GLOBAL WARMING

A future perspective on changes to wine style and terroir

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SUMMARY

Global warming is a scientific reality which is having an impact, be it good or bad, on the global wine industry. Terroir (and more specifically climate) is one of its core values. Scientific data confirms the natural changes we see around us. These include increasing temperatures, more extreme weather patterns, and rising sea-levels. Human activity (i.e. industrialisation) seems to be the major culprit in accelerating the pace of global warming. Examples include the emission of fossil fuels resulting in rising carbon dioxide levels and a growing greenhouse effect.

In this document the effects of global warming in the major wine regions of the world are individually described in order to ascertain how global warming impacts on wine style and terroir. The degree of impact differs from region to region as some regions will produce fuller, more alcoholic wines as the planet heats up, while other regions may become unsuitable for the cultivation of grapes. New wine regions will appear and innovative viti- and vinicultural practices explored to adapt to the changing environment. The South African wine industry is analysed as its wine producers are up to the same challenges of adapting to the demands of global warming.

A look into the future of the global wine industry and a new world wine order are also discussed, as well as remedies to counter global warming's impact. Two conclusions are arrived at, namely that global warming is (a) an inescapable reality which will impact on grape growing, wine production and wine marketing, and (b) that it will bring both advantages and disadvantages to the industry depending on stylistic- and regional criteria. Global warming will without a doubt re-affirm the wine industry's mysterious and ever changing nature.

1. INTRODUCTION

Global warming denotes the increase in the average temperature of the Earth's atmosphere, oceans and landmasses. As terroir (which encompasses climate) stands at the very heart of good winemaking, it is a logical conclusion that global warming is a natural force and concern to be reckoned with. The majority of scientists agree that average global temperature has risen during the past century, and this change to climate will influence winegrowing conditions on a global scale.

Vines are already grown in the United Kingdom, the Benelux and Canada: will these be the big players in the next century? Will the Western Cape, Swan Valley or California be too hot to produce high quality dry wines? What about changes to wine styles and terroir in Bordeaux and Champagne?

Scientific data and expert opinion will firstly be disclosed to provide a basis for answering these and other questions. However, global warming is such a controversial subject that academic debate will be as integral to research methodology. Secondly, the impact of certain climatic conclusions on the world's leading wine regions will be discussed, with a chapter dedicated to global warming in South African context. The assignment is then concluded with a glimpse of what the world of wine will look like in the not-so-distant future, including possible steps to curb the effects of global warming.

- Literature review and referencing:

Global warming's abstract and contemporary nature meant that most of the research was conducted via the Internet. Not many books were found on this subject, but the click-through links listed in the Bibliography chapter will make it easy to confirm facts and conclusions, and also offer the chance to read more about global warming. The Harvard method of referencing was used for both in-text- and bibliographic referencing, with the abbreviation n.d. denoting "no date".

2. GLOBAL WARMING *PER SE*: A STATUS UPDATE ON CURRENT CLIMATIC DATA

Despite scientific disagreement as to the degree of impact, there is no doubt that the Earth's population is subject to increasing global temperatures. Although the Earth has warmed and cooled many times during the past 4.65 billion years of its history, the current phenomenon seems to be unprecedented in terms of rate of warming and potential impact. Before we focus on global warming's impact specifically on the global wine industry, we will define this term and audit the world's current climatic status.

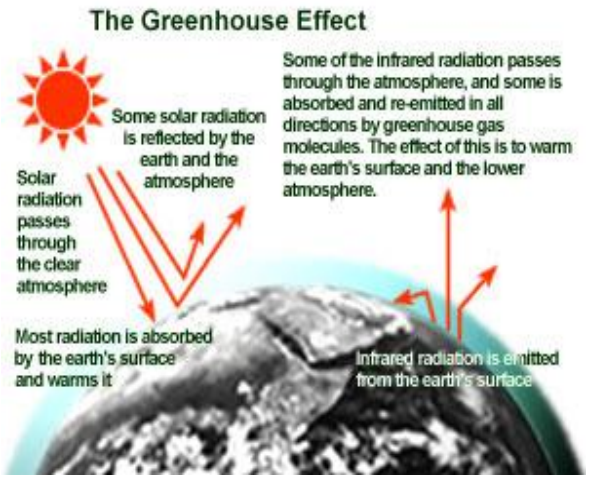
(a) The Greenhouse effect :

Scientists believe that the major culprit is (unsurprisingly) human activity, more specifically the burning of fossil fuels such as coal, oil and natural gas, which releases carbon dioxide and other substances known as greenhouse gases into the atmosphere (Encarta, n.d.).

These greenhouse gases help to regulate the Earth's temperature and are essential for life. In essence, certain atmospheric gases absorb heat (called greenhouse gases because they "trap" heat in the lower atmosphere), and re-radiation downward of some of that heat creates a natural greenhouse effect. Greenhouse gases comprise water vapour, followed by carbon dioxide and other trace gases…with the presence of these greenhouse gases keeping the Earth's current temperature around 14°C, as opposed to the -18°C it would have been without their presence (National Oceanic and Atmospheric Administration, n.d.).

* Figure 1

(U.S. Environmental Protection Agency, n.d.)



However, as per Figure 1 summarizes, problems may arise when the atmospheric concentration of greenhouse gases increases out of balance. Civilisation has industrialised, bringing carbon dioxide emissions (and methane and nitrous oxide), all of which concentrate atmospheric greenhouse gases (Schueneman, n.d.). This concentration of carbon dioxide and other greenhouse gases enhance the heat-trapping capability of the Earth's atmosphere, with the result that the global temperature inside this "shell" rises and rises (U.S. Environmental Protection Agency, n.d.).

(b) Measuring global warming :

There is not much scientific debate on the point that the Earth is warming. This general conclusion is proved firstly by the obvious rise of global temperature.

Climate is weather averaged out over time, and to understand global trends, scientists keep track of the planet's average temperature which is an important measurement of climate (Globalwarming.enviroweb, n.d.). The seriousness of global warming's climatic impact becomes visual when the following statistics are considered:

a. the 20th century's 10 warmest years all occurred in the last 15 years of the century (U.S. Environmental Protection Agency, n.d.);

b. global surface temperatures have increased about 0.6°C since the late 19th century, and about 0.2-0.3°C over the past 25 years (National Oceanic and Atmospheric Administration, n.d.);
c. warming in the 20th century was greater than at any time during the past 400-600 years, and 1998 was the hottest year globally since reliable instrumental temperature measurements began (Union of Concerned Scientists, n.d.); and
d. the United Nation's Intergovernmental Panel on Climate Change (IPCC) released its Third Assessment Report in 2001 which states that global warming is caused primarily by human activity, which adds greenhouse gases to the atmosphere, and predicts that the average global temperature will rise by another 1.4-5.8°C by the year 2100 (Encarta, n.d.).

The second criterion of measuring global warming is the change to atmospheric carbon dioxide levels which enhance the greenhouse effect. The question that then arises is how much carbon dioxide has been released into the atmosphere since industrialisation began? Let us consider the following facts:

a. around the year 1750, the concentration of carbon dioxide in the atmosphere was about 275 parts per million (ppm); today the concentration is 350 ppm, and rising (Schueneman, n.d.);
b. during the year 2003, atmospheric carbon dioxide concentration rose by approximately 2.4 ppm, compared with an average rate of 1.8 ppm per year over the past decade (U.S. Environmental Protection Agency, n.d.);
c. the same IPCC puts current carbon dioxide levels at the highest they have been in the past 420 000 years – and possibly even in the past 20 million (Joubert, *Hot wine in a changing world,* n.d.); and
d. if current predictions prove accurate and depending on remedial actions taken, carbon dioxide can reach concentrations of 540 - 970 ppm by the year 2100 (Encarta, n.d.).

These are disturbing facts made worse by the fact that we seem to have passed the point of no return. Although we will only look at the global climatic future in chapter 5,

there are some consequences of global warming that are very evident today: drought, disease, floods and lost ecosystems… mainly due to outer atmosphere thinning and its warming impact on the polar ice caps. Before we explore these two major natural phenomena, it is interesting to note that El Nino's are not caused by global warming. Clear evidence exists that El Nino's have been present for centuries – however, it has been hypothesised that warmer global sea temperatures can enhance the El Nino phenomena which have been more frequent and intense in recent decades (National Oceanic and Atmospheric Administration, n.d.).

(c) Outer atmosphere thinning :

One of the primary effects of global warming is the thinning of the atmosphere. Recent studies published in the Journal of Geophysical Research of 5 February 2004 found that the outermost layer of the atmosphere, known as the thermosphere, has become less dense during the past 35 years, most likely due to rising carbon dioxide levels. Carbon dioxide traps heat in the lower layers of the atmosphere, and cools down the higher layers where it acts to more effectively radiate heat back to space. And as the upper atmosphere cools, it contracts, bringing lower-density gas closer to the Earth's surface, and resulting in a decline in density at any given atmospheric height (U.S. Environmental Protection Agency, n.d.).

The logical conclusion for this rather technical explanation is increased solar penetration through a thinning atmosphere (read: rising global temperatures), a phenomenon known in the secular society as the "ozone attack".

(d) Oceanography and the polar influence :

Another major effect of global warming is its impact on Arctic climate and global oceanic activity. Experts found that the global mean sea level has been rising at an average of 1-2 mm per year over the past century – which is significantly higher than the averaged rate over the last several thousand years (National Oceanic and Atmospheric Administration, n.d.). Actually, the global sea level has risen about three times faster over the past 100

years compared to the previous 3000 years, and the Arctic ice pack has lost about 40% of its thickness over the past 40 years (Union of Concerned Scientists, n.d.).

The simple reason for these rising sea levels and polar melting is global warming, with a warmer climate that will partially melt glacial ice and the polar ice caps. On a geographical level, the interactions between the Atlantic Ocean, the Arctic's sea ice, Greenland's ice cap and the atmosphere in the Labrador sea and Davis Strait between Greenland and Canada seem to be at the core of polar climatic impact (Simone, n.d.).

The NASA satellite image below (figure 2) shows the current Arctic ice pack, and graphically compares the size of the current polar ice cap to the polar boundaries in 1979, proving that the summer polar ice cap has shrunk by more than 20% in the past quarter of a century (National Resources Defense Council, n.d.).

* Figure 2

(National Resources Defense Council, n.d.).

Apart from rising sea levels when the polar ice melts to water, the contraction of the Arctic ice cap is accelerating global warming, i.e. a snowball effect if you would pardon the pun. Snow and ice usually form a protective cooling layer over the Arctic and when that covering melts, the Earth absorbs more sunlight and gets hotter. This vicious circle becomes worse when the rising temperatures melt glaciers and ice sheets which raise sea levels and result in beach erosion, coastal flooding and contamination of freshwater supplies (National Resources Defense Council, n.d.). Hurricane Katrina that hit New Orleans in 2005 is one example of the extreme weather conditions possibly accelerated by global warming.

Looking ahead, the final report of the Arctic Climate Impact Assessment (a four-year study by an international team of 300 scientists), found that "the Arctic is experiencing some of the most rapid and severe climate change on Earth". Chairman Robert Corell added that "the impacts of climate change on the region and the globe are projected to increase substantially in the years to come". In Alaska, Western Canada and Eastern Russia, average winter temperatures have increased by 3-4°C in the past 50 years, snow cover has declined by 10% during the past 30 years, and the average extent of sea-ice has declined by 15-20%, also over the past 30 years (U.S. Environmental Protection Agency, n.d.).

To predict the polar melting's future impact will be to speculate, but the flooding of coastal regions (and even islands) where grapes are grown seems very possible as will be seen later.

(e) Fact or fiction? :

Global warming is a climatic phenomenon, but also a major force that impacts on commerce, culture and lifestyle. Scientists and sceptics are up in arms on what the effect of global warming will be and are bringing this controversial subject onto the public stage where everyone gets involved. There is even a current debate taking place between best-selling American author Michael Crichton and top US climate scientists after Crichton alleged in his recent novel "State of Fear" that global warming is unjustified and stoked by an environmentalist/media conspiracy. (Borenstein, 2005).

More scientifically, some experts are claiming global warming to be fiction: professor Will Alexander of the University of Pretoria considered 11 800 years of data and statistics of 6 700 rainfall events in South Africa between 1910 and 1989. Although he admits that the rate of global warming is apparently the greatest in recent history, he is playing down the effects of global warming on South African weather patterns during the past 50 years. Amongst other, he states that:

- there has been no general increase in South African temperature as a whole (during past years);
- rainfall in South Africa has increased by 9% since 1922;

- there is no evidence in South African plant- and animal species being threatened by extinction; and
- there is no evidence that severe floods and droughts have increased in frequency or severity over the past century (Alexander, 2005).

Further to professor Alexander's opinion, two Russian scientists even wagered $10 000 on their climatic predictions that average global temperatures will actually start cooling down within the next few decades (Joubert, *When scientists beg to differ*, 2005).

Be as it may, the focus of the scientific community should be to find solutions for the overwhelming evidence pointing towards global warming, rather than proving fringe theories and engaging in academic debate.

(f) Conclusion :

We have explored the definition, sources and effects of global warming, and can with confidence conclude that this phenomenon is mainly due to human activity. In the United States alone, approximately 6.6 tons of greenhouse gases are emitted per person every year, and this figure is rising. Approximately 82% of these emissions are from burning fossil fuels to generate electricity and power our cars, and the remaining emissions come from various industrial, commercial, residential and agricultural activity (U.S. Environmental Protection Agency, n.d.).

Between this plethora of statistics, facts and theories, what can we accept as certainty and what is likely? What is certain is that we have a significant increase in carbon dioxide levels and that there is a close correlation between rising carbon dioxide levels and rising temperature. What is less certain is how much of an increase will occur in the next century, and what the effects of the rise in global temperature will be on the world's wine growing regions and wine styles.

3. THE IMPACT OF GLOBAL WARMING ON THE CLIMATIC CONDITIONS OF THE WORLD'S WINE REGIONS

(a) General :

Some fatalists reason that global warming is nothing more than part of an unforgiving cycle, a necessary mechanism that the Earth has to protect itself and let the fittest survive. There has been a Stone Age and an Ice Age, so why battle against a Desert Age that is going to happen anyway? They prove their point by the fact that grapes were cultivated extensively throughout southern England from about 1100-1300, an area about 300 miles further north from where grapes are grown in France and Germany today. The amount of wine produced in England was even substantial enough to offer significant competition with the French - but with the arrival of cooler temperatures in the 1400's, temperatures became too cold and the English vineyards decreased in size (Mandia, n.d.). Whatever the motive or manifestation of global warming is, the natural cycle is indeed turning and we might have a situation in the near future where current wine producing areas are considered too hot for the cultivation of wine grapes.

There has been an article published (California Wine and Food) of the world's top 27 winegrowing regions, with specific reference to temperature's nexus to wine quality over the past 50 years. This article showed that rising temperatures have already impacted on vintage quality, though not always negatively. The study was presented by Dr. Gregory Jones of the University of Southern Oregon at the Wine Society of America's annual meeting in November 2004 in Seattle, and used records of Sotheby's 100-point vintage rating scale and temperature records dating back to the 1950's as basis. The study found an average temperature rise of 2°C in the said top winegrowing regions during the past 50 years, and predicted a further 2°C rise in the 50 years ahead. Jones considered grapes to be a particularly good indicator crop to prove global warming – mainly due to the fact that grapes are grown primarily in a temperate Mediterranean-type climate and wines were tasted regularly for quality, thus being a "good indicator of change probably effecting other crops in the same area" (California Wine and Food).

What makes the precise impact of global warming difficult to measure though, is the fact that winemaking and viticulture have improved dramatically during the past 50 years, thereby mitigating the potential harm of rising temperatures. Wine prices have increased which made it possible for winemakers to be more selective with grapes and manipulate wine styles with the best technology available. Fuller, higher alcohol wines even became fashionable – all factors arguing against the negative perception of global warming on wine quality (Goode, n.d.).

A further and more pragmatic approach might be to argue that although global wine quality *per se* has excelled during the past half-century, wine regionalism has flattened out. The traditional winegrowing regions of France can not exclusively boast perfect terroir and climate anymore; no, traditionally cooler regions like the Mosel are all of a sudden gaining on the traditional giants when the perfect climate is considered. The same Sotheby's vintage ratings from Dr. Jones *supra* for instance showed that other cooler climates (such as Oregon, British Columbia and England) benefit from warmer temperatures as these producers can obviously then obtain a higher degree of fruit ripeness – but regions that rely heavily on its established and specific climate (such as Champagne or Chianti) might be forced to give up established production methods and adapt their styles to a new climatic lingua.

