THE STATE OF THE CLIMATE 2022

A Multidecadal Report & Assessment Of Malta's Climate

NATIONAL STATISTICS OFFICE • MALTA

THE STATE OF THE CLIMATE 2022
A Multidecadal Report and Assessment of Malta's Climate

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In collaboration with Professor Charles Galdies

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This work is based on the numerous observations conducted throughout the years by the Meteorological Office of the Malta International Airport. The involvement of all staff engaged at the Meteorological Office since its establishment is therefore duly recognized.

Acknowledgements are also due to the staff members of the National Statistics Office for their cooperation and commitment to the reviewing of this publication from inception to its release.

Foreword

MR ETIENNE CARUANA

Director General

June 2022

When one mentions statistics, data on climate might not be the first to come to mind; however, considering the changes we are experiencing around us, one understands the salience of such. Climate information is essential for policy-making decisions, including but not limited to public spending, infrastructure decisions and provision of services.

This publication is the second of its kind and follows up on the one dating back to October 2011, which presented an analysis of weather-related data between 1951 and 2010. This year's edition provides an insight into data for the following ten years (2011-2020) and covers weather statistics measured by the Meteorological Office. The analysis points toward a climate that is becoming increasingly warmer and drier, thus more prone to weather extremes.

The outcomes of this publication point toward the need of urgent action for climate-related matters as stressed by the 26th UN Climate Change Conference of the Parties (COP26). The commentary, supplemented by charts, puts forward the analysis and the results so that the publication is of interest to researchers and the general public alike.

I want to take this opportunity to thank the Malta International Airport Meteorological Office for supplying the data on climatic variables. My show of gratitude also goes to Professor Charles Galdies, the author of this publication, who carried out the analysis of climatological data, and to the Environment, Agriculture and Fisheries Unit within the NSO for verifying the data and reviewing the text and the charts. Without these pillars of support, this publication would not have been possible.

About the Author

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at the University of Malta

June 2022

This is the second NSO publication authored by Charles Galdies, who is an Associate Professor at the University of Malta. He is an Earth Systems specialist with over 10 years' experience in teaching and research.

His research work across multiple scientific disciplines broadly addresses topics such as weather forecasting and climate change attribution, remote sensing and geospatial analysis of land, water and air. He is also actively engaged in public outreach activities that promote the understanding of weather and climate, astronomy and citizen science. He has provided consultancy services to various entities including United Nations agencies, governmental as well as private entities.

During his previous tenure as Chief Meteorologist with the Malta Meteorological Office between 2007 and 2011, he served as the Permanent Representative of the Government of Malta with the World Meteorological Organisation.

Contents

		Page
Chapter 01	**DURATION OF BRIGHT SUNSHINE AND CLOUD COVER**	1
	1.1 Mean duration of bright sunshine	1
	1.2 Mean extent of cloud cover	2
Chapter 02	**AMBIENT AIR TEMPERATURE**	5
	2.1 Mean monthly air temperature	5
	2.2 Mean maximum and minimum air temperatures	7
	2.3 Lowest minimum and highest maximum air temperatures	9
	2.4 Grass minimum air temperature	9
Chapter 03	**RAINFALL**	11
	3.1 Total rainfall	11
	3.2 Daily rainfall rates	14
	3.3 Number of rainfall days	15
Chapter 04	**ATMOSPHERIC PRESSURE**	17
	4.1 Mean sea level air pressure	17
Chapter 05	**NEAR-SURFACE WINDS**	19
	5.1 Mean wind speed	19
	5.2 Wind direction	21
	5.3 Frequency of gale force winds	22
	5.4 Peak wind gusts	22
Chapter 06	**RELATIVE HUMIDITY**	25
	6.1 Mean air relative humidity	25
Chapter 07	**SEA TEMPERATURE**	27
	7.1 Mean sea temperature	27
	7.2 Monthly maximum mean sea temperature	28
Chapter 08	**NUMBER OF DAYS WITH THUNDERSTORMS**	29
	8.1 Number of days with thunderstorms	29
Chapter 09	**A LOOK AT COMPOUND EXTREME EVENTS** **Case study of 2016**	33
Chapter 10	**FUTURE CLIMATE**	35

List of Charts, Tables and Figures

		Page
TABLE 1.1	Monthly average climate variables for Malta, measured on the basis of observations conducted during the 30-year period of 1991-2020	
CHART 1.1	Annual mean duration of bright sunshine anomaly from the climate average for the period 1961-2020	2
CHART 1.2	Time series of the annual mean cloud cover from 1961 to 2020	2
CHART 1.3	Annual mean cloud cover anomaly from the climate average for the period 1961-2020	3
CHART 2.1	Distribution of the mean monthly ambient air temperature values for the period 1952-2020	6
CHART 2.2	Time series of annual mean air temperature from 1952 to 2020	6
CHART 2.3	Time series of the annual mean air temperature anomaly from the climate average for the period 1952-2020	7
CHART 2.4	Time series of annual mean maximum and minimum air temperature from 1952 to 2020	7
CHART 2.5	Time series of the annual mean maximum air temperature anomaly from the climate average for the period 1952-2020	8
CHART 2.6	Time series of the annual mean minimum air temeperature anomaly from the climate average for the period 1952-2020	8
CHART 2.7	Time series of the annual grass lowest minimum air temperature anomaly for the climate average for the period 1953-2020	9
CHART 3.1	Time series of the annual total rainfall for the period 1952-2020	12
TABLE 3.1	Malta's Climate Normal total annual rainfall compared with that for the period of 1991-2020	12
CHART 3.2	Trend of the annual total rainfall anomaly from the climate average for the period 1952-2020	13
CHART 3.3	Monthly mean total rainfall based on the 30-year Climate Normal of 1961-1990	14
CHART 3.4	Monthly mean total rainfall registered during the 30-year period of 1991-2020	14
CHART 3.5	Monthly daily rainfall rates of the Cimate Normal of 1961-1990 and of the 1991-2020 period	15
CHART 3.6	Trend of the daily rainfall rate anomaly from the climate average for the period 1952-2020	15
CHART 3.7	Monthly means for the number of rainy days for the Climate Normal of 1961-1990 and the 1991-2020 period	16
CHART 4.1	Annual mean surface atmospheric pressure anomaly from the climate average for the period 1952-2020	18
CHART 5.1	Monthly means for the mean wind speed for the Climate Normal of 1961-1990 and the 1991-2020 period	20
CHART 5.2	Annual mean wind speed anomaly from the climate average for the period 1961-2020	20
CHART 5.3	Seasonal trends of the annual mean near-surface wind speed between 1961 and 2020	21
CHART 5.4	Distribution of the monthly prevailing wind direction during the period 1961-2020	22
CHART 5.5	Annual total number of days with gale force winds between 1961 and 2020	22
CHART 5.6	Monthly means for the peak wind gust (knots) for the Climate Normal of 1961-1990 and the 1991-2020 period	23
CHART 6.1	Annual mean relative humidity from 1961 to 2020	26
CHART 6.2	Annual mean relative humidity anomaly from the climate average for the 1961-2020 period	26
CHART 7.1	Time series of the annual mean sea temperature from 1978 to 2020	28
CHART 7.2	Ranked time series of the maximum monthly mean sea temperature from 1978 to 2020	28

		Page
CHART 8.1	Time series of the maximum number of days with thunderstorms recorded in a single month and the mean number of days with thunderstorms per month registered between 1952 and 2020	30
CHART 8.2	Mean monthly number of days with thunderstoms for the Climate Normal of 1961-1990 and for the 1991-2020 period	30
CHART 8.3	Annual mean number of days with thunderstoms per month anomaly from the climate average for the period 1952-2020	31
CHART 9.1	Monthly anomalies of ambient temperature, sea level atmospheric pressure, rainfall and daily rainfall rate from the climate average: 2016	33
FIGURE 9.1	European high winter temperature records for 2016 occuring due to compounding climatic conditions	34
FIGURE 10.1	Projected climate change impacts over Malta as predicted by climate change models	35
FIGURE 10.2	Current and projected climate change impacts on local crops and livestock	36

Background

The first edition of this publication was released in 2011[1]. Its scope was twofold: (i) to characterize and describe Malta's Climate Normal of 1961-1990, and (ii) to use long-term weather observations collected from Malta's only climatological station situated at Luqa during the period 1952-2010 to detect any significant climatological trends. Ranging from air temperature, rainfall patterns, to sea level pressure, relative humidity and thunderstorm events, the statistics published in the first edition showed how Malta's climate has changed in the recent past and how this might have possibly impacted a number of local socio-economic sectors. So far, it has served successfully as an excellent, official source of climatological information and analysis of Malta's climate.

A Climate Normal is considered as a typical climate experienced by a region or country and serves as a benchmark against which past observations can be compared. Traditionally, its calculation is based on the mean value of climate elements such as temperature, rainfall, humidity, sunshine hours, cloud cover and other elements over a specific period of time. A Climate Normal serves two main purposes: as a reference period for monitoring current weather and climate, and as a good description of the expected climate in a location over the seasons. It provides a basis for determining whether today's weather and climate are different from those of the past and in doing so, it can provide decision support for climate change adaptation measures for many activities such as agriculture, energy supply, public health, transportation, civil defence, and other sectors of strategic importance to the country's wellbeing.

In 1935, the International Meteorological Organization (now the World Meteorological Organization - WMO) instructed its Member States to construct their first Climate Normal that reflected the average weather from 1901 till 1930. The choice of a 30-year period was based on the need to have a reference period that reflected a relatively stable and long enough period to smooth out interannual variations. This made it suitable for long-term climate variability assessments and climate change monitoring. Global acceptance of this standard by the international meteorological community made possible inter-comparisons among observations from around the world. Subsequently, international Climate Normals were requested for the period 1961-1990, and since then many countries continued to regularly update their reference periods in line with WMO guidelines.

In this document, the choice of the reference period and the calculation methods is an important step because it defines what is climatologically normal. The collection of climate elements by the Meteorological Office is carried out in accordance with WMO's standard and recommended practices and procedures designed to bring efficiency and interoperability. The Guides describe practices, procedures and specifications which WMO Members are invited to follow or implement in order to achieve compliance[2]. These include the Guide to Climatological Practices (WMO-No. 100), the WMO Guidelines on the Calculation of Climate Normals (WMO-No. 1203); the Calculation of Monthly and Annual 30-Year Standard Normals (WMO/TD-No. 341), the Guide to Instruments and Methods of Observations (WMO-No. 8); and the Guide to the Implementation of Quality Management Systems for National Meteorological and Hydrological Services and Other Relevant Service Providers (WMO-No. 1100). The adherence to these standard procedures by the Malta Meteorological Office gives credibility to the accuracy of the findings presented by this NSO document.

This second edition provides an extended analysis of climatological data based on a select list of weather elements as observed and provided by the Meteorological Office. In order for these two editions to be comparable, the 1961-1990 Climate Normal has been used as the main climate reference from which anomalies for a longer time period have been derived and presented here. This practice is also in line with WMO guidelines that state that the 1961-1990 period is the standard reference period for long-term climate change assessments.

The choice of keeping the 1961-1990 Climate Normal as Malta's climate standard does not exclude the comparison with the average weather trends observed during the last 30 years. However, at the time of writing, Malta's official 1991-2020 Climate Normal was still not officiated by the World Meteorological Organisation. As in other parts of the world, it is expected that Malta will show higher average temperatures and an increase in the number of weather extremes because of further global warming in this most recent climate period.

Additional Information

Unless otherwise stated, the term 'climate average' in this report refers to the official 1961-1990 Climate Normal. All values quoted here have been rounded from the original unrounded values.

The observed upward or downward trends of the climate variables analysed here have been tested for statistical significance. This included tests of normality of the data and choice of appropriate parametric and non-parametric correlation. All the trends presented in this analysis are statistically significant at the 95 per cent confidence level unless stated otherwise.

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[1] Galdies C (2011) Malta's climate anomaly trends and possible related socio-economic impacts. National Statistics Office, Malta. 45pp

[2] Standards and recommended practices – https://public.wmo.int/en/resources/standards-technical-regulations

Monitoring of Malta's climate is based on the collection of data that is of the highest quality possible. Quality control is a central part of the work process of the Luqa Meteorological Office; however, human errors or equipment faults do occur from time to time. The data quality management of the Meteorological Office is partly based on an automatic quality control algorithm that checks whether parameter-specific observations fit within particular ranges. Most data then go through a second manual-checking process, aided by statistical modelling, in order to detect any outliers and confirm correct patterns. Maintenance of weather sensors is carried out weekly while calibration checks are carried out yearly or whenever deemed necessary.

Malta's Climate Profile for the Period 1991-2020

TABLE 1.1. Monthly average climate variables for Malta, measured on the basis of observations conducted during the 30-year period of 1991-2020

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average temperature (°C)	12.9	12.6	14.1	16.4	20.0	24.2	26.9	27.5	24.9	21.7	17.9	14.5
Average maximum temperature (°C)	15.7	15.7	17.4	20.1	24.3	28.8	31.7	32	28.6	25.0	20.8	17.1
Average minimum temperature (°C)	10.0	9.6	10.9	12.7	15.8	19.6	22.1	23.0	21.2	18.4	15.0	11.8
Mean duration of bright sunshine (hours)	5.4	6.6	7.2	8.4	9.9	11.2	11.9	10.9	8.4	7.0	6.1	5.3
Sea level pressure (hPa)	1,019	1,018	1,017	1,015	1,015	1,015	1,015	1,015	1,016	1,017	1,017	1,019
Rainfall (mm)	79.4	68.9	39.7	18.7	11	7.3	0.2	11.2	59.2	77.6	89.1	84.8

Source: Malta International Airport Meteorological Office.

Changing Climate: Key Findings

MALTA

- Sunshine duration shows a clear upward trend since 1961.
- Winter months showed the sharpest rise in sunshine duration since 1961, with the highest increase seen during the month of February. This is equivalent to an increase of 0.1 hours per decade for the 60-year period.
- The trend in the annual mean cloud cover shows a decrease of 0.1 oktas per decade.
- The annual mean, maximum and minimum air temperatures show a clear upward trend since 1952.
- 2016 saw the highest annual mean ambient air temperature (20.1 °C) since 1952, just above the value for 2001 (19.9 °C) which ranks second.
- 80 per cent of the warmest 20 minimum night-time temperatures since 1952 occurred during the last 20 years.
- Since 1952, Malta's annual mean ambient temperature is about 1.5 °C higher, equivalent to an increase of 0.2 °C per decade.
- The highest maximum ambient temperature has increased by 1.2 °C since 1952, translating into a decadal increase of 0.2 °C.
- Extended consecutive drought years, especially noticeable since 2000.
- 25 per cent of the top 20 years with the lowest annual total rainfall were recorded from 2001 onwards.
- During the last 20 years, 2016 had the least rainfall (324.8 mm) followed by 2001 (338.2 mm) and 2020 (386.9 mm).
- Between 1952 and 2020 rainfall decreased by 10.3 mm per decade.
- The 24-hour rainfall rate decreased by around 0.3 mm per decade since 1952.
- Between 1952 and 2020, the atmospheric pressure has increased by 0.05 hPa per decade, equivalent to 0.3 hPa over 69 years.
- During the past 69 years, atmospheric pressure for the months of January to March and December shows a positive anomaly trend[3] from the climate average.
- The wind speed shows a declining trend of 0.8 knots (0.4 metres per second) over the past 60 years.
- The steepest reduction in the overall wind speed has occurred during winter, followed by spring, summer and autumn.
- The most common wind direction continues to be north-westerly (292.5°-337.5°, centred at 315°), followed by westerly (247.5°-292.5°, centred at 270°) and the easterly (67.5°-112.5°, centred at 90°).
- A strong negative trend has occurred, equivalent to 4.7 percentage points in relative humidity for the entire period of 1961-2020. This is equivalent to 0.8 percentage points per decade.
- The strongest negative trends in relative humidity have been seen to occur during the warmer months (May to September).
- 75 per cent of the years with the lowest 20 relative humidity anomalies have been registered from 2001 onwards.
- The highest mean sea temperature was registered during August of 2003 and 2020 when a temperature of 28.0 °C was recorded.
- 60 per cent of the 20 maximum sea temperatures occurred during the last 20 years.
- Results show a decadal increase of 0.4 °C in the mean sea temperature of Maltese waters since 1978.
- The number of days with thunderstorms has increased during the period 1952-2020.
- The autumn period is Malta's most thundery season, while the month of November registered the greatest increase in thunderstorms.

[3] Climate anomaly denotes the departure of a weather element from its long-period average value for the location concerned.

EUROPE

- The average temperature increased slowly during most of the industrial era but began to rise sharply in the 1980s.
- The temperature increase for Europe is about 0.9 °C higher than the corresponding global increase. Europe has also warmed faster than any other continent in recent decades.
- 2020 was the warmest year on record, at more than 1.6 °C above average.
- The temperature for 2020 was at least 0.4 °C warmer than those of the next five warmest years, which all occurred during the last decade.
- Winter and autumn of 2020 were the warmest on record, with the winter record being particularly significant, at more than 3.4 °C above the 1981-2010 average and around 1.4 °C warmer than the previous warmest winter.
- 2020 registered a new record high sunshine duration for Europe, in line with the long-term trend towards more sunshine.

GLOBAL

- As at end of December 2021, the global annual mean carbon dioxide (CO_2) concentration reached 416.4 ppm. These are the highest levels seen on Earth in at least 2 million years.
- Globally averaged surface air temperature has warmed by over 1 °C since reliable records began in 1850.
- Each decade since 1980 has been warmer than the last, with 2010-2019 being around 0.2 °C warmer than 2000-2009.
- The world's oceans are taking up around 90 per cent of the extra energy resulting from enhanced greenhouse gases concentrations.
- Global mean sea levels have risen by around 25 cm since 1880 and continue to rise at an accelerating rate.

Executive Summary

This is a multidecadal report on the state of Malta's climate based on the data provided by the Meteorological Office situated at Luqa and compiled and analysed by Charles Galdies PhD on behalf of the National Statistics Office. This publication provides an accessible, authoritative and updated analysis of Malta's climate based on the latest set of climate-quality records, with descriptions of climate conditions and extremes covering the period from 1952 till 2020. In addition, it also explores the associated fluctuations in key climate variables and indices with those observed during the periods 1961-1990 and 1991-2020 over Malta.

The climate data presented here has been collected by Malta's only climate station situated at Luqa Airport. The data has been carefully managed and quality-controlled in line with current best practice observational standards as recommended by the World Meteorological Organisation (WMO).

This second edition presents a new section devoted to future climate projections for Malta as produced by a number of climate forecasting models. These models furnish information to the scientific and decision-making communities and are used by the Intergovernmental Panel on Climate Change (IPCC) of the United Nations[4] to issue its Assessment Reports that are published every six years.

[4] https://www.ipcc.ch

01 DURATION OF BRIGHT SUNSHINE AND CLOUD COVER

Malta's bright sunshine duration is a climatological indicator that is measured in hours per day. It reflects the local duration of sunshine and is a good indicator of the degree of cloudiness in a given period. It refers to the total hours of 'bright' sunshine when the sunlight is stronger than a specified threshold, contrary to day-light hours. Its variation is related to a number of factors including cloud cover, atmospheric transparency, air temperature, geographical location and the season. In this publication, sunshine duration and cloud cover have been grouped together under one section.

