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«Medieval Warm Period and the beginning of the Little Ice Age in Eastern Mediterranean. An approach of physical and anthropogenic evidence»

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MEDIEVAL WARM PERIOD AND THE BEGINNING OF THE LITTLE ICE AGE IN THE EASTERN MEDITERRANEAN

AN APPROACH OF PHYSICAL AND ANTHROPOGENIC EVIDENCE

1. INTRODUCTION

Climatic change is a natural factor that has a critical effect on the survival of human societies. An increasing number of extreme climatic disasters (e.g. floods, hurricanes, droughts) have accompanied the recent warming of the Earth's atmosphere and could predict harsher phenomena to come. The need for well attested future scenarios of climatic evolution and its complex impact both on natural environment and human societies has led to a greater international and interdisciplinary cooperation concerning the expansion of our knowledge of climate history during the last decades (Fig. 1)[1].

The history of the global climate of the post-glacial Epoch, may be subdivided into various periods and sub-periods. Among them, two recent climatic phases – the Medieval Warm Period *(MWP)* and the Little Ice Age *(LIA)* – have become particularly interesting for paleoclimate research, not only because of their possible relations to modern climatic trends, but also because of the importance of the response of modern societies to present and future climatic shifts. These two climatic phases do construct the climatic background of the second millennium A.D., during which the effects of accelerated human activity on the globe have dramatically affected the balance of the ecosystems. But these climatic phases are also important for the better understanding of the environmental history of the human societies of the High Middle Ages and early modern time.

The understanding of the climatic change in our century requires a lengthy perspective on the past. This perspective is constructed through paleoclimatic evidence of physical and anthropogenic origin. Written paleoclimatic evidence has been recognized as a potentially major source of past climates, especially for the millennium preceding the era of modern instrumental meteorology. Our knowledge of the climate of historical times is additionly supplemented by physical evidence from the fieldworks of various natural sciences (e.g. geomorphologic, tree ring, pollen evidence) (Fig. 2)[2].

A glance at the modern international literature concerning the climatic change in historical time shows that paleoclimatic research has focussed chronologically mainly

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[1] Cf. R. Gelbspan, Warmer Earth may mean more floods, droughts, Newspaper: *The Boston Globe* (January 20th 1992), 17; B. Frenzel (ed.), European climate reconstructed from documentary data: methods and results (Paläoklimaforschung, 7). Stuttgart–Jena–New York 1992, passim.

[2] M. J. Ingram, D. J. Underhill, G. Farmer, The use of documentary sources for the study of past climates, in: Climate and History: Studies in Past Climates and their Impact on Man (ed. T. M. L. Wigley, M. J. Ingram, G. Farmer). Cambridge 1981, 180–213; C. Pfister, The Potential of Documentary Data for the Reconstruction of Past Climates. Early 16th to 19th centuries. Switzerland as a case of study, in: Climatic Changes on a yearly to millennial basis (ed. N. Morner, W. Karlen). Dordrech–Boston–Lancaster 1984.

upon the second millennium A.D., and geographically upon North America, Japan, North, Western and Central Europe[3]. On the other hand, the literary paleoclimatic material hidden in the Byzantine historical texts of the Eastern Mediterranean and the Middle East have remained unexploited – though not neglected – as fieldwork for paleoclimatic research. The extensive European medieval literature (5th–15th centuries A.D.) and the existence of early paleoclimatic compilations and syntheses of historical climatic information (also known as "weather compilations") provided paleoclimatologists of European climate history during the decades of '60–'80 with bulky archives of literary and documentary evidence for the climate in the Middle Ages. A new generation of historians specialized in climate history appeared – after the pioneering steps of Le Roy Ladurie – and produced important works concerning medieval climate of Northwestern and Central Europe with high methodological standards, neglecting more or less the medieval climate history of the Eastern Mediterranean and the Middle East[4].

The reasons of that "exclusion" of Byzantine/Medieval Eastern Mediterranean and Middle East from the focal point of historical climatology are quite complex. I briefly refer here to the difficulties that natural scientists of paleoclimatic research inevitably faced investigating literary material deriving from sources written in non-Latin languages (Greek, Arabic, Slavonic etc.), and the accessibility of ready literary data from weather compilations, that took advantage of the wealthy paleoclimatic material hidden in European Medieval historical texts.

The aim of the present communication is to investigate the paleoclimatic evidence hidden in Byzantine literary sources, by focusing upon the study of two well-attested periods of European climatic history: the *MWP* and the beginning of the *LIA*. The question whether we can construct a firm basis of physical and anthropogenic evidence that can provide the historian of Byzantine history with data related to paleoclimatic reconstructions for the last six centuries of Byzantium, is the central issue of this communication. After a brief note on the climatic evolution during the *MWP* and the *LIA*, and after the detection of some research problems associated with the chronology and the geography of those two climatic phases, the available types of paleoclimatic evidence for the geographical area under discussion will be presented. Then, the literary paleoclimatic evidence obtained from the research of the Byzantine sources will be discussed, and some conclusions concerning the possibility of the coincidence of the *MWP* and the *LIA* in the Eastern Mediterranean and the Middle East will be drawn.

2. OVERALL PICTURE OF TWO SUCCESSIVE CLIMATIC PERIODS

In modern paleoclimatic literature the *MWP* and the *LIA* are two periods of European climate history well illustrated both by data of various types. Physical and anthropogenic evidence of meteorological nature has been found in various parts of the world to suggest a warmer epoch lasting between A.D. 1000 and around 1200. The Medieval Warm Period – also known in paleoclimatic research as "Little Climatic Optimum" – is a period in medieval time during which conditions were relatively clement in

[3] T. RABB, Climate and Society in History: a Research Agenda, in: Social Science Research and Climate Change: an Interdisciplinary Appraisal (ed. R. S. CHEN, E. BOULDING, S. H. SCHNEIDER), Dordrecht 1983, 62–76.

[4] E. LE ROY LADURIE, Times of feast, Times of Famine. A History of Climate Since the Year 1000, London 1972; M. J. INGRAM, G. FARMER, T. M. L. WIGLEY, Past climates and their impact on Man: a review, in: Climate and History: Studies in Past Climates and their Impact on Man, (ed. T. M. L. WIGLEY, M. J. INGRAM, G. FARMER), Cambridge 1981, 3–50, 18.

Europe and North America, allowing settlement in inhospitable parts of Greenland, and widespread cultivation of grapevine in England and wheat almost to the latitude of the Polar Circle.[5]

But there are some problems concerning the chronological and geographic framework of the *MWP*. The chronology of this climatic phase is still under discussion, but in general, the years 1000–1200 are acceptable time-limits of this climatic phase[6]. Moreover, until recently it was believed that the *MWP* was mainly confined to Europe, while other areas seem to have missed it or, at least, not experienced such a warm phase. Generally speaking, the available evidence does not support a global Medieval Warm Period. The available data exhibit significant decadal to century scale variability throughout the last millennium[7].

By the late 12th century the *MWP* came to a close. The mild climate in Western Europe started to deteriorate and climatic extremes characterized the two centuries that followed. Great floods and droughts occurred along with both remarkably severe and warm winters about 1350[8].

The climate of the two subsequent centuries (14th and 15th) after the *MWP* is a point of controversy among the specialists of paleoclimate research. It has been suggested that from about 1400 to 1550 the climate grew colder and from 1550 on the 300–year cold spell known as the Little Ice Age began[9]. Other scientists say that after a very cold 12th century, the period from 1200 to 1400 was warm, mainly in the Southwest of Europe. The arising question is still open: was this period the beginning of the *LIA*, or a transitional period between the *MWP* and the *LIA*?[10].

The term "Little Ice Age" is generally used in paleoclimatology to cover the period A.D. 1550–1850, during which the climate of the middle latitudes became generally harsher and there was an expansion of glaciers[11]. There is little agreement as far as the beginning of the *LIA* is concerned. There are two groups of scientists – those who believe that the *LIA* began in the late 13th century and those who favour an early 16th century onset. However, both groups agree that the *LIA* came to an end in the 19th century. The geographical framework of the *LIA* is much clearer – though not without controversy – than that of the *MWP*. There is no doubt that the *LIA* was a phenomenon experienced in

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[5] R. A. BRYSON, Summary of the Conference on the Climate of the 11th and 16th Centuries. *Bulletin of American Meteorological Society* 43 (1962) 654–657; H. H. LAMB, The Early Medieval Warm Epoch and its Sequel. *Palaeogeography Palaeoclimatology Palaeoecology* 1 (1965) 13–37, 14; C. PFISTER, Variations in the Spring-Summer Climate of Central Europe from the High Middle Ages to 1850, in: Long and short term variability of climate (Lecture Notes in Earth Sciences 16) (ed. H. WANNER, U. SIEGENTHALER). Berlin–Heidelberg–New York–London–Paris–Tokyo 1988, 57–82, 57 ff.; W. J. MAUNDER, Dictionary of Global Climatic Change. London 1994, 168.

[6] LAMB, On the nature; LAMB, The Early Medieval Warm Epoch; H. H. LAMB, Climate: Present, Past, Future II: Climatic history and the future. London 1977, 434; R. S. GOTTFRIED, Climatology, in: Dictionary of the Middle Ages, (ed. in chief J. R. STRAYER). New York 1982–1989, 3, 450–457; W. J. MAUNDER, op.cit.

