Ministry of Agriculture, Natural Resources and Environment of the Republic of Cyprus
Water Development Department

Food and Agriculture Organisation of the United Nations
Land and Water Development Division

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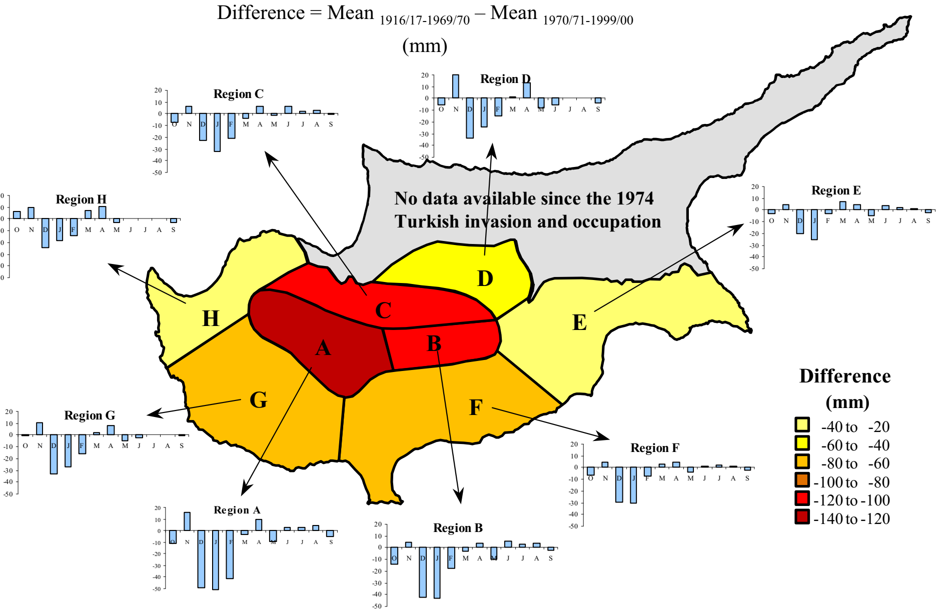
REASSESSMENT OF THE ISLAND'S WATER RESOURCES AND DEMAND

Objective 1 - Output 1.2

HYDROMETEOROLOGICAL STUDY EXAMINING

CHANGES IN RECORDED PRECIPITATION



Differences Between the Means of Regional Annual and Regional Monthly Precipitation
Difference = Mean $_{1916/17-1969/70}$ – Mean $_{1970/71-1999/00}$
(mm)

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MAIN RESULTS AND RECOMMENDATIONS

This analysis is part of the WDD-FAO project “Reassessment of the Island’s Water Resources and Demand”. Its main objectives were to analyse changes in recorded precipitation in Cyprus and the possible implication of the precipitation changes for the reassessment of the island’s water resources.

The statistical analysis of the records available over the period of hydrological years 1916/17-1999/00 demonstrates that the precipitation time series display a step change or shift around 1970 and can be divided into two separate stationary periods. The mean precipitation of the recent period is lower than the mean precipitation of the older period. From 1916/17 to 1969/70 the precipitation records do not show any trend. From 1970/71 to 1999/00 the data show a slight decrease in the precipitation but this trend is not significant compared to the variations from year to year.

The shift in mean precipitation is larger on the Troodos Mountains sector than in the coastal and inland plain areas. The mean of the annual precipitation of the recent period is by 100 mm or more lower than the mean of the older period at almost every location of elevation higher than 500 m a.m.s.l. This decrease ranges between 15% and 25% of the mean annual precipitation of the older period. The decrease of the annual precipitation is essentially due to a decrease in the precipitation during the months of December and January in the southeast of the island, and during December, January and February in all the other regions.

The precipitation was significantly lower over the last 30 years than over the previous decades. Therefore the available water in the island is probably less than what had been assumed as a basis for water development works. For the reassessment of the island’s water resources it is recommended to use only hydro-meteorological records of the 1970/71-1999/00 period that conveniently corresponds to the new WMO Standard Normal. The use of this period for the quantification of the water resources will give a more accurate picture of the water resources available today.

Secondary suggestions can also be made. For a better understanding of weather and climate changes in Cyprus it would be interesting to look for existing studies or develop an analysis of the changes in tracks of depression systems in the eastern Mediterranean sector. Discrepancies found in three precipitation time-series highlight the necessity to check the data of all stations involved in analyses of this nature to ensure that any errors missed by the Meteorological Service quality checks are picked up.

ACKNOWLEDGEMENTS

Iacovos Iacovides, Chief water engineer with the Water Development Department and National project coordinator, please find here my acknowledgements for your permanent support during my missions in Cyprus and valuable comments on the project expected results from this analysis.

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Frédéric Rossel

Lefkosia, February 2001

TABLE OF CONTENTS

1 INTRODUCTION

This study is part of the WDD-FAO project “Reassessment of the Island’s Water Resources and Demand”. The preface of this document presents the context of this study and the overall objective of the project. One of the two immediate objectives of the project is to provide updated records about the water available in the island. The main objectives of this study are to analyse recorded precipitation in Cyprus for trends and changes and the possible implication of the precipitation changes for the reassessment of the island’s water resources.

There are many different ways in which changes in hydro-meteorological series can take place. A change can occur abruptly (step change) or gradually (trend) or may take more complex forms. Although climate change is often thought of in terms of progressive trend, it is also possible for it to result in a step-like change because of complex dependencies on non-linear dynamic processes that feature cumulative effects and thresholds (WMO, 2000). Studies of precipitation change are typically complicated by factors such as missing data, seasonal and other short-term fluctuations (climate variability) and by lack of homogeneity e.g. due to changes in instrument and observation techniques. In some cases there are further problems because of unreliable data and data series that are not sufficiently long.

There are many approaches that can be used to detect trends and other forms of non-stationarity in hydro-meteorological data. In deciding which approach to take it is necessary to be aware of which test procedures are valid i.e. ensure that the data meets the required test assumptions and which procedures are most appropriate i.e. likely to correctly find change when it is present.

The present study is realised with the annual and monthly precipitation records. The northern part of the island is not analysed, as records from the area under Turkish occupation are inaccessible since the Turkish invasion of the northern part of the island in 1974. The times series used have been chosen according to the Meteorological Service data quality check and in function of the length of the period of records. All 44 time-series used are continuous from hydrological year 1916/17 to hydrological year 1999/00, as the Meteorological Service has estimated all data missing from the chosen time series.

This document presents the main results of the analysis of recorded precipitation in Cyprus for trends and changes and the possible implication of the precipitation changes for the reassessment of the island’s water resources. This document is divided into seven chapters and 16 annexes. The first chapter being the introduction. The second chapter provides an overview of the weather and precipitation regime in Cyprus. The third includes the station selection, the definition of regions and regional precipitation indices. The fourth one is the main part of this study; it includes the analysis employed to identify changes in the precipitation records. The fifth chapter gives a picture of the consequences of the identified change for water availability in the island. Conclusions and recommendations are provided in chapter six at the end of this document and also in the first pages as summary. Chapter seven contain the list of the references used. The main part of the document includes the figures for one of the eight regions defined. Annexes provide figures for all the regions and tables with values of several parameters for individual stations.

2 OVERVIEW OF CYPRUS WEATHER

2.1 General

Cyprus has an intense Mediterranean climate with the typical seasonal rhythm strongly marked with respect to temperature, precipitation and weather in general. Hot dry summers from mid-May to mid-September and rainy, rather changeable, winters from November to mid-March are separated by short autumn and spring seasons of rapid change in weather conditions (Figure 1). At latitude 35° North, Longitude 33° East, Cyprus has a change in day length from 9.8 hours in December to 14.5 hours in June.

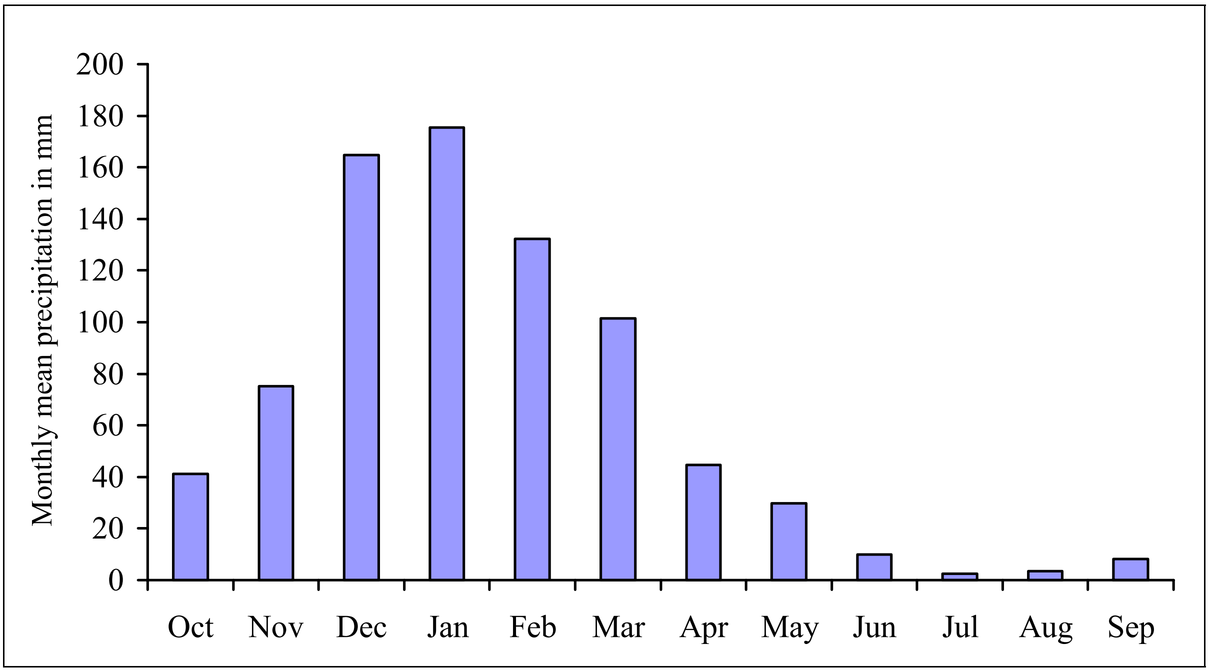

Figure 1: Typical annual distribution of the mean monthly precipitation in Cyprus (Station 110 - Ayia).

The central Troodos massif, rising to 1951 metres a.m.s.l., and to a less extent the long narrow Kyrenia mountain range, with peaks of about 1000 metres a.m.s.l., play an important part in the meteorology of Cyprus. The predominantly clear skies and high sunshine amounts give large seasonal and daily differences between temperatures of the sea and the interior of the island that also cause considerable local effects especially near the coasts.

In summer the island is mainly under the influence of a shallow trough of low pressure extending from the great continental depression centred over south-west Asia. It is a season of high temperatures with almost cloudless skies. Precipitation is almost negligible but isolated thunderstorms sometimes occur which give precipitation amounting to less than 5% of the total in the average year.

In winter Cyprus is near the track of fairly frequent small depressions that cross the Mediterranean Sea from west to east between the continental anticyclone of Eurasia and the generally low-pressure belt of North Africa. These depressions give periods of disturbed weather usually lasting from one to three days and produce most of the annual precipitation. The average precipitation from December to February being about 60% of the annual total.

2.2 Precipitation

The average precipitation for the year as a whole is about 500 mm but it was as low as 182 mm in 1972/73 and as high as 759 mm in 1968/69. The average precipitation refers to the island as a whole and covers the period 1961-1990. Statistical analysis of precipitation in Cyprus reveals a decrease of precipitation amounts in the last 30 years.

The mean annual precipitation increases up the south-western windward slopes from 450 millimetres to nearly 1,100 millimetres at the top of the central massif. On the leeward slopes amounts decrease steadily northwards and eastwards to between 300 and 350 millimetres in the central plain and the flat south eastern parts of the island (Figure 2).

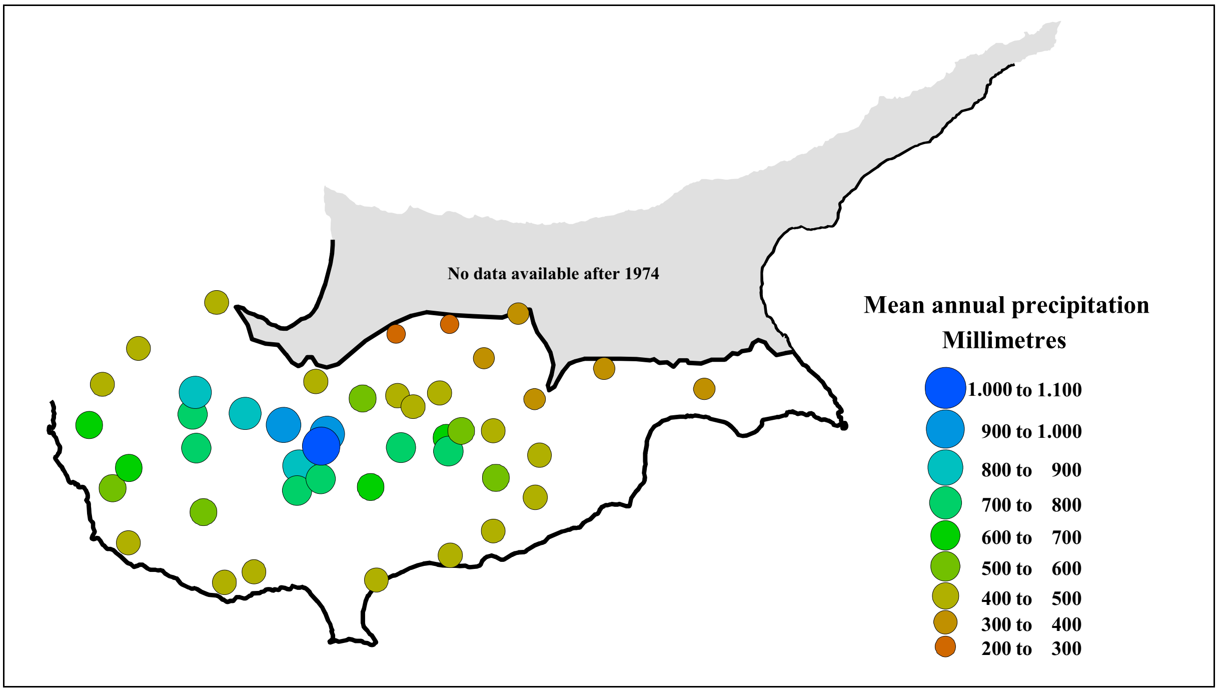

Figure 2: Mean annual precipitation (1916/17-1999/00) at 44 stations in Cyprus

The narrow ridge of the Kyrenia range, stretching 160 kilometres from west to east along the extreme north of the island, produces a relatively small increase of precipitation to nearly 550 millimetres along its ridge at about 1,000 metres a.m.s.l.

Precipitation in the warmer months contributes little or nothing to water resources and agriculture. The small amounts that fall are rapidly absorbed by the very dry soil and soon evaporated by high temperatures and low humidity. Autumn and winter precipitation, on which agriculture and water supply generally depend, is somewhat variable. About 60% of the annual precipitation is recorded during the winter months.

Snow occurs rarely in the lowlands and on the Kyrenia range but falls frequently every winter on ground above 1,000 metres a.m.s.l. It usually appears in the first week of December and stops by the middle of April. Although snow cover is not continuous during the coldest months it may lie to considerable depths for several weeks especially on the northern slopes of high Troodos.

2.3 Depressions in Mediterranean Sea

2.3.1 Classification of the depression

The depressions of the Mediterranean may be classified according to their origin into the following groups:

i) Depressions that enter the Mediterranean basin from outside.
ii) Thermal depressions that form mainly in summer as a result of surface heating over land, especially where land is completely or partly surrounded by sea. They develop between May and October over Spain, the Po valley, central and southern Italy, Tunisia, the Sahara, and the greater islands such as Sicily.
iii) Lee depressions that form on the lee side of a mountain range when a deep vigorous current moves towards the range.
iv) Wave depressions.
v) Troughs.

2.3.2 Areas of formation

The great majority of Mediterranean depressions originate within the region as lee depressions or wave depressions, the average number forming in this way being about 69 per year or 91 per cent of all Mediterranean depressions. They may be grouped according to their areas of formation as follows:

i) The western Mediterranean area. The great majority of depressions form near the Gulf of Genoa and are therefore called “Genoa” depressions. This is by far the most favoured area for the formation of depressions and accounts for about 52 per year or 69 per cent of all Mediterranean depressions.
ii) The area south of the Atlas Mountains. Depressions forming in this area are called Saharan depressions and are chiefly important in spring. Their frequency is about 14 per year or 18 per cent of all Mediterranean depressions.
iii) The central and eastern Mediterranean. The number of depressions actually forming in this area is small, about three per year or 4 per cent of all Mediterranean depressions. In central Mediterranean they form chiefly in the winter months while in the east they form mainly in autumn and spring. More commonly, old weak depressions become rejuvenated in the eastern Mediterranean, the favourite place for formation called “Cyprus” depressions.

2.3.3 Depression tracks and frequencies

Figure 3, obtained from the *weather in the Mediterranean* (U.K. Met. Off. 1962), shows the main tracks of depressions into and through the Mediterranean, with their average annual frequencies. A given depression may follow these tracks in various combinations. Many depressions behave in irregular ways that cannot be fitted into any particular scheme.

The average number of depressions arriving in the Cyprus area is about 26 or 27 in a year (that is, by tracks 2c, 2d, or 4b). If we add the number forming in the region we get a total of about 28 per year in this area. Of these, some move eastwards and others stagnate in the region until they fill up or become rejuvenated. A certain number of depressions skirt the Cyprus area itself and cross the Anatolian plateau.

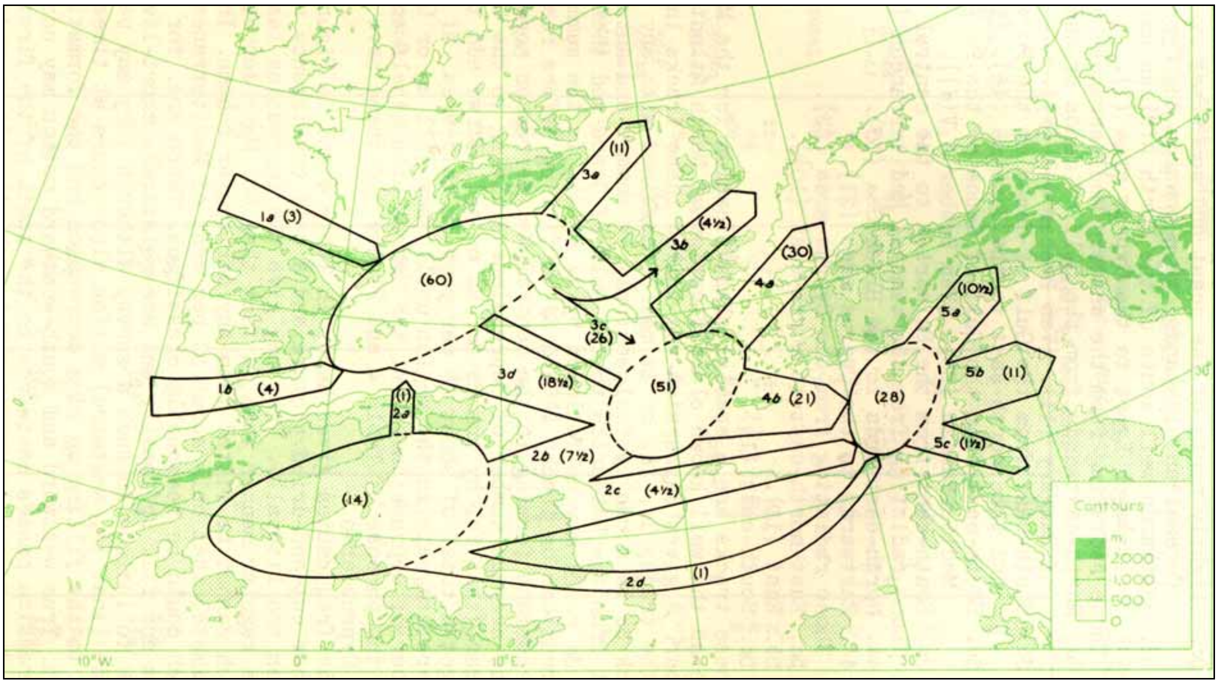

Figure 3: Tracks of Mediterranean depressions. Average annual frequencies shown in brackets are based on 1926-35 records (U.K. Meteorological Office, 1962).

3 DATA

This chapter includes the selection of the period and area of study (3.1), a quick data quality check and stations selection (3.2), the definition of climatic regions (3.3) and regional precipitation index (3.4), and finally analyses the relationships between station time series and the regional precipitation index (3.5).

3.1 Period and area of study

The area under consideration is the island of Cyprus excluding the northern part of the island for which precipitation records available stopped in 1974 with the Turkish invasion and occupation of this part of the island (Figure 4). The period of study has been chosen as long as possible in function of the data availability. The Meteorological Service has realised a data quality check over the entire island. It has also estimated daily rainfall for stations with periods of missing data. Before 1972, missing data have been estimated using data from the three nearest stations. After 1972 daily isohyetal maps were used. Monthly precipitation time series are available for forty-seven stations over the 84 years period from hydrological year 1916/17 to hydrological year 1999/00 (**Entire Period**). It is understood that the year used in this analysis is the standard hydrological year used in Cyprus. The hydrological year 1999/00 corresponds to the period including the first of January 2000, it starts on the 1st of October 1999 and finishes on the 30th of September 2000.

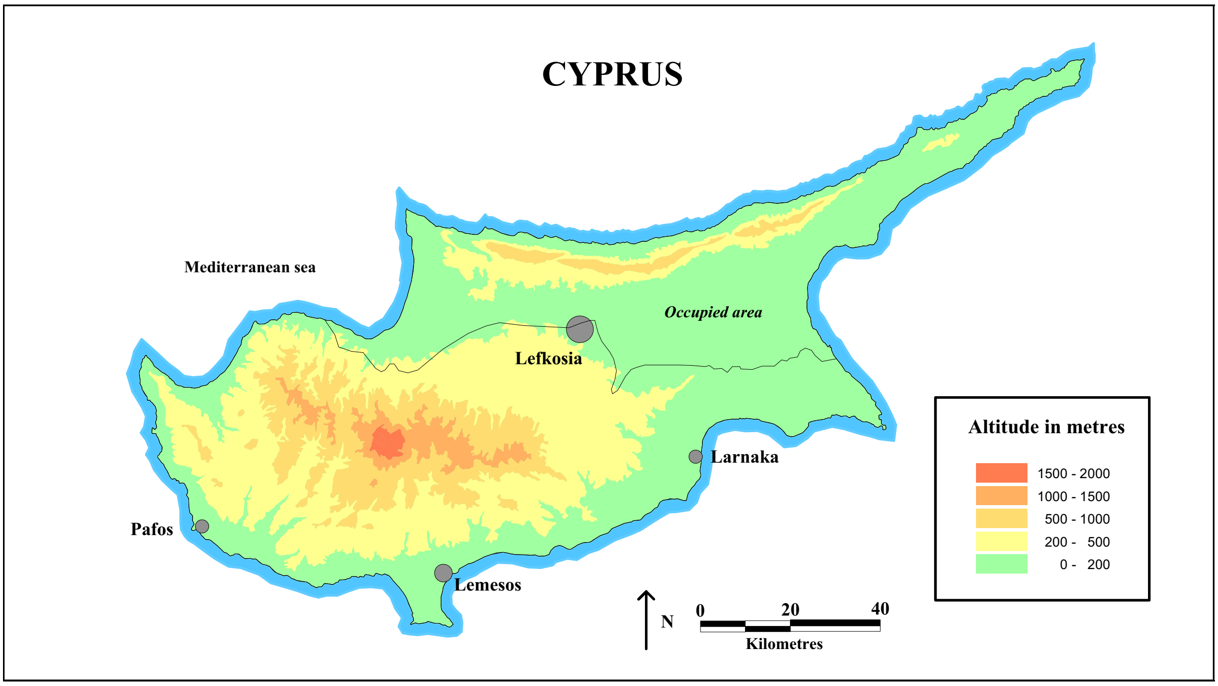

Figure 4: Topography of the island of Cyprus.

3.2 Stations selection and a quick data quality check

Initially all stations with the entire period of records (1916/17 - 1999/00) have been considered for the analysis. A double mass plot of the annual precipitation of the district defined by the Meteorological Service in millimetres against the station annual precipitation is realised for each district to identify suspect time-series. The correlation coefficients between the stations and district annual time series have also been used to identify suspect time-series. After verification with Mr. K. Piyiotis, the person in charge of the station history at the Meteorological Service, the stations 270 (Troodos, PWD), 530 (Ora, Police stn.) and 730 (Larnaca, PWD) have been excluded from this analysis. These three stations present an abrupt change in their double mass curve with neighbouring stations. We recommend a detailed review of these time series to try to identify the origin of the changes and eventually correct the data. Our summary analysis indicates that these discrepancies may include misuse of instruments before 1940. Between the remaining stations, 33 time series are of satisfactory quality and 11 time series present relatively long periods of estimated data. All the 44 stations have been used as they all have high r^2 with neighbouring stations and straight double mass curves. The stations are relatively well distributed throughout the free part of the Island (Figure 5). However some areas remain with a low density of stations. This is particularly the case for the eastern coastal area near Larnaca and the southern and north-western slopes of the Troodos Mountain.

Figure 5: Location and Station Numbers of the 44 meteorological stations used.

3.3 Definition of climatic regions

The country has been divided into climatic regions. As a first approach the meteorological districts defined by the Meteorological Service were considered (Figure 6). Our preliminary analysis shows that the districts are not the most appropriate areas for the purpose of this specific study. As only stations with the entire period of records have been considered some districts include very few stations (Region 13 for example). A second problem was associated with the lack of time series for the northern occupied part of the island. We then decided to define new regions, trying to keep the general shape of the districts but including a minimum of four stations in each region (Figure 7). We check that all the stations included in a region show similar temporal variations (see 3.5 below).

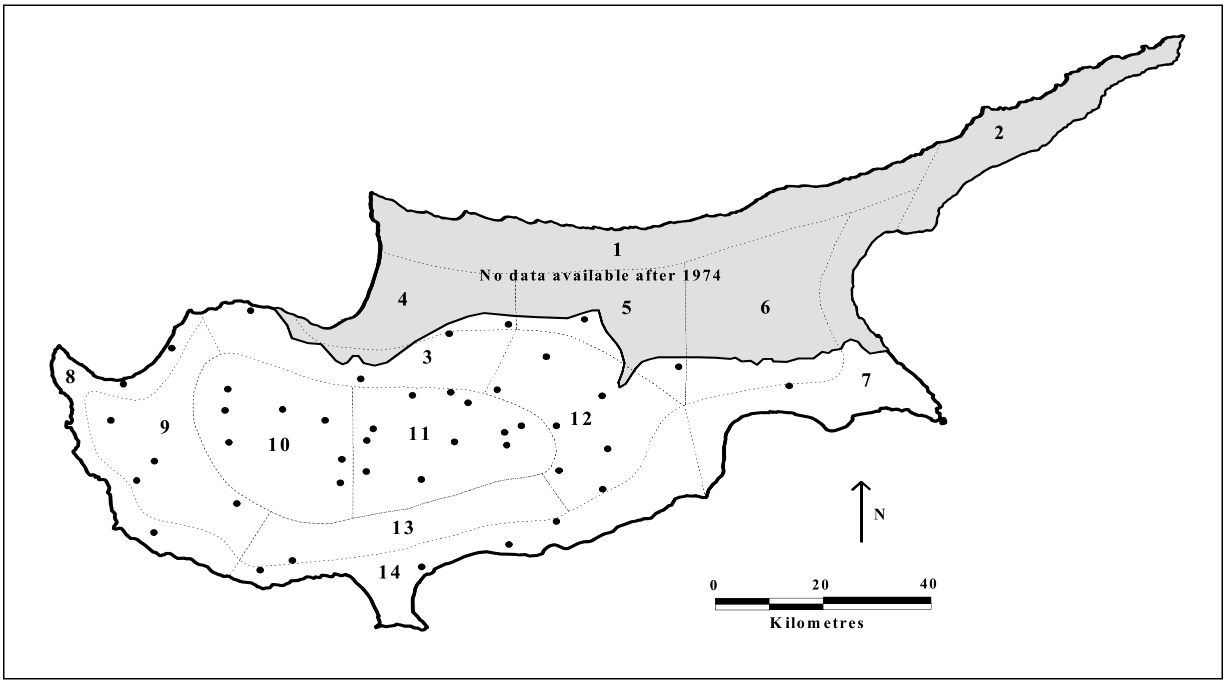

Figure 6: Boundaries of the meteorological districts and location of the 44 stations used.

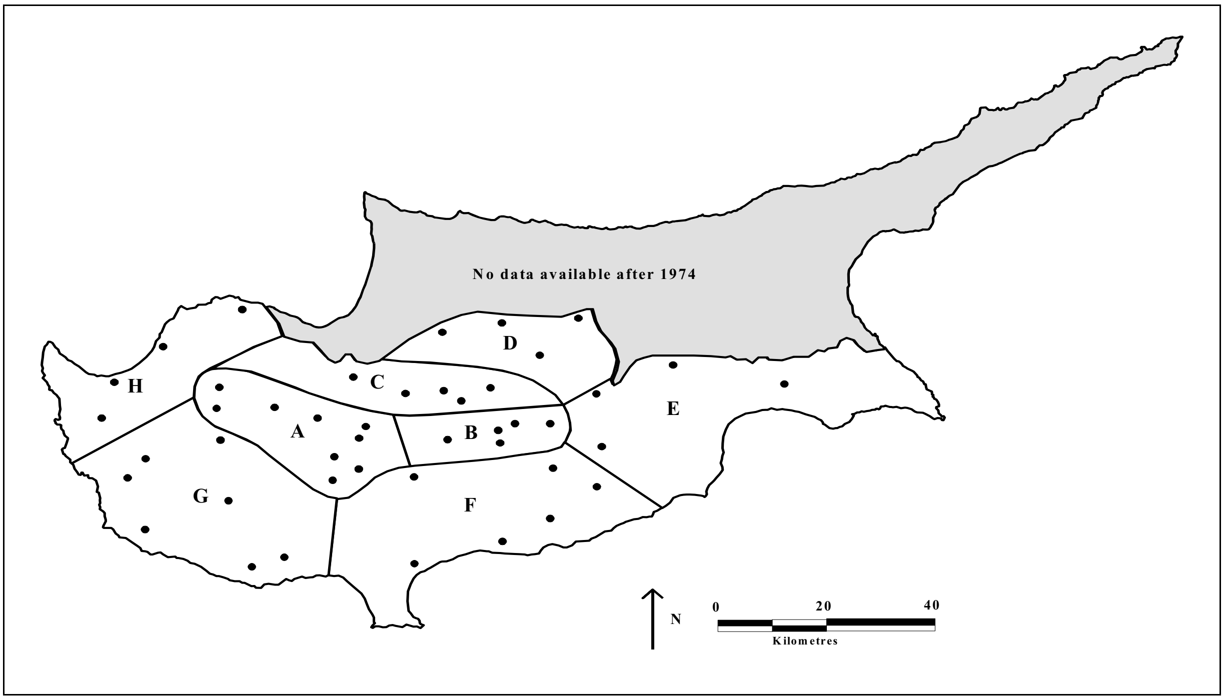

Figure 7: Boundaries and identification letters (A to H) of the regions defined for this analysis and location of the 44 stations used.

3.4 Regional precipitation index

For trend and regional temporal variations analyses it is useful to use a regional precipitation index as this eliminates part of the local variability associated with a specific station that does not reflect a regional change (Rossel et al., 1999; Rossel and Garbrecht, 2000). WMO (2000) is emphasising the importance of using areally integrated climate inputs as they provide more pertinent information on climate variability and less local "weather" type variability than station records of precipitation. The use of regional index gives a better regional significance to the analyses. The regional index used in this analysis is calculated as the average of the standardised precipitation of the stations included in the region (Figure 8). The regional index is calculated at the annual and monthly time-scale. The use of standardised value is important to allow comparison of time-series when precipitation presents a significant spatial gradient throughout the area of study. This is the case in Cyprus with mean annual precipitation ranging from less than 300 mm in the central plain area to more than 1000 mm at the top of the Troodos Mountains. The annual and monthly precipitation time-series of the stations have been standardised with the long-term (1916/17-1999/00) mean and standard deviation. For display purpose and more understandable results it was sometimes more useful to present the regional analysis with precipitation changes in millimetres than in standardised values. To this end, the average of the monthly or annual precipitation of the stations was used to represent the regional precipitation.

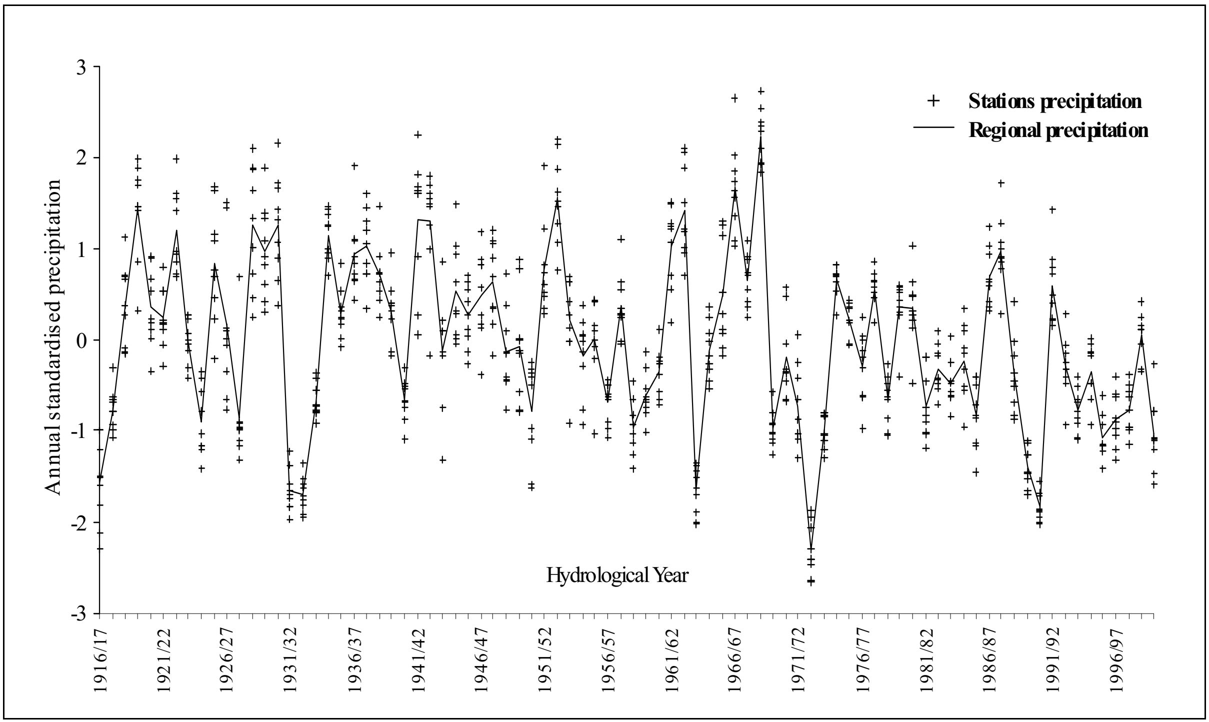

Figure 8: Station and regional standardised annual precipitation for the Region A.

3.5 Homogeneity of the regions

By homogeneity we understand that the time-series follow similar temporal variations with pseudo-proportional increase or decrease of the precipitation at all the stations included in the region. If a region is homogeneous the analysis realised with the regional index will also be valid for all the stations included in the region.

The coefficients of determination, r^2 between station and regional standardised annual precipitation time series have also been determined to quantify the homogeneity of the region. Table 1 shows the average, minimum and maximum r^2 for each region. Annex 1 gives a list of the 44 stations with Station Number, Region, and r^2. Note the low minimum r^2 value for the Region H. It corresponds to Station 160 (Kato Pyrgos) which is relatively distant from the other stations in the area.

Region	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Avg. r^2	0,85	0,89	0,91	0,81	0,85	0,82	0,82	0,82
Min. r^2	0,78	0,80	0,87	0,78	0,82	0,76	0,78	0,72
Max. r^2	0,92	0,95	0,95	0,85	0,89	0,88	0,86	0,88

Table 1: Average, minimum and maximum r^2 between station and regional standardised annual precipitation time series.

