Imperial College London

TRENDS AND MAPPING OF CLIMATE CHANGE IMPACT ON WINTER CHILL IN WESTERN CAPE, SOUTH AFRICA

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1. FRUITS PRODUCTION DEPENDS ON WINTER CHILL ACCUMULATION

This study provides an insight in the risks induced by climate change on fruits production in the Western Cape, South Africa. Trees need to accumulate a certain amount of chill during winter to break dormancy (winter chill) and this quantity can be calculated using different models (PCU, dynamic model). Looking at the evolution of winter chill with time is an accurate way to estimate climate change impact on fruit trees. The mapping of winter chill and its evolution undertaken in this work allows a better understanding of chill accumulation trends and geographical repartition.

2. DATA AND SPATIAL DOWNSCALING

Maps were obtained using temperatures *spatially downscaled* from the temperature dataset using the *elevation dataset*. The following datasets have been used:

- *Global Hourly 0.5-degree Land Surface Air Temperature Datasets* by CISL–RDA.
- *SRTM 90m Digital Elevation Dataset* by CGIAR-CSI

Linear regressions have shown an important ***temporal variability of the environmental lapse rate*** (Figure 1), explained by cyclic conditions of solar radiation. Largest gradients of temperature with elevation occur during winter nights. The maps were obtained ***calculating hourly lapse rates*** as the result of the linear regression between hourly temperature and average elevation.