Wine might lose some of its heritage and regional character based on terroir – like Pinot Noir in Burgundy where the variety is so well suited to a certain area's climate that the variety becomes synonymous with the region. Global trends, new wine styles and increased manipulation of the product could counter any negative impact global warming might have… but global warming could also introduce exciting new wine producing areas that can compete now that their climate has become more accessible (New Seasons Market, 2004). This chapter will have a look at these conflicting theories and explore the current- and future climatic predictions of the world's wine regions.

(b) Europe :

Mediterranean-type climatic conditions offer the best basis for the production of wine, with long dry summers followed by wet frost-free winters the ideal scenario. Climate is after all one of the keystones of terroir and one that is very difficult to manipulate by way of human intervention. The best viticulturists can do is to suit varieties to wine growing areas, like planting grape varieties that have a shorter ripening period in cooler areas such as Germany (Greening Earth Society, 2005). The obvious problem with global warming is that since these ideal climatic conditions are now disturbed, solutions are sought by the traditional wine producers to counter a new world wine order.

This chapter's focus will be primarily on the vineyards of France, Italy, Spain, Portugal and Germany, but a good point of departure might be to take a holistic European view on the effects of global warming. The reasons for the drier climatic conditions were explained. Analysts use these facts not only to predict impact on wine quality and quantity, but also to warn against food shortages. In both 2003 and 2004, a harsh winter and late spring frost in most parts of Europe were followed by a heat wave in June, which caused crops to develop up to three weeks early, without the back-up of sufficient soil moisture (Uhlig, 2003). The infamous 2003 vintage will be discussed later, but the unpredictability of European weather and the predictability of an increasingly warmer climate are contributing to causing widespread concern across the European wine scene.

Not only is the warmer climate directly impacting on less soil moisture and warmer microclimatic conditions, but is also indirectly influencing European climate due to an Alpine melt-down. According to Charles Wuilloud (head of the department of natural dangers at Switzerland's Valais state forestry department), these effects in the Alpine valleys are visible where meltdown have tripled to quadrupled the rate of ice melt-down. A constant rush of melt water streaming from the Ferpecles- and Mount Mine glaciers above the Rhone valley in southern Switzerland serves as an example of the so-called equilibrium line (the point at which any fresh snow or rain falling will turn to ice and not melt or run off), that has risen "984 to 1 312 feet higher up the mountain this year than usual". Scientists mention that Europe's glaciers have been shrinking since the 1850's, initially as a result of natural warming, but the rate increased since the 1970's due to

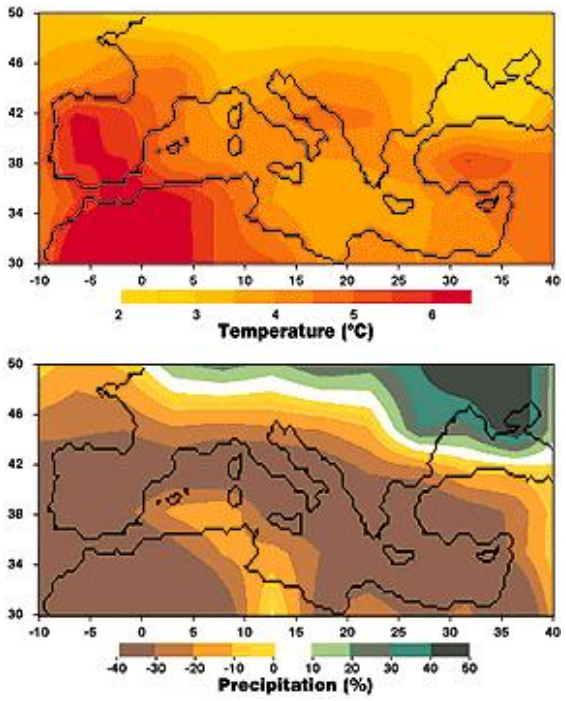
high emissions of greenhouse gases. To illustrate this point, geologists take us back to the 1990's when the Zurich-based World Glacier Monitoring Service (WGMS) forecast that by the end of the 21st century, the (European) glaciers would shrink to 10% of their size back in 1850. By 1970, half of the glaciers have already disappeared and the rest are predicted to disappear by the year 2025. This is according to geography professor Wilfried Haeberli of the University of Zurich who confirmed that "it (i.e. the glacier meltdown) is going faster than we thought". Haeberli further warned that the shrinkage of glaciers could dramatically impact on water supply: in summer approximately 50% of the water carried by the Rhone from its Alpine source via Lake Geneva to the Mediterranean sea comes from melted ice. "Glaciers hold back water in winter and let it go in summer. If they go, so will the water" (Waddington, 2003).

Add to this loss of water supply by the shrinking glaciers, the effect of lower rainfall on river levels in Europe: according to findings by Manfred Mudelsee of the University of Leipzig (published in the 11 September 2003 issue of "Nature"), there is decrease in winter flooding from the largest rivers in central Europe (the Elbe and Oder *in casu*). This occurrence is directly attributed to warmer winters which have reduced the occurrence of frozen soils and river ice which contribute to flooding when they break up in spring (U.S. Environmental Protection Agency, n.d.). The effect of polar melting on rising sea levels will be discussed later, but it will suffice to conclude with "less ice and rain, less water".

The graphic illustration on the next page (figure 3) uses the Mediterranean basin (accountable for roughly 45% of the world's grape production) as case study to illustrate the effect of global warming in Europe. It compares the potential effect of increasing greenhouse gases on food and wine production in the northern countries (Spain, France, Italy, Greece et al) to the warmer and drier southern countries (Turkey, Cyprus, Syria, Lebanon, Egypt et al) – and concludes that yields are definitely decreasing across the board. Looking forward, soil quality and the deterioration of water will exacerbate global warming trends.

* Figure 3

(Rosenzweig, 1998)



Summer seasonal mean temperature and precipitation changes for the Mediterranean region corresponding to a doubling of CO_2, as simulated by the GISS GCM. This climate might occur in the 2050s, if greenhouse gases increase very rapidly.

Water management will be a major issue, especially in semi-arid areas such as Spain, southern Italy and Greece where irrigation water will be in shorter supply, and apart from the negative effects on wine production predicted, scientists actually foresee problems with food self-sufficiency due to decreasing wheat and maize production (Rosenzweig, 1998).

Let us explore the effect of global warming on the top winegrowing areas of Europe.

France

France is the cradle of the world's wine industry and synonymous with the concept of terroir. In France, the diversity of variety and style is reflected in the complex interaction between soil, climate, topography, grape varieties, viti- and viniculture. Some writers refer to wine as "liquid geography" which emphasises the essence of the specific region's conditions on the eventual product (Perkins, n.d.).

With the phenomenon of global warming becoming increasingly relevant, many researchers have been investigating the impact of change in terroir (read: change in climate) on wine production. A team led by scientist Pascal Yiou used dates of wine harvests carefully recorded in French parish churches to track France's climatic history back for more than six centuries. These dates were used to reconstruct Burgundian temperatures from 1370 to 2003 using the Pinot noir grape grown in the region since the Middle Ages as yardstick. Yiou pledged to calculate differences in temperature to a hundredth of a degree by using the obvious principle that "the later the harvest began, the cooler the summer and the earlier the harvest, the warmer the summer." According to this study published in November 2004 in the British publication *Nature*, the warm decade of the 1990's have had several parallels, including the harvests in Burgundy in the 1380's, 1420's, 1520's and between the 1630's and 1680's. This study considers the French harvest of 2003 to be unprecedented in terms of heat and probably the highest since 1370. Although there were several warmer and cooler decades during the past 600 years in France, the 1990's were on world average the hottest decade on record (Coolscience, 2004).

According to Vidal and Stewart (n.d.), the prolonged European heat wave of course not only hurt the French wine industry, but crop harvests across the board. Grain harvests were down by approximately 20% in the infamous 2003 (as per studies by the United Nations' Food and Agricultural Organisation), and on the other side of the spectrum, the French government even linked floods around Marseilles and the Rhone estuary to global warming (Rosnoblet, n.d.). France is definitely subject to new climatic patterns, and the question now remains what impact this will have on the country's wine styles. Even more relevant is whether the traditional wine producers will manage to adapt to new wine making techniques to smooth out the challenges of these winegrowing conditions.

The mentioned Dr. Gregory Jones of Southern Oregon University looked specifically at temperature increases in (amongst others) Bordeaux and Burgundy in France, and concludes that as average temperatures rise and harvest seasons change, the type of grape best suited to a certain region will also change. Jones states explicitly that "Bordeaux may no longer be the best place" to grow its traditional wine grapes. Wine producers not only have to deal with higher alcohols and fuller wines, but also with viticultural regimes currently unknown to them (like irrigation) and types of pests (Paulson, n.d.).

In the past most wines in Bordeaux were made in the same way and only location differentiated the good from the less-good. But following the effect of global warming and increasing technology to manipulate wine styles (partly to counter possible negative climatic effects), sheer location is not the sole criterion it used to be. Some argue that you can no longer say that St. Emilion is necessarily better than the previously looked-down-upon vineyards of the Côtes de Castillon. Now it is up to the consumer to decide whether the decreasing importance of terroir is a good or bad thing: generally speaking, the Australians have commercialised their wine styles to such an extent that their wines are seen as generic in its full warm fruit-driven flavours. Will we also see a more generic Bordeaux wine style following changes to climate and adapting winemaking techniques, or will individuality and terroir cling on to protect the highly regarded wines of this region? Pragmatists and some wine writers foresee the effect of global warming as a new challenge that might bring some new exciting wines to the fore.

In the case of Bordeaux, the producers that manage to show the influence of New World winemaking techniques without losing their essential Bordeaux character, might be the ones to look out for. Ideally these wines would be fine and elegant in the truest French sense, but also offer softer tannins, more upfront fruit and, subsequently, earlier drinking potential. Listed as "innovative red Bordeaux", this new exciting generation of French producers include the likes of Chateau Terrefort-Lescalle and Essence de Dourthe (Bordeaux), Chateau Mauperey and Chateau Yot (Côtes de Castillon), Chateau Lalande de Gravet, Chateau Monlot Capet and Chateau Haut Gravet (St. Emilion Grand Cru), Chateau Les Tonnelles (Fronsac), and Chateau Fleur de Jean Gue and Chateau Haut Brouard (Lalande-de-Pomerol) (Berkmann wine cellars, n.d.).

On the other side of the debating stage we have the realists that have a less positive outlook compared to the critics that see it as a positive for Bordeaux to “commercialise” its wine styles by making it more fruity, accessible and in line with the big-selling wine styles from warmer regions… and rightly so. Wade Wolfe, general manager for Hogue Cellars in Washington, USA says that producers of Bordeaux varieties should be wary to plant a “warmer” variety of grapes until there is more certainty as to the local impact of climatic change. “There’s a lot of regional identity to wine” and if established regions such as Bordeaux have to change grapes to adapt to global warming, the wine industry would really get confusing (Paulson, n.d.).

In the end the consumer will have the deciding vote. A second effect of global warming particularly relevant to Bordeaux (apart from higher temperatures) is the effect of rising sea levels. Due to polar meltdown (as discussed earlier) the Bordeaux vineyards located on the banks of the Gironde are threatened by an increasing maritime influence. Vineyards located further from the river might also experience a changing maritime influence as the salinity of the underlying water table is increased by rising sea levels.

Looking at the immediate effect of global warming on the recent vintages of Bordeaux, there is general dissent as to the perceived impact of global warming on quality. Some wine writers, including Alex Tabarrok of Marginal Revolution conclude that wine quality is improving due to global warming. He argues that the top wine-producing regions should be located in places where the weather is optimal for grape growing. If higher temperatures are better, the top regions should have been located further to the South to begin with. His stance is backed by Doug Shafer of Shafer Vineyards in the Napa Valley who says that “a warming trend, which is what the research is suggesting, would improve wine quality, since ripeness is critical to top-quality wines.” Shafer concludes that progress in the areas of grape growing and winemaking will however have the greatest effect on increasing wine quality… all factors that Professor Stephen Bainbridge believed turned the 2000 vintage from a potential disaster into one of the great Bordeaux vintages (Professor Bainbridge on wine, 2003). No doubt that human manipulation will become a reality even for the traditional Bordeaux producers hooked up on minimal interference with terroir.

The 2001 Bordeaux vintage report showed, up until August, similar conditions to the brilliant 2000, but September 2001 brought cool and dry conditions as opposed to September 2000's torridly hot conditions. Hence a more "reserved, fine and gentle" vintage with Merlot the big success, Cabernet Sauvignon irregular, Left Bank Cabernet Franc not very good, and Right Bank Cabernet Franc very good. 2001 was a vintage for the connoisseurs of the world with 2000 the fruit-driven, expressive "drinking man's vintage" (Beffa, n.d.).

The vintage 2002 was seen as an average to fine year in Bordeaux with the infamous (or famous depending on stylistic preference!) 2003 that will go down as one of the warmest ever. Most of the Bordeaux producers suffered lower volumes and saw a major gap between phenolic ripeness and physiological ripeness. Saint-Estephe and Pauillac were the exceptions due to their relative proximity to the maritime influence of the Atlantic Ocean and a more moisture retaining clay soil. The extreme heat called for maximum human interference, including stringent grape selection and lower temperature fermentation…. resulting in some brilliant fruit-driven wines from lesser-known producers (predominantly on the Left Bank) (Fehr, n.d.).

The weather returned to a more typical pattern in 2004 with a more consistent Bordeaux vintage leading to a more balanced harvest in terms of colour, alcohol and acid. Compared to 2003, the earlier ripening Merlot will be better off in appellations such as Pomerol, whilst the dry whites have good fruit, character and acidity and look to be in the classic mould of 1998 (Hughes, et al., 2004).

Stylistic preference and the subsequent pro's and con's of global warming are emphasised further when ageability is considered. Are wines made to be enjoyed now (bring on global warming's fruit-driven accessible wines) or made to be kept for years to come (bring on the understated elegant wines from France's cooler sites)? Further to the examination of vintage quality ratings, it transpired that (for example) a 1995 Chateau Petrus rated 98 points out of 100 by Tom Stevenson's 2001 Sotheby's vintage ratings, was found to be still so tannic in 2005 that it will become drinkable only "by your grandchildren when they're of age" (Greening Earth Society, 2005). Global warming might have its followers and critics when wine quality is concerned, but that it brings forth new wine styles and challenges when considering the classic French wine regions, is a given.

As opposed to the generally accepted notion that global warming only creates generic fruity wines disregarding the individual attributes of terroir, the other side of the argument also rings true… that ironically, global warming might actually reinforce the concept of terroir. If Burgundy heats up, its wines might end up more consistent and perhaps less compelling, but it will also give regions cooler than Burgundy an edge (like Southern England). Pinot noir will never perform well in warmer regions such as the Rhône or Languedoc which proves its adaptability to a certain terroir, i.e. the concept of terroir will not disappear but merely shift from one region to another (Wine Anorak, *English wine: an introduction,* n.d.).

Looking at the Burgundian vintages of this century, 2000 was initially hyped as a classic year, but the Cote d'Or was lashed by storms at the set-in of *vendage*. With minor exceptions, most 2000 Pinot noirs are perceived to be fairly dull, white Beaunes considered not bad and Chablis under-performing again.

2001 was seen as a good year for the "powerhouse villages" of Pommard, Gevrey and Nuits St. Georges rather than the "charmers" like Volnay and Chambolle. White Côte de Beaunes seem less interesting but some very good, and Chablis good but not excellent. 2002 was a superb year in Burgundy with a fairly cool summer and then sunny September. Both the red and white wines throughout the Côte d'Or are brilliantly balanced with Vosne-Romanee the pick of the crop. Also fine balanced Côte de Beaunes and wonderful Chablis, with the Beaujolais Crus a bit rainy at harvest and inferior to 2003.

