

# Climate fluctuations and trajectories to complexity in the Neolithic: towards a theory

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**ABSTRACT** – *Theories about the emergence and spread of farming in western Eurasia have a long research history. Occasionally, climate fluctuations have served as explanations for short-term culture change. However, the entire Holocene climate fluctuation sequence has so far not been regarded. First steps towards a theory which combines the successive stages in Neolithization and early to Mid-Holocene climate fluctuations are described.*

**IZVLEČEK** – *Za teorijami o pojavu in razširitvi kmetovanja v zahodni Evraziji stoji dolga zgodovina raziskav. Klimatska nihanja so občasno služila kot pojasnilo za kratkoročne spremembe kulture. Vendar pa do sedaj ni bila pregledana celotna sekvenca holocenskih klimatskih nihanj. Opisani so prvi koraki k postavitvi teorije, ki združuje zaporedne stopnje neolitizacije in zgodnje do srednje holocenska klimatska nihanja.*

**KEY WORDS** – *climate fluctuations; Neolithization; crises; socio-political trajectories*

## Climate anomalies in the Early to Mid-Holocene North-Atlantic realm

In the past decade, it has become increasingly apparent that the Holocene in western Eurasia was punctuated by climate fluctuations. The most severe of these events was the so-called 8.2 ka event towards the end of the 7<sup>th</sup> millennium calBC, which can be detected in a variety of Northern Hemisphere marine and terrestrial climate records (e.g. *Muscheler et al. 2004; Alley and Ágústsdóttir 2005; Rohling and Pälike 2005*).

The 8.2 ka event was preceded and followed by other, less severe cooling phases. Such periodically occurring fluctuations have been postulated by a variety of research groups, occasionally for the entire globe (e.g. *Bond et al. 2001; Schulz and Paul 2002; Mayewski et al. 2004; Wanner et al. 2008*). For the North Atlantic realm, these cooling phases are explained with changes in salinity caused by shrinking stages of the Laurentian ice shield and related fresh-water outbursts into the North Atlantic, as well as iceberg discharges which equally supplied

fresh-water to the North Atlantic (*Teller and Levenson 2004*), the so-called Holocene IRD events (IRD – ice rafted debris). As IRD-events show a good correlation with insolation cycles, solar triggering is considered (*Bond et al. 2001; Bard and Frank 2006; Beer et al. 2006; Kromer and Friedrich 2007*). A less active sun, presumably, would not only have resulted in the cooling of the North Atlantic; but hemispherical effects, with teleconnections to the monsoonal cycles have been discussed (*Alley and Ágústsdóttir 2005; Wanner et al. 2008*). However, possible links between North Atlantic and Near Eastern climate fluctuations (*Migowski et al. 2006*) are not yet well understood, although Gupta (*et al. 2003*) found that cooling phases in the North Atlantic correlate with signals for weak monsoon periods in the Arabian Sea, and Hong (*et al. 2009*) postulate correlations between the North Pacific and the North Atlantic. Equally not yet well understood is the relation between Holocene IRD-phases and Glacial Heinrich events (*Bond 1999; Peck et al. 2007*).

The suggested connection between IRD-events and solar activity is not only helpful in controlling the rather loosely dated marine IRD-event record (Bond *et al.* 2001), but also helps to link terrestrial climatic events with marine data-set (Figs. 1, 2). Although no chronological fine-tuning has been applied to the proxy records in Figures 1 and 2, and all data-sets are depicted according to the originally published age models, it still does become apparent that, on the coarse level of resolution represented, certain anomalies in the North Atlantic marine records and the selected southern Central European terrestrial records are contemporaneous.

### Holocene IRD phases and the Neolithic transition

The spread of farming and the spread of pottery in western Eurasia are processes that took several millennia and may be subsumed under the designation 'Neolithic Transition' or 'Neolithization Process' (Gronenborn *in press a*). Here, only the spread of farming is discussed, the spread of pottery is treated elsewhere (Gronenborn 2003; *in press b*; Dolukhanov *et al.* 2005). In the Anglo-American literature, the spread of farming has often been viewed as a steady process radiating from a core zone – the Fer-