Key messages:

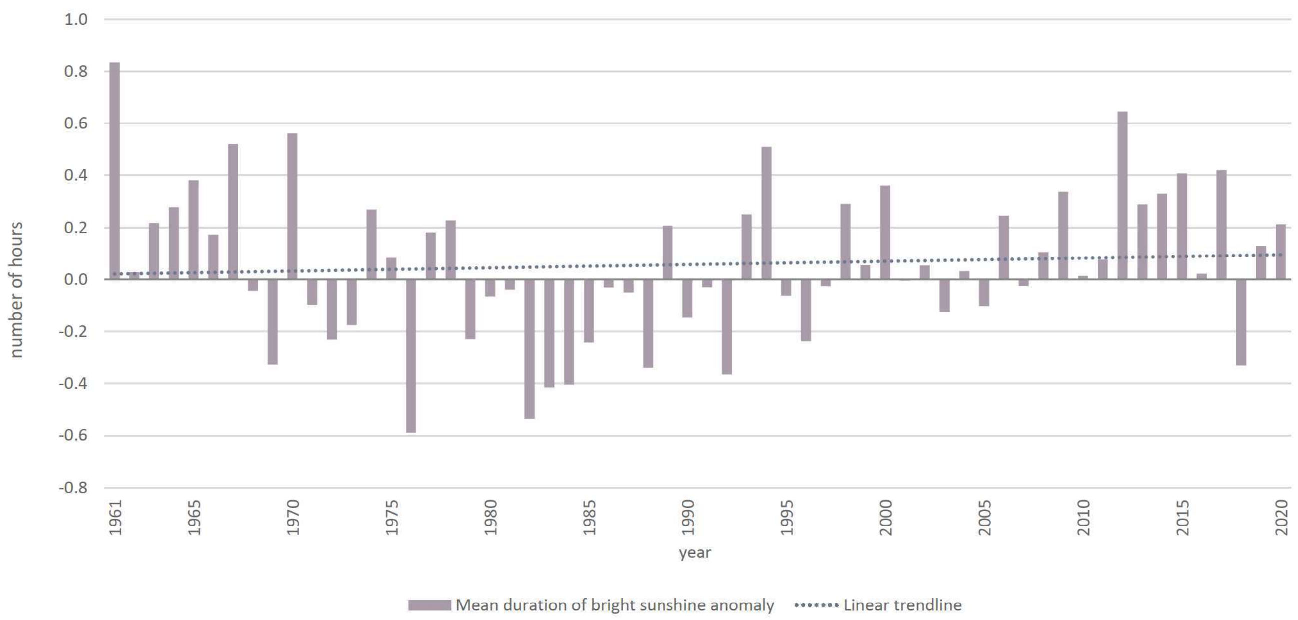
- Sunshine duration shows a clear upward trend since 1961.
- The winter months showed the sharpest rise in sunshine duration since 1961, with the highest increase seen during the month of February. This is equivalent to an increase of 0.1 hours per decade for the 60-year period.
- 1961 registered the largest number of sunshine hours since 1961, just above the value for 2012.
- The trend in the annual mean cloud cover shows a decrease of 0.1 oktas per decade.

1.1. Mean duration of bright sunshine

The mean duration of bright sunshine (in hours) registered during the period 1991-2020 is shown in **Table 1.1**. It ranges from a lowest average of 5.3 hours per day (December) to a highest of 11.9 hours per day (July). Looking at the annual total of mean monthly durations of bright sunshine per day, the latest 30-year average shows an increment of 1.3 hours over the climate average of 1961-1990.

Since 1961, Malta's annual average bright sunshine duration anomaly has been increasing when compared to the climate average (**Chart 1.1**). The calendar year 2012 had the second highest average monthly number of sunshine hours (preceded by 1961), with a sunshine duration of 0.6 hours above the climate average. Since 1961, 40 per cent of the years with the 20 highest positive anomalies have indeed been recorded since 2001.

CHART 1.1. Annual mean duration of bright sunshine anomaly from the climate average for the period 1961-2020



Data analysis showed that the winter months exhibited the sharpest rise in sunshine duration since 1961, with the highest increase seen during the months of February. This is equivalent to an increase of 0.1 hours per decade throughout the 60-year period.

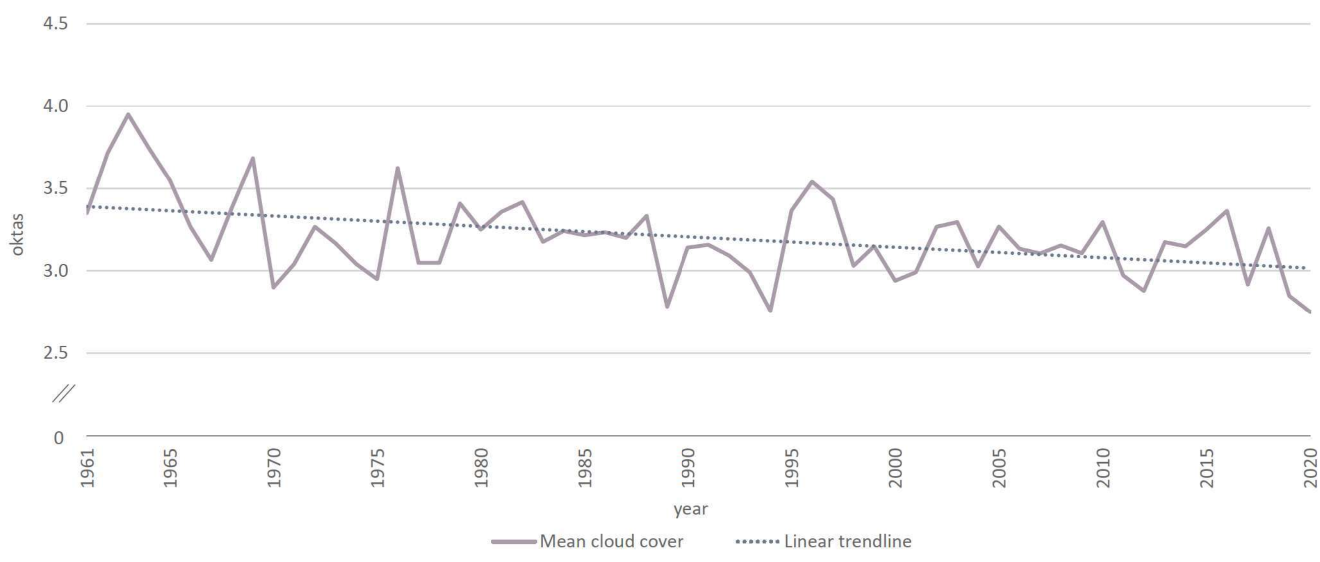
Attribution of small changes to sunshine duration over time is difficult to analyse due to the range of processes influencing it. These include changes in the degree of cloud cover that in turn can be associated with rainfall variability and the direct and indirect effects of changes to the atmospheric aerosol load.

1.2. Mean extent of cloud cover

Cloud cover is of course related to the duration of sunshine received at the surface, and these two weather elements are expected to have an inverse relationship throughout the observational period. However, anomaly patterns in sunshine duration and total cloud cover do not fully correspond, mainly because the total cloud cover is estimated for whole 24-hour periods, whereas sunshine duration is based on daylight hours.

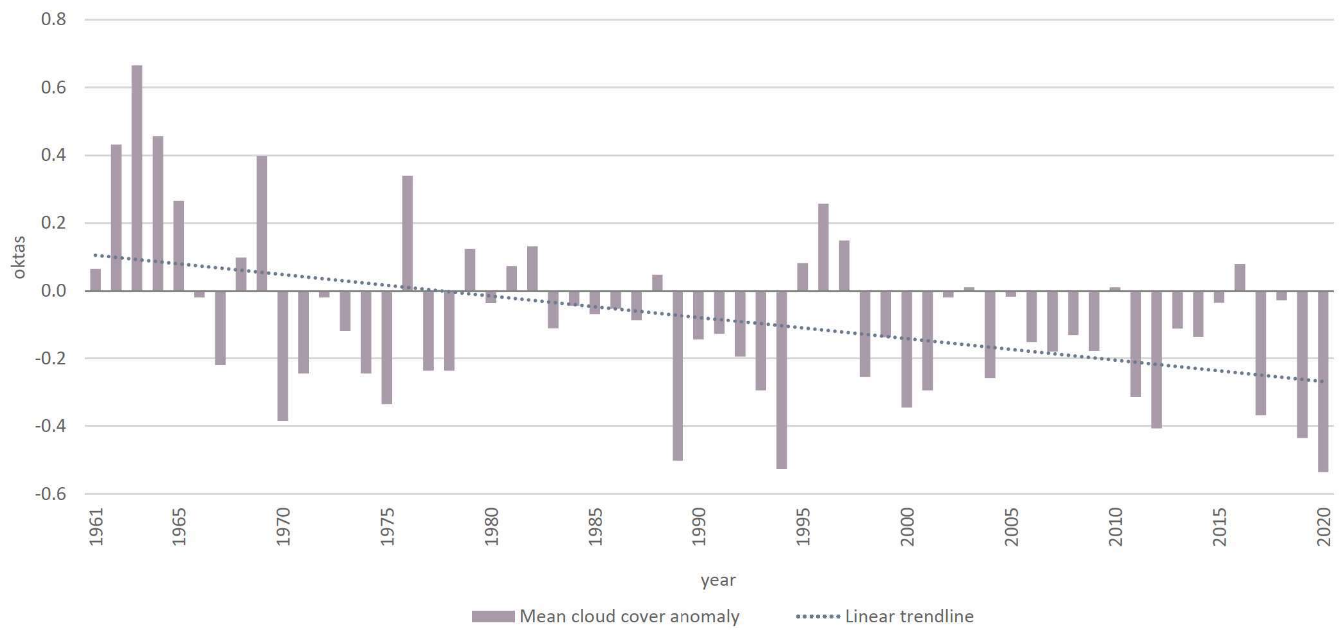
Malta's annual mean total cloud amount is characterised by high year-to-year variability, and by a weak decrease over the 1961-2020 period. This points to a decrease in cloud cover extent by 0.1 oktas every decade (**Chart 1.2**). Such an occurrence in a semi-arid environment can alter the receipt of solar radiation, resulting in increased surface temperatures which in turn can affect crop productivity and related water requirements, amongst other impacts.

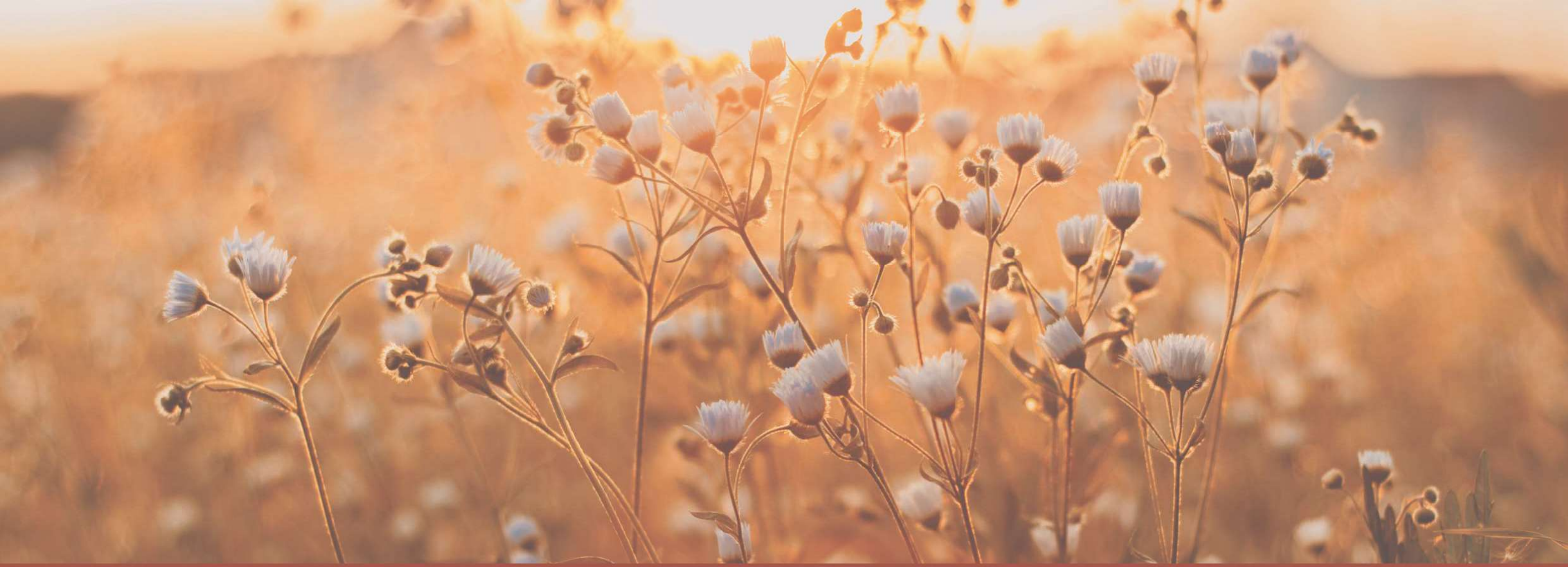
CHART 1.2. Time series of the annual mean cloud cover from 1961 to 2020



The annual mean cloud cover anomaly from the average climate is shown in **Chart 1.3**. The general reduction in cloud cover since 1983 when compared to the climate average is evident. A local reduction in the cloud cover can potentially impact the natural environment leading to a rise in soil temperatures because of the increased receipt of solar radiation, a decreased chance of rainfall and reduced soil moisture.

CHART 1.3. Annual mean cloud cover anomaly from the climate average for the period 1961-2020





02 AMBIENT AIR TEMPERATURE

Ambient air temperature is the result of the kinetic energy of atmospheric gases; in other words, it is a measure of how hot or cold the air is. It is the most commonly studied weather element by climatologists as it affects nearly all other weather elements and processes such as the rate of evaporation, relative humidity, wind as well as rainfall. Changes in ambient air temperature can lead to significant impacts on both human and natural systems. It significantly affects human health, agriculture and energy demand among other socio-economic and environmental sectors.

Key messages:

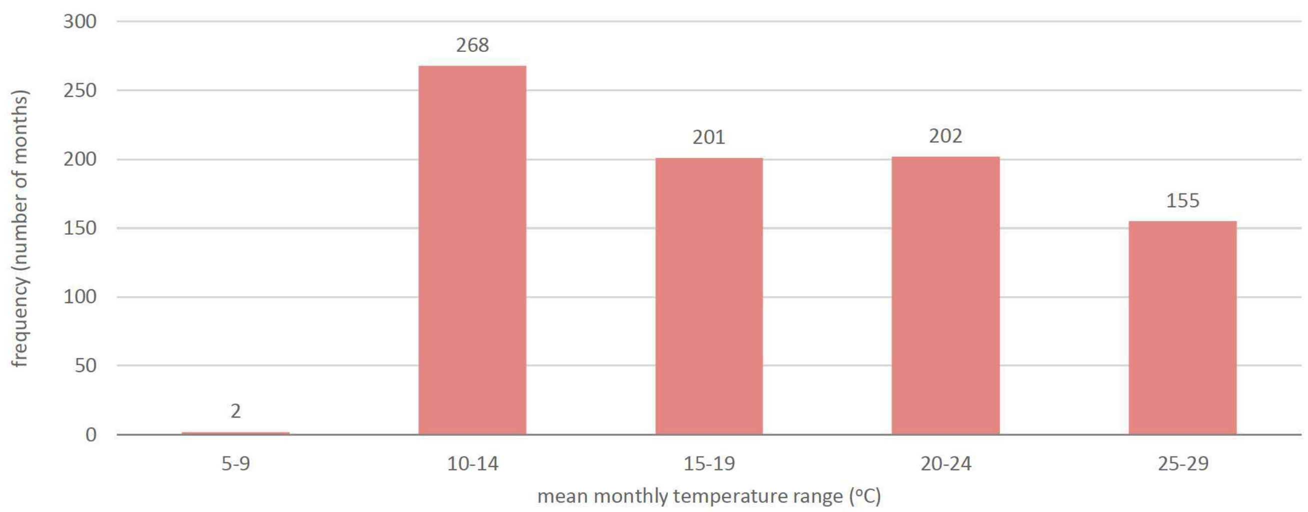
- The annual mean, maximum and minimum air temperatures show a clear upward trend since 1952.
- 2016 saw the highest annual mean ambient air temperature (20.1 °C) since 1952, just above the value for 2001 (19.9 °C) which ranks second.
- 80 per cent of the warmest 20 minimum night-time temperatures since 1952 occurred during the last 20 years.
- Since 1952, Malta's annual mean ambient temperature is about 1.5 °C higher, equivalent to an increase of 0.2 °C per decade.
- The highest maximum ambient temperature has increased by 1.2 °C since 1952, translating into a decadal increase of 0.2 °C.
- 85 per cent of the 20 warmest annual average grass minimum temperatures occurred during the past 20 years, with 2013 (9.4 °C) registering the highest grass minimum temperature, followed by 2014 (9.3 °C). Their anomalies from the 1961-1990 climate average were +3.5 °C and +3.4 °C for 2013 and 2014 respectively.

2.1. Mean monthly air temperature

Chart 2.1 shows the distribution of the mean monthly ambient air temperature values measured for the period 1952-2020. It shows that 32.4 per cent of all months during this period registered an average temperature that fell in the range of 10 °C to 14 °C. The 15 °C to 19 °C and 20 °C to 24 °C categories had almost equal distributions with 24.3 per cent and 24.4 per cent respectively, while the 24 °C to 29 °C category had a distribution of 18.7 per cent. This variation originates from the seasonality of the Maltese climate.

From a time-series point of view, Malta's climate is changing in response to a warming climate. **Chart 2.2** shows the 5-year moving average of the annual mean air temperature for the period 1952-2020. The general warming detected locally since the early 1980s is not in doubt, and is supported by recent warmer spells. So far, Malta's warmest year on record was 2016 with a mean annual ambient temperature of 20.1 °C.

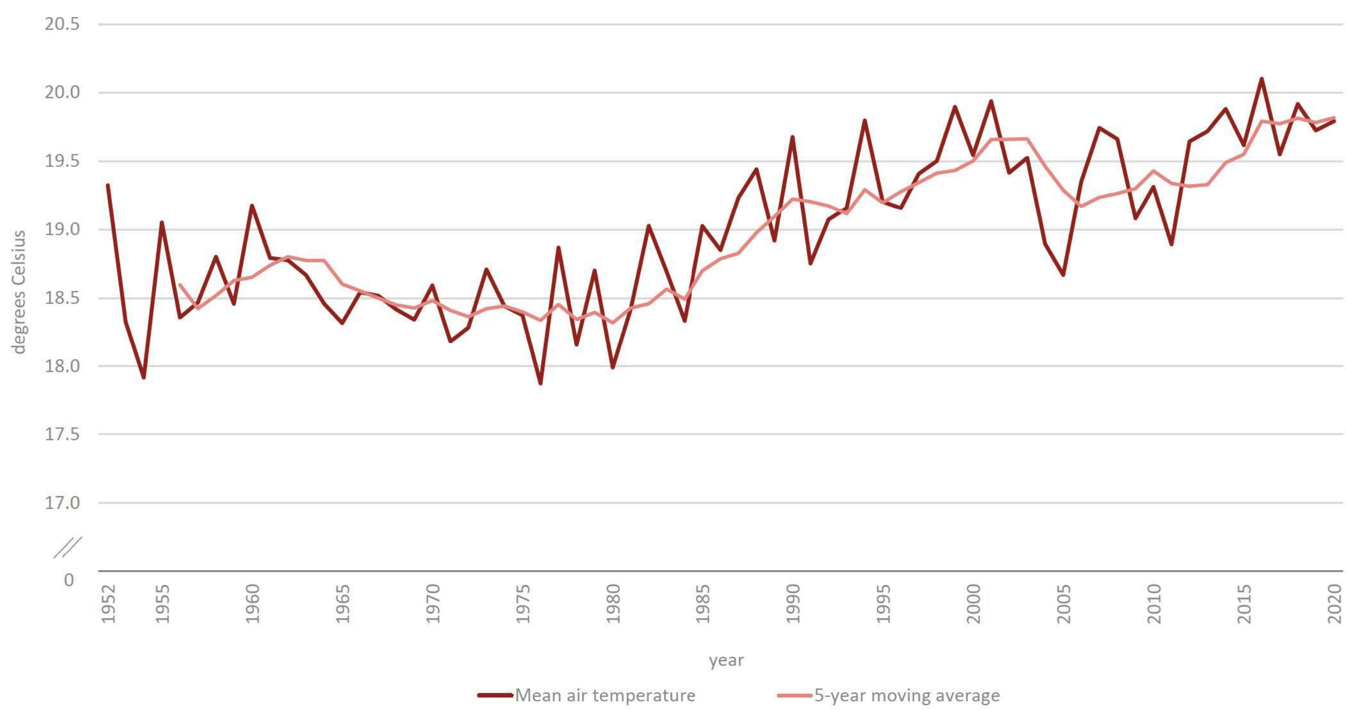
CHART 2.1. Distribution of the mean monthly ambient air temperature values for the period 1952-2020



Mean = 19.0 °C
Standard deviation = 5.3 °C

On average, this data can be translated into a warming trend of 0.2 °C every decade since 1952, with most of the warming occurring since the early 1980s. It is also worth mentioning that 70 per cent of the 20 warmest years between 1952 and 2020 have occurred during the last 20 years[5].

