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IMPLICATIONS OF EXPECTED CLIMATIC CHANGES
ON THE ISLAND OF MALTA

A STUDY OF THE CLIMATE TRENDS IN MALTA

by

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Introduction

Scientific observations and analysis show that temperature worldwide is rising. Data from the Goddard Institute of Space Studies of the US National Aeronautics and Space Administration show an average increase of around 0.25 degrees celsius in the sixty years between 1880 and 1940, a decrease of 0.2 degrees celsius between 1940 and 1970 and another rise of 0.3 degrees celsius between 1970 and 1980. The increase continues in the 1980's with 1987 being the warmest since reliable records began in 1850. 1990 and 1991 are among the warmest years in the combined land/ocean temperature record, whilst the 1980's is the warmest decade.

These figures are averaged over the whole globe. In certain areas of the earth, the increase in temperature could be more than the figures shown above; in other areas there would be a decrease in temperature.

This overall increase in temperature will definitely have an effect on the climate in different areas of the earth. A change in climate will definitely have an impact on the national economics and ways of life of peoples all over the world. Some countries will be adversely affected; others will benefit. What will be the impacts on the various sectors of the Maltese economy?

How will an increase in temperature and a decrease in rainfall affect agricultural production? What will be the effect of a temperature increase on the tourist industry in Malta? How will an increase in sea temperature affect the local fishing industry? What will be the effect on the water resources of the Maltese Islands with a temperature increase and a decrease in rainfall? How will temperature extremes affect the energy sector and the production of electricity? How will the harbours, the beaches and the yacht marinas be affected by the predicted rise of the sea around us? What will be the effect of the change in the climate on the health of the local population?

These, amongst others, are some of the questions which need to be answered so that effective steps may be taken to mitigate the adverse effects, where they exist, of this impending phenomenon.

The IPCC Scientific Assessment

In the Executive Summary of the IPCC Working Group I final report issued in 1990, it is ascertained that:-

(a)   There is a natural greenhouse effect which already keeps the earth warmer than it would otherwise be.

(b)   Emissions resulting from human activities are substantially increasing the atmospheric concentration of the greenhouse gases, carbon dioxide, methane, chloroflorocarbons (CFC's) and nitrous oxide. These increases will enhance the greenhouse effect, resulting on average in an additional warming of the earth's surface. The main greenhouse gas, water vapour, will increase in response to global warming and further enhance it.

Based on current model results, the group predicted that:

(a)   Under the IPCC Business-as-Usual (Scenario A) emissions of greenhouse gases, a rate of increase of global mean temperature during the next century of about 0.3 degrees celsius per decade (with an uncertainty range of 0.2 degrees celsius to 0.5 degrees celsius per decade); this is greater than that seen over the past 10,000 years. This will result in a likely increase in global mean temperature of about one degree celsius above the present value by 2025 and three degrees celsius before the end of the next century.

(b)   Under the other IPCC emission scenarios which assume progressively increasing levels of controls, rates of increase in global mean temperature of about 0.2 degrees celsius per decade (Scenario B), just above 0.1 degrees celsius per decade (Scenario C) and about 0.1 degrees celsius per decade (Scenario D).

(c)   That land surfaces warm more rapidly than the ocean and high northern latitudes warm more than the global mean in winter.

(d)   Regional climate changes are different from the global mean. This means that increases in Southern Europe and Central North America are predicted to be higher than the global mean, accompanied on average by reduced summer precipitation and soil moisture. The warming would be about two degrees celsius in winter and two to three degrees celsius in summer. Precipitation would increase in winter and decrease in summer by 5 to 15%; soil moisture should decrease by 15 to 25% in summer.

(e)   Under the IPCC Business-as-Usual emissions scenario, an average rate of global mean sea level rise of about 6 cm. per decade over the next century (with an uncertainty range of 3 to 10 cm. per decade) mainly due to thermal expansion of the oceans and the melting of some land ice is predicted. The predicted rise is about 20 cm. in global mean sea level by 2030 and 65 cm. by the end of the next century. It is expected that there will be significant regional variations.

