PRESENT AND FUTURE CLIMATE TRENDS

It is an accepted fact that both natural and human factors have and are still changing the Earth's climate. Since the industrial era began, humans have had an increasing effect on climate, particularly by adding billions of tons of heat-trapping greenhouse gases to the atmosphere which has led to most of the observed warming since the mid-20th century[1].

The evidence is clear: rising global temperatures have accompanied changes in weather and climate[2]. Many places have seen changes in rainfall patterns, resulting in more floods, droughts, or intense rain, as well as more frequent and severe heat waves. The planet's oceans and glaciers have also experienced warming; oceans are becoming acidic, ice caps are melting, and sea level is rising. As these and other changes become more pronounced in the coming decades, they will likely present challenges to our society and our environment. Locally, rising air and sea temperatures have been observed over the long term.

This reality is here to stay with us, for greenhouse gases continue to remain elevated and affecting our atmosphere for hundreds of years. Even if we manage to stabilise their concentrations by maintaining a steady composition of today's atmosphere (which would still require a dramatic reduction in current greenhouse gas emissions), surface air temperatures would *still continue to warm*[3].

Less well known is how this change will unfold in the *far-off distant future*; but for the *near future* (meaning up until 2100), scientists are using complex computer simulation models of the climate system to better understand and project climate changes[4]. However, such a projection is at the mercy of how good and sensitive are these climate models, as well as to assumed near-future level of emission of greenhouse gases and aerosols[5] – something which is impossible to know for the distant future. These climate 'states' take the form of emission scenarios. Due to the highly complex and dynamic nature of climate, the assumed states contain a significant level of uncertainty.

These models are coming out with a number of future projections. The basic story is a warming Earth that will significantly affect the global water cycle resulting in more frequent and heavier rainfalls. These expected increases will most likely occur in temperate regions, while in the sub-tropics (such as our Mediterranean region) a decrease in rainfall is being projected. In Europe, the chances of drought and more extreme heat is expected to increase, further aggravating drought conditions, especially in southern parts of Europe.

Future projections of our local climate require an insight into both *global* and *regional* climate expectations. Compared to global predictions, regional climate contain even more uncertainties, since small spatial and partly unknown shifts in climate patterns can lead to considerable differences in the final projections[6]. Consistent future projections for the sub-tropical Mediterranean region climate include (a) increased drought and evaporation, (b) a rising sea level, and (c) greater chance of floods and drought in the summer months. At the local small scale, the modeling of the near future climate is a formidable challenge. The resulting projections are limited by a higher margin of uncertainty,

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[1] According to NASA, the global average surface temperature in 2011 was the ninth warmest since 1880. This recent finding continues a trend in which 9 of the 10 warmest years in the modern meteorological record have occurred since the year 2000. Earth's average temperature is now 0.51°C warmer than the mid-20th century.

[2] Increased concentrations are expected to increase Earth's average temperature, influence the patterns and amounts of precipitation, reduce ice and snow cover, as well as permafrost, raise sea level, and increase the acidity of the oceans.

[3] This is because the oceans, which store heat, take many decades to fully respond to higher greenhouse gas concentrations. The ocean's response to higher greenhouse gas concentrations and higher temperatures will in turn continue to affect our climate over the next several decades to hundreds of years.

[4] Climate change refers to any significant change in the measures of climate lasting for an extended period of time.

[5] Multiple emission scenarios have therefore been used based on various assumptions about our future economic, social, technological, and environmental conditions.

[6] Therefore future improvements in regional and local climate projections become extremely important.

rendering impact assessments somewhat subjective. It is here where careful interpretation of long-term, direct observations of key climatic indicators[7] defining the likely shift of our local climate becomes indispensable.

