

# LIST OF FIGURES

	<b>Page</b>
<b>CHAPTER 2:</b>	
Fig. 2.1. Distribution of the total annual precipitation [mm] in Mexico. Map based in the 175 stations network of monthly rainfall (see section 3.2).	11
Fig. 2.2. Map of Mexican hypsometry and bathymetry. Atlas Nacional de México. Instituto de Geografía. UNAM (National University).	12
<b>CHAPTER 3:</b>	
Fig. 3.1. DAILY DATA EXTRACTION PROCEDURE	29
Fig. 3.2. Example of daily precipitation data being corrected. Two different databases are compared. In this case, missing values (-1) in one time-series (CLICOM) are corrected with the second dataset (ERIC).	30
Fig. 3.3. Example of daily precipitation data being corrected. Two different databases are compared. In this case, a systematic error (values are multiplied by a factor of 10) in the first time-series (CLICOM) are substituted by the corrected values in the second dataset (ERIC).	30
Fig. 3.4. Resulting network of 93 stations after the first stage of extraction of daily rainfall data.	33
Fig. 3.5. Meteorological network of 175 with monthly precipitation data from 1931 to 2001 as used in the analysis of Principal Components (PC).	38
Fig. 3.6. Current defined ENSO regions extracted from the Climate Diagnostics Center (CDC) website: <a href="http://www.cdc.noaa.gov/ClimateIndices/">http://www.cdc.noaa.gov/ClimateIndices/</a> .	40
Fig. 3.7. Station with daily temperature errors before being corrected. In this case Tmin values are greater than Tmax.	43
	iii

Fig. 3.8. Station with daily temperature errors before being corrected. In this case Tmin and Tmax have the same values.	43
Fig. 3.9. Annual total precipitation (in mm) for station 27042; Tapijulapa, Tabasco.	45
Fig. 3.10. Double Mass Plot for the station 27042; Tapijulapa, Tabasco.	45
Fig. 3.11. Standard Anomalised Index (SAI) for the annual precipitation of all the stations of the resulting Region 4 after the Principal Component Analysis (PCA, see section 4.1).	47
Fig. 3.12. Standard Anomalised Index (SAI) for the different regions (with total annual precipitation) after the Principal Component Analysis (PCA, see table 4.1).	48
Fig 3.13. Network of a) precipitation and b) temperature stations with daily data for the analysis of extremes (in accordance with table 3.2). The period of the records is from 1941 to 2001.	67

## CHAPTER 4:

Fig. 4.1. Determination of the number of regions (components) considered in the analysis of the annual precipitation using the cliff analogy (Wuensch, 2005).	77
Figure 4.2. Principal component analysis (regionalisation) of a network of 175 stations with annual precipitation totals (1931-2001) using two different solutions: varimax (a) and promax with $\kappa=2$ (b).	80
Fig. 4.3. Determination of the number of regions (components) considered in the analysis of the May to October (Wet Season) precipitation using the scree plot technique.	83
Figure 4.4. Principal component analysis (regionalisation) on a network of 175 stations with wet season (May-Oct) precipitation (1931-2001) using two different solutions: varimax (a) and promax with $\kappa=2$ (b).	85

Fig. 4.5. Determination of the number of regions (components) considered in the analysis of the Nov-Apr (Dry Season) precipitation using the cliff analogy (Wuensch, 2005). 89

Figure 4.6. Principal component analysis (regionalisation) of a network of 175 stations with dry season (Nov-Apr) precipitation (1931-2001) using two different solutions: varimax (a) and promax with  $\kappa=2$  (b). 93

Fig.4.7. Locations of the 52 climatological stations with monthly mean temperature during the period 1941-2001 used in the Principal Component Analysis (PCA). 97

Figure 4.8. Scree Test Plot on a) Annual and b) wet season (May-Oct) Mean Temperature. 98