tile Crescent – to the outer margins of arable land in Eurasia (e.g. Amernann and Cavalli-Sforza 1984; Pinhasi *et al.* 2005; Gkiasta *et al.* 2003). However, continental European research stresses the step-wise advance of farming (Uerpmann 1979; Guilaine 2001; Gronenborn 2003; Bocquet-Appel *et al.* 2009). Occasionally, environmental boundaries are discussed as determinant factors for phases of stasis in the expansion process (Kertész and Sümegi 2001; Kreuz *et al.* 2005; Kreuz 2007), but climatic factors are also considered (Bar-Yosef and Belfer-Cohen 2002; Bonsall *et al.* 2002; Strien and Gronenborn 2005; Cooney 2007; Gronenborn 2007a): When examined at a coarse level of chronological resolution, IRD phases are contemporaneous to the expansion phases of farming (Fig. 1). This is particularly evident for the alpine cold-events (CE) compiled by Haas (*et al.* 1998) and the IRD-events, but also for the Main-river oak anomaly and depositional rate curve (Spurk *et al.* 2002). Already, the onset of cereal domestication is correlated with the beginning of the Holocene when, following Willcox (*et al.* 2009), a warmer, more humid and possibly more

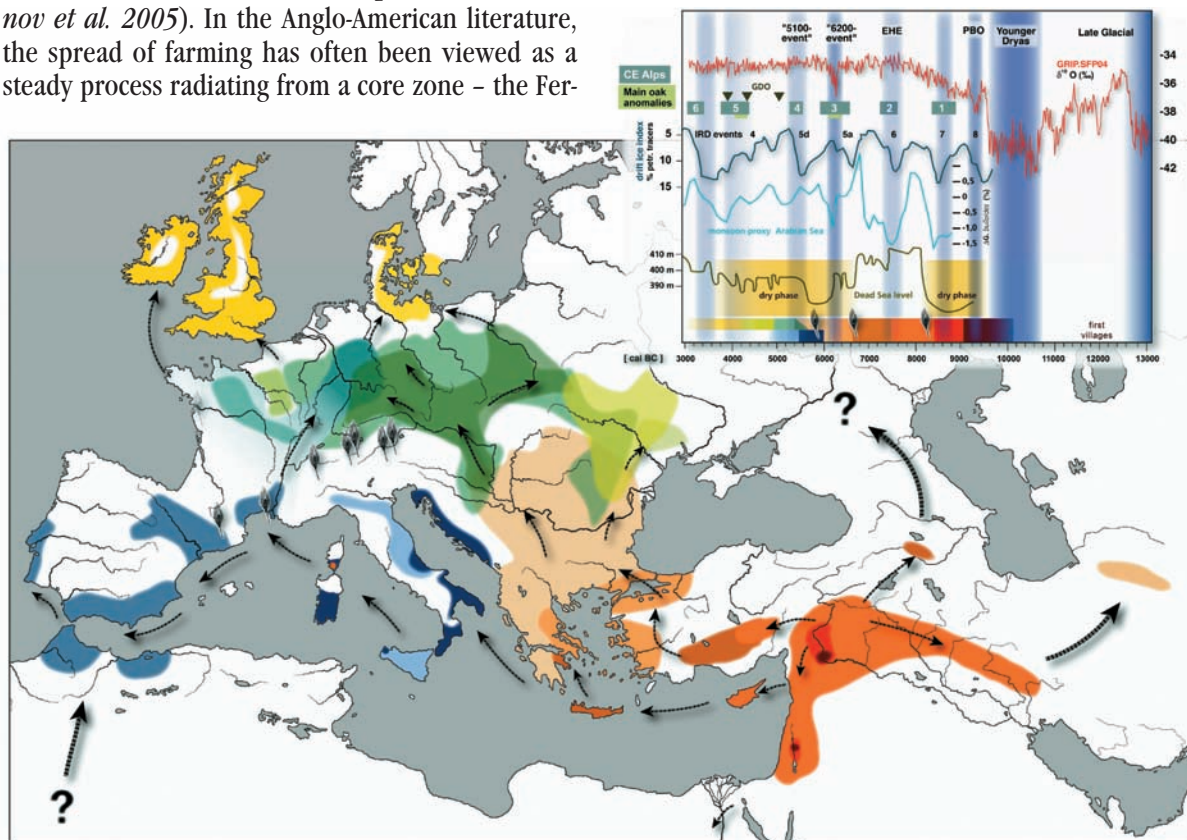
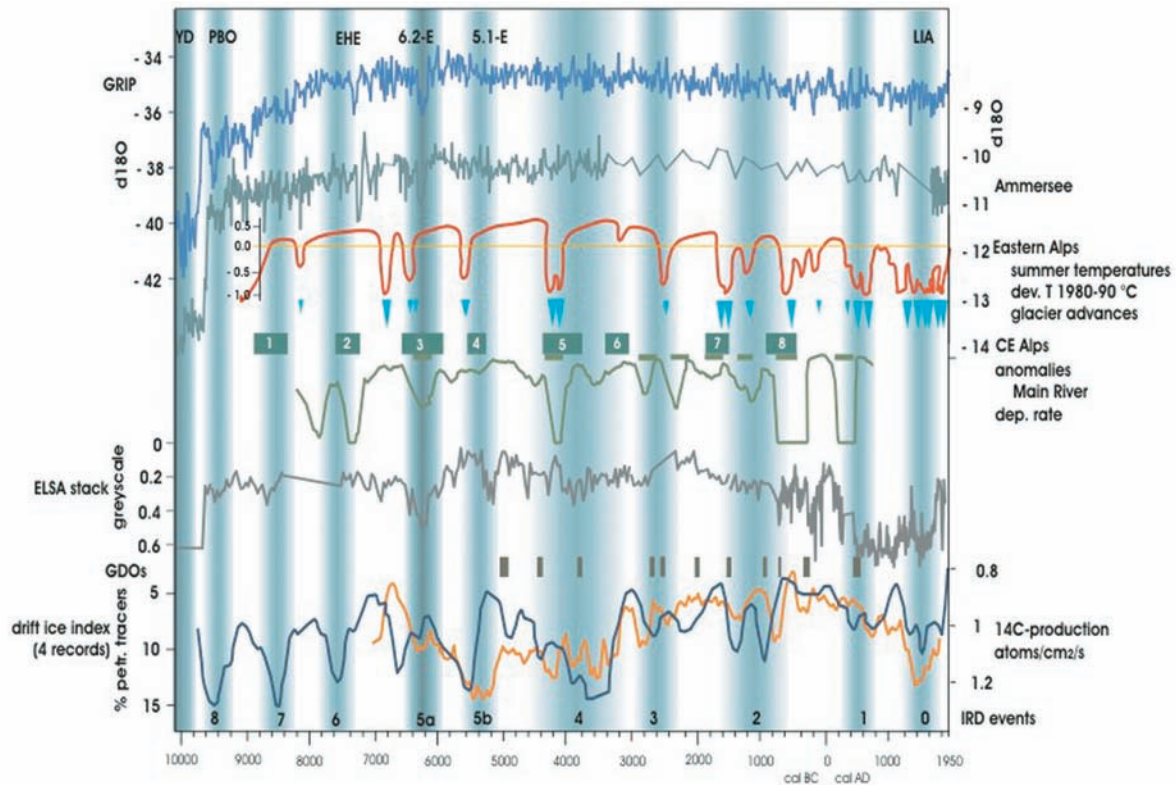