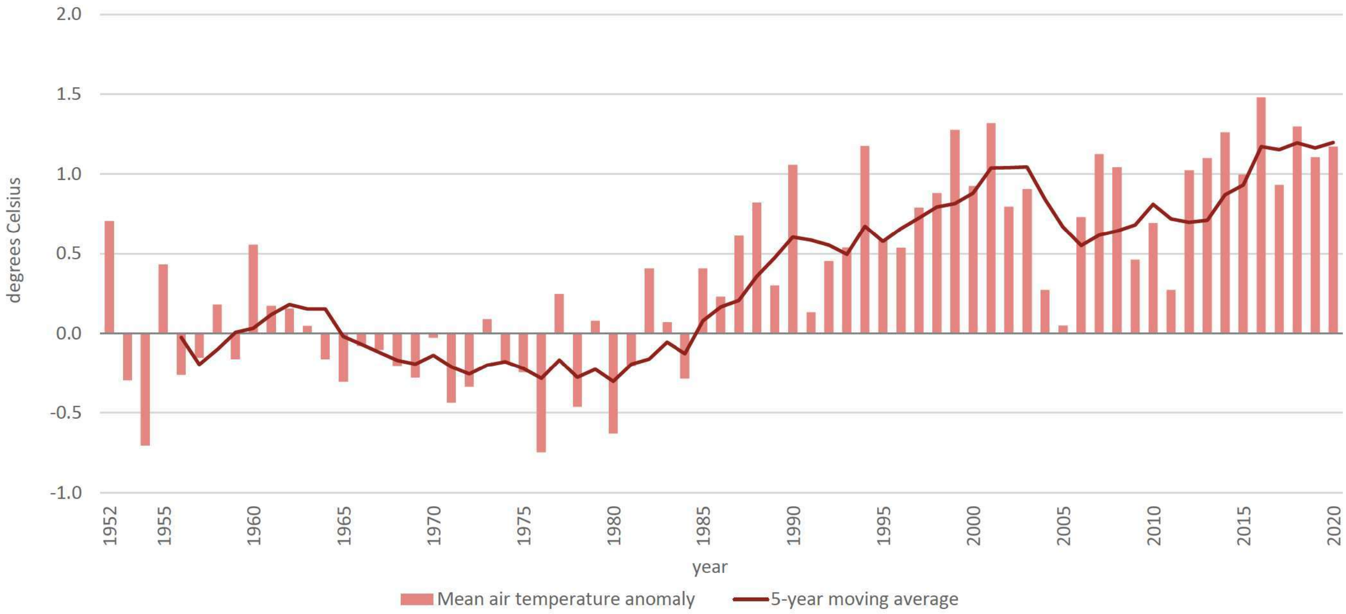
CHART 2.2. Time series of annual mean air temperature from 1952 to 2020



When this annual mean air temperature data is compared to the 1961-1990 Climate Normal, the dataset shows strong positive anomalies from 1984 onwards (**Chart 2.3**). The 2016 record mentioned earlier was around 1.5 °C warmer than the climate average.

[5] References to the 'last 20 years' refer to the period from 1st January 2001 till 31st December 2020.

CHART 2.3. Time series of the annual mean air temperature anomaly from the climate average for the period 1952-2020



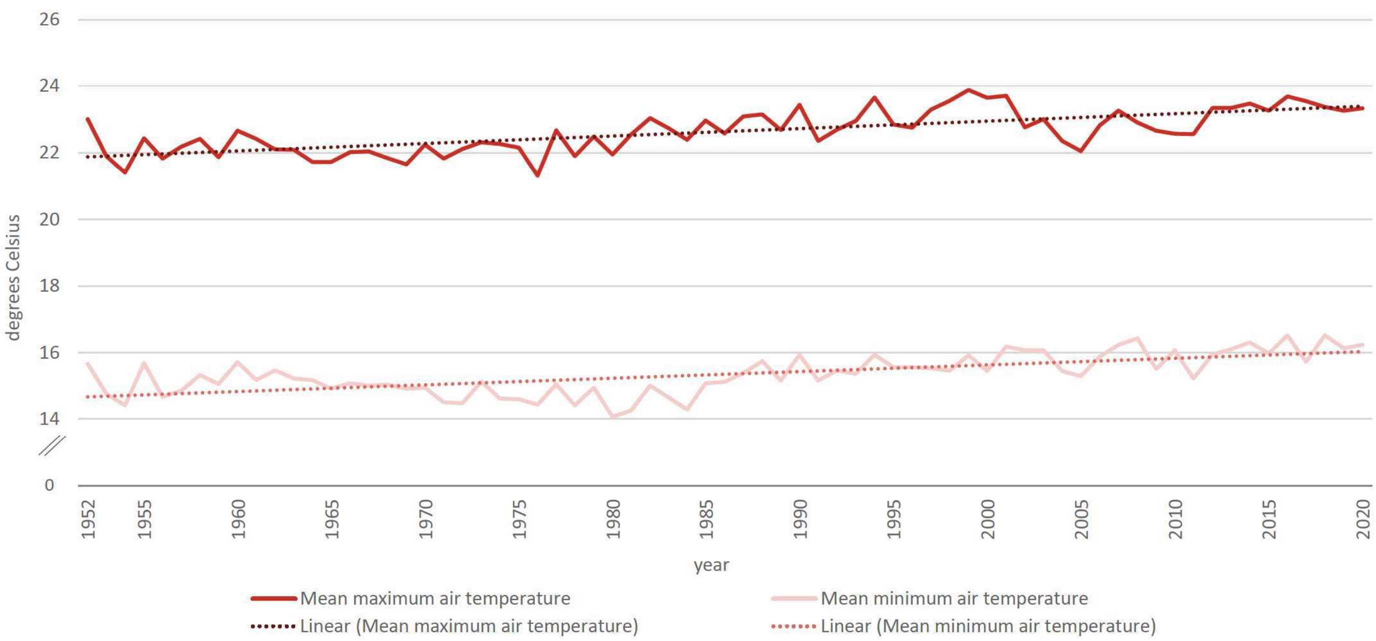
2.2. Mean maximum and minimum air temperatures

Such a warming trend is also seen by the long-term series of the average maximum and minimum air temperature anomalies. For the average maximum temperature anomalies, the highest increases were seen during July, followed by April and June in a decreasing order, while for the average minimum temperature anomalies, these were seen for October, August and November in decreasing order. This consistent shift to a warmer climate signifies warmer nights and hotter days, accompanied by more extreme heat episodes across all months (**Chart 2.4**).

In total, 55 per cent of the years with the 20 highest mean maximum ambient temperatures occurred during the past 20 years, with the figure rising to 80 per cent if data from 1991 onwards is taken into account. This percentage is even higher for the mean minimum temperature, with 80 per cent of the top 20 years occurring since 2001.

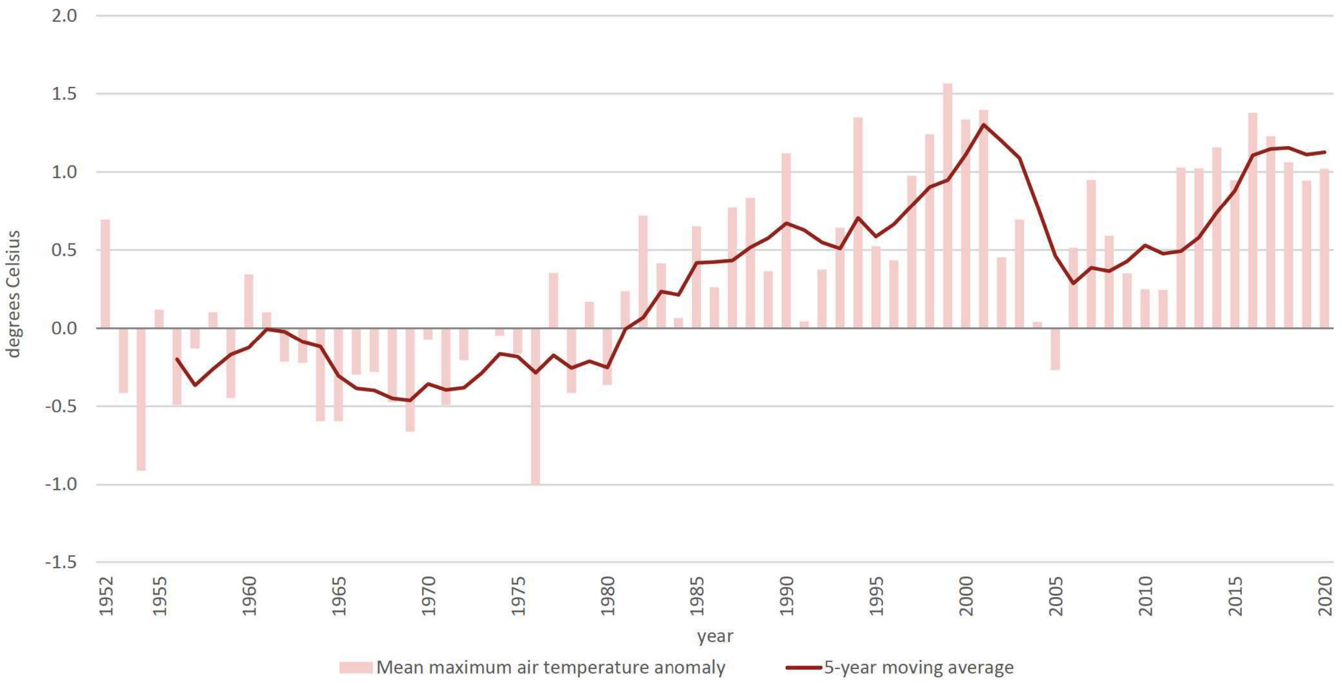
Based on this data, Malta's mean maximum ambient temperature has increased by 1.5 °C since 1952, equivalent to a warming of 0.2 °C per decade. This is due to an increase in the frequency of months that are much warmer than average. The strongest warming shown by the monthly mean maximum temperatures has been observed during July with an increase of 2.3 °C during the period under review.

CHART 2.4. Time series of annual mean maximum and minimum air temperature from 1952 to 2020



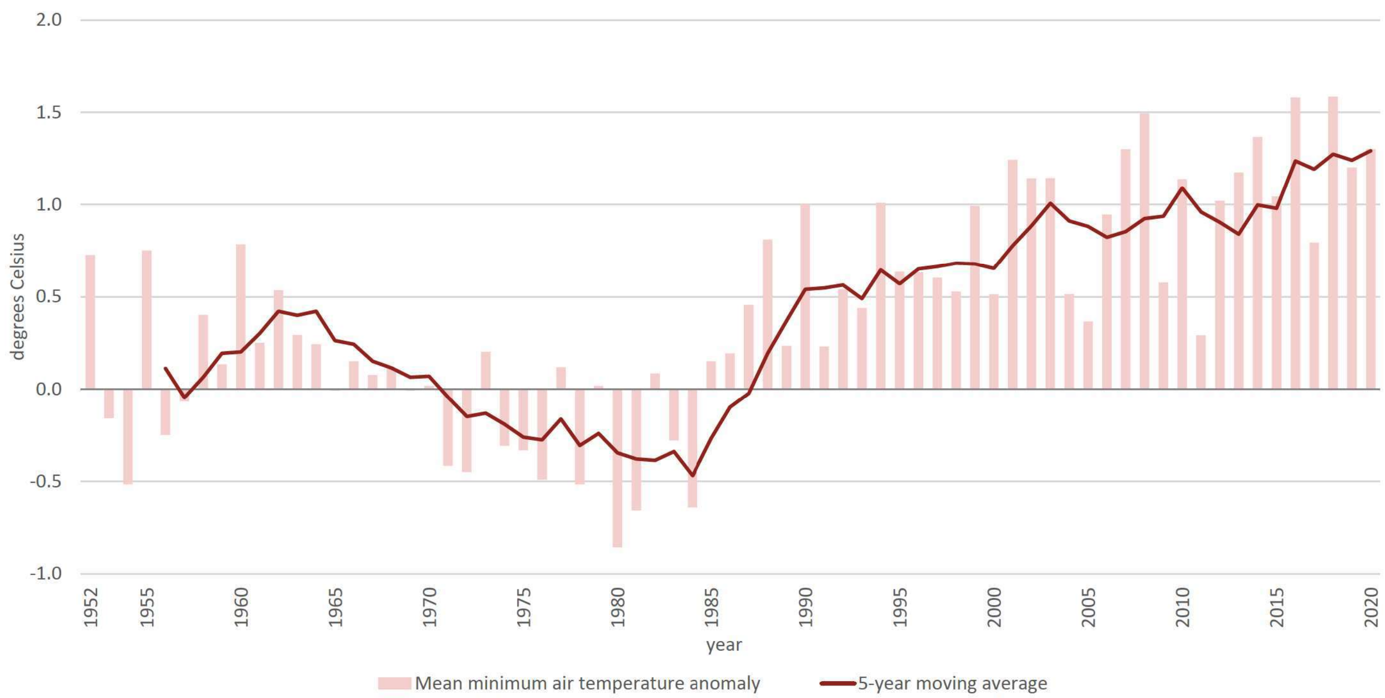
Charts 2.5 and **2.6** below show the annual mean maximum and minimum air temperature data when compared to their respective 1961-1990 Climate Normal. In both cases, strong positive anomalies can be seen starting as of mid-1980s. The warming trend of the mean minimum temperature is much clearer and more consistent.

CHART 2.5. Time series of the annual mean maximum air temperature anomaly from the climate average for the period 1952-2020



Note: The year 2005 shows anomalous cooling.

CHART 2.6. Time series of the annual mean minimum air temperature anomaly from the climate average for the period 1952-2020



2.3. Lowest minimum and highest maximum air temperatures

The lowest minimum air temperature represents the instantaneous minimum air temperature recorded during night-time. 90 per cent of the 20 warmest lowest minimum night-time air temperatures since 1952 occurred in the last 20 years, with the remaining 10 per cent occurring during the 1990s. The frequency of occurrences of cold days and nights since 1952 has therefore declined in Malta.

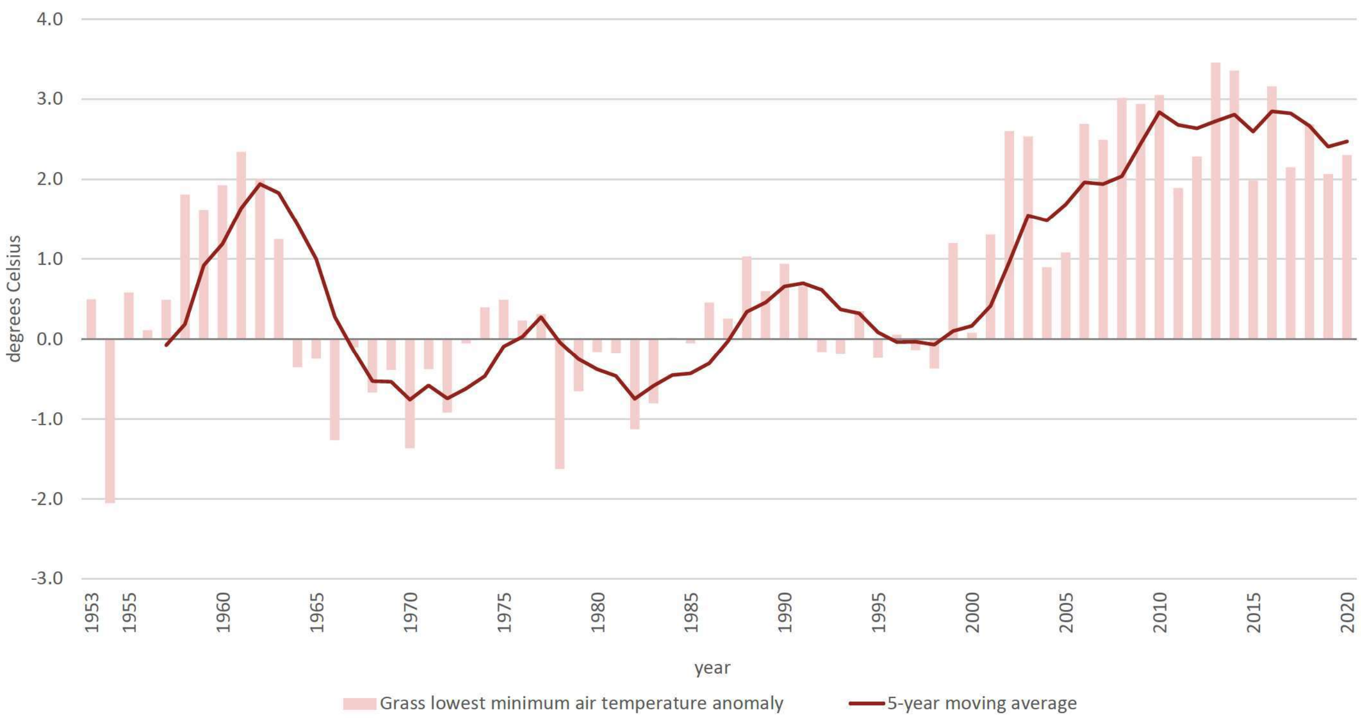
Locally, the highest maximum air temperature, which in meteorological terms represents the instantaneous maximum reading of the air temperature recorded in a specified period, has increased by 1.2 °C since 1952. The decadal increase of the highest maximum air temperature since 1952 is equivalent to 0.2 °C, which is close to that for the mean air temperature. Moreover, 45 per cent of the years with the 20 highest maximum air temperature since 1952 have occurred during the last 20 years.

2.4. Grass minimum air temperature

The grass minimum air temperature can vary significantly from the ambient air temperature. This is because it corresponds to the minimum air temperature recorded in open ground at night by a thermometer whose bulb is placed at 5 centimetres above the ground and preferably over short turf. This is unlike the measurement of the ambient air temperature, which takes place at 2 metres above the ground.

