highest vineyard in the world?

La Quebrada de Humahuaca GI*
as of 2015
Jujuy Province
Vineyards from 2,750 m (9,020 ft.) to 3,329 m (10,919 ft.)*
**see Uraqui from Claudio Zucchino*

ARGENTINA – *PATAGONIA EXTREMA*

A project of Alejandro Bulgheroni

45.5° S

Otronia Vineyard Sarmiento, Chubut Province

Chardonnay, P Gris, Gewurz, P Noir planted in 2012

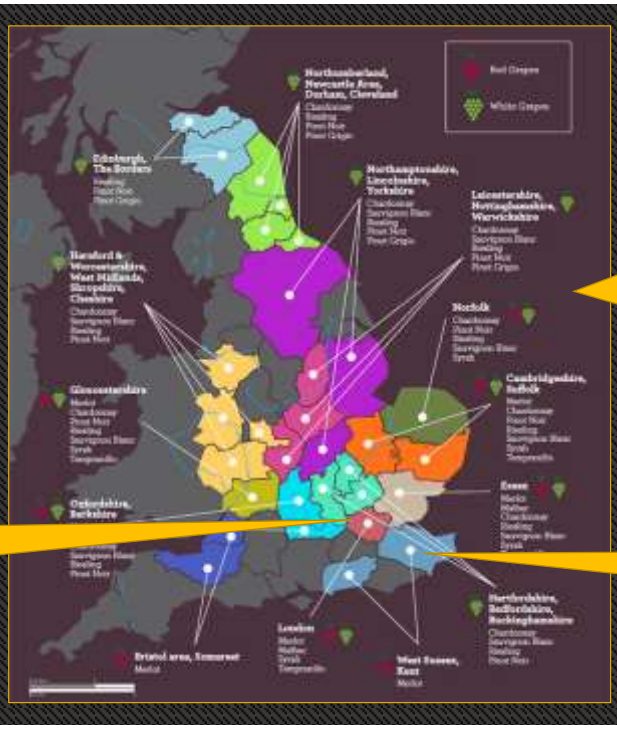
Photo Otronia
Michael Schachner, Extreme Conditions and a Changing Climate on Patagonia's Southern Winemaking Frontier, winemag.com, Dec 13, 2019

ENGLAND – *THE NEW CHAMPAGNE?*

Climate change offers sparkling prospects to English winemakers

Pauline Froissart | www.phys.org | December 6, 2018

GREAT BRITAIN 2100



Map: Laithwaites

Pinot Noir from almost everywhere??

Malbec from London?

A Kent Merlot?

https://blog.laithwaites.co.uk/wine-climate-change-uk-margaux-margate-chateau-pettus-chateau-peckham/ Dec 1, 2016

TESTING PRECONCEPTIONS – *HIGH-LATITUDE VINES IN POLAND*

53.2° N

Anna & Arthur Kojder
Winnice Kojder
Bielice, Poland

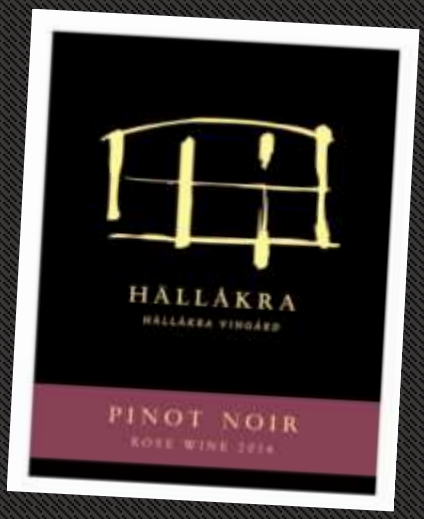
Johanniter = Riesling x (Seyve-Villard 12-481) x (Pinot Gris x Gutedel)

Wine cooler: global heating helps Sweden's vineyards to success

Jon Henley | The Guardian | 20 March 2020

55.46° N

"**We have an extra month of summer now.** And winters are not like what they used to be. That's why we can make wine, and why 50 years ago, we couldn't."
Håkan Hansson, Hällåkra Vineyards, Sweden



Solaris = Merzling x Gm 6493 (hybrid)
Cross with V. vinifera: Rieslng, P Gris, Muscat
Rondo = Zarya Severa x St. Laurent (hybrid)

Chateau Viking: Climate Change Makes Northern Wine a Reality

The Wall Street Journal | Bojan Pancevski | Oct 29, 2019

61.1° N

Slinde Vineyard Sognefjord, Norway

World's most northerly vineyard?