Fig. 1. Culture history-informed interpretative chronozone model of the spread of farming across western Eurasia (telescoped time-slice layers, non-geo-referenced). YD – Younger Dryas; PBO – pre-Boreal oscillation; EHE – early Holocene event; 6.2-E – 6.2 event; 5.1-E – 5.1 event; LIA – Little Ice Age; CE – cold events; GDO – germination/dying-off events (modified after Zimmermann 2002; Gronenborn 2003; for further sources see Appendix).



**Fig. 2. Selected marine and terrestrial palaeoclimate proxy-data for Central Europe. PBO – pre-Boreal oscillation; EHE – early Holocene event; CE – cold events; GDO – germination/dying-off events (for sources see Appendix).**

stable climate supported and facilitated the emergence of agriculture.

The possible role of the Pre-Boreal Oscillation (PBO) in the spread of cereal domestication outward from the immediate centers in the southern Levant and northern Syria is unclear; however, the PBO predates the appearance of domesticates in eastern Anatolia (Willcox 2005). IRD 7 is roughly contemporaneous with the spread of farming to Cyprus (Peltenburg *et al.* 2000; 2001) and Cappadocia (Fig. 1). IRD 7 is also contemporaneous with a notable increase in the level of the Dead Sea (Migowski *et al.* 2006), hence more humid conditions in the southern Levant. Another pronounced anomaly in a number of records (Fig. 2), among them the Ammersee record (von Grafenstein *et al.* 1999), is the Early-Holocene-Event (EHE) or 9.2 ka event, which is contemporaneous to CE-event 2 in the Alps, a notable decrease in the Main oak deposition rate and which apparently slightly postdates IRD event 6 (Fleitmann *et al.* 2008). These signals cluster towards the end of the 8<sup>th</sup> millennium calBC, and are thus contemporary with the terminal Early Mesolithic across Europe (e.g. Gehlen 1999; Crombè and Cauwe 2001; Street *et al.* 2001). Quite well known is the fact that, across Europe, the Late Mesolithic with its characteristic li-