As discussed earlier, the 2003 vintage was extremely hot and a-typical wines were found across Burgundy. Doubtful to say though that it was global warming contributing to one extremely hot year: Tim Clarke's vintage notes (Clarke, 2004) explicitly states that the 2003 Burgundies turned out to be wines of terroir, reflecting the extremely low yields and not wines of "global warming". According to his reports, very good wines came from cooler outlying areas (the wines from the Hautes Côtes and the Yonne examples), with a strange a-typical year proven when he saw Bourgogne Irancy coming out as dark as a Hermitage. White Côte de Beaunes are rich and exotic, Chablis a-typical with rich fruity wines, and good Beaujolais Crus from Morgon, Julienas, Côte de Brouilly and Fleurie.

2004 showed a big crop throughout Burgundy. A poor summer was followed by a warm dry September, showing wines with average ripeness and correct acidity. Some problems with uneven ripeness, yield and concentration with only the dedicated and diligent winemakers showing good wines and proving the increasing importance to give human assistance to terroir. According to Michel Laroche, the Chablis harvest was more successful, with a more mixed picture to the south. Frederic Drouhin believes the Cote de Nuits will be more consistent than the Côte de Beaunes but all in all a charming yet balanced year (Hughes, et al., 2004).

The Rhône is echoing Burgundy's climatic unpredictability. Although Syrah and Viognier are varieties well-known for their adaptability to dry hot summers and a bit more heat, more wines tend to be fruit-driven and "New World" in style since global warming became a household word. Some writers suggest that the same phenomenon is appearing in the Southern Rhône and Provence where the rosés nowadays lack the crisp acidity one always associates with a young Rosé from the south of France. With higher alcohols and less acidic backbone, the ageability of these wines is coming into question (Ijamming!, n.d.) Heat stress and acidification are becoming the norm in Southern France, with the 2003 harvest again proving a good, albeit isolated, example. The Northern Rhône suffered more from heat than the South with exceptionally early harvests. The reds showed "chunky" wines with Syrah showing super-ripe grapes, and Cinsault, Carignan and Mourvedre performing the best. For white grapes, high sugar and low acidity proved a problem (Harpers, 2004). Again it must be pointed out that increased temperatures are not always seen as a negative, more so in a country that has years when the grapes struggle to reach phenolic ripeness… in the Northern Rhône for instance, some producers rated the 2003 harvest as exceptional despite the heat. The Syrah of the Côte Rôtie showed lots of tannin, alcohol levels of 14% and aging potential similar to the class of 1983…. with the Rhône's of 2004 showing similar high tannins and the same or a better level of maturity compared to the 2003 vintage. The 2004's are seen as mouthfilling and structured with the French newspaper *Aujourd'hui* reporting that the wines from the Northern Rhône compare well to the wines of the 2001 vintage, and the Southern Rhônes show a similar quality and style to the very good 1999 harvest (Hughes, et al., 2004).

Add to this the commercial notion towards fruit-driven easier-drinking wines and it is easy to see why the Languedoc-Roussillon region is one of the global hotspots today. The sunny climate allows for good ripe fruit, wines that are juicy and pleasant to drink, although Vignerons Catalan's Christophe Palmowski honestly admits that the 2004 reds are "wines for the short term" (Hughes, 2004). Good balance, colour, fruit and tannin are what these wines are renowned for with Carignan, Marselan, Grenache and Syrah all carrying the banner for a region not really making a big deal of global warming.

Towards the northern parts of France however, global warming is and can be a major concern. Looking at winegrowing areas in particular, there are signs of significant changes in flowering and ripening patterns across the globe. Studies at Geisenheim showed that earlier bud break has been mapped since 1961 and flowering is currently 10 days earlier than the 30 year average… having severe implications for spring frost damage in the Champagne and Chablis areas where frost protection is a major expense already. Currently *veraison* (the point at which ripening begins) is on average 12 days earlier than the long term (European) average which indicates earlier harvests in Bordeaux and Alsace amongst others, and a clear indication that a whole new macro-, meso- and micro-climatic order is at hand (Gilby, 2005).

The impact of warmer temperatures, subsequent earlier harvests and a-typical wine styles are evident in the 2003 and 2004 harvest reports of the Loire, Alsace and Champagne… and again the impact is not necessarily bad. On the contrary, 2003 was a great year in the Loire where the generally cooler climate helped to mitigate the effect of the heat. The Sauvignon blanc producers of Sancerre and Pouilly-Fumé began harvesting early September, three weeks earlier than normal, with the resulting wines showing concentrated fruit, a high natural alcohol and low acidity. Just enough rain fell in Chinon, Bourgeuil and Saumur to prevent drought stress and sunburn with beautiful, expressive wines compared by Nicolas Joly of Coulee de Serrant of Savènnieres to the vintage of 1976 (Harpers, 2004). 2004 showed a very wet summer in the Loire but the sun did arrive in September and a good vintage was delivered, although not as showy and concentrated as 2003. A good balance between acidity and sugar rather than fuller bolder wines was the hallmark of this vintage (Hughes, et al., 2004).

The Alsace region is renowned for its dry yet rich and fruity wines and relies on the unique climatic conditions of this north-eastern fragment of France. But in 2003, Alsace had its warmest summer since 1540. Rainfall was low in the previous winter and vines had to fall back on the last of their own water reserves. The harvest already began on 25 August for Cremant d'Alsace and at Zind-Humbrecht, the Pinot noir ripened a full four weeks earlier than normal. Acidity levels in both the red- and white wines were low with Riesling that came off worse due to the heat and low rainfall (Harpers, 2004). 2004 was a good balanced year with increased yields and good fruit, spice and acidic backbone across the board.

On to Champagne, which is the one region in France especially sensitive to climatic changes. Tom Stevenson states in the new Sotheby's wine encyclopedia that "the Champagne terroir, which includes a cold, sometimes mean, northern climate and lime-rich chalk soil, is the key to the wine's intrinsic superiority…" and also makes mention of the high risk of frost in both spring and autumn (Stevenson, 1997, p.164,169).

In 2003, the said frost damaged the vines in April (the earlier-budding Chardonnay in particular) and reduced the crop by up to half. Then came a very hot June, July and September that resulted (according to the CIVC or Comite Interprofessionel du Vin de Champagne) in Champagne's earliest harvest since 1822, commencing on 18 August (Harpers, 2004). These symptoms best associated with the effect of global warming led to high ripeness levels and fuller, fruitier wines… again not necessarily a negative, depending of course on the specific consumer's preference. 2004 was a good year in Champagne with some growers putting the harvest up there with the best. Cooler ripening conditions resulted in lower sugar levels and the crisp acidity the best Champagne houses are famous for, and on top of that a big healthy harvest and a relatively high percentage of vintage wines (Hughes, et al., 2004).

Going forward, the challenge Champagne producers are facing is very simply to tailor their winemaking methods to a new warmer climate. In a New York Times article "For wines, the paradox of global warming" (Asimov, 2003), Odilon de Varine (winemaker for the Henriot house in Reims) says the problem in the Champagne vineyards is no longer praying for the grapes to ripen but preventing them from ripening too much. The secret of good Champagne lies in its crisp acidity which drops when the sugar increases, and

“if the grapes get too ripe, it is not Champagne.” Champagne styles have definitely changed due to global warming with de Varine adding “if we had Champagne like it was 20 to 25 years ago, nobody would understand what it was. It was more acidic. Now it is more fruity, with more body”… only time will tell how drastic global warming’s impact will be on Champagne’s “cold, sometimes mean” climate and the stylistic future of its wines, a hypothesis that will be explored further in chapter 5.

Before we look at global warming’s impact on the Italian wine industry, we can already deduce that the theory pertaining to global warming is not exact. Apart from the fact that one or two French vintages with extreme weather conditions are no proof of global warming (we have seen extreme climatic conditions for a few hundred years in France), we are not even sure what the consequences of global warming are. Are there changes to weather patterns and terroir, or only intrinsic stylistic shifts? Are these changes to wine style, if any, due to global warming or merely human intervention to make French wines more accessible and commercially viable? And even if we admit global warming’s role, is it necessarily bad for the industry? Speculation at best but nonetheless a debate worth having if even the hypothetical impact of global warming on the wine industry (earlier harvests and a-typical wines with higher alcohols and less acidity) is considered.

Italy

The world’s largest exporter of wine is feeling the heat of global warming to a severe extent. In 2002, the Danube and Po rivers overflowed and flooded many cities following very heavy rains and a year later, the same regions were experiencing drought. The Po was so low that in some regions one could walk across it, a phenomenon that made the media observe flatly that “the climate is changing, for the worse, and it is all our fault” (Lomborg, 2003). In another article published in 2003 (McCarthy, *Is this proof of global warming?*, n.d.) there is mention of priests in Italy asking their congregations to pray for rain. The river Po in the north was at that stage approximately eight metres below its normal levels and still dropping, and at its lowest levels for 100 years. Temperatures in Rome soared to 35°C for weeks where tourists were fined for cooling off in the Trevi fountain, and Italian farmers suffered crop losses estimated to the value of 5 billion Euros. In Southern Italy, lack of water has become a major problem with large areas of

scrubland destroyed by fires in Calabria and Salento. Other reports mention the hazardous conditions in the Alps where ski resorts were closed down for fear of rocks loosened by global warming's meltdown effect (Bonair, n.d.), and Milan reaching a June record of over 40°C in 2003. Antonio Navarra, the chief climatologist at Italy's Geophysics Institute confirmed that the increasing temperatures were further evidence of global warming. The whole Mediterranean region was 2-3 degrees Celsius warmer than usual, with Paul Horsmann, a climate campaigner with Greenpeace adding to Navarra's comments that a range of events such as these is "certainly evidence that we are living in a globally-warmed world" (Croft, 2003).

On a more regional level, the Piedmont area in Italy's North and home to the famous Nebbiolo grape, is showing sure signs of global warming. Barolo's distinctiveness derives from the soil and climate of a specific part of Piedmont in the shadow of the Alps and a long term change to climate will have a definite impact on the nature of the wines.

Again not always negative: in the Barolo and Barbaresco vineyards, producers reserve the best south-facing slopes, where the snow melts first and where every bit of sunshine can be absorbed, for their best Nebbiolo vines. In the past, it was an annual battle to get the grapes to reach phenolic ripeness and hope that the weather would be warm enough. After below-average years in the early 1990's, 1995 through to 2001 (and still counting) were all great harvests with full fruit-driven wines – which, according to wine maestro Angelo Gaja, can be attributed to the climate change. He reckons that since 1996, spring has started 20 days earlier and that the harvests nowadays start at the end of September as opposed to the end of October as in the 1970's and 1980's. "The influence of climate and light was different, and that's why you have the impression of a complete taste that in the past we didn't have" (Asimov, 2003).

This sentiment is echoed by Silvia Altare, a young winemaker from Barolo who says that weather is "90% of the work". However, the Altares (based at the foothills of the Alps) take the opposite stance to Gaja in that they blame the warmer weather for wines they call "a little bit less great". Lack of snow, almost no spring rain and searing temperatures meant a very hot (and in their case disappointing) 2003 harvest. The Nebbiolo grapes they picked were like raisins with highly concentrated flavours and sugar and a very high

alcohol content of 16% instead of the usual 14%. They had a smaller output and the heat spoilt the delicate flavour of their crop which they think might point their wines in the Australian direction producing heavier, bigger wines. The rationale of this example is that, whether you perceive global warming as good or bad, human manipulation will play a bigger role to steer the wines in the direction you want. Following the hot 2003 harvest as per the rest of Europe, the Altares came up with ways to cool down the overheated grapes after picking and learned to cope with a slow fermentation process caused by a high sugar concentration. They are discussing how they will deal with the climatic changes on the longer term and are also experimenting with new grape varieties (Poland, n.d.).

Talking of new grape varieties, Barbera might become increasingly popular in Piedmont as the past objection that Barbera's lack of full and complex flavours compared to the top Barolos and Barbarescos no longer hold true. Global warming may result in Barberas showing more natural tannins, phenolics and full-ripe fruit to balance out the late-ripener's inherent high acidity and low tannins. Blending in a bit of Nebbiolo might soon offer the world a Piedmontese blend hard to resist (Robinson, *Barbera – Piemonte's third B*, 2004).

Looking at recent Piedmontese vintages, 2000 was a hot vintage showing wines with over-ripe fruit, 2001 was brilliant with supple, soft offerings, and 2002 was washed away by rain with some producers not even bottling their Nebbiolos – although Barbera's late ripening meant it was not as badly affected as the Dolcettos for instance (Robinson, *Barbera – Piemonte's third B*, 2004).

The very hot 2003 vintage resulted overall in yields down by 20% and showed Nebbiolos with high sugar levels, particularly the grapes coming from the more exposed hilltop vineyards that usually produce the region's best wines. In some cases the Nebbiolo harvest started five weeks early, resulting in sun shrivelled grapes, and in some instances fermentations struggled to finish. Barbera and Dolcetto came through better with higher alcohol levels around 14%, good colour and good balance (Harpers, 2004).

2004 showed a very good harvest across Northern Italy, less powerful than 2003 but more delicate and balanced for the Barolos and Barbarescos. Most producers started harvesting 10-20 days later than in 2003 with yields up 20-35%. Winemakers from

Franciacorta, Lombardy, Friuli and Valpolicella (especially the Amarones) were evenly optimistic and confident that 2004 will go down as exceptional (Hughes, et al., 2004).

Heading south to Tuscany's famed Chianti vineyards where the Sangiovese grape feels best at home, global warming is worsening an already hot region and giving some pests more time to attack the vineyards (California Wine and Food, n.d.). At the 32nd World Geology Conference in Florence, Dr. Gregory Jones warned that global warming could have a drastic impact on Europe's classic wine regions. He estimates that the Bordeaux and Chianti vineyards may soon resemble those in Northern Africa, and the ideal growing environments for the grapes these classic areas are renowned for could shift northwards. He specifically mentions Chianti where he predicts that within 50 years temperatures will rise by an average of 2 degrees Celsius. Tuscany's weather will become hotter and drier, conditions that would not only change the alcohol content, colour and aroma of the Chianti Classicos but also make its vineyards increasingly vulnerable to parasites (Berry Bros. & Rudd, 2004). Jones ominously added that "the ideal climatic conditions for producing what we today call Chianti will be in Germany, just as those for producing Champagne or Bordeaux wines will be found in southern England" (Wines & Vines, 2004). This is said even if we take into account improved viticultural practices, better alignment of varieties with soil and advanced winemaking techniques in a traditional winegrowing area such as Tuscany. Chianti will have real difficulty in adapting the classic Sangiovese wine styles to the severe onslaught of global warming (Greening Earth Society, 2005).

Tuscany also saw a rain-soaked 2002 vintage with the reverse in 2003 when temperatures of 40°C and more were common from May to August. Tuscany was quite the exception to the pessimism surrounding the hot 2003 vintage firstly because Sangiovese is a late-ripening variety benefitting from higher temperatures and secondly because the area's vintners are allowed to irrigate, something which is forbidden in many other parts of Italy. The problem in Tuscany therefore was not a lack of water but rather the extreme high temperatures that turned some grapes from the younger vineyards into raisins. Again alcoholic wines and concentrated fruit were the norms where yields were down by 20-30%. In Chianti Classico the Sangioveses from the higher located vineyards showed fresher more balanced wines, ditto in Montalcino. The best performer in 2003 was Syrah which is another example of human intervention and a

growing impetus to be flexible enough to align different varieties to classic regions (Harpers, 2004). Lamberto Frescobaldi called the 2004 Tuscan vintage a five-star one characterized by wines of outstanding aromas, depth and length. Renzo Cotarella of Antinori is more reserved but confirmed excellent Montalcinos, with similar positive harvest reports coming from other parts of central Italy's Umbria and Emilia-Romagna areas (Hughes, et al., 2004).

The South of Italy looks to be caught up in even bigger global warming danger. A major United Nations conference was told in December 2000 that up to a third of Europe's soil could be affected by global warming's desert-like effects, with Italy, Spain, Portugal and Greece the four high-risk countries. "The Sahara has crossed the Mediterranean" some experts say where *inter alia* the southern part of Italy is now technically a desert… ironic if considered that Italy has a programme to help the Northern African countries to combat desertification. One expert, Maurizio Sciortino, said changing weather patterns are one of the causes of soil degradation with "conditions particularly bad in southern Italy, Spain and Greece" (Brown, *Sahara jumps Mediterranean into Europe*, n.d.)

Although 2004 showed more moderate temperatures in southern Italy compared to the infamous 2003 and brought lower-alcohol and better-balanced wines from Sardinia, Sicily, Campagnia and Puglia (Hughes, et al., 2004), the former two areas are still particularly drought-stricken and this predicts nothing good for the wine industry of this region.