The grass minimum air temperature is an important indicator of frost formation on the ground which can be influenced by factors such as wind speed, water vapour pressure, atmospheric stability, rainfall, air temperature and type and extent of cloud cover. Malta's climate shows that 85 per cent of the 20 highest annual average grass minimum air temperature (i.e. warmest values) occurred during the past 20 years, with 2013 (9.4 °C) registering the highest grass minimum air temperature, followed by 2014 (9.3 °C). The warmer anomaly from the 1961-1990 average thus stands at +3.5 °C and +3.4 °C for 2013 and 2014 respectively (**Chart 2.7**).

CHART 2.7. Time series of the annual grass lowest minimum air temperature anomaly from the climate average for the period 1953-2020



03 RAINFALL

The degree to which rainfall amounts vary over time is an important characteristic of the climate, and the study of the temporal rainfall variability is very important in understanding certain trends in the local climate. Over the coming years the expected changes resulting from increased ambient temperatures will include increased evaporation, among other atmospheric processes. From a global perspective, this increase in evaporation will result in more frequent and intense storms. In view of its semi-arid climate due to its geographical location, Malta will be more likely to experience a loss in rainfall accompanied by longer drought periods.

Key messages:

- Extended consecutive drought years, especially noticeable since 2000.
- 25 per cent of the top 20 years that had the lowest annual total rainfall were recorded from 2001 onwards.
- During the last 20 years, 2016 had the least rainfall (324.8 mm) followed by 2001 (338.2 mm) and 2020 (386.9 mm).
- Between 1952-2020, rainfall decreased by 10.3 mm per decade.
- The 24-hour rainfall amount decreased by around 0.3 mm per decade since 1952.

3.1. Total rainfall

Records dating back to 1923 show that the annual total rainfall is strongly affected by high interannual variability, making the planning and management of Malta's freshwater resources quite challenging. According to **Chart 3.1**, between 1952 and 2020 the total annual rainfall has ranged from a minimum of 274.2 mm (1961) to a maximum of 900.6 mm (2003). **Table 3.1** shows the average total annual rainfall for two consecutive 30-year periods.

CHART 3.1. Time series of the annual total rainfall for the period 1952-2020

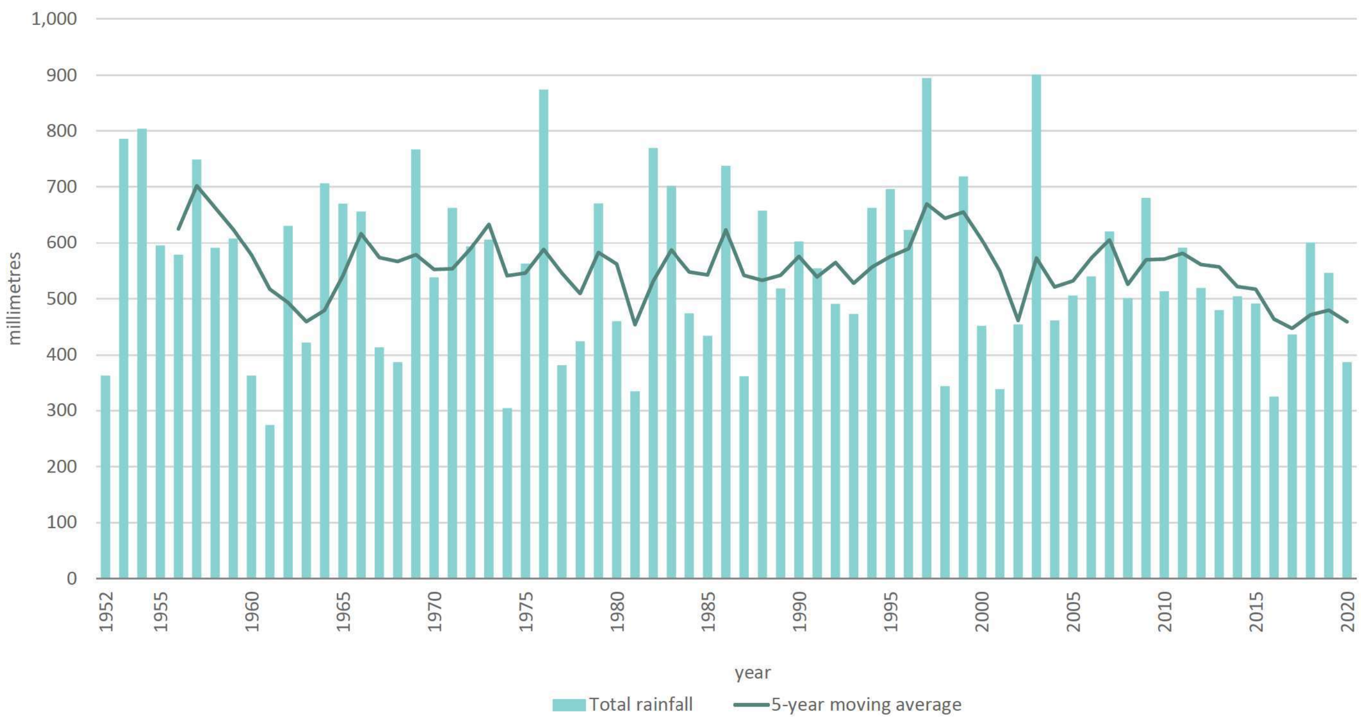


TABLE 3.1. Malta's Climate Normal total annual rainfall compared with that for the period of 1991-2020

Period	Annual total rainfall (mm)
1961-1990 Climate Normal	553.1
1991-2020	543.4

Despite this observed variability in Malta's rainfall record, statistical analyses of this dataset indicate some definitive long-term shifts. During the 69-year period, there has been a shift towards a drier condition with more frequent years showing below average rainfall especially for the cool season months. More recently during the past 20 years, there have only been 5 years (2003, 2007, 2009, 2011, and 2018) that showed higher rainfall amounts than the climate average. It is interesting to note that since 1952, 25 per cent of the driest years have occurred during the past 20 years while another 25 per cent have occurred during the 1981-2000 period, 40 per cent were registered from 1961 to 1980 and the remaining 10 per cent occurred from 1952 to 1960.

Results also show that 2016 had the least rainfall (324.8 mm) followed by 2001 (338.2 mm) and 2020 (386.9 mm). The occurrence of dry years such as these is very likely to be due to a combination of long-term natural variability and changes in regional circulation caused by increasing greenhouse gas levels in the atmosphere[6].

Data for the annual total rainfall anomaly during the 1952-2020 period shows a negative trend of around 10.3 mm of rainfall per decade (**Chart 3.2**). Local drought conditions seem to have increased in frequency especially during the last two decades; however, an explanation of the related physical processes is beyond the scope of this publication.

[6] https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Headline_Statements.pdf

CHART 3.2. Trend of the annual total rainfall anomaly from the climate average for the period 1952-2020

When compared to the climate average, the month of October shows the strongest decrease in rainfall since 1952, followed by December and January. The decrease in rainfall for October over this period is calculated to be 46.5 mm, which is equivalent to 6.7 mm per decade.

The decrease in rainfall during autumn and winter is indeed problematic for several economic sectors, primarily agriculture, since these months customarily provide most of the natural freshwater supply for growing seasonal crops and for the replenishment of Malta's freshwater aquifers and water reservoirs.

A monthly comparison of the Climate Normal of 1961-1990 with the last 30-year period of 1991-2020 shows that the three months that registered the highest increases in rainfall were September (18.9 mm), November (9.1 mm) and February (7.6 mm) (**Charts 3.3** and **3.4**). September's positive trend anomaly with respect to the climate average is equivalent to an increase of 3.6 mm per decade for that month, which is much less than the measured decrease observed for the month of October.

CHART 3.3. Monthly mean total rainfall based on the 30-year Climate Normal of 1961-1990

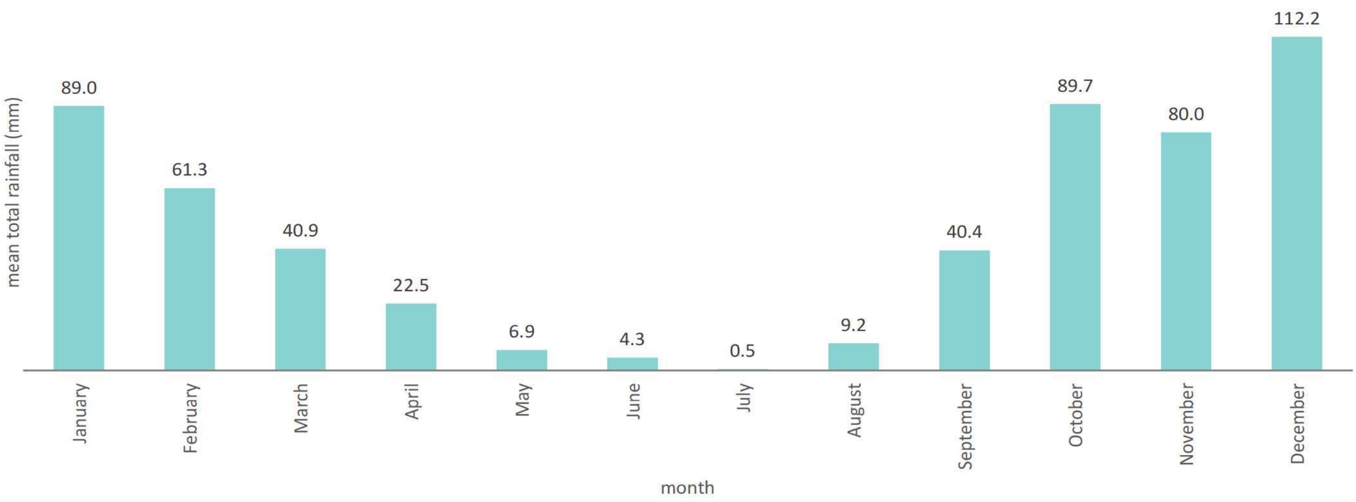


CHART 3.4. Monthly mean total rainfall registered during the 30-year period of 1991-2020

The observed declining trend in rainfall is most probably associated with higher atmospheric pressures over Malta accompanied by a shift in large-scale weather patterns characterised by more highs and fewer lows (see further below). The observed increase in atmospheric pressure over Malta and in the central Mediterranean in general is a known response to a changing climate[7]. Other studies also document a reduction in the number and duration of weather instabilities and cyclonic features over the central Mediterranean, which are considered to be the most important processes that induce local rainfall during the cooler part of the year.

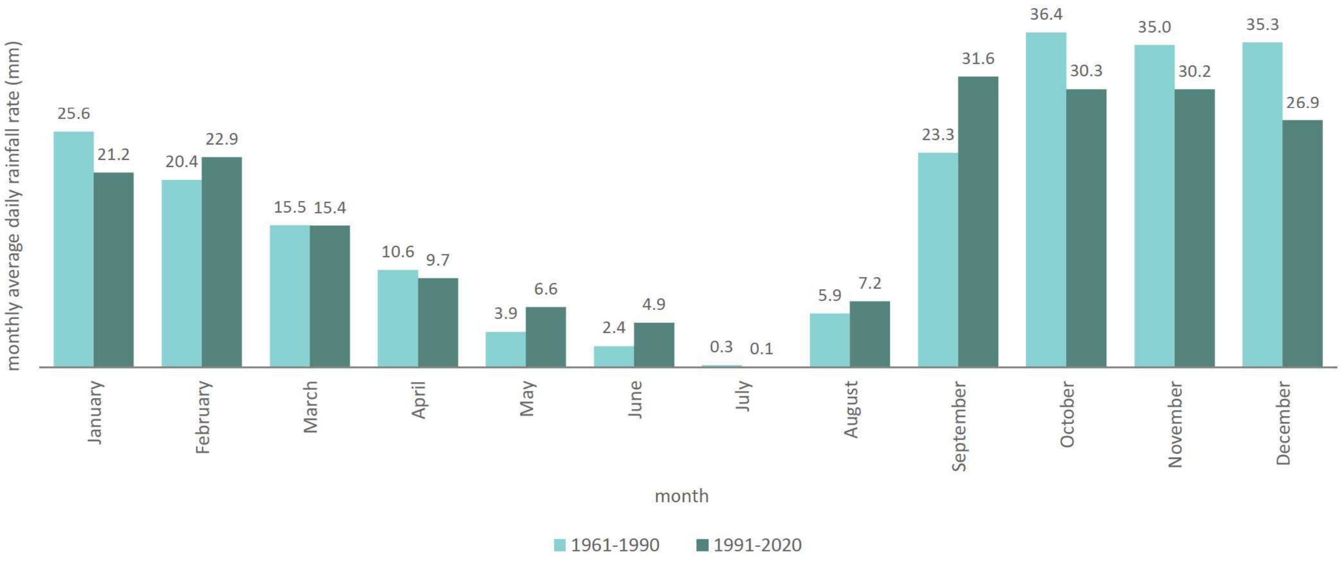
3.2. Daily rainfall rates

The calculation of rainfall rates quantifies how much it rains over a certain location in a set period. It provides a measure of how heavy the rainfall is and because extreme rainfall can cause floods, it is often used as a valuable weather element for studies on urban planning and hydrology. The analyses of the temporal distribution of rain in terms of rainfall rate provides a way to distinguish light from heavy rainfall events.

Chart 3.5 shows some interesting patterns for the daily rainfall rates. During the typically wet months, such as October till December, the daily rainfall rates are clearly decreasing. This can be attributed to less vigorous rainfall associated with weaker lows over the central Mediterranean. On the other hand, the usually dry months of May, June, August and September are showing higher daily rainfall rates during the past 30 years (1991-2020). This can be attributed to a shift in the intensification of the water cycle during this period over the central Mediterranean due to increased atmospheric warming.

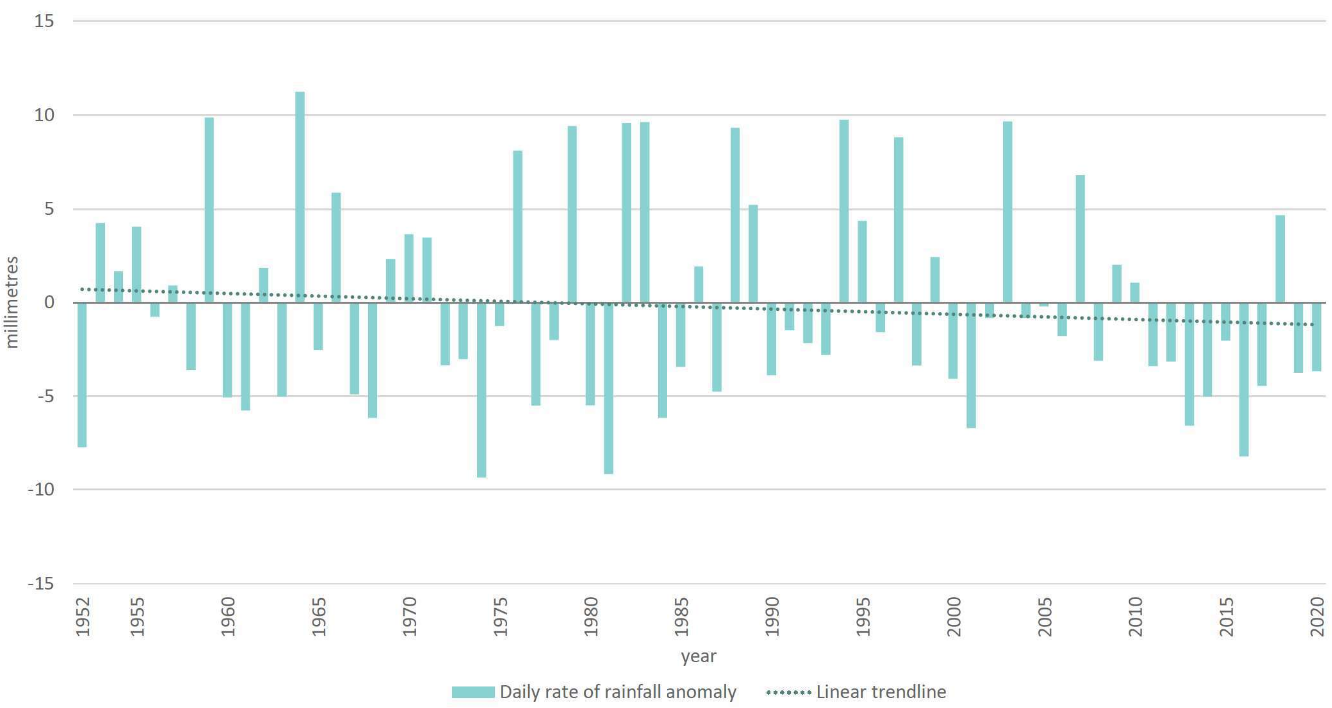
[7] Tuel A, and Eltahir E A B, (2020). Why Is the Mediterranean a Climate Change Hot Spot? Journal of Climate 33.14; 5829-843.

CHART 3.5. Monthly daily rainfall rates of the Climate Normal of 1961-1990 and of the 1991-2020 period



Generally, the trend of the daily rainfall rate anomaly measured at Luqa Airport is decreasing over time with respect to the climate average, amounting to around 0.3 mm per decade since 1952 (**Chart 3.6**). In a similar fashion to monthly rainfall totals, the strongest decrease during the 1991-2020 period when compared to the climate average is seen to occur during the rainy season months of October, November, December and January.

CHART 3.6. Trend of the daily rainfall rate anomaly from the climate average for the period 1952-2020



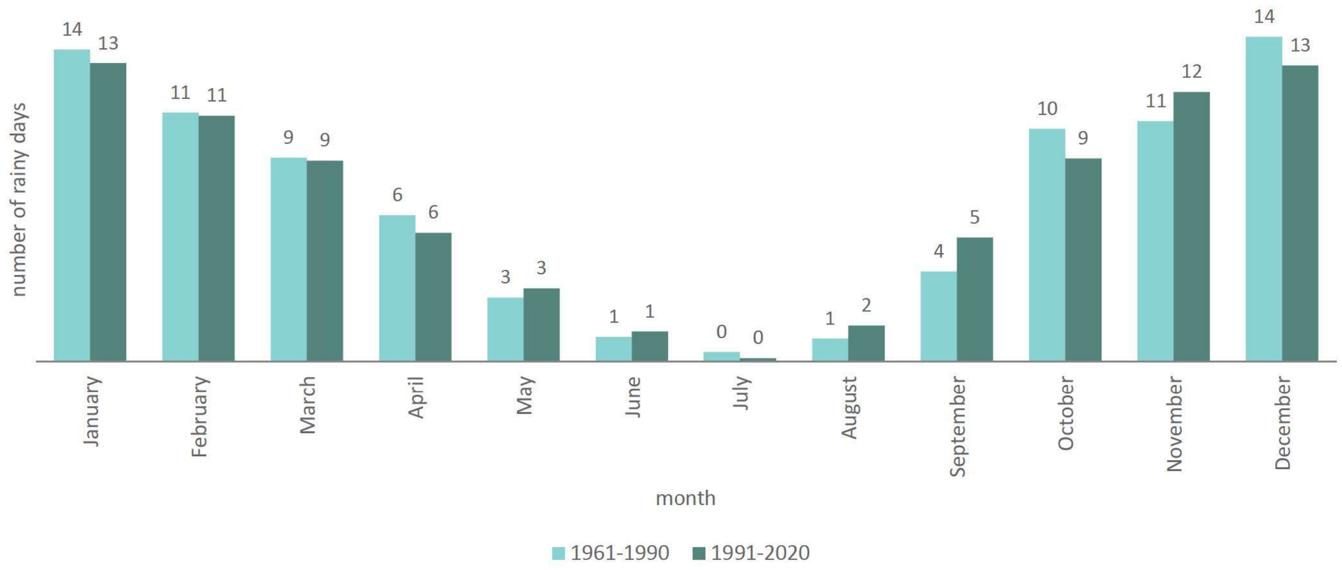
Since 2001 there have only been three years that rank among the 20 highest daily rainfall rate episodes occurring from 1952 onwards, these being 2003 (27.5 mm/day), 2007 (24.7 mm/day) and 2018 (22.6 mm/day).