[7] M. K. HUGHES, H. F. DIAZ, Was there a 'Medieval Warm Period', and if so, where and when. *Climatic Change* 26 (1994) 109–142, 109; I. D. WHYTE, Climatic Change and Human Society. London–New York 1995, 46.

[8] N. J. G. POUNDS, An historical geography of Europe 450 B.C. –A.D. 1330. Cambridge 1973, 15.

[9] R. FAIRBRIDGE, Climatic Variation (Historical Record), in: The Encyclopedia of Atmospheric Sciences and Astronomy, (ed. R. FAIRBRIDGE). New York–Amsterdam–London 1967, 2, 205–211, 209; MAUNDER, op.cit. 40 f.

[10] J. GUIOT, The combination of historical documents and biological data in the reconstruction of climate variations in space and time, in: European climate reconstructed from documentary data: methods and results, (Paläoklimaforschung 7) (ed. B. FRENZEL). Stuttgart–Jena–New York 1992, 93–104, 101; It has not GOTTFRIED, op.cit. 455.

[11] MAUNDER, op.cit. 168.

many parts of the globe, but more extensively documented by physical and anthropogenic evidence in the Northern Hemisphere[12].

The arising questions that emerge from this general information about the *MWP* and the *LIA* given above are obvious: what was the evolution of climatic conditions in the Eastern Mediterranean during the centuries under discussion? What was the climate like in the region of Eastern Mediterranean and the Middle East during the *MWP* and during the controversial period of the 14th and 15th centuries, which we identify as the "beginning of the *LIA*"? The climatic sequence in the Eastern Mediterranean during those centuries has attracted remarkably little attention so far[13]. A survey of the physical and anthropogenic paleoclimatic evidence from the Eastern Mediterranean and the Middle East from the 9th to the 15th century could shed some light on the situation of the research and could provide the historian of Byzantine history with a sound basis of climatic reconstructions for the last six centuries of Byzantium.

3. PHYSICAL AND ANTHROPOGENIC PALEOCLIMATIC EVIDENCE FROM EASTERN MEDITERRANEAN (10TH–15TH CENTURIES A.D.)

GEOMORPHOLOGIC EVIDENCE

During the 1960s Claudio Vita-Finzi was the first to propose the hypothesis that a distinctive "Younger Fill", identified around the Mediterranean Sea and the adjacent regions, was formed due to intensified stream deposition in the Mediterranean valleys. According to Vita-Finzi, aggradation began in the 6th century A.D. and continued until A.D. 1500, 1800 or even later. The evidence comes from all countries around the Mediterranean, and climatic change was proposed as the dominant explanation: a change to a much moister climate throughout the Mediterranean during that period (Fig. 3)[14]. Several studies on stream deposition and erosion appeared in support or criticism to the "Younger Fill" scenario. However, it is generally accepted that geomorphologic data concerning the fluvial systems in the Eastern Mediterranean and the Middle East are still incomplete and the interference of the anthropogenic influence in regard to fluvial landscapes is a significant non-climatic parameter[15].

On the other hand, variations in the level of the water in lakes and inland seas around the Mediterranean have been studied for possible relations to changes of climate. The history of the levels of the Caspian Sea during those centuries, though archaeologically

[12] R. S. BRADLEY, P. D. JONES, When was the "Little Ice Age"?, in: International Symposium on the Little Ice Age Climate (Tokyo, Japan 1991). (ed. T. MIKAMI). Tokyo Metropolitan University 1992, 1–4.

[13] J. M. GROVE, A. T. GROVE, Little Ice Age climates in the Eastern Mediterranean, in: European climate reconstructed from documentary data: methods and results (Paläoklimaforschung 7) (ed. B. FRENZEL). Stuttgart–Jena–New York 1992, 45–50, 45.

[14] For recent results of Vita-Finzi's research with references to older works see: C. VITA-FINZI, Medieval mud and the Maunder Minimum, in: Solar output and climate during the Holocene. (Paläoklimaforschung 16) (ed. B. FRENZEL). Stuttgart–Jena–New York 1994, 83–93; C. VITA-FINZI, Solar history and paleohydrology during the last two millennia. *Geophysical Research Letters* 22 (1995) 699–702.

[15] W. C. BRICE (ed.), The Environmental History of the Near and Middle East since the last Ice Age .London–New York–San Francisco 1978, passim; J. L. BINTLIFF, Climatic change, archaeology and Quaternary science in the eastern Mediterranean region, in: Climatic Change in Later Prehistory, (ed. A. F. HARDING). Edinburgh 1982, 143–161, 150 ff.; J. M. WAGSTAFF, The Evolution of Middle Eastern Landscapes. An Outline to A.D. 1840. London–Sydney 1985, 219 ff.; A. C. IMERSON, I. M. EMMER, Implications of Climatic Change on Land Degradation in the Mediterranean, in: Climatic Change and the Mediterranen. Environmental and Societal Impacts of Climatic Change and Sea-level Rise in the Mediterranean Region, (ed. L. JEFTIC, J. D. MILLIMAN, G. SESTINI). London–New York–Melbourne–Auckland 1992, 95–128.

determined, indicates a time of greater moisture than the present century[16]. From historical evidence it is concluded that the level of the Lake Ostrovo in West Macedonia was high in the 11th and 13th centuries and low from at least 1400 on[17]. There are also limnological data of the Dead Sea, indicating that from A.D. 1000 on meteorological conditions were generally moister in Israel than what is known today[18].

Tree-ring evidence

The available tree-ring data for the entire Mediterranean area are sufficiently numerous, but there exist only disconnected dendrochronological sequences for the same region (Fig. 4). Besides, few paleoclimatic reconstructions based on the study of the tree-rings' widths have been attempted, particularly with regard to the Eastern Mediterranean and the Middle East, and only a few temperature reconstructions for Europe, based on tree-ring widths, extend back to the *MWP*[19].

There are also methodological problems associated with tree biology and ecology, site chemical and hydrological conditions, interaction of the various climate factors that might control tree growth. These problems diminish the utility of paleoclimatic reconstructions based on tree-ring data[20]. However, from temperature reconstructions in Northern Italy, based on tree-ring series, it has been concluded that the *MWP* was marked by an equal distribution of cold and warm summer episodes and the climate deterioration from A.D. 1300 reported by several authors is not really found in that region[21].

Pollen evidence

In the last decade, various palynological studies in the Eastern Mediterranean and the Middle East have been carried out regarding the relation between paleo-pollen samples and climatic fluctuations. Pollen diagrams down to the end of the Upper Paleolithic may be significant indicators for climatic change, but after intensive agricultural exploitation since the Neolithic there is always the danger that a certain element of anthropogenic "noise" has been introduced in the palynological record[22]. On the other hand, pollen sequences coming from the Mediterranean region suffer from a bioclimatological disadvantage. The Mediterranean climate is characterized by summer drought:

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[16] The Caspian Sea was ± 10.3m above its present level in the beginning of the 10th century, ± 2.7m lower in the 12th century, and again ± 12.7m above in the late 13th century; in the early 15th century its water level rose again. K. W. Butzer, Quaternary Stratigraphy and Climate in the Near East (Bonner Geographische Abhandlungen 24). Bonn 1958.

[17] C. E. P. Brooks, Climate through the Ages. A study of climatic factors and their variations. London 1949, 302.

[18] Especially during the periods A.D. 1170–1320, 1360–1430, 1470–1650. Cf. H. J. Bruins, The impact of man and climate on the central Negev and northeastern Sinai deserts during the Late Holocene, in: Man's Role in the Shaping of the Eastern Mediterranean Landscape, (ed. S. Bottema et al.). Rotterdam 1990, 87–99, 96.

[19] P. I. Kuniholm, Archaeological evidence and non-evidence for climatic change. *Phil. Trans. Roy. Soc. Lond.* A330 (1990) 645–655, 649; F. Serre-Bachet, Tree-rings in the Mediterranean Area, in: Evaluation of climate proxy data in relation to the European Holocene, (Paläoklimaforschung 6) (ed. B. Frenzel). Stuttgart–Jena–New York 1991, 133–147, 137.

[20] M. K. Hughes, H. F. Diaz, op.cit. 117–120.

[21] F. Serre-Bachet, Middle Ages Temperature Reconstructions in Europe, a Focus on Northeastern Italy. *Climatic Change* 26 (1994) 213–224.

[22] P. I. Kuniholm, op.cit. 646.

thus, in humid sites, which are indispensable for a good pollen preservation, the accumulation and preservation of the pollen material may suffer from dry episodes[23].

From a recent palynological research carried out in Asia Minor by the Biological-archaeological Institute in the Netherlands, one can obtain an *ex silentio* argument concerning the reconstruction of climatic fluctuations during the *MWP* and the *LIA* in the Eastern Mediterranean. Between approximately 1200 B.C. and A.D. 500 (the so-called "Beyşehir Occupation Phase") cooler conditions have been prooved, that may have meant more summer precipitation in at least part of the Eastern Mediterranean, according to lower values of certain types of pollen records (Fig. 5). Such a change is not observed in later periods, neither during the *MWP*, nor the *LIA*. Therefore, no major climatic fluctuations can be proved for those periods given the "silence" of the available palynological evidence. Besides, as stated by John Bintliff, despite the difficulty to interpret physical records from the north of the Eastern Mediterranean because of human interference with woodland distribution, vegetation history in those regions shows no significant changes attributed to climate[24].