Spain

Spain has always been known as a warm country with writers referring back to the previous century to conclude that the hot European weather of nowadays has actually always been present to an extent. The United Nations conference held in December 2000 added this country to Italy, Portugal and Greece on the list of EU countries already so badly affected by global warming that they had to join the United Nations Convention to Combat Desertification (CCD). A fifth of Spanish land is already so degraded that it is turning into desert (Brown, *Sahara jumps Mediterranean into Europe*, n.d.). This phenomenon

will without a doubt have an impact on the regional identity of Rioja, Ribera del Duero, the Penedes, Jerez and the upcoming areas such as the Priorat and La Mancha.

Spain's climate varies from hot and continental in the northern- and central parts to becoming more Mediterranean towards the Catalonian coast to the north-east and the whole southern coast between Cadiz and Valencia. Rioja, Navarra and Ribera del Duero to the north are home to Tempranillo as well as Garnacha (Grenache), Graciano and the white Viura variety. The Cantabrian mountains provide good protection against the devastating winds from the Bay of Biscay and moderates the climate of what would have been a very dry arid area (Stevenson, 1997, p.359). This area is getting increasingly warm with temperatures nowadays hovering around 40°C on average in summer. In 2003, the Rioja winemakers complained of soaring sugar levels and low acidity with only some mitigating rains late in August and September that saved the vintage. Severe water stress, halted ripening, leaf damage and sunburn problems were common with lower-yielding Tempranillos showing higher alcohol levels of up to 15%. In Ribera del Duero, the heat brought the harvest forward by 15 days and only the producers that had drip irrigation or altitude had a good harvest with full fruit-driven wines (Harpers, 2004). The 2004 vintage was a good balanced vintage across northern Spain with higher yields and optimum fruit, sugar levels and ripeness reported in the Rias Baixas, Rioja and Navarra regions (Hughes, et al., 2004).

Travelling east, the Mediterranean influence tempers the heat in Catalonia's Penedes region, which is a major benefit to wine-growing. The Bordeaux varieties, Tempranillo, Carignan, Garnacha and the traditional Cava varieties of Macabeo, Parellada and Xarello are all grown here, with the high vineyards of Alto Penedes even allowing for white and aromatic varieties in a cooler environment… before the continental heat steps in when moving westwards and inland towards Terra Alta (Stevenson, 1997, p.364). In general Penedes is well-equipped to handle hot, dry summers. The hot 2003 weather was preceded by a rainy winter, with the cool breezes of the Mediterranean introducing a good vintage with particularly the indigenous red varieties performing well (Harpers, 2004). 2004 brought even more restrained weather conditions to Penedes where cool cloudy spells and then sunshine resulted in a good harvest in most of the various microclimatic environments (Hughes, et al., 2004).

Moving south, the temperatures get extremely high with Jerez the hottest wine region in Spain. There is a general Mediterranean influence but towards the Portuguese border the Atlantic influence appears and the climate reaches continental conditions around Montilla-Moriles. Fortunately the Palomino, Pedro Ximenez and Moscatel grapes that are grown on the white *albariza* soils combine well with hot weather conditions to produce the region's famous sherries (Stevenson, 1997, p.366). Even Jerez feels the impact of global warming with an early harvest in 2003 and yields down by about 10% (Harpers, 2004), before bouncing back to a very good 2004 with good weather through the ripening season (except in Andulasia where drought conditions were found). Jerez had 25% more rain than the previous year with the good dry weather in August and September, and the Levante wind keeping out mildew (Hughes, et al., 2004).
This is the irony of global warming's influence on Spanish wines. Despite Spain being red-flagged as a country destined to turn into a desert, certain regions seem to embrace these conditions. And the media loves the country's even fuller, spicier and fruitier wines, in some instances referred to as "Spanish Chateauneuf du Papes" (Wine Exchange, n.d.). It remains to be seen however to which extent the warmer conditions will be allowed to increase before having a negative effect on wine production.

Looking at the future, Spain is literally and figuratively a hotspot when predicting what global warming's impact will be in the century to come. According to the Spanish Environment minister Cristina Narbona, the country is particularly vulnerable to global warming and could see a future of heat waves and coastal erosion that could destroy beaches and jeopardize tourism. The ministry's report states that whilst the global average at which the Earth has warmed during the last hundred years is approximately 0.6°C and Europe's average 0.95°C, Spain has warmed up an average of 1.5°C during this period. Looking at a general prediction, global warming could increase summer temperatures in Spain to 50°C by the years 2070-2100 with winters that would also get warmer. On top of this, polar meltdown means that sea levels could rise by up to 68 centimetres which would destroy the vulnerable beaches of Spain. The Spanish ministry further warned that the risk of extreme weather usually associated with global warming, including floods, heat waves and fires, will increase. "We have a responsibility to reduce the causes of climatic change. This means above all innovation in technology and a change in our habits", a remark that can directly be applied to the wine industry where producers will have to adapt to climate change (Reinlein, 2005). This will include the

possible cultivation of different varieties (the renowned Tempranillo which is an early-ripener in contrast to some late ripening alternatives) and increased irrigation in contrast to the current mostly dryland cultivation.

Portugal

Portugal lies on the western-most part of the Iberian peninsula between continental Spain and the cooler Atlantic seaboard. Summers are extremely dry and hot, the winters mild and wet, with conditions becoming more continental and extreme in the Douro valley, the home of Port (Stevenson, 1997, p.378).
The potential impact of global warming on the Portuguese wine industry echoes that of Spain and even worse. A study of the timing of leaf unfolding on four European tree species showed that Portugal had the greatest amount of warming between 1969 to 1998: average air temperatures in early spring (February to March) increased by nearly 0.6°C per decade, and the beginning of the growing season has advanced by approximately 14 days since 1969 (Climate Hotmap, n.d.).

The one region that might be better suited to withstand global warming's threats however is the Douro valley: not only is the Douro protected by four mountain ranges that makes it a micro-cosmos of unique climatic conditions, but the traditional Port varieties, including Touriga Nacional, Tinta Barroca and Tinta Roriz are well-suited to the hot climate and hilly schist soils of the Douro (Stevenson, 1997, p.378). These soils are extremely important in summer as they are free draining and allow the vine roots to penetrate deep to seek out a steady though moderate water supply. The different vineyard sites within the valley (an area that in summer could be 15°C warmer than Porto or the coast), also mean flexibility when micro-climate is considered: there are differences in elevation and altitude, the position along the Regua river and the exposure of the vineyards (north-facing vineyards being cooler for example) (Wine Anorak, *The New Douro*, n.d.).

Although the Ports of the Douro might therefore be safer against the threats of global warming when compared to areas producing dry wines, increased temperatures and

extreme conditions will have a big effect on the Port styles of the future. The 2002 vintage was very rainy (Wine Anorak, *The New Douro*, n.d.), with 2003 a good, though very hot year. Temperatures across Portugal rose to more than 40°C on a daily basis and approximately 1 700 forest fires hit 15 of the country's 18 regions and destroyed more than 26 000 hectares of scrub and trees (McCarthy, *Is this proof of global warming?*, n.d.). Following only two days of rain between the starting of the harvest in middle September to the end on 10 October, the hot weather led to the Port wines having dark colours, rich fruit and tannin, and overall a good, though not brilliant, year for Port. In other regions, temperatures of up to 50°C were measured in some parts of Alentejo and Dao, with slightly more moderate conditions and a better vintage for Vinho Verde, Ribatejo, Estremadura and the Setubal peninsula (Harpers, 2004).

The 2004 vintage showed better in the Douro although the unpredictable weather of a dry growing season and then a wet August had the producers worried. Sunshine arrived just in time to prevent rot, and with increased sugar levels good Ports were produced. Finer, more fragrant and less jammy red wines came from the other parts of Portugal which delivered wines well-balanced in alcohol, intensity and acidity (Hughes, et al., 2004).

Port is simply due to its natural characteristics better-equipped to deal with a limited increase in global warming, but the Portuguese wine industry *per se* runs the same risk as the rest of Europe where extremely unpredictable weather patterns could lead to less consistency and a subtle shift in winemaking methods and wine styles.

Germany

Being the northern-most and coolest of Europe's commercial wine producing countries, Germany might gain the most from the possible effects of global warming. Year after year German producers struggle in many parts to get their grapes to reach maturity and phenolic ripeness, and with higher temperatures and more sunny weather we might soon see fuller and riper (albeit a-typical) wines coming from areas such as the Mosel and Rheingau (California Wine and Food, n.d.).

An article in the New York Times (Asimov, 2003) mentions the fact that for winemakers

from historically cool grape-growing areas, global warming is anything but a fearsome proposition. Johannes Selbach, a producer from Zeltingen in the Mosel valley, reckons that since 1988, every vintage has been a good one and strikingly warmer than anything he can remember. For years in Germany, the grapes were classified according to ripeness at the time of picking, a criterion that also determined the perceived value and price of the wine. The grapes with the least amount of sugar were called kabinett, while grapes with more sugar were called spatlese, and then auslese, beerenauslese, eiswein and trockenbeerenauslese. From the late 1980's until 2002 when the sugar standards were raised, no true kabinetts were made, at least according to producer Ernst Loosen from the Mosel. The grapes were ripe enough to be called spatlese, but declassified and used to produce good kabinett. He reckons the benefit of warmer weather is that consumers can now learn what to expect from German producers who can consistently make good wine as opposed to only once a decade as before.

However, while the dry Riesling producers are positive about an increasingly warm climate, Dr. Robert Pincus, a scientist at the Climate Diagnostics Center at the University of Colorado foresees danger in areas where wine production is closely linked to a current (cooler) climate. He predicts that wines that depend on a chilly climate, like German ice wine and Austrian Grüner Veltliner, may become increasingly difficult to produce. The production of ice wine in particular, where grapes are left on the vines until they freeze, will become problematic: if the frost does not come early enough, the grapes will rot, so producers now have to time their picking dead right for the one to three days maximum that they get frost (Asimov, 2003).

We must also remember that global warming will not only bring the warmer weather that Germany craves, but also other extreme conditions such as heavy rains that will be detrimental to optimum grape growing. In areas where very steep slopes are found on the banks of the Rhine for instance, erosion would become a big problem with heavy downpours of rain: you could plant cover crops to stabilise the surface, but that in turn will mean an increased water demand.

According to professor Hans Schultz of the Geisenheim Research Institute, historically the best sites in Germany were the exposed ones at altitude, the same ones that now

face the biggest problem when vines shut down due to heat stress. The irregularity of irrigation in Germany is another problem since being permitted in 2003: the vines go through more "stress and relief" cycles, as opposed to New World wine producers used to consistent irrigation and less weather dependency. These are all criteria impacting on the expression of terroir. He calls for more research on the impact of climatic change on white wines as most research up until now has been done on red varieties. It is easier to examine stress related colour changes on red wines and on top of that, the quality of some red wines are even enhanced by a limited amount of stress. White wines on the contrary are more susceptible to the negative effects of global warming, confirmed by trials at Geisenheim in 2003 that showed a reduction in wine quality in white wines made from stressed vines compared to irrigated vines. This quality discrepancy will become even more apparent in aged white wines as Rieslings from the hot 2003 vintage showed earlier kerosene characters and look to have lower ageing potential than wines from the more moderate 2002 vintage (Gilby, 2005).

Changes to climate will also impact on the occurrence of pests and diseases. *Black Rot* and *Esca* are but two diseases that are nowadays regularly seen in Germany; 20 years ago these would never have been present due to the severe winter cold. So the challenge German producers face is to re-evaluate the adaptability of certain varieties to certain regions. The more fragrant varieties that Germany has become renowned for, like Sylvaner, Müller-Thurgau, Pinot gris and Pinot blanc, are all known to produce off flavours when confronted with heat stress. Riesling is somewhat sturdier, but German research has shown that Merlot, Cabernet Sauvignon and some other red varieties will become more suited to the Rhine valleys by the year 2050. The researchers used the 2003 vintage as an example when the Rhine region that year showed a very similar temperature pattern to Montpellier in the south of France.

Figure 4 shows a graph of the heliothermic Huglin graphic index used to predict a grape variety's ripening capacity in the Rhine valley. Different varieties have different needs when it comes to ripening, so this index uses the sunshine hours and temperatures during a vine's vegetative period to arrive at the suitability of a variety to a certain region. Looking at this index, Müller-Thurgau needs 1500 "units" to ripen, Riesling 1600 and Cabernet Sauvignon 1900 which makes the latter grape not suitable for colder, cloudier areas. As global warming increases, a region's index will go up and the varieties that can

ripen in that area will change too… confirming the argument that as early as 2030-2040, Cabernet Sauvignons and Merlots might be better propositions for Germany's Rhine regions (Gilby, 2005).

* Figure 4 (Gilby, 2005).

The potential impact global warming can have on German wine production can also be illustrated by looking at the wines from the warm 2003 vintage which saw the highest temperatures in Germany since 1976 (McCarthy, *Is this proof of global warming?*, n.d.). Michael Knobelsdorf, a meteorologist at the German weather service, actually reckons 2003 showed Germany the longest "extended period of dry weather and sunny days since records began (in about 1870)" (Croft, 2003). Most wine producers did not object though, and hailed 2003 as a vintage of exceptional quality: as a result of the hot weather, the a-typical vintage brought lower yields, lower acidity and higher natural sugar levels. August saw tropical temperatures of 36-38°C and introduced a harvest that began 3 weeks earlier than normal. Red grapes had a good year, and the whites were very a-typical but opulent and full. The racy acidity for which German Rieslings are renowned (the Mosel Rieslings in particular) was suppressed by the summer… to such an extent that the German government made a first-ever announcement late in September that producers would be allowed to add tartaric acid to the juice prior to fermentation. The only producers that felt let down were the frost dependent

Trockenbeerenauslese and Eiswein producers as the dry weather made it difficult for botrytis to develop (Harpers, 2004).

It will be very interesting to see how global warming treats a traditionally cool country like Germany. Perhaps Caroline Gilby MW sums it up best in her article that mainly deals with the impact global warming could have on German wines: “It is clear that global warming trends are already having an effect on both the style and quality of the wines we drink. If trends continue, grape growers (and wine drinkers) will need to rethink a lot of what they currently take for granted” (Gilby, 2005).

Before looking at the impact of global warming on the other top wine producing areas of the world, it will suffice to conclude the European part by noting that similar consequences could be expected from Europe’s other wine countries. In Hungary there are big concerns surrounding the drier conditions and the shrinking of Lake Balaton, Europe’s biggest freshwater lake. This is blamed on global warming which also brought four consecutive hot summers at the turn of the millennium and the hottest stretch since records began in 1865 (Geoghegan, n.d.). In Austria, glacial ice is more reduced today than at any stage during the past 5 000 years (Climate Hotmap, n.d.), and the country’s aromatic white varieties are expected to suffer from excessive heat as far as the delicacy of flavours are concerned - but can count on fuller fruitier wines and rounded reds. Bulgaria, Romania, Moldova, Ukraine and Russia have all reported signs of increasing temperatures and even desertification (Brown, *Sahara jumps Mediterranean into Europe*, n.d.), conditions that will bring fuller-bodied, higher-alcohol wines but also lower yields and even heat stress in certain areas (Harpers, 2004).

Grapevines are best adapted to Mediterranean-type climatic conditions which mean long, dry and cloud-free summers, followed by cool winters with sufficient and consistent rainfall (Greening Earth Society, 2005). To align these natural and ideal conditions and Europe’s staunch emphasis on terroir to a warming climate will be a big challenge. Dr. Gregory Jones from the University of Southern Oregon maintains that even if improvements in grape growing and winemaking technology minimize the effect of global warming, climate will still be the domineering factor impacting on vintage variation (California Wine and Food, n.d.).

(c) North America :

The United States and Canada are two wealthy industrialised countries and subsequently also two of the biggest culprits when it comes to greenhouse gas emissions. The effect of global warming is very visible and includes climatic changes such as polar warming in Alaska, glacier melting in Montana and animal range shifts in California. The impact of global warming in North America is further evident when considering the sudden heat waves reported in Texas, Florida, Illinois, New York and other states over the past decade, the current rate of sea-level rise in Chesapeake Bay that is three times the historical rate, regular reports of hurricanes such as the severe Katrina, the permafrost surface of interior Alaska that has warmed by about 1.9°C since the 1960's, the Bering Sea's sea-ice extent that has shrunk by approximately 5% over the past four decades (and the Arctic ocean by 6%), and the fact that some glaciers in the Canadian Rockies have retreated by hundreds of meters and the climate has warmed by a rate of 1.1°C per century, twice the global average (Climate Hotmap, n.d.).