The Group also maintained that there were many uncertainties in their predictions particularly with regard to the timings, magnitude and regional patterns of climate change, due to their incomplete understanding of:

(a)   Sources and sinks of greenhouse gases, which affect predictions of future concentrations.

(b)   Clouds which strongly influence the magnitude of climate change.

(c)   Oceans, which influence the timing and patterns of climate change.

(d)   Polar ice sheets which affect predictions of sea level rise.

The Group concludes by stating that the complexity of the system may give rise to surprises.

The Data studied:

Temperature

The Meteorological Office started making weather observations in 1922 at Gwardamangia. In 1927 the Office was moved to St. John's Cavalier in Valletta and in 1947 it was moved to Luqa. Only the temperature records from 1927 to 1988 are taken into consideration in the Luqa temperature graphs. This is due to the fact that we have no overlap of records for both Gwardamangia and Luqa. On the other hand, temperature was recorded simultaneously in Valletta and Luqa for a period of five months from January to May 1947.

The graphs derived by plotting respectively Luqa against Valletta maximum and minimum temperatures indicate that the maximum temperature at Luqa is higher than that at Valletta and on the other hand the minimum temperature at Luqa is lower than that at Valletta. This conclusion is both plausible and acceptable because Luqa is an inland station and Valletta a coastal one. Consequently, regression equations could be derived and the Valletta maximum and minimum temperature observations amended accordingly by using the regression equations:-

Luqa Maximum Temperature in Degrees Celsius =
{(Valletta Max. Temp. in degrees celsius) x 1.0329} - 0.1361 Luqa Minimum Temperature in Degrees Celsius =
{(Valletta Min. Temp. in degrees celsius) x 1.0395} - 1.5322

in order to add 20 years of temperature records to the 42 years available for Luqa.

Figures 1 and 2 were therefore derived from data available at the Meteorological Office for the period 1927 to 1988.

Figures 23 and 24 show the graphs derived by using the highest and lowest temperatures recorded at Luqa for each year from 1947 to 1990.

Another series of graphs (Figures 34 to 39) was derived by using the temperature observations made at the University of Malta in Valletta from 1865 to 1953. Because of the fact that 7 years of simultaneous temperature observations are available for both Valletta and Luqa, the Luqa temperatures were amended accordingly by using the regression equation:-

Valletta Temperature in degrees celsius =
(Luqa Temperature in degrees celsius x 0.96333) + 1.1852

to add nearly 36 years of data to the Valletta long term temperature series.

Rainfall

Malta measurements of rainfall began in 1840. For only very brief periods during the past 150 years or so is there no acceptable record from the Valletta locality. Hence, the rainfall records for the Valletta region were also analysed with those of Luqa because of the length of the records, 150 years, as opposed to the 42 years of Luqa. The standard series for Valletta as prepared by P.K. Mitchell (October 1963) who used rainfall totals corresponding to the natural break of the seasons was used in this analysis. Consequently, the rain year for the Valletta area has been calculated from August to July. For the period 1962 to 1988 the rainfall records of the Argotti Gardens in Floriana were used to update the records of Mitchell up to 1988. Figures 3 and 4 show the curves derived by plotting the 10 and 20 year running means for Valletta against the corresponding 10 and 20 year periods.

In the calculation of the 5 and 10 year running means for Luqa, calendar years' totals have been used (see Figures 5 and 6). The 10 year running means for the days with precipitation greater than or equal to a certain value have been derived from available Luqa records i.e. from 1951 to 1990. Similar records for Valletta are not available. Calendar years have again been used to derive the graphs shown in Figures 7 to 11.

Another series of graphs (Figures 28 to 33) were derived from the Mitchell series, the Argotti readings in Floriana, and the Luqa readings (from 1980 to 1990). The year was divided into four seasons by taking March, April and May for spring; June, July and August for summer; September, October and November for autumn and December, January and February for winter.