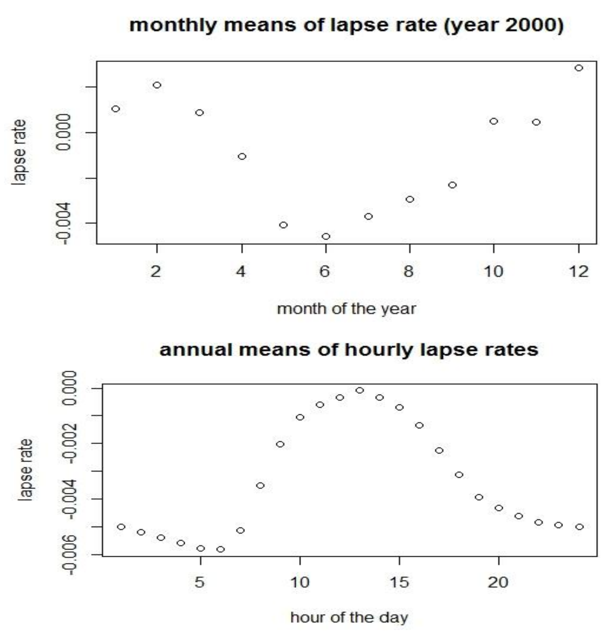

Figure 1: Temporal variations of lapse rate

3. HIGH RESOLUTION CHILL UNITS MAPS (LEVEL AND EVOLUTION)

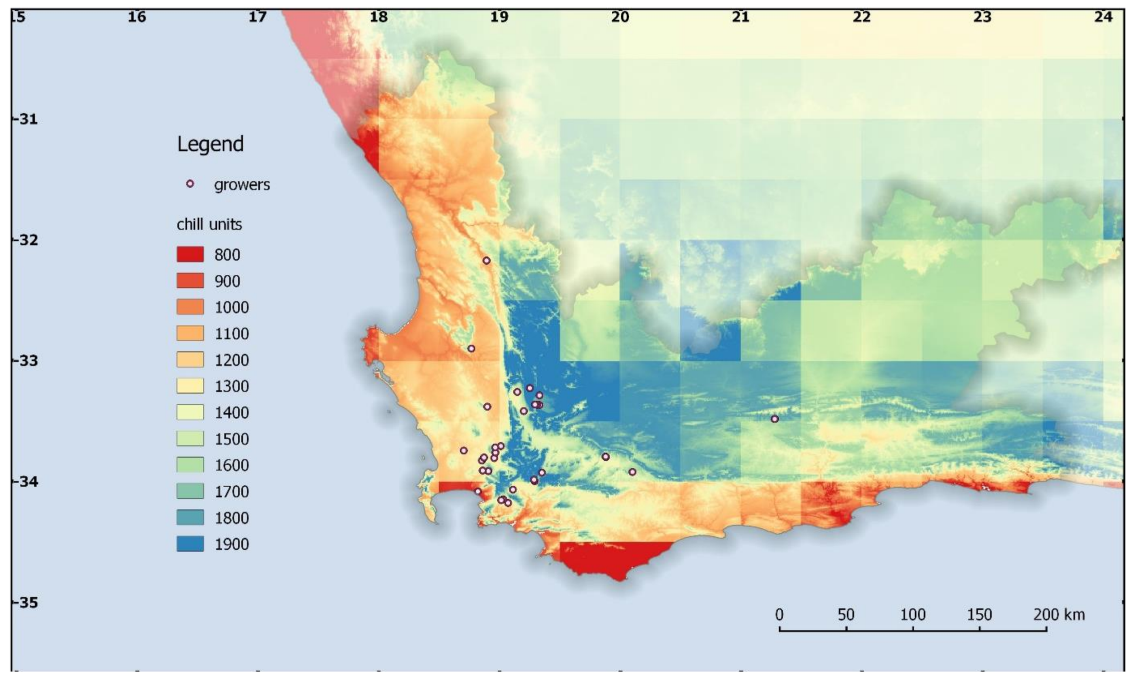

Figure 2: Chill units (PCU) high resolution map of the Western Cape (period: average 1948-2009)

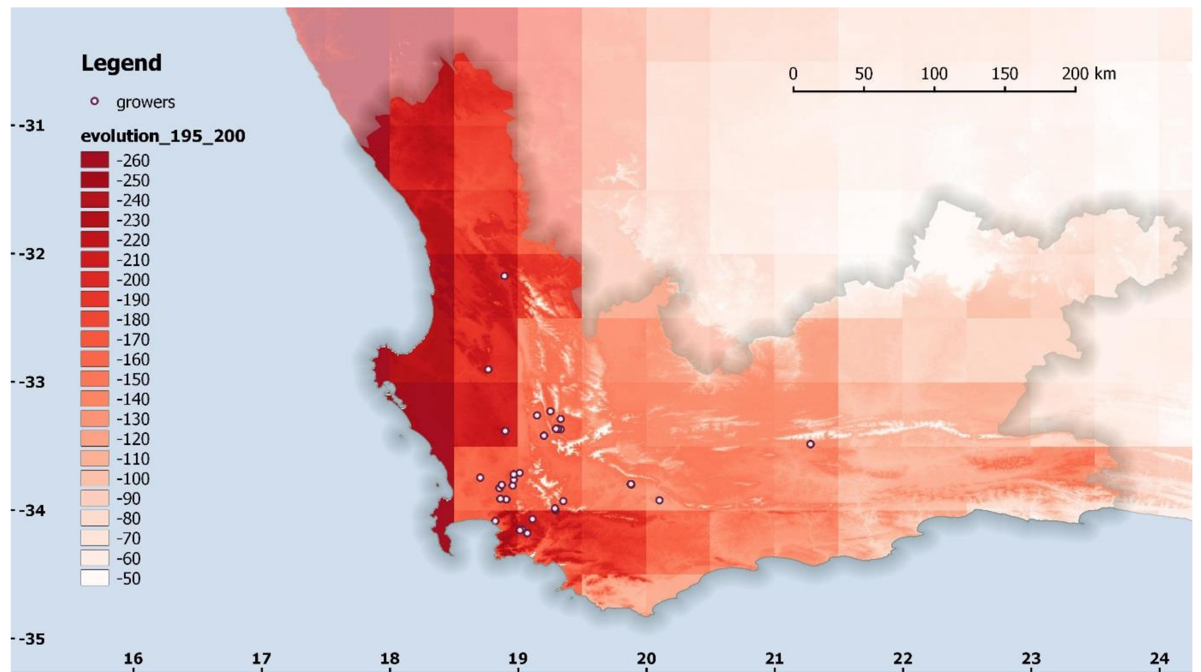

Figure 3: Decrease in chill units between the 1950's and the 2000's

Because climate in the Western Cape is warm, chill accumulation occurs at night when temperature gradient with altitude is the largest; this is why the mountains appear clearly.

