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Climatic and Coastal Evolution During Little Ice Age: some considerations
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CLIMATIC AND COASTAL EVOLUTION DURING LITTLE ICE AGE: SOME CONSIDERATIONS*

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Abstract

Modern Age (1453-1789) coincides approximately with a time of low temperatures through most of the world, a period called Little Ice Age (LIA). So, much of the ports history during this time must be understood inside a framework of a cold period, with river discharges, sea level, possible coastal advance and estuaries evolution that may be, in some sense, the opposite of the situations that we face today. Our main objective is to emphasise this idea because we believe that it may be a clue for the understanding of seaports evolution during that time.

Natural circumstances are interrelated with the man's influence modifying them (agricultural practices, forest exploitation, river embankment and dam's construction).

For these reasons the correct investigation must not rely merely on a deductive model approach. However, the utilisation of this inferential approach may be helpful, awaking new ideas and hypothesis that may guide the necessary historical investigation.

1. Introduction – About Little Ice Age

The Little Ice Age (LIA) was a period of cooling lasting approximately from the 14th to the mid 19th centuries[2].

The beginning of LIA is still object of discussion and its limits are quite variable according to different sources. This happens partially because of the difficulty in reconstructing past temperatures. Instrumentally measured temperatures were widely used only since 1850, so they didn't exist in the beginning of LIA[3]. Because of that, all the limits that we established are somehow artificial and prone to revision.

In addition, climate can vary continuously in time and space (Jones & Briffa, 2001). For instance, Barlow (2001) points out a significant discrepancy of LIA onset between Greenland and Europe. In Greenland LIA began earlier, around 1350.

It seems that LIA had its deepest temperatures in Europe during the 17th century while in North America the coldest period seems to be during the 19th century (Grove,

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[2] http://en.wikipedia.org/wiki/Little_Ice_Age

[3] http://en.wikipedia.org/wiki/Historical_temperature_record#The_quasi-global_period:_from_1850

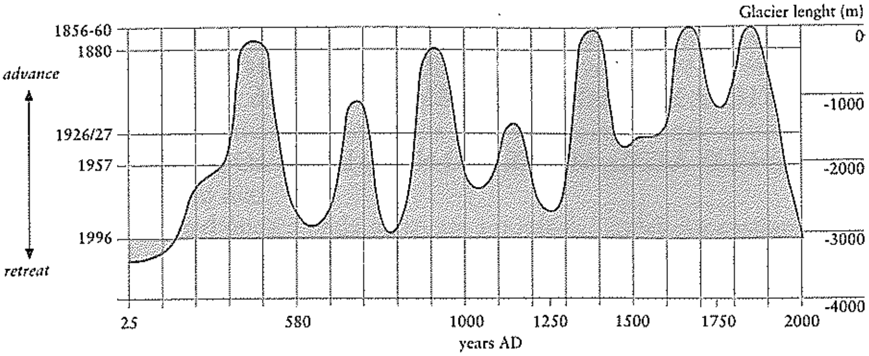

Fig. 1: Fluctuations in the length of the Grosser Aletsch glacier (the Alps, Switzerland) in the last 2000 years. Source: Brádzil et. al., 2005

2001). Besides that, the same episode may have meaningful climatic differences in different areas. It is the case of MWP in the south and North of Europe: it seems that Doñana Park had a drier climate during MWP and a wetter climate during LIA and this precipitation characteristics were more important than temperature issues in LIA climate definition (Sousa & García-Murillo, 2003).

Therefore, it is not a simple task to define the boundaries of his period, as temperature variation was rather complex with several highs and lows. In fact, it is easier to define LIA in opposition to the surrounding periods: MWP and modern warm period. However, though the variation is quite complex, it is possible to find a meaningful contrast between the average temperatures during Medieval Warm Period (MWP) and LIA (Grove, 2001).

We can define MWP "as the period between the 10th and 14th centuries when global temperatures were about 1.0°C warmer than present" [4]. According to the first International Panel for Climate Change (IPCC) report, medieval temperatures were considerably higher than recent temperatures. This seems to be true also for the NW Iberian Peninsula (Martinez-Cortizas et al., 1999).

After Medieval Warm Period, began a period of cooling. That period is designed as Little Ice Age (LIA) and can be characterised by several advances (including minor retreats) of the glaciers (Brádzil et. al., 2005).

Little Ice Age can be defined as a time interval of about 330 years (c. AD 1570–1900) when Northern Hemisphere summer temperatures fell significantly below the AD 1961–1990 mean. This episode was also characterised by a stronger snowfall in winter and both facts are responsible for a general advance of alpine glaciers (Matthews & Briffa, 2005).

The beginning of LIA was not very well defined. However, its end is quite clear: after 1850, temperatures began climbing arriving to the actual warm period.