Figure 4.9. Principal Component Analysis (PCA regionalisation) of a network of 52 stations with annual mean temperature (1941-2001) using two different solutions: a) varimax and b) promax with  $\kappa=2$ . 99

Figure 4.10. Principal Component Analysis (PCA regionalisation) of a network of 52 stations with May-Oct mean temperature (1941-2001) using two different solutions: a) varimax and b) promax with  $\kappa=2$ . 101

Figure 4.11. Scree Test Plot on a) DJF b) MAM c) JJA and d) SON periods for the selection of number of components. 102

Figure 4.12. Principal Component Analysis (PCA regionalisation) applying an orthogonal rotated solution (Varimax) of a network of 52 stations with a) DJF b) MAM mean temperature (1941-2001). 104

Figure 4.12. Principal Component Analysis (PCA regionalisation) applying an orthogonal rotated solution (Varimax) of a network of 52 stations with c) JJA and d) SON mean temperature (1941-2001). 105

Figure 4.13. Principal Component Analysis (PCA regionalisation) applying an oblique rotated solution (Promax) of a network of 52 stations with a) DJF b) MAM mean temperature (1941-2001). 106

Figure 4.13. Principal Component Analysis (PCA regionalisation) applying an oblique rotated solution (Promax) on a network of 52 stations with c) JJA and d) SON mean temperature (1941-2001). 107

Figure 4.14. Cluster Analysis (K-mean) of a network of 52 stations with a) annual b) wet season mean temperature (1941-2001). 108

## **CHAPTER 5:**

Fig. 5.1. Extreme precipitation indices maps. A Kendall's tau-b (linear) correlation analysis has been applied between the precipitation extreme indices and time. Circles red represent a positive and in blue negative correlations. 115

Fig. 5.2. Linear trends calculated using a least-squares fitting on the annual total precipitation (PRCPTOT) of the stations with the largest number of statistically significant results (see Table 5.1). 124

Fig. 5.3. Linear trends calculated using a least-square fitting on the Very Heavy Precipitation Days (R20mm) index of the stations with the largest number of statistically significant results (see Table 5.1). 125

Fig. 5.4. Linear trends calculated using a least-square fitting on the Very Wet Day Precipitation (R95P) index of the stations with the largest number of statistically significant results (see Table 5.1). 127

Fig. 5.5. Linear trends calculated using a least-square fitting on the Severity Daily Intensity Index (SDII) index of the stations with the largest number of statistically significant results (see Table 5.1). 128

## CHAPTER 6:

Fig. 6.1. Extreme temperature indices maps, intensity in °C. A Kendall's tau-b (linear) correlation analysis has been applied between the temperature extreme indices and time. Circles in red are representing a positive and in blue a negative correlation. 141

Fig. 6.2. Extreme temperature indices maps, frequency measured in days. A Kendall's tau-b (linear) correlation analysis has been applied between the temperature extreme indices and time. Circles in red are representing a positive and in blue a negative correlation. 145

Fig. 6.3. Extreme temperature indices maps, frequency measured in days. A Kendall's tau-b (linear) correlation analysis has been applied between the temperature extreme indices and time. Circles in red represent a positive and in blue a negative correlation. 150

Fig. 6.4. Mean Annual Range of Temperature according to Mosiño and García (1974). 154

Fig. 6.5. Linear trend analysis applied to the Cool Day frequency (TX10p) using the least-square approach of the R software (see section 3.3.4). Two stations in northern Mexico are considered [El Paso de Iritu, a); Ahuacatlán b)] and two in the southern part of the country [Salamanca, c); Matías Romero d)]. 156

Fig. 6.6. Linear trend analysis applied to the Hottest Day (TXx) using the least-square approach of the R software (see section 3.3.4). Two stations in northern Mexico are considered [El Paso de Iritu, a); Ahuacatlán b)] and two in the southern part of the country [Salamanca, c); Matías Romero d)]. 158