	Alt.	CU	ΔCU
Mean	609 m	1432	-170
Sd	302 m	186	56

Table 1: Altitude, chill units at growers' locations

Growers are located in semi-mountainous areas, in regions where winter chill is regional average. In mountainous regions, winter chill is higher but other characteristics may provide from growing fruits : higher risk of frost, more complex topology, less accessible… (Table 1)

Despite large variability, a sensible decrease in winter chill can be noticed over the last period: 1948-2009, especially from the 1980's (Figure 4). At growers' locations (Figure 5), the same trend is visible and sensibly correlated with mean winter temperature, helpful for basic predictions

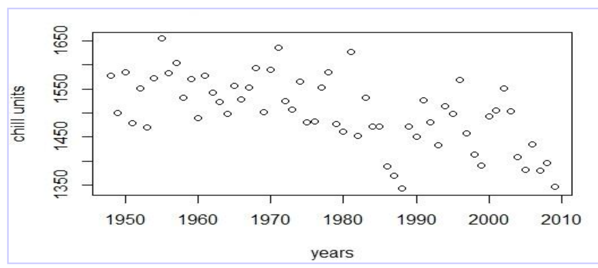

Figure 4: Evolution of CU over the period 1948-2009

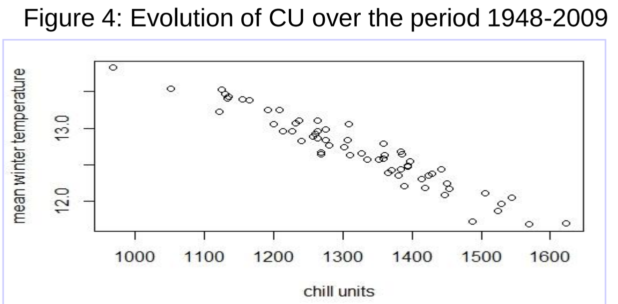

Figure 5: Correlation with mean winter temperature

- ➢ Chill units (PCU) variability among growers is low → Winter chill is a determining factor for location.
- ➢ Their evolution (1948-2009) is close to the standard deviation of chill units among growers → a decrease of the same intensity in future would lead to a great shift in orchards climatic conditions

ACKNOWLEDGEMENTS

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4. ACCURACY OF SATELLITE DATA

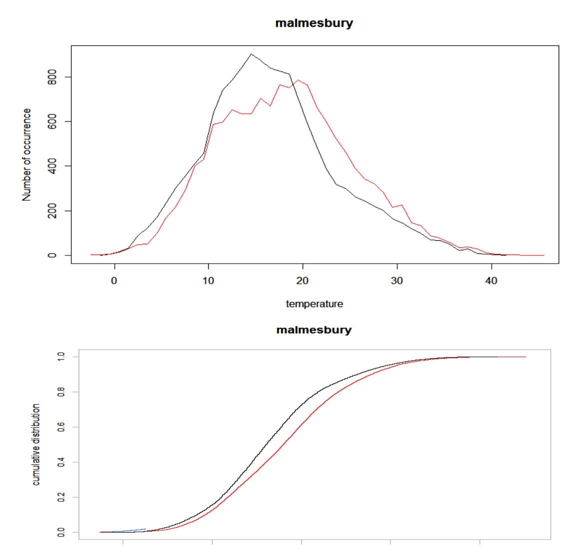

Figure 6: comparison of satellite (red) and stations (black) data (MALMESBURY)

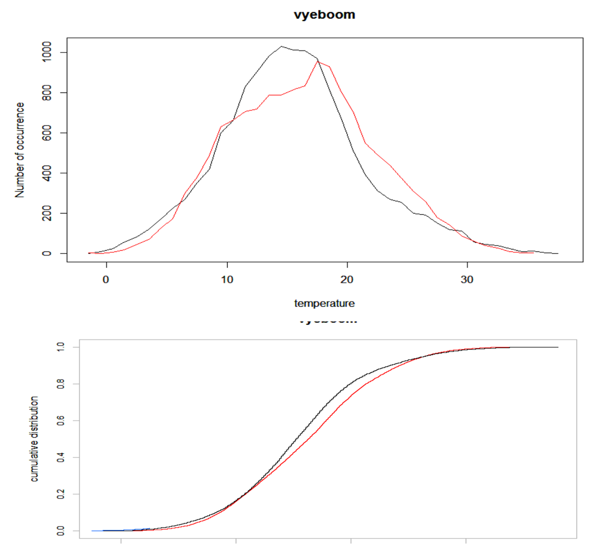

Figure 6: comparison of satellite (red) and stations (black) data (VYEBOOM)

Four stations datasets were used to evaluate satellite data accuracy: ***Malmesbury, Robertson, Vyeboom and Worcester***. Cumulative distribution and repartition curves were studied (Figure 6 and 7). The overall fit is considered as satisfying (NSE numbers ranging around 0,80). Comparison of percentiles showed imprecision in recording coldest temperatures.

