

Original Research Article

Changing weather/climate and prevalence of Cerebro Spinal Menigitis in some selected stations in Nigeria

Abstract

This study examines the effects of some weather parameters, such as maximum and minimum temperature ($^{\circ}\text{C}$), rainfall (mm) and relative humidity (%), on the prevalence of Cerebro Spina Meningitis (CSM) in South west and North West, Nigeria. Monthly data of reported cases of in- and out- patients of this disease between 1990 and 2007 were collected from Ondo State Specialist Hospital, Akure, and Specialist Hospital, Sokoto while data of relative humidity, rainfall, maximum and minimum temperatures for the same years were collected from the Nigeria Meteorological Agency, Oshodi, Lagos. CerebroSpinal meningitis (CSM), showed a strong correlation with all the weather elements considered but much stronger in the northern station. The study also reveals that CSM occurrence is linked with low minimum temperature (usually less than 20°C) and relative humidity (of less than 40%) which is more common in the northern region. In the south, the numbers of CSM cases are few throughout the year but have a peak during the dry season which is also when the effects of the north east trade winds are being felt. Minimum temperature and relative humidity combinations were used to distinguish between areas with high and low risk of epidemics. Findings from this work can be used for designing early warning decision support systems that can enable the efficient and timely spatial targeting of preventive and control measures against the disease.

Keywords CSM, Temperature, Prevalence, Relative Humidity

26 1.0 Introduction

27 Cerebrospinal meningitis (CSM) is a major public health problem in many parts of the world
 28 (Peltola, 1983; Schwartz *et al*, 1989; Tikhomirov *et al*, 1987; WHO, 1973). Meningitis
 29 (CSM) is a contagious infection disease which is caused by the bacteria *Neisseria meningitis*.
 30 CSM epidemics occur worldwide but the highest incidence is observed in the "meningitis
 31 belt" of sub-Saharan Africa, stretching from Senegal to Ethiopia (Lapeyssonnie, 1963;
 32 Greenwood, 1999). This belt extends some 4,200 km from Ethiopia to Senegal (Remy, 1990),
 33 and an average of 600 km from north to south within the 300-mm and 1,100-mm rainfall
 34 lines, with a southward digitation going deep into Benin republic. Across this Sudano-
 35 sahelian area, endemo-sporadic infections occur annually during the dry season (October-
 36 May), while large epidemics appear at longer intervals (Greenwood 1987). The mean annual
 37 incidence is about 70 cases per 100,000 persons, yet attack rates during epidemics range from
 38 100 to 1,000 per 100,000 inhabitants per year. CSM is known in Mali as finyabana, literally
 39 'wind illness'. In other countries, people have also noted that the outbreak of the epidemics
 40 nearly always coincides with the setting in of the harmattan, a north to east wind, blowing
 41 from the Sahara towards the Gulf of Guinea (Cvjetanovic *etal*, 1978; Greenwood *etal* 1984,
 42 Greenwood *etal*, 1985; WHO,1973). The harmattan, described as forming part of the trade
 43 wind circulation (Bokonon-Gant 1995), is most prevalent from November till February, when
 44 the barometric gradient between the subtropical anticyclonic cell and the equatorial trough is
 45 most marked, although the wind can be experienced in some locations as late as May.
 46 Temperatures during this period are low (sometimes 16-19⁰C at 06:00 h), but they rise
 47 sharply towards the end of the season. The inhaled air is so dry that children and adults have
 48 badly chapped lips and nasopharyngeal mucosa become irritated. However, presumably the
 49 most distinctive characteristic of the harmattan is the dust it carries - almost impalpable
 50 particles of quartz and clay, colloids or fine mica flakes which can remain airborne for days

and which occasionally reduce visibility below 200 metres for up to forty-eight hours. Therefore, the spread of CSM during the harmattan season was empirically recognized, as was the belief that meningitis activity reduces at the onset of the rains. From the revealed literature above, it is almost possible to believe that no research work has been extended to study and model cases of prevalence of this disease and weather parameters in Nigeria. Therefore, the present study attempts to describe the effects of some weather parameters on the prevalence of CSM at two locations in different climatic zones in Nigeria.