Due to the said high emissions of greenhouse gases in the Unites States, the country is particularly vulnerable to the effects of global warming. Approximately 6.6 tons of greenhouse gases are emitted per person per year, of which about 82% of come from burning fossil fuels mainly used for generating electricity and powering cars. This will result in most of the USA expected to warm and an overall trend towards increased precipitation and evaporation, as well as the unpredictability of more rainstorms and drier soils (U.S. Environmental Protection Agency, n.d.).

The hub of the US wine industry is of course California, whose climatic future seems even worse. According to a study published in the National Academy of Sciences, the average temperature in California could rise by as much as 10°F (5.6°C) by the end of the century if the world does not tone down on greenhouse gas emissions. The study used two computer models, one in which the industrial world maintained its reliance on coal, gas and oil, and a second hypothesis where there was investment in new technology and alternative energy sources. Even the best-case scenario showed that there would still be significantly longer summer heat waves and an almost 90% reduction of the Sierra snow pack from which California's $3.2 billion wine industry gets much of its irrigation water.

Higher temperatures would cause problems for growers near the coast and make viti- and viniculture very difficult in the Central Valley. The study forecast that the average temperatures in California's coastal cities would be similar to the current conditions of their inland counterparts that will experience "Death Valley-like" temperatures. Christopher Field, director of the Carnegie Institution's Department of Global Ecology in Stanford said that even though California has taken up procedures to reduce greenhouse gas emissions, "it cannot save itself. California has something like 2% of the world's total global greenhouse emissions. Even if California were to aggressively adopt emissions controls, global climate wouldn't respond to that directly" (Wines & Vines, 2004).

A 2004 Reuters article titled "Global warming menaces California wine industry" (Fox, *2004)* takes the Field study further and warns that under the highest greenhouse-emissions forecast (the most probable route considering high economic growth, globalization and strong use of fossil fuels), carbon emissions by the end of this century will be 28 billion tons per year (compared to the current rate of 6-7 billion tons a year). The low emission trajectory (albeit more improbable) using lower economic- and industrial growth as hypothesis forecasts that emissions would stay at its current level. Even the best-case scenario would see heat waves and extreme temperatures in Los Angeles quadruple in frequency and under the worst-case scenario six to eight times as frequent. This could "fundamentally disrupt California's water rights system" and have severe consequences for the wine- and dairy industries in particular (Fox, *California Wine Industry Threatened by Global Warming*, 2004). Grape growing depends on optimum climatic conditions and even if the lowest possible greenhouse emissions were achieved, the "Californian wine industry is inevitably doomed by the end of the century" (Lechmere, 2004).

Despite these gloomy predictions, the jury is still out on the short-term climatic changes in California. This state has five categories of vine-growing regions, graded from Region I (the coolest) to Region V (the hottest) by a heat summation system that measures in "degree days" the amount of heat useful for vine growth a region has each year. This model helps growers predict which varieties will thrive in which areas. The Mendocino area to the northern part of the state generally has relatively warm winters and cool summers, providing for a growing season with many warm days and cool nights. Sonoma county traditionally has extreme climatic conditions ranging from warm in the

north of the county to cool in the south due to oceanic breezes flowing in. Napa county, the heart and soul of the country's wine industry, also has a climate that varies from cool near the San Francisco Bay to warm in the northern part of the Napa- and Pope valleys. The other wine-producing areas of California, more specifically the North- and South Central coastal parts and the Central valley also host various macro- and meso-climatic environments which allow winemakers the luxury of aligning climate to viti- and vinicultural practices (Stevenson, 1997, p.448).

In the Napa valley, some winemakers have not experienced the full effects of global warming (yet): according to Bob Steinhauer of Beringer Blass Estates, they have not seen the direct impact of global warming but they "wouldn't want it to be any hotter" (Asimov, 2003). It must also be said though that not many winemakers would admit the negative effect of heat stress on its vines if that would prevent their wine from selling.

Looking at two recent vintages, 2003 proved his point by offering a warm and dry summer but with few really hot spells. The harvest started later than usual resulting in a fairly good yet light harvest (Harpers, 2004). 2004 saw a hotter year with bloom arriving a month earlier than in previous years and early picking throughout September. Some areas had heat waves with 37°C days coupled with daily talks about global warming. Most of the Chardonnays and Pinot noirs were barrelled early and Cabernet Sauvignon was harvested a month earlier than normal. The mountain appellations showed the best Merlot, Zinfandel and Cabernet Sauvignon although the initial high sugar levels resulted in high alcohol wines and might impact on longevity (Hughes, et al., 2004).

This is the increasing problem with modern vineyards in a hot summer nowadays, namely that sugars build up in the grapes much more rapidly than the phenolics. So producers find themselves with high sugar levels, low acidity and a distinct lack of potential character and mid-palate in the wines…. leading Michael Havens of Havens winery in the Napa valley to say that "California's biggest challenge today is getting phenolics ripe before the grapes are ready to pick". Jancis Robinson explores this theme by pointing out that it is now customary for top wine producers in very respected parts of California (and Australia) to harvest only when the phenolics have fully developed and sugar levels have gone past being ideal. To then turn these less-than-perfect grapes into well-balanced wines, the winemakers add water and acidity, usually before fermentation

by draining off the least concentrated juice and adding back twice as much water. A Napa vintner George Hendry confirmed this to Robinson when stating rather proudly that "it's difficult to build phenolics in hot regions but we can make the alcohol levels whatever we want" (Robinson, *Making wine not stronger but better*, 2004).

Looking at other regions, the prime winegrowing areas of America's North-West has definitely taken a hit from global warming, and the effects are more visible as Oregon and Washington states are both renowned for Burgundian varieties that prefer a cool climate. Exhaustive research has been done to investigate the positive and negative effects of global warming, including a Cool Climate Viticulture and Oenology Symposium that began in 1984 in Oregon. This forum deals with all issues surrounding growing grapes in a cool climate and includes the topic of global warming (the 2000 topic of the Symposium held in Melbourne). A "Cool Climate region" is considered by the Symposium members to be "one in which moderate temperatures and a gradual progression from budburst to harvest protects delicacy and nuance in the resulting fruit." They recognize that wine quality from many grape varieties are better where the fruit gets fully ripe, but not too quickly and without temperature extremes. The wine producers from Cool Climate regions need to get geared for the threat of global warming as predictions are that over the next 50 years in Cool Climate areas, the average temperatures of 11.5°C will rise with 1.8-2.5°C, that carbon dioxide levels will double leading to a 20% or greater increase in humidity and 30-50% reduction in soil moisture, and that precipitation will decrease to half the normal level. Weather events will become more extreme and in Oregon, these changes to climate will require irrigation in the drier summers and good erosion control in the wetter winters. Marginally cooler sites might be allowed greater success with their Pinot noir and Chardonnay as warmer temperatures will bring forth riper grapes and fuller wines, and the currently successful warmer sites might have the opportunity to experiment with Californian or Bordeaux varieties (Pederson-Nedry, n.d.).

The winemakers from Oregon, found at a much higher latitude than California, are therefore (similarly to most German vintners) quite impressed with the impact global warming has had on their harvests. Lynne Penner-Ash who specialises in Pinot noir at Penner-Ash wine cellars in the Willamette valley is adamant that the climate has warmed, and is quite positive about it. "In Oregon, the saying used to be you got two

really good vintages in 10 years, and in the last 10 years we've probably had nine". Though she is concerned that the reputation of Oregon for making lean elegant Pinot noirs might be jeopardised as the wines become increasingly powerful, she confirms that the benefits of a warmer climate are clear. The winemakers will simply have a stylistic challenge now that the grapes are harvested much riper and the resulting wines show darker jammier fruit (Asimov, 2003).

The much quoted Oregon climatologist Dr. Gregory Jones reckons that global warming could be "iffy" for Washington but great news for British Columbia across the Canadian border. Most, but not all parts of central- and eastern Washington state showed warming trends: the Yakima valley and the vineyards around Walla Walla appear to be heading towards an above-average rise in temperature, which Dr. Jones and his team say could either help or hurt the wine producers depending upon how the environment responds to this change. The average temperature for the wine-growing regions of Washington State will increase faster over the next half-century than the global average of 2°C. In the Yakima valley, a temperature increase of 2.27°C is predicted and for Walla Walla an increase of 2.81°C (Paulson, n.d.).

To ensure that the correct grape varieties are planted in the best possible sites, Dr. Jones and colleagues have developed a model that can assess a particular plot of land's promise as a vineyard. One part of this model uses computerised topographical maps: in Oregon's Umpqua valley for example, the best sites are found 120-240 metres in elevation on hillsides with a slope of 5°-15°C that face in a southern direction. These areas provide the best sunlight exposure, and the gently sloping hills allow cold air to flow away from the vines and so protect them from mild freezes. The computer model also looks at a site's potential according to its drainage, pH and water-holding capacity. Climate variables include the site's coldest winter temperature, frost intervals, temperatures during growing season and the frequency and amount of rainfall. Pinot noir would do better in the cooler areas of the Umpqua valley, with Tempranillo and Syrah better suited to the warmer zones. To pick the correct site is half the battle won according to Jones, which stresses the fact that global warming would not necessarily eliminate the concept of terroir but rather make growers more conscious in deciding on which varieties to plant where.

Further to Dr. Jones's model discussed here, the USA is at the forefront of technological initiatives to align climatic changes with optimum viticulture. To trace the effects of global warming, Susan Hubbard and her team at the Lawrence Berkeley National Laboratory in California have developed a way to use ground-penetrating radar to easily measure soil moisture. Radar waves travel slower in wet soil, so the speed at which the beams travel will be a good indicator as to the soil's moisture content. In the Napa valley, field tests have enabled grape growers to refine their irrigation schemes on a row-by-row and even plant-by-plant basis, which ensures that the vines receive optimum moisture throughout the growing season. Hubbard admits that these technological tricks probably would not make a great vintage any better, but it could indeed improve what could have been an average winemaking year (Perkins, n.d.).

Looking at the secondary wine regions of the United States, global warming has not had a direct effect yet on the North-Eastern parts, more particularly the Finger Lakes region in New York. This is at least according to the opinion of Willy Frank of Dr. Konstantin Frank's Vinifera wine cellars in Hammondsport who attributes the moderating effect to the deep Finger Lakes which tend to cool warm air and warm cool air (Asimov, 2003).

No-one knows for sure what the impact of global warming on the USA's wine industry will be: the possible temperature increases foreseen for the next half-century were discussed above, and following research by the National Academy of Sciences, some wine writers even advise wine lovers to buy Californian wine now as "Napa will soon be a desert" (Vinography: a wine blog, 2004).

The impact and extent of global warming in North America will differ from region to region. On top of that, each producer might have a different attitude towards the positive- and negative effects of increased temperatures and less water availability. The USA is most definitely geared with a futuristic view and cutting edge technology to help them prepare for the onslaught of global warming.

(d) South America :

From a global and commercial perspective, Chile and Argentina are the only two wine-producing countries of note on the South American continent.

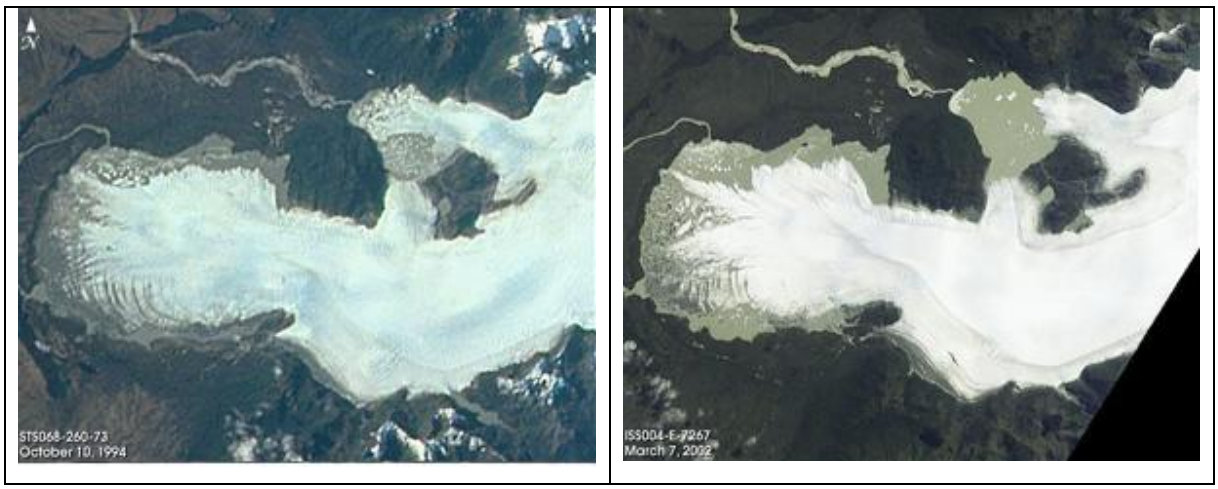
Looking at the current climatic status of South America's wine regions, Chile is generally blessed with a moderate yet versatile climate. Vines are grown along 1 300 km of Pacific coast and against the foothills of the bordering Andes which ensure both cool breezes and enough elevation to counter most high temperature onslaughts. Conditions vary from arid and extremely hot in the north to very wet in the south. The wine area around Santiago's Central valley (comprising the top wine districts of the Curico-, Maipo-, Maule- and Rapel valleys) has a low rainfall with no spring frosts and clear sunny skies. At night the temperatures drop substantially due to the proximity of the snow-covered Andes, enabling the grapes to retain their acidity levels. New areas like the Casablanca valley are proving to be increasingly suitable for winegrowing, and more so the coastal range of hills since they receive enough rainfall to allow modest yields without the need for irrigation, as well as benefitting from a cool maritime influx from the ice-cold Humbolt Current. The climate of Argentina's intensively cultivated Mendoza district is officially described as continental-semi-desertic. Found east of the Andes, the region is subject to harsher conditions as most rain is cut off by the mountains to the benefit of the Chileans. Mendoza sees a mere 20-25 cm of rain per year, although this is spread over the summer growing months when temperatures range from 10°C at night to 40°C during the day (Stevenson, 1997, p.507).

Across the continent, however, the impact of global warming is as severe as in the rest of the wine world: higher global temperatures along with more frequent El Ninos are bringing increased drought; and melting glaciers in the Andes threaten the region's water supply. Signs of global warming have already appeared both at high elevations (in glacial retreat) and along the coast in rising sea levels and coral bleaching. The edge of the Qori Kalis glacier on the Peruvian side of the Andes has stepped up to retreating 30.1 metres per year since 1995, average minimum temperatures along Peru's North coast have increased with 2°C from the 1960's to 2000, the rate of warming in the tropical Andes has doubled in the last 40 years and more than tripled in the last 25 years to about 0.33°C per decade, and of the six glaciers in the Venezuelan Andes in 1972,

only two remain and scientists predict that they will be gone within the next decade (Climate Hotmap, n.d.).

Heading south towards Chile and Argentina, their Patagonian Icefields (the largest non-Antarctic ice masses in the Southern hemisphere) are thinning at an astonishing pace and now account for almost 10% of global sea-level change from mountain glaciers. This is according to studies by NASA and Chile's Centro de Estudios Cientificos published in the journal *Science* which also claims that the Patagonia Icefields lost ice at a rate equivalent to a sea level rise of 0.04 mm per year during the period 1975-2000. As per the 2001 Intergovernmental Panel on Climate Change Scientific assessment, this equals 9% of the total annual sea-level rise from mountain glaciers. From 1995 to 2000 however, the rate of ice loss from the icefields more than doubled to an equivalent sea level rise of 0.1 mm per year. The two satellite images in figure 5 of the San Quintin glacier in Patagonia (the largest outflow glacier of the Northern Patagonian Ice field in southern Chile) were taken only seven years apart, in October 1994 (left) and February 2002 (right) and clearly demonstrates the loss of ice mass and change of structure, particularly in the lobe (NASA Press Release, 2003).

* Figure 5 (NASA Press Release, 2003).