thic inventory makes its appearance in the following centuries. Unfortunately, the exact first appearance of this ‘blade-and-trapeze-horizon’ cannot be dated with the necessary accuracy, due to a plateau in the <sup>14</sup>C-curve (Gronenborn 1997a). Moreover, exactly how trapezes and the effects of IRD 6 may be linked is another problem. Any postulations are currently mere speculation – the entire range of the Early-to-Late-Mesolithic transition is only coarsely researched, and the necessary information from Eastern Europe and the Russian steppe zones is spotty. But what should also be taken into account when approaching this complex set of questions is the expansion of pottery from Eurasian centers across eastern Europe (Gronenborn 2003; *in press b*; Dolukhanov *et al.* 2005), with its earliest appearance around Samara (Vybornov 2008). Both trapezes and ceramics spread west-ward and may have their origins somewhere in Central Asia or further east (e.g. Brunet 2002). Future investigations should focus on the possible connections of this general westward drift and the climate fluctuations towards the end of the 8<sup>th</sup> millennium. Equally unclear is the situation for the 7<sup>th</sup> millennium calBC: Crete seems to have been settled by Neolithic farmers during the earlier half of the millennium (Efstratiou *et al.* 2004), but the early phases of IRD 5a setting in around 6500 calBC appear to

be contemporary with current models of the spread of farming to Western Anatolia and Central Greece (e.g. *Perlès 2003; 2005; Lichter 2005; Reingruber 2008*). During these centuries, evidence for the possible appearance of cereals across Temperate Europe appears (*Gehlen and Schön 2003; Tinner et al. 2007* – but for a critique see *Behre 2007*).

The 8.2 ka-event is part of IRD 5a (*Heiri et al. 2004*). Culture change-climate fluctuation interrelations for this phase are better researched; it marks the spread into the Balkans and southeastern Central Europe (*Weninger et al. 2006; Bonsall 2008; Budja 2007; Gehlen and Schön 2005; Berger and Guilaine 2009*). During the 6.2 ka-event, long-distance contacts existed across temperate Europe, connecting the transitional Late Mesolithic societies of temperate Europe with early farmers in the South-East (*Gronenborn 1999; Mauvilly et al. 2008*). After IRD 5a/8.2 ka, farming societies also appear in Turkmenistan (*Harris et al. 1993*) and in the Caucasus (*Chataigner et al. 2007*). IRD 5b sets in around 5700 calBC and ends relatively abruptly around 5100 calBC with the 5.1-event (*Strien and Gronenborn 2005*). With these outer margins it covers more or less the entire extension of the LBK (*Gronenborn 2007a; Dubouloz 2008*). Particularly the end is contemporaneous with the shift to the Middle Neolithic with the Hinkelstein Group in the West, the appearance of Stichbandkeramik (STK) in central parts (*Zápotocká 2007; Jeunesse and Strien 2009*), but also of Proto-Lengyel/Lužianky further East (*Pavúk 2007*).

In the western Mediterranean, the Neolithic apparently starts around 5800 calBC (*Manen and Sabatier 2003*). This type of Neolithic seems to have been introduced by small settler communities thought to originate in Liguria, where the earliest dates center around 6000 calBC (*Guilaine and Manen 2007*). The Cardial might have started at, or somewhat earlier than 5350 calBC (*van Willigen et al. 2008*), but a date of 5600 calBC is equally discussed (*Guilaine and Manen 2007*). Early dates in North Africa indicate the arrival of the Neolithic economy there around 5600 calBC (*Linstädter 2004*), but technological innovations possibly originating from the African continent are thought to have reached the southern Iberian peninsula towards the latter sixth millennium calBC (*Manen et al. 2007*). The somewhat complicated and intensively debated situation in the western Mediterranean makes it currently difficult to come to any robust conclusions about possible links to climate fluctuations, but for the 8.2 ka-event at least hypotheses may be formulated, and lately

IRD events where found to have had an influence on sedimentation rates of fluvial systems in Morocco and Tunisia (*Zielhofer et al. 2008*).