Salient points:

Regional climate trends[8]	***Local climate trends***[9]
The average temperature for the European land area for the last decade (2001-2011) is 1.3°C above the pre-industrial level, which makes it the warmest decade on record. Heat waves have increased in frequency and length[10]*.* *Since the mid-20th century, annual precipitation has been generally increasing across most of northern Europe, most notably in winter, but decreasing in parts of southern Europe. In Western Europe intense precipitation events have significantly contributed to the increase*[11]*.* *Storm frequency shows a general increasing trend from the 1960s to 1990s, followed by a decrease to the present*[12]*.* *Ocean acidification in recent decades is occurring a hundred times faster than during past natural events over the last 55 million years*[13]*.* *Sea surface temperature in European seas is increasing more rapidly than in the global oceans. The rate of increase in sea surface temperature in all European seas during the past 25 years is the largest ever measured in any previous 25-year period.* *Many marine organisms in European seas appear earlier in their seasonal cycles than in the past. In recent decades, some plankton species have advanced their seasonal cycle by 4 to 6 weeks*[14]*.*	*Between 1923 and 2005, the rate of temperature increase was 0.71 °C, which is expected to increase in the next hundred years.* *The anomaly exhibited by the local annual mean air temperature from the climate norm of 1961-1990 shows a rise after 1981 where the highest anomaly of +1.2 °C was reached in 2001, followed by a reduction to +0.69 °C in 2010.* *The rate of temperature change between 1951 and 2010 was 1.1 °C*[22]*. This local rate of change is greater than that global rate of change.* *The overall rate of warming is by far strongest in the summer period at around 1.5°C/100years, which is around three times higher than that in winter and twice that in spring.* *Local temperature data show a shift in both the mean and variance for the period 1951-2010, implying an increased hot weather and previous record high temperatures being exceeded far more often.* *Since 1951, 5 out of the 10 warmest years in terms of mean air temperature occurred during the past 10 years (2001, 2007, 2008, 2000 and 2003 in decreasing order of magnitude).* *The strongest anomalous warming has occurred during the past 30 years, particularly during the months of June, August and October. This study shows differences in the climate trends, especially pronounced between the two 30-year periods of 1951–1980 and 1981–2010.*

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[7] Climate changes indicators include greenhouse gases concentrations, weather and climate, oceans, society and ecosystems. These provide multiple, independent lines of evidence that climate change is already happening.
[8] Taken from the most recent source: Climate change, impacts and vulnerability in Europe 2012 - An indicator-based report. EEA report – No 12/2012.
[9] Taken from the most recent sources: The Second National Communication of Malta to the United Nations Framework Convention on Climate Change, 2010, MEPA; The Climate of Malta: statistics, trends and analysis 1951-2010; NSO, 2011. Galdies C (2012). Temperature trends in Malta (central Mediterranean) from 1951 to 2010. Meteorology and Atmospheric Physics, Springer-Verlag 2012 10.1007/s00703-012-0187-7.
[10] Land surface temperature in Europe is projected to increase between 2.5 °C and 4.0 °C for the period 2071–2100.
[11] Most climate model projections show continued precipitation increases in northern Europe (most notably during winter) and decreases in southern Europe (most notably during summer). The number of days with high precipitation is projected to increase.
[12] Available climate change projections show no clear consensus in either the direction of movement or the intensity of storm activity.
[13] Average surface-water pH is projected to decline further to 7.7 or 7.8 by the year 2100, depending on future CO_2 emissions. This decline represents a 100 to 150 % increase in acidity relative to present conditions.
[14] Projections of the phenological responses of individual species are not available, but phenological changes are expected to continue with projected further climate change.

A major northward expansion of warmer-water plankton in the north-east Atlantic plankton has taken place. Sub-tropical species are occurring with increasing frequency in European waters and sub-Arctic species are receding northwards.

Sea level of some European seas projected to rise more than the global average[15]*.*

Several European plant species have shifted their distribution northward and uphill. Mountain ecosystems in many parts of Europe are changing as plant species expand uphill[16]*.*

There is a clear poleward trend of butterfly distributions from 1990 to 2007 in Europe. Migration of many species is lagging behind the changes in climate, suggesting that they are unable to keep pace with the speed of climate change[17]*.*

About 130 million ha of land in the EU is affected by soil erosion by water[18]*. The thermal growing season of a number of agricultural crops in Europe has lengthened by 11.4 days on average from 1992 to 2008*[19]*.*

The impact of fire events is particularly strong on already degraded ecosystems in southern Europe[20]*.*

Climate change is the main factor behind the observed northward and upward move of the tick species Ixodes ricinus in parts of Europe[21]*.*

About one quarter of the European coastline for which data is available is currently eroding, due partly to increasing human activities in the coastal zone.