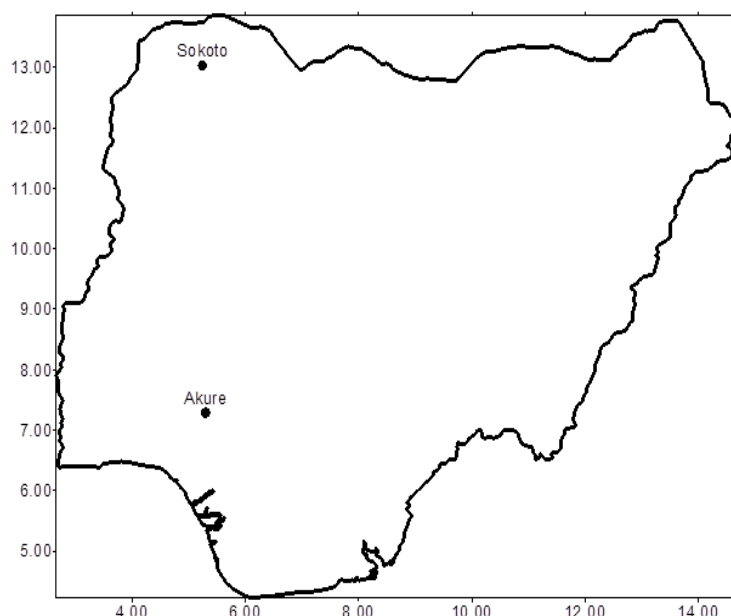
2. Methodology

2.1 Study areas

Akure is the capital city of Ondo State in the South West, Nigeria, with population of about 500,000 people (Census 2006). It is situated in the humid forest zone of Nigeria. It has an annual rainfall which exceeds 1400mm, and falls between March and November. Average relative humidity is about 55% during the dry season and 90% during the rainy (wet) season. The mean daily maximum temperature ranges from 26⁰C to 35⁰C, while the mean daily minimum temperature range is between 15⁰C and 23⁰C.

Sokoto, the capital of Sokoto State is a city located in the extreme northwest of Nigeria, near to the confluence of Sokoto and the Rima Rivers. As of 2006 it has a population of about 427,760. Sokoto is in the sandy savannah. It has an annual average temperature of 28.3 °C, Sokoto is one of the hottest cities in the world, however the maximum daytime temperatures are most of the year generally under 40 °C, and the dryness makes the heat bearable. The warmest months are February to April, where daytime temperatures can exceed 45°C. Highest recorded temperature is 47.2 °C, which is also the highest recorded temperature in Nigeria. The rainy season is from June to September, during which showers are a daily occurrence. The showers rarely last long and are a far cry from the regular torrential showers known in many tropical regions. From late

October to February, during the 'cold season', the climate is dominated by the harmattan wind blowing Sahara dust over the land. The dust dims the sunlight, thereby lowering temperatures significantly and also leading to the inconvenience of dust everywhere in the house. Figure A shows the stations used for the study.



79

80 Fig A: Map of Nigeria showing the stations used for the study

81 2.2 Data

82 Monthly data of reported cases of in- and out- patient and death of CSM data were collected
83 from standard government hospital in Akure and Sokoto between 1990 and 2007. These were
84 extracted from the records of the standard government hospital in the study areas which are the
85 major hospitals located within the cities. Akure data were collected from the Ondo state
86 General Hospital while Sokoto data was collected from Specialist Hospital, Sokoto. These data
87 were obtained for at least ten years spanning between 1990 and 2007. However, only
88 continuous health data were used in the analysis. Monthly maximum and minimum

temperatures ($^{\circ}\text{C}$), rainfall (mm) and relative humidity (%) data were collected for the same stations as the medical data from Nigerian Meteorological agency (NIMET), Oshodi, Lagos. This agency is the only approved government agency that collects and archives meteorological data in Nigeria. These data were collected for at least twenty years spanning between 1990 and 2010.