Anthropogenic evidence

Anthropogenic paleoclimatic evidence comprises man-made literary (documentary) and material (archaeological) records on past meteorological conditions (Fig. 2). Because of the long unbroken and continuous presence of man around the Mediterranean one should expect rich paleoclimatic material from the fields of archaeology and historical science. What is really known so far from the study of anthropogenic paleoclimatic evidence for the Eastern Mediterranean during the centuries under discussion?

Most of the archaeological evidence that can be associated with climatic fluctuations is related to the "Younger Fill" geomorphologic theory, and to the changes of the water level of lakes and inland seas, as presented above. Archaeological indications in rivers of Sicily, as well as harbor works, fortifications and other human constructions on the western shore of the Caspian Sea, indicate moister conditions during the 13th and 14th centuries.[25]

From the rich literary historical sources of the various literatures of the Eastern Mediterranean and the Middle East, little systematic research on paleoclimatic evidence concerning the *MWP* and the beginning of the *LIA* hidden in the Byzantine, Syrian, Arabic, Slavonic etc. texts has been carried out so far. Meteorological references derived from isolated texts of those literatures have appeared in the so-called "weather compilations" and have provided modern paleoclimatologists with ready paleoclimatic material. Humbert Lamb in the decades of 1970s took advantage of such material and described the climate history of the Eastern Mediterranean and the Middle East during the *MWP* and the beginning of the *LIA*[26].

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[23] A. Pons, Pollen Proxy Data from Western Mediterranean Europe, in: Evaluation of climate proxy data in relation to the European Holocene, (Paläoklimaforschung 6) (ed. B. Frenzel). Stuttgart–Jena–New York 1991, 51–62, 55.

[24] J. L. Bintliff, Palaeoclimatic Modelling of Environmental Changes in the East Mediterranean Region since the Last Glaciation, in: Palaeoclimates, Palaeoenvironments and Human Communities in the Eastern Mediterranean Region in Later Prehistory (BAR Int. Ser. 133/ii) (ed. J. L. Bintliff and W. Van Zeist). Oxford 1982, 277–323, 313; S. Bottema, Pollen proxy data from Southeastern Europe and the Near East, in: Evaluation of climate proxy data in relation to the European Holocene, (Paläoklimaforschung 6) (ed. B. Frenzel). Stuttgart–Jena–New York 1991, 63–79.

[25] Lamb, Climate: Present, Past, Future 133, 439.

[26] Lamb, On the nature: Lamb, Climate: Present, Past, Future 428, 439, 450; H. H. Lamb, Climate, History and the Modern World. London 1982, 173 f., 195 f.

Recently detailed paleoclimatic research on archival sources has been done dealing with adjacent areas, such as Italy and the Middle East. From the study of the literary records on the floodings of the river Tiber in Italy it has been concluded that during the 11th century there were no floods, while during mid-13th through mid-14th the flooding was normal. Only at the end of the 1400s it reached a marked peak. From the study of the sea flooding at Venice based on documentary evidence, it results that the period 1250–1350 was part of a stormy period which characterized the transition of the end of the *MWP*. As far as the Venice Lagoon is concerned – according to the "silence" of the sources – at the beginning of the 14th century the Lagoon never froze[27].

A recent systematic research in Arabic chronicles for climatically relevant information has led to interesting results concerning the evolution of climatic conditions in the Middle East during the centuries under discussion. Thus, from the 9th to the 13th century wet conditions seem to have prevailed in Mesopotamia. For Syria and Palestine there are not any indications for wet conditions in the same period, whereas the next three centuries (A.D. 1270–1530) appear to have been wet. For Egypt the wet period lasted from 1320 to 1460 (Fig. 6)[28].

Finally, paleoclimatic evidence hidden in the administrative documents of the Venetian archives in Venice and on islands of the Ionian and Aegean Seas has recently attracted the attention of paleoclimatologists. This fieldwork is quite promising for the collection of rich documentary paleoclimatic evidence referring to the *LIA* in the Eastern Mediterranean, but much work is still to be done[29].

4. METEOROLOGICAL RECORDS FROM THE BYZANTINE SOURCES

As mentioned also in the introduction of this communication, the literary paleoclimatic evidence hidden in the Byzantine texts has remained more or less unexploited as fieldwork for paleoclimatic and further historical research until recently. General references to climatic conditions or fluctuations and sporadic exploitation of meteorological testimonies from the Byzantine texts have been incorporated by Byzantinists into historical analyses. But no serious attempt to collect, analyze and correlate such paleoclimatic material from an interdisciplinary point of view has been made so far. Evangelos Chrysos and Brian Croke were among the first of the Byzantinists to realize the need for systematic collection and evaluation of climate-relevant information from the Byzantine texts in the late 1980s. Ever since work has been carried out in this field, mainly at the University of Ioannina, Greece[30].

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[27] D. CAMUFFO, S. ENZI, Climatic features during the Spörer and Maunder Minima, in: Solar output and climate during the Holocene, (Paläoklimaforschung 16) (ed. B. FRENZEL). Stuttgart–Jena–New York 1995, 105–124.

[28] H. GROTZFELD, Klimageschichte des Vorderen Orients 800–1800 A.D. nach arabischen Quellen. *Würzburger Geographische Arbeiten* 80 (1991) 21–43.

[29] GROVE and GROVE, op.cit.

[30] B. CROKE, Climatology and Byzantine Studies, in: VIth Conference of the Australian Association for Byzantine Studies (July 14th–16th 1989). Sydney, Australia 1989; I. TELELIS, E. CHRYSOS, D. METAXAS, Documentary evidence from the Byzantine Sources for the Severe Winter A.D. 763/4. (in Greek, with English summary) *Dodone* 18 (1989) 105–127; I. TELELIS, E. CHRYSOS, The Byzantine Sources as Documentary Evidence for the Reconstruction of Historical Climate, in: European climate reconstructed from documentary data: methods and results, (Paläoklimaforschung 7) (ed. B. FRENZEL). Stuttgart–Jena–New York 1992, 17–31; I. TELELIS, Meteorological Phenomena and Climate in Byzantium. Approach of documentary information and empirical indications concerning climatic fluctuations in Eastern Mediterranean and the Middle East (A.D. 300–1500) (Doctoral Thesis, in Greek, University of Ioannina 1995). Thessalonike 2000 (in print); J. KODER, "Zeitenwenden". Zur Periodisierungsfrage aus byzantinischer Sicht. *BZ* 84/85 (1991/1992) 409–422,

The question whether there are data that can provide the historian of Byzantine history with a sound basis for climatic reconstructions for the last six centuries of Byzantium can be answered in the affirmative. But one should consider some restricting parameters concerning the density and the reliability of the records, as well as their spatial and temporal coordination[31].

The material presented in this section derives from my doctoral thesis entitled: "Meteorological Phenomena and Climate in Byzantium. Approach of documentary information and empirical indications concerning climatic fluctuations in the Eastern Mediterranean and the Middle East (A.D. 300–1500)". This material comes from the most informative genres of the Byzantine narrative sources for the purposes of a paleoclimatic research: i.e. (i) the actual historical writers, (ii) the chronographers, (iii) the church historians, (iv) the Saints' Lives *(Vitae Sanctorum)*, and (v) from some historical writers and chronographers belonging to the oriental lingual and historicogeographic cultures adjacent to Byzantium (e.g. Arab, Syrian, Armenian historians and chronographers).[32].

For the period under discussion more than 550 records with paleoclimatic significance have been unearthed from the Byzantine sources and have been critically evaluated with all techniques of modern historical research. 37% of those records are classified as records providing direct climatic information about meteorological phenomena of long duration (weeks, months, years): e.g. severe winters, droughts, continuous rainfalls etc. This type of record is the most comprehensive in paleoclimatic information, allowing further interpretation. Records concerning phenomena of short duration (e.g. gales, hailfalls, winds etc.), and phenomena with possible indirect relation to climate (e.g. floods, famines, etc.) are also interesting for paleoclimate research. However one needs continuous, homogeneous and quantitative data sets for specific territorial units in order to apply sophisticated statistical methods of interpretation[33].

A statistical presentation of this material (Fig. 7) reveals a considerably higher density of records during the 11th and 12th centuries, though the excerpted sources of the same period are not equally numerous. In this case such a growth of information seems to be positively affected by the number of records preserved in each source. This may have happened not only because of the existence of extended chronographic texts in those centuries (e.g. Johannes Scylitzes, Bar Hebraeus, Michael Syrus), but also because of the frequency and the significance of particular meteorological events (e.g. severe winters, droughts).

If we confine our view to the bits of direct climatic information about meteorological phenomena of long duration provided by the previously mentioned records and divide them according to their relevance to the most crucial variables for the history of climate meteorological variables, i.e. Temperature and Precipitation, then Figure 8 gives us a clearer picture of the relationship between those two variables and their significance in the documentary evidence of each 50-year period.