The two graphs shown in Figures 28 and 29 were derived for six month periods - April to September and October to March respectively.

Atmospheric Pressure

Atmospheric pressure readings taken by the Meteorological Office at Gwardamangia, Valletta and Luqa were used in this analysis. The pressure readings were all reduced to mean sea level by using standard procedures. Since all pressure readings have been reduced to a standard level, the different localities where they were taken will not affect the homogeneity of the records. Consequently, the 10 year and 20 year moving means curves (see Figures 12 and 13) were derived from available Meteorological Office records from 1923 to 1990.

Cloud Cover

Cloud cover is observed every half hour and is measured in octas (eights).

But the values used in this analysis are those pertaining to the three-hourly synoptic observations at Luqa, i.e. the cloud amounts at 00, 03, 06, 09, 12, 15, 18 and 21 UTC. The Luqa mean monthly values for the years 1951 to 1990 were used to derive the 10 year moving means curve (Figure 15).

Sunshine

The hours of bright sunshine for the years 1928 to 1990 have been recorded regularly at Valletta and at Luqa by means of a Campbell-Stokes recorder. This instrument focuses the heat radiation from the sun to burn a trace on a specially treated card used specifically with this instrument.

The mean yearly values for the number of hours of bright sunshine for Valletta from 1928 to 1946 together with those for Luqa from 1947 to 1988 were used to derive the 10 year moving means curve (Figure 14).

Vapour Pressure

The wet and dry bulb temperature readings are observed every half-hour and the vapour pressure is derived from these two parameters every three hours to be included in the three-hourly synoptic observations, i.e. at 00, 03, 06, 09 UTC etc. The Valletta readings from 1928 to 1946 were added to the Luqa values (1947-199) to derive the 10 year moving means graph (Figure 18).
Number of Days with Gusts \= 34 KT.; Thunderstorms; Fog and Hail. The data used to derive the graphs shown in Figures 16, 17, 19 and 21 all refer to the observations made at Luqa Airport during the period 1947 to 1990. The number of days in each year when the respective weather parameter was observed at Luqa was used to derive the graphs referred to above.

The Day Maximum Rainfall

The maximum rainfall recorded in a 24 hour period in each year from 1922 to 1990 was used to derive the Day Maximum fall graph shown in Figure 20. These observations, besides the Luqa ones, include those taken at Gwardamangia and at Valletta.

Wind Speed

The mean monthly wind speed from 1959 to 1990 was used to derive the mean for each year. The observations were taken at a height of 10 metres at Luqa Airport, using a cup anemometer (Munro type).

Analysis of the Data

Climate data may be subject to variations or oscillations with time because of changing environmental conditions or random processes. The trends are often hidden in the rather large variations which occur from year to year in climatic series. However, a number of statistical techniques have been employed to detect these changes and to smooth out short-term irregularities. A frequently used method of smoothing out the short term fluctuations from meteorological time series is to use some type of weighted mean. The commonest is the running or moving mean. Any method of analyzing a time series may introduce spurious cycles which must be distinguished from those which have physical validity. The practice of using overlapping means derived from a series of completely random numbers may produce sine curves so that it is not clear whether the features of the smoothed curve are due to the phenomenon or the process. Generally, a much more rigorous analysis is necessary (H.C.S. Thom, 1966). However, in this study, the running or moving mean analysis was applied to the data, since the objective was to detect trends rather than cycles.

All the parametres that have been analysed show these cycles when the 5, 10 etc. year running means were plotted against the number of years that the data span. However, the graphs also indicate the trend by the line that is drawn on each of them. The maximum temperature graph (Figure 2) has a positive gradient, thereby indicating a trend towards higher mean monthly maximum temperatures. On the other hand, the minimum temperature graph (Figure 1) has a negative gradient, thereby indicating a decrease in the mean monthly minimum temperature.

It is pertinent to mention at this stage that from 1980 to 1990 the extreme maximum temperature at Luqa for each month of the year has shown an increase in the months of January, April, June, July, August, September, October and November whilst the extreme minimum temperature at Luqa for the same period of years has decreased in the months of January, March and July. The highest ever mean sea level pressure of 1040.9 hPa was recorded on the 2nd January of this year (1992).