3.3. Number of rainy days

Changes in the pattern of the number of rainy days may significantly affect the attribution of a shifted hydrological cycle over the central Mediterranean Sea, including runoff, floods and droughts. A study of the change in the number of rainy days in combination with the rainfall rate can be valuable towards the further understanding of the climate system and of the underlying weather dynamics.

A study of the mean number of rainy days aggregated by month over the two 30-year periods of 1961-1990 and 1991-2020 show a small but noticeable shift in the pattern of rainy days (**Chart 3.7**). Reductions in the number of days occurred for January, October and December, while increases were noted for August, September and November. The number of rainy days for the remining months remained relatively stable.

CHART 3.7. Monthly means for the number of rainy days for the Climate Normal of 1961-1990 and the 1991-2020 period



The year 2020 ranks as the 4th year for the lowest amount of annual rainy days since 1952. It is interesting to note that while a statistically significant negative anomaly trend has been observed in both the total rainfall and the daily rainfall rate (**Charts 3.2** and **3.6**), the annual mean anomaly trend in the number of days with rain is not statistically significant at the 95 per cent confidence level. Evidently, a longer time-series is needed in order to determine the nature of any upward or downward trend of the number of rainy days over time, given the nature of its variability.

04 ATMOSPHERIC PRESSURE

Surface atmospheric pressure is an essential meteorological element controlling weather systems and therefore is an important indicator of the behaviour of weather. Its observation is a requirement for the understanding of long-term past weather systems that are closely linked to known variations in global and regional climate. The mean sea level pressure is one of the most familiar variables that is communicated to the public.

Key messages:

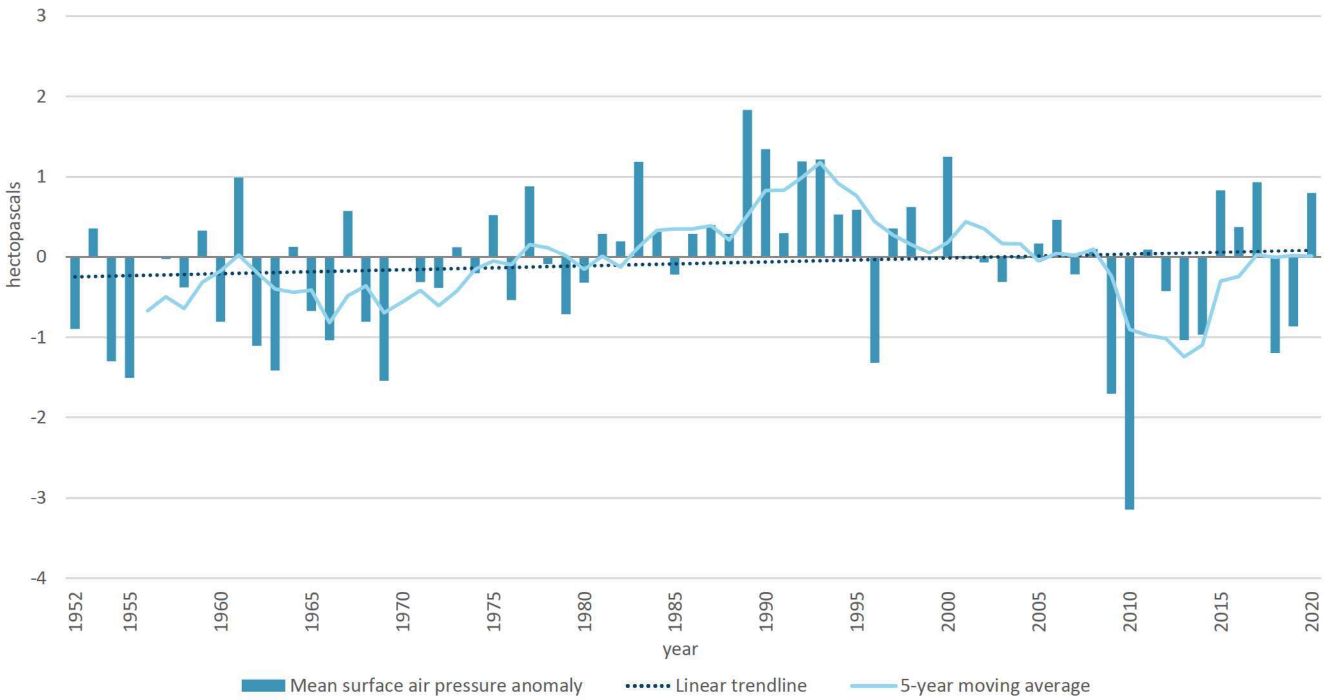
- Between 1952 and 2020, the atmospheric pressure has increased by 0.05 hPa per decade, equivalent to 0.3 hPa over 69 years.
- During the past 69 years, atmospheric pressure for the months of January to March and December shows a positive anomaly trend from the climate average.

4.1. Mean sea level air pressure

This important weather element is compiled and published daily on the local media. In actual fact, atmospheric pressure is monitored continuously at a much higher temporal resolution and its dissemination to the civil aviation community happens at least every 30 minutes. Its continuous monitoring is very important for activities that are particularly weather sensitive such as aviation, maritime, agriculture, construction sectors as well as outdoor events, including sports. The most obvious information of the surface atmospheric pressure is its variation with respect to atmospheric stability. Its variation indicates the likelihood of weather instability, rainfall, and changes in temperature as well as wind strength.

During the period 1952-2020, the atmospheric pressure has increased by 0.05 hPa per decade, or 0.3 hPa over 69 years. Looking at the average annual values of this weather element, an overall positive anomaly trend from the climate average can be seen (**Chart 4.1**). It also features a conspicuous negative anomaly of 3.1 hPa for 2010, a first since 1952. On the other end of the scale, the calendar year 1989 registered the highest average annual positive anomaly of 1.8 hPa since 1952.

CHART 4.1. Annual mean surface atmospheric pressure anomaly from the climate average for the period 1952-2020



From a monthly point of view, all months except April to November show a positive anomaly trend from the climate average during the past 69 years. The overall annual positive trend seen in **Chart 4.1** is signifying that that the overall positive trend seen during the cooler seasons is strong enough to completely override the negative anomalies. From a meteorological point of view, the overall increasing trend in the surface pressure during the cooler months has a determining effect on the local climatology and is indicative of a higher frequency of anticyclonic, atmospherically stable conditions over Malta, leading to less cloud cover (**Charts 1.2** and **1.3**) and rainfall (**Chart 3.2**), lower wind speeds (**Chart 5.1**) and warmer temperatures (**Charts 2.2** and **2.3**).

05 NEAR-SURFACE WINDS

Winds over Malta are associated with the variability of the regional-scale air circulation patterns over the Atlantic, Euro-Mediterranean and African regions. Near-surface winds, measured at 10 metres above the ground, influence those physical processes related to the transfer of energy between the atmosphere and the underlying surface. They drive ocean waves and storm surges whenever strong enough. The 10-metre wind is a sensitive indicator of the state of the climate system and its analysis is very important for understanding climate variability and climate change. Moreover, a proper understanding of this weather element can have direct application to many sectors including aviation safety and efficiency, construction, energy production, air quality and emergency management. It also provides essential information to Malta's maritime sector, with particular relevance to fishing, transhipment, bunkering and other related activities that are affected by strong winds.

Key messages:

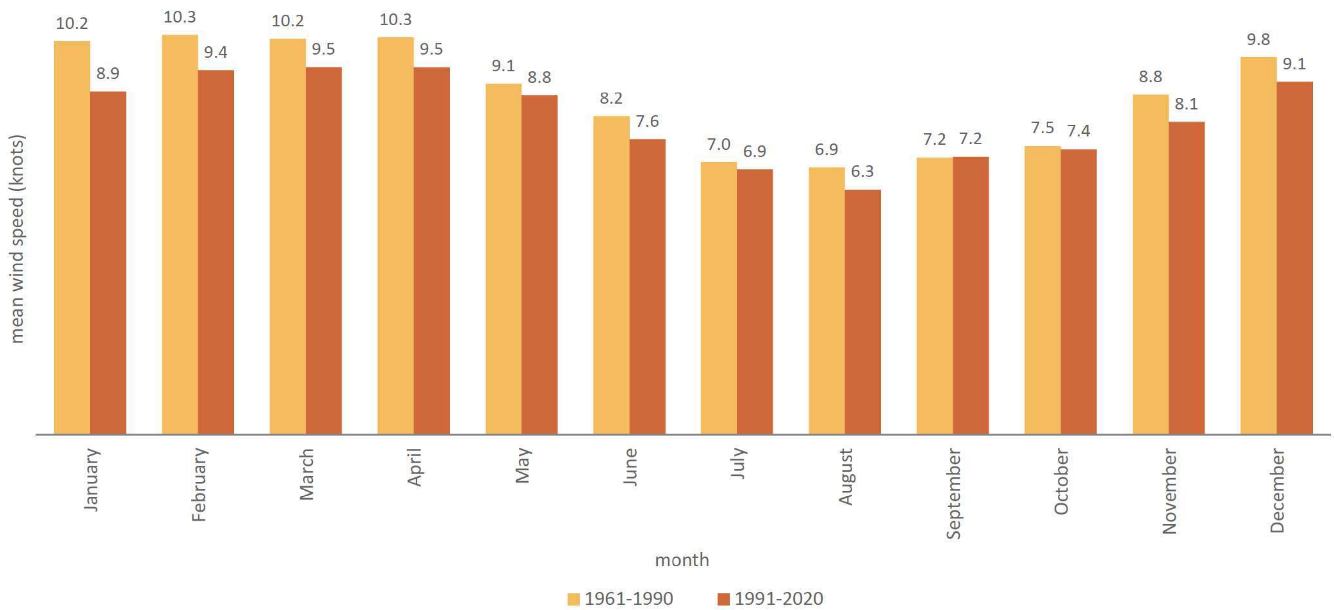
- The wind speed shows a declining trend of 0.8 knots (0.4 metres per second) over the past 60 years.
- Since 1961, 65 per cent of the top 20 calendar years that showed the highest decrease in wind speed from the climate average occurred since 2001.
- The steepest reduction in the overall wind speed has occurred during winter, followed by spring, summer and autumn[8].
- The most common wind direction continues to be north-westerly (292.5°-337.5°, centred at 315°), followed by westerly (247.5°-292.5°, centred at 270°) and the easterly (67.5°-112.5°, centred at 90°).

5.1. Mean wind speed

The monthly climatology of the near-surface winds determined from anemometers situated at Luqa Airport is shown in **Chart 5.1** below. The information shows the difference in the observed wind speed between Malta's Climate Normal of 1961-1990 and the latest 30-year period of 1991-2020. A slight but consistent decrease in the wind speed can be seen during the past 30 years when compared to the climate average. From a dynamic point of view this meteorological pattern is suggestive of a more stable atmosphere over Malta, reinforcing yet again the assertion of a local climate that is becoming warmer and drier.

[8] In the Northern Hemisphere meteorological seasons are constituted as follows: Winter – December, January, February; Spring – March, April, May; Summer – June, July, August; Autumn – September, October, November.

CHART 5.1. Monthly means for the mean wind speed for the Climate Normal of 1961-1990 and the 1991-2020 period

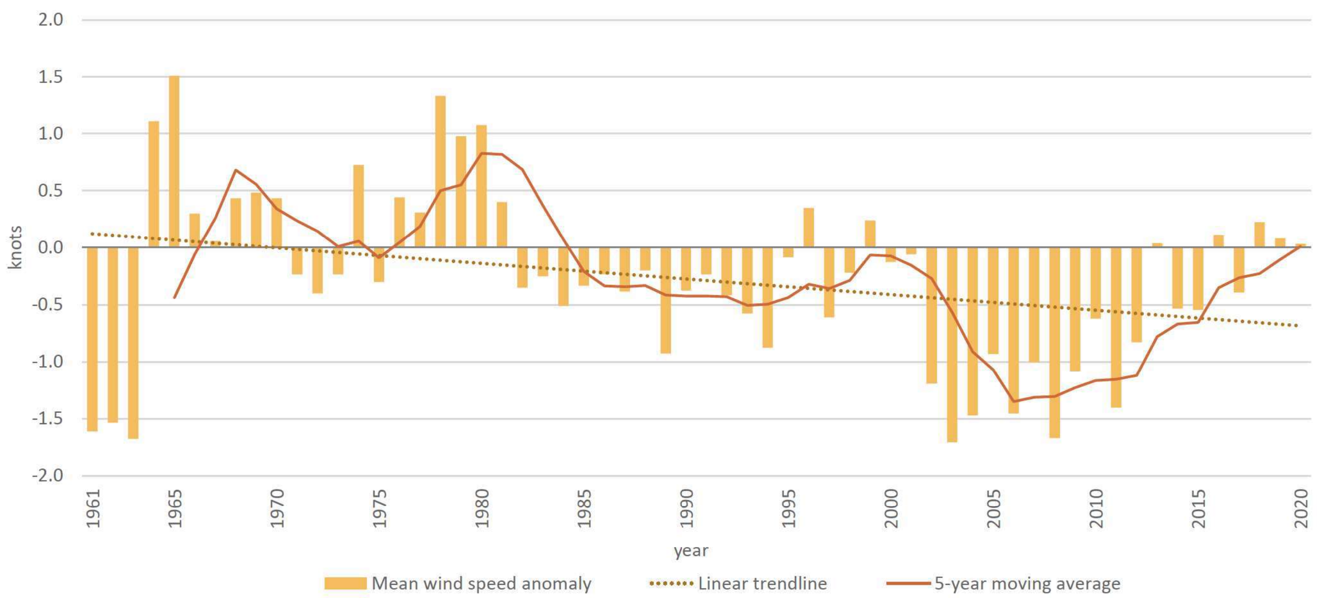


Similar declining trends have also been observed in mid-latitudes (Vautard et al. 2010[9], McVicar et al. 2012[10]) and this has been attributed mainly to an increasing trend in the mean sea level atmospheric pressure (**Chart 4.1**).

An analysis of the wind speed over the past 60 years shows an overall decline of 0.8 knots (0.4 metres/second), equivalent to 0.1 knots (0.07 metres/second) per decade. Since 1961, 65 per cent of the top 20 calendar years that showed the highest decrease from the climate average have occurred since 2001. The rest are spread out over the remaining 40 years. This may be indicative of climatic processes that have affected the local wind speed as a result of increased anomalies in the other co-dependent climate variables, such as the mean sea level pressure over Malta.

The annual average wind speed anomaly from the climate average is shown in **Chart 5.2**. The 5-year moving average brings out both (i) a cyclic nature of this climatic variable, and (ii) the diminishing magnitude of the wind speed since 1961. Future data in the next 20 years or so will tell us whether the local climate will continue to be under the spell of a positive anomaly cycle but at a reduced wind speed.

CHART 5.2. Annual mean wind speed anomaly from the climate average for the period 1961-2020

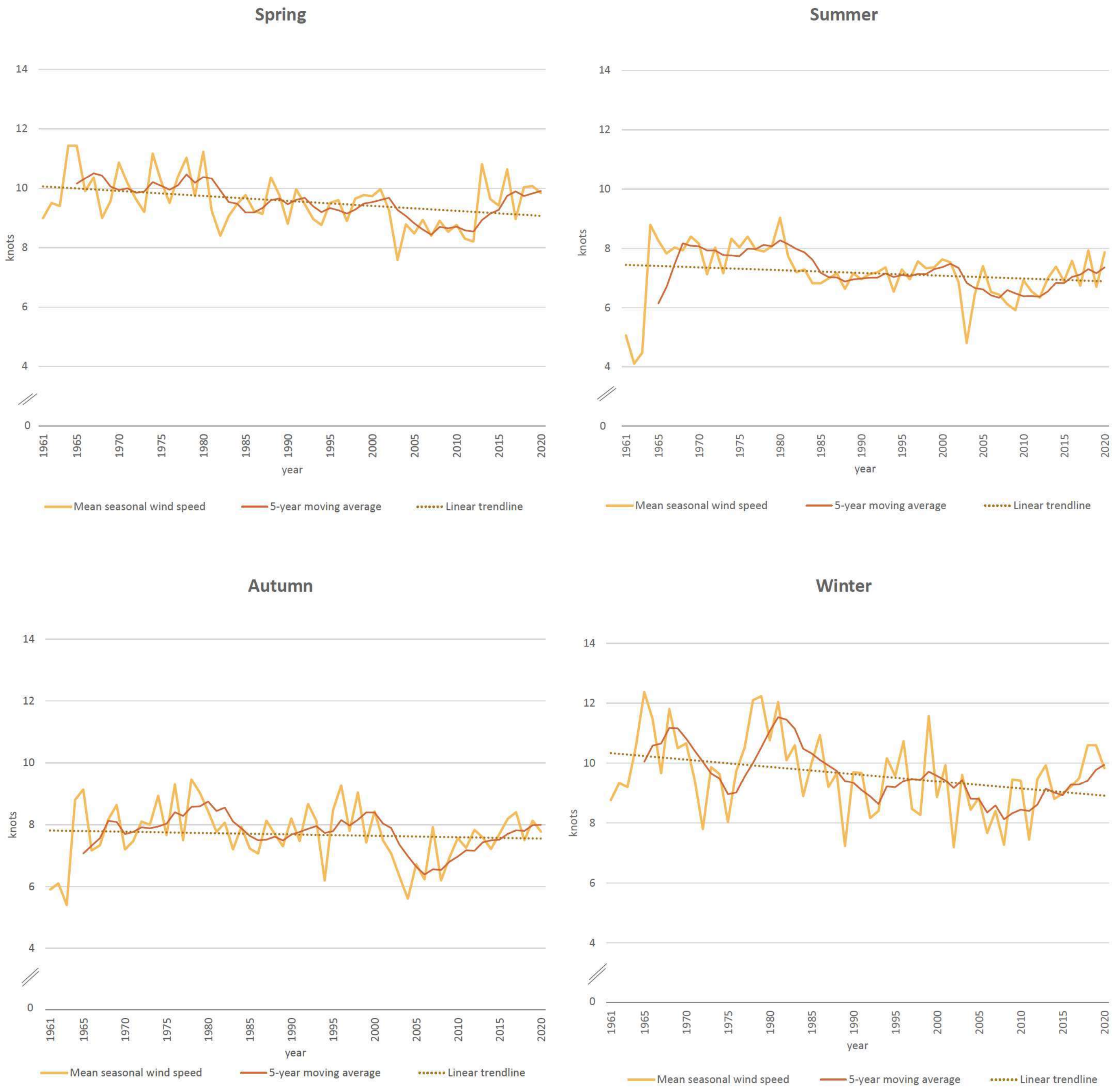


9 Vautard R, Cattiaux J, Yiou, P. et al. (2010). Northern Hemisphere atmospheric stilling partly attributed to an increase in surface roughness. Nature Geoscience 3, 756–761. https://doi.org/10.1038/ngeo979

10 McVicar TR, Roderick ML, Donohue RJ, Li LT, Van Niel TG, Thomas A, Grieser J, Jhajharia D, Himri Y, Mahowald NM, Mescherskaya AV, Kruger AC, Rehman S, Dinpashoh Y,(2012). Global review and synthesis of trends in observed terrestrial near-surface wind speeds: Implications for evaporation. Journal of Hydrology, Volumes 416–417, 182-205. ISSN 0022-1694. https://doi.org/10.1016/j.jhydrol.2011.10.024.