Fig. 6.7. Linear trend analysis applied to the Cool Night frequency (TN10p) using the least-square approach of the R software (see section 3.3.4). Two stations in northern Mexico are considered [El Paso de Iritu, a); Ahuacatlán b)] and two in the southern part of the country [Salamanca, c); Matías Romero d)]. 161

Fig. 6.8. Linear trend analysis applied to the Coolest Night (TNn) using the least-square approach of the R software (see section 3.3.4). Two stations in northern Mexico are considered [El Paso de Iritu, a); Ahuacatlán b)] and two in the southern part of the country [Salamanca, c); Matías Romero d)]. 163

Fig. 6.9. Linear trend analysis applied to the Daily Temperature Range (DTR) using the least-square approach of the R software (see section 3.3.4). Two stations in northern Mexico are considered [El Paso de Iritu, a); Ahuacatlán b)] and two in the southern part of the country [Salamanca, c); Matías Romero d)]. 165

## CHAPTER 7:

Fig. 7.1. Linear correlations (Kendall tau-b) between the standardised versions of the precipitation regional averages and the Southern Oscillation Index (SOI). Red numbers represent positive and blue numbers negative correlations. \* means statistical significant at 5% level and \*\* at 1% level. 174

Fig. 7.2. Linear correlations (Kendall tau-b) between the Extreme Precipitation Indices and the Annual Southern Oscillation Index (SOI). Circles in red are representing a positive and in blue negative correlations. 179

Fig. 7.3. Linear correlations (Kendall tau-b) between the Extreme Precipitation Indices and the May-Oct (wet season) Southern Oscillation Index (SOI). Circles in red are representing a positive and in blue negative correlations. 181

Fig. 7.4. Linear correlations (Kendall tau-b) between the Extreme Precipitation Indices and the Nov-Apr (dry season) Southern Oscillation Index (SOI). Circles in red are representing a positive and in blue negative correlations. 184

Fig. 7.5. Linear correlations (Kendall tau-b) between the Extreme Temperature Indices and the Annual Southern Oscillation Index (Annual SOI). Circles in red are representing a positive and in blue negative correlations. 188

Fig. 7.6. Linear correlations (Kendall tau-b) between the Extreme Temperature Indices and the wet season Southern Oscillation Index (wet season SOI). Circles in red are representing a positive and in blue negative correlations. 190

Fig. 7.7. Linear correlations (Kendall tau-b) between the Extreme Temperature Indices and the Dry Season Southern Oscillation Index (dry season SOI). Circles in red are representing a positive and in blue negative correlations. 193

Fig. 7.8. Lag cross-correlations between the standardised versions of Regional Precipitation Averages and the Southern Oscillation Index (SOI). Red circles represent positive and blue circles negative correlations. 197

Fig. 7.9. Lag cross-correlations between the RX1day (Max 1-day Precipitation) Index and the standardised version of the Southern Oscillation Index (SOI). Red circles represent positive and blue circles negative correlations. 199

Fig. 7.10. Lag cross-correlations between the RX5day (Max 5-day Precipitation) Index and the the standardised version of the Southern Oscillation Index (SOI). Red circles represent positive and blue circles negative correlations. 201

Fig. 7.11 Lag cross-correlations between the DTR (Daily Temperature Range) and the Southern Oscillation Index (SOI). Red circles express positive correlations, and blue circles show negative correlations. 202

Fig. 7.12. Lag cross-correlations between the TN10P (Cool Night Frequency) and the Southern Oscillation Index (SOI). The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 204

Fig. 7.13 Lag cross-correlations between the TN90P (Hot Night Frequency) and the Southern Oscillation Index (SOI). The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 206

Fig. 7.14. Lag cross-correlations between the TNn (Coolest night) and the Southern Oscillation Index (SOI). The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 208

Fig. 7.15. Lag cross-correlations between the TNx (Hottest night) and the Southern Oscillation Index (SOI). The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 210