The 9th and 11th–12th centuries seem to be better documented in relation to the variable of Precipitation than that of Temperature, whereas during the 14th century emphasis is given to the variable of Temperature.

A more detailed picture of the frequency of warm/cold and wet/dry climatic events by half-centuries is shown in Figure 9. The prevailing tendency is to report more and

415–416: J. KODER, Climatic Change in the 5th and 6th Centuries?, in: IX Conference of the Australian Association for Byzantine Studies (July 7th–9th 1995), (Byzantina Australensia 10) (ed. P. ALLEN and E. JEFFREYS). Brisbane 1996, 270–285).

31 INGRAM, UNDERHILL, FARMER, The use of documentary sources: TELELIS, Meteorological Phenomena and Climate in Byzantium ch. C.2.3.

32 TELELIS, op.cit.

33 Cf. INGRAM, UNDERHILL, FARMER, op.cit. 200 ff.

more cold episodes from the 9th century onwards. The 14th century shows the greatest number of cold reports, though the 13th and the 15th centuries are quite poor in cold reports. On the other hand, reports on drought are quite numerous during the 11th–12th centuries, whereas wet events show a tendency to higher rates in the period 900–1100 and 1150–1200.

5. DISCUSSION ON DATA AND APPLIED METHODS

The statistical analysis of the literary paleoclimatic information from the Byzantine texts has considerable inadequacies.

One could observe that a certain type of evidence (records referring to phenomena of long duration) was selected for further analysis, while other types of evidence (records referring to phenomena of short duration or phenomena with indirect relation to climate) were excluded. A second observation might concern the geographical scale of the analysis. The records report events for specific territorial units, and we have selected for the needs of the above analysis to present the data in the general geographical scale of the Eastern Mediterranean and the Middle East. Finally, one might also protest against the 50-year or 100-year time scale, which is relatively long-term and does not permit the evaluation of shorter-term fluctuations.

At this point we are obliged to admit that the available literary paleoclimatic evidence for the reconstruction of the Mediterranean climate history is characterized by considerable imperfections. Unfortunately, most of the paleoclimatic information obtained from Byzantine literary sources does not form a systematic series, because the evidence is highly sparse, discontinuous, non-homogeneous and biased towards the recording of extreme meteorological events. Thus, it does not encourage the application of sophisticated statistical methods for ambitious climatic reconstructions. However, the whole task is far from being meaningless. When the available data are very fragmentary, a more "impressionistic" approach may not be excluded in order to provide some indication of possible major climatic trends. In this case, the usefulness of the physical paleoclimatic evidence is obvious. Conclusions from the study of geomorphologic, tree-ring and pollen evidence indicating long-term climatic fluctuations may be used as the "background" for posing questions about shorter-term fluctuations derived from anthropogenic evidence[34].

Therefore, the application of descriptive statistical methods of analysis, and the approach of the material on the basis of wider geographic and chronological scales (in 50- and 100-year scale), is the only way to detect some possible climatic indications, with all appropriate signals of caution.

6. CONCLUDING REMARKS

The question whether there is any convincing climatic evidence, that can affirm warmer regional climatic episodes in the Eastern Mediterranean and the adjacent areas, synchronous to those of Western Europe during the *MWP* and colder spells during the *LIA*, cannot be proved with any degree of certainty. The available physical and anthropogenic data from all disciplines can only permit the shaping of some crude hypotheses.

The shortage and limitations of physical evidence make detailed reconstructions of past climatic variations in the area almost impossible. The investigation of the paleocli-

[34] Op.cit. 203 ff.

matic literature concerning climate history of the Eastern Mediterranean and the Middle East during the *MWP* and the beginning of the *LIA* (section 3), based on this type of evidence shows that the relevant climatic reconstructions are still imperfect. Further systematic and homogeneous research of various types of physical data (especially geophysical, pollen and tree-ring data for the Eastern Mediterranean and the Middle East) is desirable.

The *MWP* was a phenomenon of northern and north-western Europe rather than of southern Europe. The concept of a globally synchronous *MWP* and *LIA* is no longer supported by the growing array of paleoclimatic data. Thus, it is becoming apparent that significant regional spatial and temporal variability characterized the climatic change of the past millennium. Paleoclimatic information originating from the north of Europe cannot be directly transferred to Southern Europe[35].

Geomorphologic evidence suggests generally moister climatic conditions in the Eastern Mediterranean and the Middle East during the *MWP* and the beginning of the *LIA*, while tree-ring and pollen data indicate a mild climatic phase with minor cold and dry episodes.

On the other hand, there can be no doubt of a sharp change of climate over much of Europe in the early 14th century. European literary sources indicate a succession of very wet years. The years 1315–17 were a period of unusually severe weather, poor harvests and famine for many European regions. Wet and stormy conditions of the 14th century led at some point in the 15th century to conditions that were colder but somewhat drier. This climatic fluctuation initiated the *LIA*, a climatic regime which was not merely local, but was possibly experienced in the Mediterranean region as well as in northern Europe[36].

In general, these scenarios correspond to the trends formulated in the basis of the sparse evidence of the Byzantine sources. More indications of coldness can be observed for Constantinople, Asia Minor, Armenia and Mesopotamia during 1000–1350, as well as for Thrace and Macedonia during 1250–1400. Indications of wetness are comparatively more for Asia Minor, Armenia and Mesopotamia during 1000–1100. Dry spells appear more frequently during, 1150–1200, 1250–1300 for Egypt, Palestine, Syria, and Cyprus, as well as for Constantinople, Asia Minor, Armenia and Mesopotamia during, 800–850, and 1000–1050 A.D. (Fig. 9 and Appendix).

The reconstruction of climatic conditions during the *MWP* and the *LIA* in the Eastern Mediterranean region suffers from considerable temporal and spatial dispersion of all kinds of evidence. This situation creates major problems of interpretation and prohibits the application of standardized methodological tools. Consequently, further systematic historical and climatological research in all scientific fields is an essential means towards stating more precisely and completing the available information about climatic fluctuations in those regions in historical time.

Some thoughts inevitably come to the mind of the Byzantinist regarding the possible links between climatic fluctuations and socio-economic affairs in the middle and late Byzantine era.

Twelve years ago Alexander Kazhdan and Ann Epstein stated in their book: "Change in Byzantine Culture in the Eleventh and Twelfth Centuries", that "western observers in 11th–12th century, participants in the crusades, described the abundance of grain, wine, oil, and cheese in Eastern Mediterranean. Besides, English chroniclers commented that there were more olives in the southern Peloponnese than anywhere else in the world". If

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[35] T. M. L. Wigley, G. Farmer, Climate of the Eastern Mediterranean and Near East, in: Palaeoclimates, Palaeoenvironments and Human Communities in the Eastern Mediterranean Region in Later Prehistory, (BAR Int. Ser. 133/ii) (ed. J. L. Bintliff and W. Van Zeist). Oxford 1982, 3–37.

[36] N. J. G. Pounds, An historical geography of Europe 450 B.C. – A.D. 1330. Cambridge 1973, 15.

we take this information literally, should we infer that those centuries were meteorologically clement, or that such observations took place during a climatically moderate short period, when the climate fluctuated from harsh to moderate and back to harsh? The distinction between long-term climatic change and short-term climatic fluctuation is very important for the modern researcher, because on the basis of that, any theoretical models concerning the impact of climatic change/fluctuations upon human societies can be applied to certain historical cases of study. This, of course, presupposes well attested paleoclimatic reconstructions, established by sufficient and clear data.

Recently a tendency towards the detection of climatically induced human response in the Byzantine era is observable in Byzantine studies[37]. This tendency is methodologically very important, because it motivates the interdisciplinary cooperation of the Byzantinists with scientists of other fields. But, it also includes the danger of environmental determinism. The primary impact of climate on the biosphere (crops, animals etc.) is indisputable. But higher order impacts on prices, social unrest, politics etc. are extremely complicated because of the implication of other social factors. Such a complexity makes the construction of realistic explanatory models almost impossible, and presses the historian for more caution.

ACKNOWLEDGMENTS

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APPENDIX

Important meteorological phenomena (A.D. 800–1500) reported by Byzantine and oriental sources for the Eastern Mediterranean and the adjacent regions [I. Telelis, Meteorological Phenomena and Climate in Byzantium. Approach of documentary information and empirical indications concerning climatic fluctuations in Eastern Mediterranean and the Middle East (A.D. 300–1500) (Doctoral Thesis, in Greek, University of Ioannina 1995). Thessalonike 2000 (in print)].

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[37] J. KODER, "Zeitenwenden"; J. KODER, Climatic Change in the 5th and 6th Centuries?

ABBREVIATIONS

Year

(): year not literary reported in the sources, but inferred from the elaboration of the evidence.
/: duration of the described phenomenon for successive years.
- - : phenomenon that took place in an unspecified year among two year-limits.

