Climate, Grapes and Wine: Understanding Terroir Influences in a Variable and Changing Climate

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Session Outline

- Changing Wine Map
- State of the Climate
- Climate Structure and Suitability
- Climate Change the Past and Future
- Summary
Changing Wine Map
A New World of Wine: How the Viticultural Map is Changing

[Map of the world with various markings representing wine regions and growing season temperatures]
Change Factors

- National to international economics
- Growing demand, changing demographics
- New markets, new consumers, new styles
- New purchasing trends
- Changes in the tastes of wine writers/raters
- Production and movement of bulk wine
- Organic, biodynamic production and sales
- Pioneers looking for ‘fringe’ or new areas
- Climate
The State of the Climate
Globally 2015 was the warmest year since 1880 (0.95°C or 1.71°F above average)

Beat the record set in 2014 by 0.17°C or 0.31°F
The US and Europe both ended up having a top 5 warmest year on record.

Continued global ocean warming and strong El Niño assured 2015 the record.
Jan-Jun were all the warmest individual months on record (now 15 months in a row)

Overall 1.05°C or 1.89°F above average

Preliminary July data shows the trend continuing
Global Land and Ocean Temperature Anomalies, January-December

1880-2015 Trend
-0.67°C/Century

Temperature Anomalies

Anomaly (°C)

Anomaly (°F)

January-December Precipitation Anomalies
1900-2015

Millimeters

Year

1900 1920 1940 1960 1980 2000

-60 -40 -20 0 20 40 60
Change in Earth’s Total Heat Content

- Ocean Heating
- Land + Atmosphere + Ice Heating

Change in Total Heat Content since 1961 ($10^{21}$ Joules)

Arctic Sea Ice Extent
(area of ocean with at least 15% sea ice)

Portions of the Arctic have averaged up to 13°C (23°F) above normal during the spring.
Tropics to Poles Temperature Gradient
Arctic amplification has produced a slower jet stream, with more amplified north-south waves, more extreme weather and greater swings in climate conditions from year to year, season to season, and month to month. Some indication of similar changes in the Southern Hemisphere.
Climate Structure and Suitability for Viticulture
Weather and Climate present three distinct spatial and temporal scales of influences and risks to viticulture:

- **Individual Weather Events (short-term/localized)**
  - Hail, frost/freezes, heavy rain, etc.

- **Climate Variability (seasonal-decadal/regionalized)**
  - Dry or wet & warm or cold periods

- **Climate Structure/Change (long-term/regional-global)**
  - Average temperatures, rainfall regimes
  - Warming, cooling, changes in moisture regimes
Weather & Climate Influences on Vine Growth, Productivity, and Quality

- Harvest
- Bud Break
- Flowering
- Véraison
- Harvest

- Slow hardening of vines, sufficient chilling units, low impact from winter extreme temperatures
- Combined effects of soil temperature, atmospheric temperature, and day length changes
- Optimum daytime maximum temperatures, high solar potential, low cloud cover and rainfall
- Optimum heat accumulation, low temperature variability, low heat stress
- High diurnal temperature range, truncation of season, day length changes, low rainfall
Variety-Climate Thresholds

- **Too Cold Threshold**
  - Lower sugar levels,
  - Unripe flavors,
  - Unbalanced

- **Too Warm Threshold**
  - Lower retention of acids,
  - Overripe flavors,
  - Unbalanced

- **Optimum Zone**
  - Consistent sugar levels,
  - Ripe flavors,
  - Generally balanced
  - Vintage variations driven by seasonal climate factors (frost, untimely rain, etc.)

- **Climate Metrics**
  - Growing Season Temperatures, Heat Accumulation

- **Variety-Climate Thresholds**
  - Plasticity – Adaptation Management (short-term)
  - Varietal (long-term)

- **Yield/Production**
- **Balanced Composition**
- **Typical Varietal Flavors**
- **Vintage Ratings/Price**

- **Wine Production and Quality Metrics**
  - Growing Season Temperatures
  - Heat Accumulation
  - Optimum Zone
**Climate Suitability**

- All varieties have inherent climatic thresholds for optimum quality and production characteristics.
- Pinot Noir exhibits one of the most narrow climatic niches for premium quality production.
- From what we know about today’s Pinot Noir regions, growing season average temperatures range from ~57-61°F, or ~ a 4°F climatic niche.