Even considering that the correlation between different proxies is sometimes haz-

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[4] http://www.co2science.org

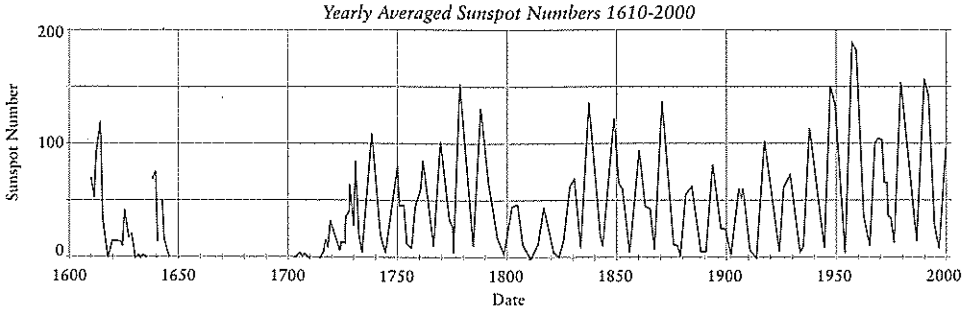


Fig. 2: Sunspot number during the last 400years.
Source: Wikipedia: http://en.wikipedia.org/wiki/Image:Ssn_yearly.jpg

ardous and the fact that MWP and LIA evidences are not contemporaneous world-wide it seems that both the Little Ice Age and Medieval Warm Period "have been climatic anomalies with world-wide imprints"(Soon & Baliunas, 2003).

2. Possible causes of climate change during the last millennia

According to Mörner (1993) most of climate and sea level changes "represent the redistribution of heat and water masses via the ocean current system". However, "solar effects are not ruled out, especially during the periods of sunspot minima".

In fact, there are striking similarities between climate evolution during LIA and a very meaningful drop in the sunspot number (fig 2). Two periods can be distinguished easily: the Maunder Minimum is the name given to the period roughly from 1645 to 1715 A.D., when sunspot became very rare, as noted by solar observers of the time. The Dalton Minimum was a period of low solar activity, lasting from about 1790 to 1820.

Besides orbital parameters pointed out by Milankovitch since 1941, many scientists believe in the influence of solar irradiance, at several timescales. One of the most discussed is the 11-year cycle (Schwabe cycle, Oldfield, 2005). The solar irradiance variation is quite small (about 0,08% within the 11 years sunspot cycle, Oldfield, 2005). The principal question remains in how a small amount of radiation variation can induce all these consequences. However, as the biggest augmentation due to sunspots stays in the ultraviolet range, its absorption at the stratosphere can produce important modifications on global circulation at troposphere level.

Svensmark and Friis-Christensen (1997) demonstrated a high degree of correlation between total cloud cover and cosmic ray flux between 1984 and 1991. The mechanism is quite complex but can be described in a simple way: when the Sun is more active (more sunspots), the magnetic field that is carried by the solar wind intensifies, pro-

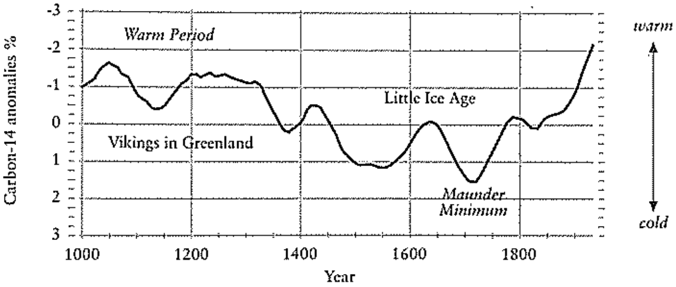


Fig. 3: Changes in 14C production over the past 1000 years relative to 1950. The negative 14C anomalies correspond to high solar activity periods. The positive anomalies correspond to low solar activity periods. The Medieval Warm Period and the Little Ice Age are clearly discernible. (Source: Svensmark, 2000).

viding more shielding of the earth from low-energy galactic cosmic rays. This effect may lead to a decrease in ion production in the lower atmosphere, possibly resulting in the creation of fewer cloud condensation nuclei and less low-level cloud cover.

This phenomenon also influences 14C production: the interaction of cosmic ray particles upon the atmospheric gases produces 14C. Solar wind intercepts cosmic rays: thus, variability in 14C production is mainly a result of changes in solar activity. High solar activity leads to stronger shielding from the solar wind and thus a reduction in the 14C production rate. Confirming the correlation between these different processes, at fig. 3, we can see that 14C anomalies have a negative correlation with temperatures.

Solar forcing is no doubt a large field of possibilities to be explored: even the scientists who think that solar forcing is not a dominant cause of 20th century Northern Hemisphere warming and insist on a anthropogenic causes agree that it could produce a very significant forcing of pre-industrial climate (Damon & Peristykh, 2005).

Because of all the obvious implications in politics, climate change is a delicate field of work. Much of it is still controversial science. Within a controversial science framework, the opinions are sometimes clearly divergent. The most important is to keep an open mind on these subjects trying to listen to both side arguments.

Therefore, even if the conclusions are still uncertain it is important to open the discussion to discuss the scientific mainstream on these subjects. The subject clearly deserves to be pointed out beyond the scientific discussion and controversies, because the misinformation and the catastrophic views are impregnating much of the discussion on these themes.