IRD 4 sets in around 4400 calBC and terminates around 3200 calBC with the so-called Piora II/Rotmoos II cold phase, or CE 6 in the Alps (*Haas et al. 1998*), the event which might have led to the conservation of the Similaun glacier mummy (*Magny and Haas 2004*). IRD 4 is the most extensive of all IRD phases, covering more than 1000 years, but the <sup>14</sup>C-Production curve shows several marked peaks, the first around 4200 calBC, the second around 3600 calBC (Fig. 2). These correlate with terrestrial markers in the River-Main oak curve (*Spurk et al. 2002*) and possibly rainfall patterns in the Eifel (*Gronenborn and Sirocko 2009*). The onset correlates with the shift from the Middle Neolithic to the Upper Neolithic (Germ. Jungneolithikum), notably the Michelsberg Culture in Western Europe and western Central Europe and Boleraz 2 and Baden in the Southeast (e.g. *Eisenhauer 2002; Jeunesse et al. 2004*). With Trichterbecher (TRB) in the North and Northeast, IRD 4 also covers the spread of farming to northern Europe (*Karlén and Larsson 2007; Larsson 2007; Hartz et al. 2007*) and the British Isles (*Sheridan 2007; Whittle 2007*).

The contemporaneity of climate fluctuation phases and shifts in the spread of farming are evident on a coarse scale of chronological resolution of one to several centuries on a supra-regional level. Particularly striking is the Temperate European situation, with IRD-events 5 and 4 being contemporaneous with the two major shifts in the Neolithization Process (*Gronenborn in press a*). For further evaluation of any possible correlations, the next step has to be to 'zoom' into the chronologies, down to the level of decades or below where possible (dendrochronology), and to compare local and regional fine-resolution archaeological chronologies with local and regional fine-resolution proxy-data age models. This has already been attempted for some periods and regions, such as the 8.2 ka-event (see above), but also the expansion and the end of LBK in the years following the 5.1-event (*Schmidt et al. 2004; Strien and Gronenborn 2005; Dubouloz 2008*), or the 37<sup>th</sup> century calBC, which might have had an effect on the end of Michelsberg (*Gronenborn and Sirocko 2009; Schibler et al. 1997; Seidel in press*). But the general and historically most important question as to how IRD events affected humans and their modes of subsistence on the ground is still poorly researched. This may first and foremost be due to the scarcity

of studies integrating local and regional terrestrial data from archaeobotany, geology, sedimentology or archaeology with supra-regional or hemispherical marine and solar proxy-data. Often, only very general assumptions are phrased – as in this paper – or possible relations between the different levels and scales are simply not discussed. Hence, at this point, questions around the actual effects of IRD events for humans on the ground are rather difficult to address. In any case, these effects are not expected to be homogeneous, but highly variable in time and space. General trends may be a cooling of summer temperatures, as has been suggested as a result of melt-water flux for the early and mid-Holocene (Heiri *et al.* 2004), and as is also visible in some of the proxy data shown in Figure 2. However, it must be kept in mind that the period in question experienced the warmest temperatures during the Holocene (Wanner *et al.* 2008) and thus any relative cooling must be seen against this background.

Also helpful in understanding how IRD-event phases may have directly and indirectly affected human societies may be a look at the historical climatology of the Little Ice Age (LIA). Such analogical endeavors are based on the assumption that the LIA may be equaled with IRD 0 (Bond *et al.* 2001), or at least resemble an IRD-situation; there are, however, problems with this general assumption, as the climatic effects of LIA seem to be composed of a number of unique late Holocene orbital and terrestrial forcings not entirely comparable to earlier periods (Wanner *et al.* 2008.1819). However, one particularity of the LIA may be worth considering, namely the greater rate of anomalies with more pronounced amplitudes (Bradley and Jones 1993; Pfister 1999; Luterbacher *et al.* 2001); this seems to have been particularly the case in the transitional phases from the Medieval Warm Period to the solar minima (Glaser 2001.209). Also, spring seasons appear to have been affected

most during these transition phases (*ibid*; Luterbacher *et al.* 2001.442).