Plots of the standardised annual values of the stations and regional precipitation have been realised for each region to visually check the homogeneity of the region (Figure 8 and Annex 2). A plot of the seasonal distribution of the mean (Figure 9 and Annex 3) and coefficient of variation (Figure 10 and Annex 4) of the monthly precipitation of all the stations included in the region is realised to verify the similarity between the annual regimes of the precipitation at all the stations. The differences between the coefficients of variation during the months of June, July, August, and September are due to isolated storms during these dry months. The existence of rare precipitation events during the dry summer months leads to high standard deviation.

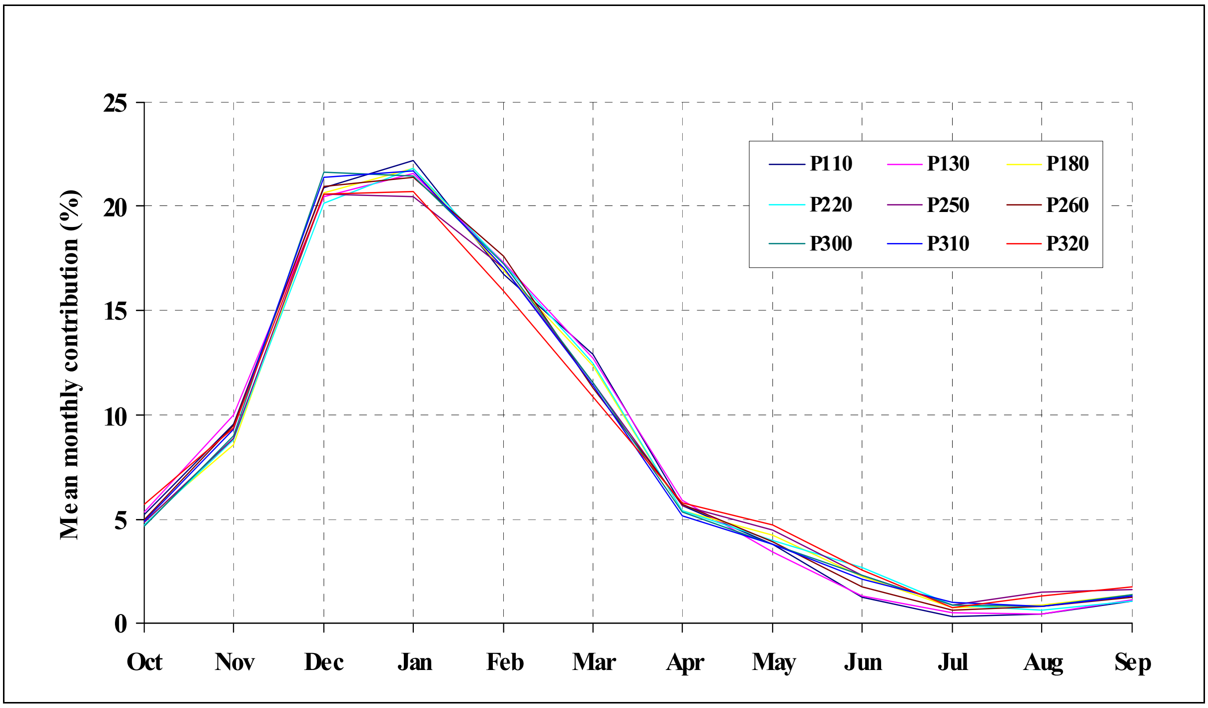

Figure 9: Annual distribution of the mean monthly precipitation of the stations in Region A over the 1916/17-1999/00 period.

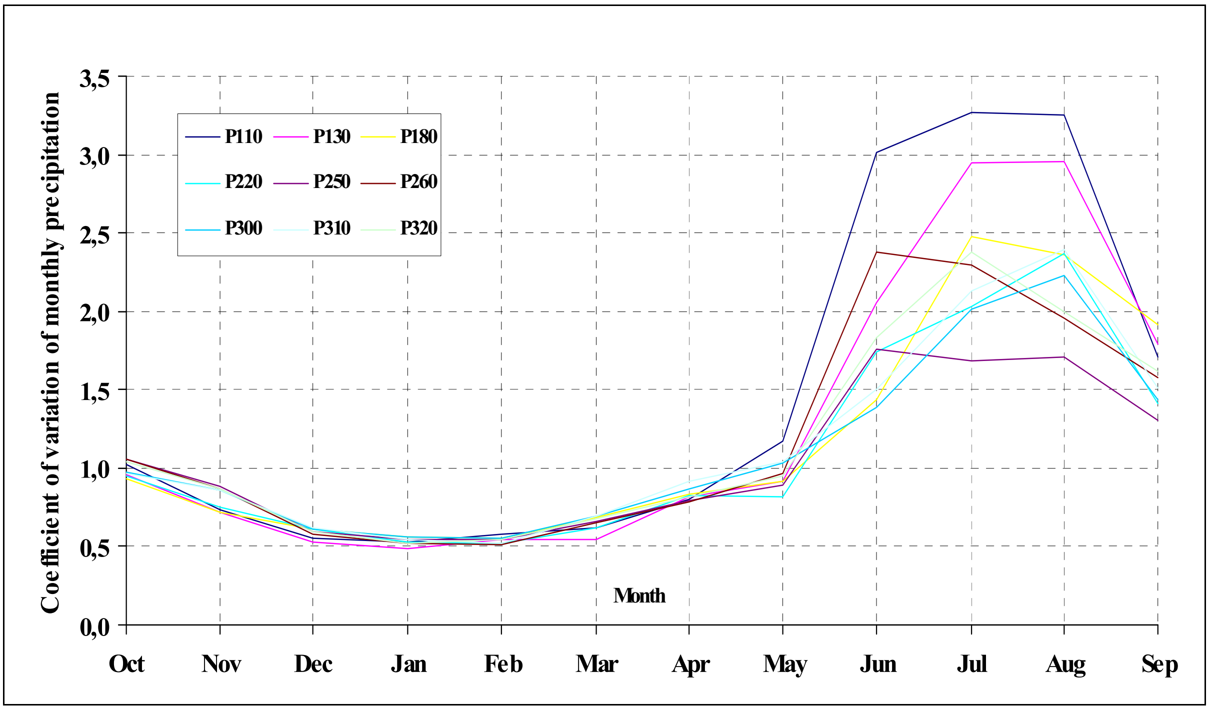

Figure 10: Coefficients of variation of monthly precipitation for the stations in Region A over the 1916/17-1999/00 period.

4 IDENTIFICATION OF TEMPORAL CHANGES IN ANNUAL PRECIPITATION

This chapter covers the main objective of this study, analysing the precipitation records for temporal changes throughout the last century. The first step includes the understanding of the precipitation evolution with the help of graphs and simple filtering of the annual precipitation (4.1). A series of statistical tests is then applied to the annual precipitation records to identify temporal changes, either in the form of a regular trend or in the form of a step change in the mean precipitation (4.2). The final paragraph compares this analysis with similar studies around the world and discusses the differences between regular trend and step change (4.3).

4.1 Visual evidences of precipitation changes through the last century

We try here with graphs and tables to highlight and understand the general patterns of the precipitation decrease observed on the island of Cyprus. Exploratory data analysis using graphs to explore and understand data is an essential component of any statistical analysis.

4.1.1 Overview of the inter-annual variability of annual precipitation

Figure 11 and Figure 12 show the high inter-annual variability of the annual precipitation. The regional precipitation of the wettest region of the island (Region A, western part of the Troodos Mountain) varies from less than 400 mm to more than 1300 mm. These figures also give a first idea on the type of precipitation change. It can already be seen that not many very wet years have been observed over the last 30 years, but the dry years of the same period are not drier than the dry years observed during the first 54 years. Similar comments can be made for all eight regions of the study (Annex 5 and Annex 6). However some differences are observed. Very wet years have been observed during the last 30 years in the central plain part of the island (Region D : 1972), in the southwest part of the island (Region G : 1975) and in the south-east part of the island (Regions B, E and F: 1992).

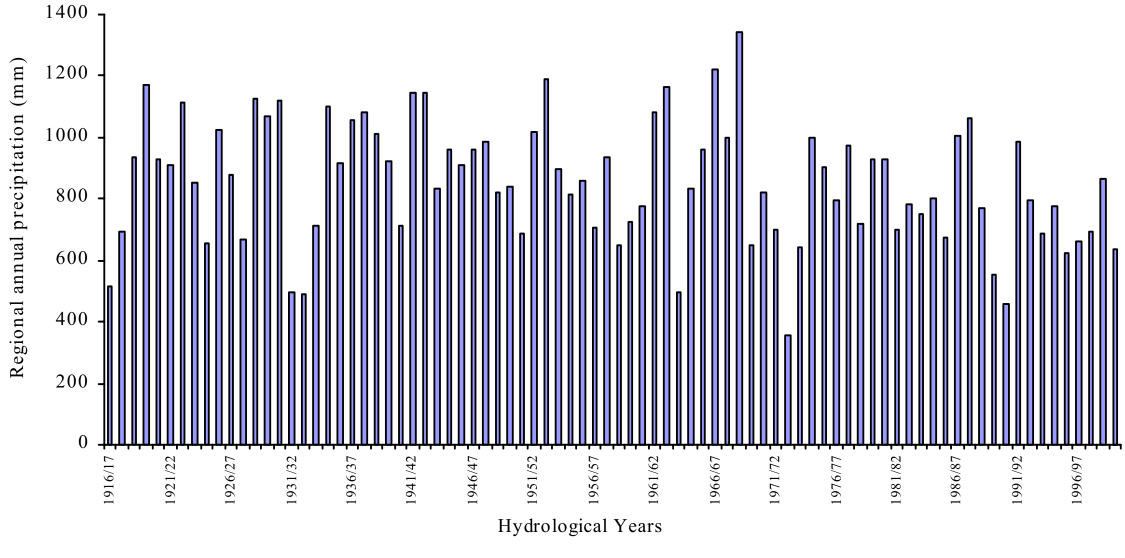

Figure 11: Regional annual precipitation for Region A.

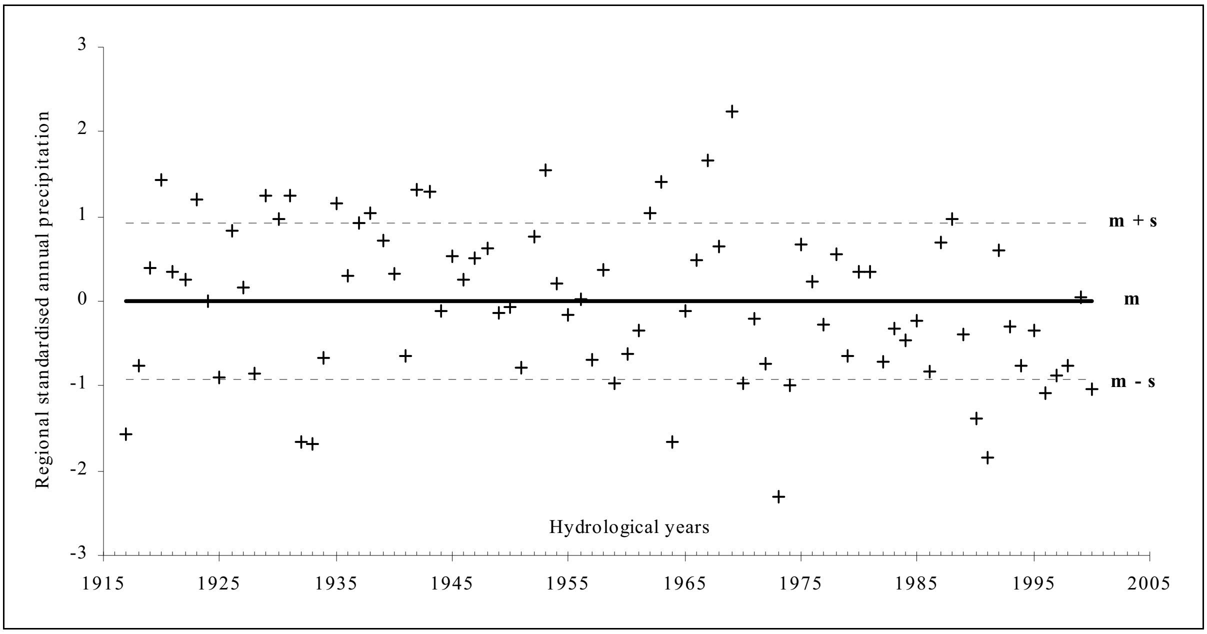

Figure 12: Regional standardised annual precipitation with indication of the mean (m) and standard deviation (s) for Region A.

4.1.2 Moving average

The use of low frequency filters, five and eleven years moving averages, highlights the decade scale variability of the precipitation. The five years scale variability is characterised by large variations Figure 13, Annex 7). The period of negative values starting in 1990 is the longest in the record but up to now it is not more severe than the ones of the early 70's or 30's in the south-eastern regions. These graphs indicate the possibility of a shift around 1970. As it can be seen on Figure 13, the majority of the values are positive in the period 1917 to 1970 and negative in the period 1970 to 2000. This shift is clearly apparent in most of the other regions as well, especially in Region C, but it is less notable in Regions G and H.

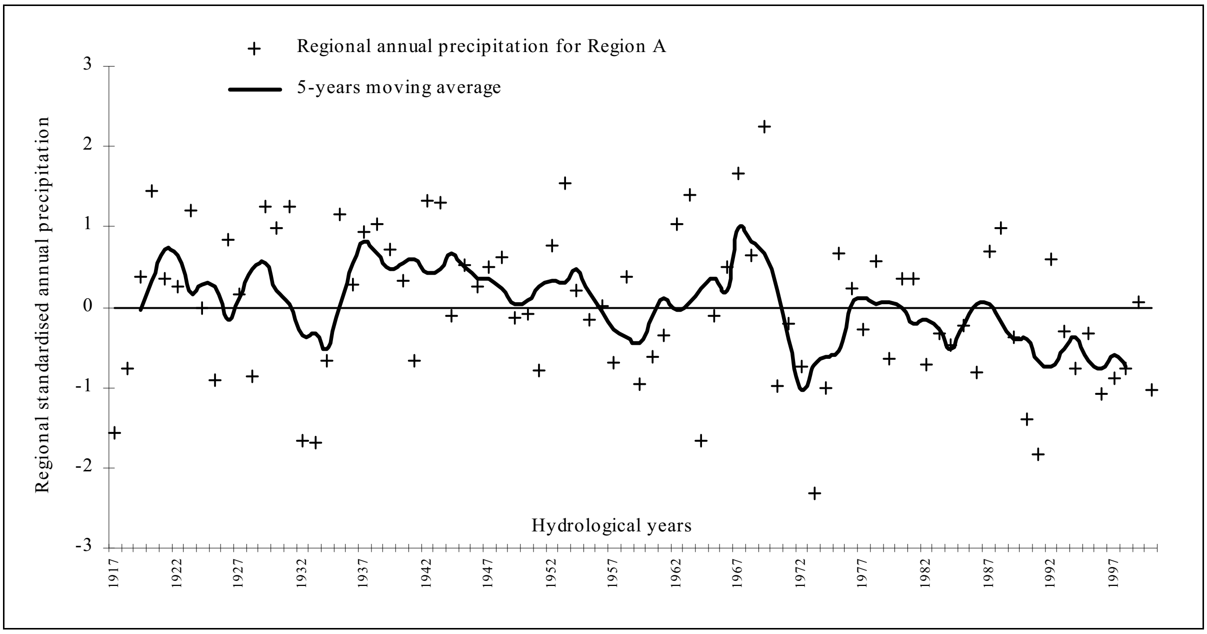

Figure 13: Regional standardised annual precipitation and 5 years moving average for Region A.

The eleven years moving average filters out more of the inter-annual variability (Figure 14 and Annex 8). It suggests an overall decreasing trend even though there are periods of slight increase (1930-40, 1960-65 and 1975-80). This general decrease is evident for the Troodos Mountain regions (Regions A, B and C). For the central plain (Region D) it is notable only since the 70's and for the coastal regions (Regions E to H) it is imperceptible on the graphs.

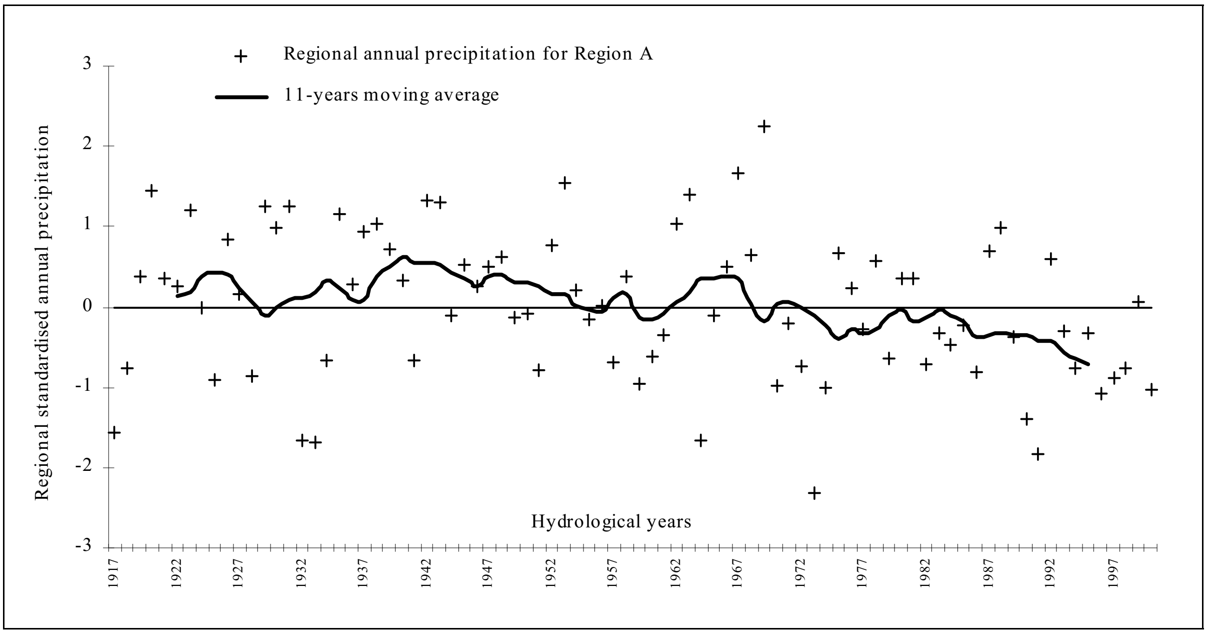

Figure 14: Regional standardised annual precipitation and 11 years moving average for Region A.

4.1.3 Mean precipitation characteristics over the WMO 30- year standard periods

The mean, standard deviation and coefficient of variation of the annual precipitation were determined for each region over the 30 years WMO periods: 1921-50, 1931-60, 1941-70, 1951-80, 1961-90 and 1971-2000. For Region A, the three parameters are relatively stable over the first three periods with values around 900 mm, 180 mm and 0,21 respectively (Figure 15). During the two following periods, the mean is about 50 mm lower, the standard deviation 20 mm higher resulting in an increase of the coefficient of variation to a value of 0,25. The higher values of the standard deviations during these periods are essentially due to the presence in them of the driest (1972/73) and wettest (1968/69) year of the record. The coefficients of variation of the other periods are similar with values near 0,21. During the last period, the mean reduces by an additional 70 mm. Because of the absence of the two extreme values the standard deviation and coefficient of variation are lower than for the two previous periods. The coefficient of variation of the last period is in fact similar to the coefficient of variation of the first three periods. The other regions show similar variations with a decrease over time of the mean and standard deviation, and a relatively stable coefficient of variation (Annex 9).

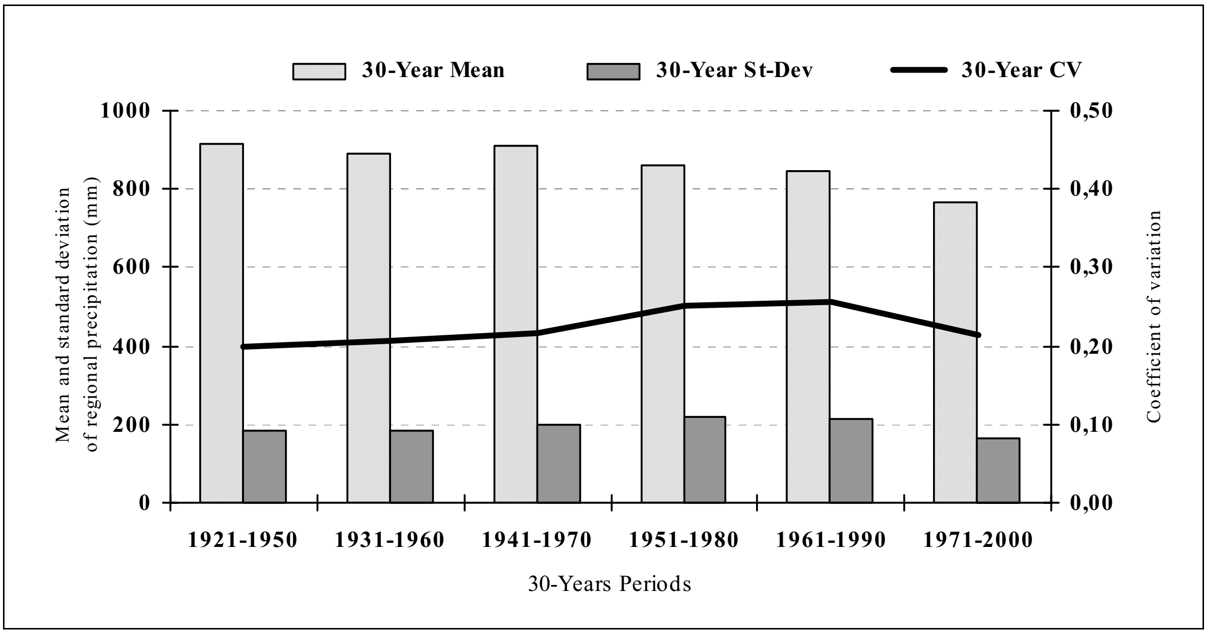

Figure 15: Mean, standard deviation and coefficient of variation of the regional annual precipitation over the WMO Standard Normal 30 year periods for Region A.

4.2 Statistical evidence of precipitation changes during the last century

Most of the statistical tests used here are well documented in the recent WMO publication "*detecting trend and other changes in hydrological data*" (WMO, 2000). Additional information can be found in the following references: Sneyers (1975), Saporta (1990), Haan (1994), Hubert (1997).

4.2.1 Preliminary statistical tests

This is an attempt to explain in layman's words the meaning of the level of significance of statistical tests. The objective of this first section is also to check whether the annual precipitation totals are normally distributed and independent of each other, and to check whether their time series are stationary through time. Several statistical tests require that these conditions are met.

What does *significant* mean? A *significant* trend is a trend that does not vary a lot if you add to or remove only few points from the time series. A non-significant trend will certainly disappear if you add one or two points that go against the trend. A significant trend is generally associated with an external factor affecting the process under consideration.

Three assumptions are commonly made when carrying out statistical tests: the form of the distribution e.g. normally distributed, the constancy of the distribution and the independence between the observations. By constancy of the distribution it is understood that the form of the distribution does not vary with time. Table 2 shows the results of the test for these three characteristics on the regional annual precipitation of the eight regions. Because of the presence of a trend, the observations are not independent. For this reason, statistical tests based on the hypothesis of independence of the data should not be used. The normal character of the distribution of the annual precipitation allows the use of parametric tests like the linear regression. Most of the tests used here are not based on the hypothesis of a normal distribution; they are rank-based, non-parametric or distribution-free tests.

Region	A	B	C	D	E	F	G	H
Normal	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Constancy	No	No	No	No	Yes	No	Yes	No
Independent	No	No	No	Yes	Yes	No	Yes	Yes

Table 2: Results of the tests for normality (Cornu normality), constancy of the distribution (Mann-Kendall) and independence (Wald-Wolfowitz) for the regional annual precipitation time series. The significance level of all tests is 5%.

4.2.2 Linear trend in mean precipitation

The objective of this section is to determine whether there is a significant linear trend in annual precipitation or not. All the regions records show a decreasing linear trend (Figure 16 and Annex 10). Table 3 shows that this trend is not significant at the 5% level according to the Mann-Kendall and Spearman tests for Regions E and G. The linear regression r^2 of all the coastal regions (Regions E to H) is not significant at the 5% level. In other words, a decrease in mean precipitation is observed everywhere throughout the island, but the decrease is statistically significant only for the Troodos Mountain regions and the dry central plain.

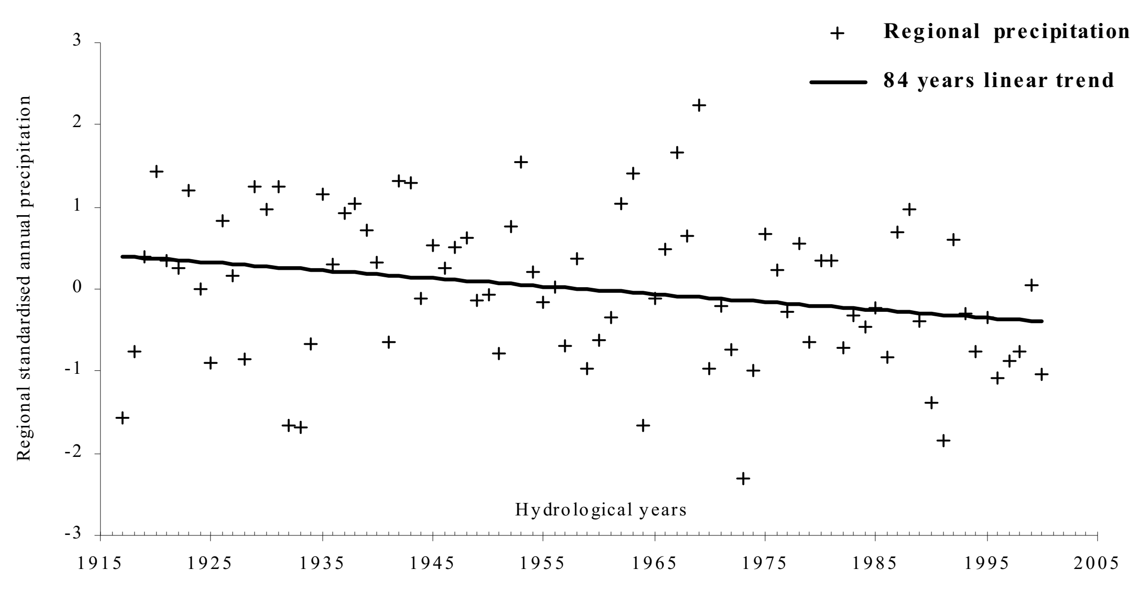

Figure 16: Regional standardised annual precipitation and linear regression trend over the Entire Period (1916/17-1999/00) for Region A.

Region	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Mann-Kendall	Yes	Yes	Yes	Yes	No	Yes	No	Yes
Spearman	Yes	Yes	Yes	Yes	No	Yes	No	Yes
r^2 (Linear Regression)	Yes	Yes	Yes	Yes	No	No	No	No
Linear slope (%)	-0,96	-0,85	-1,83	-1,03	-0,68	-0,76	-0,40	-0,42

Table 3: Results of three tests for trend in the regional standardised annual precipitation at 5% significance level and the slope of the linear regression line.

4.2.3 Step change in mean precipitation

The objective of this section is to check whether it is possible to divide the time-series in two stationary periods? All eight regions' records include a shift or step change in mean which is significant at the 5% level (Table 4). The Hubert segmentation procedure suggests a segmentation of the time series between the hydrological years 1968/69 and 1969/70 for seven regions and between 1970/71 and 1971/72 for the central plain region (Region D). All steps are significant at the 5% level according to the Scheffe test.

Region	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Von Neumann	Shift	Shift	Shift	Shift	Rapid Variation	Shift	Shift	Shift
Hubert	1968/69 - 1969/70	1968/69 - 1969/70	1968/69 - 1969/70	1970/71 - 1971/72	1968/69 - 1969/70	1968/69 - 1969/70	1968/69 - 1969/70	1968/69 - 1969/70

Table 4: Results of the Von Neumann homogeneity test and of the Hubert segmentation procedure. The 5% level of significance is used in both tests.

The segmentation procedure splits the time series into two periods. Given the fact that the latter period corresponds closely to the latest WMO Standard Normal (1916/71-1999/00) and that the effect of the change is expected to be negligible all statistical tests were carried out on slightly modified segmentation periods:

1916/17-1969/70 (Period 1)

and **1970/71-1999/00 (Period 2)** which corresponds to the latest WMO Standard Normal

Table 5 gives the results of Student's t-test that was applied to check for the equality of the means of Period 1 and Period 2. The mean of Period 2 is lower than the mean of the Period 1 (Figure 17 and Annex 11). The greater differences appear in the Troodos Mountain regions (Regions A, B and C). The least differences appear in the western coastal region (Region H).

Region	A	B	C	D	E	F	G	H
m $_{\text{Period 1}}$ = m $_{\text{Period 2}}$	No	No	No	No	No	No	No	No

Table 5: Results of the Student's t-test for equality of the means, m of Period 1 and Period 2. The Student's t-test is coupled with the Fisher-Snedecor test for equality of the standard deviations. The 5% Significance Level is used.

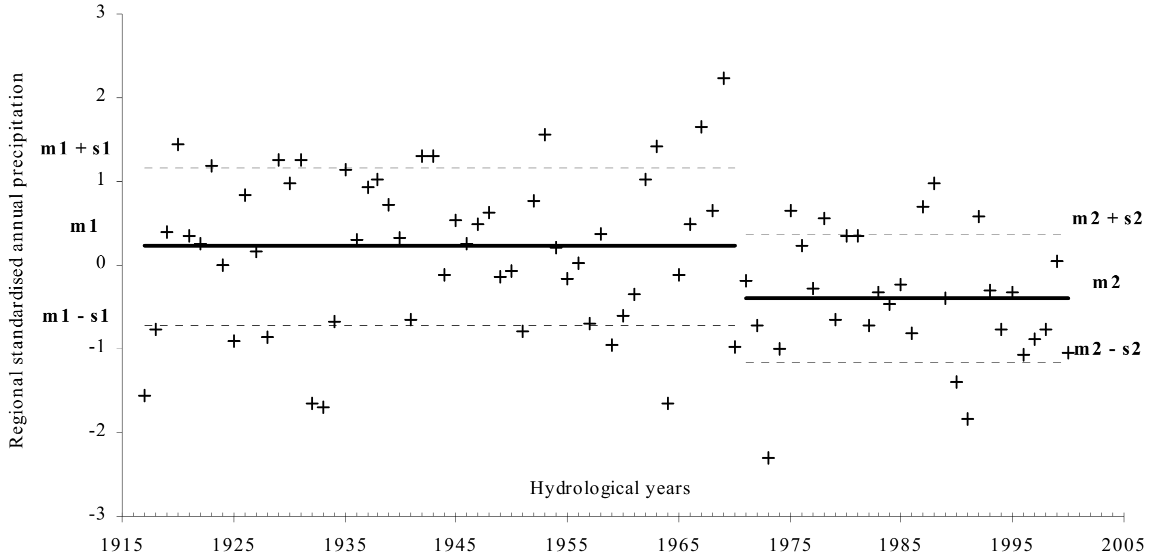

Figure 17: Regional standardised annual precipitation with indication of the mean (m) and standard deviation (s) of Period 1 and Period 2 for Region A.

4.3 Is there a linear trend or a shift in the mean annual precipitation?

4.3.1 Statistical analysis

Both types of changes i.e. linear trend and shift are statistically significant. However, it is obvious that a linear trend is imposed on a time series by the existence of a step change in the records. To illustrate this, let us consider a time series including 60 values each one equal to 500 followed by 30 values each one equal to 400. The trend techniques identify a significant linear decreasing trend over this entire time series, but it is obvious that each sub-period does not include a trend. In its publication "*detecting trend and other changes in hydrological data*", WMO is warning about the possibility of this kind of misuse of trend technique saying: *"if there has been a marked step change in a data series then it is likely that a test for trend will give significant results, even though there is no trend"* (WMO, 2000, page 51). To check if this is the case for the annual precipitation time series in Cyprus the time series have been split in two periods as defined previously : Period 1 (1916/17-1969/70) and Period 2 (1970/71-1999/00).

The trend test and linear regression analysis carried out in all regions for both periods show that the decreasing trend is no longer significant, except for Period 1 in Region C and Period 2 in Region D (Table 6). The statistical significant decrease observed in Region D is essentially due to the high amount of rainfall of 1970/71. The segmentation procedure was including this year in the first period for this region. For clarity, we decide to use the same periods for all regions and then include the year 1970/71 in the second period. The annual precipitation of Region D does not present a statistical significant trend over the period 1971/72-1999/00.

Region	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Period 1	No	No	Yes	No	No	No	No	No
Period 2	No	No	No	Yes	No	No	No	No

Table 6: Results of the Student's t-test (5% Significance Level) carried out on the r^2 values (linear regression) of Period 1 and Period 2.

The linear regression lines are almost horizontal over Period 1 for most of the regions (Figure 18, and Annex 12). Over Period 2 they show a decrease but the decrease is not significant. As can be seen in Figure 19 a single positive value in 2001 (Fictitious Value) completely modifies the slope of the regression line.

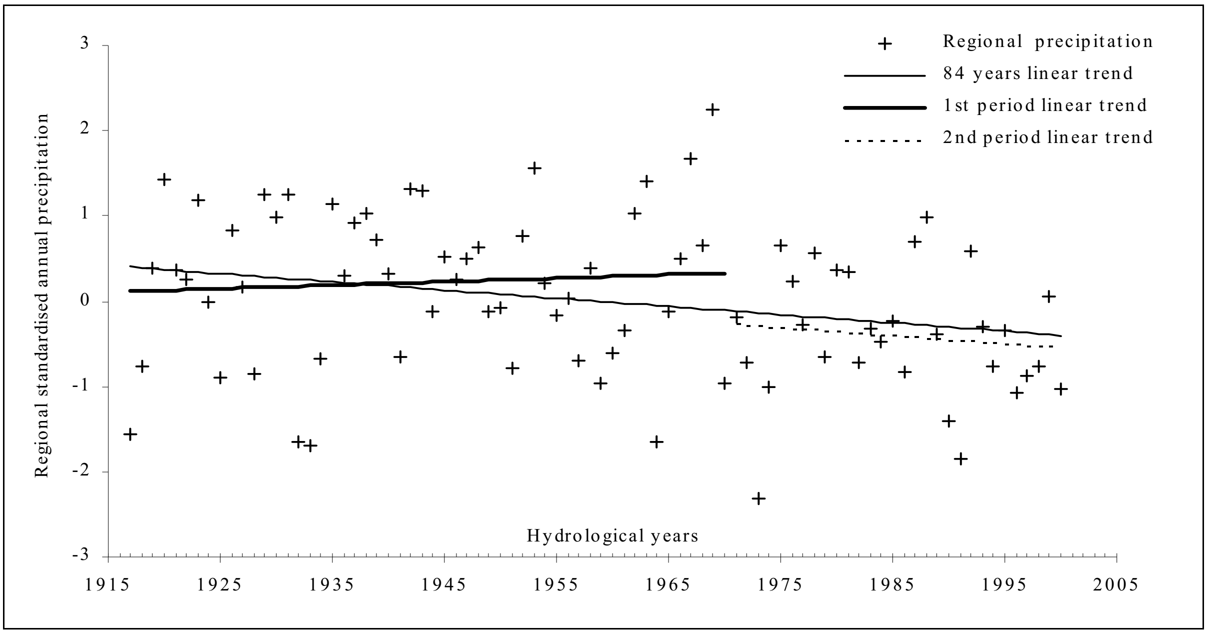

Figure 18: Regional standardised annual precipitation and linear regression trend over the Entire Period, Period 1 and Period 2 for Region A.