Date/Duration

I...XII: Latin numbers for the months of the year (starting with January).
digits: Arabic numbers for exact dates.
d.: days
m.: months

Area

Af.: Africa	Cr.: Crete isl.	Pal.: Palestine	N: North
Al.: Albania	Cy.: Cyprus isl.	Per.: Persia	E: East
Ar.: Arabia	Eg.: Egypt	Ser.: Serbia	S: South
As.Min.: Asia Minor	Gr.: Greece	Syr.: Syria	W: West
Bul.: Bulgaria	Mac.: Macedonia	Thr.: Thrace	
Con.: Constantinople	Mes.: Mesopotamia		

Meteorological Phenomenon

ws: winter severe (cold)	#: freezing of water (rivers, lakes, etc.)	*: much snow
wr: winter rainy	f: floods	
wm: winter mild		
c: cold harsh		
rh: rainfalls heavy	f: floods	
d: drought	@: famine	
bw: blow of winds	N: northern	S: southern
h: heatwave		

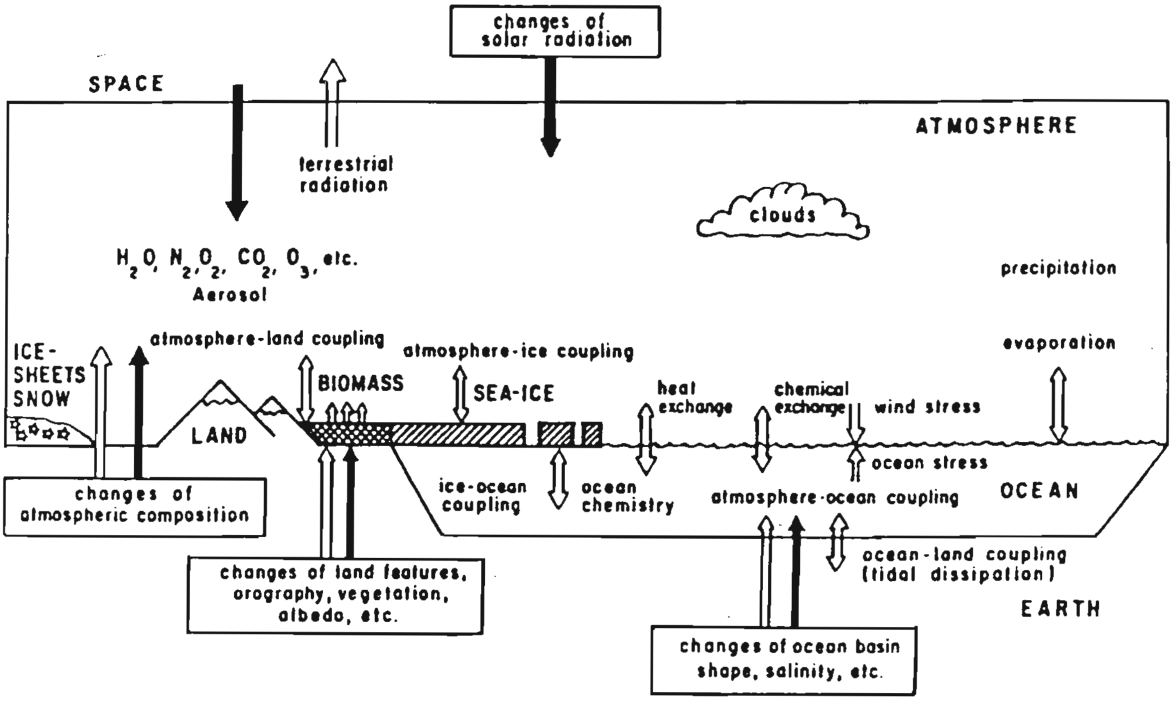
Columns

Met. Phen.: Meteorological Phenomenon
Temp. i.: Temperature index ±1 concerning the temperature significance of the meteorological phenomenon
Prec. i.: Precipitation index ±1 concerning the Rainfall significance of the meteorological phenomenon
Cit.: number of Citations in the sources

Year	Duration	Area	Met. Phen.	Temp. i.	Prec. i.	Cit.
(803- -811)	–	As.Min. W	rh/f		+1	1
(806+)	–	As.Min. N	rh/f		+1	1
810/11	XII–I:10	Mes.	wm/rh	+1		1
811	I:11–I:19	Mes.	bw(N)	–1		1
813	XII (8 d.)	Thr.	rh/f		+1	2
(820- -821)	–	Mes.	d		–1	1
(821- -897)	–	Con.	d		–1	1
822	XI–II	Thr.	ws	–1		1
(829- -842)	–	Con.	d		–1	6
832/33	XI–II	Eg., Mes.	ws/#	–1		2
839	–	Mac.	d		–1	2
842/43	XII–III	Syr.	d		–1	1
843	IV	As.Min. E	rh		+1	1
851/852	XI–II	Arm.	ws	–1		1
(852/853)	XI–II	Mac.	ws	–1		1
897	II-XI	Eg., Mes.	d		–1	2
902	VII	Syr.	c/bw(N)#	–1		1
908	II	Con.	*	–1	+1	2
918- -919	–	Mes.	ws/#	–1		1
921	XI–II	Gr.	ws	–1		1
923- -924	–	Syr.	d		–1	1
927/928	XII–III (120 d.)	Con., Mes.	ws	–1		10
(933/934)	XII–III (120 d.)	As.Min. W	ws	–1		1
935	VI	Syr.	rh		+1	1
(952/953)	XI–II	Gr.	ws	–1		1
957/58	XI–II	Mes.	rh		+1	1
960/961	XI–II	Cr.	wr		+1	2
966	XII	Syr.	rh		+1	2
969	V	As.Min. NE	bw(S?)	+1		5
(969- -1004)	XI–II	Mac.	ws	–1		1
989	VII–VIII (2 m.)	Mes.	bw(S)	+1		1
999	–	Mes.	c/#	–1		1
(1005- -1019)	–	Mac.	d		–1	1
1007	XII?	Mes., Af. E	*	–1		1
1010/1011	XI–II	Con.	ws/#	–1		2
1025	–	Con.	d		–1	2
1026	–	Con.	d		–1	2
1027	–	Con.	d		–1	2
1027	XI–II	Mes.	ws/#	–1		1
1028	–	Con.	d		–1	2
1029	–	Con.	wm/rm	+1		1
1029/1030	–	Con.	wr		+1	2
1031/1032	XI–II	Mes.	ws	–1		1
1031/1032	XI–II	Mes.	d		–1	1
1034	–	Mes.	rh		+1	1
(1035)	XI–II	As.Min. NE, Bul.	ws/#	–1		2
1037	III–VIII (6 m.)	Con.	d		–1	2
1037	XII (6 d.)	Mes.	c/*#	–1	+1	1
1038- -1039	–	Con.	rh		+1	1
(1040)	–	Con.	d		–1	1
1040	yearly	Af. N	d		–1	1
1041	yearly	Af. N	d		–1	1
1042	yearly	Af. N	d		–1	1
1046- -1047	–	Arm.	rh		+1	1
1048	XII	Ser.	ws/#	–1		4
(1054)	I:5	Arm.	c/#	–1		1
(1054- -1055)	I:5	Arm.	c/#	–1		1
1055/1056	XII–VII	As.Min.	wm		+1	2

Year	Duration	Area	Met. Phen.	Temp. i.	Prec. i.	Cit.
1058/1059	XI–II	As.Min. E	*	–1	+1	1
1063	X–XII	Mes.	h	+1		1
1064	I	Mes.	ws/#	–1		1
1068- -1069	XI–II	Arm.	d		–1	1
1073/1074	XI–II	Mes.	wr/f		+1	1
(1081)	VI-VIII	Gr.	d		–1	1
(1085±)	–	Gr.	d		–1	1
(1091)	II–III	Con.	ws/*	–1	+1	1
(1091- -1105)	–	Gr.	ws/*	–1	+1	1
1095	II	As.Min. SE	d		–1	1
1099/1100	yearly	Mes., As.Min. SE	d		–1	3
(1115- -1223)	–	As.Min. NE	d		–1	1
(1115- -1223)	–	As.Min. NE	ws/*	–1	+1	1
(1116)	VI–VIII	Bul.	h	+1		1
(1120- -1121)	XI–II	Mes.	ws/#	–1		1
1122/1123	IX-II	Syr.	d		–1	1
1124/1125	XI–II	Mes., Syr.	d		–1	1
1126/1127	XI–II	Syr.	ws	–1		1
(1134)	XI–II	Cy., Syr.	d		–1	1
(1135)	–	Cy., Syr.	d		–1	1
(1134/1135)	XI–II	As.Min. E	ws	–1		2
1135	XI–I	As.Min. E	wm	+1		1
1135/1136	II-?	As.Min. E	ws/#	–1	–	2
1138/1139	XII–II	Mes.	ws/#	–1		1
~~1139~~	I–V	Mes.	d		–1	2
(1139)	XII	As.Min. NE	ws	–1		3
1147- -1148	–	Syr.	d		–1	2
1148	X-XII	Syr.	d		–1	1
1149	I–II	Syr.	wm/rm	+1		1
1149/1150	XI–II	Thr.	ws	–1		1
(1150)	IV	Pal.	rh		+1	1
1150	IV	Mes.	rh/f		+1	2
(1150)	–	As.Min. E	rh/f		+1	1
1150/1151	XI–II	As.Min. E	ws	–1		1
1151	–	Syr	rh/f		+1	2
1167	XI–II	As.Min. NE	c	–1		1
1172/1172	XI–II	Eg., Arm., Mes., Pal., Per., Syr.	ws/#rh	–1	+1	4
1172- -1173	–	Mes.	rh		+1	1
(1174)	yearly	Arm., Pal., Syr., Per.	d/		–1	1
(1175)	yearly	Arm., Pal., Syr., Per.	d/		–1	1
(1176)	yearly	Arm., Pal., Syr., Per.	d/		–1	1
(1177)	yearly	Arm., Pal., Syr., Per.	d/		–1	1
1176	III–IV	Mes., Pal., Syr.	d		–1	2
1177/1178	XI–II ?	Mes., Arm., Pal., Syr.	d		–1	1
1178	IV	Syr.	rm		(+1)	1
(1178/1179)	XI–II	Syr.	wm	+1		1
(1187/1188)	XI–II	Bul.	ws/#*	–1	+1	1
(1199)	VII	Mac.	h	+1		1
(1231)	VII	Mes.	rh		+1	1
1235/1236	XI–II	As.Min. E, Mes.	ws/#d	–1		1
(1242)	XII	As.Min. W	ws/*	–1	+1	2
(1256)	I–III	Thr.	c/*	–1	+1	2