### Grapevine Climate/Maturity Groupings

<table>
<thead>
<tr>
<th>Average Growing Season Temperature (NH Apr-Oct; SH Oct-Apr)</th>
<th>Cool</th>
<th>Intermediate</th>
<th>Warm</th>
<th>Hot</th>
</tr>
</thead>
<tbody>
<tr>
<td>55 - 59°F</td>
<td>Muller-Thurgau</td>
<td>Pinot Gris</td>
<td>Gewurztraminer</td>
<td>Riesling</td>
</tr>
<tr>
<td>59 - 63°F</td>
<td>Sauvignon Blanc</td>
<td>Semillon</td>
<td>Cabernet Franc</td>
<td>Tempranillo</td>
</tr>
<tr>
<td>63 - 67°F</td>
<td>Malbec</td>
<td>Viognier</td>
<td>Syrah</td>
<td>Table grapes</td>
</tr>
<tr>
<td>67-72°F</td>
<td>Cabernet Sauvignon</td>
<td>Sangiovese</td>
<td>Grenache</td>
<td>Carignane</td>
</tr>
</tbody>
</table>

Length of rectangle indicates the estimated span of ripening for that varietal.

Jones, 2006
**Climate Suitability**

- This framework also allows for region comparisons...
- Burgundy
- Willamette Valley
- Bordeaux
- Napa Valley

Jones, 2006
Climate Suitability

- This framework also allows for mapping where current and future suitable zones are/will be located.

- For example ... cool climate regions have growing seasons that average 55-59°F.

Jones, 2006
Cool Climate Zones Worldwide

April-October
Growing Season Average Temperatures (55.0-59.0°F)
October- April

Area Suitable 55.0-59.0°F

Represents 1950-2000 Average Growing Season Temperatures (WorldClim database, 1 km resolution)
Cool Climate Zones in Europe

Growing Season (Apr-Oct)
Average Temperatures

Area Suitable 55.0-59.0°F

Represents 1950-2000 Average Growing Season Temperatures (WorldClim database, 1 km resolution)
Cool Climate Zones in North America

Growing Season (Apr-Oct)
Average Temperatures
(55.0-59.0°F)

Area Suitable 55.0-59.0°F

Represents 1950-2000 Average Growing Season Temperatures (WorldClim database, 1 km resolution)

Gregory Jones, PhD
Cool Climate Zones in Australia & NZ

Growing Season (Apr-Oct)
Average Temperatures (55.0-59.0°F)

Area Suitable 55.0-59.0°F

Represents 1950-2000 Average Growing Season Temperatures (WorldClim database, 1 km resolution)

Gregory Jones, PhD
Cool Climate Zones in South America

Growing Season (Apr-Oct)
Average Temperatures (55.0-59.0°F)

Area Suitable 55.0-59.0°F

Represents 1950-2000 Average Growing Season Temperatures (WorldClim database, 1 km resolution)
Cool Climate Zones in South Africa

Growing Season (Apr-Oct)
Average Temperatures (55.0-59.0°F)

Area Suitable 55.0-59.0°F

Represents 1950-2000 Average Growing Season Temperatures (WorldClim database, 1 km resolution)
Climate Change – The Past & Present
Climate Influences on Vine Growth, Productivity, and Quality

- **Harvest**
  - Slow hardening of vines, sufficient chilling units, low impact from winter extreme temperatures

- **Bud Break**
  - Combined effects of soil temperature, atmospheric temperature, and day length changes

- **Flowering**
  - Optimum daytime maximum temperatures, high solar potential, low cloud cover and rainfall

- **Véraison**
  - Optimum heat accumulation, low temperature variability, low heat stress

- **Harvest**
  - High diurnal temperature range, truncation of season, day length changes, low rainfall
Climate Influences on Vine Growth, Productivity, and Quality

- Harvest
- Bud Break
- Flowering
- Véraison
- Harvest

Warmer dormant periods reducing chilling and cold hardiness, but winter freezes still occur.
Climate Influences on Vine Growth, Productivity, and Quality

Warmer soil temperatures and spring air temperatures driving earlier growth, but frosts still occur.
Climate Influences on Vine Growth, Productivity, and Quality

Evidence of rainfall and cloud cover shifts in some regions that affect flowering and set
Climate Influences on Vine Growth, Productivity, and Quality

Overall longer growing seasons and higher heat accumulation, higher temperature variability and heat stress in many regions.
Climate Influences on Vine Growth, Productivity, and Quality

Harvest  Bud Break  Flowering  Véraison  Harvest

Lower diurnal temperature ranges in many regions, fruit ripens too early, sugar ripe, but not flavor/aroma … ripeness clocks out of sync
Climate Influences on Vine Growth, Productivity, and Quality

Phenology has shown shifts to:

- Earlier occurrences (3-6 days/1°F), and
- Compressed phases (5-15 days on average)
Climate Influences on Vine Growth, Productivity, and Quality

- Altered/new disease/pest timing and severity
- Changes in soil fertility and erosion
- $\text{CO}_2$ fertilization ... but wine effects?
- Water availability and timing of irrigation
Emissions have slowed, but not enough ...
... likely continuing the planet on the higher temperature path in the future.
Global Viticulture Zones
Growing Season Average Temperature Isotherms (55-72°F)
Northern Hemisphere (Apr-Oct); Southern Hemisphere (Oct-Apr)

Isotherms shift poleward ~175-325 miles (from 1950)
Some expansion NH, mostly declines SH

Jones et al. (2012) The Geography of Wine

National Center for Atmospheric Research’s Community Climate System Model (CCSM) A1B (mid-range scenario): 1.4° x 1.4° Lat/Lon
April - October
Area Too Warm > 59.0°F

New Area (55.0-59.0°F)

Cool Climate Zones Worldwide +2°F

Represents ~2°F warming from the 1950-2000 time period for Average Growing Season Temperatures, based on an A1B emission scenario for 2050.