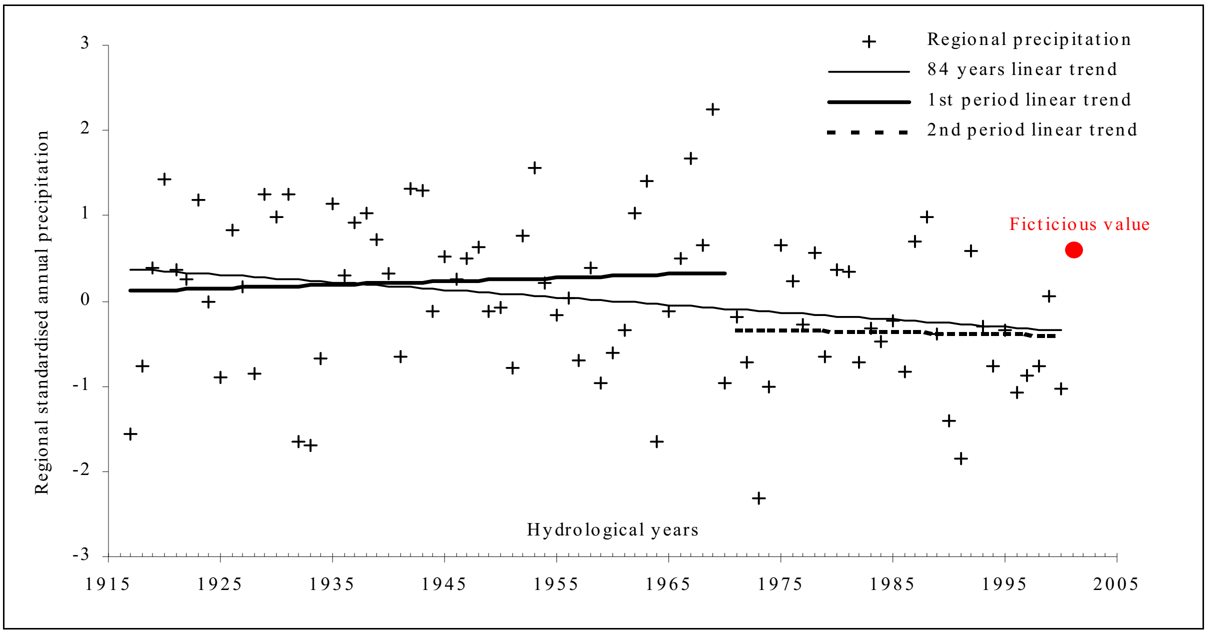

Figure 19: Regional standardised annual precipitation and linear regression trend over the Entire Period, Period 1 and Period 2 for Region A. The Fictitious Value for 2001 is added here only to highlight the non-significance of the trend shown on Figure 18.

4.3.2 Similar step changes around the world

Studies for changes in mean annual precipitation have been realised in several parts of the world. The results of a selection of them are presented here to place the results of the study carried out on Cyprus records in a more general context.

A step decrease in the precipitation in 1970 has been identified in part of Bulgaria and Romania (Carbonnel and Hubert, 1994). Several authors have analysed hydro-meteorological time series in West Africa from Niger to Senegal (Carbonnel and Hubert, 1985; Snijders, 1986; Hubert and Carbonnel, 1987; Hubert et al. 1989; Paturel et al., 1997). They point out the non-stationarity of the series and suggest a climatic jump down sometime between 1965 and 1972; the majority of the shifts appearing between 1969 and 1970. Precipitation in the Great Plains of the United States of America also show a significant change with an increase since the late 60´s, the last two decades being the wettest of the 20th century (Garbrecht and Rossel, 2000 and 2001). The Brazilian Amazon basin precipitation records show a shift near 1975, downward in the northern area and upward in the southern part (Marengo, 1999). Marengo suggests a link of the precipitation change with the inter-decadal (10 years scale) variability of the sea surface temperature (SST) in South Atlantic and South Pacific. Pacific SST is increasing with strong and more frequent El Niño/Southern Oscillation events since the 70´s (NASA, 1999). The earth global air temperature was relatively stable from the 30´s to the 70´s; it is since then showing a considerable increase.

All the above studies suggest the possibility of a world wide new climatic phase since the start of the 70´s. The origin of the climatic change can certainly be found in a general perturbation of the atmospheric and oceanic circulation at a planetary scale with different regional impacts. Even though climatic changes do not occur in one day, it is known that threshold effects and small variations in latitude of atmospheric systems such as jet-streams and low pressure convergence zones can result in relatively abrupt change in local mean precipitation. For a better understanding of weather and climate changes in Cyprus it would be interesting to look for existing studies or develop an analysis of the changes in tracks of depression systems in the eastern Mediterranean sector.

4.3.3 Discussion and conclusion

Most of the precipitation time series show a significant decreasing linear trend over the entire period of records. These results are in agreement with most of the previous studies realised with Cyprus precipitation records indicating a decrease in annual precipitation (Kornev, 1996; Retalis et al., 1997; Hadjioannou, 1998). However, we demonstrate that these trends are essentially due to a step change in mean precipitation around 1970. Several statistical tests indicate that the precipitation records include a significant shift or step change in the mean value of their time series. The segmentation procedure used and graphical analyses indicate that this shift occurs between the hydrological years 1968/69 and 1972/73 that are respectively one of the dryer and wetter years of the records in Cyprus. This period corresponds to other climatic shifts observed in other parts of the world. The results of the present analysis and those of previous studies demonstrate that the Cyprus precipitation records can be divided into two separate stationary periods.

5 QUANTIFICATION OF THE PRECIPITATION STEP CHANGE

The previous chapter demonstrated that mean precipitation is lower during the last three decades of the 20th century. The main objective of this chapter is to realise a preliminary quantification of the precipitation changes. Both regional and station time series are used in this section to quantify the magnitude of the change and highlight the spatial variation of the changes. The values of the mean annual and mean monthly precipitation of Period 1 (1916/17-1969/70) and Period 2 (1970/71-1999/00) are determined and compared.

5.1 Changes in mean annual precipitation

The differences in millimetres between the mean annual precipitation of Period 1 and Period 2 have been calculated for the 8 regions and their associated 44 stations (Table 7, Figure 20, Figure 21, and Annex 13). The differences are maximal in the Troodos Mountain area. They are larger than 100 mm at almost every station of elevation higher than 500 m a.m.s.l. However, the differences are under 50 mm in the eastern and western coastal areas (Regions E and H). The lack of long records of precipitation on the southern slope of the Troodos Mountain, where some of the major dams are located, does not allow reliable deductions regarding mean precipitation changes for this area.

Region	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Diff. (mm)	-135	-113	-116	-46	-38	-64	-63	-29
Diff. (%)	-14,9	-16,3	-23,0	-13,8	-9,9	-12,4	-11,0	-5,8

Table 7: Differences between the means of regional annual precipitation of Period 2 and Period 1 in millimetres and in percent of the mean of the Period 1. Diff. (mm) = Mean $_{\text{Period 2}}$ – Mean $_{\text{Period 1}}$; Diff. (%) = (Mean $_{\text{Period 2}}$ – Mean $_{\text{Period 1}}$) * 100 / Mean $_{\text{Period 1}}$

The differences between the mean annual precipitation of Period 1 and Period 2 in percent of the mean of Period 1 are given in Table 7, Figure 22, Figure 23 and Annex 13. The larger differences appear in the Troodos Mountain area with maximum values on the northern slope (Region C).

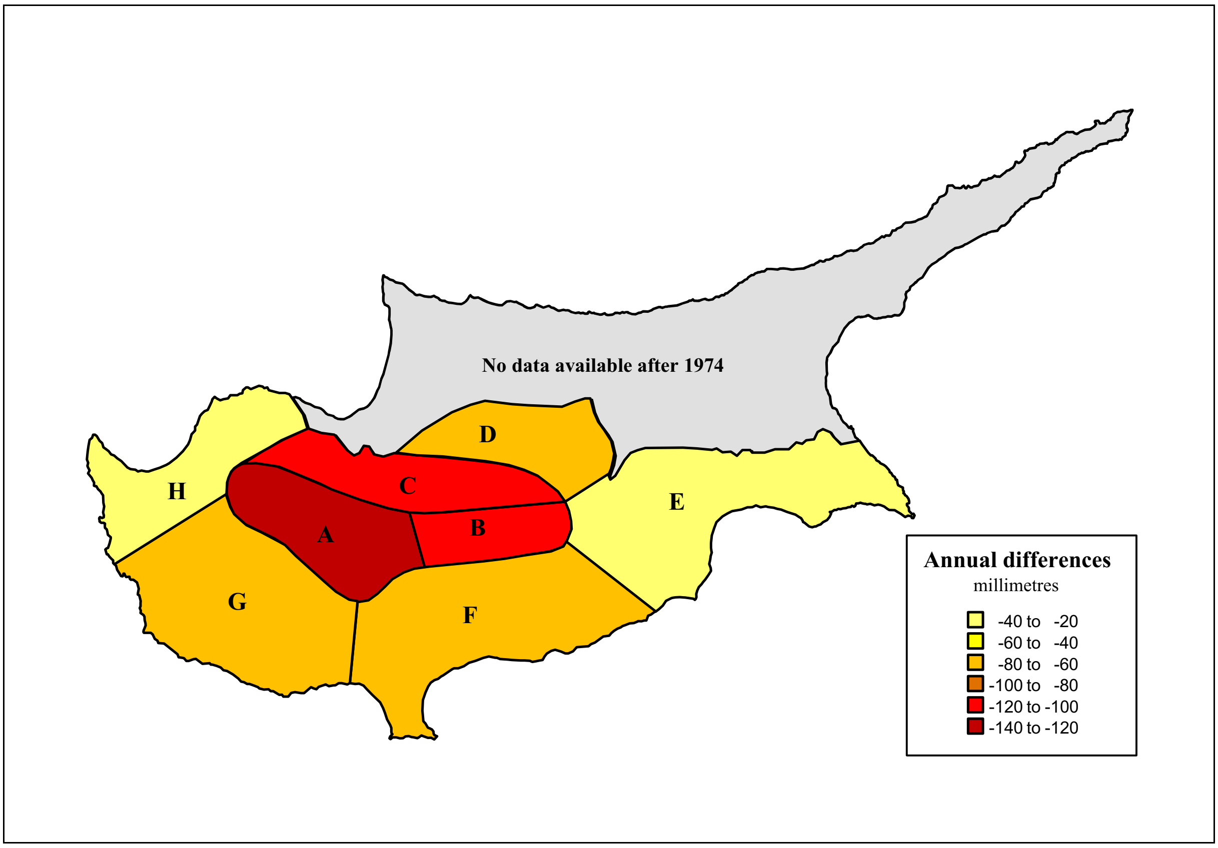

Figure 20: Differences between the means of annual precipitation of Period 2 and Period 1 in millimetres for the 8 regional precipitation indices (Difference = Mean $_{\text{Period 2}}$ – Mean $_{\text{Period 1}}$).

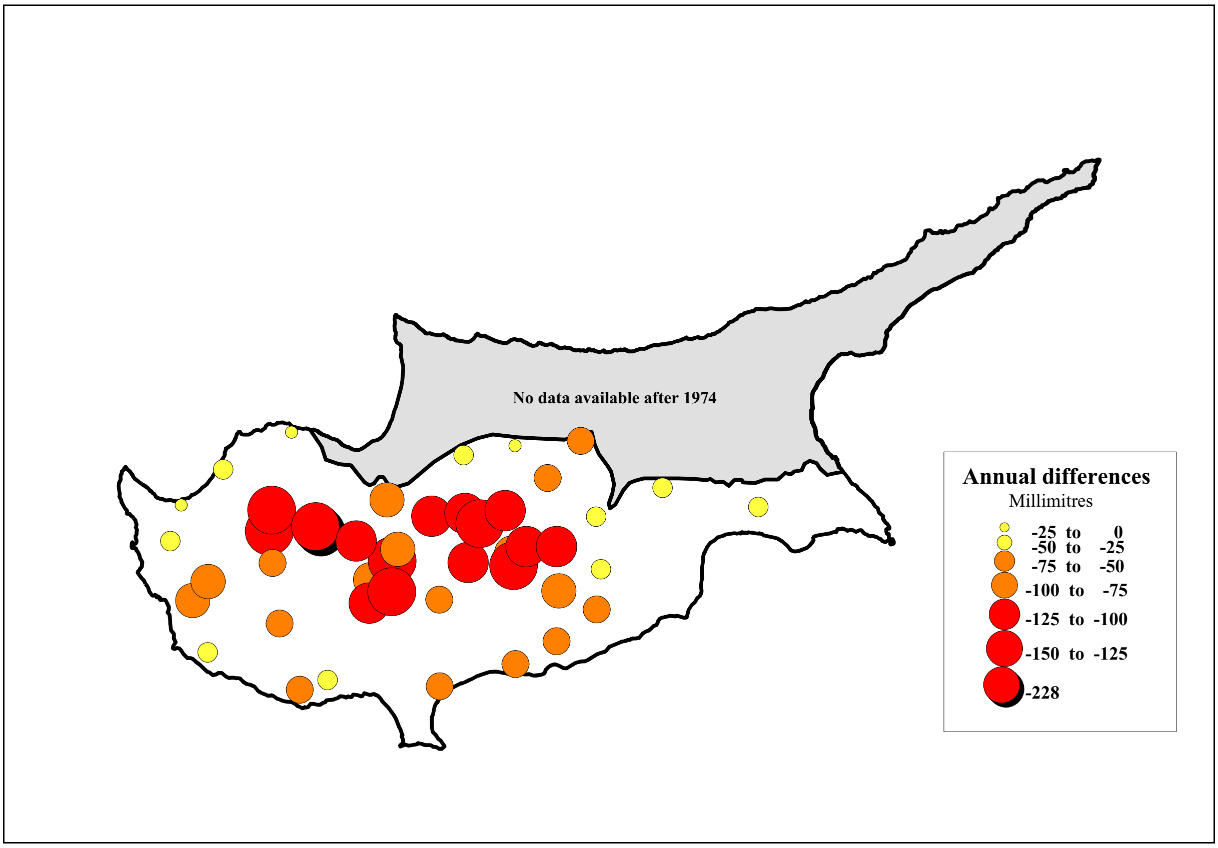

Figure 21: Differences between the means of annual precipitation of Period 1 and Period 2 in millimetres at 44 stations (Difference = Mean $_{\text{Period 2}}$ – Mean $_{\text{Period 1}}$).

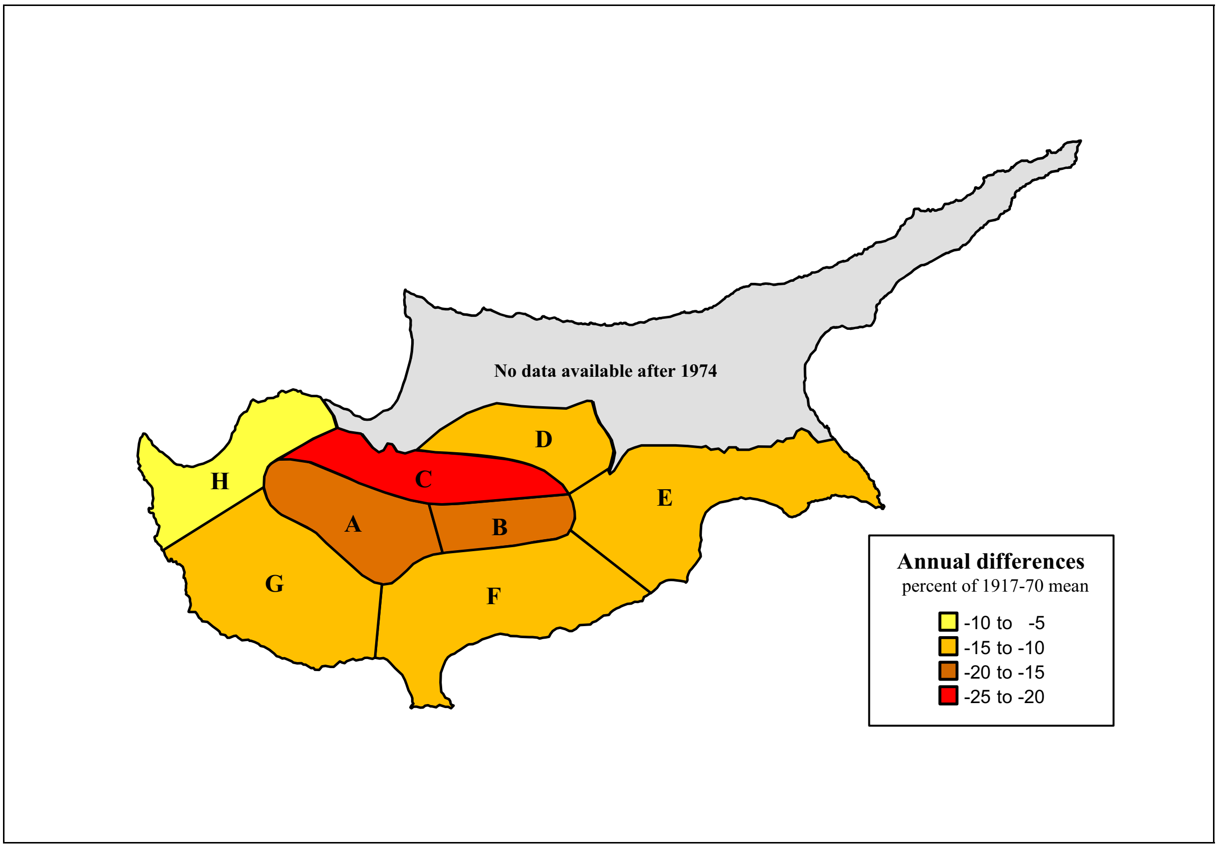

Figure 22: Differences between the means of annual precipitation of Period 2 and Period 1 for the 8 regional precipitation indices (Difference = (Mean $_{\text{Period 2}}$ – Mean $_{\text{Period 1}}$) * 100 / Mean $_{\text{Period 1}}$).

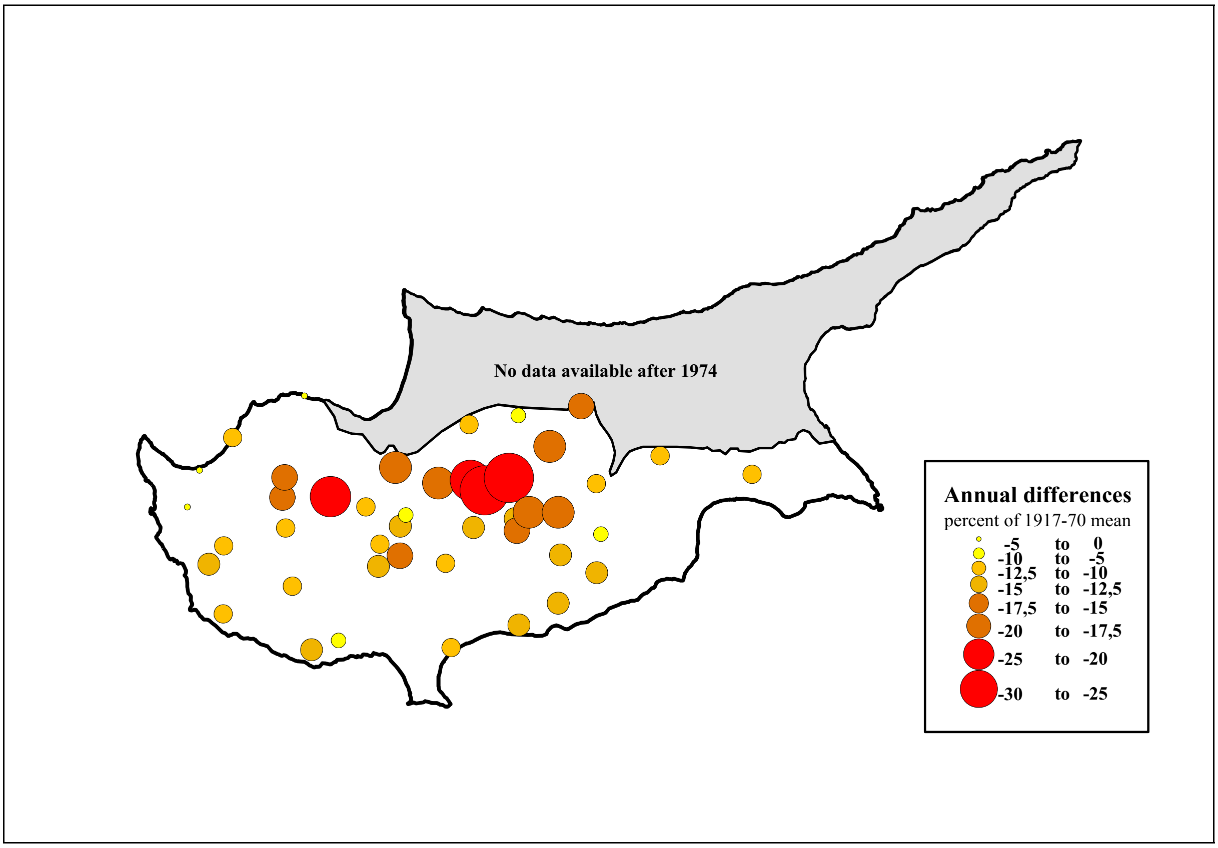

Figure 23: Differences between the means of annual precipitation of Period 1 and Period 2 at 44 stations (Difference = (Mean $_{\text{Period 2}}$ – Mean $_{\text{Period 1}}$) * 100 / Mean $_{\text{Period 1}}$).

5.2 Changes in the distribution of annual precipitation

The objective of this section is to highlight the shift in the distribution of the annual precipitation.

The precipitation time series were divided into three categories: Dry, Normal and Wet. To this end, the annual precipitation values of the Entire Period (1916/17-1999/00) were ranked. The lower third (0% to 33%) corresponds to the Dry category, the central third (33% to 66%) to the Normal category and the higher third (66% to 100%) to the Wet category. In an evenly distributed time series, any 30-year sub-period includes approximately 10 Dry years, 10 Normal years and 10 Wet years. The time series of annual precipitation in Cyprus is not evenly distributed. A shift appears around 1970. Table 8 shows the number of Dry, Normal and Wet years over the last thirty years (1970/71-1999/00). This table shows how rare Wet years are during the last 30 years compared to the number of Wet years of an evenly distributed time series. In four regions Wet years have been observed only 5 times, and only two and three times in the eastern part of the Troodos Mountain (Regions B and C). The distributions are highly asymmetrical displaying a prominent positive skewness. The number of Wet years in all Regions during the last 30 years is lower than in an evenly distributed time series, whereas the number of Normal and Dry years are larger; the number of Dry years being generally larger than the number of Normal years.

Region	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Dry	14	14	16	13	13	15	14	10
Normal	11	13	12	12	9	10	11	12
Wet	5	3	2	5	8	5	5	8

Table 8: Number of Dry, Normal and Wet years over the last thirty years (Period 2).

Figure 24 and Annex 14 show the cumulative distributions of annual precipitation over Period 1 and Period 2. These charts confirm the results given in Table 8. Using Figure 24 as an example it can be seen that the difference between the two curves along their first quarters is only about 100 mm whilst the differences along their fourth quarter is about 200 mm. This indicates that the decrease in mean annual precipitation is essentially due to a reduction of the number of wet years and not to the presence of extremely dry years. The difference between the medians (50%) is roughly equal to the difference between the means. The change in probability of non-excess of annual precipitation between the two periods can also be seen in Figure 24 and Annex 14. For example, precipitation of 800 mm or less has been observed only in 30% of the years between 1916/17 and 1969/70 and in 55% of the years between 1970/71 and 1999/00. The median of Period 1 (900 mm) has been observed or exceeded in only 20% of the time during the last 30 years (Period 2).

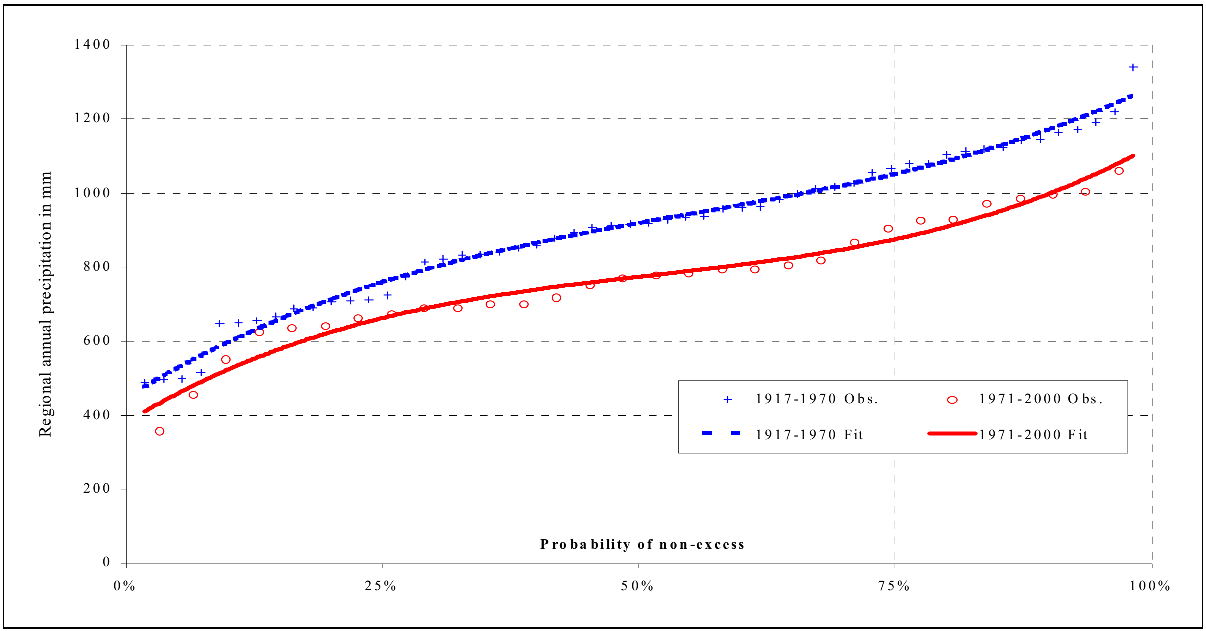

Figure 24: Cumulative distributions of annual precipitation over Period 1 and Period 2 for Region A

5.3 Changes in seasonal distribution of monthly precipitation

The objective of this section is to determine if the decrease in the precipitation appears throughout the year or if it is concentrated during specific months. Mean monthly precipitation has been determined for the twelve months of the year for both Period 1 and Period 2 for all regions and all stations.

Figure 25 and Annex 15 show that the general shape of the seasonal distribution of the precipitation has not changed significantly. In both periods the mean monthly precipitation rapidly increases during the fall to a maximum in either December or January and decreases more slowly through spring.

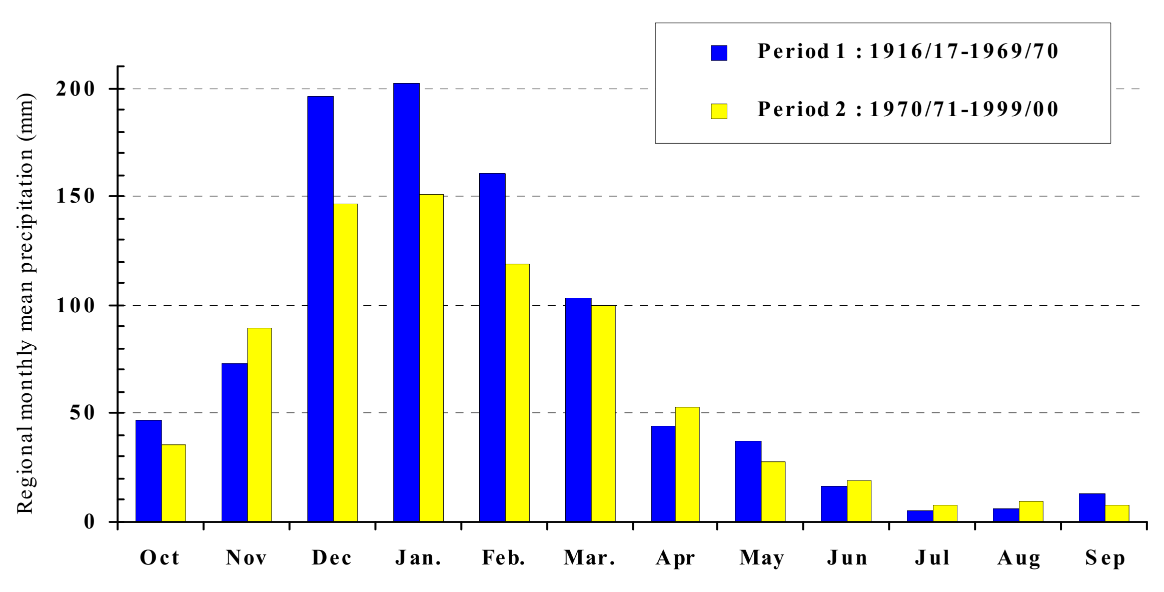

Figure 25: Regional mean monthly precipitation for Period 1 and Period 2 in millimetres for Region A.

The differences between the monthly means of the two periods are represented in Figure 26, Figure 27 and Annex 16. The greater decrease appears in the two wettest months (December and January) in all regions. The decrease is large in February over most of the island except the south-eastern part (Regions E and F) where the decrease is very small. November and April are slightly wetter during Period 2 than during Period 1 in all the north-western regions (Regions A, C, D, G and H).

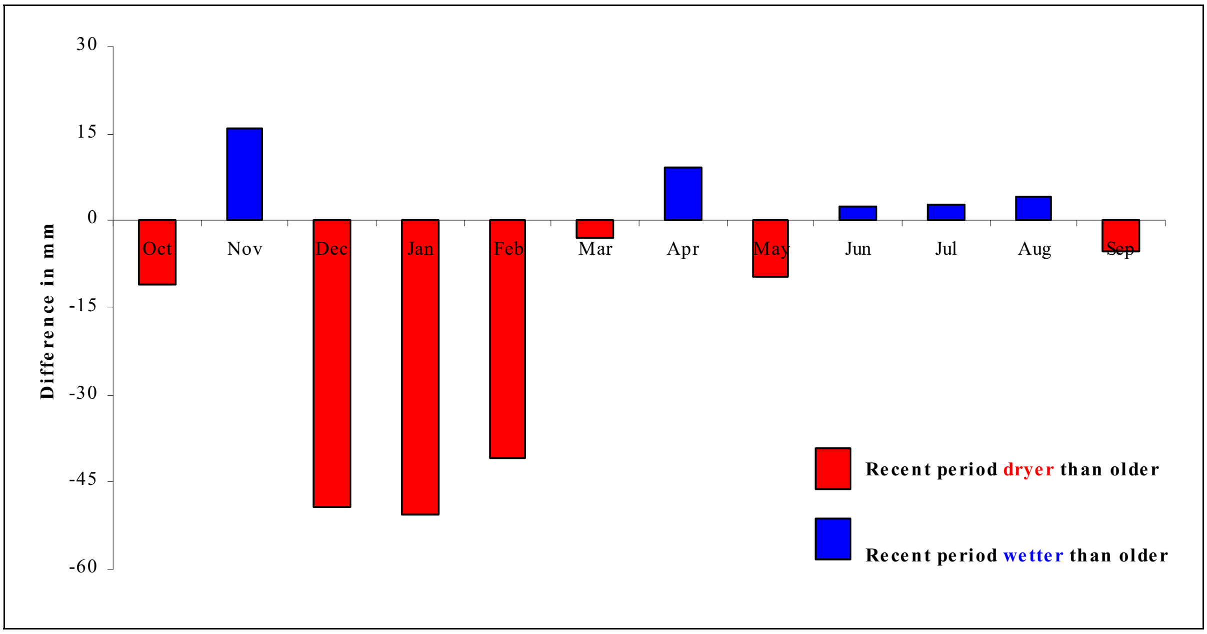

Figure 26: Differences between the means of the regional monthly precipitation of Period 1 and Period 2 in millimetres for Region A (Difference = Mean $_{\text{Period 2}}$ – Mean $_{\text{Period 1}}$).

Figure 28 presents the differences between the monthly means of the two periods for the 44 stations. It shows that in December and January the decrease in precipitation is observed over the entire island. In February, the decrease in precipitation is confined to the western part of the Troodos Mountain. Figure 28 also shows that there is a slight increase in November in few stations of the western slopes of the Troodos Mountain.

Changes in mean annual and mean monthly precipitation at regional scale

1971-2000 mean minus 1917-1970 mean in millimetres

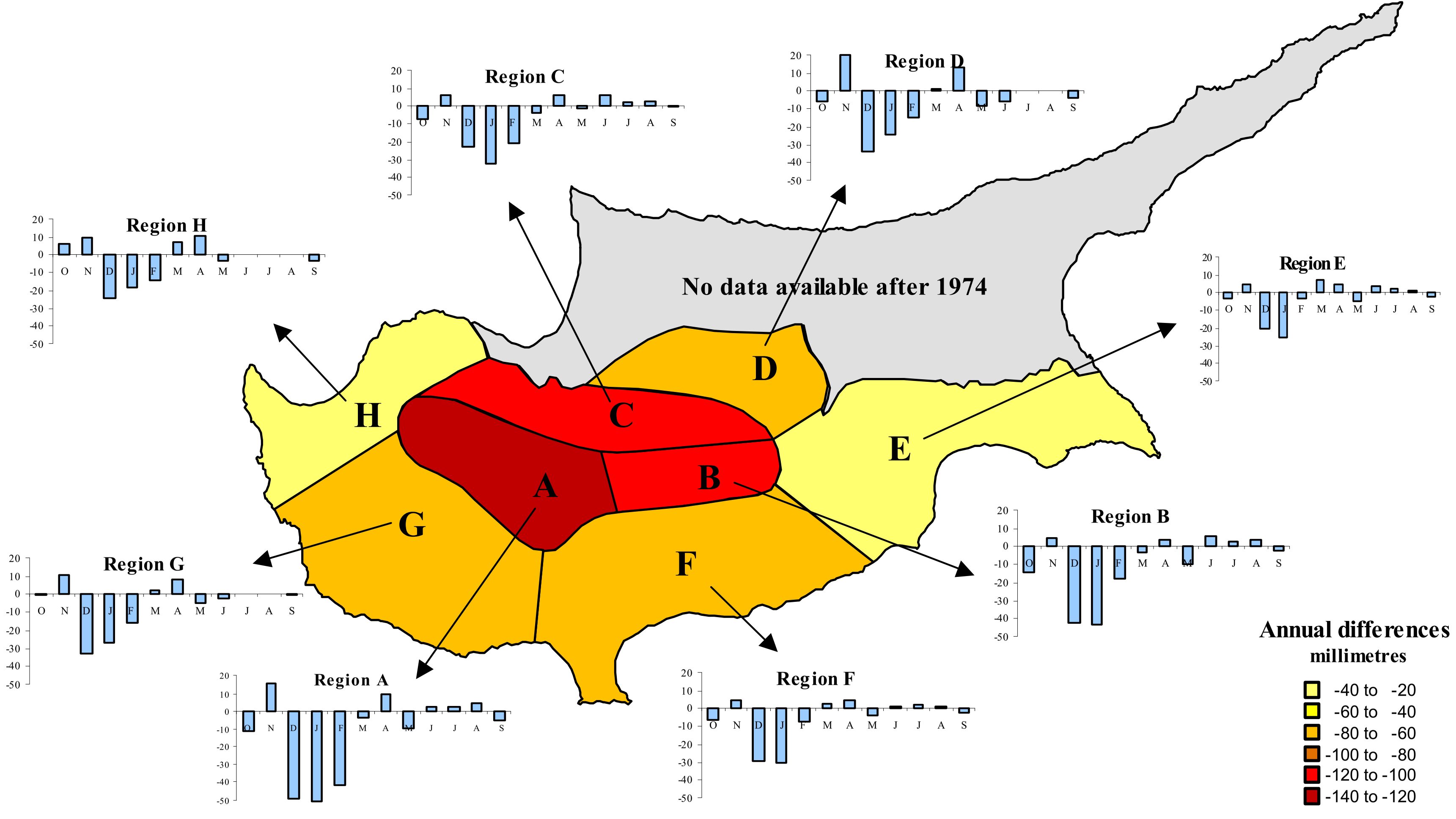

Figure 27: Differences between the means of regional annual and monthly precipitation of Period 1 and Period 2 in millimetres (Difference = Mean $_{\text{Period 2}}$ – Mean $_{\text{Period 1}}$).