The long term series mean temperature curves (Figures 38 to 40) for the period 1865 to 1990 show an increase in the mean yearly temperature for Malta. Similar trends appear in the graphs for spring, winter and summer where it is much more marked for summer. Surprisingly enough, the autumn curve shows a trend towards a decrease in temperature of about 0.5 degrees celsius over 136 years. All the curves (except the winter one) show an increase in temperature from 1980 onwards.

All but two of the rainfall curves for Luqa and Valletta worked out using the 5, 10 and 20 years running means have a negative gradient for the trend line. Surprisingly, only the summer rain curve from 1865 to 1990 shows a positive gradient. The autumn curve does not show a trend. All in all, we can conclude that there is a trend towards lower yearly rainfall totals for Malta. This is also borne out by the April to September curve (Figure 28), the October to March curve (Figure 29) as well as the August to September yearly curves (Figures 3 and 4).

Also interesting are the Luqa 10 year moving means curves for the number of days with rain greater or equal to a certain value (see Figures 7 to 11).

Whilst the 0.1 and 10 mm. days do not show any appreciable trend (indicated by the nearby horizontal trend line), the number of days with rain greater or equal to 1 mm., 2 mm., and 50 mm. all show a negative gradient or trend thereby indicating a trend towards a decrease in the number of days in the categories mentioned above.

Both atmospheric pressure curves (Figures 12 and 13) indicate an increase in atmospheric pressure over the Maltese Islands thereby indicating a trend towards an increase in anticyclonic conditions.

The 10 year moving means of the mean monthly cloud amount in octas for Luqa for the period 1951 to 1990 were plotted against the corresponding 10 year periods (see Figure 15). The curve again shows a trend towards a decrease in the amount of cloud cover over Malta thereby confirming the earlier conclusions when rainfall, pressure and temperature were discussed. An increase in atmospheric pressure diminishes frontal activity and enhances atmospheric subsidence, both of which inhibit cloud formation. This fact would lead to a decrease in the average amount of cloud cover, which is borne out by the analysis of the cloud amount graph.

The duration of bright sunshine graph shown in Figure 14 shows a downward trend in the number of hours per year. This somewhat contradicts the earlier conclusions when discussing pressure, rainfall and temperature. If anticyclonic conditions are increasing frontal cloud should decrease and subsidence should increase thereby giving an increase in the hours of sunshine.

As already indicated, there is a trend towards a decrease in the amount of cloud cover. Consequently, the trend towards a decrease in the bright sunshine hours is certainly not due to an increase in cloud cover. Another factor must therefore be the cause of the decrease in the amount of hours of bright sunshine. A low-pass filter (the Binomial Coefficient method) was used to smooth out fluctuations in the temperature graphs (Figures 1 and 2). The same low-pass filter was also used to smooth out fluctuations in some of the rainfall graphs shown.

The number of days with gusts greater than 34 knots shows a downward trend from 54 per year to about 35 per year (Figure 16). This confirms the fact that anticyclonic conditions and hence slack pressure gradients are becoming more frequent as shown by the increase in the atmospheric pressure at Malta (Figure 12).

The number of days with thunder shows an upward trend from about 25 to 32 per year (Figure 17). This implies that convective type of rainfall is on the increase since maximum temperatures have been observed to be increasing over the last 70 years or so (see Figure 2). Convective type of rainfall also implies an increase in the amount of daily maximum rainfall, since this type of rainfall is of short duration and often heavy. This is borne out by the increase in the day maximum rainfall between 1922 and 1990 shown in Figure 20, notwithstanding the fact that the number of days with rain greater than 1 mm., 2 mm. and 50 mm. is decreasing (Figures 7 to 11).