Fig. 7.16. Lag cross-correlations between the TX10P (Cool day frequency) and the Southern Oscillation Index (SOI). The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 212

Fig. 7.17. Lag cross-correlations between the TX90P (Hot day frequency) and the Southern Oscillation Index (SOI). The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 214

Fig. 7.18. Lag cross-correlations between the TXn (Coolest day) and the Southern Oscillation Index (SOI). The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 216

Fig. 7.19. Lag cross-correlations between the TXx (Hottest day) and the Southern Oscillation Index (SOI). The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 218

Fig. 7.20. Linear correlations (Kendall tau-b) between the standardised versions of the regional precipitation averages and the Niño 3.4 index. Red numbers represent positive and blue numbers negative correlations. \* means statistical significant at 5% level and \*\* at 1% level. 222

Fig. 7.21. Linear correlations (Kendall tau-b) between the Extreme Precipitation Indices and the Annual Niño 3.4 Index. Circles in red are representing a positive and in blue negative correlations. 228

Fig. 7.22. Linear correlations (Kendall tau-b) between the Extreme Precipitation Indices and the Wet Season (May-Oct) Niño 3.4 Index. Circles in red are representing a positive and in blue negative correlations. 229

Fig. 7.23. Linear correlations (Kendall tau-b) between the Extreme Precipitation Indices and the Dry Season (Nov-Apr) Niño 3.4 Index. Circles in red are representing a positive and in blue negative correlations. 232

Fig. 7.24. Linear correlations (Kendall tau-b) between the Extreme Temperature Indices and the Annual Niño 3.4 Index (Annual Niño 3.4). Circles in red are representing a positive and in blue negative correlations. 235

Fig. 7.25. Linear correlations (Kendall tau-b) between the Extreme Temperature Indices and the Wet Season (May-Oct) El Niño 3.4 Index (Wet Niño 3.4). Circles in red are representing a positive and in blue negative correlations. 240

Fig. 7.26. Linear correlations (Kendall tau-b) between the Extreme Temperature Indices and the Dry Season (Nov-Apr) El Niño 3.4 Index (Dry Niño 3.4). Circles in red are representing a positive and in blue negative correlations. 243

Fig. 7.27. Lag cross-correlations between the standardised versions of Precipitation Regional Averages and the El Niño 3.4 index. Red circles represent positive and blue circles negative correlations. 245

Fig. 7.28. Lag cross-correlations between the RX1day (Max 1-day Precipitation) Index and the standardised version of the El Niño 3.4 Index. Red circles represent positive and blue circles negative correlations. 246

Fig. 7.29. Lag cross-correlations between the RX5day (Max 5-day Precipitation) Index and the standardised version of the El Niño 3.4 Index. Red circles represent positive and blue circles negative correlations. 247

Fig. 7.30. Lag cross-correlations between the TN10P (Cool Night Frequency) and El Niño 3.4 Index. The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 249

Fig. 7.31. Lag cross-correlations between the TN90P (Hot Night Frequency) and El Niño 3.4 Index. The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 250

Fig. 7.32. Lag cross-correlations between the TNn (Coolest night) and El Niño 3.4 Index. The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 251

Fig. 7.33. Lag cross-correlations between the TNx (Hottest night) and El Niño 3.4 Index. The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 252

Fig. 7.34. Lag cross-correlations between the TX10P (Cool Day Frequency) and El Niño 3.4. The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 253

Fig. 7.35. Lag cross-correlations between the TX90P (Hot Day Frequency) and El Niño 3.4 Index. The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 254

Fig. 7.36. Lag cross-correlations between the TXn (Coolest Day) and El Niño 3.4 Index. The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 255

Fig. 7.37. Lag cross-correlations between the TXx (Hottest Day) and El Niño 3.4 Index. The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 256

Fig. 7.38. Lag cross-correlations between the DTR (Daily Temperature Range) and El Niño 3.4 Index. The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 257