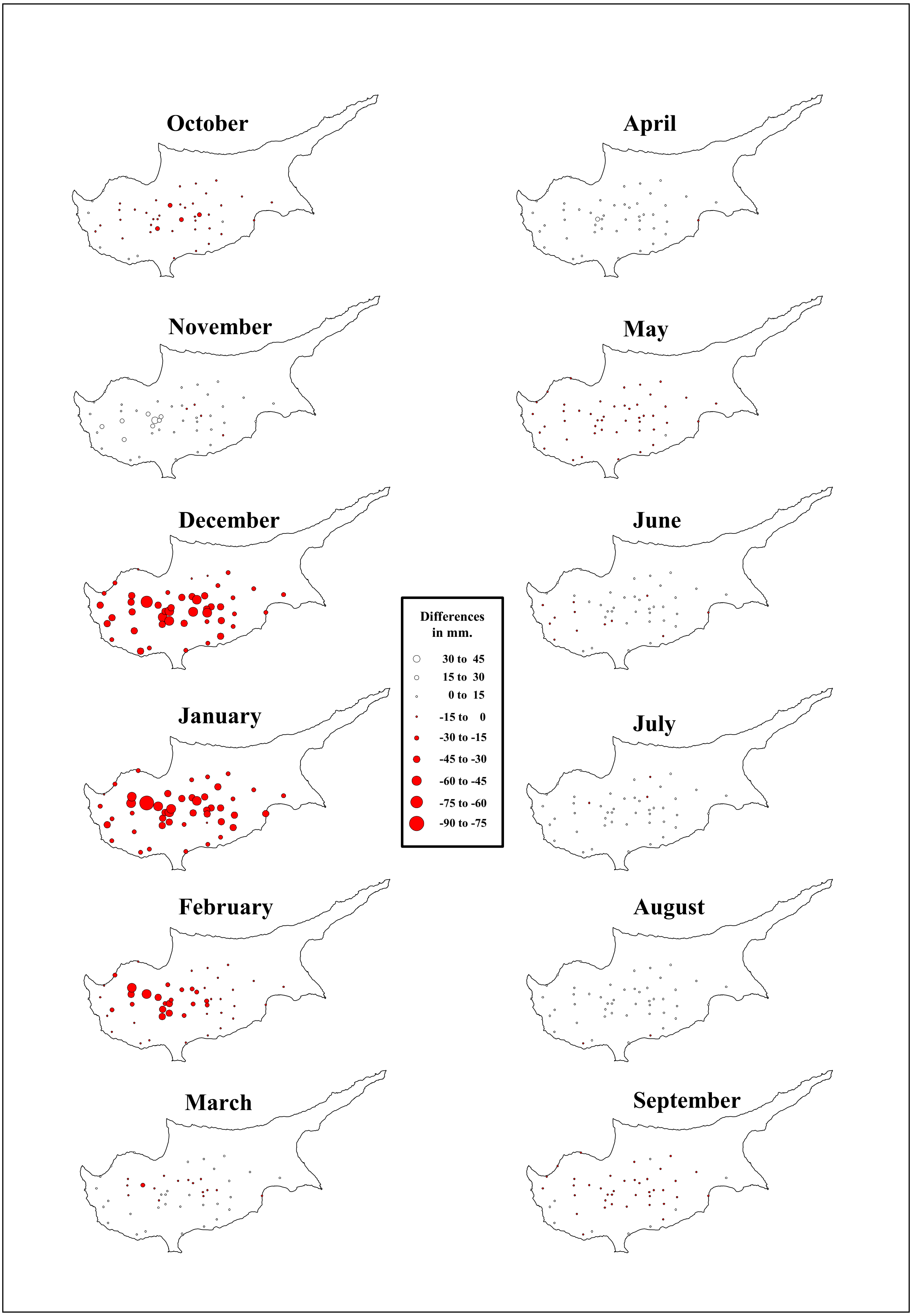

Figure 28: Differences between means of monthly precipitation of Period 1 and Period 2 in millimetres at 44 stations (Difference = Mean $_{\text{Period 2}}$ – Mean $_{\text{Period 1}}$).

6 CONCLUSIONS AND RECOMMENDATIONS

The main objectives of this analysis were to analyse changes in recorded precipitation in Cyprus and the possible implication of the precipitation changes for the reassessment of the island's water resources.

The statistical analysis of the records available over the period 1916/17-1999/00 demonstrates that the precipitation time series display a step change or shift around 1970 and can be divided into two separate stationary periods. The "older period" last from 1916/17 to 1969/70 and the "recent period" from 1970/71 to 1999/00. The mean precipitation of the recent period is lower than the mean precipitation of the older period. From 1916/17 to 1969/70 the precipitation records do not show any trend. From 1970/71 to 1999/00, the data show a slight decrease in the precipitation but this trend is not significant compared to the variations from year to year.

The shift in mean precipitation is larger on the Troodos Mountains sector than in the coastal and inland plain areas. The mean of the annual precipitation of the recent period is by 100 mm or more lower than the mean of the older period at almost every location of elevation higher than 500 m a.m.s.l. This decrease ranges between 15% and 25% of the mean annual precipitation of the older period. The decrease of the annual precipitation is essentially due to a decrease in the precipitation during the months of December and January in the south-east of the island, and during December, January and February in all the other regions.

The precipitation was significantly lower over the last 30 years than over the previous decades. Therefore the available water in the island is probably less than what had been assumed as a basis for water development works. For the reassessment of the island's water resources it is recommended to use only hydro-meteorological records of the 1970/71-1999/00 period that conveniently corresponds to the new WMO Standard Normal. The use of this period for the quantification of the water resources will give a more accurate picture of the water resources available today.

Secondary suggestions can also be made. For a better understanding of weather and climate changes in Cyprus it would be interesting to look for existing studies or develop an analysis of the changes in tracks of depression systems in the eastern Mediterranean sector. The discrepancies found in three precipitation time-series highlight the necessity to check the data of all stations involved in analyses of this nature to ensure that any errors missed by the Meteorological Service quality checks are picked up.

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ANNEXES

TABLE OF CONTENTS

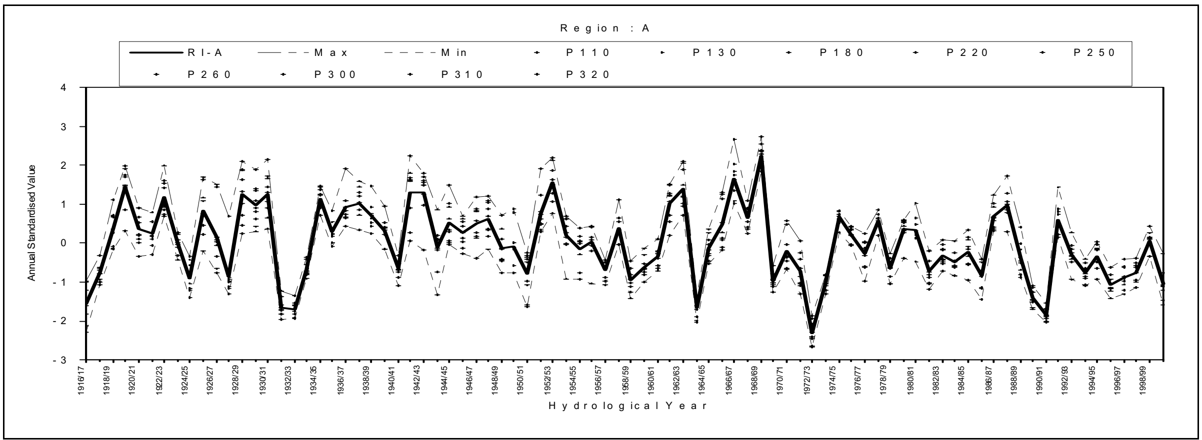
Annex 1

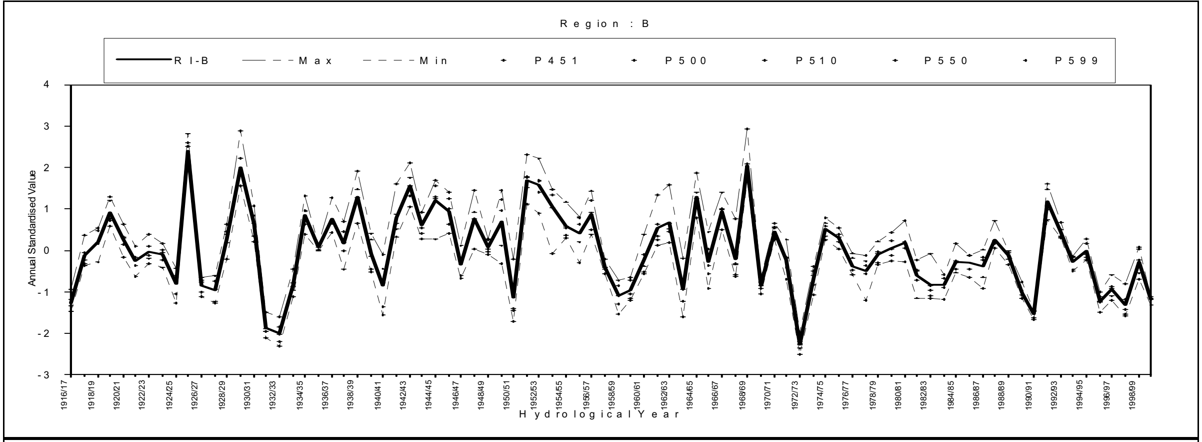
Stations code number, region and r^2 between their annual standardised time series and the regional index.

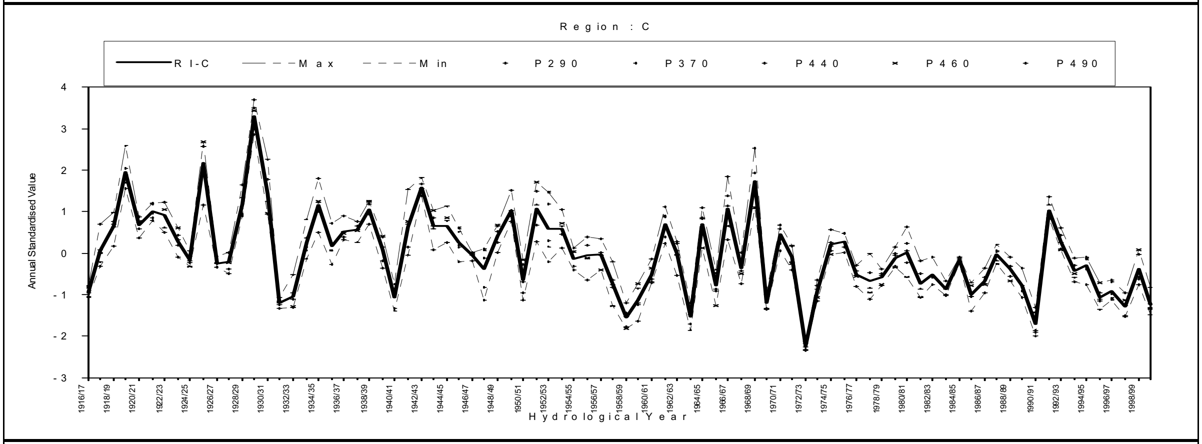
Code #	Region	r^2
10	H	0,86
40	H	0,88
50	G	0,86
60	G	0,86
80	G	0,82
90	H	0,83
110	A	0,88
120	G	0,82
130	A	0,83
140	G	0,78
160	H	0,72
170	G	0,83
180	A	0,78
190	G	0,78
220	A	0,85
250	A	0,82
260	A	0,84
290	C	0,87
300	A	0,92
310	A	0,89
320	A	0,86
370	C	0,89
390	F	0,82
400	F	0,76
430	D	0,84
440	C	0,95
451	B	0,80
460	C	0,92
490	C	0,93
500	B	0,93
510	B	0,91
520	D	0,85
540	F	0,83
550	B	0,95
580	D	0,78
595	F	0,88
599	B	0,89
600	F	0,83
640	D	0,78
648	F	0,80
650	E	0,85
660	E	0,82
690	E	0,89
800	E	0,83

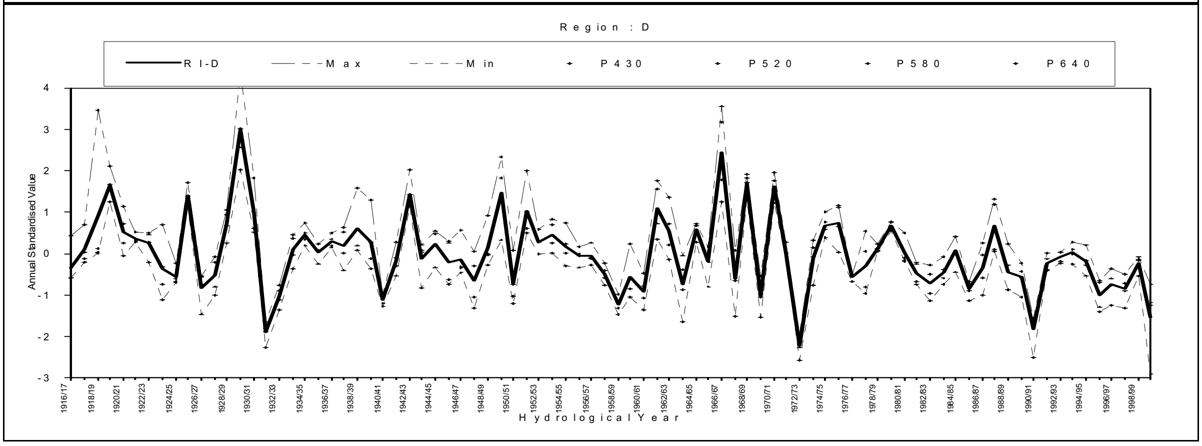
Annex 2

Stations and regional standardised annual precipitation for regions A to H



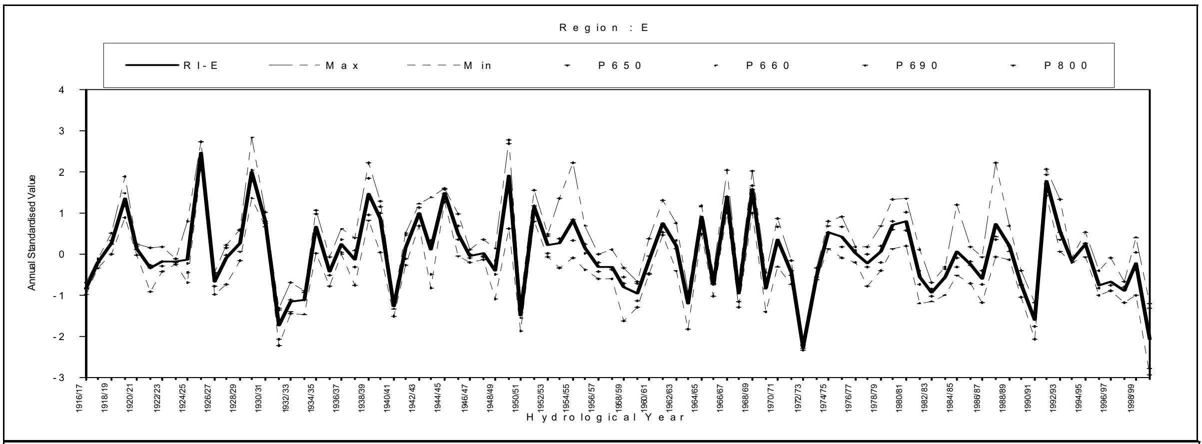


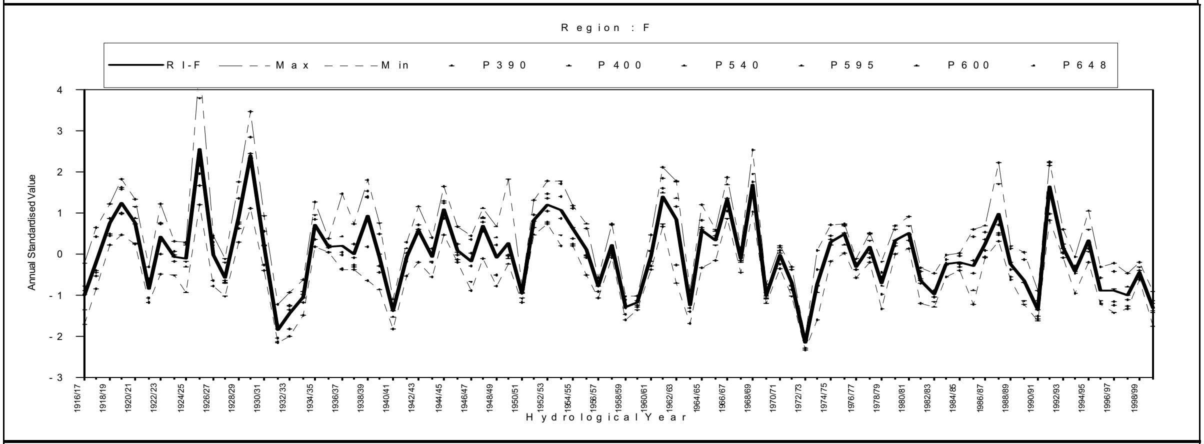


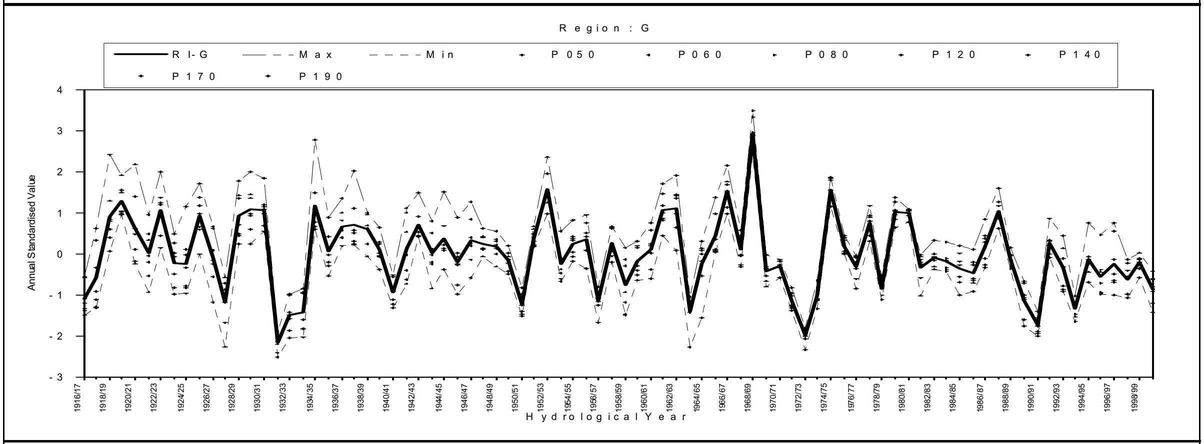


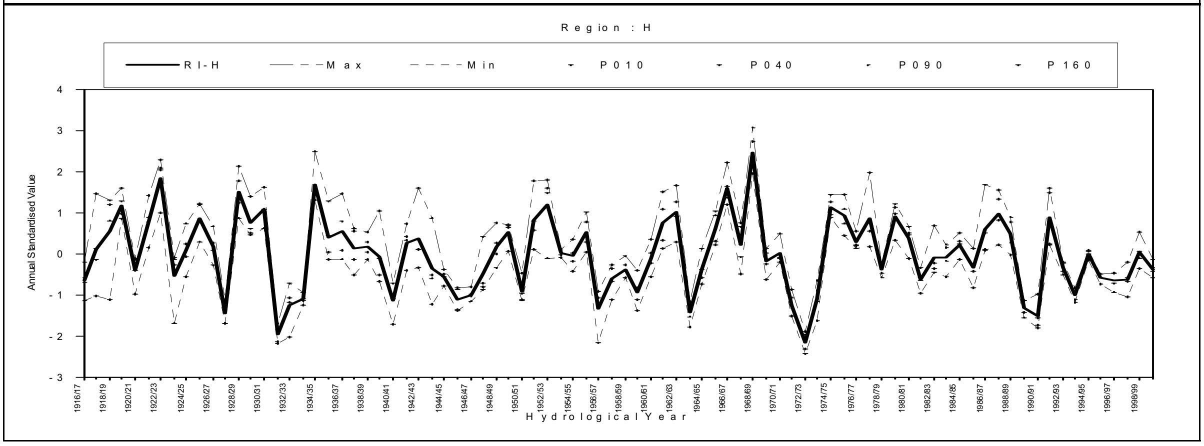
Annex 2 continue

Stations and regional standardised annual precipitation for regions A to H



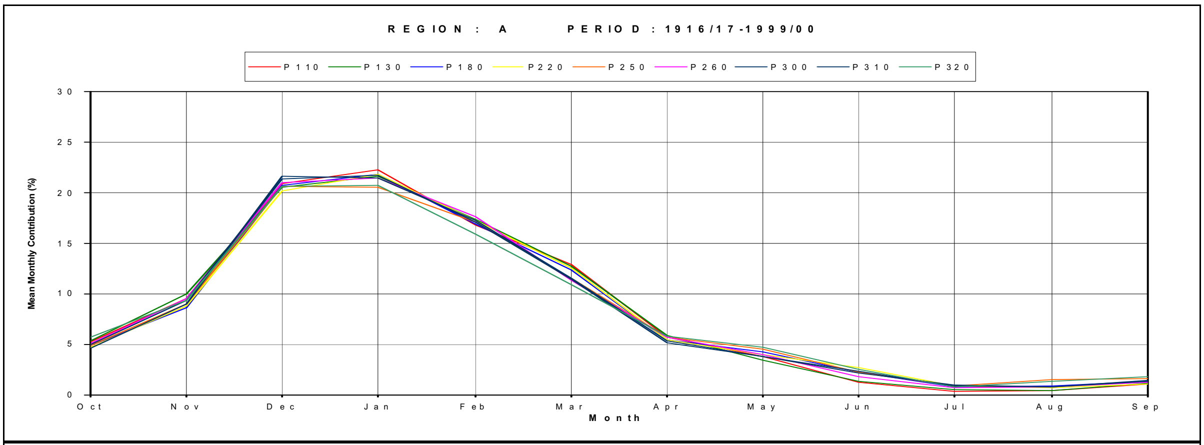


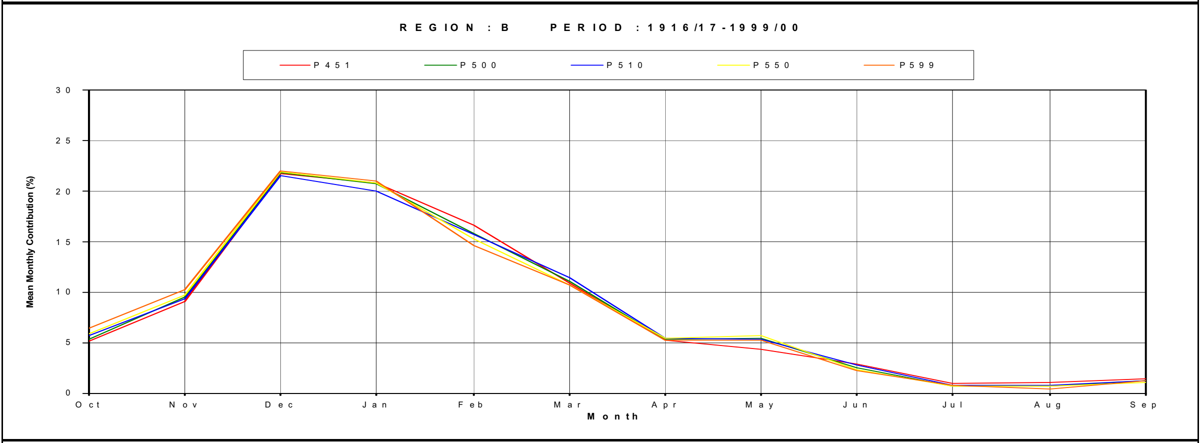


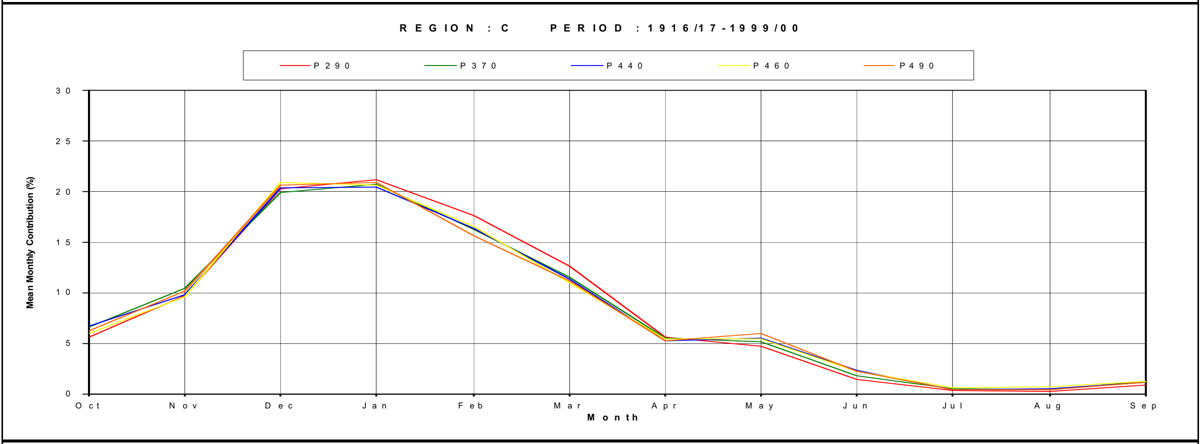


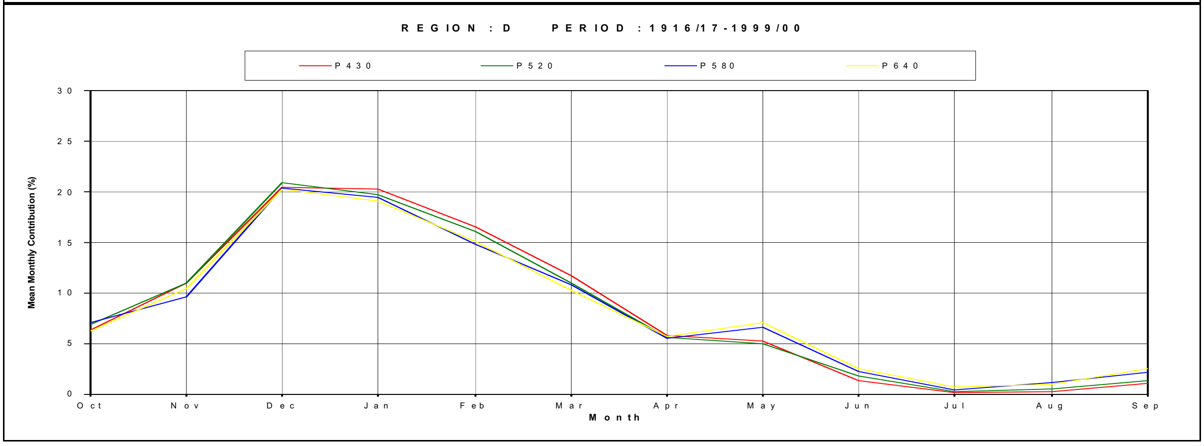
Annex 3

Seasonal distribution of the mean monthly precipitation of the stations of regions A to H



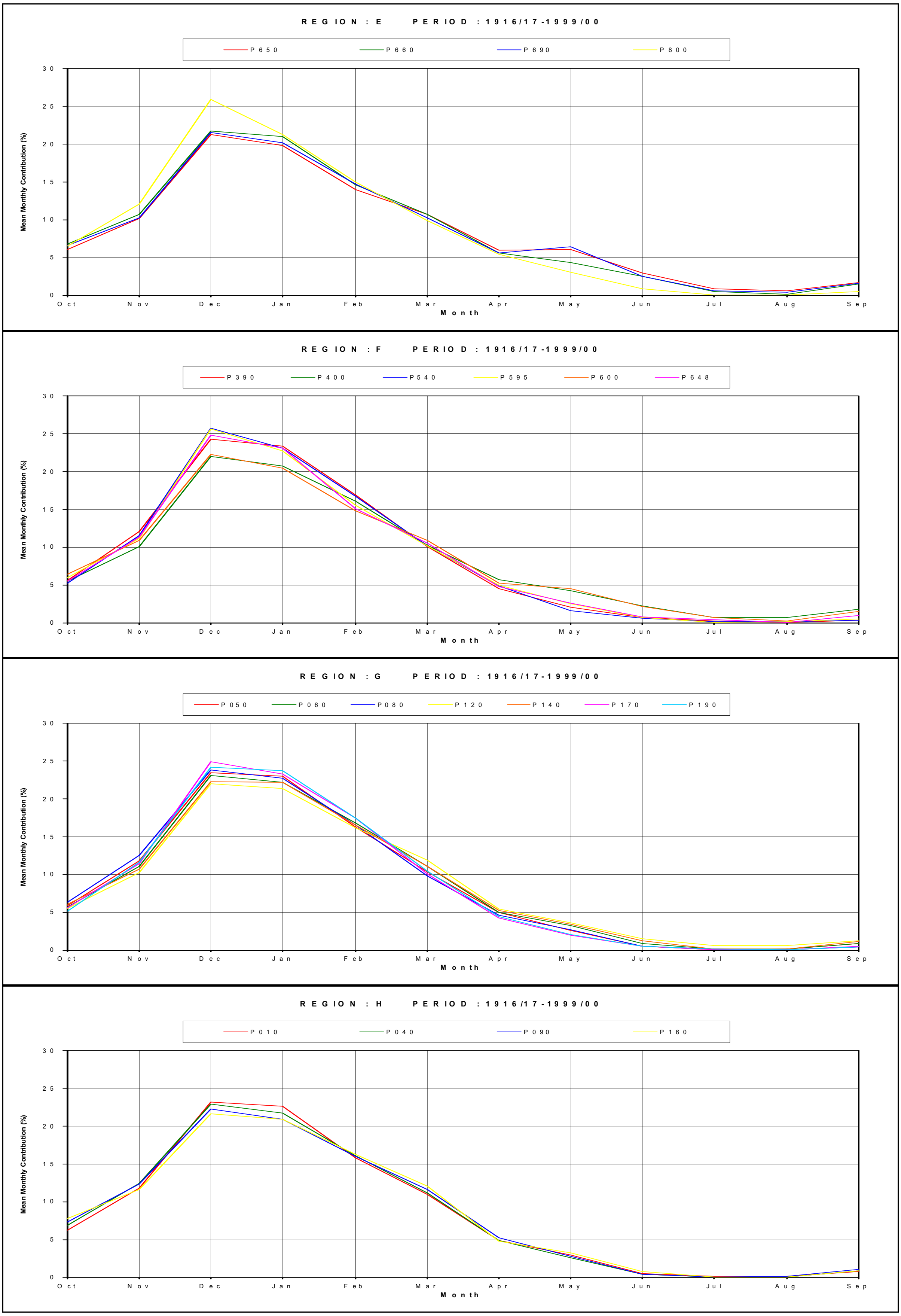






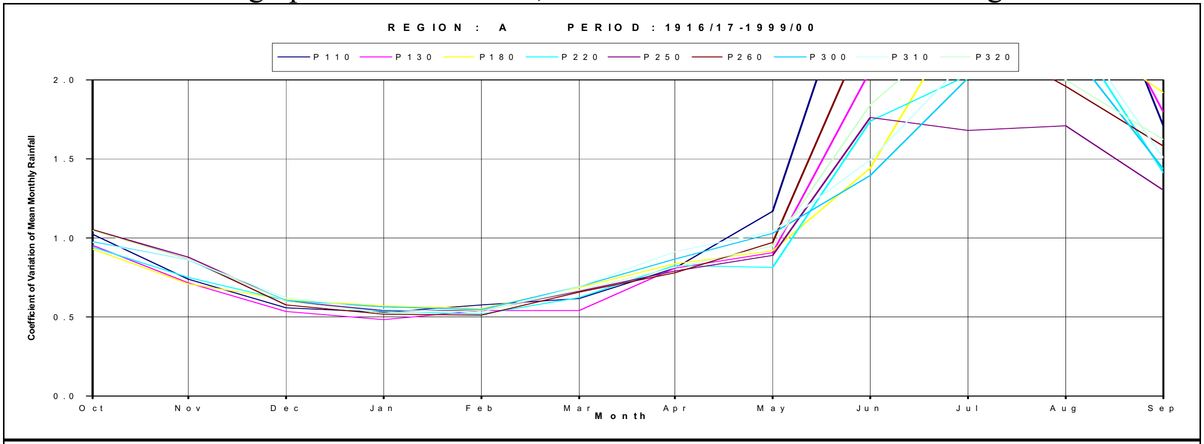
Annex 3 continue

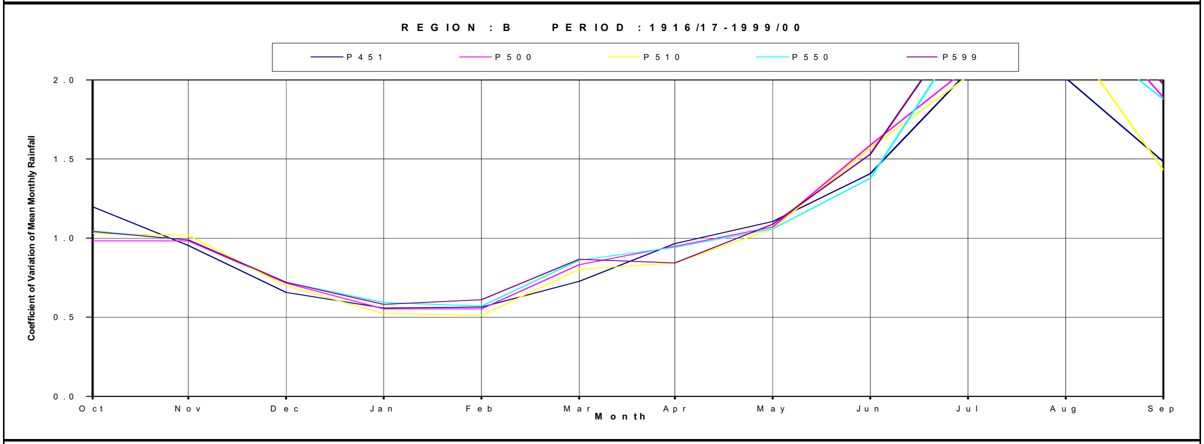
Seasonal distribution of the mean monthly precipitation of the stations of regions A to H.

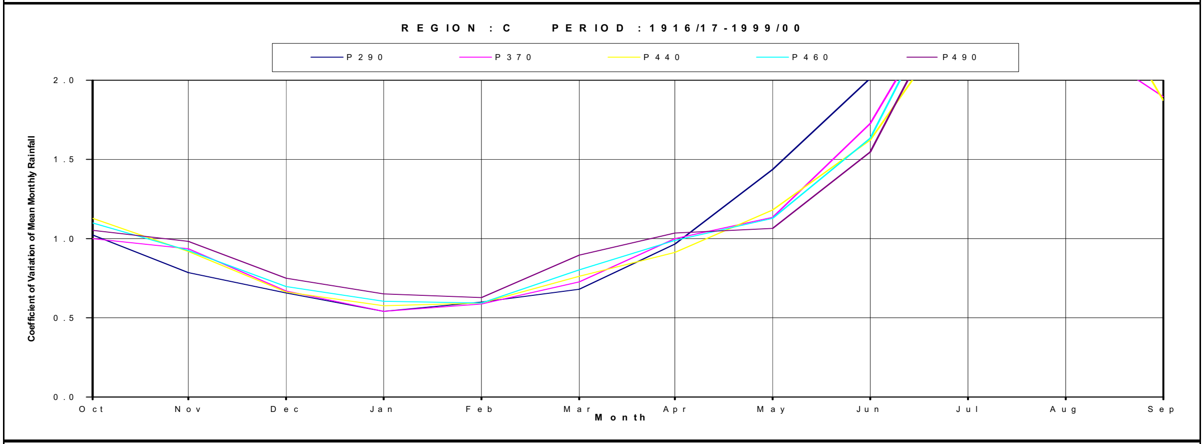


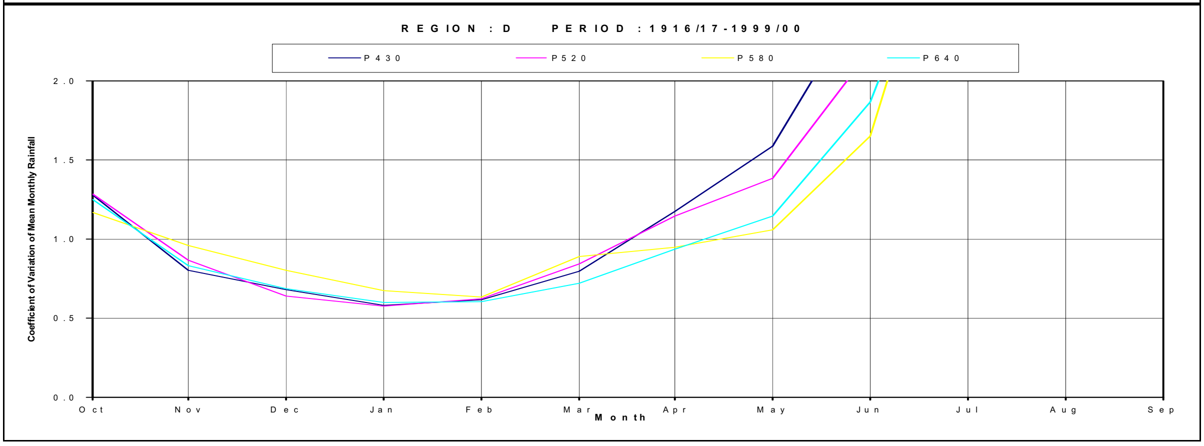
Annex 4

Monthly coefficients of variation of precipitation for the stations of regions A to H.
The Y-scale of the graphs are limited to 2,0 to be able to see the values during the winter.