2.3 Method of Analysis

The CSM data and meteorological variables were analysed using time series analysis ranging from monthly, seasonal and annual levels. For each time frame, the mean of all the variables over the period were calculated. Time series analysis to assess the periodicity [A. Matzarakis 2006] was conducted on CSM data and meteorological variables. The CSM data and meteorological data were deseasonalized in order to control seasonality and assess the influence of weather variables on CSM prevalence. The statistical relationship between CSM prevalence and meteorological variables before and after deseasonalization of data were carried out in order to determine correlation coefficient (r), coefficient of determination (R^2) and p-value [Draper, and Smith 1981, Storch and Zwiers 1999]. In order to assess the magnitude of meteorological variables (independent covariates) on CSM occurrence (dependent variable), Poisson multiple regression models in Generalized Linear Models, GLMs [Schwartz et al 1996, McCullagh and Nelder 1989] was used after deseasonalization of both meteorological and malaria data

112 2.3.1 Meteorological Conditions

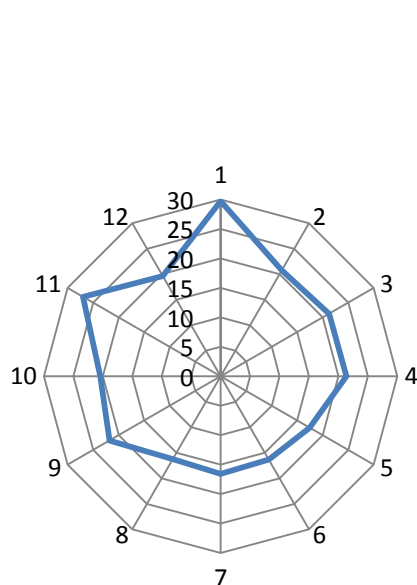
113 The harmattan ambiance was identified and defined to an extent, an arbitrary matter, but it
 114 was based on a long experience of the study areas and it had already proved to be relevant in
 115 climatopathological studies (Bokonon-Ganta, 1992; Oke, 1994).

116 To get an expression of harmattan exposure, the following specific meteorological situation
 117 were identified when these conditions were simultaneously satisfied, namely a minimum
 118 mean temperature of less than 20⁰C and a mean relative humidity of less than 40%.

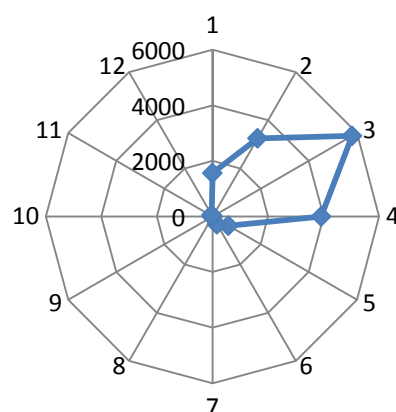
119 3. Results

120 3.1 DESCRIPTIVE EPIDEMIOLOGY

121 The stations for this study fall within different climatic zones. The mean monthly occurrence
 122 of this disease is presented in figure 1(a and b)



(a) Akure



(b) Sokoto

Fig. 1(a, b) Mean monthly occurrence of CSM (a) Akure and (b) Sokoto

From the above figure, occurrence of CSM varies from station to station and from month to month. It is observed that it occurs all year round in Akure while about four months have no reported cases in Sokoto. However, a very high number of cases were reported within the epidemic months of January and April in Sokoto. The highest number of cases in Akure is 30 which were observed in January while about 6000 cases were observed in March in Sokoto. The total number of cases between 1990 and 2007 in Sokoto is 15,600 while that of Akure is only 2,983 cases. It is therefore, evident that meteorological conditions have roles to play in the occurrence and spread of this disease since the stations fall in different climatic zones resulting in a marked difference in the distribution of the disease.