### Extreme anomalies during IRD phases – situations of increased socio-political unrest?

It may indeed have been those particularly extreme anomalies, or series of anomalies, which had the most consequential effects on Neolithic societies. A simplified scenario extracted from a model constructed by Pfister and Brazdil (2006) for the effects of the Little Ice Age may be helpful here (Fig. 3). It was adapted to the tribal societies of the Temperate European Neolithic, where long-distance transport of food-stuffs or state-level aid for impoverished, crisis-stricken groups and regions would have been non-existent. Neolithic – or Mesolithic – responses to external, non-human and human threats were organized on a local, at best a regional level in complex chiefdoms (Earle 1997). External climate or weather-induced shortages would have resulted in almost immediate economic and socio-political reactions as societies destabilized. Simple agrarian economies might not have been able to subsist for more than two to three years on the basis of stored foods. Relatively rapid changes in food-obtaining strategies would have been the result of shortages, but such economic changes should have also left traces in the forms of political organization. Established forms of organization, based on established economic systems, would have been shaken when harvests failed (*e.g.* Anderson *et al.* 1995 for tribal societies in woodland environments). Economically and socio-politically destabilized societies would have drifted into phases of segmentation and political cycling. Violent conflicts could well have been the results of such destabilization phases (Milner 1999; Gronenborn 2007; Zhang *et al.* 2007). With more stable – as a homage to processualism, here termed ‘equilibrium’ – conditions returning, societies would have re-organized

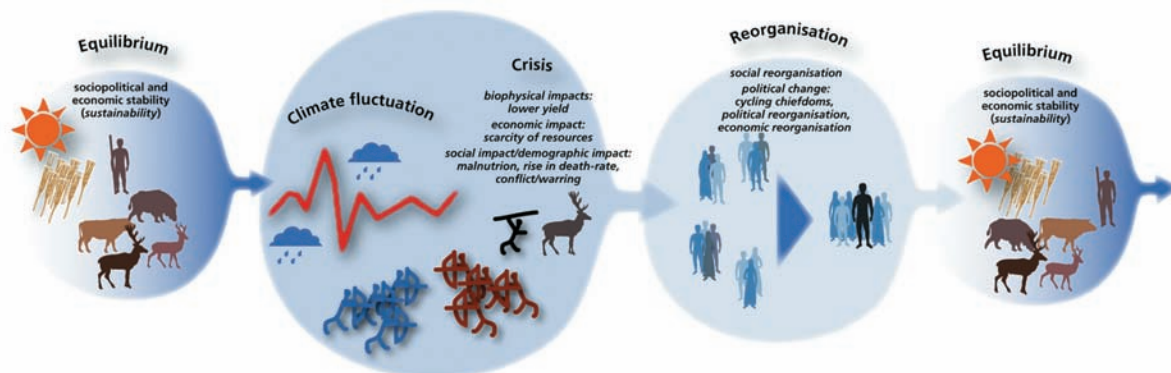


Fig. 3. Simplified scenario of climate-induced culture change in pre-state societies (modified after Pfister and Brázdil 2006.118, Fig. 2).

and adapted to the new situation (*Adger 2003*). Apart from violent conflicts and/or sociopolitical reorganization, societies might also have responded to stress situations with migration. Such phases of increased mobility have, for instance, been suggested for the 8.2 ka-event (*Clare et al. in press*).

This simple – indeed somewhat simplistic – model of a one-off, single-incidence fluctuation can nevertheless be taken as a basic module of what in reality are much more complex scenarios (*e.g. Redman 2005*), where eventually it needs to be embedded; but it helps to underline the effects of climate fluctuations on the non-state-level of simple agrarian or complex hunter-gatherer societies.

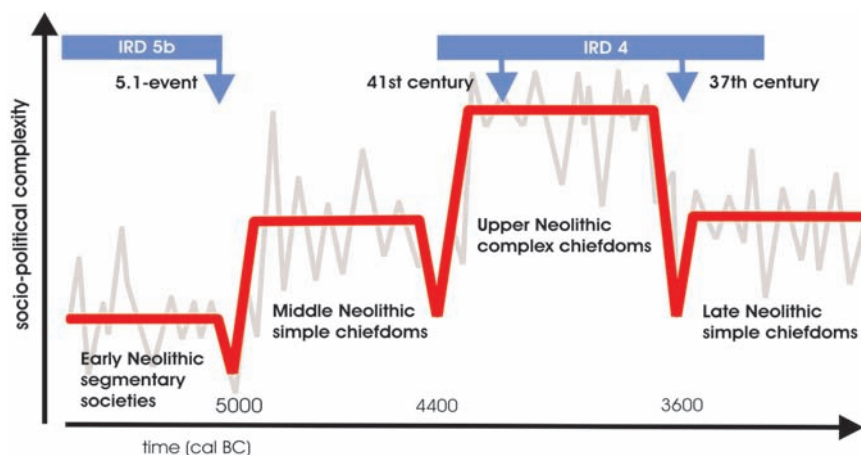
Thus, as a working hypothesis, apart from periods of generally cooler and moister conditions, IRD-event phases may also be understood as periods during which an increased rate and intensity of climate fluctuations occurred. The latter effect in particular might have had a greater impact on human societies and would have resulted in periods of increased socio-political unrest.