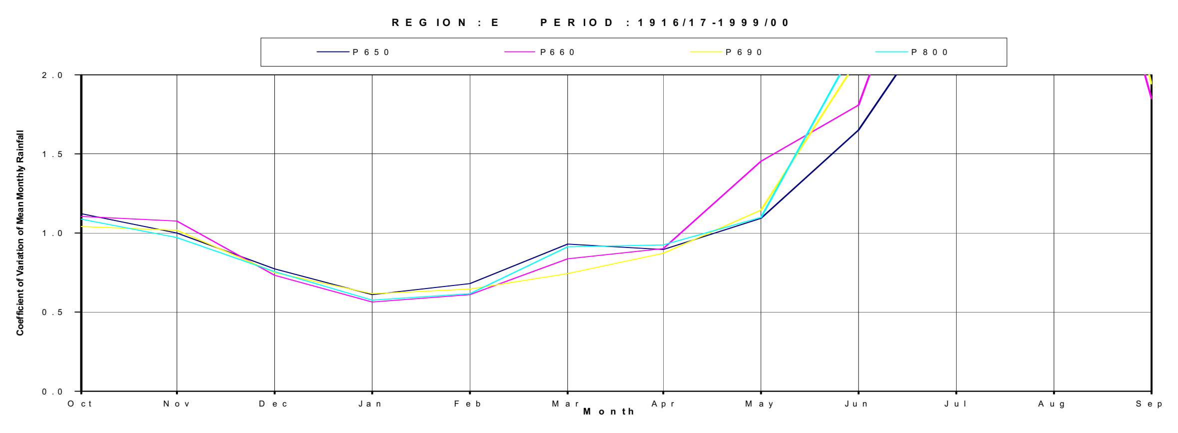


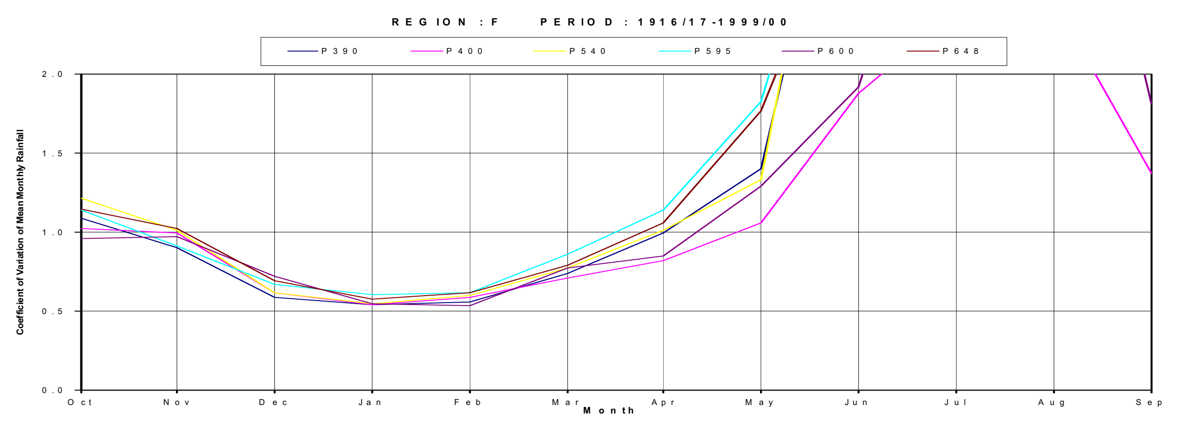


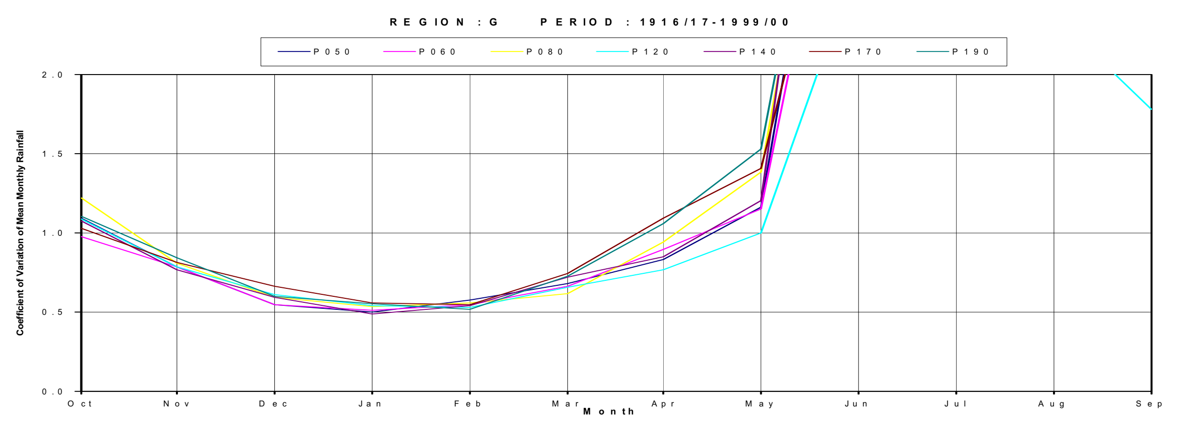


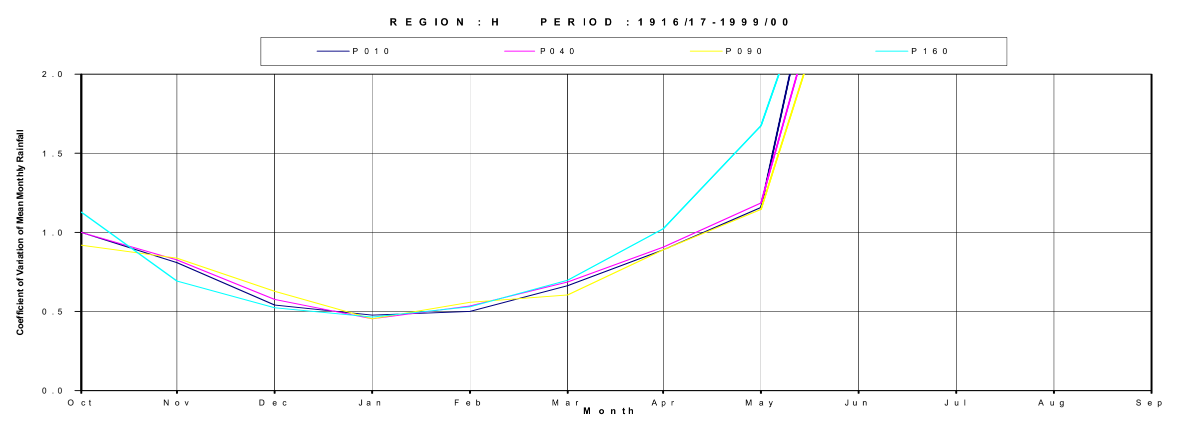
Annex 4 continue

Monthly coefficients of variation of precipitation for the stations of regions A to H
The Y-scale of the graphs are limited to 2,0 to be able to see the values during the winter.



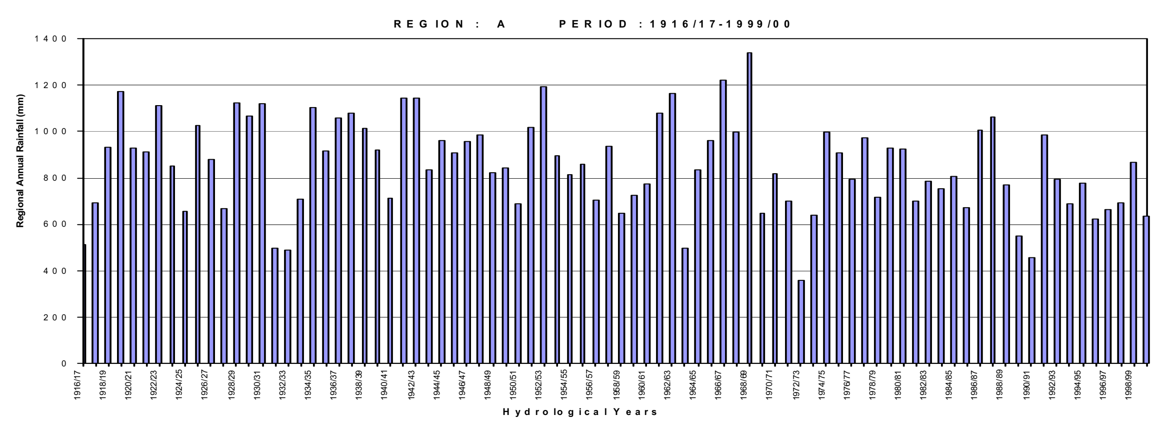


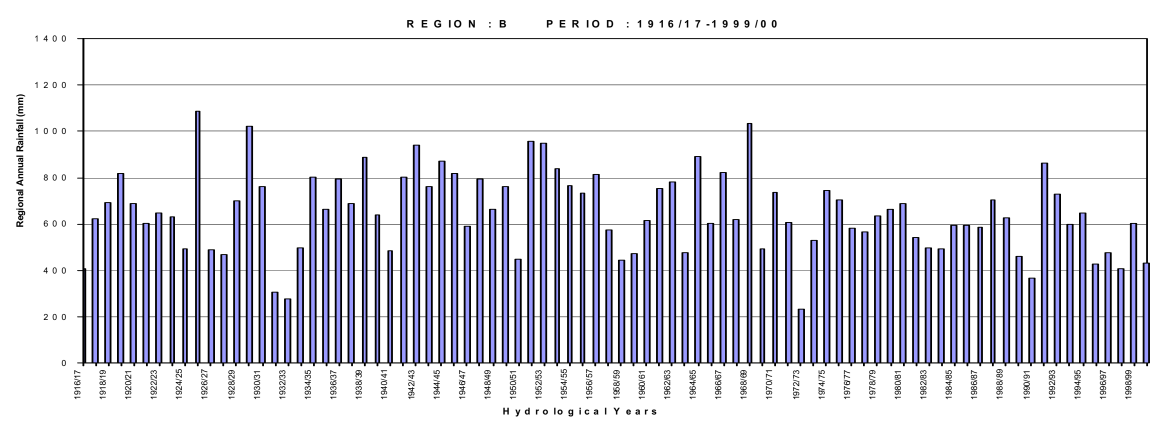


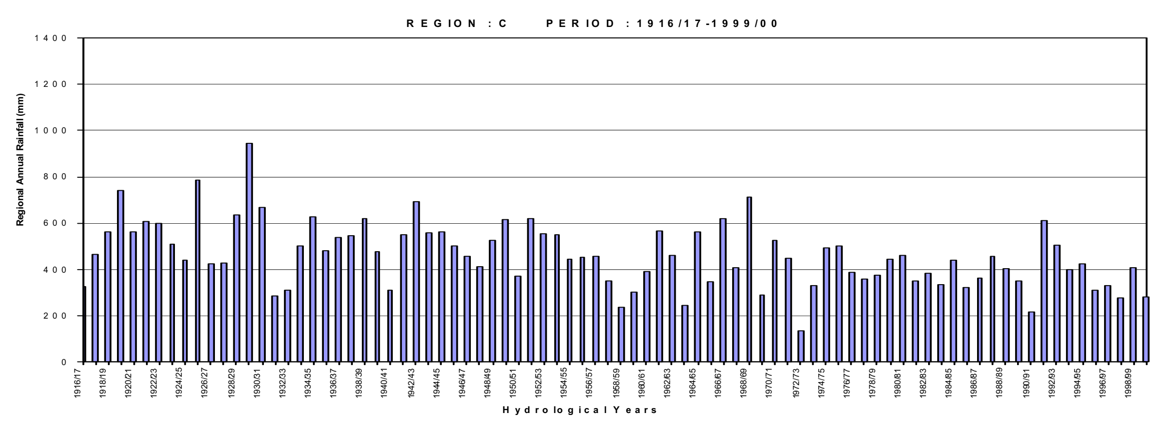


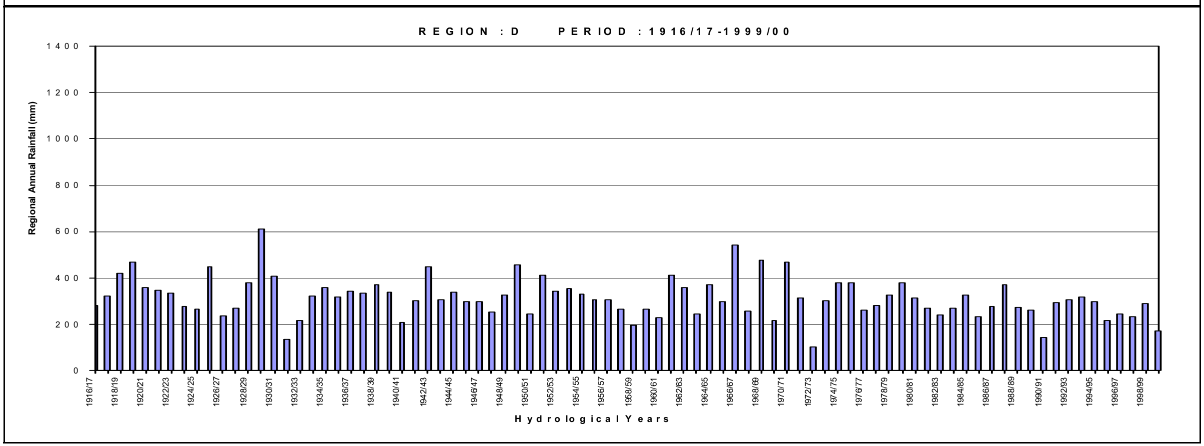
Annex 5

Regional annual precipitation in millimetres for regions A to H.



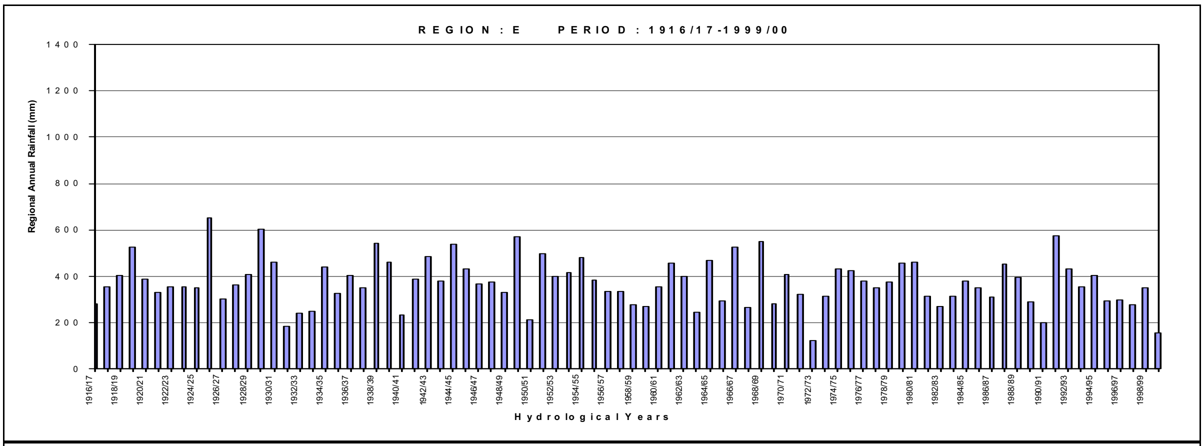


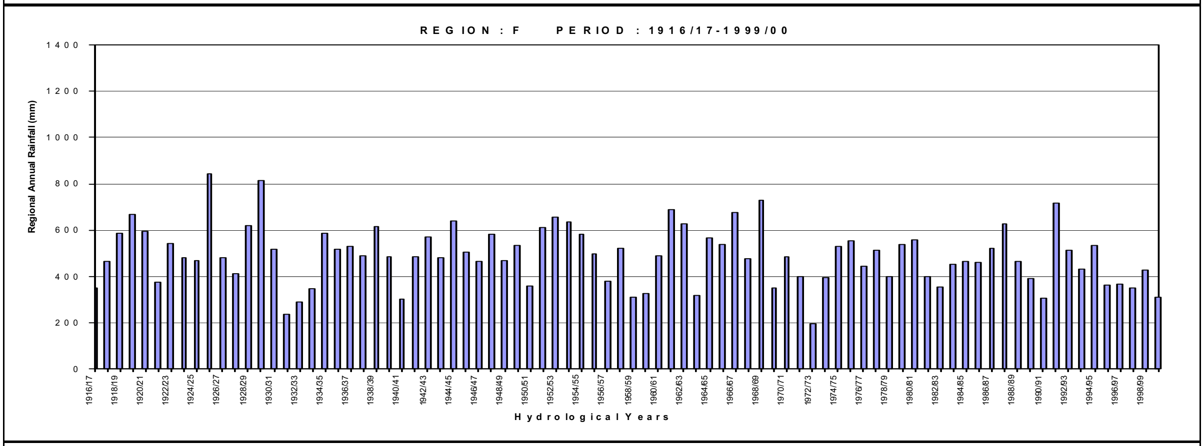


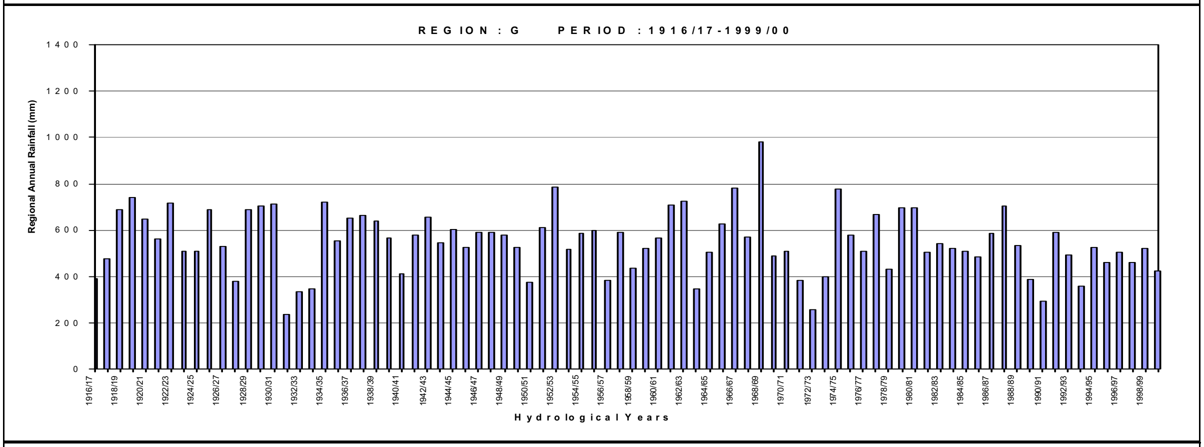


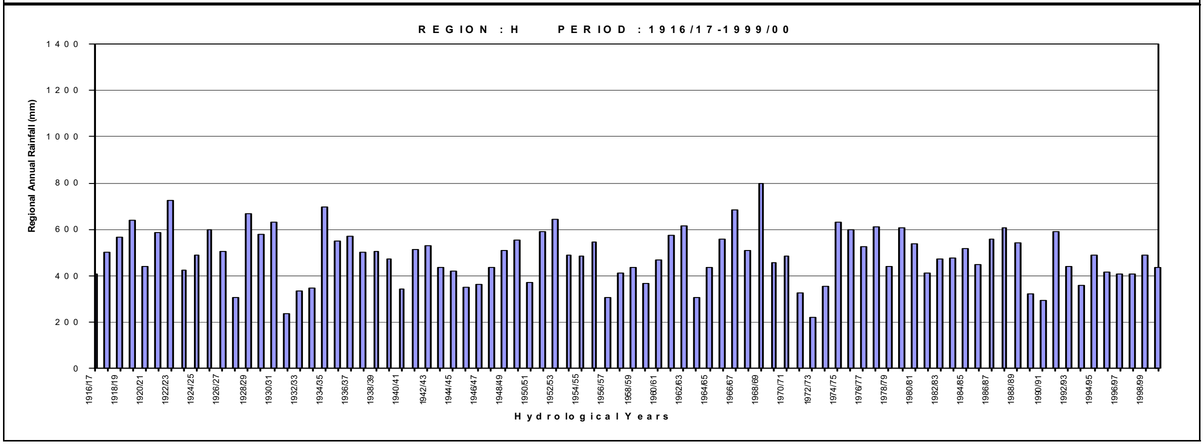
Annex 5 continue

Regional annual precipitation in millimetres for regions A to H.



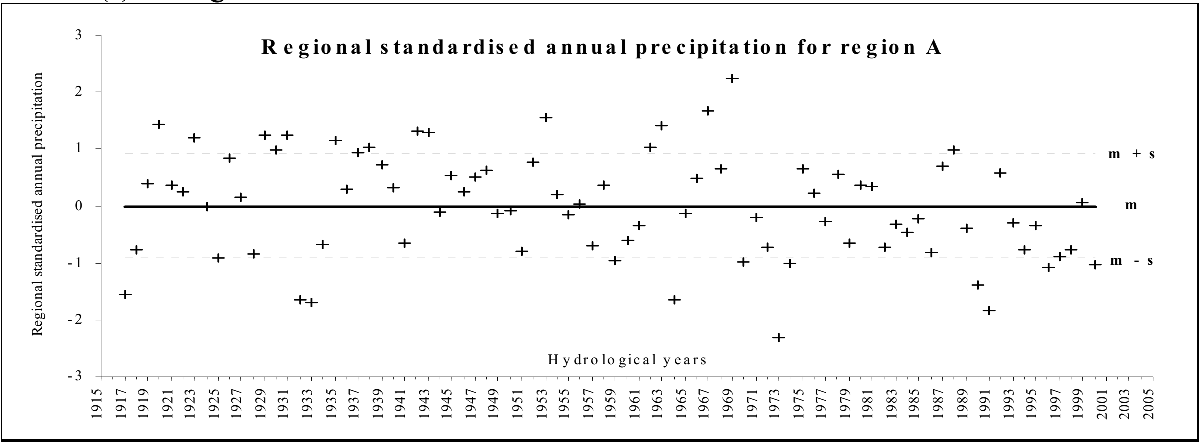


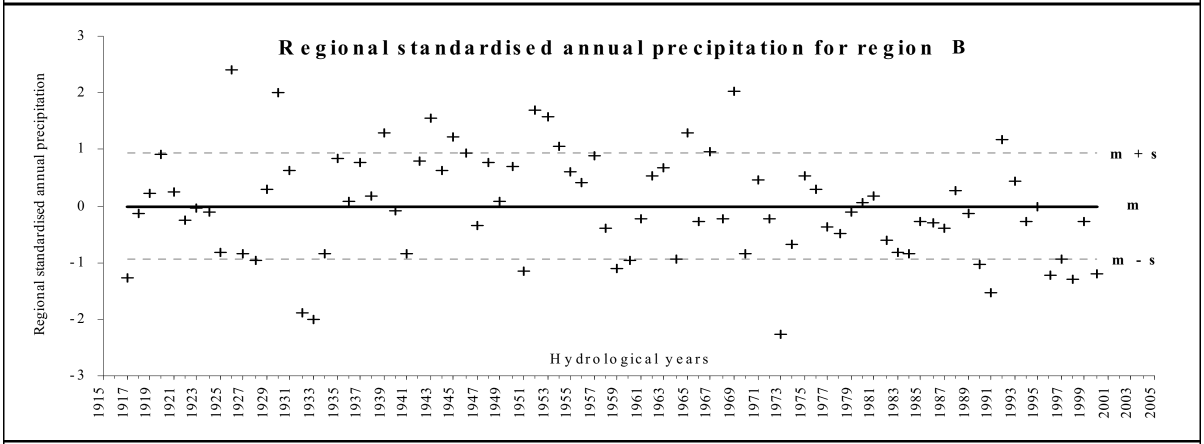


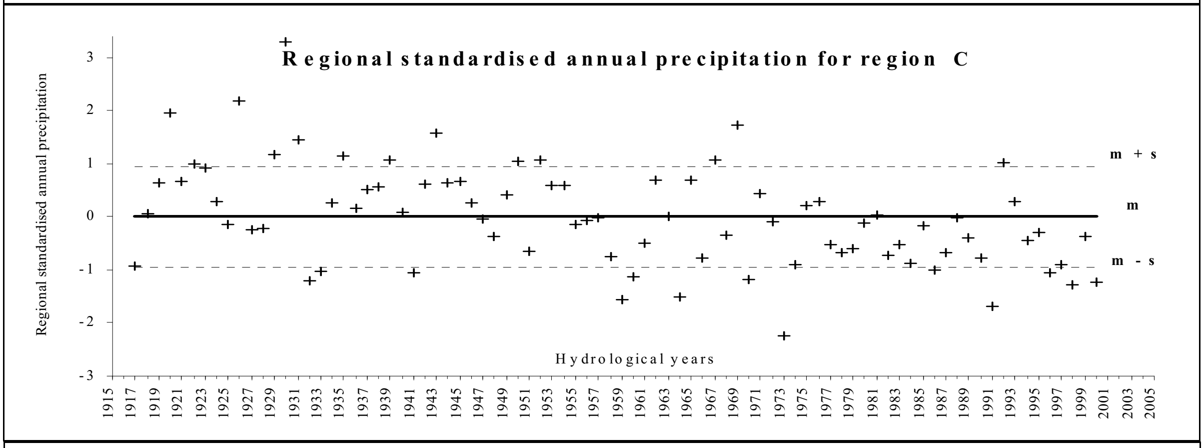


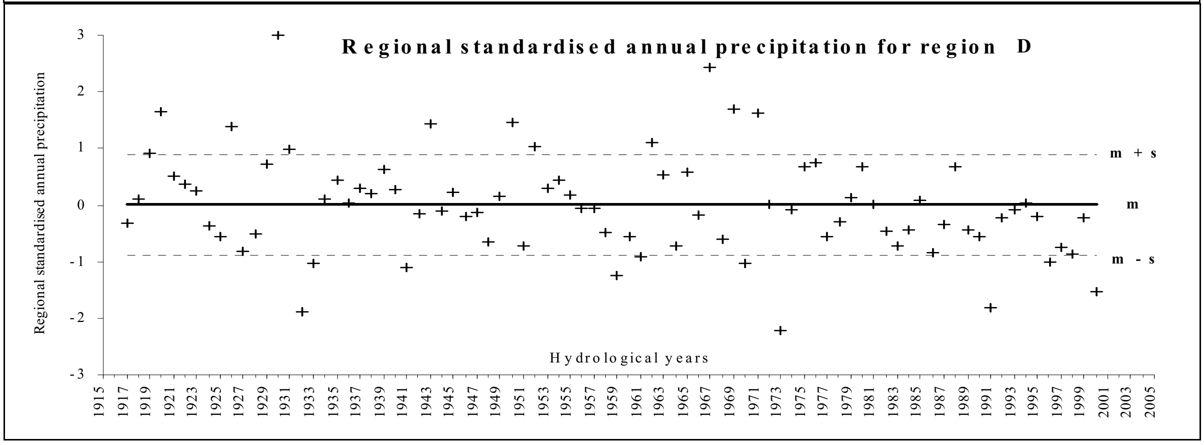
Annex 6

Regional annual standardised precipitation with indication of the mean (m) and standard deviation (s) for regions A to H



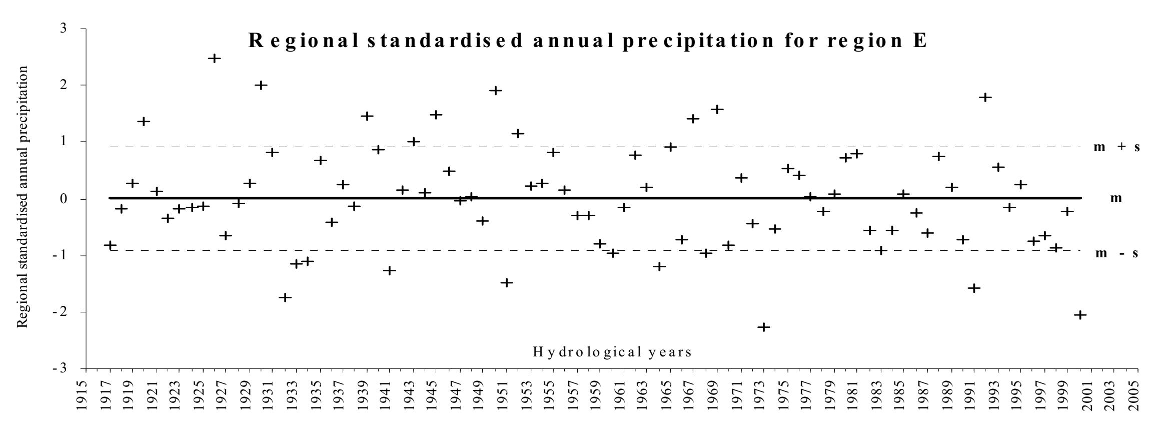


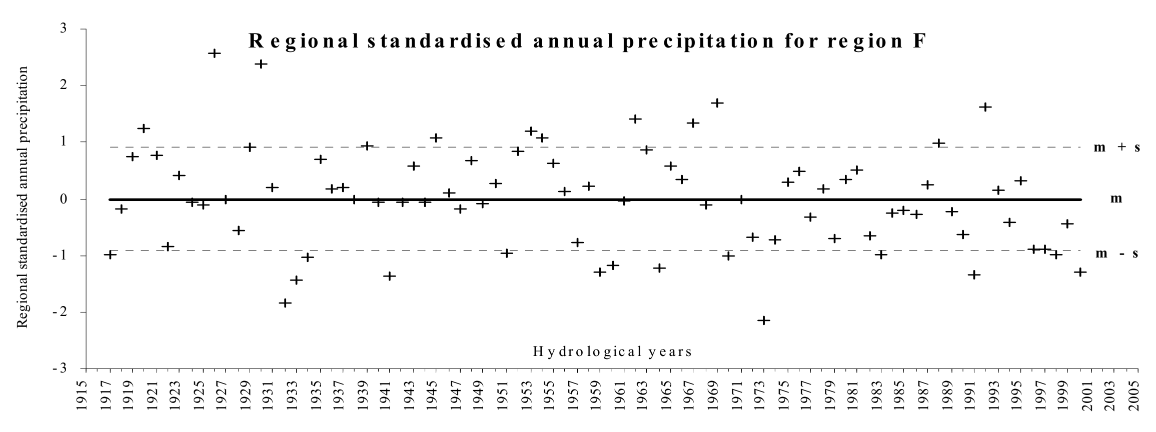


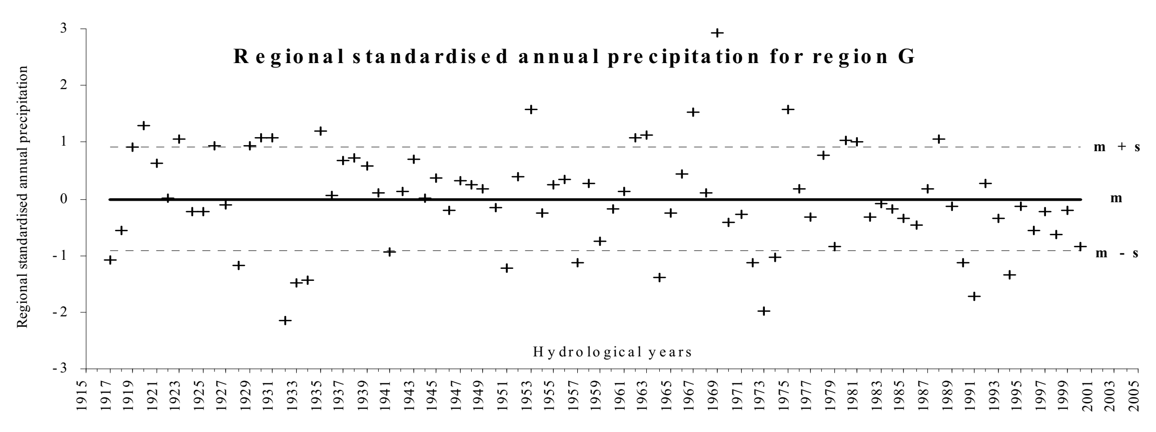


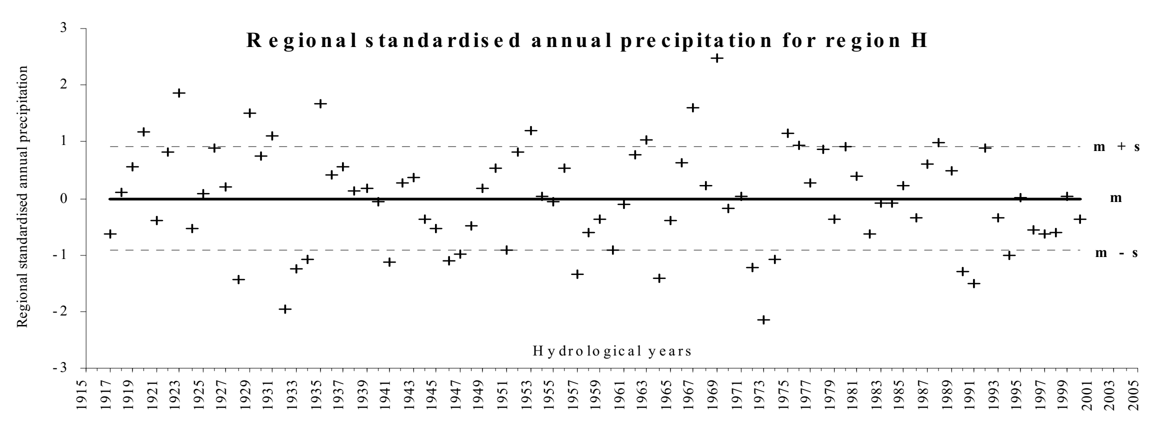
Annex 6 continue

Regional annual standardised precipitation with indication of the mean (m) and standard deviation (s) for regions A to H