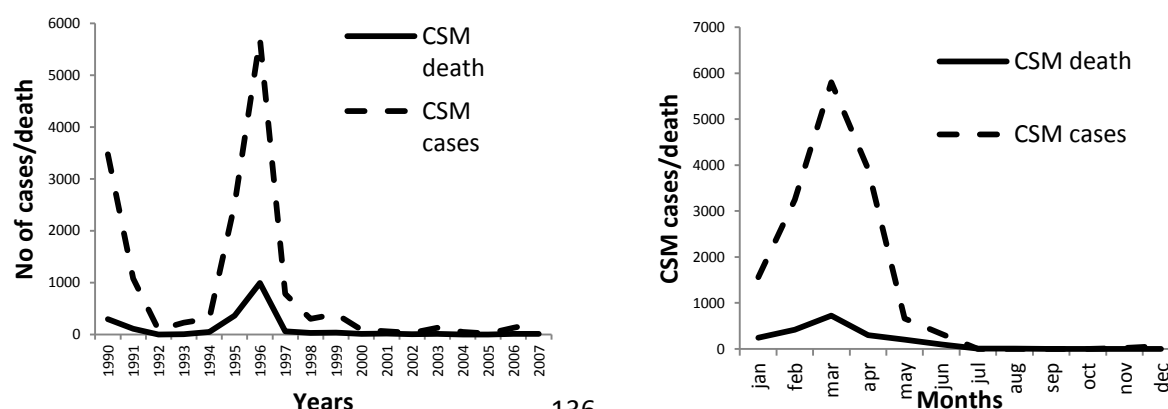


Figure 2: (a) Annual variation of CSM cases and death (b) Mean monthly variations at Sokoto

From the figure, the period 1990 to 2000 can be considered to be epidemic years because reported cases were high especially in 1996. Also, maximum number of cases and deaths occur between the months of January to May. This indicates that most occurrences and death occur during the dry season. Considering the case-death ratio, it is as high as 3:1 in April and May while it is 5:1 in 1996 the year of maximum, which is still high. Thus, CSM appeared to be proportionally the most deadly in the area.

145 3.2 Relationship between CSM and Meteorological variables

146 The relationship between CSM and some weather elements was considered by looking at their
147 correlation coefficients. These coefficients are presented in table 1.

148 **Table .1 Correlations between CSM and weather variables**

Station/Weather variables	Max. Temp.	Min Temp	Rainfall	Relative Humidity
Akure	0.50	0.22	-0.46	-0.55
Sokoto	0.60	0.54	-0.40	-0.58

149
150 From the table, a positive relationship exists between CSM and Temperature (maximum and
151 minimum) while it is negative with both rainfall and relative humidity in both stations. These
152 correlation values are significant. However low values less than 0.50 were observed in Akure
153 for minimum temperature and rainfall in Sokoto.

154 3.3 Regression Equation

155 The analysis of the effects of weather parameters on CSM suggests a need to distinguish
156 between two main geographical areas, northern and southern Nigeria. Table 2 shows the
157 regression equations for the stations while table 3 shows the observed and estimated number of
158 CSM patients.

159 **Table 2 CSM-weather relationships: results of the linear regression for the period 1990-**
160 **2007**

Station/Variables	Constant	Max. Temp	Min. Temp	Rainfall	Relative Humidity	R	R Square	significance
Akure	102.21	2.02	-4.40	0.01	-0.47	0.68	0.46	0.05
Sokoto	-1148.91	319.2	387.95	32.09	-175.29	0.90	0.81	0.05

162 The regression model showed an undeniable statistical dependency of CSM on the weather
 163 variables (Table 2) .Thus, with R square values ranging from 0.46 in Akure to 0.81 in Sokoto
 164 shows that the strong dependency is not in doubt.

165

166 **Table.3 (a-b) Observed and estimated number of CSM patients**

167 (a) Akure

Month	Std. Residual	Observed value	Estimated Value	Residual
Jan	0.735	30	27	3
Feb	-0.682	21	23	-2
Mar	0.076	21	21	0
Apr	0.302	21	20	1
May	-0.528	17	19	-2
Jun	-0.997	16	20	-4
Jul	-0.063	17	17	0
Aug	-0.305	16	17	-1
Sep	0.776	22	19	3
Oct	0.076	20	20	0
Nov	1.671	27	21	6
Dec	-1.062	20	24	-4