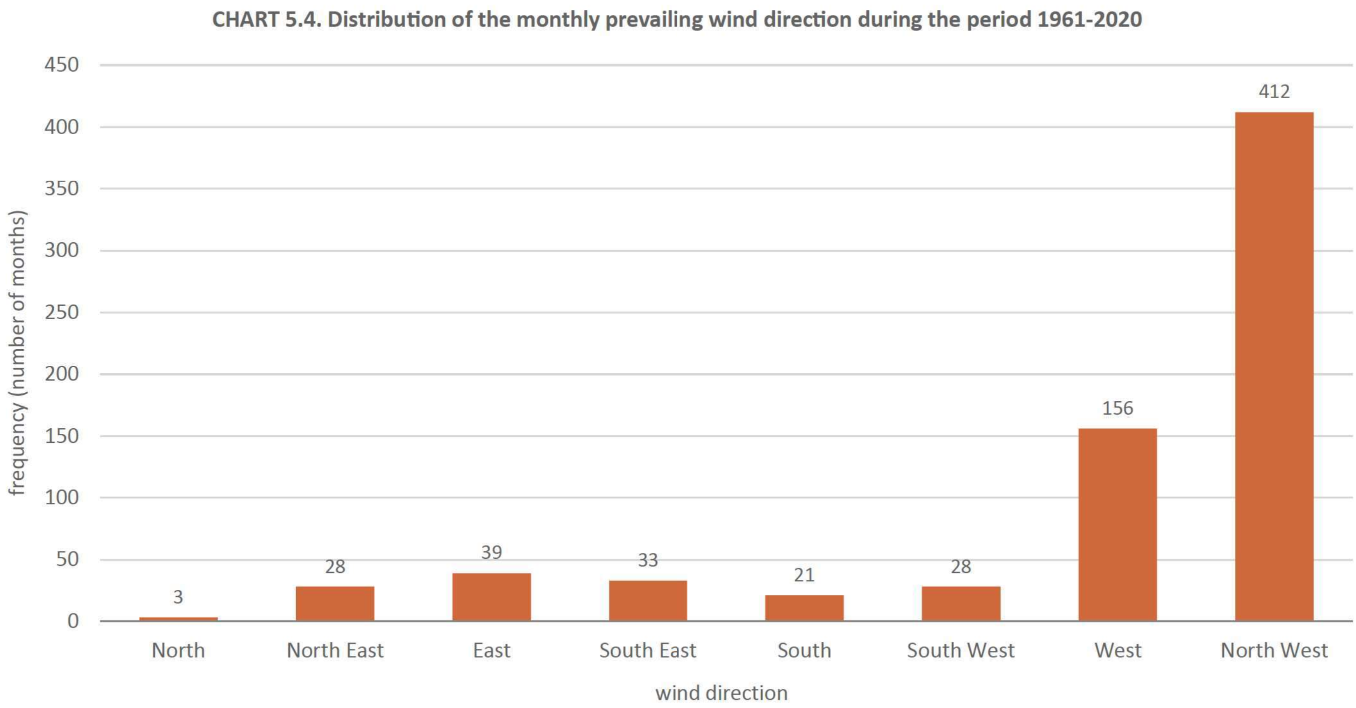
A seasonal analysis of the 60-year period shows that the steepest reduction in the overall wind speed has occurred during winter, followed by spring, summer and autumn (**Chart 5.3**). This is indicative of a generally calmer winter over Malta. However, this tendency does not exclude the occurrence of extreme wind events such as local gale force winds and storm surges.

CHART 5.3. Seasonal trends of the annual mean near-surface wind speed between 1961 and 2020



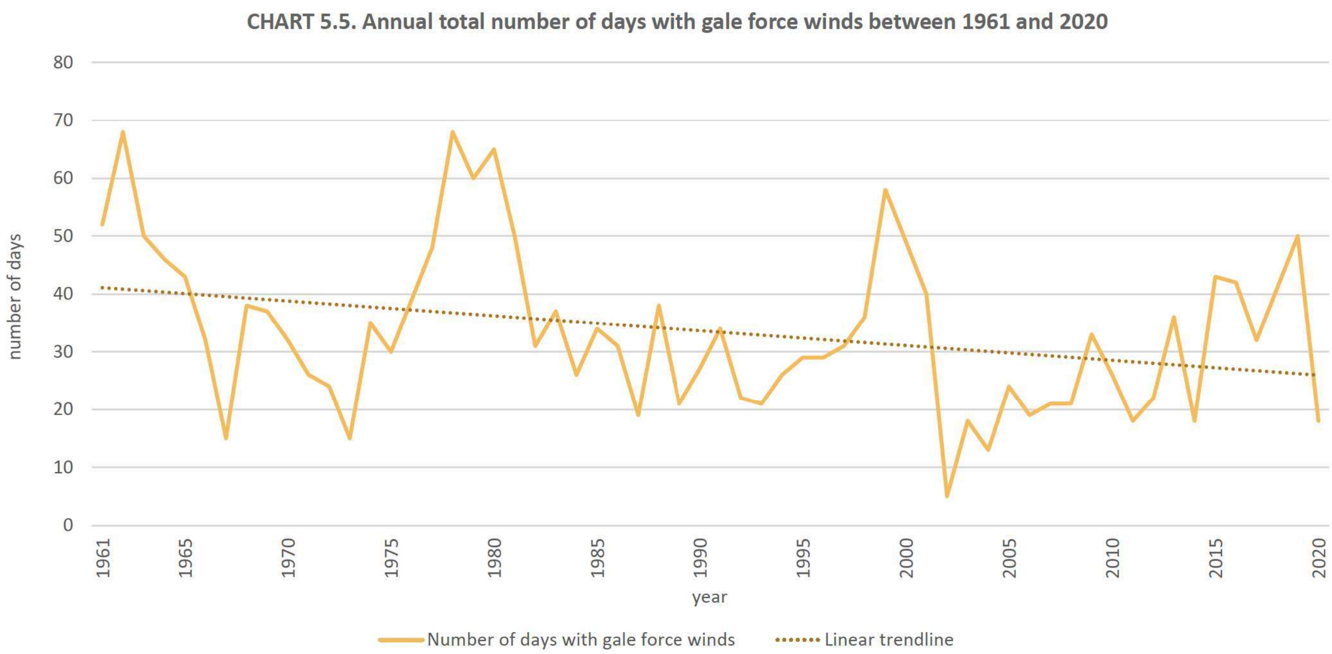
5.2. Wind direction

During the 1961-2020 period, the most common wind direction continued to be the north-westerly (292.5°-337.5°, centred at 315°), followed by the westerly (247.5°-292.5°, centred at 270°) and the easterly (67.5°-112.5°, centred at 90°) (**Chart 5.4**).



5.3. Frequency of gale force winds

All months show an overall decreasing trend in the number of gale force wind events between 1961-2020. The month of April shows the strongest decrease followed by February and December. This overall decreasing trend is in conformity with a local climate that is being characterised by an increasing surface air pressure (**Chart 4.1**) and a decreasing wind speed (**Chart 5.2**).

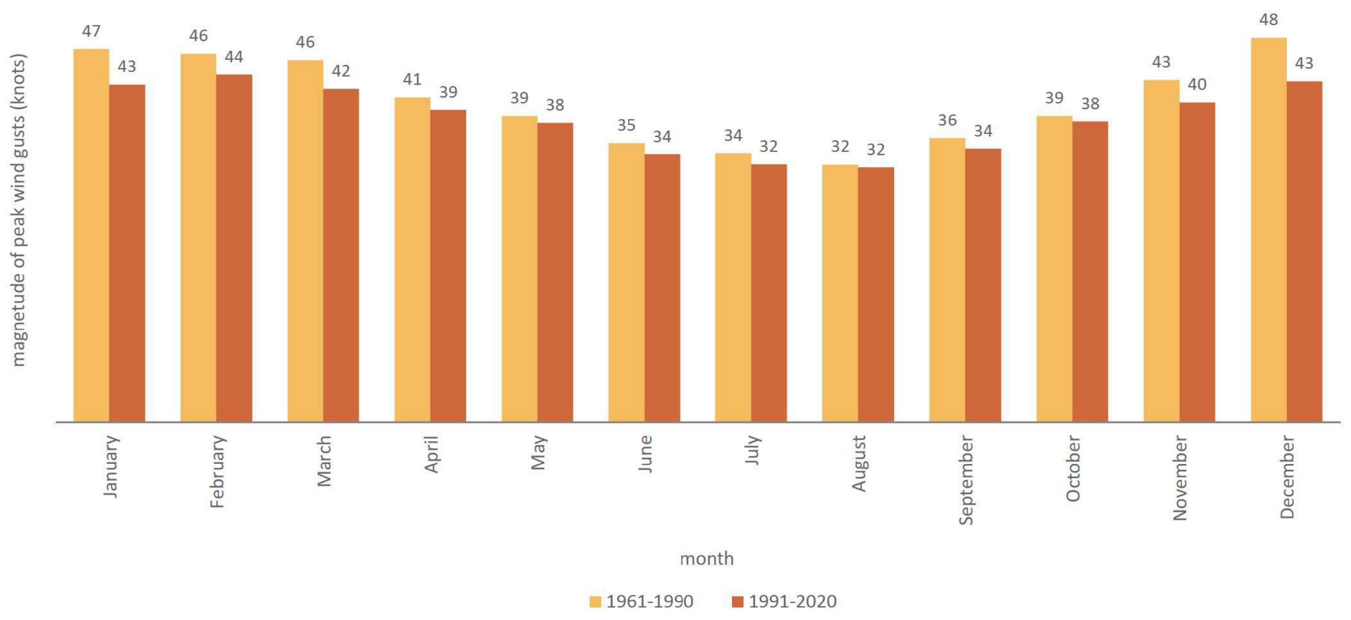


5.4. Peak wind gusts

A wind gust is a sudden, brief increase in the speed of the wind followed by a lull. The strongest wind gust recorded in Malta was a gust of 72 knots that occurred in October 1982. Gusts at the ground are caused by either turbulence due to friction, wind shear or by solar heating of the ground. These three mechanisms can force the wind to quickly change speed as well as direction.

The monthly climatology of the peak wind gust for the 1961-1990 Climate Normal together with the average over the 1991-2020 period are shown in the chart below (**Chart 5.6**). Yet again a slight decrease in the peak wind gust for all months during the latter 30-year period in comparison to the Climate Normal can be detected. This conforms with an increasingly stable, less windy weather over Malta.

CHART 5.6. Monthly means for the peak wind gust (knots) for the Climate Normal of 1961-1990 and the 1991-2020 period



06 RELATIVE HUMIDITY

Humidity is a measure of the amount of water vapour contained in the atmosphere. Surface humidity is an important component of local weather; moreover, high or relatively low humidity levels can have significant ecological, agricultural and health-related impacts. Humidity governs the increasing likelihood of heavier rainfall and more dangerous heatwaves arising from increased thermal heat stress. There are many ways how humidity content can be measured and monitored in the atmosphere. The relative humidity is one such type of measurement and is defined as the ratio of mole fraction of actual water vapour, to a mole fraction of water vapour that can be saturated in dry air, where the two values are obtained at the same temperature and pressure.

Key messages:

- A strong negative trend has occurred, equivalent to 4.7 percentage points in relative humidity for the entire period of 1961-2020. This is equivalent to 0.8 percentage points per decade.
- The strongest negative trends in relative humidity have been seen to occur during the warmer months (May-September).
- 75 per cent of the years with the lowest 20 relative humidity anomalies have been registered from 2001 onwards.

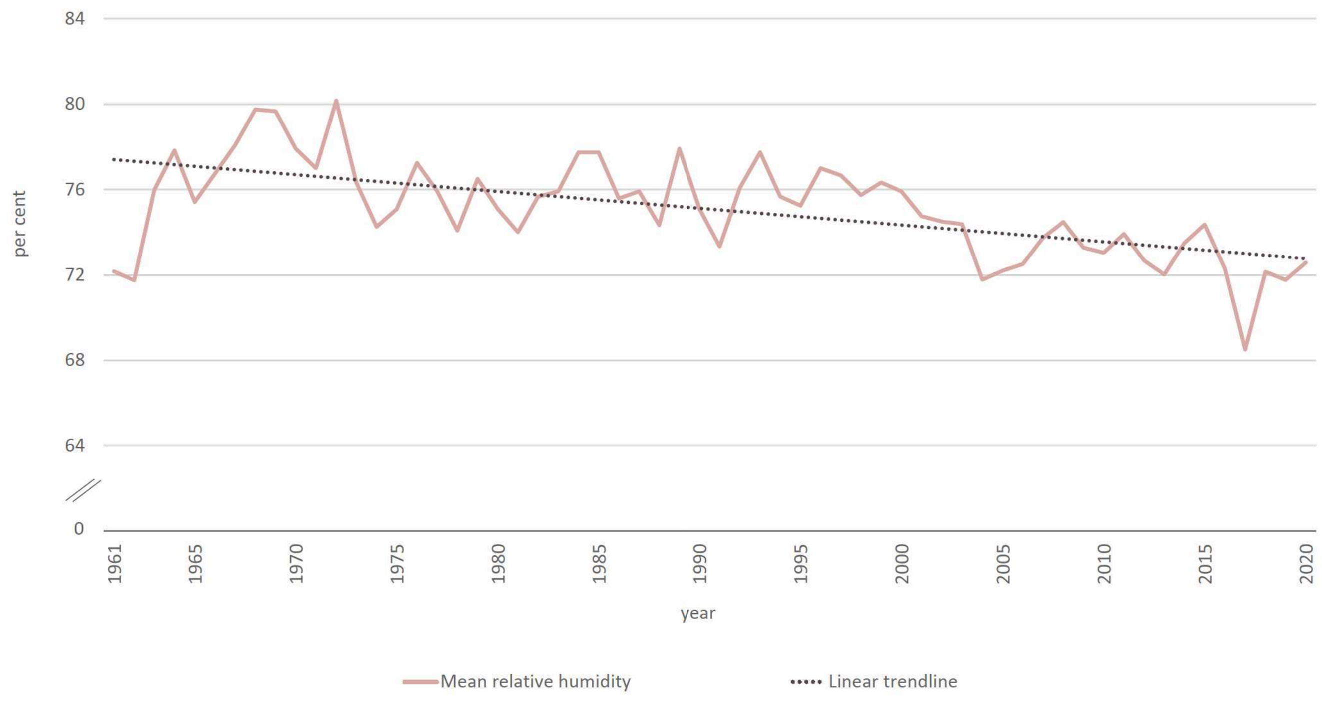
6.1. Mean air relative humidity

Global atmospheric levels of specific humidity (defined as the weight of water vapour in the air), have increased[11]. This is in line with the theoretical expectation for an atmosphere that can hold more water vapour in virtue of its warming, making humidity and temperature the twin pillars of a changing climate. Moreover, global observations show that the air over land is becoming less humid which is consistent with land warming at a faster rate than the ocean, where most evaporation happens.

When looking at the local relative humidity levels over time, a strong negative trend can be seen (**Chart 6.1**). The decrease is equivalent to 4.7 percentage points for the entire period of 1961-2020, or to 0.8 percentage points per decade. Interestingly, the strongest negative trends in relative humidity have been observed to occur during the warmer months (May-September). Based on the above explanation, this conforms with the local trends in temperatures observed during the same period (**Chart 2.3**).

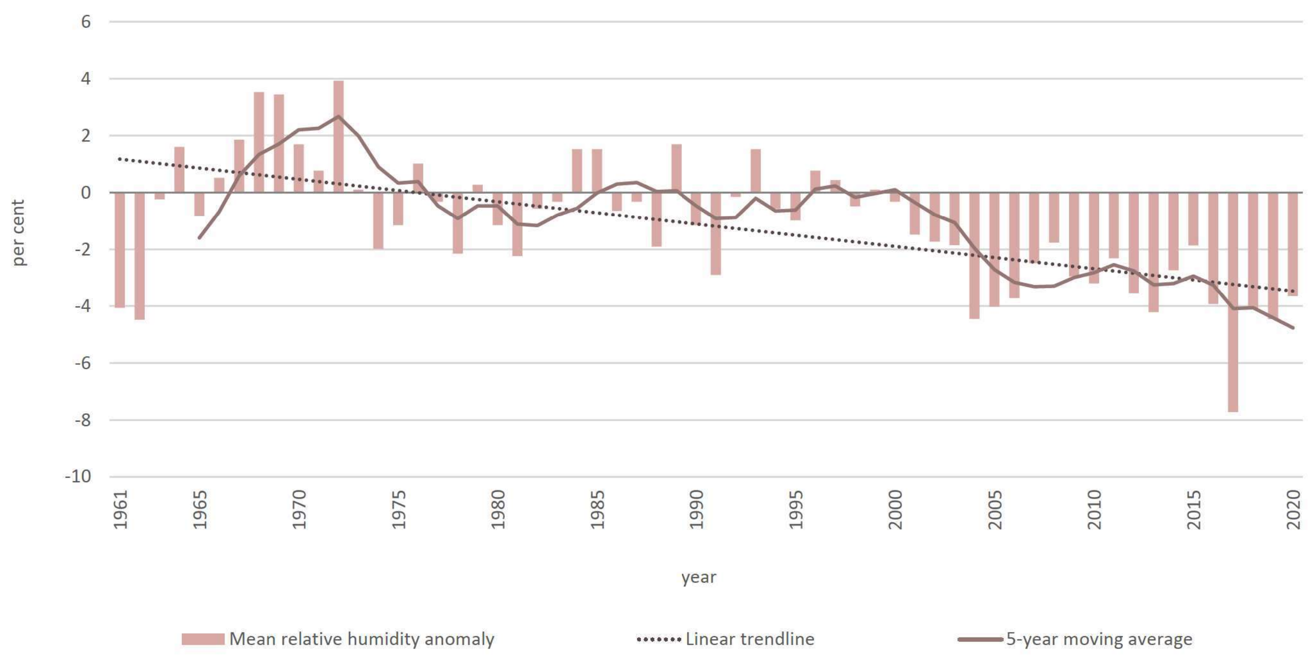
[11] Stocker TF, Qin D, Plattner GK, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, and Midgley PM (eds.), IPCC, (2013). The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

CHART 6.1. Annual mean relative humidity from 1961 to 2020



The latest meteorological records show that since 1961, 75 per cent of the years with the 20 lowest relative humidity anomalies have occurred during the past 20 years (**Chart 6.2**). This corroborates the tendency of a warming climate with an atmosphere that can hold more water vapour, and therefore the relative humidity tends to decrease as a result of this increased capacity.

CHART 6.2. Annual mean relative humidity anomaly from the climate average for the 1961-2020 period



07 SEA TEMPERATURE

The large-scale spatial patterns of sea temperature are related to large-scale weather patterns and since the oceans continuously interact with the atmosphere, the sea temperature can also have profound effects on global climate. For example, increases in sea temperature have led to an increase in the amount of atmospheric water vapor over the oceans affecting therefore the water cycle. Changes in sea temperature can shift storm tracks, potentially contributing to droughts in some areas[12], such as the central Mediterranean.