### Trajectories to complexity? An example from southern Central Europe

Such periods of increased socio-political unrest and economic instability may not only be seen as periods during which societies collapsed, but also as turning points during which societies reorganized and eventually evolved into more – or less – complex political entities (*e.g. Anderson 1994; 1996*). If we look at the history of cultures of the southern Central European Neolithic during the period between 7000 calBC and 3000 calBC, the succession of archaeological cultures may also be tentatively understood as a succession and cycling of stages of socio-political complexity (*Fig. 4*). The terms applied here derive

from classic neo-evolutionism and are applied solely for this first hypothetical model, which only coarsely depicts the historical processes. Certainly, any actual variation or shifting levels of complexity will be much more differentiated and eventually better described with more appropriate terms which may relate better to the specific conditions of temperate European societies (initial discussion in *Gronenborn 2006*). Nevertheless, for the time being, the terminology applied in *Figure 4* may suffice: Late Mesolithic socio-political scaling is not depicted, but the Early Neolithic (LBK etc.) may – in neo-evolutionary terms – be described as ‘segmentary societies’ which then evolve into more complex ‘chiefdom’-type entities with the onset of the Middle Neolithic. With the beginning of the Upper Neolithic (Germ. Jungneolithikum), southern Central Europe undergoes a further shift towards complexity, which in the French literature (*Coudart et al. 1999*) is subsumed under the term ‘chalcolithisation’. With the termination of Michelsberg around 3600/3500 calBC, societies seem to collapse into less complex entities, which dominate the political landscape of the Late Neolithic in southern Central Europe.

When this simple scheme is compared to the climate proxy-data from *Figure 2*, certain fluctuations are contemporaneous with the suggested socio-political turning points. This may, of course, be simply coincidental; however, the apparent synchronicity and regularity with which climate fluctuations are intertwined with cultural trajectories warrants future closer examination. Specifically, these cultural turning points need to be investigated in order to come to a better understanding of the dynamics of Neolithic societies in southern Central Europe and elsewhere. To sum up: what I have attempted to present is a simple working hypothesis as part of a theory yet to be developed – it concerns the emergence and spread of farming, as well as associated socio-political chan-



*Fig. 4. Schematic (light grey line) and smoothed (thick red line) socio-political trajectory for southern Central European Neolithic societies with selected schematic prominent climate phases and events (not to scale).*

ges, and is based on archaeological and palaeo-climatological empirical observation.

I posit that Early to Mid Holocene climate fluctuations affect farming, but other innovations like pottery, perhaps, spread across western Eurasia, and these fluctuations also had an effect on socio-political dynamics. The effects varied greatly across the continent and in time, as the actual impact of the fluctuations differed, but societies also underwent considerable transformations. Generally, within the frame of this hypothesis, the spread of the Neolithic – but also the emergence of farming, perhaps – is seen as having been paced by crisis periods which led to an amplification of socio-political dynamics, such as political cycling and/or migrations. This hypothesis is based to a certain degree on climatic determinism, but only in so far as it regards long-term climate development as a component in a complex interplay of diverse internal and external factors.

Current field projects aimed at validating the above hypothesis focus on regional and local fine-grained studies of the interrelation between climate, environment and human societies in southwestern Central Europe (e.g. *Gronenborn 2007; Bleicher in press; Regner-Kamlah 2009*). Of course, the envisaged theory may be developed further in any other study area across western Eurasia.

### Beyond fieldwork

Archaeologically and economically based theories about the emergence and spread of the Neolithic and the associated socio-political changes have been formulated for more than a century (e.g. *Benz 2000; Scharl 2004; Weisdorf 2005*), and climate has often played a role in these endeavors (*Gronenborn 2005*). What has so far not been formulated in the archaeologies is a hypothesis like the one presented above, in which the overall process of the spread of farming across western Eurasia is connected with the entire sequence of Early- to Mid-Holocene climate fluctuations in the North Atlantic realm. However, outside archaeology, *Wirtz and Lemmen (2003)* transformed archaeological knowledge into a mathematical model which entails Holocene climate fluctuation cycles. The model reproduces the emergence and spread of farming worldwide. The spread of farming in western Eurasia is particularly well represented. Further results of this – in the archaeologies, so far largely unnoticed – study may be subsumed as follows: the major factors for the spread of the Neolithic are continuous innovation and competition bet-

ween resource strategies; population pressure is a less prominent agent – climate fluctuation expressed as food extraction potential determines the rate and pace of migrations, and on a global level may also account for the time lag in the emergence of farming between the Americas and Afro-Eurasia. The latter result is further refined in newer model versions (*Lemmen and Wirtz in press*): climate fluctuations delay the onset of farming in the respective centers – the Fertile Crescent and Ecuador were selected – with increasing intensity, but they do not prevent the onset entirely.