168

169

170 (b) Sokoto

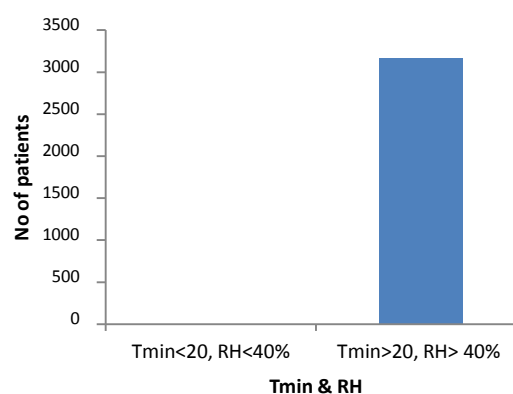
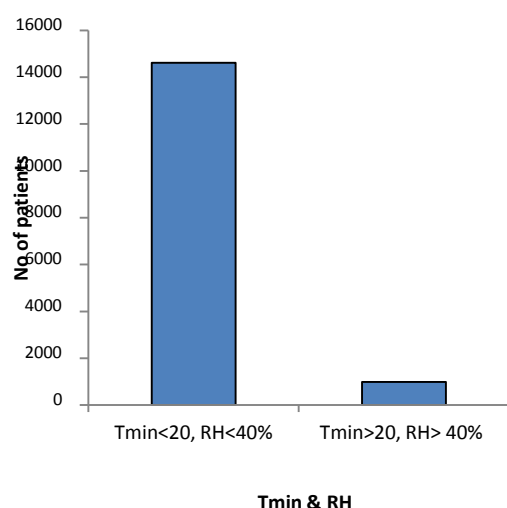
Month	Std. Residual	Observed value	Estimated Value	Residual
Jan	1.015	1561	475	1.09E+03
Feb	0.377	3249	2845	403.529
Mar	0.347	5802	5431	371.099
Apr	0.706	3915	3160	754.626
May	-0.162	661	834	-172.737
Jun	0.223	324	85	238.954
Jul				
Aug				
Sep				
Oct				
Nov	-1.987	24	2149	-2.13E+03
Dec	-0.298	64	382	-318.242

171

172 The strong association is obvious in Table 3 which shows the closeness of the observed and
173 estimated number of CSM patients.

174 3.4 Meteorological conditions and CSM prevalence

175 A meteorological index was used to investigate whether weather conditions could explain the
176 spatiotemporal variations of CSM. A weather pattern was defined, to a certain extent it's
177 arbitrary, but it has been used by Bokonon-Ganta (1992) and Oke (1994) based on a long
178 experience of the country of study. It had however proved to be relevant in the
179 climatopathological studies (Bokonon-Ganta 1992 and Oke 1994). To get an expression of this
180 index, a specific meteorological situation when two conditions were simultaneously satisfied,
181 was identified, namely, a minimum temperature of not more than 20°C , a mean relative
182 humidity of not more than 40%. Figure 3 was obtained from the index for Sokoto. The
183 condition was not satisfied in Akure, therefore, all the CSM cases reported occurred outside the
184 said meteorological condition.



185

186

b. Sokoto

187

(a) Akure

188

189 **Figure 3: Different Meteorological condition and CSM occurrence**

190

191 It is noted that the set meteorological condition is synonymous with the period of harmatan.
192 Therefore, there is a link between harmatan and occurrence of CSM and this condition is
193 common between December and May in Sokoto. This work has clearly identified the spatial
194 variation of the conditions for CSM between northern and southern Nigeria.

195

196

197 **4. Discussions**

198 The meteorological factors that can trigger the occurrence of CSM have (to an extent) been
199 identified. However, the results may possibly generate some questions. First, does CSM always
200 prevail during the dry season? Secondly, can changing weather and climate expand the spread
201 of this disease? It can be defended that the results are consistent with the previous findings and
202 actually support the classical explanatory model of CSM-weather relationship (Greenwood,
203 1987; Besancenot, 1997) but these studies identified occurrence of CSM prior to harmatan
204 which was possible because weekly data were used while monthly data were used for this
205 study. In an averaged situation, the risk increases for seasons and locations where the north east
206 trade wind blows with the greatest regularity which actually differentiate the prevalence of
207 these two stations.. Samways (1976) stated that meningitis is completely in the wake of the
208 harmattan. However, it is probable that the impact of weather/climatic elements could hardly
209 exceed the degree of correlation because two scenarios are interfering with each other; one
210 relating to season and the other relating to people referred or coming from another location. A
211 latent period of 3-8 days usually separates a climatic aggression and the disease outbreak
212 (Greenwood 1987). It follows that monthly report of cases or deaths can only give a rough
213 indication of the prevalence trend, and it is probable that meningitis case counts over a 10-day
214 period would have provided more significant results. Similarly, incidence rates at the regional
215 level may not accurately reflect the intensity of the disease at the village or city level since it