Key messages:

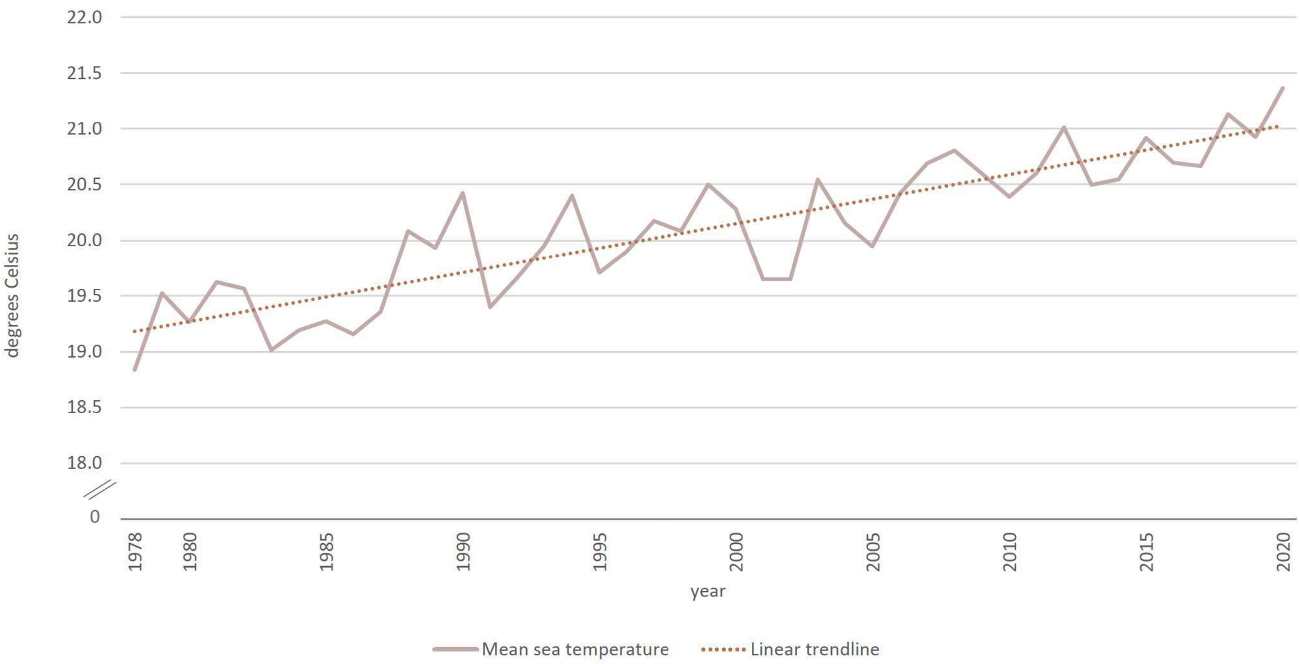
- The highest mean sea temperature was registered during August of 2003 and 2020 when a temperature of 28.0 °C was recorded.
- 60 per cent of the 20 maximum monthly mean sea temperatures occurred during the last 20 years.
- Results show a decadal increase of 0.4 °C in the mean sea temperature of Maltese waters since 1978.

7.1. Mean sea temperature

When looking at the 1978-2020 time-series trend of the annual mean sea temperature for Malta's coastal waters, the calculated increase over this 43-year period is 1.9 °C which translates into a decadal increase of 0.4 °C (**Chart 7.1**). This is indeed significant and can be detrimental to the survival of coastal and marine ecosystems that are highly sensitive to changes in their ambient temperature.

[12] https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_TS.pdf

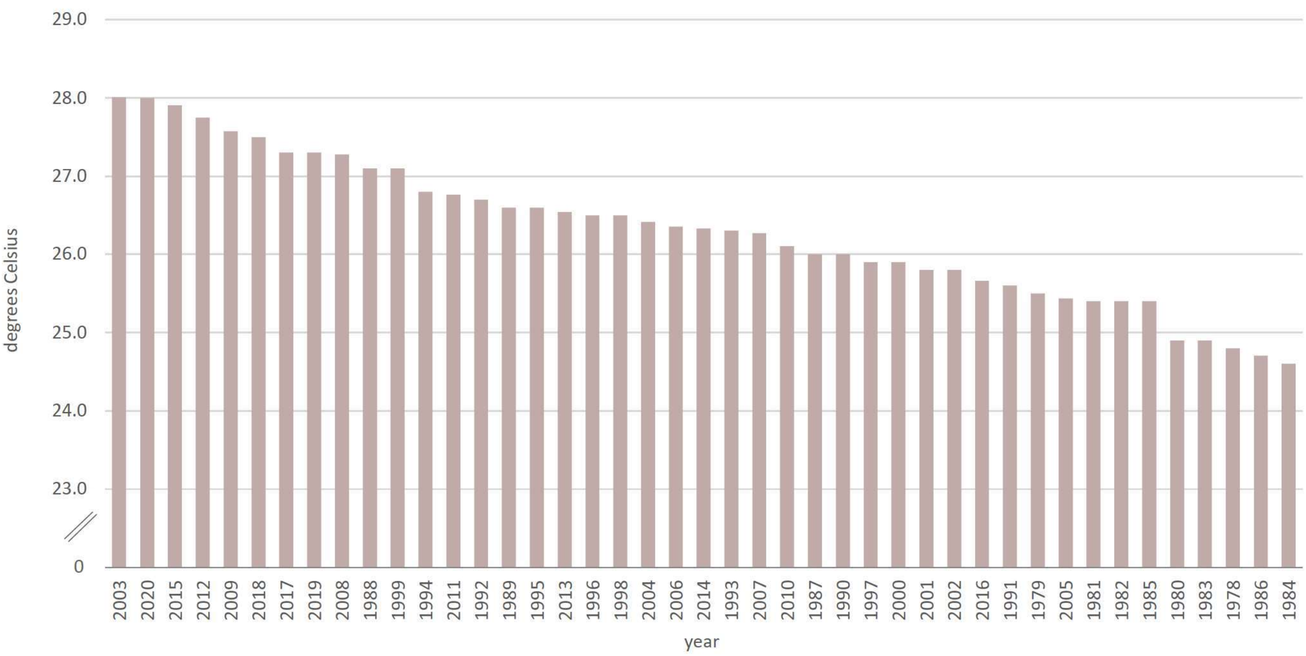
CHART 7.1. Time series of the annual mean sea temperature from 1978 to 2020



7.2. Monthly maximum mean sea temperature

The highest maximum mean sea temperature reported by the Meteorological Office since the start of this data collection in 1978 was during August of 2003 and 2020 when a temperature of 28.0 °C was recorded. This was followed by August 2015 (27.9 °C) and August 2012 (27.8 °C). Interestingly, 60 per cent of the 20 highest maximum monthly mean sea temperatures that occurred since 1978 were registered during the last 20 years, while 30 per cent were recorded during the 1990s (**Chart 7.2**). This points to the occurrence of stronger oceanic changes occurring in recent years due to increased heat absorption.

CHART 7.2. Ranked time series of the maximum monthly mean sea temperature from 1978 to 2020



08 NUMBER OF DAYS WITH THUNDERSTORMS

Thunderstorms result from atmospheric instability and may be classified as airmass thunderstorm, frontal thunderstorm, and squall-line thunderstorm on the basis of the overall weather situation at the time of their occurrence. Studies show that global warming should increase atmospheric instability arising from increased surface warming and higher water vapour loads in the atmosphere[13].

Key messages:

- The number of days with thunderstorms has increased during the period 1952-2020.
- The autumn period is Malta's most thundery season, while the month of November registered the greatest increase in thunderstorms.

8.1. Number of days with thunderstorms

Climate records show an increase in the number of days with thunderstorms between 1952 and 2020 (**Chart 8.1**). In general, local meteorological records point towards an increase in the number of days with thunderstorms during the most recent 30-year climate period when compared to the previous one.

From a monthly point of view, when comparing the 1991-2020 period to the Climate Normal, thunderstorm activities have increased or remained stable during all months except for April, October and December (**Chart 8.2**). These records show that the autumn period is Malta's most thundery season, while the month of November registered the greatest increase.

[13] Trapp RJ, Diffenbaugh NS, Brooks HE, Baldwin ME, Robinson ED, Pal JS (2007). Changes in severe thunderstorm environment frequency during the 21st century caused by anthropogenically enhanced global radiative forcing. Proceedings of the National Academy of Sciences, 104 (50) 19719-19723; DOI: 10.1073/pnas.0705494104

CHART 8.1. Time series of the maximum number of days with thunderstorms recorded in a single month and the mean number of days with thunderstorms per month registered between 1952 and 2020

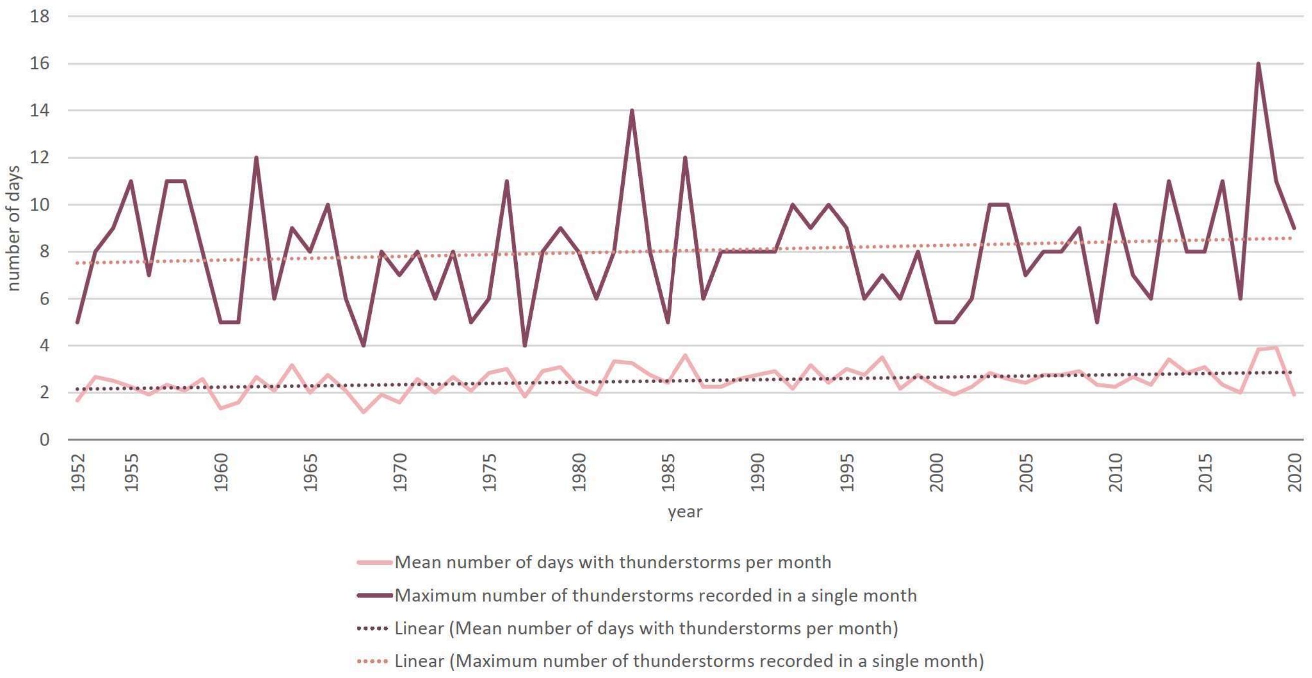
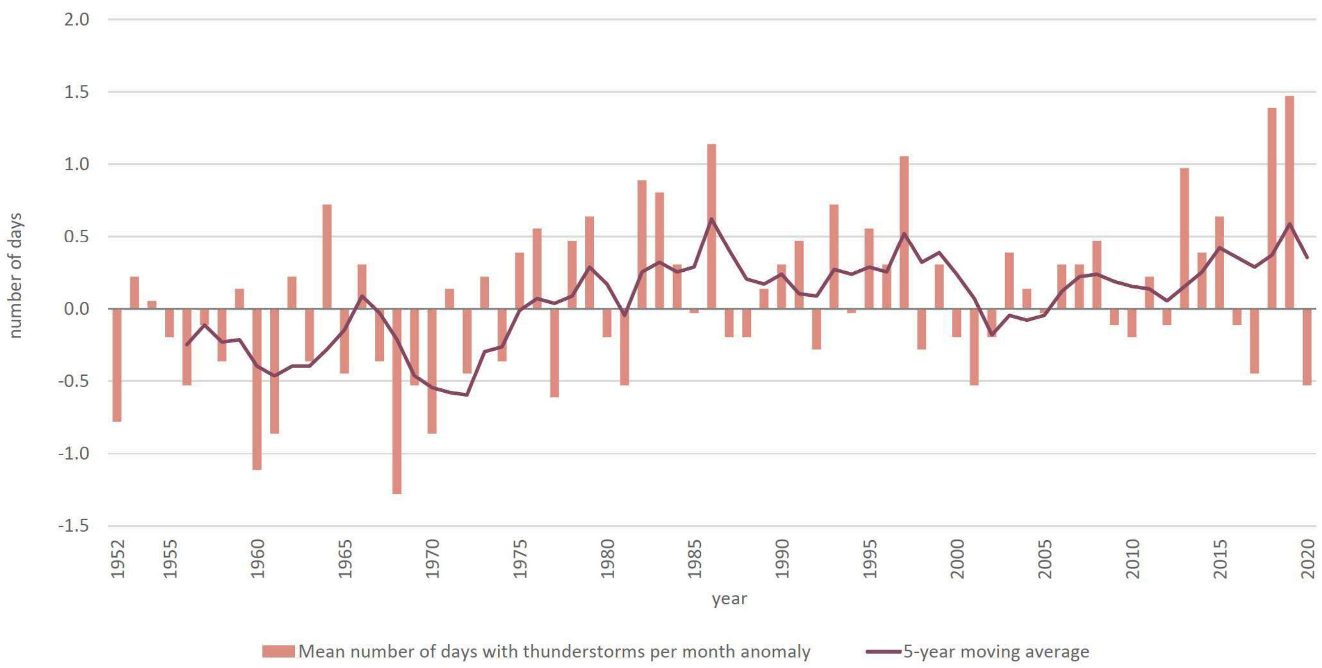


CHART 8.2. Mean monthly number of days with thunderstorms for the Climate Normal of 1961-1990 and for the 1991-2020 period

The average annual number of days with thunderstorms anomaly for the period 1952-2020 is shown in **Chart 8.3**. The increase in the frequency of positive anomalies is evident from 1982 onwards. Besides, whenever negative anomalies occur, these do not exceed the 0.5 days per month, in contrast to previous years where the magnitude of negative anomalies is higher. These results can be indicative of the impacts arising from a warmer Mediterranean Sea and of an increased Convective Available Potential Energy (CAPE)[14] over Malta.

[14] http://www.atmo.arizona.edu/students/courselinks/spring08/atmo336s1/courses/fall10/atmo551a/CAPE.pdf

CHART 8.3. Annual mean number of days with thunderstorms per month anomaly from the climate average for the period 1952-2020

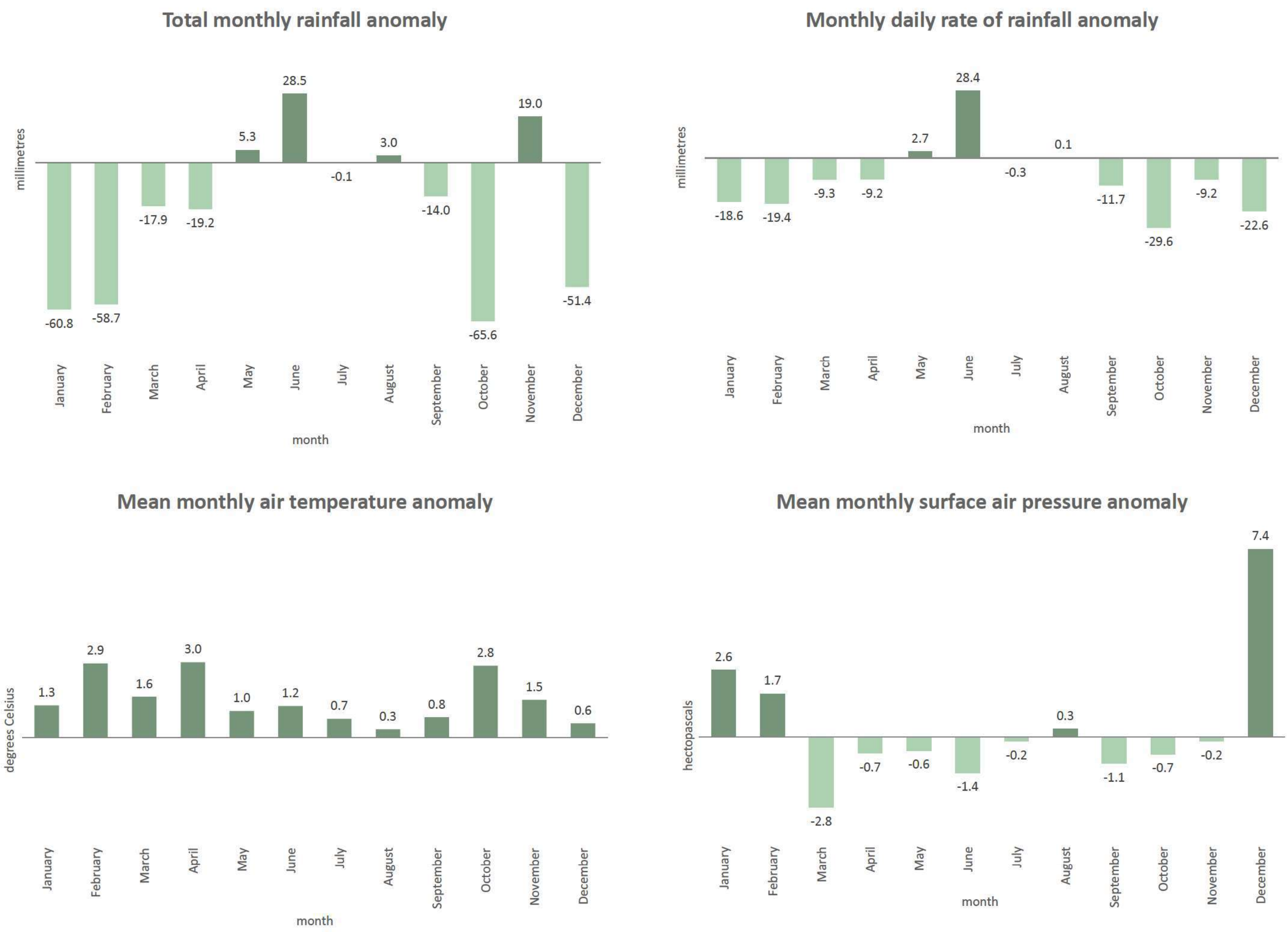


The increased frequency of days with thunderstorms can be explained through the influence which warmer seas have on atmospheric stability. On average, the observed increase in Malta's sea temperature is calculated to be 0.04 °C per year since 1978.

09 A LOOK AT COMPOUND EXTREME EVENTS
Case study of 2016

Malta's 2016 state of the climate was a particular one. **Chart 9.1** shows the anomalies registered during the months of 2016 with respect to the climate average. Most evident are the temperature anomalies during the 'cooler' seasons that were accompanied by abnormally high atmospheric pressure and therefore drier conditions. The lack of rainfall registered during 2016 is shown by the negative monthly anomalies registered throughout the year except for June, November and to a much lesser extent May and August. This was also characterised by a lower monthly average daily rainfall rate anomaly throughout the year except for May and June.

CHART 9.1. Monthly anomalies of ambient temperature, sea level atmospheric pressure, rainfall and daily rainfall rate from the climate average: 2016



Note: The zero line represents no shift from the average.