Two other interesting graphs are shown in Figures 19 to 21. The number of days with fog at Luqa shows a decrease from 11 to about 8 per year. This is also borne out by the fact that the vapour pressure from 1928 to 1990 (Figure 18) also shows a downward trend implying an overall decrease in the atmospheric water vapour in the Central Mediterranean area. The number of days with hail has also decreased from about 13 to about 5 to 6 per year (Figure 21). Again this could be attributed to the increase in daily maximum temperatures since thunderstorms are on the whole more frequent during the afternoon and evening when the convective process is at its maximum.

The wind speed graph (Figure 22) does not show any significant long term trends.

The highest temperature recorded each year at Luqa (Figure 23) shows a marked increase in the last 10 to 12 years.

Conclusions

The UNEP report No. 27 "Implications of Expected Climate Changes in the Mediterranean Region: An overview" gives an overall global warming of 0.5 degrees celsius in the past 100 years. This figure is also valid for the last 130 years.

Our temperature and rainfall graphs therefore indicate that for a global warming of 0.5 degrees celsius over the last 125 years:

Mean Yearly Rainfall has decreased by 30 mm.	- 6 %
Mean Yearly Temperature has increased by 0.2 deg.C.	- 1 %
Spring Rainfall has decreased by 3 mm.	- 10 %
Summer Rainfall has increased by 1.3 mm.	- 52 %
Autumn Rainfall has decreased by 1 mm.	- 1 %
Winter Rainfall has decreased by 7 mm.	- 7 %
Spring Temperature has increased by 0.3 deg.C.	- 1.9%
Summer Temperature has increased by 0.8 deg.C.	- 3.3%
Autumn Temperature has decreased by 0.4 deg.C.	- 1.9%
Winter Temperature has increased by 0.05 deg.C.	- 1 %
April to September Rainfall has decreased by 8 mm.	- 10 %
October to March Rainfall has decreased by 20 mm.	- 4.4%

A plausible hypothesis to explain the trend towards a decrease in the hours of bright sunshine at Malta could be due to the fact that there is an increase in the density of suspended particles in the atmosphere. This increase is significant enough to affect the transparency of the atmosphere especially at low elevations of the sun, particularly around sunrise and around sunset. The increase in the dust and smoke particles of a size comparable

with, or larger than, the wavelength of light could be scattering the incoming short wave radiation from the sun as it passes through the earth's atmosphere. The increase in dust/smoke particles may be due to a number of factors which include atmospheric pollution.

The results of the analysis of the other parameters studied fit into a pattern. An increase in atmospheric pressure diminishes frontal activity, which necessarily implies less rainfall. Furthermore, certain anticyclonic situations enhance subsidence thereby restricting convection and hence rainfall. Less cloud cover would increase the maximum temperature during the day and decrease the minimum temperature during the night. Besides, an increase in atmospheric pressure implies an increase in anticyclonic situations which in turn implies more low level inversions. These inversions trap the atmospheric pollutants which are not dispersed by the wind due to the slack pressure gradient associated with anticyclonic conditions. This would necessarily increase the incidence of haze.

Simultaneous trends towards extremes in the maximum and in the minimum temperatures are typical of a desert region. These facts lead one to conclude that a process of desertification is already in action at our latitude. We must bear in mind the fact that the Maltese Islands are situated on the edge of one of the largest deserts in the world namely the Sahara. This fact leads

one to argue that the area of atmospheric subsidence is shifting northwards from the Sahara, thereby enhancing a desert type of microclimate. It is pertinent to point out at this stage, that the shift in the location of deserts is one of the possible effects of the "greenhouse" mechanism that is threatening the world at large.

APPENDIX

Contact with the Climatic Research Unit of the University of East Anglia was established in December 1991 after the First Meeting of the Task Force. Malta data was sent to the Research Unit which in turn produced the report "The Temperature and Precipitation Scenarios for the Malta Region", a copy of which is being attached as Annex I.

Composite Global Climate Models (GCM) scenarios for the Mediterranean, a study of the Climate Division of the University of Norwich, East Anglia, U.K., is also attached as Annex II.