Chile at one stage even considered a desperate proposal to fertilize the sea to produce more plankton in a bid to reduce global warming. Far-fetched as it may seem, *New Scientist* magazine reported that Australian oceanographer Ian Jones patented his plan

and presented to the Chilean government a proposal in 1999 to fertilize water with nitrogen to encourage the growth of plankton. As the organisms photosynthesise, they use up carbon dioxide dissolved in the water, causing the ocean to draw more out of the atmosphere and so reduce the main greenhouse gas driving global warming. Arguments against this plan included the fact that the planet would be overloaded with yet more nitrogen which is already a major pollution problem in its own right (ClimateArk.org, 2000).

Again it remains to be seen what impact global warming will have on wine production in Chile and Argentina. Though an isolated example, 2004 brought an earlier and smaller harvest to the Chileans after the grapes reached maturity very quickly. According to Santa Rita winery the combination of fruitiness and concentration is rare and they are impressed with the fuller higher-alcohol wines resulting from increased temperatures (Hughes, et al., 2004).

(e) Australasia :

The climate of the Oceanic region is strongly influenced by the ocean and the El Nino phenomenon. The coastal regions are very vulnerable to coastal flooding and erosion due to the rising sea level, and the inland parts under scrutiny due to high temperatures making continental climatic conditions even worse.

Australia

Australia is an enormous country with various climatic conditions present across the geographic spectrum. New South Wales on the southern part of Australia's east coast have temperatures similar to those of the Languedoc: cloud cover can temper the high temperatures in the Hunter Valley, Mudgee is sunny and dry, while it is even hotter and drier in the inland Murrumbidgee area. Climates in Victoria state are very diverse, ranging from hot continental conditions in North-West Victoria around Mildura, to the moderate coastal conditions of the Yarra Valley near Melbourne, and through to the cooler conditions of Tasmania. The hub of the country's wine industry is South Australia which also offers great variation in climate: the inland volume-producing Riverland area

is extremely hot and continental, the Barossa Valley less extreme but still hot and dry, and the Coonawarra region cooler but still dry. The Adelaide plain also receives a low annual rainfall with sea breezes reducing humidity. Western Australia's weather patterns include the long, very hot dry summers and short wet winters of the Swan Valley (considered one of the hottest winegrowing areas in the world), the Mediterranean-type conditions of the Margaret River with a higher rainfall and summer heat tempered by ocean breezes, and the even cooler Lower Great Southern Area which receives some light rainfall in summer (Stevenson, 1997, p.522,526,533,539).

Amongst other scientific methods, a "Heat degree days" concept as developed at the University of California at Davis, is used to measure climatic data. This complex temperature summation model shows that Australia generally has a hot yet versatile climate. Whereas some vineyards in parts of New Zealand's South Island fall off the bottom end of the scale, Australia's Roma area in Central Queensland borders the maximum range of "heat degree day units", with Barossa, Margaret River and the Coonawarra still hot yet less extreme (Walterfang, n.d.).

Global warming is changing the *status quo* and for the past few years, Australia has seen rising temperatures across the country with its continental-average temperature rising about 0.7°C from 1910 to 2001 (with most of the increase occurring after 1950) (Hartley, n.d.). Side effects include coral reef bleaching and the 34 glaciers on the southern Heard Island decreasing by 11% in area since 1947 (Climate Hotmap, n.d.). The one positive aspect of global warming's double-sided sword is that the cooler winegrowing regions such as the Macedon Ranges, Mornington Peninsula, Tasmania, Gippsland and Mount Barker are warming up to allow their vineyards to obtain consistent physiological grape ripeness; the negative effect however being that the increased amount of heat waves in already hot areas like Griffith, the Swan Valley or Clare Valley might soon make these wines too alcoholic and over-concentrated to enjoy (Oliver, n.d.). Apart from the impact on temperature and rainfall, increasing Ultraviolet-B levels are as big a problem: high radiation levels can severely affect plant constituents that are important in fruit and wine flavours, and even fruit-set and photosynthesis itself as DNA absorbs the high-energy radiation. In Australia, the intensity of UV-B radiation has increased by 10-15% in the last two decades with the only small positive the fact that it inhibits powdery mildew (Pederson-Nedry, n.d.).

Rick Kinzbrunner from the Beechworth vineyard at Giaconda in Victoria uses the hot vintages of 2001, 2003 and 2004 to back up his concerns over the increasing heat: “I believe global warming is a reality and that some years in the future it will be more difficult for Pinot noir in this area”. To combat the increased temperatures, he is gradually moving his Pinot noir to vineyards which are 150 metres higher in altitude than Giaconda. 2003 was a particularly hot year when 3-4 weeks of extreme heat in February in the Barossa Valley and McLaren Vale caused vines to wilt, leaves to fall off and bunches to be overexposed to the sun. Unsurprisingly the vines shut down and only recovered when cooler weather arrived in March. Although the producers managed to pick the white varieties without big problems, the harsh reality of global warming presented itself with the red varieties. According to Natasha Mooney (senior winemaker at Adelaide Hills-based Xanadu Normans which sources grapes from McLaren Vale and the Barossa), they had to wait for the red grapes to ripen up again and by the time they did, the analysis of the best fruit showed 15 Baume (equivalent to ±15% alcohol). Corina Rayment at Oliver’s Taranga vineyards in McLaren Vale had big problems with uneven ripening and remembers bunches in which some individual grapes were registering 12 Baume and others 18 Baume: “you had green tannins and overripe fruit characters fighting each other”. After fermentation and maturation, some Barossa and McLaren Vale winemakers saw some Cabernet Sauvignon and Shiraz with a weak structure, low tannins and almost no mid-palate flavours (Port, 2004). One McLaren Vale producer, Fox Creek, decided not to release a reserve Shiraz, with its managing director Jim Watts stating that global warming will have a long term impact on the future of premium wines in Australia (Winestate, n.d.). In the Hunter Valley, Bruce Tyrell of Tyrell Wines had to use non-conventional methods to save his 2003 red wines. He picked the white variety Trebbiano at 6.5 Baume, sterile-filtered it and then blended this into his red wines. He reckons that climatic conditions now are quite similar to the 1960’s and that global warming is nothing new since New South Wales has been in drought since 1991 anyway. Coonawarra also had a hot 2003 vintage with a warm, short season and a small crop (Port, 2004).

The year 2004 brought a better Australian harvest following the 2003 drought. Good winter- and spring rains and low levels of disease ensured healthy vines and a good crop from especially the Yarra Valley, Margaret River and Coonawarra. Clare Valley and Riverland had too much sun though and the over-ripe grapes will deliver concentrated,

fruity and even jammy wines in some instances (Hughes, et al., 2004).

Looking ahead at the likely acceleration of global warming, there are grim predictions for the future of some of Australia's wine regions. In October 2004 researchers reported a sharp increase in the amount of carbon dioxide in the Earth's atmosphere during the past two years, with no corresponding increase in oil or coal consumption. Researcher Leanne Webb of the University of Melbourne is studying the impact of global warming on the wine industry (South Australia *in casu*) and predicts dire consequences should the trend continue. Wine quality in areas like the Barossa Valley will be significantly reduced in the long-term: "by the year 2030 the impact's not that great, it's between 0 and 5 percent negative impact on quality, but looking out to 2050 this would increase to between 11 and 15 percent negative impact on quality" (ABC News Online, 2004).

Even if rainfall stays consistent (best-case scenario), there is a risk of more violent flooding and because of a rise in temperature, evaporation and moisture balances will make the continent drier. In terms of annual water balance, Australia will be 15-169 mm worse off by 2030 and all regions will experience moisture stress. The one or two regions that will experience higher summer rainfall will have to deal with an increased botrytis threat on varieties where it is not desired, which will in turn increase the need to use chemical sprays to protect crops. Higher carbon dioxide levels due to greenhouse gas emissions will increase the foliage and production of pathogens, and strict canopy management may become increasingly necessary to prevent under-ripe fruit. Due to a general rise in temperatures, researchers predict that viniculture might come to an end in areas such as the Riverina and Murray Valley. CSIRO projections estimate that Australian temperatures will rise between 0.4°-2°C by 2030 and that the country will be up to 6°C hotter in 2070. According to a Special Report on Emissions Scenarios (SRES), the average number of 35°C+ days that Melbourne experiences in summer could rise from 8 to 10-20 by 2070, or in Canberra the winter days below 0°C could drop from the current 44 to 6. A temperature increase of 0.3-1.7°C is projected for McLaren Vale, Barossa and Clare Valley. The Murray Darling river system could expect a reduction of rainfall between +5 to -45% by 2070, with the only good news the amount of frost days that will decrease by 17-27% for the low warming scenario and 60-90% for the high warming scenario (however, if budburst is brought forward due to higher spring temperatures, the risk of frost will actually remain the same) (Hartley, n.d.).

The wine-drinking world is already picking up on this unfortunate warming trend and could be turning their backs on Australia's "signature super ripe, high-octane alcohol, heavily oaked, fruit bomb styles" in favour of lower alcohol finely structured wines. Some researchers and wine writers reckon that the Australian wine industry must seriously rethink their choice of wine varieties and could be forced to plant more Mediterranean grapes such as Mourvedre, Grenache, Sangiovese and Tempranillo in order to produce Amarone-style wines or even Ports in the warmer areas (White, 2005).

The Australians are not reactively waiting for global warming to influence the quality of their wines and, as per the Americans, are putting technological mechanisms in place to trace the progress of global warming. In "precision viticulture", grape growers tailor their agricultural practices to different parts of the vineyard. The first step is to create detailed maps of a vineyard depicting the major parameters such as the quality, depth, clay- and water content, pH as well as the amounts of water, fertilizers and pesticides in the soil. Thereafter the yield and quality of grapes harvested are assessed, using parameters such as the number of grape bunches per vine, the weight of each bunch, leaf area per vine, the pH of a grape's juice and the various flavour chemical concentrations in the grape. Australian assessments of precision viticulture have been in place for more than 5 years which help vintners to adjust their practices as per the data received. Some studies have shown that annual grape yields per acre within the same vineyard can vary by a factor of 10. For a particular site, that variation typically holds, regardless of yearly changes to the weather, as per Rob Bramley of the Cooperative Research Center for Viticulture in Glen Osmond. This concept of precision viticulture will enable Australian vintners to monitor the impact of changing weather patterns and plant the correct varieties as per terroir changes brought along by global warming (Perkins, n.d.).

This is but one example of the commitment of the Australian wine industry to deal with renewed global warming challenges. The Ministry for the Environment and Heritage also committed themselves to the "ecological sustainability" of the Australian wine industry, in terms whereof certain mechanisms will be put in place to ensure the sustainable use of limited water resources. Investments from the Natural Heritage Trust in projects to divert, treat and re-use wastewater at plants in South Australia, and wineries being challenged to sign up as Greenhouse Challenge members and to commit themselves to the National Packaging Covenant to minimise the amount of packaging waste, are further

proof of a progressive country not merely waiting for global warming to jeopardise their wine industry (Hill, 2000).

New Zealand

Due to its southern location and strong oceanic influence, New Zealand is for most parts a cool country. The North Island has a cool maritime climate similar to Bordeaux in temperature but with a much higher rainfall. Heavy rains and high humidity lead to problems of grape damage and rot in autumn. The South Island is significantly cooler, but also sunnier and drier. Marlborough, famous for its Sauvignon blancs, is the warmest area on the South Island and often has the country's most hours of sunshine. The amount of rainfall varies between the various regions of the South Island (Stevenson, 1997, p.545).

For much of the past, New Zealand winemakers had to deal with many vineyards that were planted on flat sites with inadequate draining and very fertile soils, *inter alia* resulting in the rampant growth of leaf-canopy in a cool climate which often resulted in under-ripe, potentially vegetal wines. Between scientific extensive canopy management and rising temperatures however, Kiwi winemakers are increasingly allowed to make aromatic wines with a good acidic backbone and reflecting an expressive varietal character (About wines, n.d.).

This trend might continue as New Zealand is now experiencing its warmest summers ever with the average elevation for glaciers in the Southern Alps shifting upslope by more than 91.4 metres over the past century (Climate Hotmap, n.d.). According to The New Zealand Climate Change Office, the following climate changes can be expected in the country if no actions are taken against global warming:

a. higher temperatures, more in the North Island than the South (likely to be less than the global average though);
b. rising sea levels (sea levels globally are expected to rise between 9 and 88 cm by 2100, compared with an average rise of 10-20 cm in the 20th century);

c. more frequent extreme weather such as floods and droughts (especially in the east of New Zealand); and
d. a change in rainfall pattern with more rainfall in the west and less in the east.

These changes will have both positive and negative effects for New Zealand: the cool Hawke's Bay for example might emerge as a full-bodied red wine region but be too hot to produce quality Pinot noir (Hartley, n.d.). Agricultural productivity will increase in some instances but there is also the risk of drought in other areas; drier conditions in some regions are likely to be coupled with the risk of more frequent events such as floods, droughts and storms; rising sea levels will increase the risk of erosion and saltwater intrusion; and snowlines and glaciers are expected to retreat and change the water flows in some South Island rivers (New Zealand Climate Change Office, n.d.).

A top New Zealand researcher, professor Peter Barrett (director of Victoria University's Antarctic Research Centre) recently took the concerns about global warming a step further when he warned the audience at his awards ceremony in Christchurch in November 2004 that humans face extinction by the end of the century. After studying the Antarctic ice sheets for 40 years, he is convinced that at the present rate at which global warming is accelerating, large areas of the world could be uninhabitable by the end of the century. By the end of the century, the Earth could be 3-4°C warmer than now, conditions that last existed 30-40 million years ago before there were ice sheets in the Antarctic. The last temperature change of this magnitude was 20 000 years ago: ice caps covered large parts of Europe, the sea level was 120 metres lower, and then temperatures rose 5°C which resulted in the ice caps melting and the oceans rising. The climate stabilised about 10 000 years ago and it has been quite stable since. "Now they're talking about temperatures rising three or four degrees and of course there isn't as much ice to melt but the climate will be profoundly different. Civilisation will be very different" professor Barrett warned (TWM, 2004).

Getting back to the New Zealand wine industry, steps are taken to prevent these potential threats of global warming. Nitrous oxide emissions from fuel combustion and agricultural production are reduced with waste treatment systems (FRST, 1991), and innovative viticultural techniques (including new use of mulch to preserve water resources) have been put in place. Apart from this, compatibility of variety and terroir is

becoming even more important, and one example is the application of scientific models estimating bud break that will prevent a high risk of frost: according to the Moncur et al. model and Lincoln University daily temperature data, Pinot noir bud-breaks in New Zealand were recorded and analysed… and showed that from 1930 to 2000, the average bud break date would have advanced by 7.6 days. (Trought, 2004). One initiative to counter global warming has been greeted with scepticism however: according to an article in the National Geographic News titled "New Zealand tries to cap gaseous sheep burps", scientists are trying to curb their country's influence on global warming by dictating the diet of their sheep and cattle. The country is unique in that about 90% of its greenhouse emissions arise from methane released by enteric fermentation of the 45 million sheep and 10 million cattle, and by feeding livestock certain plants containing less methane, gas emissions can be reduced (Roach, 2002).

To conclude, it is safe to assume (as per Germany and the other cooler viticultural areas of the world) that global warming can bring a lot of good to New Zealand's wines. Climate has limited the choice of wine varieties planted and could now afford winemakers a broader spectrum of possibilities (Bodenstein, n.d.). In the interim they would need to adapt their wine styles to the new climatic changes as in 2003 when a hot vintage saw fuller, fruitier yet more a-typical wines being produced. In 2004, Canterbury for instance saw a long hot summer with very good yields, although it resulted in higher sugar levels and higher alcohols. Marlborough, Hawke's Bay and Gisborne also showed good fruit and full-bodied wines coming from areas sometimes struggling to obtain phenolic ripeness (Hughes, et al., 2004). The ball is in the court of the viticulturists and winemakers to show their global audience how they will handle this climatic challenge.