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Cool Climate Zones in Europe +2°F

Growing Season (Apr-Oct) Average Temperatures
- Area Too Warm > 59.0°F
- Warmer but still suitable
- New Area (55.0-59.0°F)

Represents ~2°F warming from the 1950-2000 time period for Average Growing Season Temperatures, based on an A1B emission scenario for 2050.
Cool Climates Zones in North America +2°F

Growing Season (Apr-Oct) Average Temperatures

- Purple: Area Too Warm > 59.0°F
- Red: Warmer but still suitable
- Pink: New Area (55.0-59.0°F)

Represents ~2°F warming from the 1950-2000 time period for Average Growing Season Temperatures, based on an A1B emission scenario for 2050.
Cool Climate Zones in Australia & NZ +2°F

Growing Season (Apr-Oct)
- Area Too Warm > 59.0°F
- Warmer but still suitable
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Represents ~2°F warming from the 1950-2000 time period for Average Growing Season Temperatures, based on an A1B emission scenario for 2050
Cool Climate Zones in South America +2°F

Growing Season (Apr-Oct) Average Temperatures

- **Area Too Warm > 59.0°F**
- **Warmer but still suitable**
- **New Area (55.0-59.0°F)**

Represents ~2°F warming from the 1950-2000 time period for Average Growing Season Temperatures, based on an A1B emission scenario for 2050.
Cool Climate Zones in South Africa +2°F

Growing Season (Apr-Oct) Average Temperatures
- Area Too Warm > 59.0°F
- Warmer but still suitable
- New Area (55.0-59.0°F)

Represents ~2°F warming from the 1950-2000 time period for Average Growing Season Temperatures, based on an A1B emission scenario for 2050
Used a spatial model to define the landscape and climate characteristics of 18 wine regions in Europe. Trained the model to ‘know’ the current conditions in these regions.
Moriondo et al. (2013) Climatic Change

Used the trained the model to predict where the current conditions in these regions would be in the future (2050) under moderate warming and drying conditions.

European Viticulture Zones
Historic vs Future Temperature Distributions in the Western US
Growing Season Temperature Distribution Changes in the Western US - Historic

Each Standard Deviation is equivalent to +/- 1.5°F
Growing Season Temperature Distribution
Changes in the Western US - Recent

1895-2015

15 of the last 20 years

2015
Growing Season Temperature Distribution Changes: Historic and Projected

1895-2015
1981-2020
2040-2060

Each Standard Deviation is equivalent to +/- 1.5°F

15 of the last 20 years
Climate Suitability

- What does a changing climate mean for the Willamette Valley?
- Average warming from current conditions would push the regions climate envelope ...
  - +2°F
  - +4°F
  - +6°F
- The 4-6°F warming is projected to occur by 2050-2070

Jones, 2006 and others
Summary
Global Climate Summary

- The planet is warmer than at any time in our recorded past
- Continued warming is highly likely
- Modeling efforts indicate a ~2.0-8.0°F warming in wine regions globally by 2050-2070, best estimate ~2.7-4.5°F
- However, the past 15 years in many regions has already produced conditions that were expected to be on average by 2050
Global Climate Summary

- Oceans are absorbing much of the heat, disrupting biogeochemistry cycling and climate feedbacks as we know them.
- Climate variability has been more pronounced in the last 15-25 years; wider swings, more record extremes, and increased severity and frequency in some aspects of the climate.
- Models are projecting continued increases in variability, bringing further risk on top of the average changes in climate.
Viticulture/Wine Production Summary

- Altered phenological timing (globally 3-6 days earlier per 1°F) and shorter periods between events
- Altered ripening profiles (challenges in managing timing of sugar, acid, flavor and phenolic development)
- New and/or altered disease and/or pest timing and severity
- Altered irrigation needs, especially with drying summers and higher Tmax
Adaptive Potential

- While challenges exist for all regions, opportunities for a more sustainable industry through reduced vulnerability and increased adaptive capacity are being addressed in the industry and the research community:
  - Realizing the large genetic potential for adaptation
  - Realizing the large landscape potential for adaptation
  - Potential changes in traditional training systems
  - Optimization of canopy geometry, row orientation, and increasing the use of shading materials
  - Improved understanding of scion-rootstock combinations for a region’s soils and climate
  - Improved grapevine water use efficiency and irrigation management, where necessary/possible
Thank You!

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