Such simulation studies – so far, rarely applied in any of the historical sciences – will in the future be mandatory to test archaeologically formulated hypotheses. They may become increasingly valuable in assessing complex archaeological-palaeo-climatological models such as the one presented here. The first results formulated by *Lemmen and Wirtz* already indicate the potential: rather than arguing for simple climate-determined trajectories, the model indicates that while climate fluctuations under Holocene climatic conditions do have an impetus on cultural trajectories, this impetus does not fully explain the process. The model studies show that, rather than looking for simple, triggered, push or pull mechanisms, future investigations will have to consider the manifold complex and diverse interactions between climate, environment and internal socio-political and interconnected economic processing constantly in operation. Apart from mathematical testing, future work will have to focus on the construction of detailed fine-grained histories of the immediate turning-points in cultural history. However, contrary to past post-processual ‘anti-climate’ paradigms, these theoretical approaches will have to regard climate effects on global, hemispherical, supra-regional, regional and local levels. Once a new ‘climate-friendly’ paradigm has eventually emerged, it may become intellectually challenging to conceive certain changes in the archaeological record – such as sudden shifts in settlement patterns or economic strategies – as cultural proxies for which adequate explanations may be sought in the palaeo-climatic archives (*Bleicher in press*). For many, such reasoning is still unthinkable.

### ACKNOWLEDGEMENTS

*I am indebted to Christine Chataigner, Lyon, for providing me with articles, which otherwise would have been very difficult to obtain. Bernd Kromer, Heidelberg, kindly permitted the use of the  $^{14}\text{C}$ -production rate curve in Figure 2.*

## Appendix

### Sources for Figure 1

#### *Climate proxies*

GRIP  $\delta^{18}O$ : *Shackleton et al. 2004*; GDO: *Leuschner et al. 2002*; Cold events Alps: *Haas et al. 1998*; Main River oak anomalies: *Spurk et al. 2002*; IRD events: *Bond et al. 2001*; Monsoon proxy Arabian Sea: *Overpeck et al. 1996*; Dead Sea level: *Migowski et al. 2006*.

#### *Farming-spread chronozones/archaeological cultures*

British Isles: A. Whittle, pers. information; interpolation by author; early Funnel Beaker Culture: *Midgley 1992*; later LBK/Villeneuve-Saint-Germain/Augy-Sainte-Pallaye: *Lüning 1988*; *Jeunesse 1998–99*; earliest LBK/La Hoguette: *Gronenborn 1997b*; early cereal horticulture: *Erny-Rodmann et al. 1997*; *Jeunesse 2003*; Cucuteni-Tripolye/Bug-Dnestr: *Kozłowski 1993*; Impresa/Cardial: *van Willigen 2006*; Italian

Impresa: *Fugazzola Delpino, Pessina and Tiné 2002*; Balkanic Early Neolithic (Starčevo-Körös-Criş; Greek Middle Neolithic): *Kalicz/Virág/Biró 1998*; Greek/Bulgarian Early Neolithic: *Böhner and Schyle 2008*; Djeitun: *Harris et al. 1993*; Georgian Neolithic: *Chataigner et al. 2007*; West Anatolian Early Neolithic/PPNA/Incipient Neolithic/Neolithic core zones: *Böhner and Schyle 2008*; *Willcox 2005*.

### Sources for Figure 2

GRIP: *Shackleton et al. 2004*; Ammersee: *von Grafenstein et al. 1999*; Eastern Alps temperature/glaciers: *Nicolussi and Patzelt 2006*; Cold events Alps: *Haas et al. 1998*; Main River anomalies/deposition rate: *Spurk et al. 2002*; ELSA stack greyscale: *Sirocko et al. 2005*; GDOs: *Leuschner et al. 2002*; IRD events: *Bond et al. 2001*;  $^{14}C$ -production rate: *Kromer and Friedrich 2007*.

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