(f) Conclusion :

Growing-season temperatures determine the ripening potential for grape varieties grown in certain climatic regions. Pinot noir is grown in areas with a cooler climate where growing-season temperatures vary from 14-16°C (as in Champagne, Burgundy and Northern Oregon). Cabernet Sauvignon again is grown in warm to hot climates where the growing-season temperatures span 16.5-19.5°C (as in Bordeaux or Napa). Results have shown that from 1950-1999, most of the world's premium wine regions have seen

average growing-season warming of 1.26°C. This warming has coincided with a general increase in vintage ratings over the last 20-40 years in the same regions which shows that, ironically, global warming can be good for some wine-producing areas. Although cooler climates such as Oregon, the Mosel and Canterbury appeared to have gained from global warming, the issue remains how many of these regions are either at, or nearing, their optimum climates where the specific varieties and wine styles are concerned. In a warmer-than-ideal environment for a particular variety, the vine will go through its phenolic stages more rapidly which will result in earlier sugar ripeness. While the grower is waiting for the flavours to develop, acidity is lost through respiration, which leads to high-alcohol wines with very little acidity to retain freshness (Jones, n.d.). Global warming may force vintners to manage their vines differently to produce similar wine styles, or to plant different varieties better suited to the new climate….news that could be unsettling for an industry that prides itself on regional identity.

4. GLOBAL WARMING'S IMPACT ON THE SOUTH AFRICAN WINE INDUSTRY

(a) Current climatic status :

South Africa's prime winegrowing area, the Western Cape, has a Mediterranean climate with the coastal regions being cooler and having a higher rainfall than inland parts in spring and autumn. The versatility of terroir is reflected in the fact that cooler regions such as the Overberg falls in Region I as per the earlier discussed heat summation system (i.e. less than 2 500 degree days per year), Constantia and Stellenbosch ranging between Region III (3 000 – 3 500 degree days) and Region IV (3 500 – 4 000 degree days), and the Klein Karoo, Tulbagh, Olifants River and parts of Paarl falling between high Region IV and low Region V (more than 4 000 degree days) (Stevenson, 1997, p.428).

(b) The impact of global warming :

Signs of a changing climate have already emerged with warming temperatures across the country: sea-levels are rising, and Southern Africa's average temperature has increased by 0.56°C over the past century (Climate Hotmap, n.d.). The arid Karoo area to the north-east of Cape Town is drying out even further, conditions that are threatening the survival of the indigenous succulent plants. "The greatest challenge to these plants may be a rapidly warming climate" warned Guy Midgley, a scientist/plant physiologist at the National Botanical Institute or NBI (these days the South African National Biodiversity Initiative or SANBI) that is investigating the impact of rising temperatures on the Karoo flora (Trivedi, 2003). According to a 2004 report released for the United Nations' Framework Convention on Climate Change, the west coast of Southern Africa up to Namibia's Skeleton coast could be submerged by the end of the century due to global warming. Apart from a rise in sea-level, warmer sea temperatures have also been recorded over the northern Benguela region (Weidlich, 2004).

The South African branch of the World Wide Fund for Nature (WWFSA) reports further that climate change within the next 50-100 years would reduce the country's biomass (fynbos, grasslands, succulent Karoo and forest) to 35-55% of its current extent (West, 2003). Add to these criteria the effect of rising carbon dioxide levels and it is easy to see why Western Cape producers should consider global warming a threat. The increasing rate of global carbon dioxide concentration is the most extreme it has been the past 20 000 years with methane levels that have increased by 151% in this time and nitrous oxide by 17% (Joubert, *Agriculture: the new X factor in climate* change, 2005).

In July 2003, a satellite image taken of the Western Cape showed a dry brown land with only the Agulhas Plain offering a patch of green. The local government had to support farmers in drought stricken areas and the picture forward looks just as bleak. According to Francois Viljoen of Vinpro, the current problem began specifically with 2003's dry winter when underground water levels were not adequately replenished by the season's rainfall. Soil moisture is crucial in the four to six weeks prior to the harvest, as the vine will shut down photosynthesis if there is not enough moisture in the ground. Viljoen added that if conditions worsen further, the vine might shed its leaves to stop transpiration and will then extract water from the grapes to survive. Chrisna Du Preez (meteorologist at the Institute of Soil, Climate and Water) also conducted some interesting studies and found that apart from not enough rainfall, the limited amount of rainfall that the Western Cape is receiving tends nowadays to fall outside the expected seasonal periods (Joubert, *Drought lingers as harvest ripens*, 2004).

These drought and heat conditions in the Western Cape during the past five years are taking its toll on grape harvests. Fuller-bodied wines are made with high alcohol and pH levels, and most winemakers from the warmer Stellenbosch, Paarl and Robertson areas and beyond have to adjust tartaric acid levels prior to fermentation. The 2002 and 2003 harvests showed irregular weather patterns following dry winters, with 2004 and 2005 also suffering from a low inherent water table. Again quality depends on the interpretation of the winemaker with some cooler areas that will benefit from higher temperatures and resulting in concentrated full-bodied wines. Producers from the warm areas however will have an increasingly difficult task to produce wines that have the acidic backbone to enhance elegance and longevity (Hughes, et al., 2004).

(c) Future trends :

With global warming a reality, there is no doubt that South Africa must act to preserve its limited water resources and a primary challenge will be put to South African winemakers to adapt to the changing climatic environment. Global warming is to blame when it comes to alcohol levels, but we have to deal with the fact that we have a lot of sunshine and that we will never have wines with alcohol levels of 11.5% going down to 9% as they do in Bordeaux. Renowned wine trader Vaughan Johnson says that while the European growers look for south-facing vineyards with maximum sun exposure, the South African wine growers in the Southern hemisphere also look for south-facing slopes but in this instance to keep the vineyards away from the sun. For this reason, cooler regions such as Elgin, Hermanus and Caledon will become increasingly popular in future (Wrottesley, 2004).

This sentiment is echoed by Dr. Stephanie Wand, horticulturist at the University of Stellenbosch. A steady increase in maximum and minimum temperatures over the past three decades has taken place in the Cape, averaging a 1°C increase overall and up to 2-3°C in certain areas. The mentioned SANBI (then the NBI) also foresees that by 2050, large areas in the southern hemisphere might experience much drier conditions and temperatures rising by up to 3°C. Northern Cape vineyards can expect the most extreme increases of 2.5-4.5°C due to its continental climate, with the Western Cape seeing a more subtle climatic impact due to the proximity of the ocean. Less rainfall coupled with a seasonal shift will add further concern. Professor Eben Archer, one of South Africa's leading viticulturists, is concerned about the South African wine industry's ability to adapt to a changing climate. There seems to be no official support from the local government or even tertiary institutions to research global warming's impact on the wine industry and ways to counter its impact. Archer believes that wine growers will have to pay extra attention in deciding on rootstock and where to plant heat sensitive varieties like Sauvignon Blanc (Joubert, *Hot wine in a changing world*, 2004).

Fortunately the Western Cape is blessed with a wide spectrum of geological bio-diversity which will allow a pro-active vintner to seek out cooler areas of land suited to heat sensitive varieties. This climatic diversity of the Western Cape also means wine quality variation within a small demarcated area: cool pockets of vineyard delivering good

quality grapes can be found in the semi-arid regions of Lutzville and the Klein Karoo, regions more renowned for the production of bulk product. The cool Agulhas Plain offers different flavour profiles compared to the neighbouring Walker Bay, hence the former area being planted to Sauvignon Blanc and cool-climate Shiraz, and Walker Bay focusing on the Burgundian varieties. The valleys and slopes of Stellenbosch, Durbanville and Constantia all differ. The list goes on with even vineyard blocks and individual rows offering different climatic regimes… in line with the individualistic nature of terroir as originally defined by the French. The versatility of the Western Cape's soil and climate is surpassed by no other wine producing country, and justifies a confident global message of versatility based on terroir.

Looking ahead, the signs of a changing climate are there. Following the unprecedented impact of Hurricane Katrina in the United States in 2005, SANBI, CSIR and local government have updated South African climate change predictions. They confirmed that temperature increases can be expected for the Western Cape, that winter will see a decrease in early- and late-season rainfall, and that increased humidity will see an increase in late summer rainfall across the interior and eastern regions of the Western Cape (Joubert, *Taking it to the extreme*, 2005).

The Western Cape inland and semi-arid areas up the West coast might become even drier, and the impetus of quality wine growing will swing towards the southern and eastern parts of the Western Cape. Cool climate winegrowing is a buzz concept nowadays and will become a production (and marketing) benefit to be exploited by the winegrowers of the cooler regions such as Cape Agulhas.

In the more established wine-producing areas such as Stellenbosch, Paarl or Robertson, global warming will steer South African consumers on a new route as they will have to get accustomed to a new taste profile. The quality of these regions' wines will not be inferior *per se*, but they will be different. As per professor Archer, these wines could be more fruity rather than vegetal, and offer less body and longevity (Joubert, *Hot wine in a changing world*, 2004).

It is therefore time to be pro-active: Environmental Affairs and Tourism minister Marthinus van Schalkwyk mentioned at a National Climate Change Conference held in

Gauteng during October 2005 that climate change is a reality with no longer room for academic debate (Joubert, *Call to change with our climate,* 2005). The government's financial support for research and enforcement of water preservation regulations, alongside better viticultural practices can go a long way in dealing with the new climatic regime.

According to professor Pieter Pansegrouw of Port Elizabeth's Nelson Mandela Metropolitan University, South Africa needs a well-funded institute to research water demand management. More sophisticated water sources such as cloud seeding, desalination of sea water and purification of sewage should be considered to counter the potential effects of global warming (Earth, Air and Water, 2005).

One project that has been called to life is the R 1.8 billion Berg Water project that will commence in 2007 and which plans to dam the Berg River in the vicinity of Franschhoek to boost the Western Cape's water supply. *Bona fide* as this initiative will be, it is projected to only meet the region's need for seven years (Joubert, *Liquid gold*, 2004).

(d) Conclusion :

The agricultural future of the Western Cape is uncertain and there is definitely reason enough for concern. Realists such as Richard Worthington, coordinator of the South African Climate Action Network (SACAN) predicts that the climatic pattern of the Western Cape might change quite drastically within the next few years when global temperatures rise above a 2°C increase… and this might mean the end of our fruit- and wine industries (Van Rensburg, n.d.).

Even scientists claiming global warming to be overestimated in South African context call for transparent and reproducible methodology in global warming research. Professor Will Alexander of the University of Pretoria claims that climate change will not have an adverse effect on South African agriculture and offers statistics that the country's average annual rainfall has actually increased from 497mm to 543mm between 1922 and 2000. Although his opinion is in stark contrast to the grim predictions of some of his peers, he emphasises the need for the South African government to "appoint a high-

level commission of inquiry into global warming and its effects on agriculture and industry" (Alexander, 2005).

Whether you side with professor Alexander or believe that global warming will have an adverse effect on our wine industry, South African vintners will need all their skill to adapt to a new challenge.

5. THE FUTURE

(a) A changing global climate :

Over the last 700 000 years, the Earth's climate has shown a relatively predictable pattern of cooling and warming, operating on cycles of approximately 100 000 years each. Each of these glaciation cycles as they are called are characterised by 90 000 years of cooling, an ice age, and then followed by a warming period called an interglacial which lasts 10 000 – 12 000 years. The last ice age reached its coolest point 18 000 – 20 000 years ago with the Earth currently in a warm interglacial period called the Holocene that commenced about 10 700 years ago. During the current Holocene, there have been about seven major warming- and cooling trends varying between 650 – 3 000 years. The interesting thing is that three of these periods produced warmer temperatures than the present average temperature, a fact that proves global warming not only to be a currently reality, but also part of an unavoidable natural sequence (Carlisle, 1998).

This takes nothing away from the obvious impacts of this phenomenon as described in previous chapters. At present, sea levels are rising as summer temperatures in the northern parts of Antarctica are approaching the melting point of water (0°C) with the annual melting season that has increased by 2-3 weeks in the past two decades. Warmer temperatures are experienced across the globe, coupled with increased occurrences of drought, floods, glacier melting and extreme climate variations (Climate Hotmap, n.d.). These observations are officially backed up by the World Meteorological Organisation (WMO) which says that these record extreme events are all used to calculate monthly and annual averages, which for temperatures, have been increasing over the past century with about 0.6°C as earlier mentioned (Climate Rescue, 2003). Rising carbon dioxide levels are a further manifestasion of global warming and are due to human activity, the culprit that could be the one factor fast-tracking the natural progression of global warming. Climate experts such as George Philander of Princeton University mention that we have been clearing forests, burning coal, oil and gas, and pouring carbon dioxide into the atmosphere faster than plants and oceans can soak them up. He then warns that we have turned into "geological agents, capable of affecting the processes that determine climate" (Earth Renewal, 2005), countering the somewhat

naïve argument that global warming is *only* a natural phenomenon.

Looking ahead, reliable statistics sketch a grim picture. Scientists predict that the northern parts of the Northern hemisphere will warm up more than other parts of the Earth, with conditions globally getting more humid due to more water evaporating from the oceans. Greater humidity might increase rainfall but as water will also evaporate more rapidly from the soil, it will dry out faster between periods of rainfall and consequently increase drought in certain areas (Encarta, 2004).

The Intergovernmental Panel on Climate Change (IPCC) projects an average global temperature increase of 1.4 - 5.8°C from 1990 – 2100 depending on the rate of greenhouse gas emissions (National Oceanic and Atmospheric Administration, n.d.). Even more dramatic figures were released by Oxford University early in 2005 that predict temperature increases of up to 11°C within the next century which is almost double this maximum increase predicted by the IPCC in 2001 (Joubert, *Soothsaying or scaremongering?*, 2005).

Best-case scenario, sea levels could rise by 9 – 88 cm in the 21st century (National Oceanic and Atmospheric Administration, n.d.), but recent research from the Cambridge-based British Antarctic Survey found that a massive Antarctic sheet, whose collapse could raise global sea levels by more than 5 metres, might be starting to disintegrate. Survey director Professor Chris Rapley then warned an international conference in Exeter, called by Prime Minister Tony Blair, that earlier views that the West Antarctic Ice sheet would not collapse before the year 2100 had to be reviewed and that "there is real concern" (McCarthy, *Antarctic threat to sea level*, n.d.).

According to findings of Thomas R. Knutson of NOAA's Geophysical Fluid Dynamics Laboratory (Princeton, New Jersey) and Robert Tuleya of Old Dominion University (Norfolk, Virginia) as published in the 15 September 2004 issue of the *Journal of Climate*, a global average 6% increase in hurricane winds can be expected by the year 2080. This deduction is based on assumptions that atmospheric carbon dioxide levels will increase by 1% per year over the next 80 years. Further to this, global warming research done on 1 000 plant- and animal species by an international team of 19 researchers (published in the 8 January issue of *Nature*), showed that nearly 25% of

these species could be “committed to extinction” by the year 2050 (U.S. Environmental Protection Agency, n.d.).

These scientific conclusions are increasingly embraced by the public sphere, with insurance companies and politicians referring to global warming as a “weapon of mass destruction” (Johansen, n.d.) and a “critical national security issue” (Stipp, n.d.).

Let us now look at how the abovementioned climatic predictions will impact on the global wine scene of the near future.

(b) A new world wine order :

Although vines can grow nearly anywhere, a temperate climate (enough sunshine, no frost and a good overall temperature), rainfall of about 500 millimetres per year, and soils with good water retention are attributes of the ideal terroir (Walterfang, n.d.). A change in global climate however means a change to terroir which in change means a change to wine style and wine regionalism. Traditionally cooler areas or currently unexploited areas will benefit from global warming as phenolic ripeness can at long last be achieved, whereas already warm areas will either produce even fuller more alcoholic wines, or struggle to produce quality dry wines at all.

As seen in the previous chapters, global warming will impact not only on the quality wine producing areas of the world, but anywhere grapes are grown, whether it is Napa, Long Island, Virginia, Chianti and Argentina… (Walker, 2004) and even the current export markets of the wine producing countries. Some wine writers reckon global warming can turn the global wine industry upside down: as temperatures are warming up in the United Kingdom for instance, the lucrative UK market could disappear due to an increase in sales of locally produced British wines. Germany might abandon the Riesling grape and plant more profitable Shiraz or Chardonnay, and the cooler wine regions of France could produce consistently good vintages year after year (Hartley, n.d.).