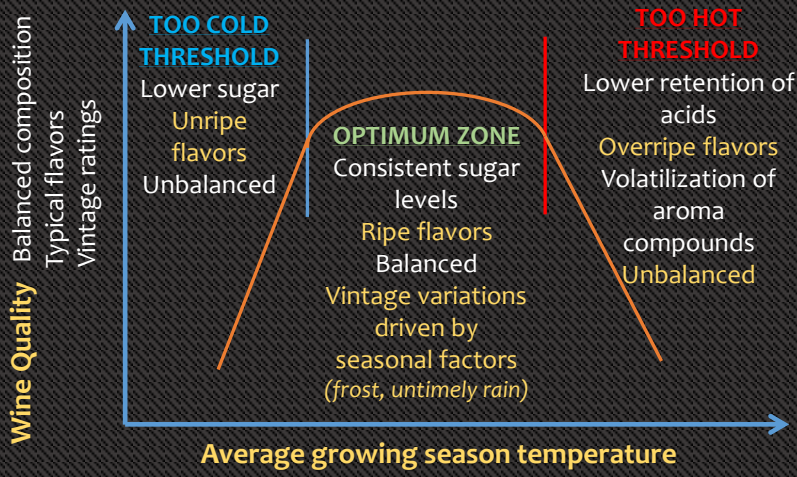
"We have won gold medals in a blind wine tasting competition for our white wine Lydia (Solaris), our red wine based on Leon Millot and our special blended white wine."
Bjorn Bergum, owner
Slinde Vineyard, Norway

Léon Millot = M & G 101-14 x Goldriesling (hybrid)

APPENDIX

AvGST – *FUNDAMENTAL IMPACTS ON WINE*

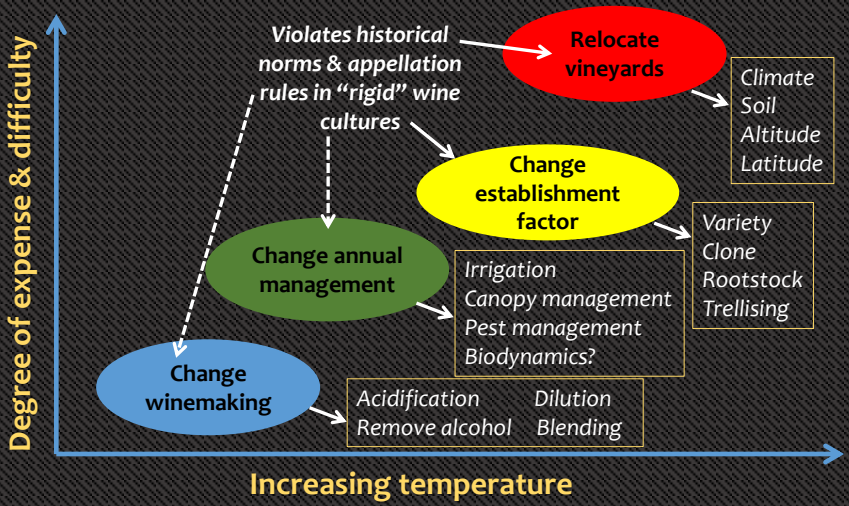
APPENDIX A



Adapted from G. V. Jones, 2005

APPENDIX B

HOW CAN WINEGROWERS MITIGATE & ADAPT?



Adapted from Cahill, K. N. and C. B. Field. 2008. Future of the Wine Industry: Climate Change Science. Practical Winery and Vineyard.

APPENDIX B1

! = Potential conflict with laws, traditions

VITICULTURAL "FIXES" FOR A CHANGING CLIMATE

Level of difficulty – cost – disruption:

Low | Moderate

- ✓ Pick some grapes/parcels earlier
- ✓ Harvest at night
- ✓ Shade the grapes
- ✓ Reduce leaf area to fruit weight ratio (espec. whites)
- ✓ Change timing of pruning
- ✓ Mulch to hold moisture
- ✓ Plant winter cover crops
- ✓ Raise trunk height !

High | Extreme

- ✓ Convert to biodynamics?
- ✓ Irrigate !
- ✓ Change clones
- ✓ Change rootstock(s)
- ✓ Change ratio of cultivars !
- ✓ Change cultivar(s) !
- ✓ Alter training system !
- ✓ Increase row spacing !
- ✓ Avoid N/S orientation
- ✓ Face away from equator !
- ✓ Plant at higher altitudes !
- ✓ Plant at higher latitudes !!

APPENDIX B2

WINEMAKING "FIXES" FOR A CHANGING CLIMATE

Level of difficulty – cost – disruption:

Low | Moderate

- ✓ Alter blends of varieties, lots
- ✓ Co-ferment/add white grapes in red blends
- ✓ Use yeasts tolerant of higher alcohol
- ✓ Leave white wines on lees longer
- ✓ Reduce enrichment, dosage
- ✓ Acidification !
- ✓ Dilution (add water) !
- ✓ Remove alcohol !

High | Extreme

- ✓ GMO yeasts, bacteria & additives !!

! = Potential conflict with laws, traditions