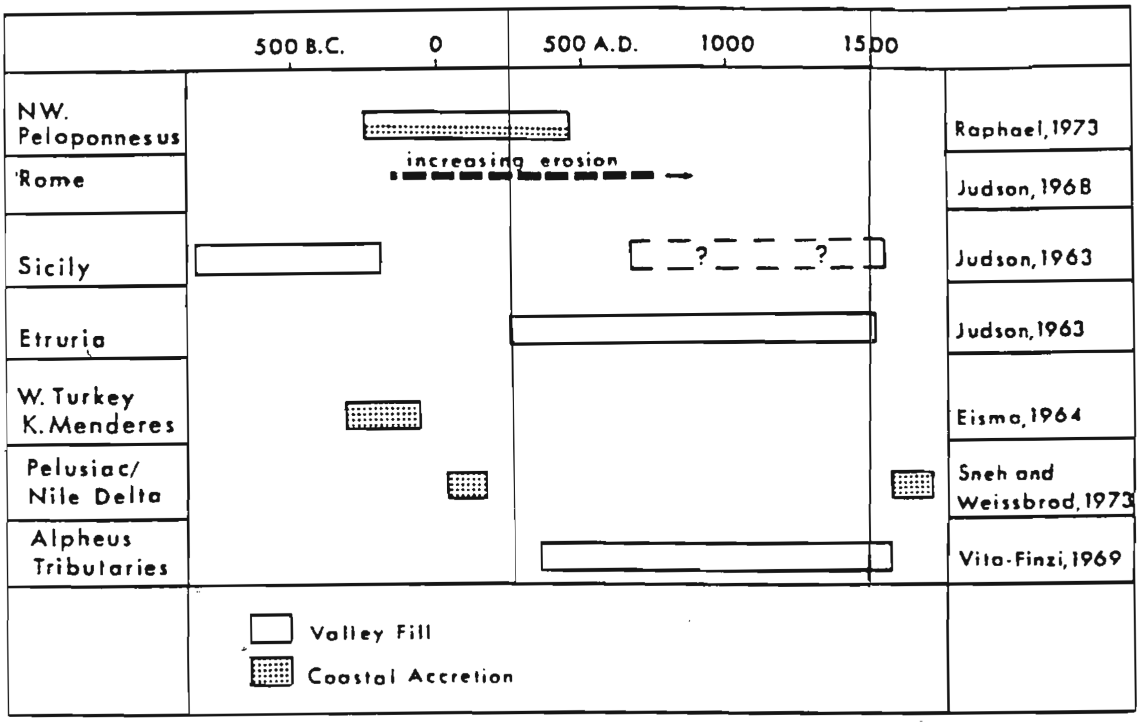
Year	Duration	Area	Met. Phen.	Temp. i.	Prec. i.	Cit.
(1256)	XI–XII	Mac.	c/bw#	−1		4
1273	I:5	As.Min. S	*	−1	+1	1
(1277–1288)	XI–I	Thr.	c/#	−1		1
(1282/1283)	XII–II	Mes., Per.	ws	−1		1
1296	–	Syr., Pal., Eg., Ar.	d		−1	1
1297	–	Eg., Af. N, Pal., Syr.	d		−1	1
(1297/1298)	XI–II	Con.	ws/#	−1		1
(1301)	III–IV	As.Min. E	d		−1	1
(1321)	XII	Thr.	c	−1		1
(1322)	XII	Con.	bw(N)/c/rh	−1		2
(1325–1328)	XII–II	Con.	ws/#	−1		1
(1325–1328)	–	Con.	ws	−1		1
(1333)	XII	Gr.	*	−1	+1	1
(1341/1342)	XII	Thr., Con.	ws/rh*#	−1	+1	6
(1342)	III–V	Mac.	rh/f		+1	1
(1342/1343)	XII–II	Thr.	ws	−1		2
(1343)	V	Mac.	rh/f		+1	1
(1346/47)	XII–IV	Con.	ws/#*	−1	+1	1
(1346–1353)	XII–II	Mac.	*	−1	+1	1
(1350)	I	Mac.	c	−1		1
(1352)	II–V	As.Min. NW	c/rh	−1	+1	2
(1354)	III:12	Thr.	rh/*	−1	+1	1
(1358/1359)	XII–II	As.Min. W	ws	−1		1
(1359)	VI-VIII	Con.	h	+1		1
1373	I:13	As.Min. NE	c/*	−1	+1	1
(1384)	XII–II ?	Mac.	*/#	−1	+1	1
1384	XII–II ?	Syr.	c	−1		1
1395	IV–V	Syr.	d		−1	1
1397	III–IV	Syr.S	d		−1	2
1397	III	Syr.S	rh/*	−1	+1	1
1397	IV:2	Syr. N	c/#	−1		1
(1403/04)	XII–II	As.Min. W. Eg.	ws	−1		2
1419	IX–XI	Mac.	d		−1	1
1420	IX–VIII	Mac.	d		−1	1
(1435)	VIII:29	Gr.	c	−1		1
(1436)	I–II	Al.	ws	−1		1
(1456)	I–II	Con.	ws	−1		1
1470	XII–II	Gr.	ws	−1		1



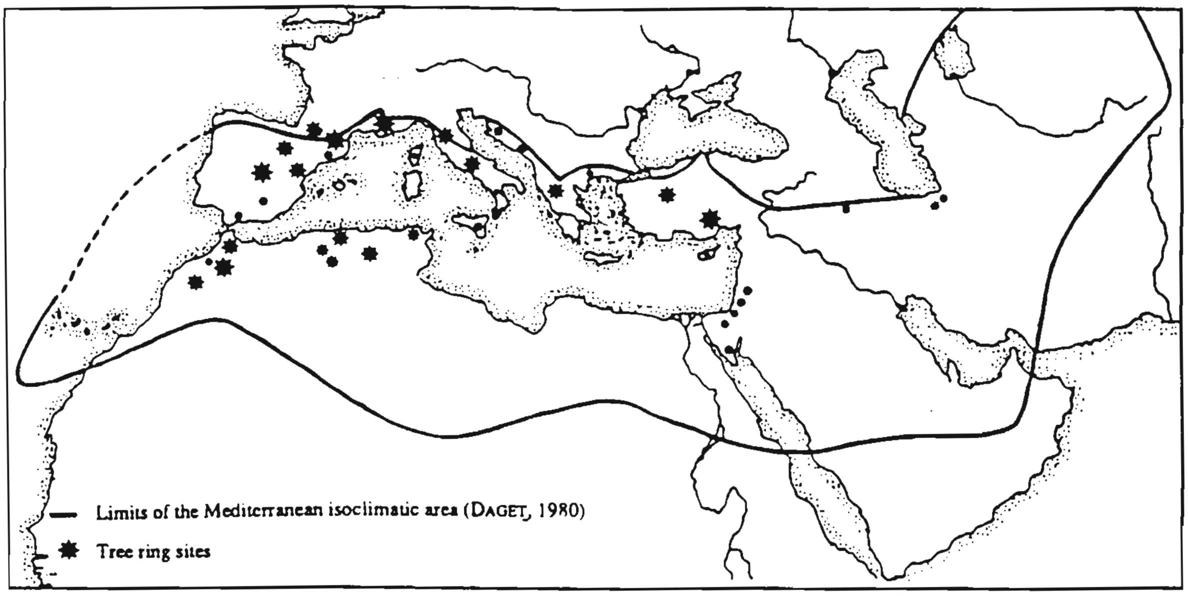
1 Schematic outline of earth's climate system, showing principal internal couplings between the several parts of the system and extrinsing environmental influences on the system. Source: H. OESCHGER, B. MESSERLI, M. SVILAR (eds.), Das Klima. Analysen und Modelle. Geschichte und Zukunft. Berlin–Heidelberg–New York 1980, 32