The point is that the dynamics of the wine world will change whether good or bad. Dr. Gregory Jones as per the previous chapters states that the ideal environments for

growing vines will shift northward and then explicitly adds that "the ideal climatic conditions for producing what we call Chianti will be in Germany, just as those for Champagne or Bordeaux wines will be found in southern England" (Berry Bros. & Rudd, 2004). He and his team did further (quite subjective) climatic tests on the world's top 27 leading wine regions to prove that an average global temperature increase of 2°C up until 2049 are aligned to higher vintage ratings, but that a further 2°C rise may stress wine growth in the current established wine producing areas. Certain regions might have to change grape varieties which will of course impact on regional- and cultural identity. Warmer regions such as Chianti would face pest problems related to earlier harvests as the weather warms up, with cooler regions on the other side of the spectrum that would benefit from more consistent ripening (Catchpole, 2003). Although other factors (including better winemaking techniques) are also attributed for increasing wine quality, Dr. Jones's statistics show that 10-62% of vintage quality can be explained by growing season variability, with the greatest effect shown in cool climatic regions such as the Mosel (Goode, n.d.). The predicted increase in global temperature also bodes well for the Rhine Valley, and vineyards are showing up again in southern England which is quite remarkable as the last time the British had planted vineyards was in the 1600's and early 1700's during a warm spell preceding the "Little Ice age" cooling period of the 19th century. Thriving vineyards in British Columbia on Canada's west coast is another sign of the benefit global warming can have (Paulson, n.d.). However, already warm regions such as Chianti, Rioja and Australia are being hurt by this further 2°C rise in temperature (Lynne, 2003).

The relatively good news for South Africa is that the projected changes for the Northern Hemisphere seem to be greater than the Southern Hemisphere. Although the growing-season temperatures between 2000 and 2049 will increase on average with 2°C across the world's leading wine regions, the trends range from a 0.18°C – 0.58°C increase per decade, with the smallest amount of warming predicted for South Africa (0.88°C) and the greatest warming for Portugal (2.85°C) (Goode, n.d.). The climatic parameters of each wine region differ and subsequently also its threshold whereby continued warming would push a region outside the ability to ripen its established varieties.

According to Dr. Jones in a related 2004 Geotimes article (Jones, n.d.), global warming in the next 50 years will impact specifically on changes in grapevine phenolic timing,

disruption of balanced composition in grapes and wine, alterations in varieties grown and regional wine styles, and spatial changes in viable grape-growing regions. The consequences stretch further when considering that many Old World producers have stringent standards by which varieties, yields and winemaking techniques are governed to ensure quality and regional identity. The 2003 heat wave in Europe for instance brought very early harvests that without irrigation (largely outlawed in Europe) resulted in lower yields and a-typical flavours. New World wine producers have fewer governmental constraints and vintners are allowed the freedom to viti- and viniculturally adapt to the changing climate.

A country that springs to mind when a new world wine order is discussed, is England. During the past decade, warm wine growing conditions last seen in the 13th century have resulted in reasonable to good quality wines. In the *London Times* of 25 April 2004, John Walples and John Elliot reported that a venture between winemakers from Champagne on the one side and Kent and Sussex on the other will result in the first vinicultural collaboration between France and England. This news was followed by a BBC report on 2 June 2004 that a blind tasting conducted by *Which?* Magazine in London saw several English sparkling wines (Nyetimber, Ridgeview and Chapel Down) score higher than a Premier Cru champagne. The same Chapel Down was visited by madame Carol Duval-Leroy of Champagne Duval-Leroy in September 2004 with the aim of buying English property to plant vines, which is not surprising taking into account that the Sussex and Kent coasts are only 80 miles north of Champagne and have similar chalky sub-soils and south-facing slopes (Honigsbaum, n.d.).

Even if English non-sparkling wines are still to prove their quality in the long term, the recent series of warm dry summers and the predictions going forward are enough reason for optimism. Frazer Thompson, managing director of the English Wine Group producing Chapel Down, confirms that 2003 was a sensational vintage following an increase in sunshine and warmth in the preceding five years. They have not had frost for 15 years and the more moderate temperatures are resulting in wines with a favourable balance of sugar and acidity. Thompson however qualifies that not all English producers are hoping for global warming nor want to become part of a major wine-growing region: “the world doesn’t need another California Chardonnay or another Australian red… what

the world needs are more distinctive flavours, and you can only get those from marginal areas". Site selection and a terroir based winemaking approach will stay the norm.

Richard Selley, a geologist at the Imperial College London states that the conditions for winegrowing in England have not been this good since the Medieval Warm Period more than 700 years ago. Today there are approximately 400 wineries in England and Wales with this number expected to rise rapidly. Further good news is that in addition to higher temperatures, the geology of southern England is suited to wine growing. Selley says that the geology of Britain is comparable to the European continent with the biggest interest in the sporadic chalk-rich limestone soils similar to those in Champagne (Jones, n.d.). High acidity and low potential alcohol levels remain problematic however with a fair bit of chaptalisation done prior to fermentation. Most sparkling wines are bone dry, with less producers adding sugar to the final wine to fatten up the palate.

Most probably the noble varieties such as Cabernet Sauvignon, Shiraz and Sauvignon blanc will never bring its best qualities to Britain: currently most red wines are still light in colour with cherry flavours, and the whites are somewhat acidic and watery… but quality is improving across the spectrum. Curious Grape, Three Choirs, Davenport and Denbies are UK producers making quality natural wines, with the said Nyetimber and Ridgeview turning out brilliant bottle-fermented sparkling wines that are already rivalling France (Wine Anorak, *English wine: an introduction*, n.d.).

We are already aware of the wine virtues of Canada that is very confidently stepping onto the major wine scene, and here we do not only refer to the odd icewine. In Western Canada, average winter temperatures have increased by as much as 4–7°F (equivalent to approximately 2.2-3.9 °C) during the past half century, and are predicted to rise further over the next 100 years (Natural Resources Defense Council, n.d.). The country is still by default a wine consuming country but small growing areas (notably in British Columbia) are producing good wines from the noble French varieties (Dr. Vino, n.d.).

Even Danish wines seem a realistic commercial possibility: Dons is a small village on Denmark's Jutland and is home to the country's first commercial wine made in 2001. The Danes were initially forbidden by the European Union from producing wine due to the big European wine lake, but these restrictions were lifted in 2001 and Sven

Moesgaard could release the first wine from his Skaersoegaard vineyard, one of the most northern in the world. Global warming is credited for making Danish wines possible with the extra long days in summer when the sun sets only at 11 p.m. adding the sunshine and heat the vines need to fully ripen their grapes. Moesgaard is producing a very good sparkling wine and his red wine is favourably compared to Beaujolais (Brabant, 2002).

Far-fetched as it may seem, German Chianti, Canadian Cabernets or fortified wines from the Barossa may be the preferred choice of wine lovers in the near future…

(c) The Kyoto Protocol :

The impacts of global warming on the world's wine industries were discussed in earlier chapters, with higher temperatures, extreme weather conditions, rising sea-levels and increasing greenhouse gas emissions the most important manifestations of this phenomenon. Human activity has been found to be the biggest culprit in this regard as greenhouse gas emissions of carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, hydrofluorocarbons and perfluorocarbons are seriously accelerating the rate of warming (Malan, n.d.). Following much debate around the seriousness of global warming and high-level steps to curb its effects, a global treaty called the Kyoto Protocol came into effect on Wednesday 16 February 2005.

The Kyoto Protocol grew out of several meetings of world leaders around environmental issues: an Earth summit was held in 1992 with its aim to limit the emissions of greenhouse gases, but its goals were not met. In 1997, government leaders met again in Kyoto in order to set official legal parameters to curb emissions. Very broadly, industrialised countries are expected to cut their emissions by an average of 5.2% by the year 2012. Each country has its own targets depending on their level of industrialisation, with developing countries exempted from targeted cuts. Japan's emissions of greenhouse gases for example would need to be cut by 6% below 1990 levels and the broader European Union would have to reduce its emissions by 8% (Contreras, 2005). Russia and France have no restrictions, but Germany needs to cut back by a massive 21%, Britain by 12.5% and Italy by 6.5%. South Africa, India and China are all part of the

portfolio of developing countries that are only urged to keep emissions on reasonable levels without any official parameters being set. The United States and Australia are the two big players deciding not to ratify the Kyoto Protocol (the USA would have had to reduce its emissions by 7% had it participated), which is also the reason why the Protocol took so long to be ratified: according to pre-set criteria, the treaty would have official standing only if at least 55 countries representing 55% of total greenhouse emission figures, ratify the agreement. After the United States (contributing 36% of emissions in 1990) withdrew from treaty discussions in 2001, Russia (contributing 17.4% of 1990 levels) had to sign the treaty to reach the 55% target. The latter only approved in November 2004 and the Protocol could then be "activated" early in 2005 (Malan, n.d.).

More than 140 countries (including South Africa) have up until now ratified the Protocol (United Nations Framework Convention on Climate Change, n.d.), but the treaty's restrictions only apply to the developed portfolio of 35 countries (the developing countries argued that restrictions would hinder their quest to industrialise up to the level of their First World counterparts, hence their free hand). This means a big discrepancy considering that China (the world's second largest source of greenhouse gases and predicted to surpass the United States by 2030) is seen as a developing country and allowed to industrialise without restrictions. Amongst other reasons, the industrial handbrake put on developed countries as opposed to the developing ones, led the United States to withdraw from discussions. According to president Bush's administration, the Kyoto Protocol "exempts 80 percent of the world from compliance, and would cause serious harm to the U.S. economy" (Contreras, 2005).

The countries that did ratify the Kyoto Protocol are encouraged to tax their industries that emit high levels of greenhouse gases, to legislatively reduce fuel consumption, and to educate households on how to curb pollution and greenhouse gas emissions (Malan, n.d.). Some environmentalists however feel that the Protocol's goals are too modest to make a significant difference in curbing greenhouse gas emissions, with its impact weakened further by the United States not being part of this global accord. And it might be too late anyway as the treaty governs only future emissions and will have no effect on past emissions: as there is a lag effect of 50-100 years (which is how long carbon dioxide remains in the atmosphere after being emitted), the Earth will continue warming for decades even if humanity stopped burning fossil fuels immediately (Hertsgaard, 2005).

Best-case scenario though, should the ratifying nations each reach their targets, global greenhouse gas emissions could possibly be reduced by only 2-3% by 2012. The Protocol is further seen as unprecedented and complicated (Malan, n.d.), with the fact that a country can sell its "emissions permits" to other countries if it under-emits out of own accord, one example of this complexity (Economist.com, 2004).

All in all, the treaty is a moral statement of intent rather than a practical enforceable mechanism that needs the buy-in of the whole world to have any effect. Russell Jones, the research manager of the pro-business lobbying group the American Petroleum Institute sums it up best when he says that "if climate is a serious problem, it cannot be addressed without the developing countries because that is where the growth in emissions are going to be" (Thomas, 2005). This sentiment is echoed even by the ratifying nations: Pieter Van Geel, president of EU environmental ministers and secretary of state for the Netherlands, said that apart from the EU that stands fully behind the Kyoto Protocol, developing nations (the likes of China and India in particular) will clearly need to be part of a global effort to curb global warming as they will soon be emitting as much greenhouse gases as the First world states (ClimateArk.org, 2004).

Looking at the road ahead until 2012, Spain, Portugal, Ireland, Greece, New Zealand and Canada (all of whom have signed the Protocol) are currently far above their emission targets. Spain and Portugal for instance are 40.5% above their 1990 levels and it will be very difficult for them to meet their targets. The countries that do not meet their individual goals by 2012, would need to provide nothing more than updates on their progress and commit to more aggressive reductions in a second period commencing in 2013 (Contreras, 2005).

A follow-up conference to re-establish the values of the Kyoto Protocol was held in Montreal in December 2005. The United States agreed to engage in "dialogue" to limit the effects of global warming, but confirmed their stance not to ratify the Protocol. The president of the Montreal Conference, me. Stephanie Dion, admitted that she would prefer the United States ratifying the Protocol, but also re-affirmed the commitment of 157 member countries to limit carbon dioxide emissions towards 2012 (Die Burger, 2005). The Bush administration has been criticised by the media for only giving "lip service" to the threat of global warming. Canadian Prime Minister Paul Martin reacted to the United

States' resistance by claiming that "there is such a thing as a global conscience" (Tennessean.com, 2005), and former United States president Bill Clinton prominently labelled the refusal of president Bush to ratify the Kyoto Protocol as "flat wrong". He summarised the threat of global warming by saying that "we are uncertain about how deep and the time of arrival of the consequences, but we are quite clear that they will not be good". In the interim, the United States and Australia are conspicuous in their status as the only industrial nations to refuse to consider mandatory carbon dioxide reductions (Houston Chronicle, 2005).

Are there better alternatives than the ill-fated Kyoto Protocol and what is actively been done to at least reduce the scepticism surrounding this treaty? Rajendra Pachauri, chairman of the IPCC (the United Nations' Intergovernmental Panel on Climate Change) has a team working on a 2007 U.N. climate report that will incorporate research of more than 2 000 scientists to reduce the uncertainties regarding global warming and the Kyoto Protocol's role (Doyle, 2004). Some researchers, including the UK government's chief scientist Sir David King, are proposing a more immediate pro-active approach, such as governments giving tax concessions to oil companies to pump carbon dioxide from coal-fired power stations into nearly exhausted oil and gas wells in the North Sea (Brown, *CO2 gases may be buried at sea*, n.d.). Others propose building more carbon dioxide-free nuclear institutions to look at fusion research, or pursue solar energy (Helmer, 2004).

The best option might be to enforce financial penalties against companies that overstep environmental parameters. Further to recent claims by lung cancer victims against tobacco companies, some experts believe that successful claims against the big greenhouse gas emitters might be a realistic prospect. Although it will be very difficult to trace the source of a heat wave back to the greenhouse emissions of a certain company, you can calculate by how much the risk of that event is increased by rising concentrations of greenhouse gases in the atmosphere. Recent examples of global warming accountability include (a) a June 2005 federal case brought by communities in the Niger Delta against the Nigerian government and several petroleum companies to counter excessive pollution by the burning of natural gas; and (b) a July 2005 federal case brought by the Wildlife Preservation Society of Queensland-Proserpine against the Australian government for contravening environmental laws due to excessive burning of

coal and subsequent greenhouse gas emissions (Joubert, *Pay up for flooding my vineyard!*, 2005).

Looking at the near future, a positive sign is the first world conference on "Global warming and wine" that is scheduled to take place in Barcelona on 24-25 May 2006. This conference, organised by the Wine Academy of Spain, will feature lectures, seminars and discussion forums dedicated to the impact of global warming on the wine industry. Experts such as Dr. David Smart and Dr. M.J. Truco from the University of California Davis, Dr. Richard Smart from Smart Viticulture, Dr. Greg Jones from the University of Southern Oregon, Adam Lechmere from Decanter, as well as several other authorities, will lead this conference and analyse global warming's future repercussions on the wine industry (LocalWineEvents.com, 2005).

(d) Conclusion :

Global warming is a reality hard to stop and one that will have a severe impact on the global wine industry. Whichever route world leaders take in order to prevent global warming, the world's wine producers must take this scenario as a given and adapt their winegrowing and winemaking techniques accordingly. To count on the Kyoto Protocol's provisions to make any climatic difference within the next few decades will be a waste of time and thought. Despite a *bona fide* attempt at executing a global conscience, the Protocol is currently nothing more than a moral code of conduct.

6. GENERAL CONCLUSION

Despite minor academic dissent, overwhelming scientific evidence confirms global warming as a current reality. The effects of global warming include an increase in atmospheric levels of carbon dioxide and temperature. Rising sea levels and unpredictable weather patterns are further proof of global warming. As climate is one of the key criteria of terroir, global warming's impact on climate will influence wine style and quality.

Winemakers from the leading winegrowing regions of Europe, North America, South America, Australasia and South Africa will need to adapt to these new climatic challenges. In most regions, wine styles will change for the better or worse and winemakers might need to manipulate and innovate to ensure consistency. We will see new wine regions coming to the fore as cooler areas become accessible to quality winemaking. Looking further ahead, the global wine community needs high-level political and economical support to curb the effects of global warming. The Kyoto Protocol is an idealistic set of moral obligations with limited chance of enforcement.

Whatever our climatic future, standard winegrowing principles will remain unchanged and terroir will remain the building block for good wine. There will always be cool and warm winegrowing regions. However, consumers might get their preferred wines from new areas or have to get used to fuller, more alcoholic wines from established areas. Wine has always been a flexible and enigmatic phenomenon, and the impact of global warming will bring exciting new challenges with regard to both terroir and style.

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