Executive Summary

In the framework of the activities of the Mediterranean Task Team, Malta was chosen for a specific site study on the implications of the Climatic Changes.

From a study carried out by the Climatic Research Unit of the University of East Anglia the sub-grid scale scenario of the climatic changes for the Central Mediterranean indicates that between now and the year 2050:

A.   Annual temperature will increase by 0.8 to 0.9 degrees celsius per degree global change.

B.   There will be little if any change in the annual rainfall amounts around Malta.

C.   The Summer (June, July and August) temperatures should rise by slightly more than the global increase, i.e. 1.05 degrees celsius per degree global change.

D.   No prediction could be made for the Summer precipitation.

E.   The Winter (December, January and February) temperature should rise by 0.9 degrees celsius per degree global change.

F.   The precipitation amount for Winter should decrease by 9% per degree global change.

G.   The Spring (March, April and May) temperature should rise by 0.8 degrees celsius per degree global change.

H.   The precipitation amount for Spring should decrease by 13% per degree global change.

I.   The Autumn (September, October and November) temperature should decrease by 0.8 degrees celsius per degree global change.

J.   The Autumn precipitation should increase by 14% per degree global change.

The confidence that the unit places in the above precipitation scenarios is low.

The General Circulation Models (GCM) scenarios for precipitation are slightly different from those indicated by the sub-grid scenarios. The GCM scenarios indicate that for a degree celsius global temperature change:

        Annual rainfall should increase by 1%.
        Winter rainfall should show no change.
        Spring rainfall should increase by 1%.
        Summer rainfall should show no change.
        Autumn rainfall should show a 3% increase.

Under the IPCC Business-as-Usual emissions scenario, an average rate of global mean sea level rise of about 6 cm. per decade over the next century, is predicted. By 2030, the predicted rise will be 20 cm. by the end of the next century.

A study carried out on the Malta data shows that for a global warming of 0.5 degrees celsius over the last 125 years:

Annual Rainfall has decreased by 30 mm.	- 6 %
Annual Temperature has increased by 0.2 deg.C.	- 1 %
Spring Rainfall has decreased by 3 mm.	-10 %
Summer Rainfall has increased by 1.3 mm.	-52 %
Autumn Rainfall has decreased by 1 mm.	- 1 %
Winter Rainfall has decreased by 7 mm.	- 7 %
Spring Temperature has increased by 0.3 deg.C.	- 1.9%
Summer Temperature has increased by 0.8 deg.C.	- 3.3%
Autumn Temperature has decreased by 0.4 deg.C.	- 1.9%
Winter Temperature has increased by 0.5 deg.C.	- 1 %
April to September Rainfall has decreased by 8 mm.	-10 %
October to March Rainfall has decreased by 20 mm.	- 4.4%

Over the last 70 years or so:

Minimum Temperature has decreased by 1.5 deg.C.	- 9.4%
Maximum Temperature has increased by 1.0 deg.C.	- 4.7%
Atmospheric Pressure has increased by 1.5 hPa	-10 %
The number of hours of Bright Sunshine has decreased by 0.6 hours	- 3.1%
Vapour Pressure has decreased by about 0.5 hPa	- 3.1%

Over the last 40 to 45 years:

Cloud cover has decreased by 0.2 octas	- 5.9%
The days with thunderstorms have increased by 8	-32 %
The days with gusts greater than 34KT has decreased by 20	-36.4%
The days with fog has decreased by 3.5	-30.4%
The days with hail has decreased by 8	-61.5%
The Maximum rainfall in a day has increased by 15 mm.	-27.3%
The Highest Temperature recorded each year has increased by 1 deg.C.	- 2.8%
The Lowest Temperature recorded each year has decreased by 0.8 deg.C.	-20 %

It is pertinent to point out at this stage that observed temperature trends over the last 100 years or so should not be compared with Global Climate Model (GCM) predictions as the observed trends do not cater for the expected increases in greenhouse gases and other forcing factors eg. methane, ozone, sulphur, etc. inherent in the GCM models.