has been reported that meningitis is never uniform over large areas (Moore et al 1990). Furthermore, a lot has been discussed about the dry season prevalence of the disease across sub-Saharan Africa with only a few rare exceptions (Cheesbrough, 1995; Ghippon, 1971). The transmission of aerosol particles containing potentially pathogenic meningococci continues throughout the year. It is also worthy to note that upper respiratory infections and CSM almost follow the same seasonal pattern (Besancenot et al, 1997). In particular, throat infections diagnosed from 1987 to 1992 on clinical grounds peaked between January and February in two health care services of Natitingou in Benin republic (Besancenot, 1997), while they reached their highest incidence in June or July at Cotonou in Benin republic (Besancenot, 1997). In both locations, the peak of pharyngeal diseases occurred about one month before meningitis cases become the most frequent. Furthermore, deforestation is also an issue which can cause harmattan to blow with increased force near ground level, (Monnie, 1992). In conclusion it can be said that CSM mainly affects the northernmost regions of Nigeria from November to March, April while few cases are observed in the south throughout the year and peaks in January. Regression analysis confirmed that a notable part of the space/time variability of the disease is due to the weather. However, the climate-meningitis relationship proved to be stronger than is sometimes despite the anthropic effects (vaccination campaigns).

6. Limitations of this work and directions for future research

The data analyzed in this study has obvious limitations related to coverage and completeness, and thus can underestimate or overestimate the actual diseases incidence rate in the population. Although the data were of relatively good quality compared to those available in many private hospitals. Nonetheless, this study illustrates the importance of meteorological data in identifying diseases hotspots and distribution, which cannot be accomplished using population surveys.

240 It is possible that more accurate disease modelling may require the inclusion of non-climatic
241 causes as well. Nonetheless, statistical time-series modelling to analyse meteorology-human
242 disease link appears to be a promising approach to predicting diseases incidence and give room
243 for further investigation.

244 **7. Conclusion**

245 This work has investigated the effects of some weather parameters, such as maximum and
246 minimum temperatures, rainfall and relative humidity, on the incidence of Cerebro Spina
247 Meningitis (CSM) in some stations in Nigeria. Monthly data of reported cases of in and out
248 patients of these diseases between 1990 and 2007 were collected from Sokoto State specialist
249 hospital, Sokoto while data of relative humidity, rainfall, maximum and minimum temperature
250 for the same years were collected from the Nigeria Meteorological Agency, Oshodi, Lagos.

251 This human disease can be identified as one of the most deadly diseases in Nigeria which
252 threaten the well-being of the people. This disease is classified as tropical disease because the
253 weather within the region can help in triggering it, which the results of this work have
254 confirmed.

255 CSM showed a strong correlation with all the weather elements considered but much stronger
256 in the northern station. The analysis indicates not only that they are strongly related but the
257 occurrence is more prevalent in the northern station. The work also reveals that CSM
258 occurrence is linked with low minimum temperature (usually less than 20⁰C) and relative
259 humidity (of less than 40%) which is more common in the northern region. In the south, the
260 number of CSM cases is few throughout the year but get to the peak during the dry season
261 which is also when the effects of the north east trade winds are being felt. Minimum
262 temperature and relative humidity combinations can be used to distinguish between areas with
263 high and low risk of epidemics.

264 For public health scientists and officials, the primary goal is to prevent any increases in disease
 265 associated with changing weather and climate. Both scientists and policy-makers are interested
 266 in the magnitude of potential effects and their distribution, which regions is the most likely to
 267 be affected? Why? When? How can vulnerability be reduced and adaptive capacity increased?
 268 Findings from this work can be used for designing early warning decision support systems that
 269 enable the efficient and timely spatial targeting of preventive and control measures against the
 270 disease.

