**Climate, Grapes, and Wine: Structure and Suitability in a Variable and Changing Climate**

**Talk Outline**
- Climate Influences, Risks, and Challenges
- Climate Structure and Suitability
- The State of the Climate
- Climate Variability and Change Impacts
- Adaptation in the Wine Industry
- Summary/Conclusions

**Climate Influences, Risks, and Challenges**

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

**Climate Structure and Suitability**
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

Plasticity – Adaptation Management (short-term) Varietal (long-term)

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 ~14-16°C, or ~2°C climatic niche

Jones, 2006

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

State of the Climate
**Global Temperature Departures 2012**

- Globally 2012 was the 10th warmest year on record.
- All 12 years to date in the 21st century rank among the 14 warmest.
- Only one year during the 20th century (1998) was warmer than 2012.

- 2012 was the 36th year in a row above the 20th century mean.
- If you were born after April 1985 (27 or younger), you have never lived through a month that the Earth was colder than average.

**Global Temperature Departures 1880-2012**

- Much has been said about the slow down of the warming
- But observations and modeling have shown that cooler than normal Pacific SST have been absorbing much of the heat to great depth
- Also there has been little cold season warming
- But the warm season has seen significant warming, greater ice loss, extremes, etc.
- Combined, the warming has slowed, but still much warmer than the past

**2013 ... so far**

The average global January to July temperature was 0.6°C above the 20th century average, tying with 2003 as the sixth warmest such period on record.

Record wetness was observed over parts of the north central and eastern United States, much of Europe, across areas of Russia, and much of India.

Record dryness was scattered across different parts of the globe, including northern Argentina, eastern Brazil, South Africa, England, the western US, and parts of southeast Asia and Japan.

**Climate Variability**
**Increased Climate Variability**

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.

For example in the US, March 2012 was exceptionally warm over most of the US, while March 2013 was much cooler than average.

Over the last 10 years in the US, more extreme records in temperatures (both cold and warm) and precipitation (both heavy events and drought severity) have been broken than in the previous 40 years combined.

**Significant Climate Events Worldwide in 2010-2013**

**Recent Vintage Climates Worldwide**
Recent Vintage Climates Worldwide

The drought broke in eastern Australia in 2010-11, but record rainfall brought floods and heavy disease pressure.

Western Australia recently experienced one of its hottest and driest summers on record in 2012.

2010 and 2011 were years of extremes in the western US wine regions.

Europe - Record breaking heat during June/July 2010, drought in 2012

Europe - Record breaking cold during Dec/Jan 2010-11 from Russia to Iberia

France – Record cold spring, summer rain and hail events cause severe damage

2010 was one of the best vintages ever in the eastern US and Canada – high production, low disease pressure, great quality – 2013 is the exact opposite, cool-wet-difficult
Recent Vintage Climates Worldwide

Particularly severe fire season in 2009 gave way to extreme rainfall and flooding over most of South Africa in 2010

Recent Vintage Climates Worldwide

Chile - Cool and late growing season in 2010-11
Argentina - Record breaking heat in the south, cold in the north in 2010-11
Brazil - Extreme rainfall events and flooding
South America – Record breaking extreme cold air outbreak during winter/spring 2010-11

Observed and Predicted Climate Change in Wine Regions

Recent Climate Research

Time series and linear trends for the average phenological dates of the 18 V. vinifera cultivars for budbreak, bloom, veraison, and harvest during 1964-2009 in Conegliano, Italy.

Tomasi et al. (2011) American Journal of Enology and Viticulture
Recent Climate Research

V. vinifera 18 cultivar phenology before (1964-1990) and after (1991-2009) the average breakpoint and for the two extreme years 2003 and 2007 in Conegliano, Italy

A) Overall Cultivar Average

<table>
<thead>
<tr>
<th>Period 1964-1990</th>
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<td>Year 2007</td>
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<td>39</td>
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<td>144</td>
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</tbody>
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Tomasi et al. (2011) American Journal of Enology and Viticulture

Recent Climate Research

Total acidity data at harvest for Schloss Johannisberg since 1932. Data are means of 8 to 125 individual values for different Riesling vineyards around Johannisberg/Geisenheim for any particular year. Lines are 5-year running averages for total acidity and April to October average temperatures.


Recent Climate Research

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.

Hannah et al. (2013) PNAS

Moriondo et al. (2013) Climatic Change
Recent Climate Research

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.

The Climate of the Douro: Structure, Trends and Mitigation and Adaptation Responses to a Changing Climate

Comprehensive climate assessment conducted in 2010-11, with goals of:
- Examining historic climate conditions in the Douro Wine Region
- Analyze the structure and trends in climate parameters and indices
- Analyze the structure and trends in weather/climate extremes
- Analyze regional climate variability mechanisms
- Developing a better understanding of the spatial characteristics of climate in the region
- Depict and summarize climate change projections for the region

http://tinyurl.com/nrf2kzf - Portuguese
http://tinyurl.com/l9ctm7 - English
**Douro Wine Region Summary**

- Climate trends in the Douro Wine Region show:
  - Higher Tmax, Tmin, but lower DTR
  - Increases in extreme temperatures with ...
  - Fewer cold events and not as cold
  - More heat stress events
- Future projections for the Douro Wine Region indicate growing season warming of:
  - 0.8-1.8°C by 2020, 1.8-4.3°C by 2050, 2.5-6.6°C by 2080
- A range of annual precipitation decreases of:
  - 0-7% by 2020, 0-15% by 2050, 0-22% by 2080
- With a greater reduction in precipitation during the growing season than during the winter

**Risk and Adaptive Capacity/Strategies**

- Growers/Producers continually undergo tactical and strategic changes to climatic conditions, but not in isolation
- Growers/Producers operate in a multi-risk environment (climate, markets, policy) and the status of adaptation determines future vulnerabilities
- The gradual nature of climate change should provide growers/producers sufficient time to develop/utilize adaptation strategies
- However, research/innovation/technology transfer must be done to minimize vulnerability and maximize adaptive capacity
Summary/Conclusions

- While challenges exist for the Douro and other regions, opportunities for a more sustainable industry through reduced vulnerability and increased adaptive capacity are being addressed in the industry:
  - 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 possibly 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 possible

Summary/Conclusions

- Continued warming, although at a slower rate currently
- Increased climate variability may be more of a concern with greater extremes (e.g., hail, flood, heat stress events) and wider swings between seasonal conditions (record warm/cold occurrences)
- Large disparity between temperature changes in different areas ... some with greater Tmax changes, others greater Tmin changes
- Soil temperatures are following air temperatures, and will likely present numerous issues
- Upper limit of climate for varieties needs more study to help understand the plasticity that is occurring due to both management responses and vine adaptability
Thank You!

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Grower/Producer Actions

- If projections are realized we need to clearly prepare for water shortages for both cities and agriculture
- We can fight over an increasingly smaller pie of water when it is needed the most ...
- ... or we can be innovative and study, design, and implement capture and delivery systems that adapt to changing climate conditions
- Attempting to divide up a shrinking pie only creates more confrontation and battles
- Building a larger, more innovative pie creates opportunities for collaboration and benefits all
Grower/Producer Actions

- Sequester CO$_2$ in biomass and soils
- Increase low till and no till farming practices
- Increase efficiency and reduce farm inputs such as fuel, fertilizers, and pesticides
- Increase production and usage of agricultural biofuels to replace fossil fuel energy use on site
- Improve nitrogen use efficiency as the primary means of decreasing N$_2$O emissions
- Decrease CH$_4$ (methane) emissions by capturing or reducing emissions from composting and animal manure storage