Fig. 7.39. Linear correlations (Kendall tau-b) between the standardised versions of the regional precipitation averages and the Multivariate El Niño Index (MEI). Red numbers represent positive and blue numbers negative correlations. \* means statistical significant at 5% level and \*\* at 1% level. 261

Fig. 7.40. Linear correlations (Kendall tau-b) between the Extreme Precipitation Indices and the Annual Multivariate ENSO Index (MEI). Circles in red are representing a positive and in blue negative correlations. 265

Fig. 7.41. Linear correlations (Kendall tau-b) between the Extreme Precipitation Indices and the wet season (May-Oct) Multivariate ENSO Index (MEI). Circles in red are representing a positive and in blue negative correlations. 267

Fig. 7.42. Linear correlations (Kendall tau-b) between the Extreme Precipitation Indices and the dry season (Nov-Apr) Multivariate ENSO Index (MEI). Circles in red are representing a positive and in blue negative correlations. 269

Fig. 7.43. Linear correlations (Kendall tau-b) between the Extreme Temperature Indices and the Annual Multivariate ENSO Index (Annual MEI). Circles in red are representing a positive and in blue negative correlations. 273

Fig. 7.44. Linear correlations (Kendall tau-b) between the Extreme Temperature Indices and the wet season (May-Oct) Multivariate ENSO Index (Annual MEI). Circles in red are representing a positive and in blue negative correlations. 274

Fig. 7.45. Linear correlations (Kendall tau-b) between the Extreme Temperature Indices and the dry season (Nov-Apr) Multivariate ENSO Index (Annual MEI). Circles in red are representing a positive and in blue negative correlations. 277

Fig. 7.46. Lag cross-correlations between the standardised versions of Precipitation Regional Averages and the Multivariate El Niño Index (MEI). Red circles represent positive and blue circles negative correlations. 278

Fig. 7.47. Lag cross-correlations between the Maximum 1-day precipitation (RX1day) Index and the Multivariate El Niño Index (MEI). Red circles represent positive and blue circles negative correlations. 279

Fig. 7.48. Lag cross-correlations between the Maximum 5-day precipitation (RX5day) Index and the Multivariate El Niño Index (MEI). Red circles represent positive and blue circles negative correlations. 280

Fig. 7.49. Lag cross-correlations between the DTR (Daily Temperature Range) and the Multivariate El Niño Index (MEI). Red circles express positive correlations, and blue circles show negative correlations. 281

Fig. 7.50. Lag cross-correlations between the TN10P (Cool Night Frequency) and the Multivariate El Niño Index (MEI). Red circles express positive correlations, and blue circles show negative correlations. 282

Fig. 7.51. Lag cross-correlations between the TN90P (Hot Night Frequency) and the Multivariate El Niño Index (MEI). Red circles express positive correlations, and blue circles show negative correlations. 283

Fig. 7.52. Lag cross-correlations between the TNn Index (Coolest Night) and the Multivariate El Niño Index (MEI). The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 284

Fig. 7.53. Lag cross-correlations between the TNx Index (Hottest Night) and the Multivariate El Niño Index (MEI). The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 285

Fig. 7.54. Lag cross-correlations between the TX10P Index (Cool Day Frequency) and the Multivariate El Niño Index (MEI). The linear correlation is calculated using the Pearson function. Red circles express positive correlations, and blue circles show negative correlations. 286

Fig. 7.55. Lag cross-correlations between the TX90P Index (Hot Day Frequency) and the Multivariate El Niño Index (MEI). Red circles express positive correlations, and blue circles show negative correlations. 287

Fig. 7.56. Lag cross-correlations between the TXn Index (Coolest Day) and the Multivariate El Niño Index (MEI). Red circles express positive correlations, and blue circles show negative correlations. 288

Fig. 7.57. Lag cross-correlations between the TXx Index (Hottest Day) and the Multivariate El Niño Index (MEI). Red circles express positive correlations, and blue circles show negative correlations. 289