Regional standardised annual precipitation for region E

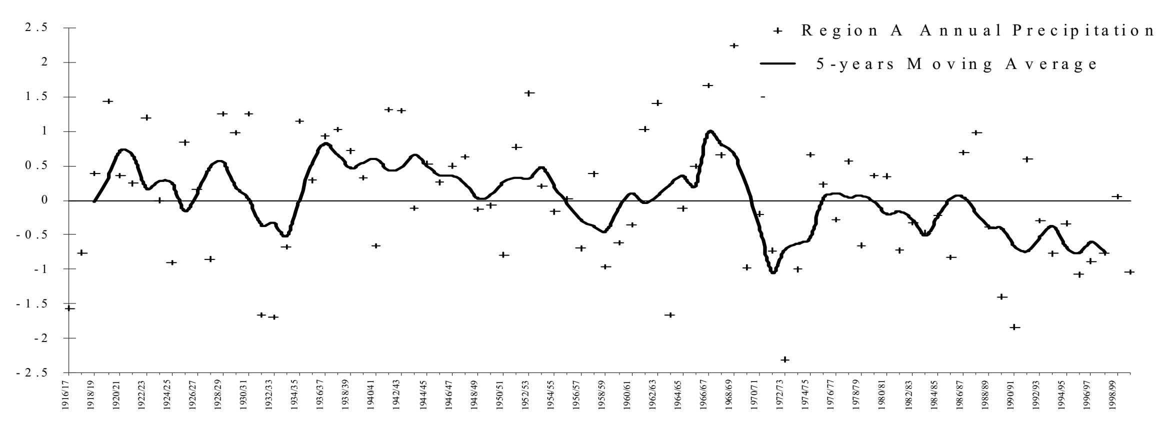

Regional standardised annual precipitation for region F

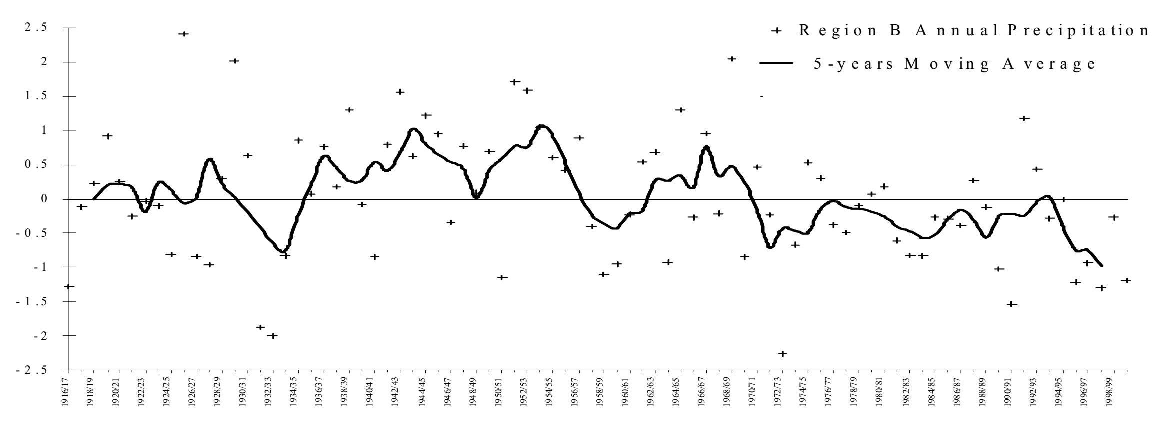

Regional standardised annual precipitation for region G

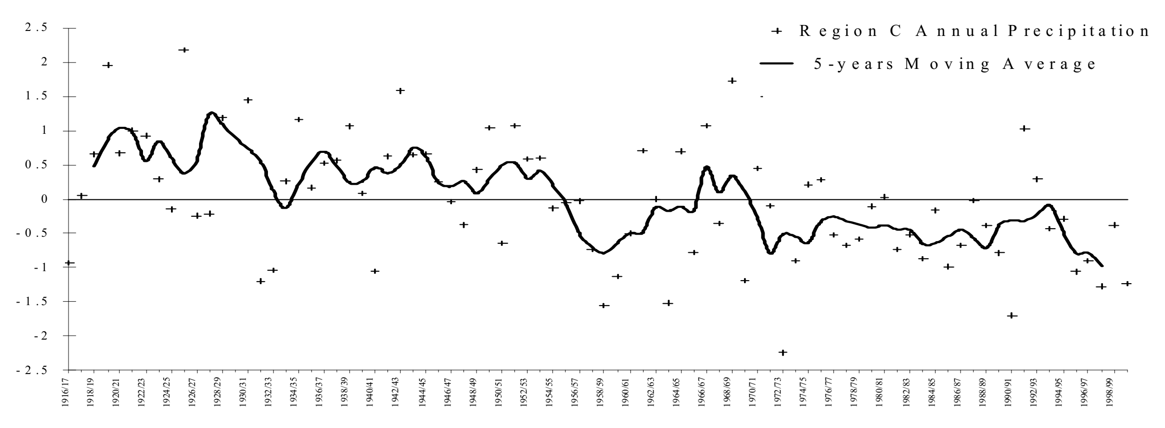

Regional standardised annual precipitation for region H

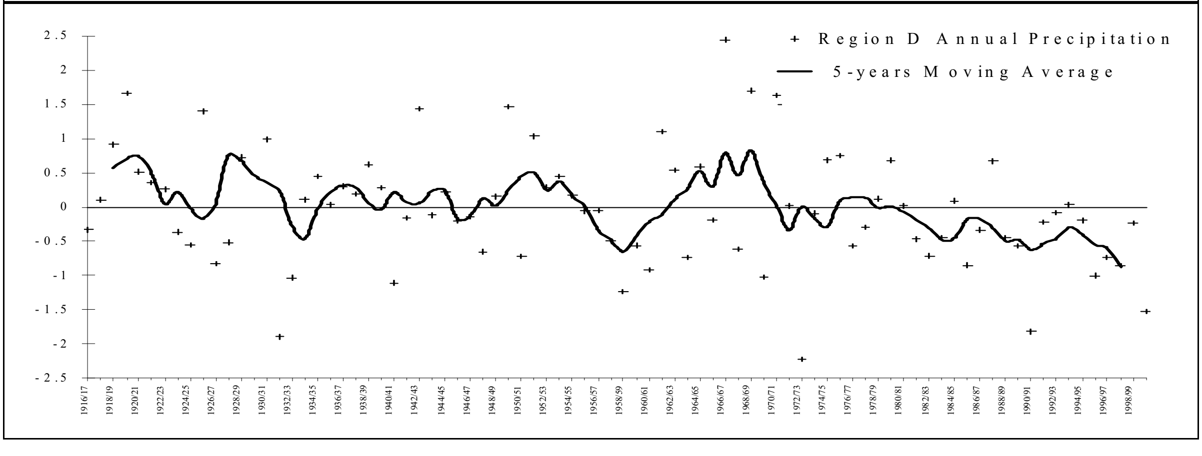
Annex 7

Regional annual precipitation and 5 years running mean for regions A to H



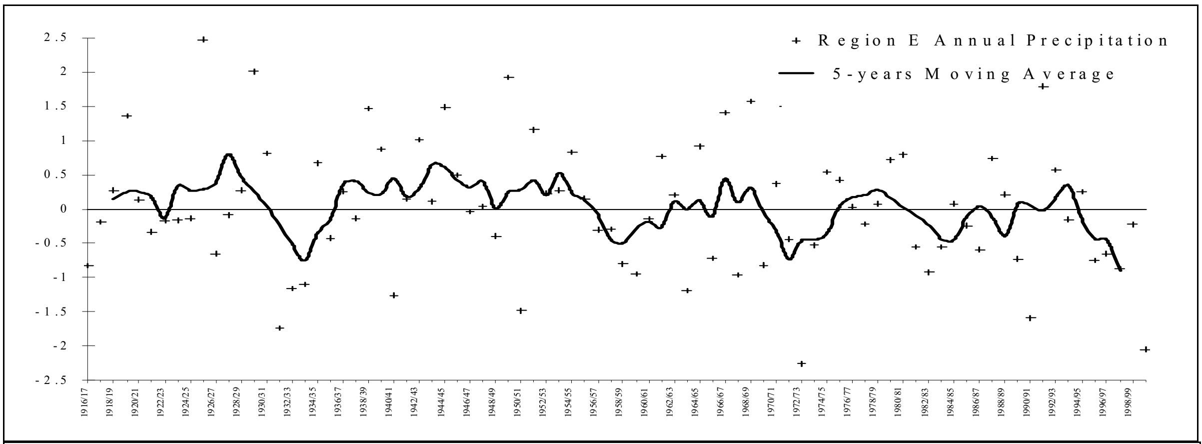


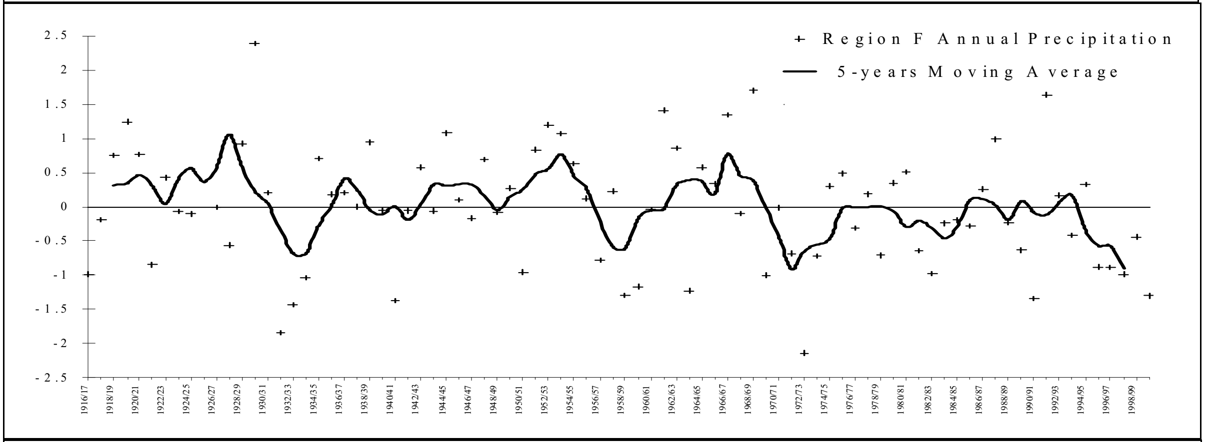


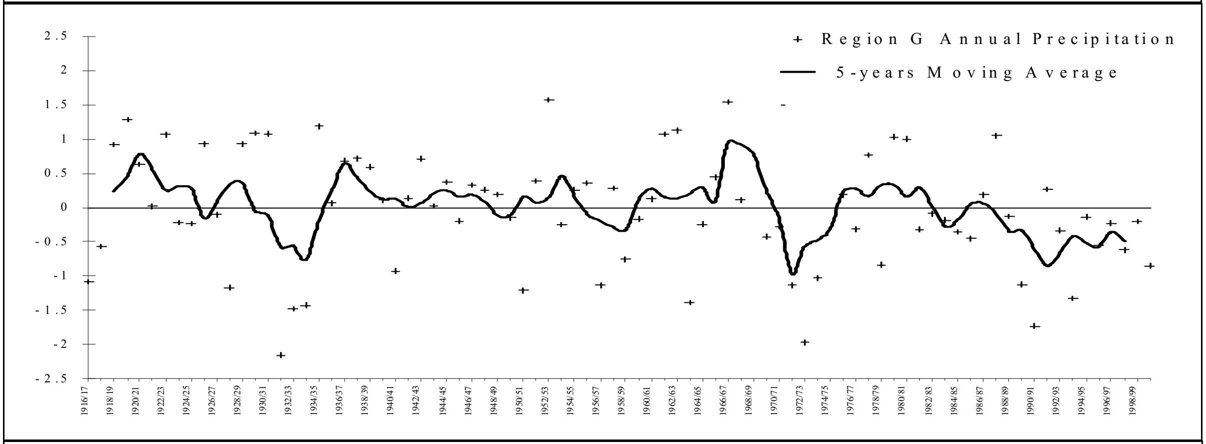


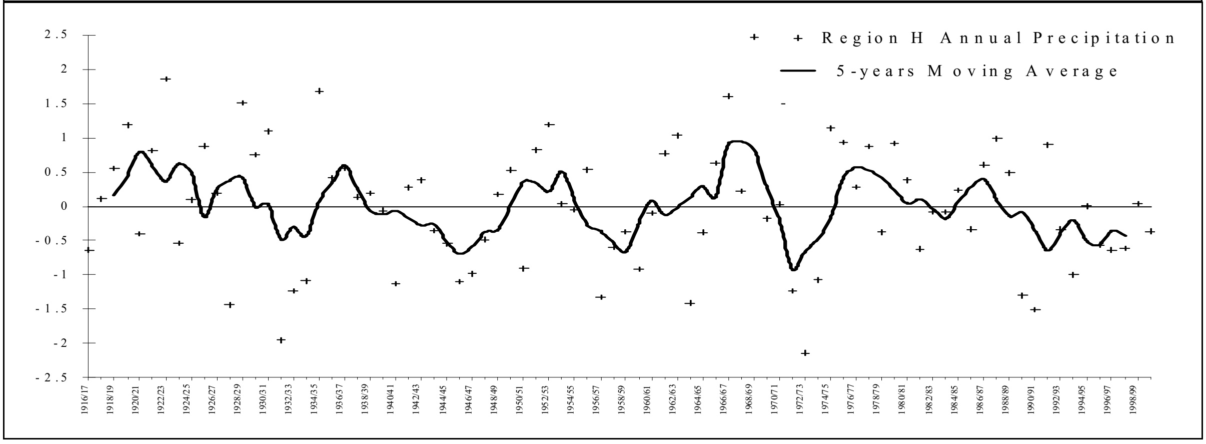
Annex 7 continue

Regional annual precipitation and 5 years running mean for regions A to H



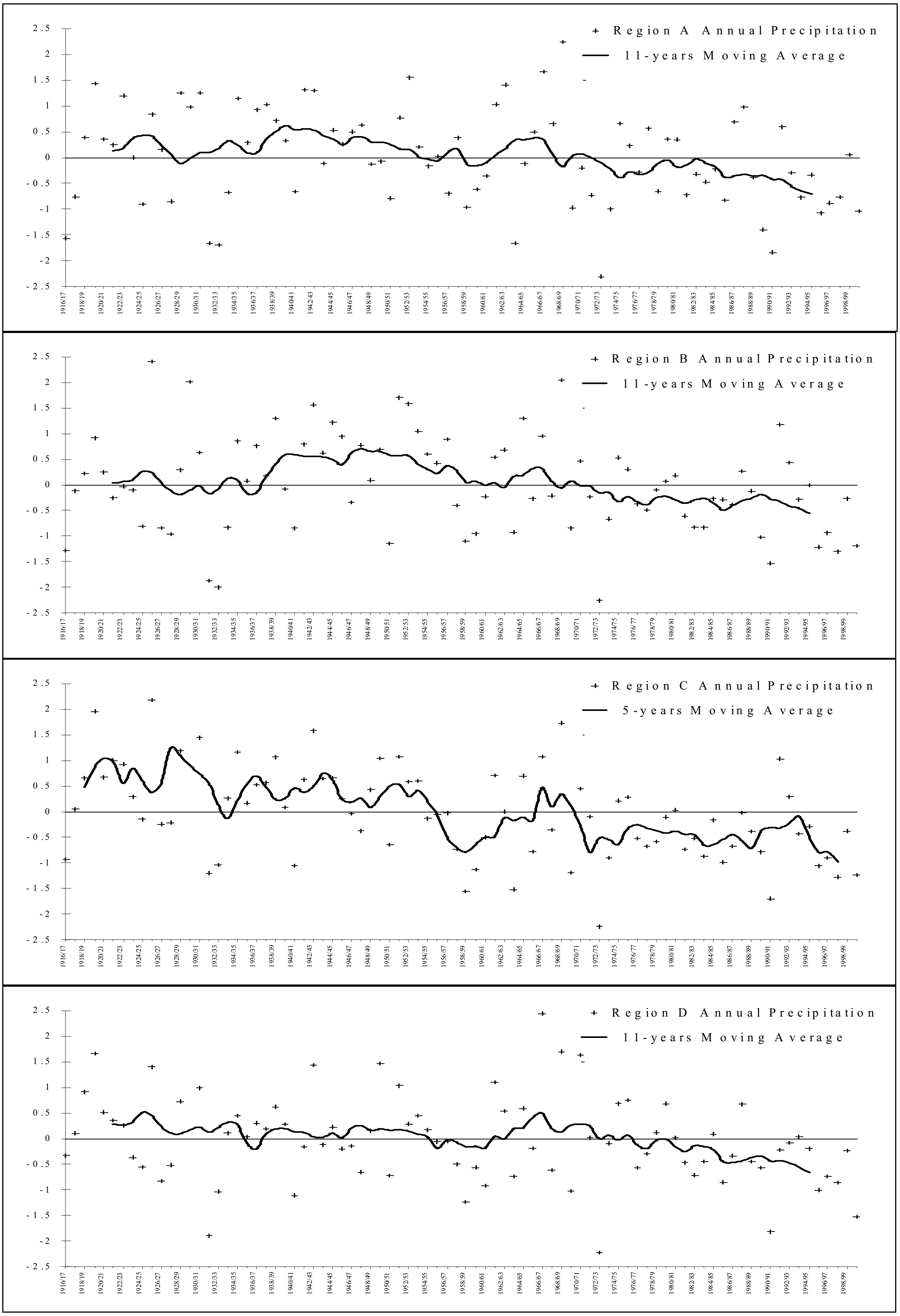






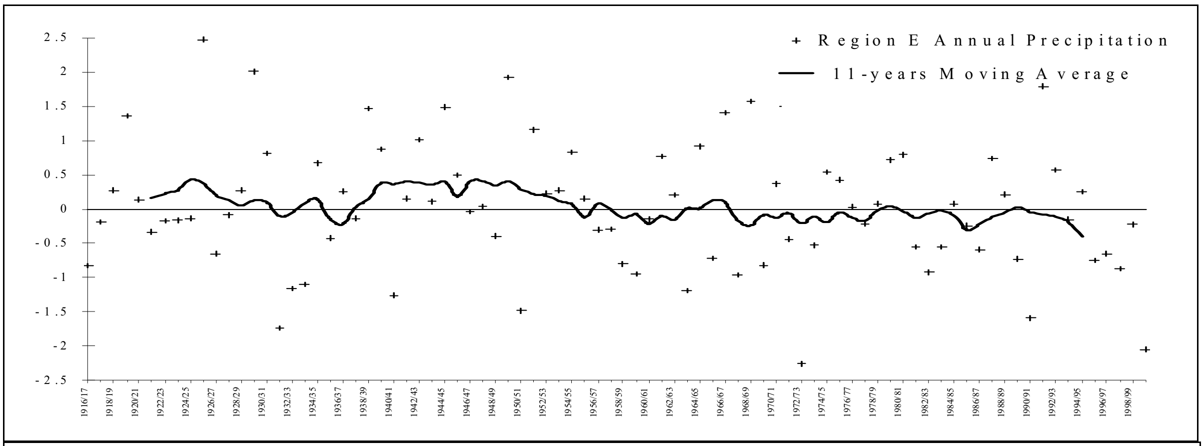
Annex 8

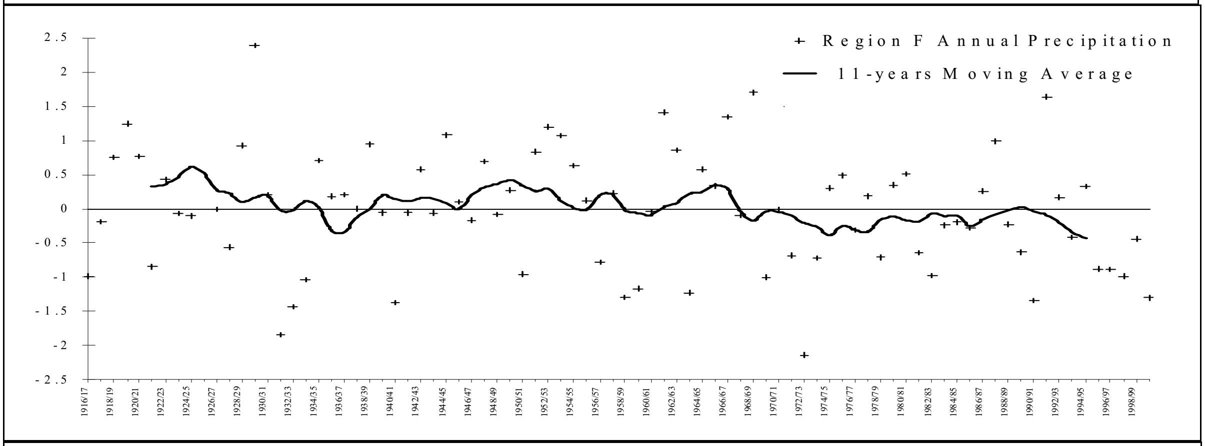
Regional annual precipitation and 11 years running mean for regions A to H

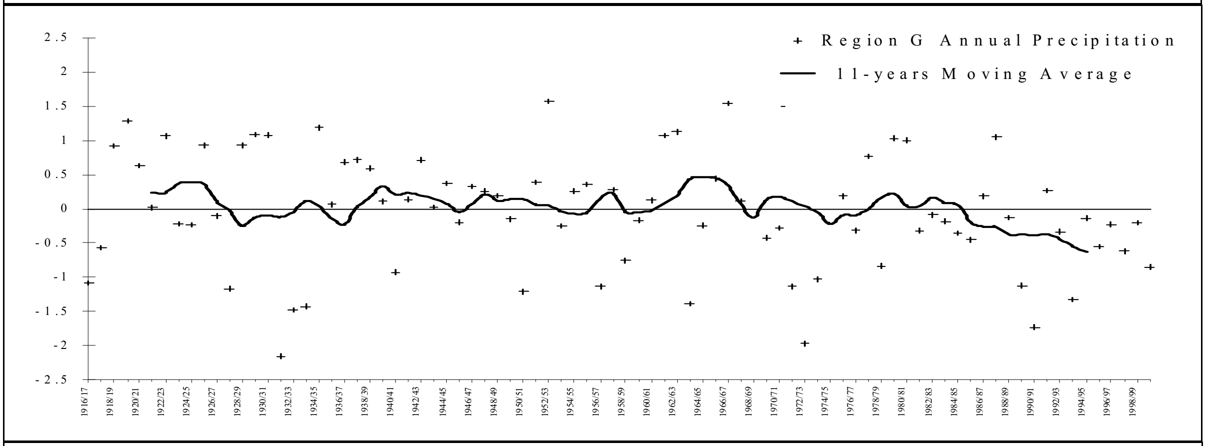


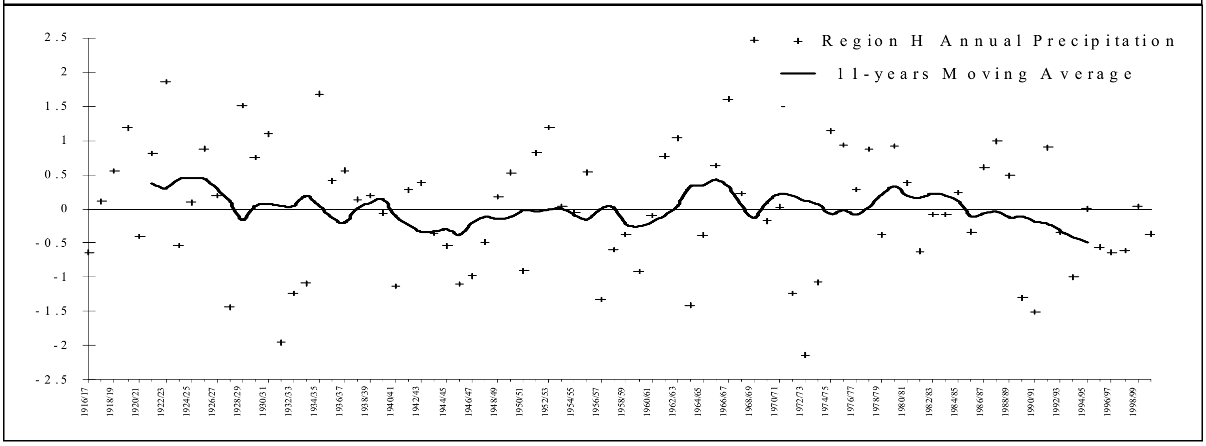
Annex 8 continue

Regional annual precipitation and 11 years running mean for regions A to H



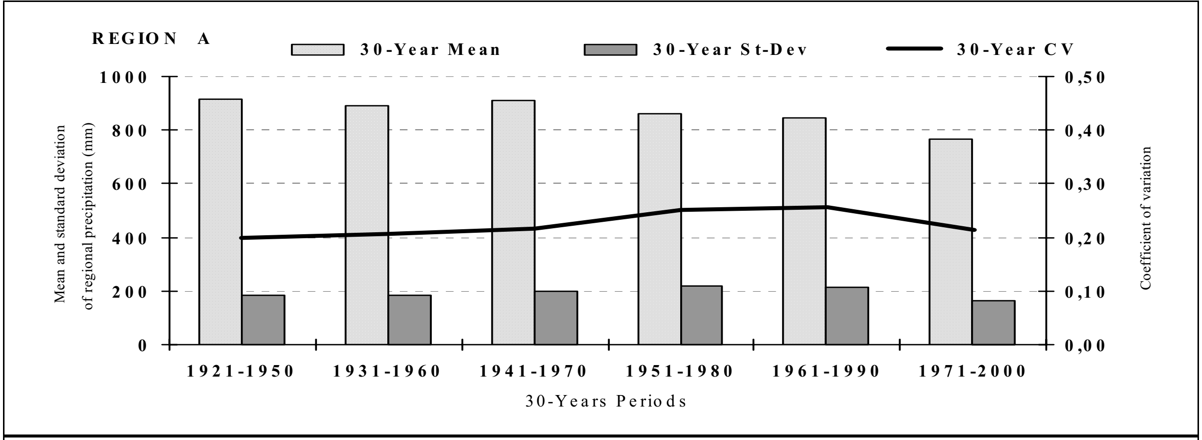


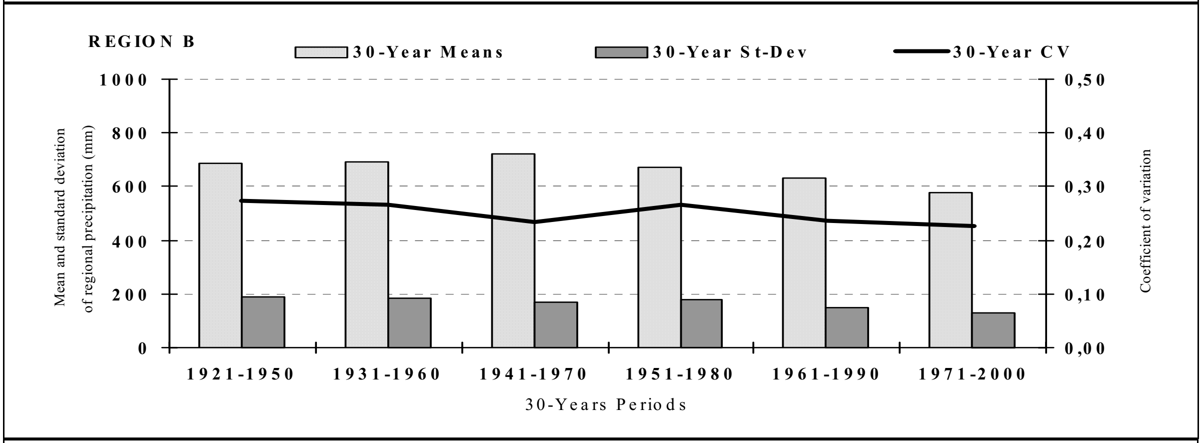


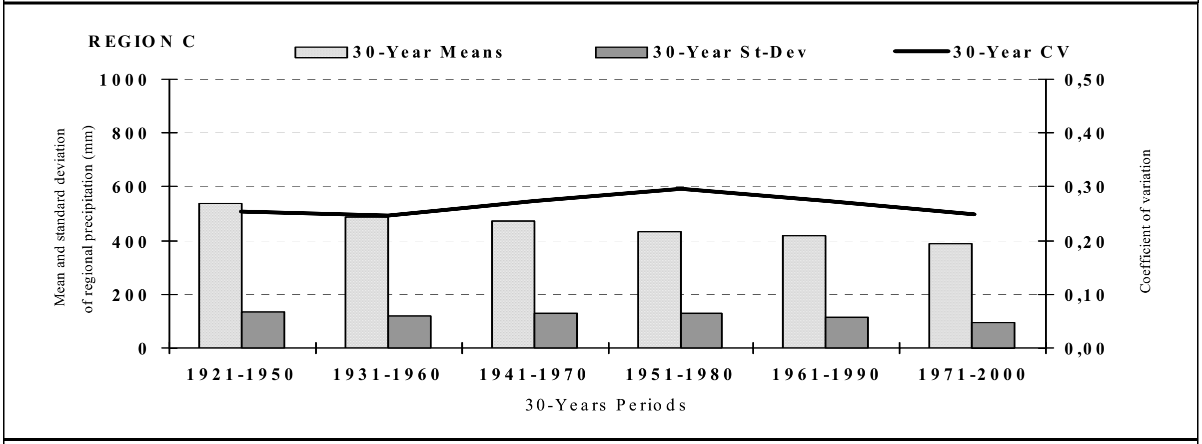


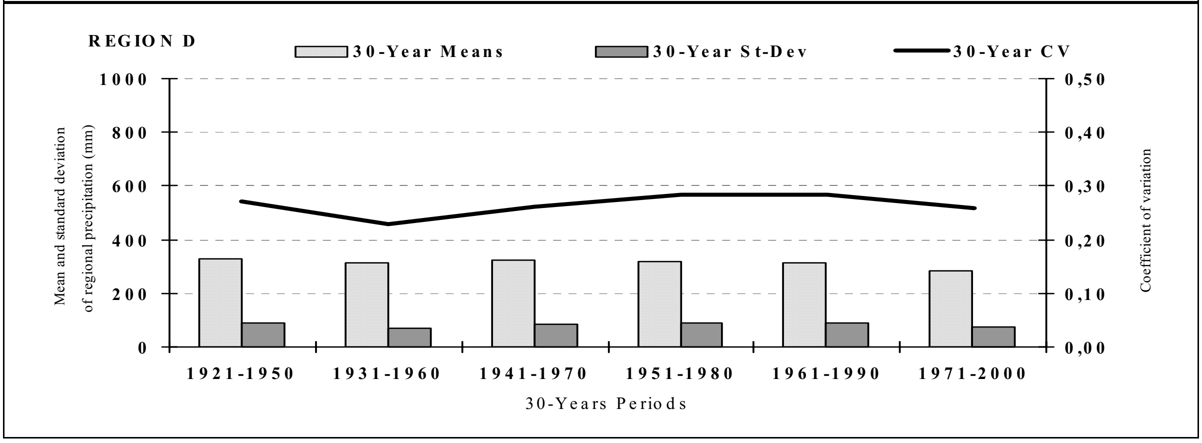
Annex 9

Mean, standard deviation and coefficient of variation of the yearly regional precipitation over the WMO standard 30 years periods for regions A to H



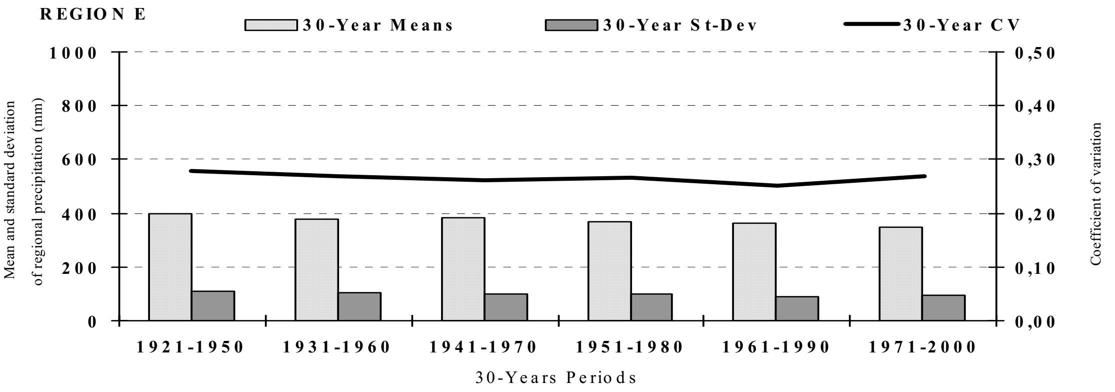


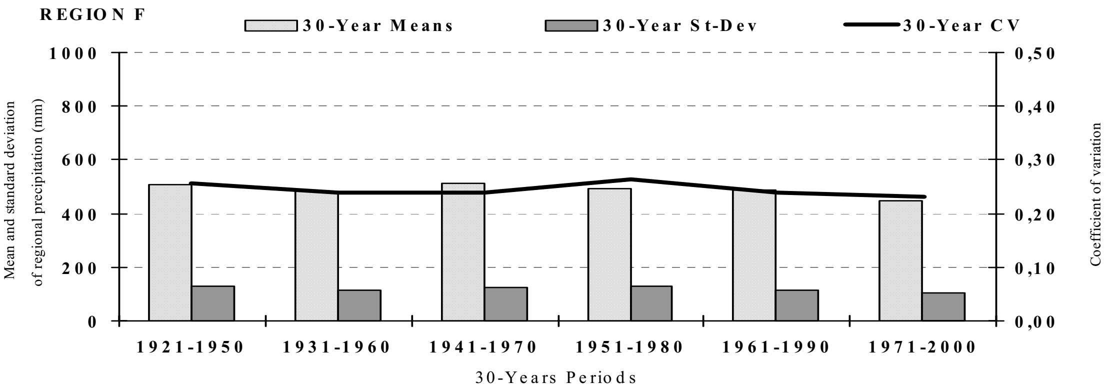


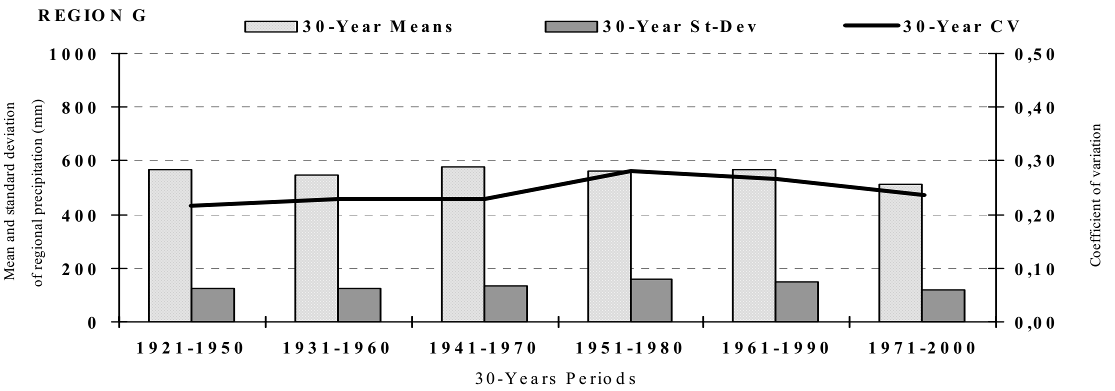


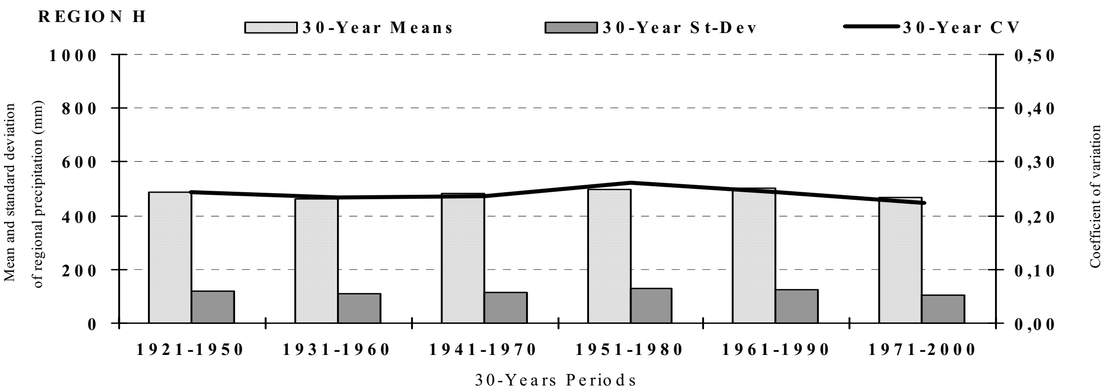
Annex 9 continue

Mean, standard deviation and coefficient of variation of the yearly regional precipitation over the WMO standard 30 years periods for regions A to H



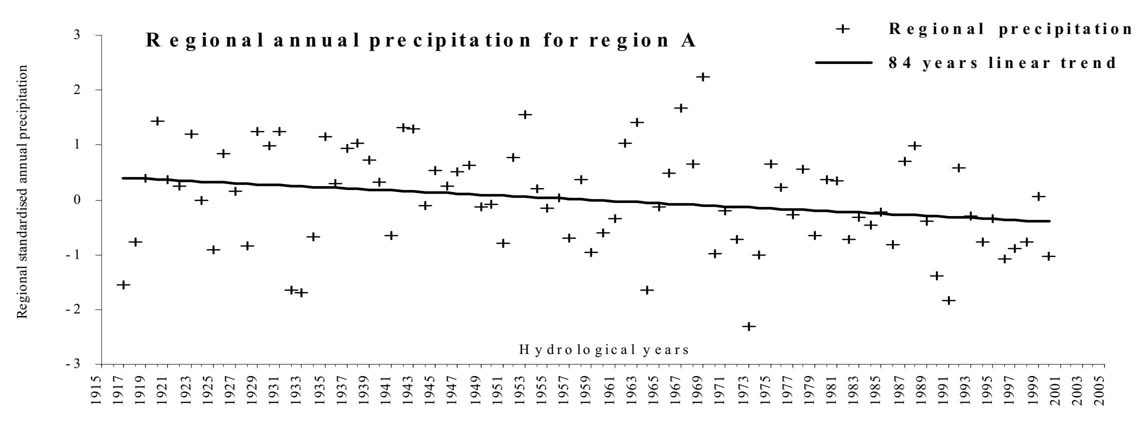


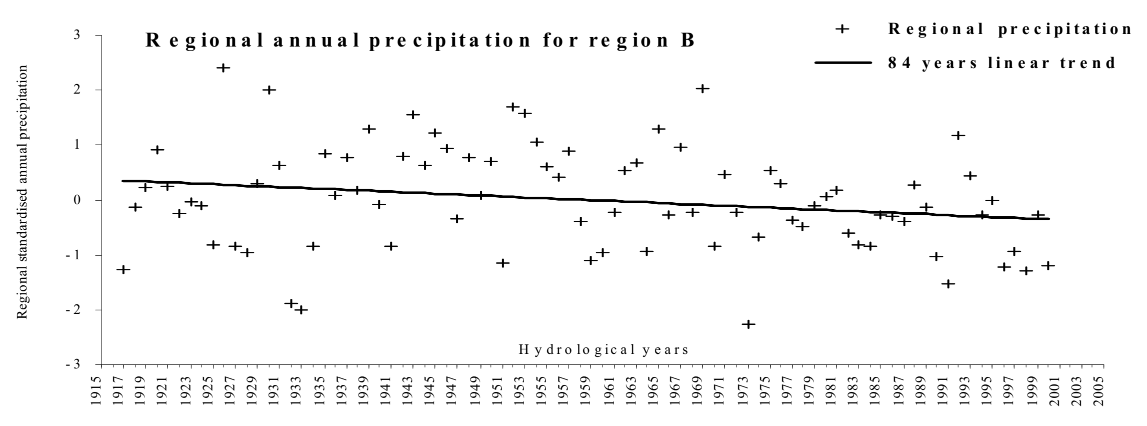


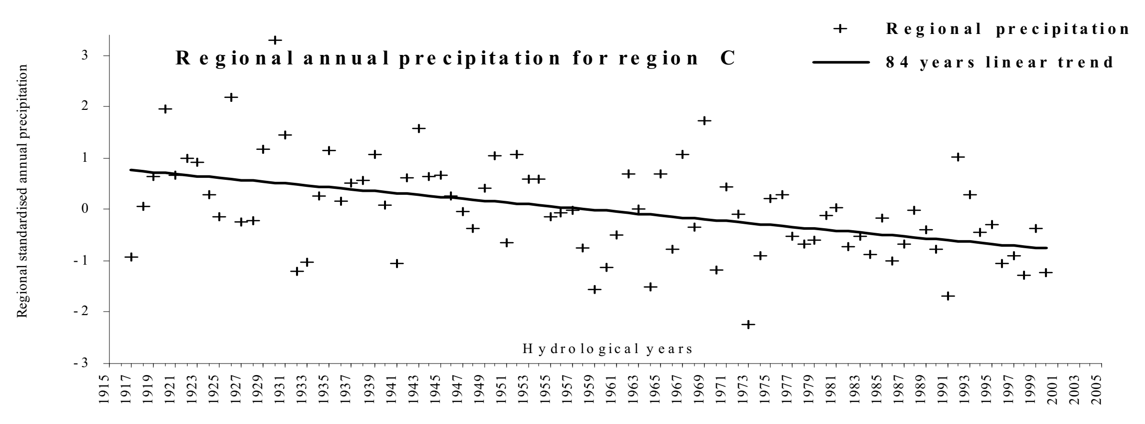


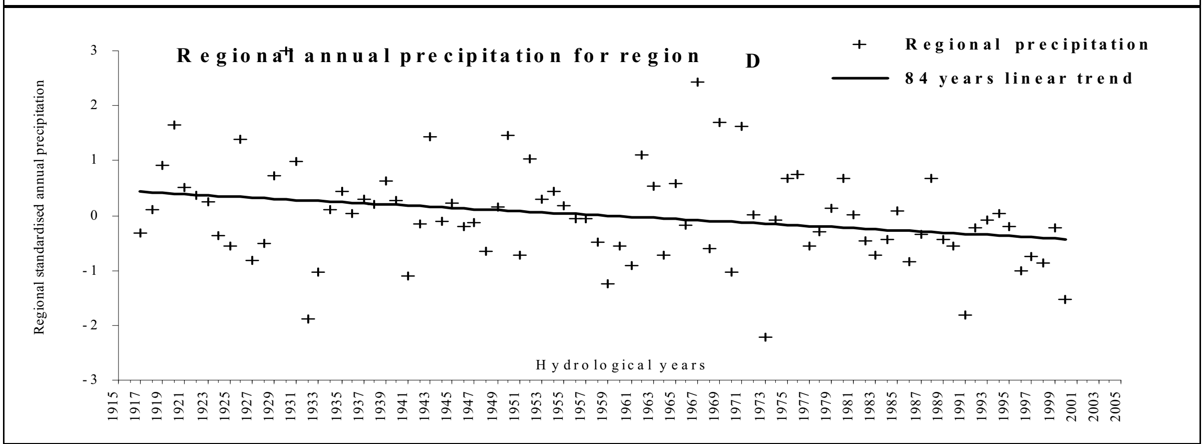
Annex 10

Annual regional precipitation and linear regression trend over the entire 1917-2000 period for regions A to H.