To conclude: *Satellite data is efficient in large scale studies such as mapping winter chill but can be inaccurate at very local scale.*

5. GLOBAL ESTIMATIONS

These maps were obtained using low resolution satellite data and the dynamic model which performs better for global comparisons.

In Figure 8 appear in green the most suitable areas for growing fruits (mostly areas with temperate climate). No statistically significant decreasing trend in winter chill were observed at global scale.

But Figure 9 shows an important shift in chill units repartition. Cold regions (Northern Europe, Eastern Europe, Russia) become more suitable for fruits production whereas warmer areas, especially Southern Australia, Northern Africa and Southern Africa suffer from a dramatic decrease in chill units.

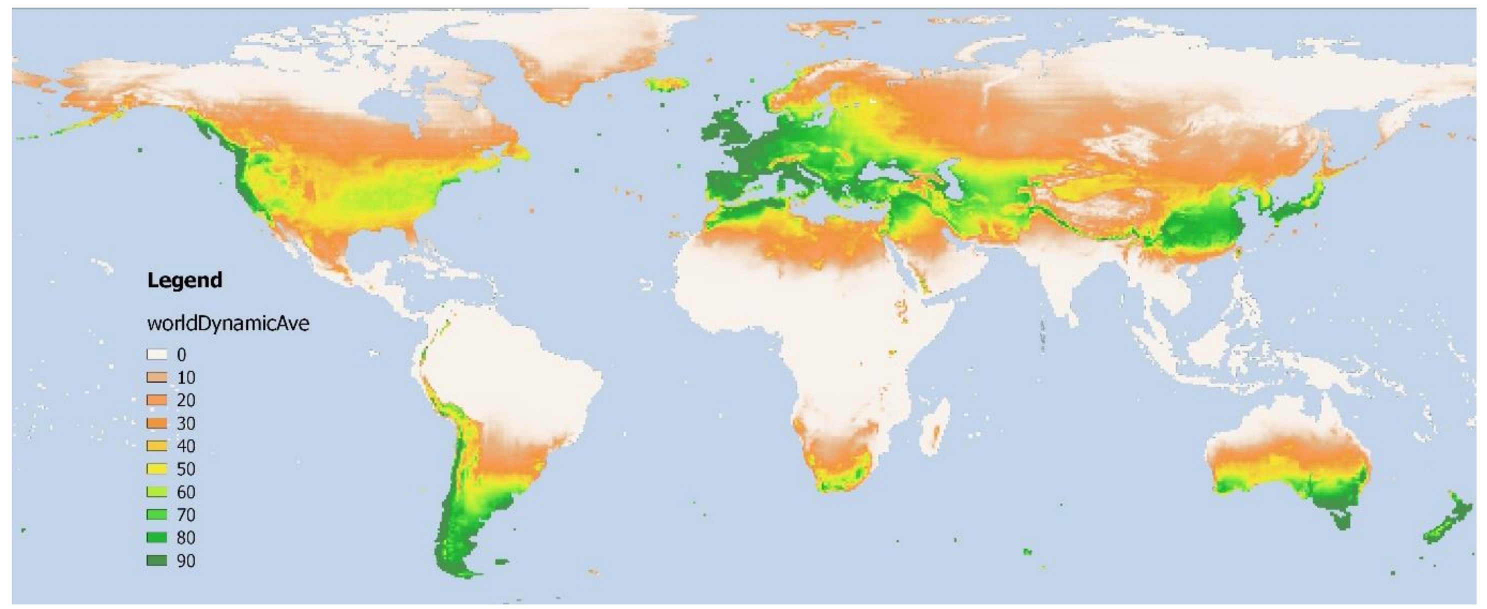

Figure 8: Global map of chill portions (dynamic model) averaged over the period 1948-2009