The local warming trend is in the same category of nearby mean air temperature trends observed in the Island of Sicily (Catania, Italy), Perpignan (France) and Dar el-Beida (Algeria).

No statistically significant anomaly in the annual and daily total rainfall anomaly for the period 1951-2010 has been detected[23]*.*

Analysis of local atmospheric pressure shows an increasingly positive trend by 0.6 hPa since 1951 as registered at Luqa Airport indicating the progression of a weather that is calmer and fairer.

The incidence of days with gale-force winds is decreasing, reflecting a general decrease in the occurrence of stormy weather.

Over Luqa Airport a negative tendency in cloud cover has been detected for the period 1951-2010, although it is not statistically significant.

On average, local sea level measurements taken between the period 2002-2006 show an average rise of 0.45 ± 0.15 cm per year.

A decrease in wind gusts of the order of 50% in 50 years has been observed locally[24]*.*

Sea temperature monitored at Delimara shows a steady increase of around to +0.05°C/year since the late 70s, compared to a global average increase of +0.01°C/year[25]*.*

A downward, but not statistically significant trend in the mean annual cloud cover has been observed.

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[15] Projections of global mean sea-level rise in the 21st century range between 20 cm and about 2 m by the end of the century. Modelling uncertainty contributes at least as much to the overall uncertainty as uncertainty about future greenhouse gas emission scenarios.

[16] By the late 21st century, European plant species are projected to shift several hundred kilometres to the north, forests are likely to contract in the south and expand in the north, and about half of the mountain plant species may face extinction. The rate of climate change is expected to exceed the ability of many plant species to migrate, especially due to landscape fragmentation.

[17] Europe's breeding birds are projected to shift nearly 550 km northeast by the end of the 21st century under a scenario of 3 °C warming, with the average range size shrinking by 20 %.

[18] Increased variations in rainfall pattern and intensity are expected to make soils more susceptible to erosion. At the same time, increased aridity would make finer-textured soils more vulnerable to wind erosion. However reliable quantitative projections are not available.

[19] The growing season is projected to increase further throughout most of Europe, allowing a northward expansion of warm-season crops to areas that are currently not suitable.

[20] In a warmer climate, more severe fire weather and, as a consequence, an expansion of the fire-prone area and longer fire seasons are projected, but with considerable regional variation.

[21] Climate change is projected to lead to further northward and upward shifts in the distribution of *Ixodes ricinus*. It is also expected to affect the habitat suitability for a wide range of disease vectors, including *Aedes albopictus* and the *Phlebotomine* species of sandflies.

[21] As observed by Malta's **fixed** climatological Station at Luqa (WMO: 16597).

[23] Extremes in rainfall patterns/rates is projected to increase.

[24] During the period 1996-2005 the observed wind speed decreased, especially during winter. This decrease is around 3.5% with respect to the overall mean over the full period since 1946.

[25] This trend is higher than the average trends in the Mediterranean for the last 25 years (1982-2006) of (probably underestimated) +0.03°C/year.

Parameter	Likelihood of future trends based on MAGICC/SCENGEN version 5.3[26] applicable to the region of the Maltese Islands for the period 2025-2100[27]. 2100.
Increase in regional mean temperature	1.1 °C (2025); 2.0 °C (2050); 2.6 °C (2075); 2.8 °C (2100).
Change in regional mean precipitation	-2.4 % (2025); -4.4 % (2050); -3.7 % (2075); -1.8 % (2100).
Changes in global mean sea level rise	7cm (2025); 14cm (2050); 23cm (2075); 30cm (2100).

[26] The spatial resolution of the SCENGEN components is 2.5 by 2.5, which is too coarse for impact assessments and vulnerability and adaptation studies since the Maltese islands cover an area which is less than 0.5% of that for a single grid cell. The best solution is to use a numerical atmosphere-ocean general circulation model for the desired region, which has to be very computationally intensive, requiring a large computer cluster and substantial computer time.

[27] These model projections, which were based on emission scenario A1T-MES, were generated using 14 atmosphere-ocean general circulation models. The climate model used for the associated *global* projections is HadCM3 with a climate sensitivity of 3°C per [CO_2] doubling. Uncertainty analysis shows that these projections are quite reliable, with minimal model artifacts. Their use in vulnerability and adaptation studies for the Maltese Islands has been recommended to national authorities.