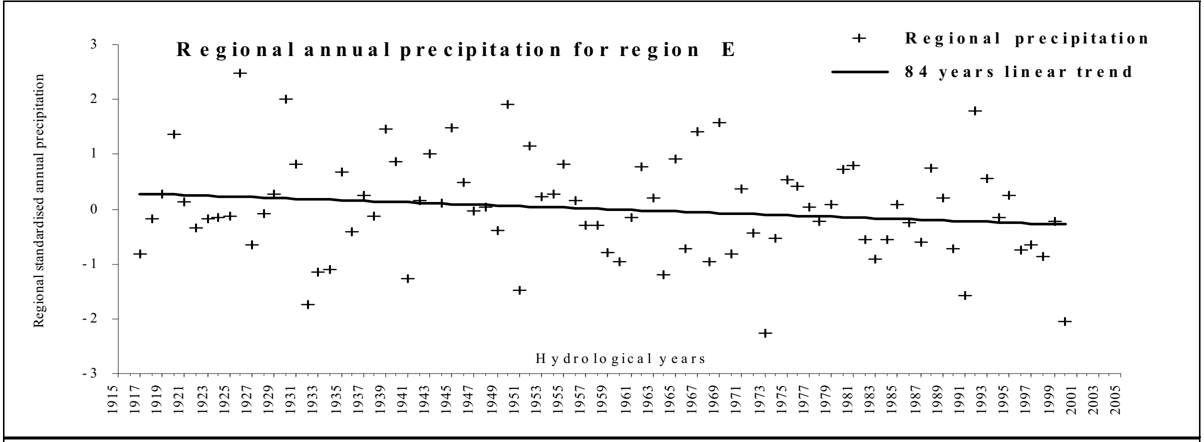


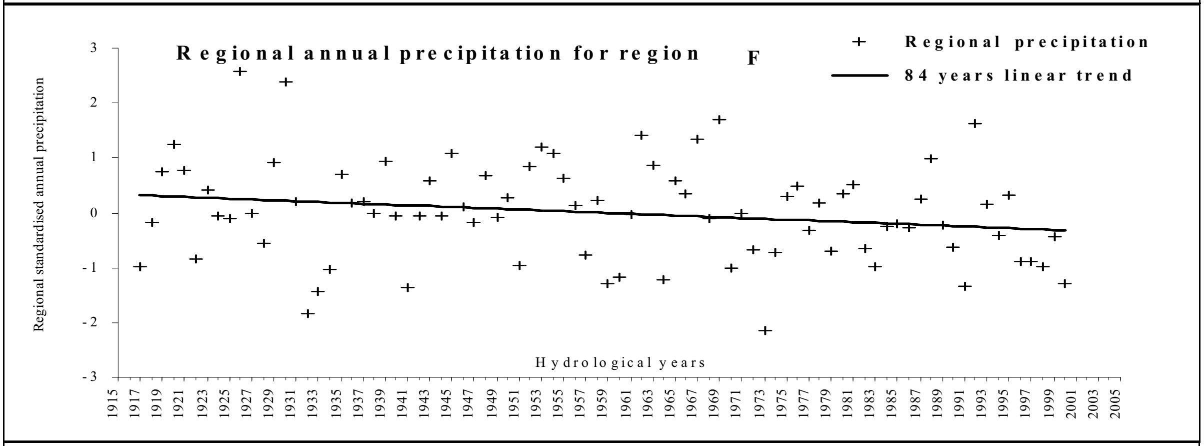


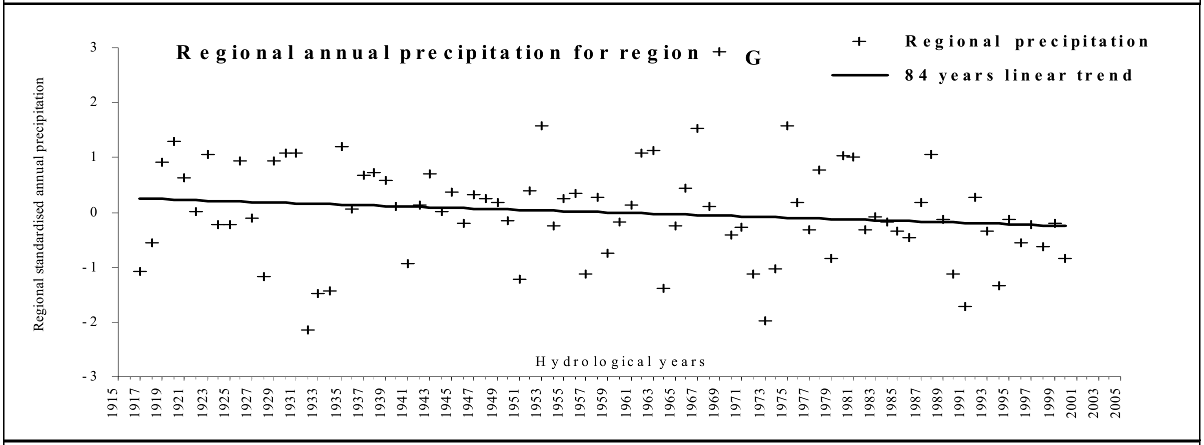


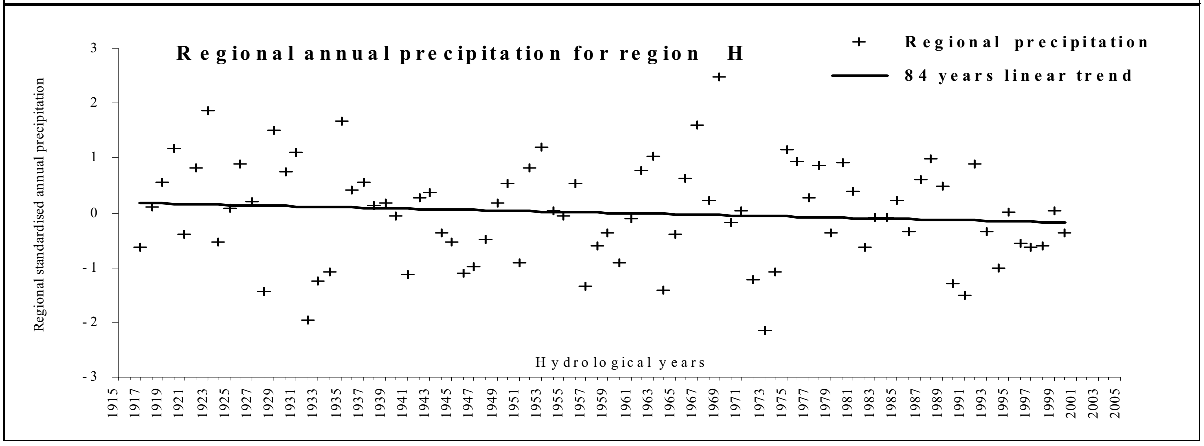
Annex 10 continue

Annual regional precipitation and linear regression trend over the entire 1917-2000 period for regions A to H.



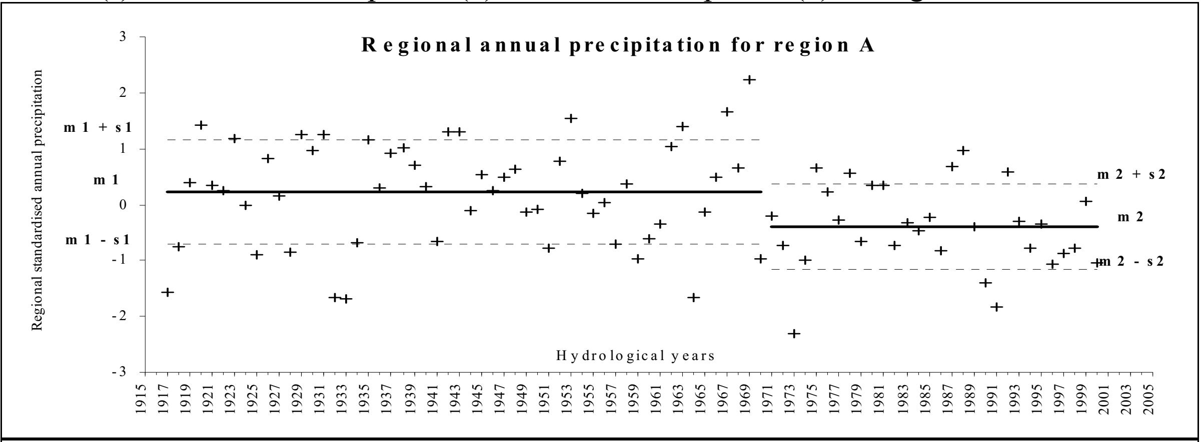


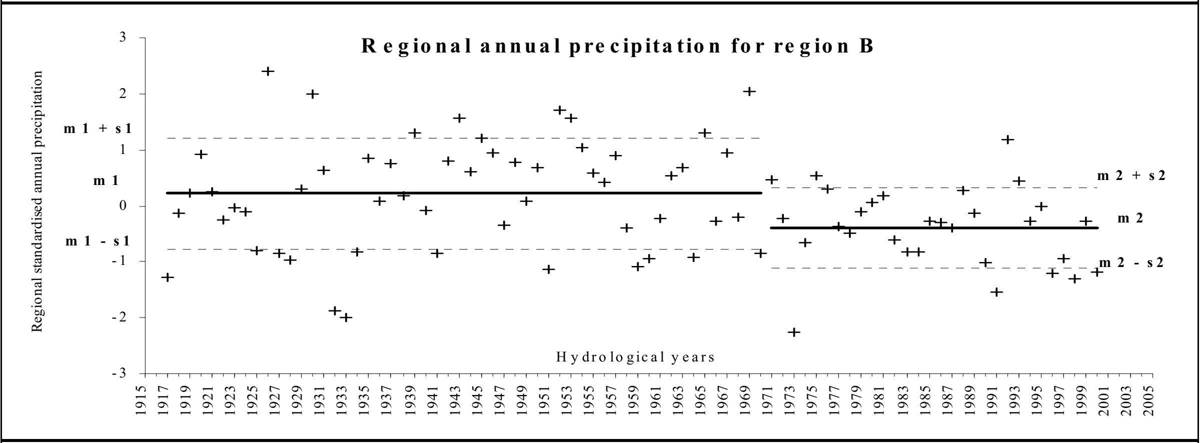


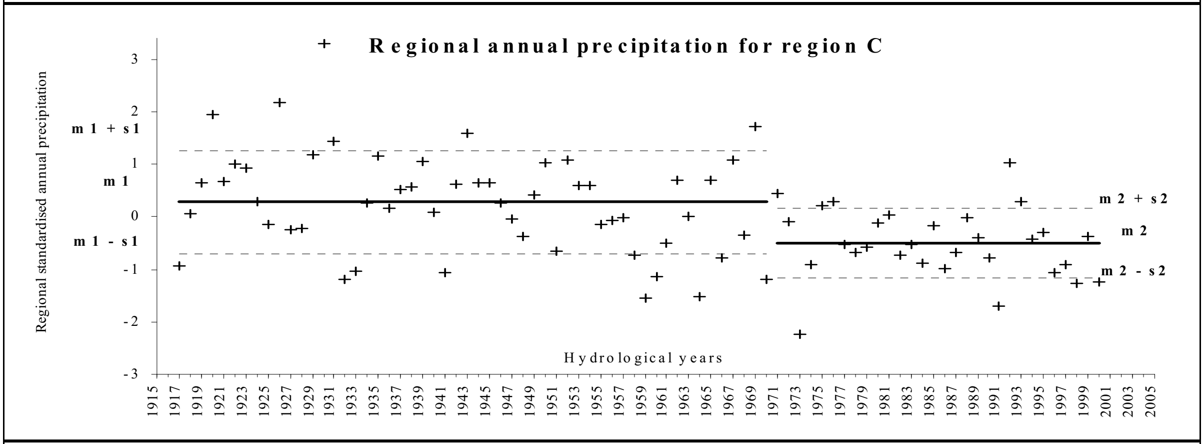


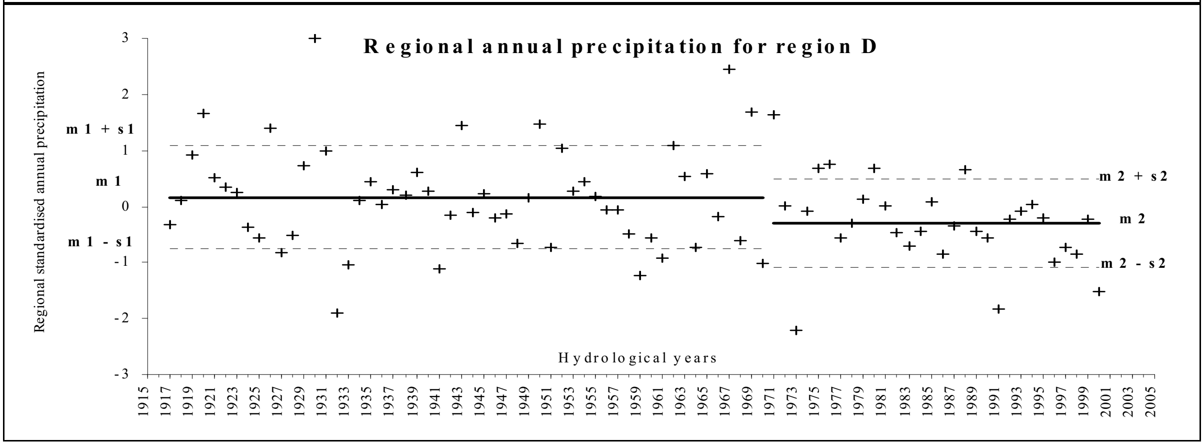
Annex 11

Regional annual standardised precipitation with indication of the mean (m) and standard deviation (s) of the 1917-1970 period (1) and 1971-2000 period (2) for regions A to H.



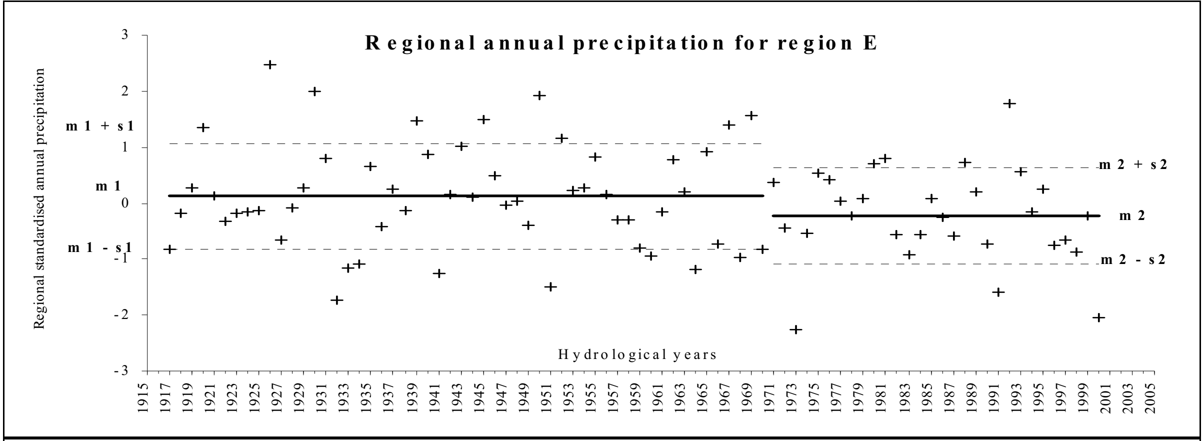


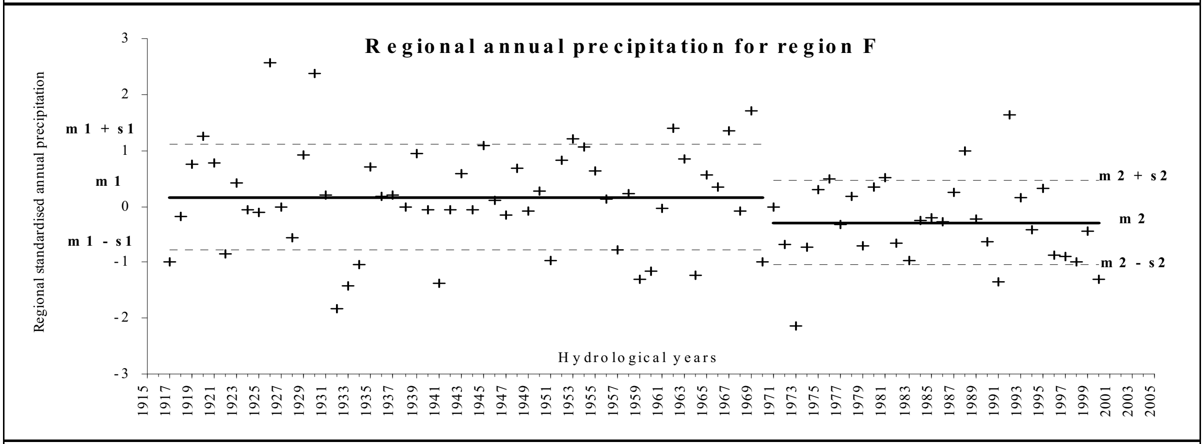


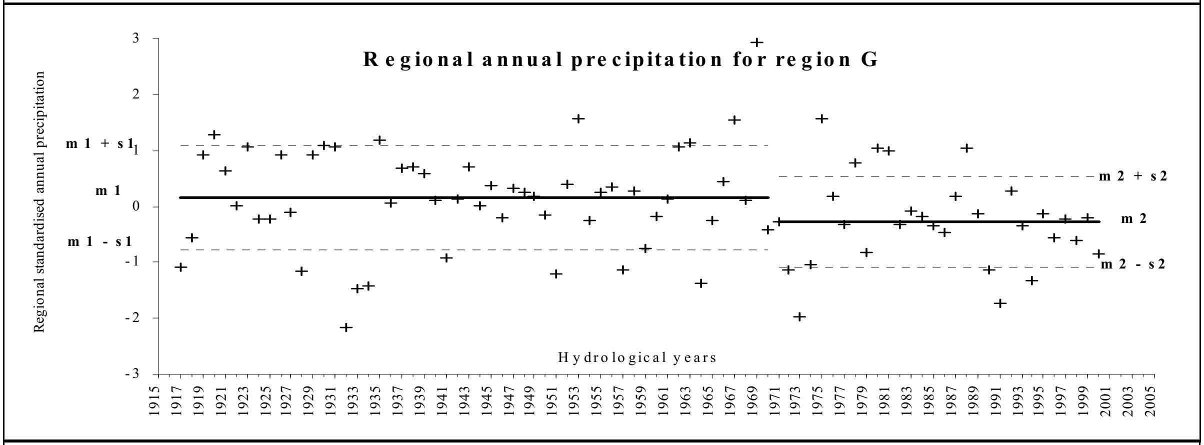


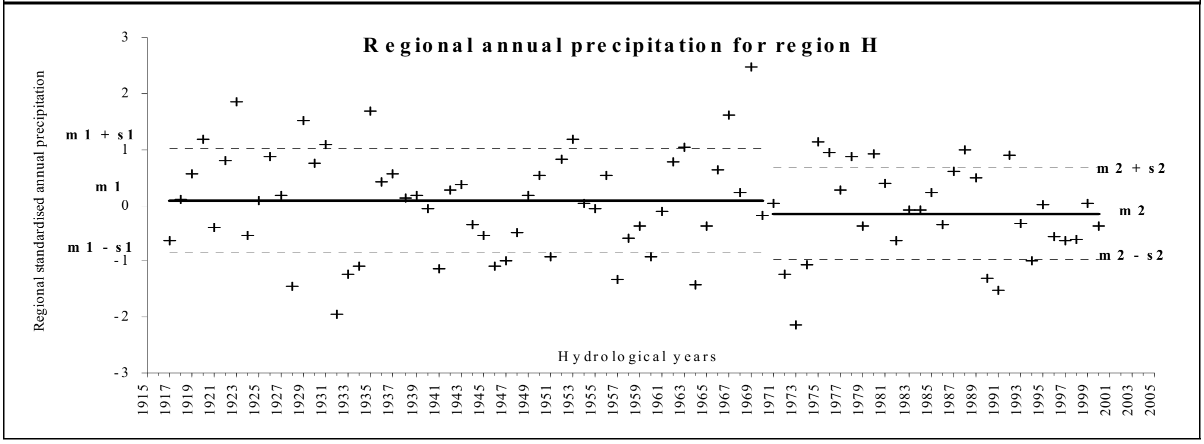
Annex 11 continue

Regional annual standardised precipitation with indication of the mean (m) and standard deviation (s) of the 1917-1970 period (1) and 1971-2000 period (2) for regions A to H.



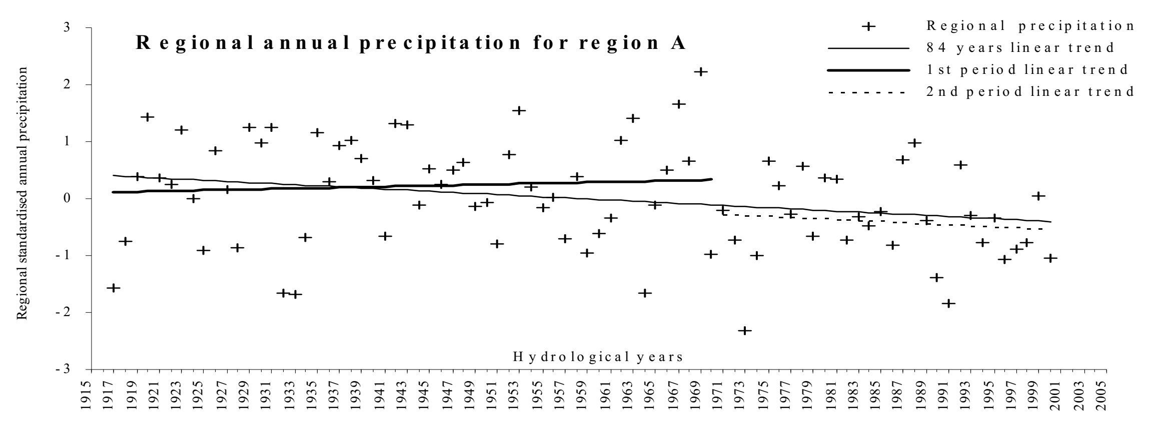


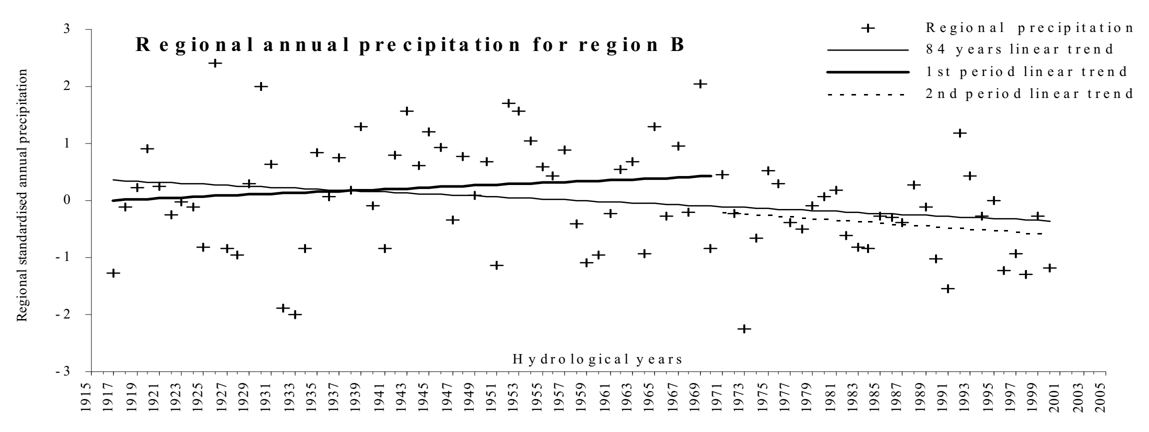


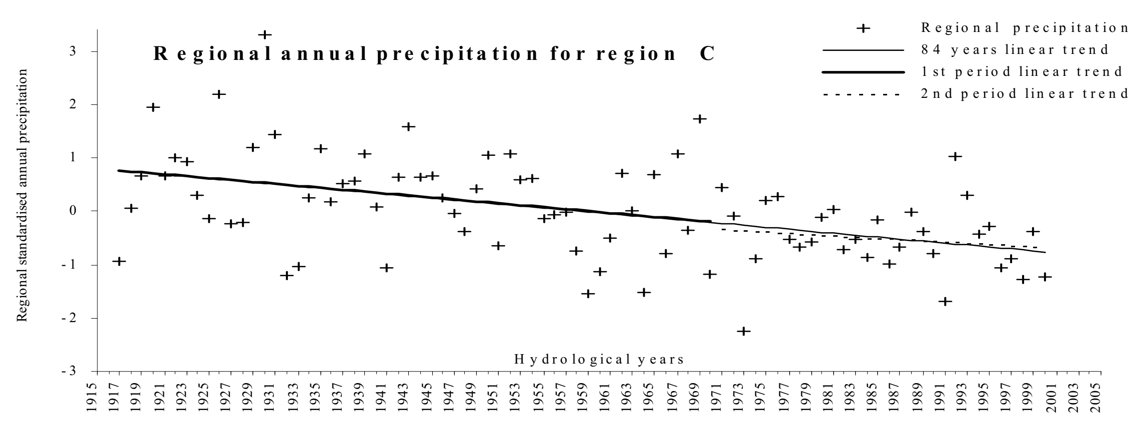


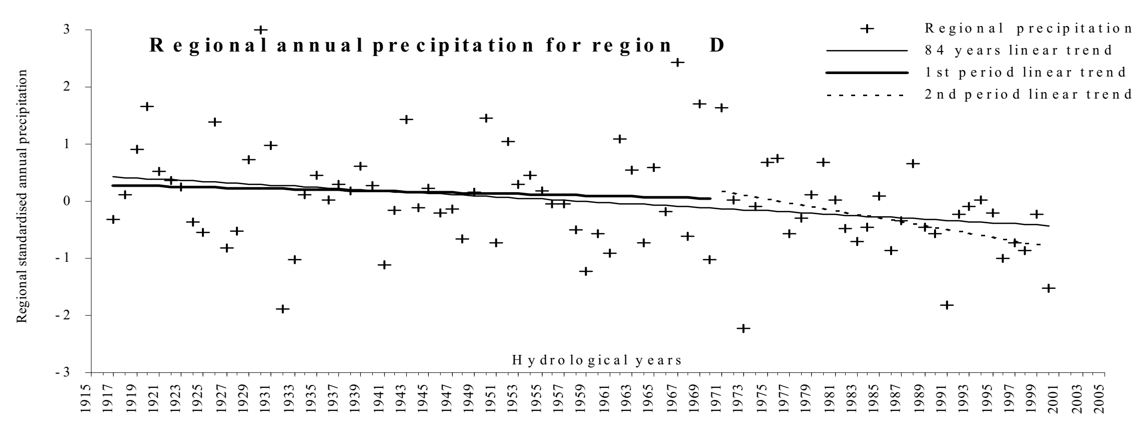
Annex 12

Annual regional precipitation and linear regression trend over the periods 1917-2000, 1917-1970 and 1971-2000 for regions A to H



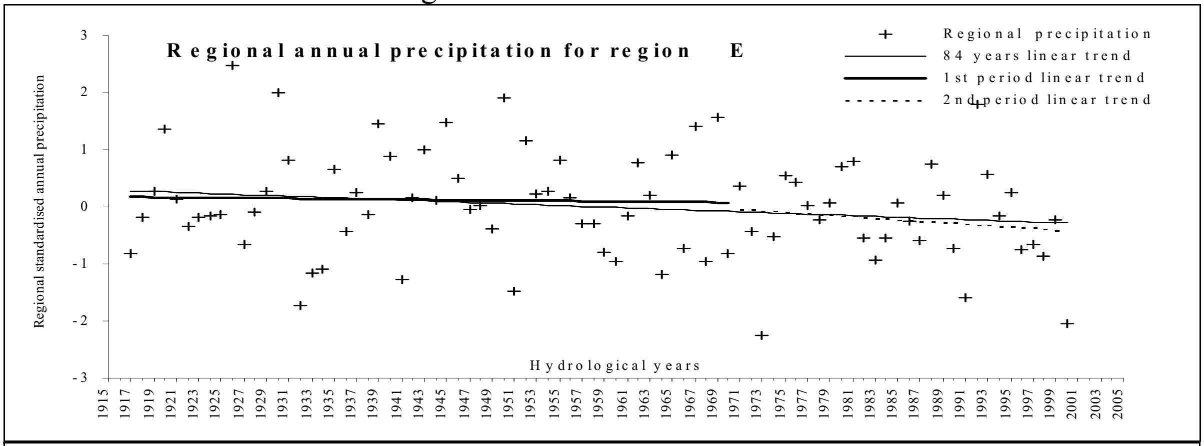


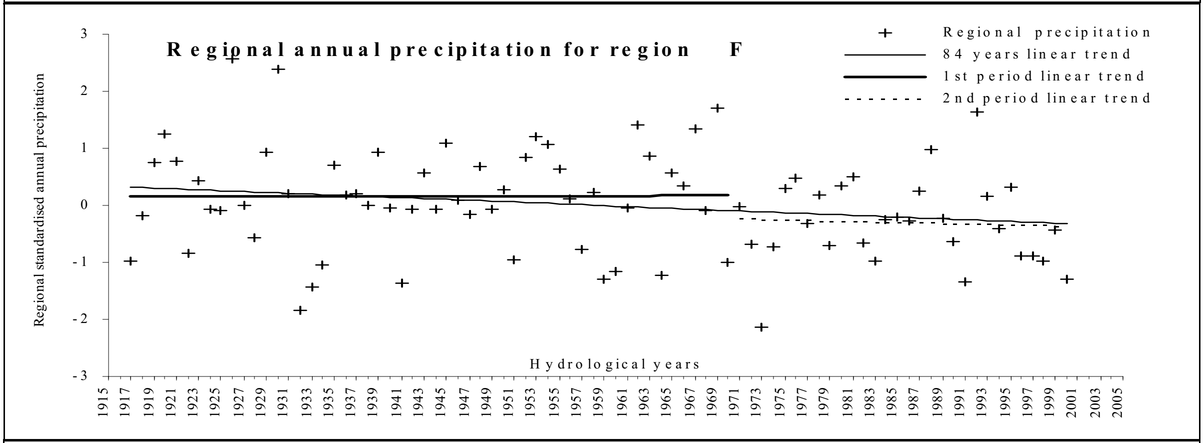


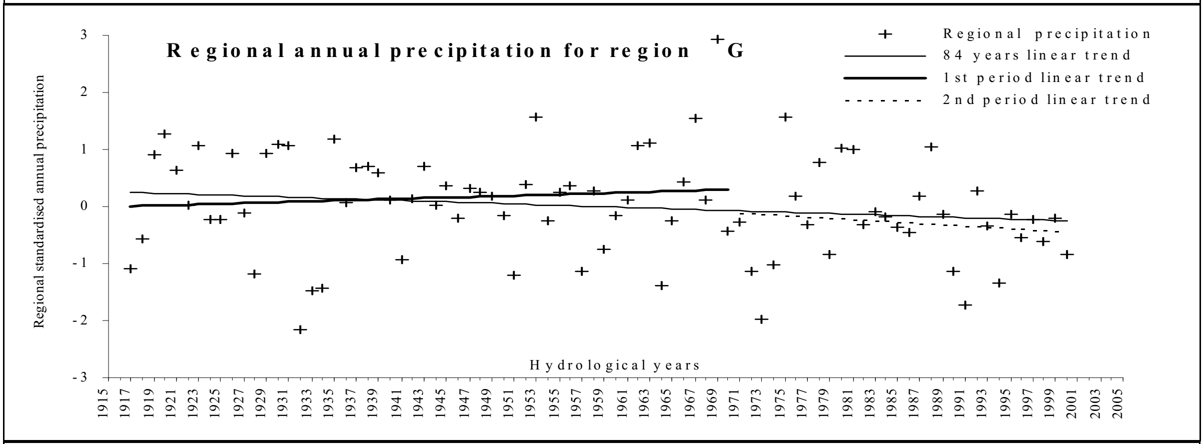


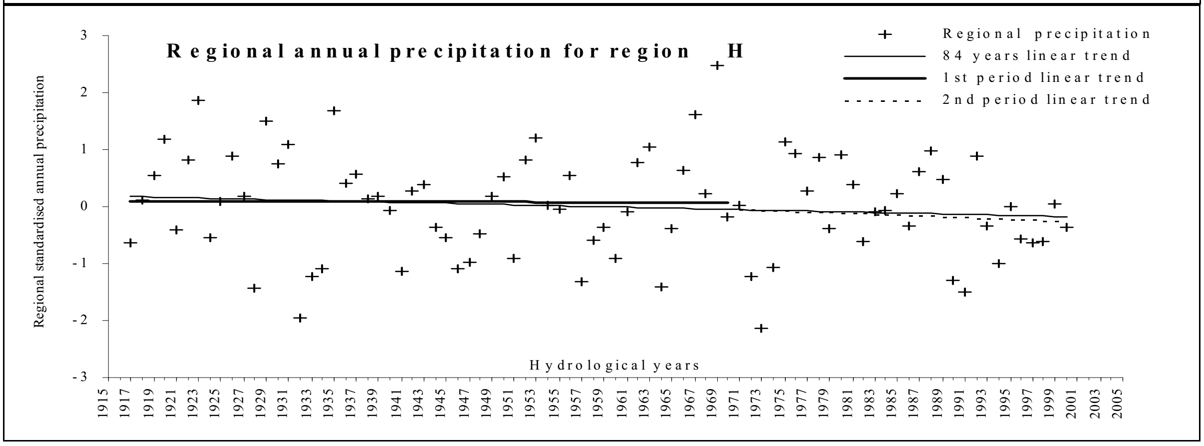
Annex 12 continue

Annual regional precipitation and linear regression trend over the periods 1917-2000, 1917-1970 and 1971-2000 for regions A to H









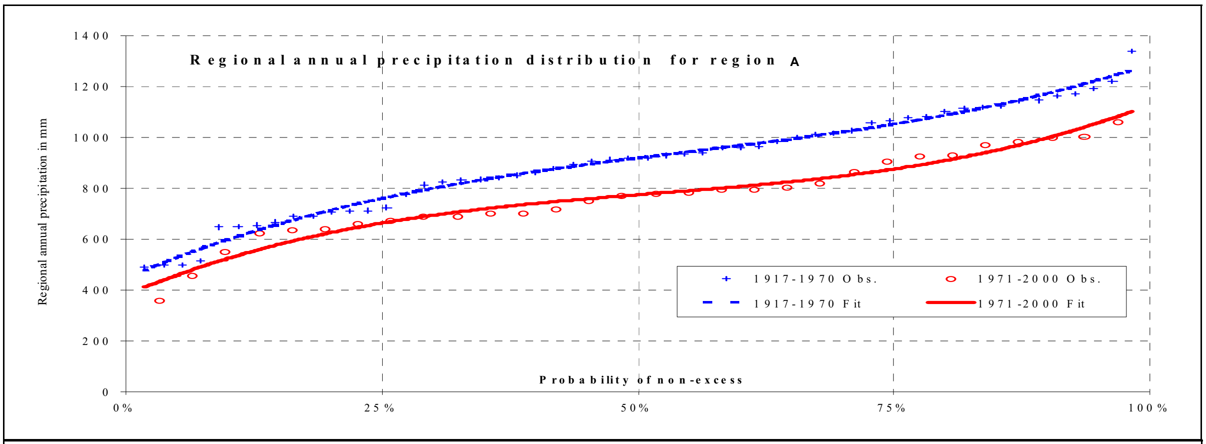
Annex 13

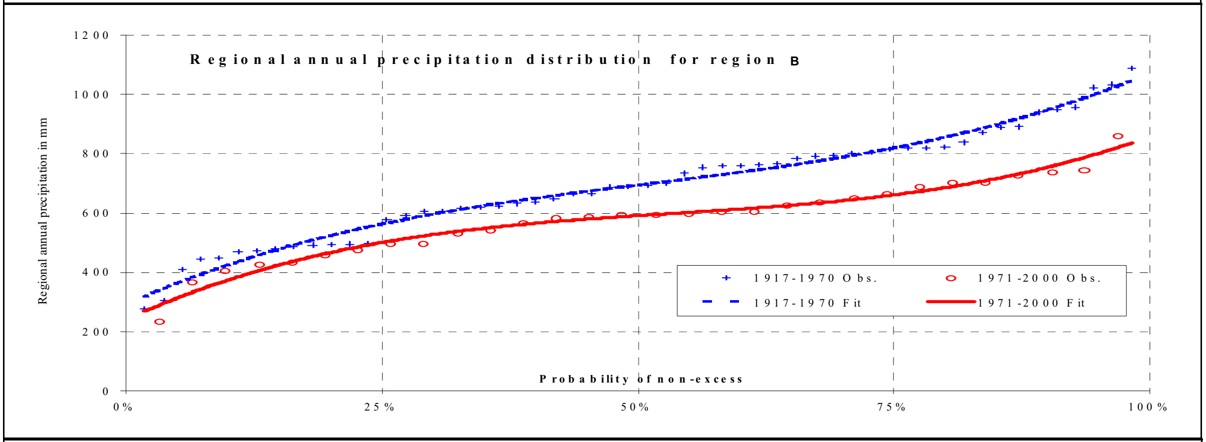
Differences between the stations annual mean precipitation of the recent and old periods in millimetres and in percent of the mean of the old period.