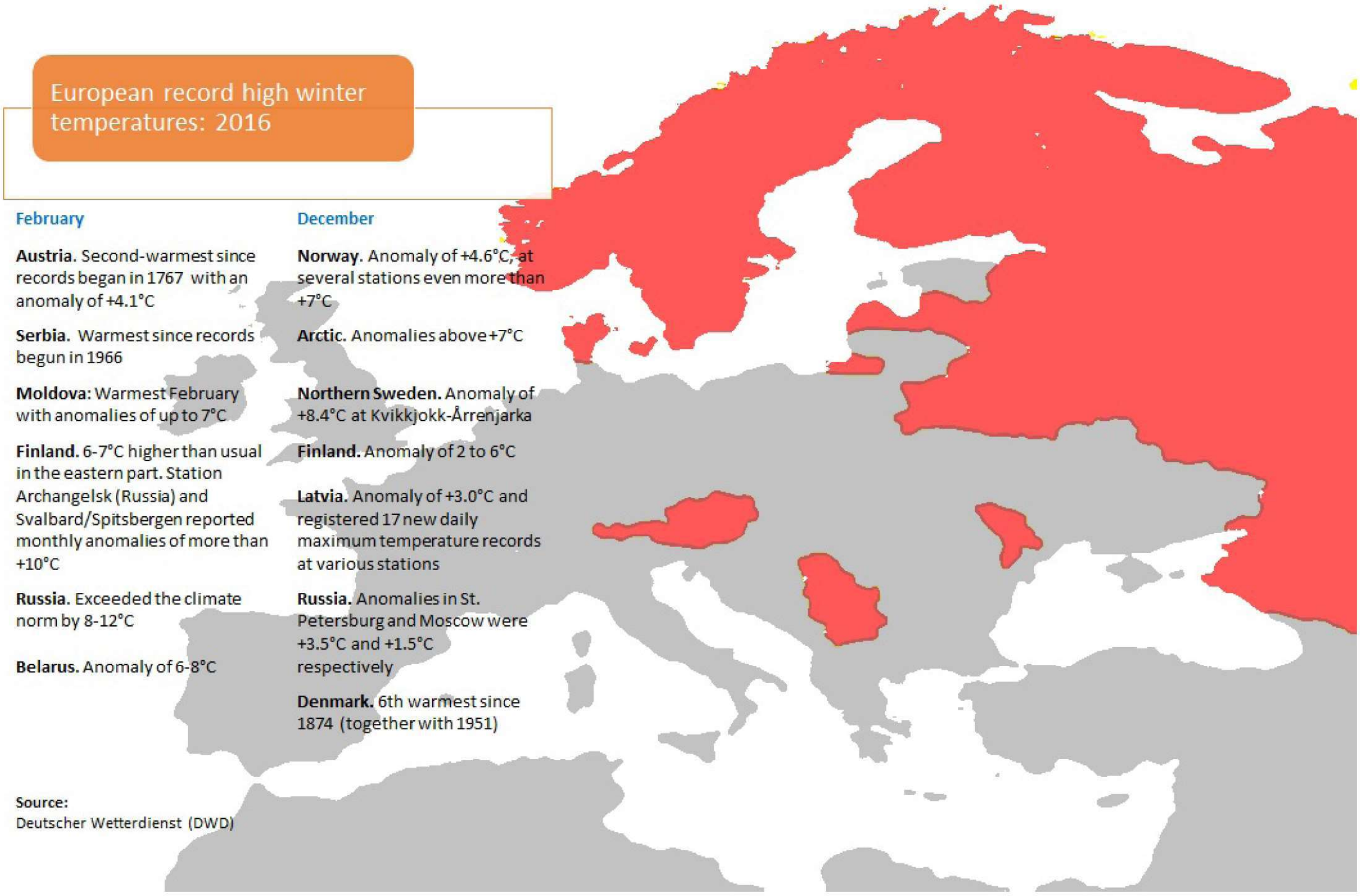
This case study illustrates how coinciding changes of certain climatic indices can lead to 'compounded' extreme events; in other words, shifts in extreme weather can become worse due to the presence of additional or intensifying weather elements. This explains why the dominance of a high-pressure system during Malta's 2016 winter months has suppressed regional convection and vertical instability, resulting in less rainfall and higher ambient temperatures. When extreme weather and climate events occur consecutively within a short timeframe of each other, or when multiple types of extreme events coincide, the local impacts can be compounded and their severity amplified. This effect can become detrimental to both human health and to natural systems especially if it is repeated year after year. For example, prolonged long-term high temperatures (such as in the form of multiple heatwaves) can have a larger impact on the agricultural sector when combined with the stress caused by multi-annual drought situations.

Such events happen because the physical processes that underpin atmospheric conditions are strongly interlinked and changes to their normal patterns are able to influence the frequency, magnitude and impacts of weather events, resulting in extreme climatic conditions.

The winter of 2016 provides a good example of compounding extreme weather conditions and illustrates the effect of background climate trends that are able to amplify natural climate variability. According to Malta's records, for the period 1952-2020, the calendar year 2016 ranked the 3rd for the highest mean maximum temperature and for the lowest rainfall, and 2nd for the highest mean minimum temperature.

The interlinkage mentioned above can also be seen at the European level. In fact, the European regional weather variability during the winter of 2016 also exacerbated long-term climate trends. These combined influences led to severe warmth over many countries in Europe (**Figure 9.1**) during which national climatological records were broken.

FIGURE 9.1. European high winter temperature records for 2016 occurring due to compounding climatic conditions



Note: The affected countries are shown in red.

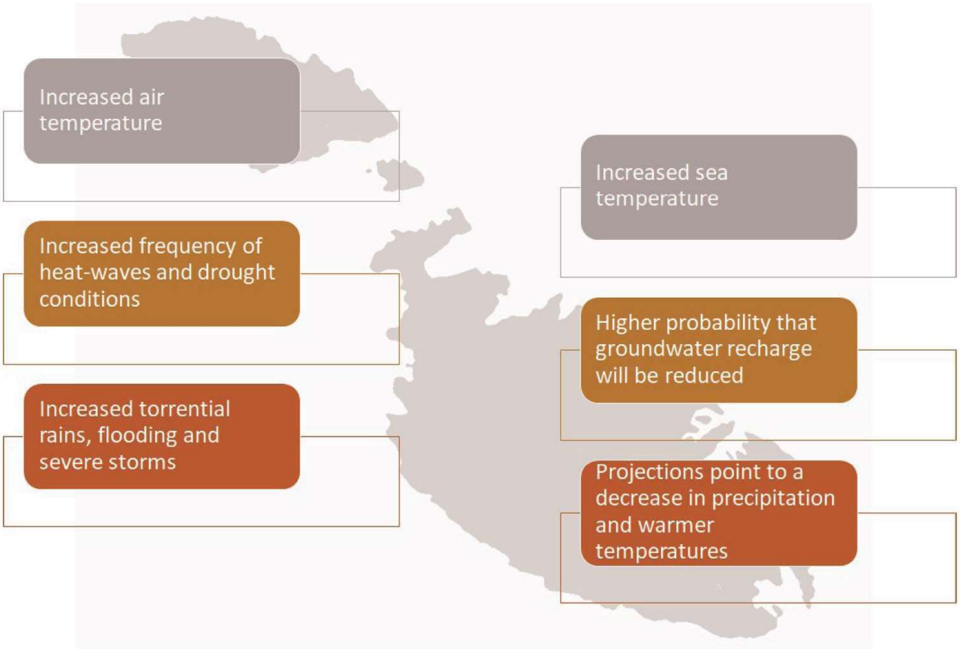
10 FUTURE CLIMATE

Reference is here made to the 5th Assessment Report of the IPCC which predicts changes in the magnitude and distribution of regional precipitation and temperature. This information, produced by a long list of IPCC-approved climate change models, is available to researchers for global regional and local impact analysis.

On the basis of this data, two recent studies conducted by Galdies and Vella (2019)[15] and Galdies and Meli (2021)[16] assess the projected changes in temperature, rainfall and a set of bioclimatic variables for 2050 and 2070. This is based on the data generated by an ensemble of 11 Coupled Model Intercomparison Project phase 5 (CMIP5) models under IPCC's four Representative Concentration Pathways (RCPs) for these two years. Irrespective of which RCP scenario is considered, this study highlights a number of significant negative impacts.

Quantitative results from these two local studies show that future climate change will negatively affect natural freshwater supplies, livestock and crop survival (**Figures 10.1 and 10.2**). They are consistent with continued (i) increases in air temperature, more heat extremes and fewer cold extremes, and (ii) decreases in cool season rainfall and stronger drought conditions.

FIGURE 10.1. Projected climate change impacts over Malta as predicted by climate change models[17]



[15] Galdies C, & Vella K (2019). Future impacts on Malta's agriculture based on multi-model results from IPCC's CMIP5 climate change models. In book: Climate Change-resilient Agriculture and Agroforestry – Ecosystem Services and Sustainability. Edition 1st Chapter 8; Publisher: Springer. Editors: Paula Cristina Castro, Anabela Marisa Azul, Walter Leal Filho, Ulisses M Azeitero. January 2019; DOI: 10.1007/978-3-319-75004-0_8

[16] Galdies C, & Meli A, (2022). An Analysis of the Impacts of Climate on the Agricultural Sector in Malta: A Climatological and Agronomic Study. In: Leal Filho, W., Djekic, I., Smetana, S., Kovaleva, M. (eds) Handbook of Climate Change Across the Food Supply Chain. Climate Change Management. Springer, Cham. https://doi.org/10.1007/978-3-030-87934-1_23

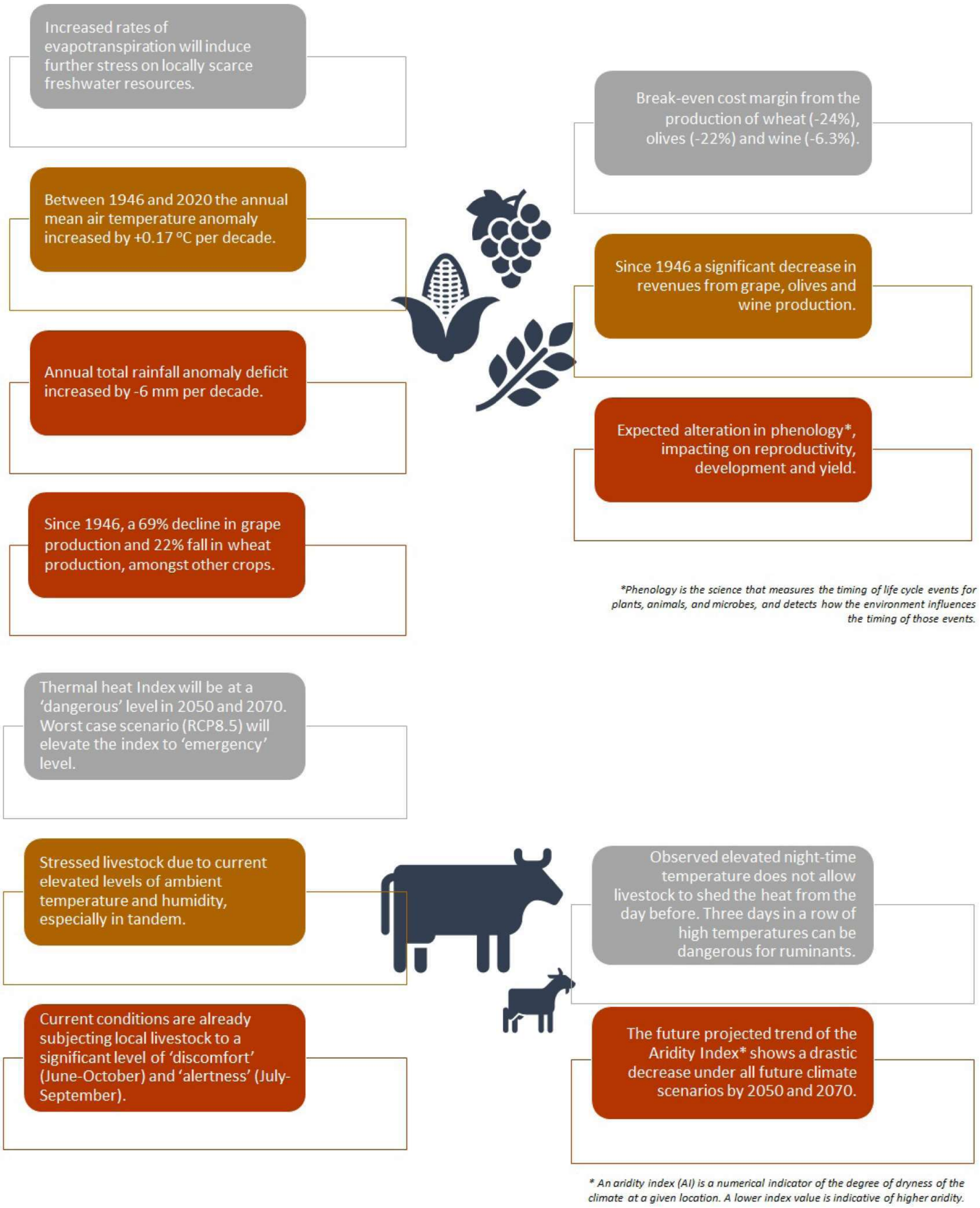
[17] Malta Resources Authority, Malta

The adverse socio-economic impact on agriculture productivity is also discussed, with a particular emphasis on the reduced monetary income resulting from decreased productivity and higher labour costs associated with the cultivation of both permanent and seasonal crops. As a consequence, the spatial distribution of the already stressed local arable land will change, modifying production patterns and economics.

The scarcity of local adaptation measures as a response to a changing climate exposes a current lack of awareness on the nature of the changes that are expected to occur on the basis of these future climate projections.

Climate change impact studies that use the latest CMIP6 climate model data and which are based on the new Shared Socio-economic Pathways (SSPs) are ongoing by the author.

FIGURE 10.2. Current and projected climate change impacts on local crops and livestock[18]



[18] Galdies C, & Vella K, (2019). Future impacts on Malta's agriculture based on multi-model results from IPCC's CMIP5 climate change models. In book: Climate Change-resilient Agriculture and Agroforestry – Ecosystem Services and Sustainability. Edition 1st Chapter 8; Publisher: Springer. Editors: Paula Cristina Castro, Anabela Marisa Azul, Walter Leal Filho, Ulisses M Azeitero. January 2019; DOI: 10.1007/978-3-319-75004-0_8; Galdies C, & Meli A, (2022). An Analysis of the Impacts of Climate on the Agricultural Sector in Malta: A Climatological and Agronomic Study. In: Leal Filho, W., Djekic, I., Smetana, S., Kovaleva, M. (eds) Handbook of Climate Change Across the Food Supply Chain. Climate Change Management. Springer, Cham. https://doi.org/10.1007/978-3-030-87934-1_23

Concluding remarks

This publication shows how the description of the state of the climate can be understood after analysing a set of interlinked meteorological elements. Natural weather variability will continue to affect Malta's climate from one year to the next. However, the observed occurrence of weather extremes and climate shifts will increase the likelihood of compounding extreme events that go beyond our experiences. Predicting the occurrence and severity of extreme weather events remains a highly challenging activity yet an essential exercise in the calculation of future risk assessments, climate adaptation strategies and responses.

The climatological parameters analysed here have direct and indirect impacts on Malta's various economic sectors, including agriculture, tourism, maritime and health sectors as well as on Malta's natural environment.

Taking the agricultural sector as an example, changes in temperatures and precipitation patterns are bound to take their toll on production if adaptation measures are not implemented. Extended drought periods may lead to stunted crop growth and lower crop yields while warmer winters may cause higher incidences of diseases and pests. Decreased cloudiness can also bring about higher land surface temperatures and increased rates of evapotranspiration, both of which can be detrimental to an agricultural sector that is reliant on seasonal rainfall and the extraction of groundwater that depends upon rainfall for its replenishment.

The decrease in rainfall is likely to result in a decrease in the natural recharge of Malta's aquifers, leading to higher pressure on the sole natural water resource that the country has. With regards to the tourism industry, projected climate change impacts will lead to increased infrastructure damage, additional emergency preparedness requirements, and higher operating expenses. These are just examples of the impacts that climate change is bound to have on these and other sectors. To mitigate the effect of such impacts, adaptation measures need to be implemented. To this effect the Government of Malta published the National Strategy for Climate Change and Adaptation in May 2012[19].

The reality of climate change[20] means that accurate and consistent meteorological observations must continue unabated in order to keep track of the extent of such changes. This will uphold a much-needed focus on the application of adaptation measures[21], which would serve as a buffer against the significant impacts on Malta's socio-economic and environmental sectors that these weather extremes are bound to generate.

[19] https://mra.org.mt/climate-change/adaptation-to-climate-change

[20] https://www.ipcc.ch/report/sixth-assessment-report-working-group-i

[21] Galdies C, Said A, Camilleri L, Caruana M (2016). Climate change trends in Malta and related beliefs, concerns and attitudes toward adaptation among Gozitan farmers. European Journal of Agronomy 74:18-28.

About this publication

The climatological state of Malta draws on the latest monitoring, science and climate projection information. It constitutes the most updated, official climate analysis based on air temperature, rainfall, cloud cover extent, hours of bright sunshine, relative humidity, frequency of thunderstorms and gale-force winds, mean sea level pressure, wind speed and direction and sea temperature observations up until December 2020.

This study shows long-term anomalies of a select number of meteorological parameters recorded from 1952 onwards from Malta's 30-year Climate Normal of 1961-1990 and from those observed during the past 30 years (1991-2020). Parametric and non-parametric statistical tests of correlation were used depending on the normality or otherwise of the long-term observations being investigated[22]. Both the sign and magnitude of the trend-line slope were noted and tested at 95 per cent confidence level.

The National Statistics Office

The National Statistics Office (NSO) is Malta's reference institution for national statistical data. The Office collects data on a wide range of socio-economic and environmental topics as part of its national and international obligations. These data are compiled according to European standards and are disseminated through various means to the general public. The main channel for statistical dissemination is through the NSO website which can be accessed from www.nso.gov.mt. The NSO is ISO 27001 certified.

The NSO came into being in March 1947. In its current format, it is the executive arm of the Malta Statistics Authority. Information provided to the NSO is treated as confidential. This information is used solely in the compilation of statistical reports. No information on individual returns can be given to any external public or private entity. The NSO and its activities are governed by the Malta Statistics Authority Act, 2000.

Information pertaining to climate illustrated by this document has been provided by the Environment, Agriculture and Fisheries (EAF) Unit which forms part of the Office's Business, Sectoral, and Regional Statistics Directorate. The EAF Unit sourced this data from the Meteorological Office of the Malta International Airport. For more information one may contact the EAF Unit on 2599 7330 or by email at environment.nso@gov.mt.

The Meteorological Office of the Malta International Airport

The Meteorological Office of the Malta International Airport is Malta's reference source for national meteorological data. Continuous collection of meteorological observations is one of the central functions of the Meteorological Office. Along the years, the data collection and quality control procedures have become of paramount importance throughout its operations that cover civil, aviation and maritime purposes. By means of its continuous observations, Malta's Meteorological Office has kept track of the changing weather since its inception at Luqa airport in 1947. Thanks to these long-term observations, the Office is able to provide statistics that can be used to assess the current state of Malta's climate.

The Malta Meteorological Office is Malta's Official Weather Service, accredited to the World Meteorological Organisation, and ISO 9001:2015 certified. It provides updated online information that is gathered by seven automatic weather stations around Malta and Gozo, together with weather forecasts. To obtain this information one may access the Office's website on www.maltairport.com/weather.

Suggestions or recommendations for similar future editions are welcome. Please send any feedback to the National Statistics Office at nso@gov.mt.

[22] Galdies C (2011). Malta's climate anomaly trends and possible related socio-economic impacts. National Statistics Office, Malta. 45pp; Galdies C (2012) Temperature trends in Malta (central Mediterranean) from 1951 to 2010. Meteorol. Atmos. Phys. DOI 10.1007/s00703-012-0187-72012

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