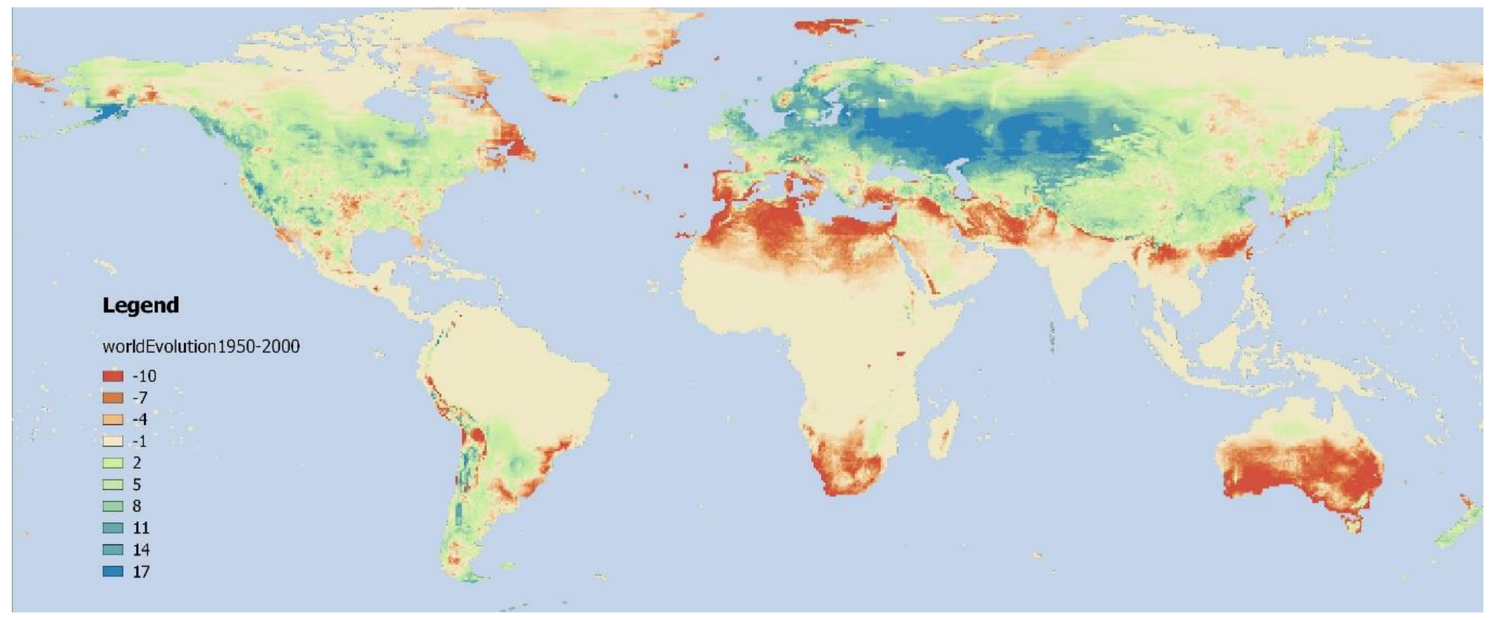

Figure 9: Global map of chill portions evolution between the 1950's and the 2000's

6. CONCLUSION

- Climate predictions for South Africa and correlation between winter chill and mean annual temperature tend to show that ***winter chill accumulation is likely to decrease of more than 150 chill units at growers' locations by 2050*** and these locations could cease to be suitable for horticulture.
- Sustainable strategies may include: shifting orchards to new production areas [1], selecting new cultivars, developing orchard management practises. Their design may require the installation of new weather stations as satellite precision is limited in mountainous regions and for coldest temperatures.
- As past studies have already highlighted decreasing trends in winter chill [2], the main interest of this work relies on their mapping, the reflexion at growers' locations and the statistical work on satellite data.

REFERENCES

1. LUEDELING, E., GIRVETZ, E.H., SEMENOV, M.A. and BROWN, P.H., 2011. Climate change affects winter chill for temperate fruit and nut trees. *PLoS One*, **6**(5), pp. e20155.

2. MIDGLEY, S. and LÖTZE, E., 2008. Climate change in the western cape of South Africa: trends, projections and implications for chill unit accumulation, *IX International Symposium on Integrating Canopy, Rootstock and Environmental Physiology in Orchard Systems 903* 2008, pp. 1127-1134.