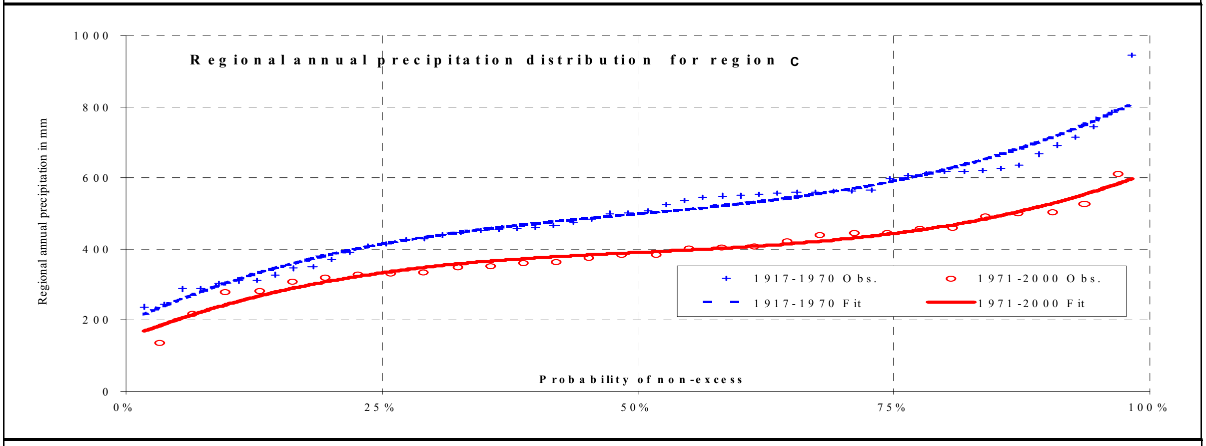
Code #	Diff. in mm	Diff. In %
10	-29	-5
40	-24	-5
50	-82	-14
60	-79	-12
80	-44	-10
90	-43	-10
110	-147	-17
120	-75	-10
130	-146	-16
140	-61	-10
160	-19	-4
170	-71	-15
180	-228	-24
190	-27	-6
220	-103	-11
250	-97	-11
260	-119	-15
290	-85	-19
300	-139	-13
310	-89	-9
320	-143	-18
370	-107	-20
390	-52	-11
400	-68	-10
430	-28	-10
440	-114	-22
451	-118	-15
460	-148	-27
490	-125	-27
500	-94	-13
510	-128	-16
520	-18	-6
540	-57	-13
550	-121	-19
580	-70	-19
595	-62	-14
599	-103	-19
600	-79	-13
640	-67	-18
648	-62	-14
650	-42	-11
660	-37	-8
690	-37	-11
800	-36	-11

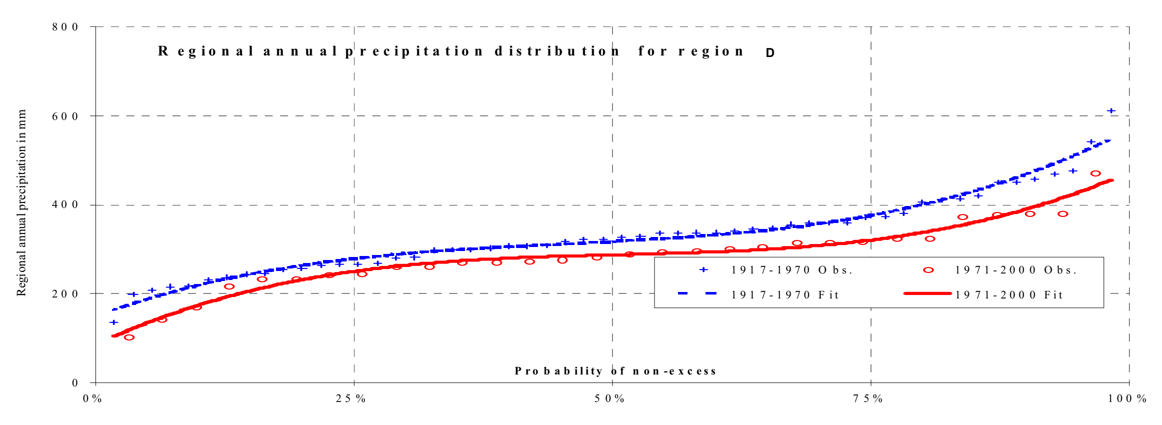
Annex 14

Cumulative distribution of annual precipitation over the recent and older periods for regions A to H.



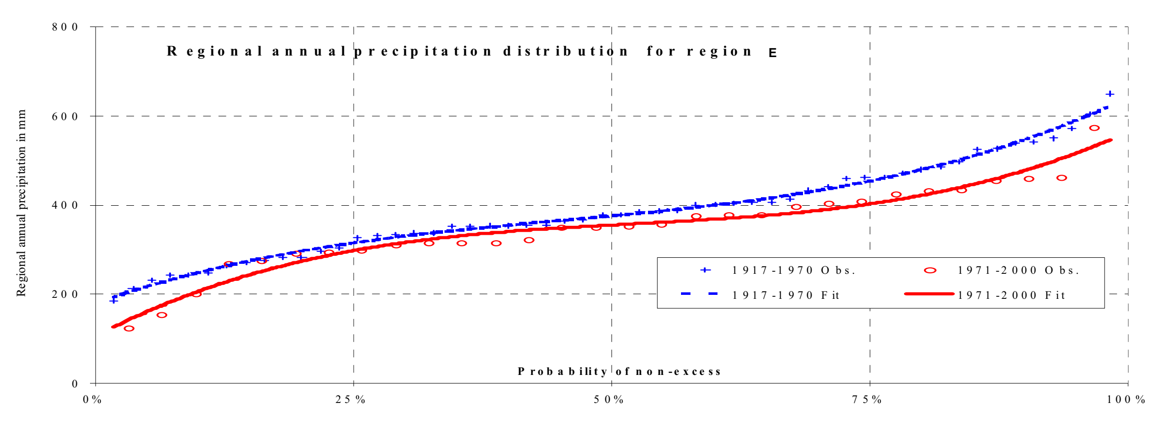


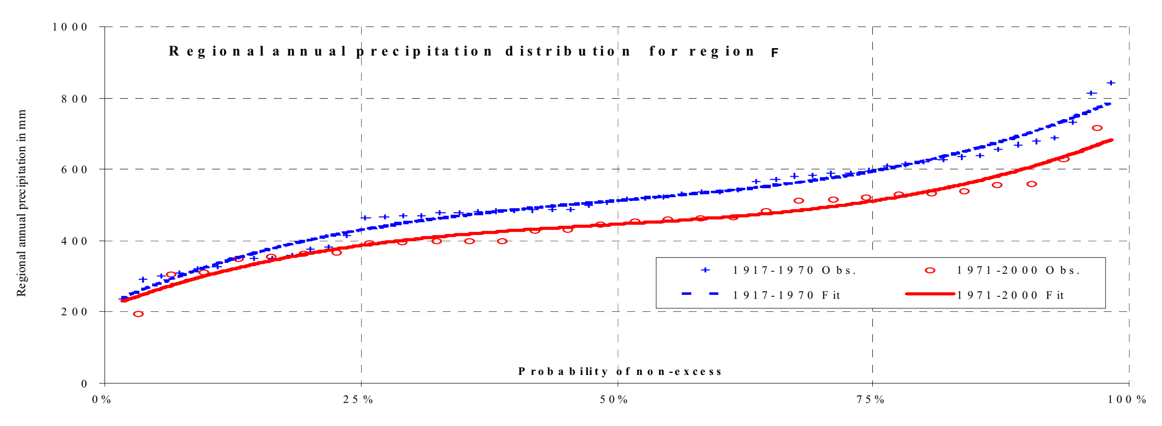


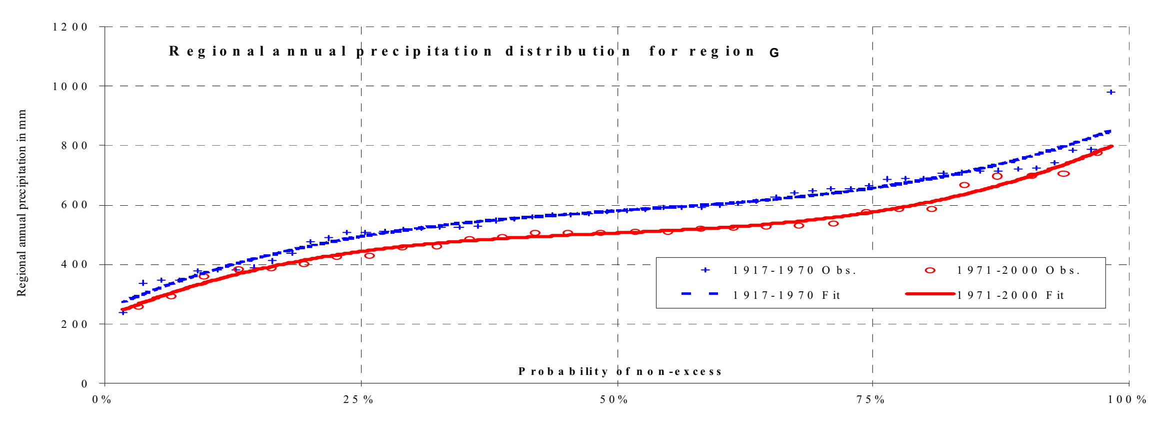


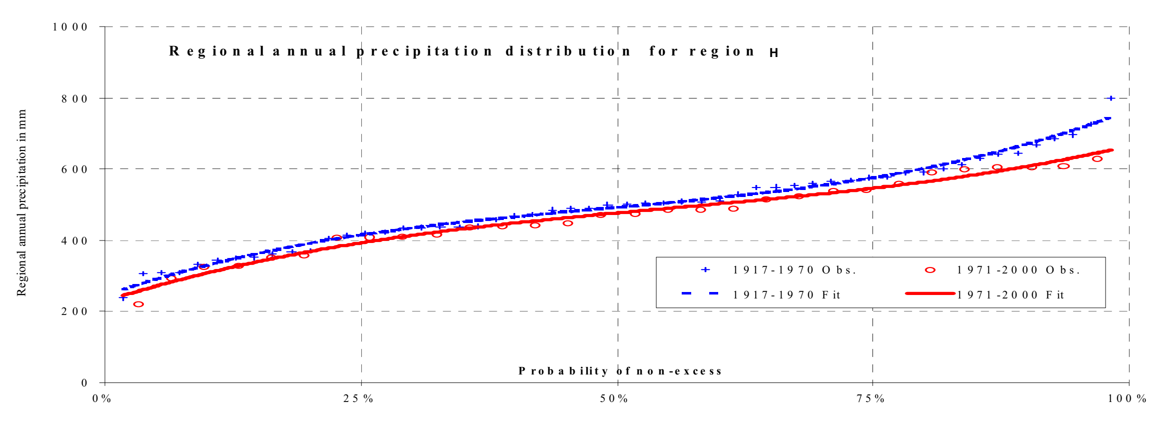
Annex 14 continue

Cumulative distribution of annual precipitation over the recent and older periods for regions A to H.



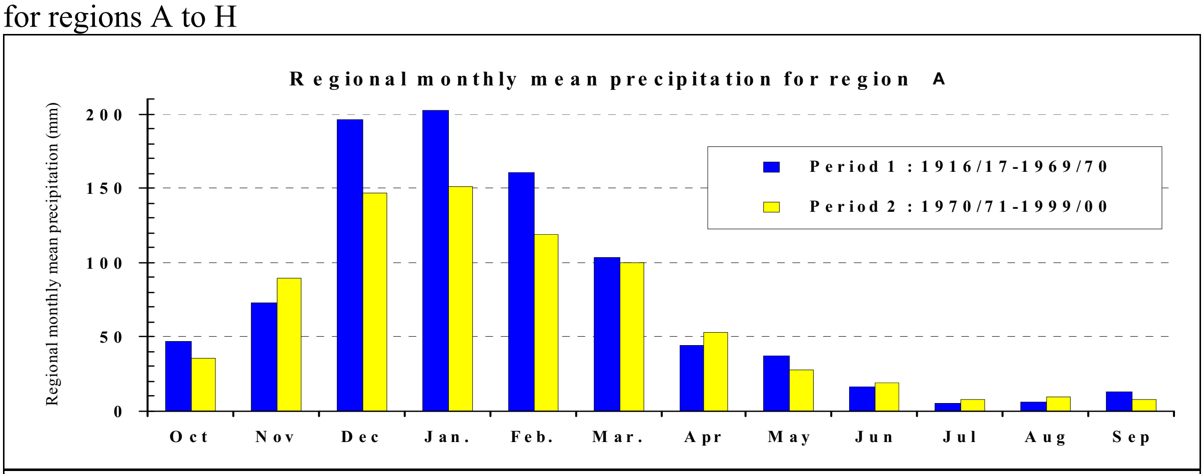


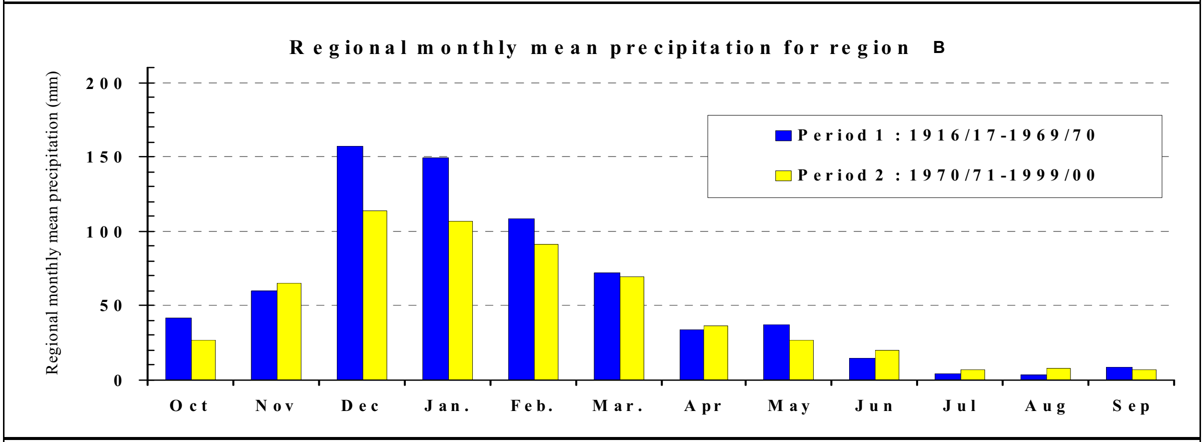


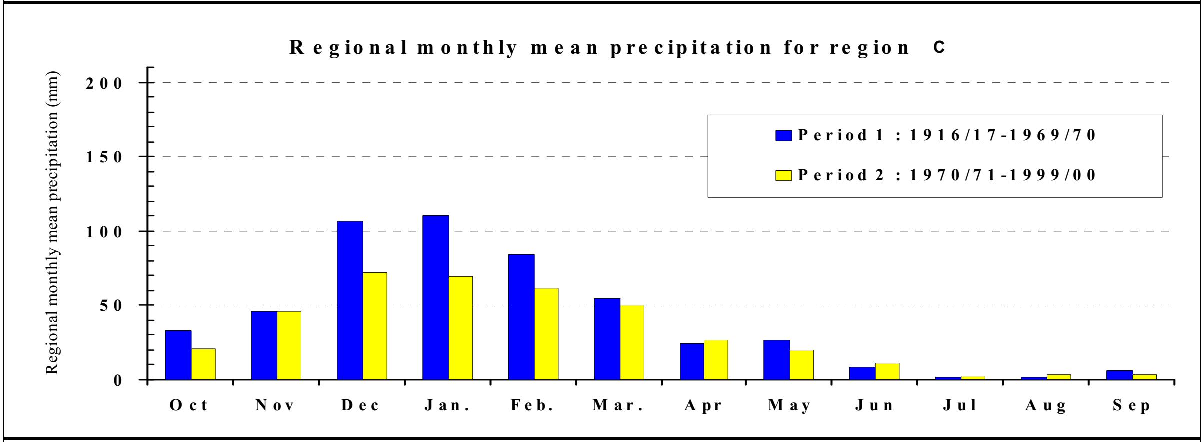


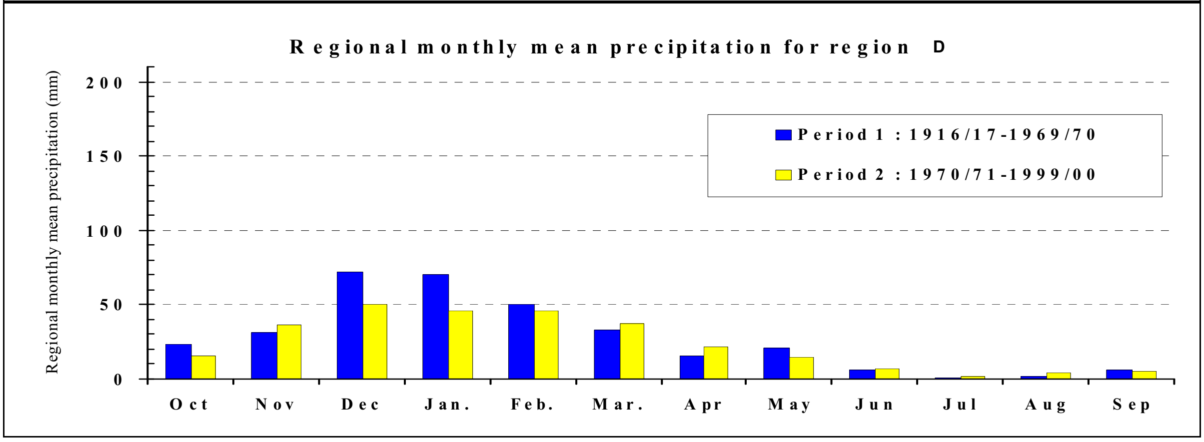
Annex 15

Regional monthly mean precipitation for the periods 1917-1970 and 1971-2000 in millimetres for regions A to H



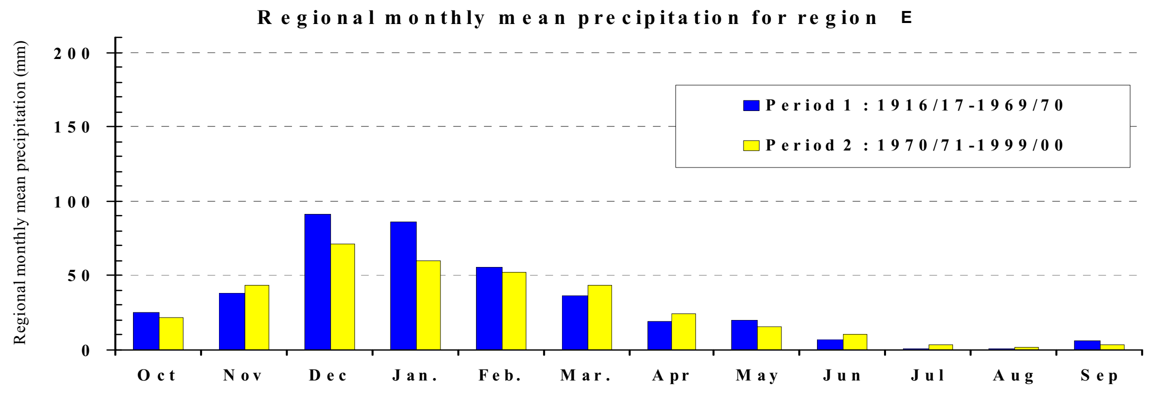


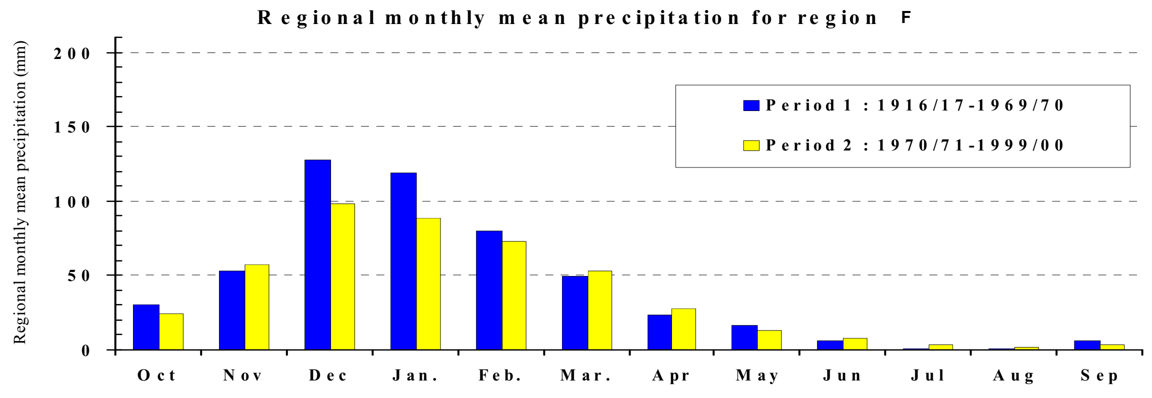


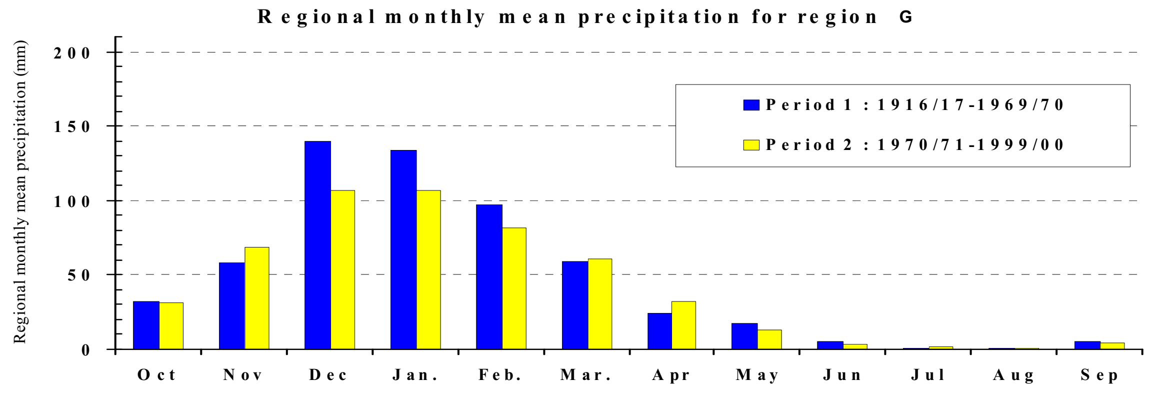


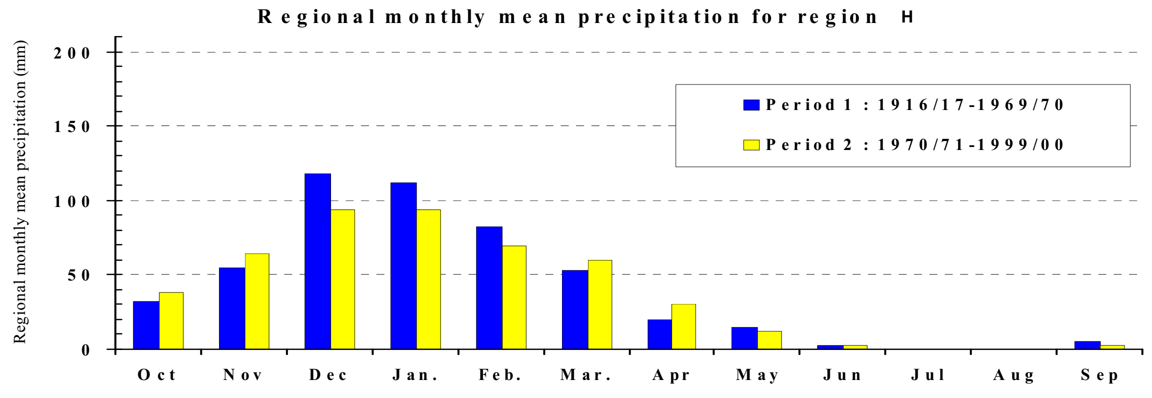
Annex 15 continue

Annual regional precipitation and linear regression trend over the periods 1917-2000, 1917-1970 and 1971-2000 for regions A to H



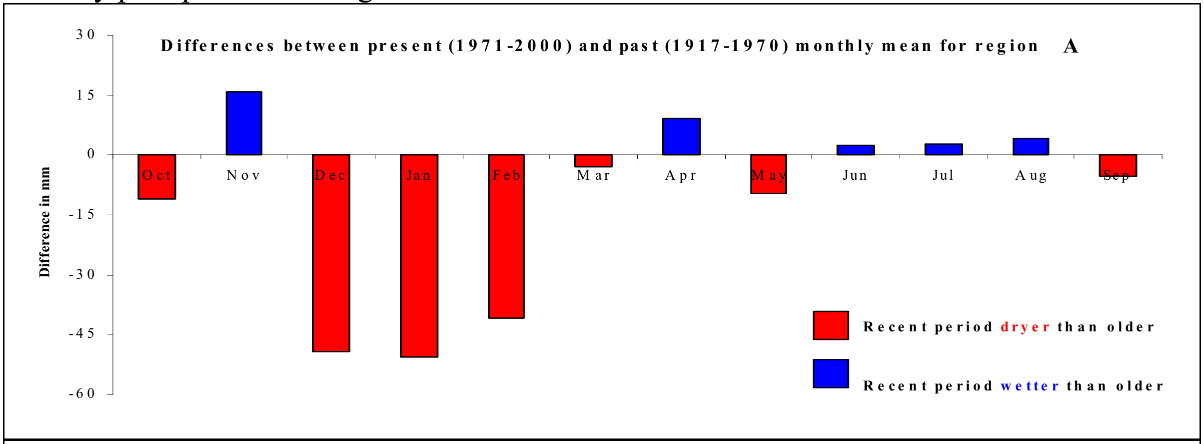


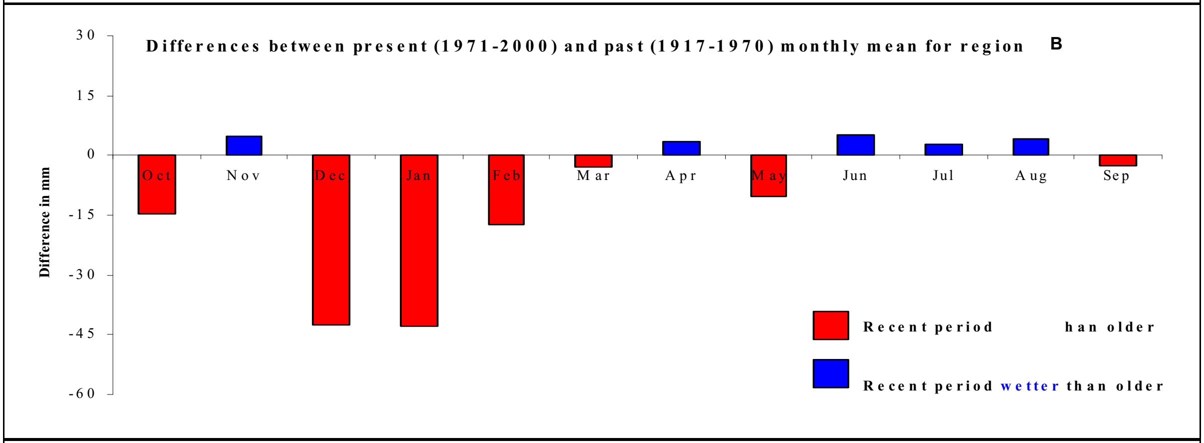


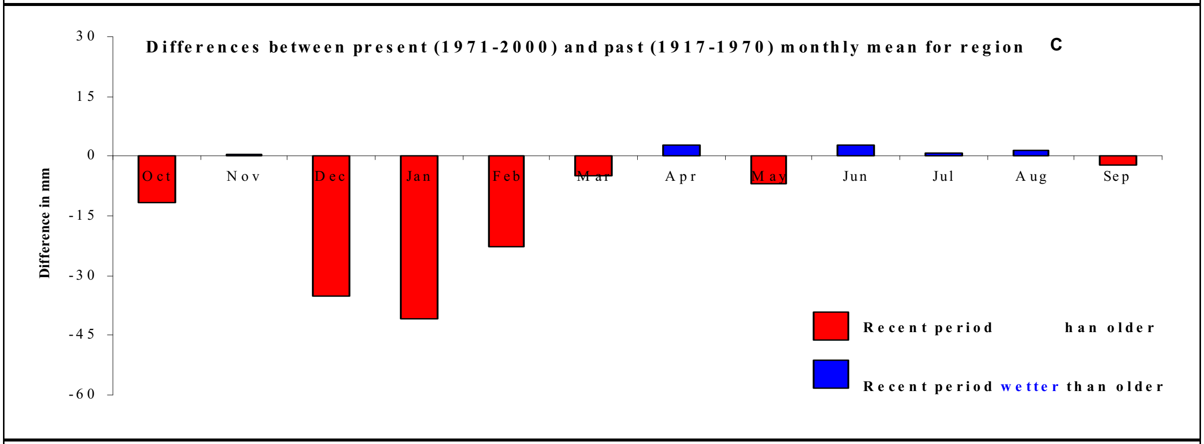


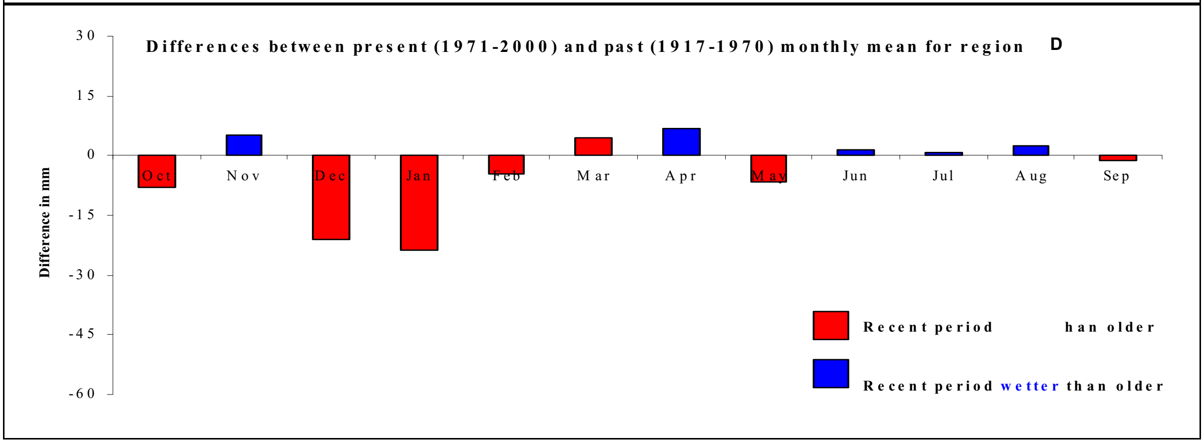
Annex 16

Differences in millimetres between the 1971-2000 mean and 1917-1970 mean of the regional monthly precipitation for regions A to H









Annex 16 continue

Differences in millimetres between the 1971-2000 mean and 1917-1970 mean of the regional monthly precipitation for regions A to H