INFORMATION \ ORIGIN	NATURAL		MAN-MADE		
Direct weather patterns and meteorological parameters			*Documentary sources*	*Descriptive Reports* - extreme events - rough sequence of weather situations - daily weather	*Instrumental observations* - barometric pressure - temperature - precipitation - water-gauge
Indirect (proxy data) phenomena governed or affected through meteorological parameters	*Geophysical* - isotopes - sediments - moraines etc.	*Biological* - marine plankton - pollen - tree rings etc.	*Documentary sources*	*Geophysical / para-meteorological* - water levels - snow falls - duration of snowcover - freezing-over of water bodies	*Biological* - time of blossoming and ripening of plants - yield and sugar content of vine - time of grain harvest and vintage
			Material sources	- paintings, prints and photographs; maps and charts - buildings, settlements, roads, waterways - abandoned farms and fields - archeological remains	

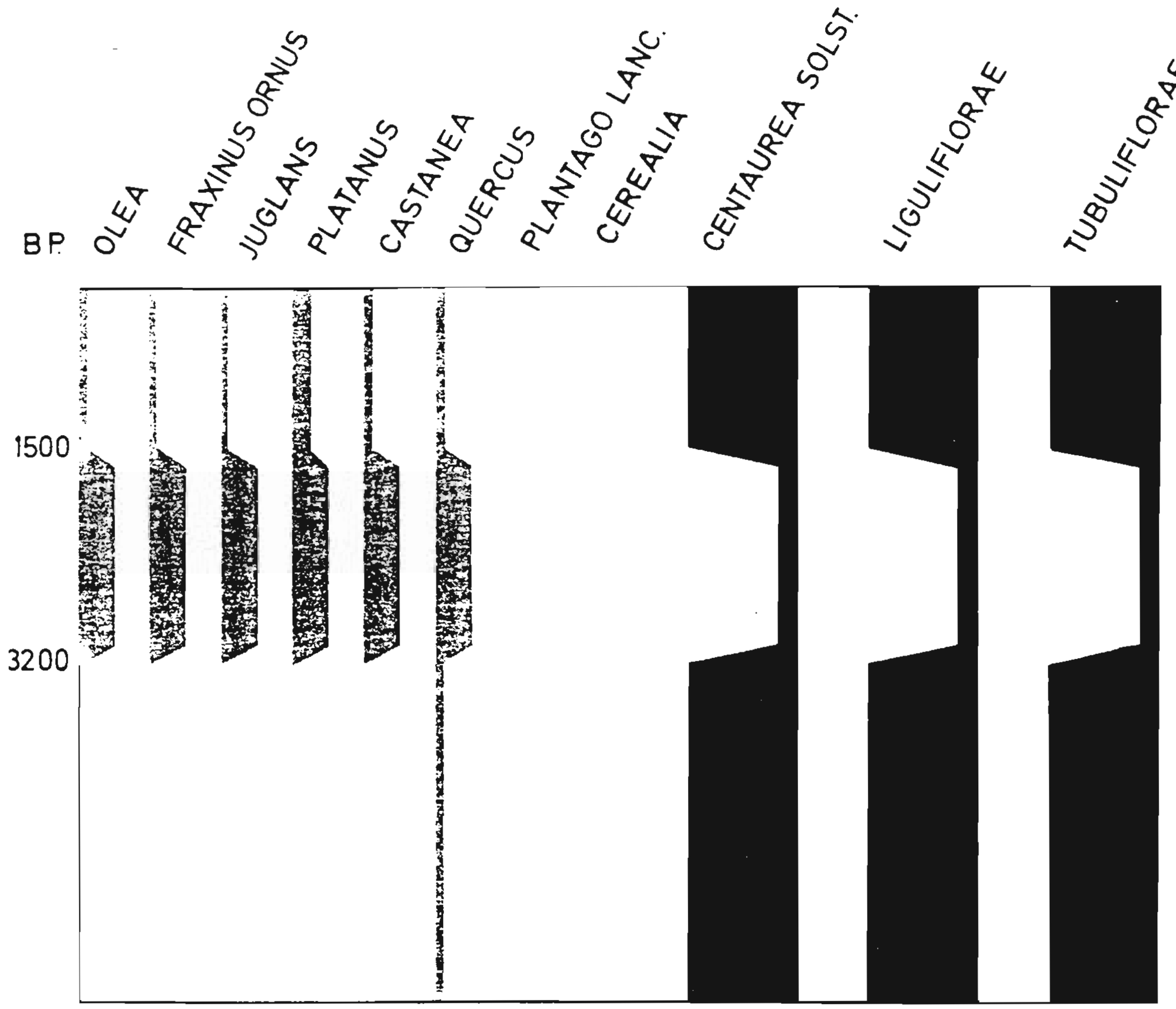
2 A survey of natural and man-made evidence for reconstructing past weather and climate. Source: C. PFISTER, Monthly temperature and precipitation in central Europe from 1525–1979: quantifying documentary evidence on weather and its effects, in: Climate Since A.D.1500 (eds. R. S. BRADLEY and P. D. JONES). London–New York, 118–142



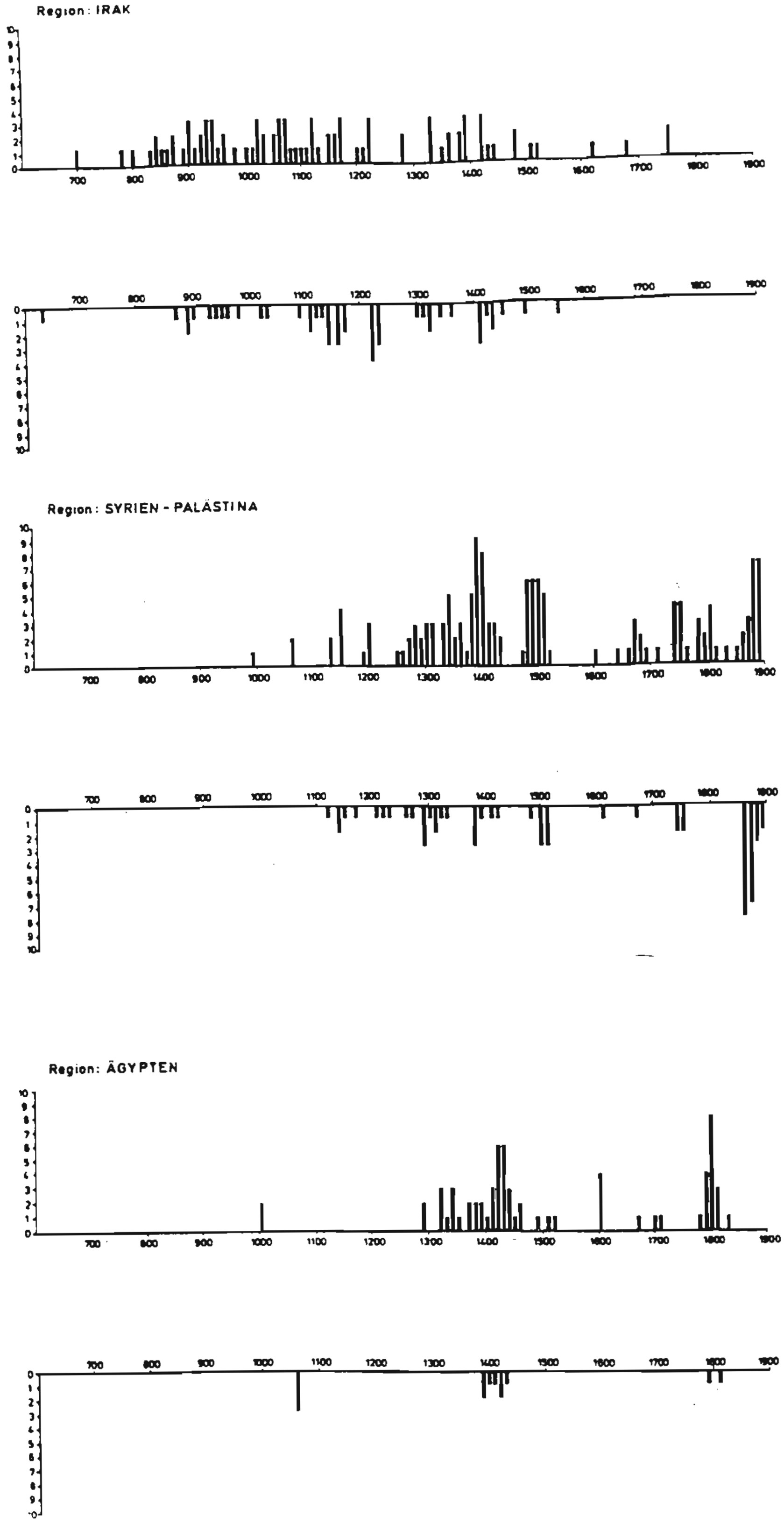
3 Chronology of late historical deposits in the Eastern Mediterranean. Source: W. C. BRICE (ed.). The Environmental History of the Near and Middle East since the last Ice Age. London–New York–San Francisco 1978. 64