271

272 5. References

273 Besancenot JP, Boko M, Oke PC. (1997): Weather conditions and cerebrospinal meningitis
 274 in Benin (Gulf of Guinea, West Africa). *Eur J Epidemiol*;13:807–15.

275 Cheesbrough JS, Morse AP, Green SDR. (1995): Meningococcal meningitis and carriage in
 276 western Zaire: a hypoendemic zone related to climate? *Epidemiol Infect*; 114:75–92.

277 Cheesebrough M (2006). *District Laboratory Practice in Tropical Countries*, part 1.
 278 University Press, Cambridge, pp. 239-258

279 Chestnut, L.G. (1998): Analysis of differences in hot-weather-related mortality across 44
 280 United States metropolitan areas. *Environmental Science and Policy* 1: 59–70.

281 Cifuentes, L. (2001): Assessing the health benefits of urban air pollution reductions
 282 associated with climate change mitigation (2000–2020): Santiago, Sao Paulo, Mexico
 283 City, and New York City. *Environmental Health Perspectives* 109, supplement 3:
 284 419–425.

285 Corvalán, C.F. (1999): Health, environment and sustainable development: identifying links
 286 and indicators to promote action. *Epidemiology* 10(5): 656–660.

- 287 Greenwood B.(1999): Meningococcal meningitis in Africa. Trans R Soc Trop Med Hyg
288 1999; 93:341–53.
- 289 Greenwood BM, Blakebrough IS, Bradley AK, Wali S, Whittle HC. (1984): Meningococcal
290 disease and season in sub-Saharan Africa. Lancet 1984; 326:1339–42.
- 291 Greenwood, B., Marsh, K., and Snow, R. (1991): Why do some children develop severe
292 malaria? Parasitology Today; 7: 430-440.
- 293 Griguolo S. ADDAPIX (1996): Pixel-by-pixel classification for zoning and monitoring. FAO
294 Technical Report, SD: GCP/INT/578/NET. Rome: FAO; 1996.
- 295 H. von Storch, F.W. Zwiers, Statistical Analysis in Climate Research, Cambridge University
296 Press, 1999.
- 297 J. Schwartz, C, Spix, G. Touloumi, L. Bacharova, T.Barumamdzadeh, A. le Terte,
298 Methodological issues in studies of air pollution and daily counts of deaths or
299 hospital admissions, Journal of Epidemiology and Community Health 50 (1996) S3-
300 S11.
- 301 Kunkel, K.E.(1999): Temporal fluctuations in weather and climate extremes that cause
302 economic and human health impacts: a review. Bulletin American Meteorological
303 Society 80(6): 1077–1098 (1999).
- 304 Lapeyssonnie L.(1963): La méningite cérébro-spinale en Afrique. Bull World Health Organ
305 1963;28(Suppl 1):3–114.
- 306 Lindgren, E. & Gustafson, R.(2001): Tick-borne encephalitis in Sweden and climate change.
307 Lancet 358 (9275): 16–87.

308 Molineaux L.(1969): Climate and meningococcal disease. [PhD Thesis]. Berkeley (CA):
 309 University of Berkeley; 1969.

310 Moore PS.(1992): Meningococcal meningitis in sub-Saharan Africa: a model for the
 311 epidemic process. Clin Infect Dis;14:515–25.

312 Mpairwe Y, Matovu HL.(1971): Cerebrospinal meningitis in east Africa 1911–1965. Trans
 313 R Soc Trop Med Hyg ;65:70–7.

314 Myers MF, Rogers DJ, Cox J, Flahault A, Hay SI (2000): Forecasting disease risk for
 315 increased epidemic preparedness in public health. Adv Parasitol , 47:309-330.

316 Naeem, S. (1994): Declining biodiversity can alter the performance of ecosystems. Nature
 317 368: 734–737.

318 N.R. Draper, H. Smith, Applied Regression Analysis, Wiley, New York, 1981.

319 P. McCullagh, J.A. Nelder, Generalized Linear Models, 2nd ed., Chapman and Hall/CRC,
 320 1989.

321 Waddy BB.(1952): Climate and respiratory infections. Lancet 1952; 263:674–7.

322 W. Fuller, Introduction to Statistical Time Series, John Wiley and Sons, Inc., New York,
 323 1976.

324

325