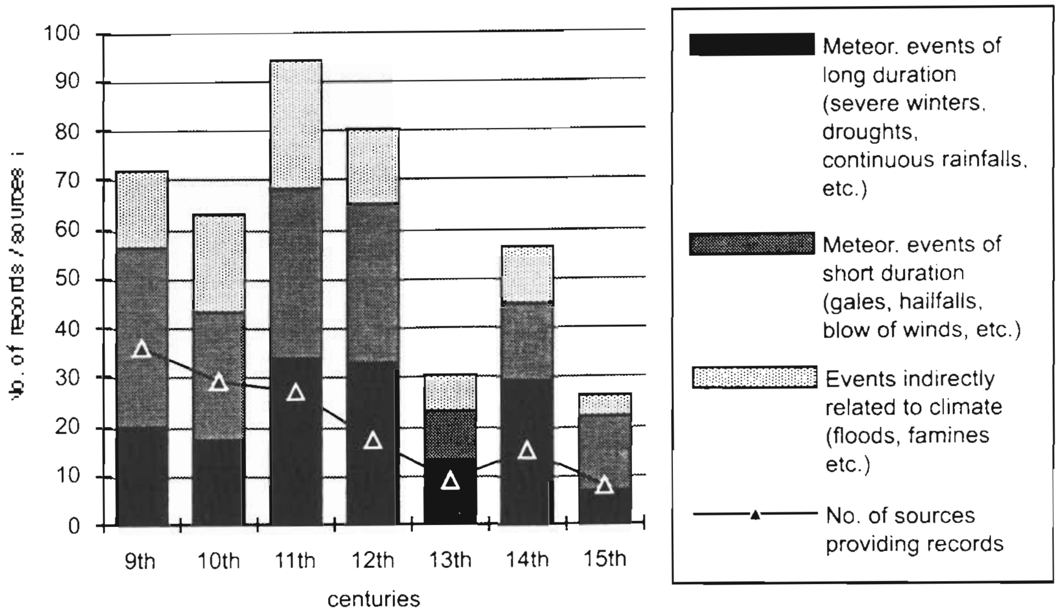
4 Geographical distribution of tree-ring sites over the Mediterranean area. Source: F. SERRE-BACHET, Tree-rings in the Mediterranean Area, in: Evaluation of climate proxy data in relation to the European Holocene, (Paläoklimaforschung 6) (ed. B. Frenzel). Stuttgart–Jena–New York 1991, 133–147, 136



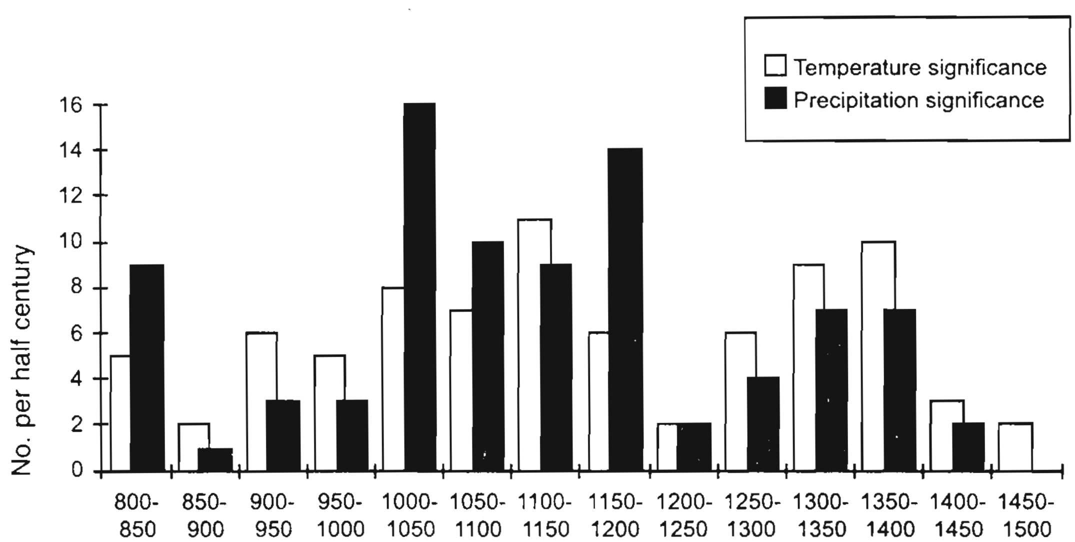
5 Schematic pollen diagram showing a selection of types indicating human or climatic activity in southwestern Turkey. Source: S. Bottema, Pollen proxy data from Southeastern Europe and the Near East, in: Evaluation of climate proxy data in relation to the European Holocene. (Paläoklimaforschung 6) (ed. B. FRENZEL). Stuttgart–Jena–New York 1991, 63–79, 76



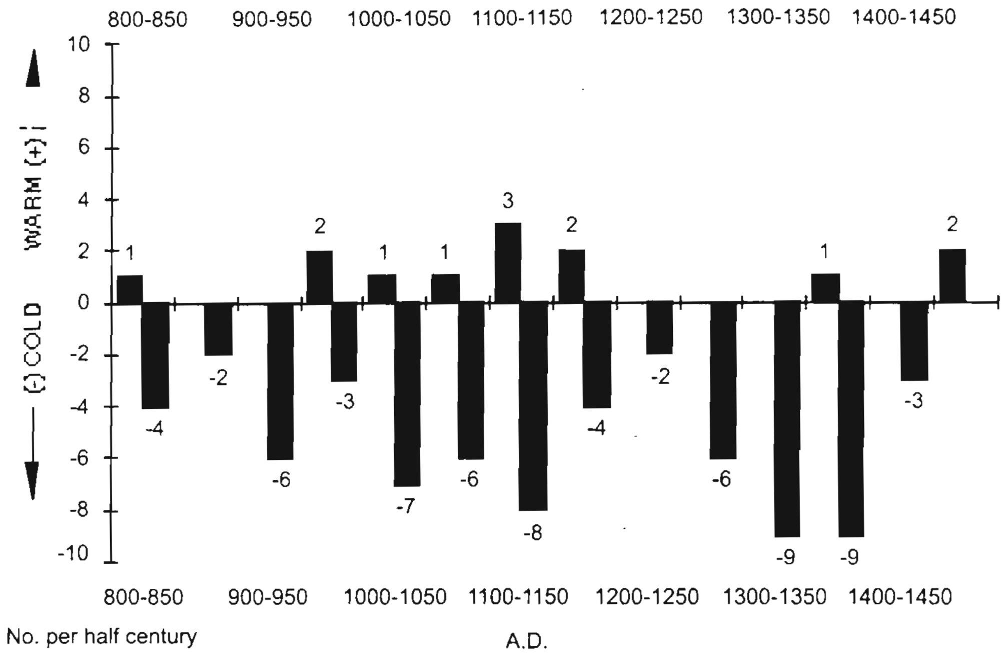
6 Frequency of wet and dry half-years per century in Iraq, Syria-Palestine and Egypt (A.D. 600–1900). Source: H. Grotzfeld, Klimageschichte des Vorderen Orients 800–1800 A.D. nach arabischen Quellen. *Würzburger Geographische Arbeiten* 80 (1991) 21–43, fig. 2, 3, 4

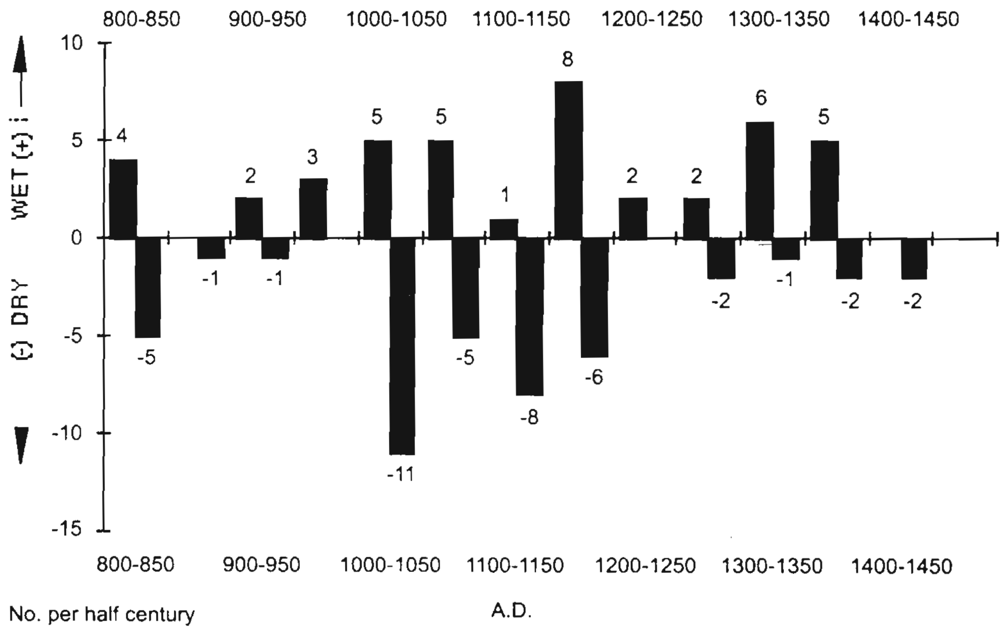


7 Distribution of various types of meteorological events reported in the Byzantine sources (9th–15th century A.D.) and number of sources providing paleoclimatic records in each century



8 Distribution of records with Temperature and Precipitation significance reported in the Byzantine sources (9th–15th century A.D.) in 50-year scale





9 Frequency of Cold/Warm and Dry/Wet meteorological events reported in the Byzantine sources (9th–15th century A.D.) in 50–year scale