[5] http://www2.sunysuffolk.edu/mandias/lia/little_ice_age.html

3. Climate characteristics and Geomorphologic consequences of LIA

During the LIA cooling of the climate, glaciers in many parts of Europe began to advance (fig. 1). Glaciers negatively influenced almost every aspect of life for the people living in their path. Glacial advances throughout Europe destroyed farmland and caused massive flooding. There was a high frequency of storms. As the cooler air began to move southward, the polar jet stream strengthened and followed, which directed a higher number of storms into Central Europe. Large hailstorms occurred over much of Europe due to the very cold air aloft during the warmer months[5].

For our purposes, it is most important to notice that the LIA was accompanied by a greater frequency of floods. It seems that the same situation was happening at the Mediterranean areas. Grove (2001) refers the existence of great floods in places so far away as Setúbal, Bordeaux and Rome during the winter 1694-95. This situation should be responsible for a greater discharge on rivers and that could lead to a greater transportation of sediments until the coastline. The augmentation of snow or rain during winter could increase floods and the rivers would carry more sediment. Some of it should be deposited inside intramountain basins or piedmont plains. After LIA, the transition to a less resistatic climate (Ehrardt, 1956) would imply the down cutting of previous deposited sediments transforming these old sediments into fluvial terraces. This sediments are generally designed as the "younger fill" (Grove, 2001) and they are a typical occurrence of circum-alpine areas.

Deltas were also advancing and during 1604 Venetian authorities tried to alter the Po River valley, dragging its mouth to the south to prevent a further silting of Venice lagoon (Grove 2001).

Due to strong winds, great sand storms acted upon coastal land regions, redistributing through the coastal areas the increased sediments brought to the littoral by the rivers. This increase in dune construction can be traced also in Portugal. In the northern coast, near Esposende, a medieval cemetery is covered by sand dunes. This shows an advance of coastal dunes after MWP (Granja, 1990)

Rodrigo et al. (1998) analysed climatic information in private correspondence of the Jesuit order in Castille (Spain) for 1634–1648. They showed prevalence of intense rainfall and cold waves in that period. Doñana Park also had a wetter climate during LIA (Sousa & García-Murillo, 2003), contrasting with a drier one, actually.

In Portugal, according to Alcoforado (1999), during Maunder minimum (1675-1715), the climate was not too different from today: there were a little more anticyclone conditions in winter and spring, producing a dryer climate.

This seems to be true also for other areas of Mediterranean Europe. According to Grove (2001), during Maunder minimum (1675-1715), the winters were mostly cold and dry, with the exception of 1690 that was quite snowy.

Still according to Grove (2001), the intensification of fluvial activity happened from 1250 to 1550 and from 1750 to 1900 in northern, western and central Europe.

Martins et al., (2006) showed the occurrence of muddy events from 2200-1200 years BP and after 500 Cal BP at Vigo's Ria in the NW coast of Iberian peninsula, about 30 km from Portuguese border: they conclude that these muddy events are a sign of contrasting climatic conditions. The last period corresponds to LIA and so, it seems that also in Iberian Peninsula, LIA was characterised by increased erosion on the inland and the transportation of sediments to the coastline.

In fact, Grove (2001) comparing the historical evolution of population density and the erosion features concludes that forest clearance issue is only a part of reasons to explain the increased sedimentation during LIA and according to him, the "younger fill" could have mostly a climatic origin.

4. Climate variation and sea level changes

Actually, we are in a period of slowly rising sea level. This happens because of thermal expansion of seawater and because of glaciers retreat after Little Ice Age. Mörner's curve (1973) shows precisely a rising sea level departing from a low around 1830, which coincides with Dalton minimum and one of the last cold advances of LIA.

This curve, constructed after the comparison of tide gauges from Stockholm, Amsterdam, Warnmünd (near Rostock, Germany) and Swinemünde (Polish coast, North of Stettin) proves the close relationship between climatic cooling, glacier advance and eustatic lowering, which can be recorded throughout the last 20,000 years (Mörner, 1973). It seems clear that LIA was a period of relatively low sea level.

According to this principle, as MWP was a warm period sea level must have been higher in MWP than during the subsequent LIA.

Van de Plassche et. al. (1998) studied the sea level in the last 1400 years for Hammock River marsh, Clinton, Connecticut. They conclude that it "correlates positively with large-scale regional variations in sea-surface and summer-air temperature, indicating a link between sea-level and the climate-ocean system". According to this research, "real sea level oscillated centimetres to decimetres on a century time scale over the past 1400 years". It was "25±25 cm higher ca A.D. 1050 (Medieval Warm Period) than ca A.D. 1650 (Little Ice Age)". This clearly agrees with Mörner's curve and it seems to be quite well established since the results are obtained from two continents: Europe and North America.

5. Coastal evolution: LIA versus modern situation

It seem quite probable that during LIA:

1 – Due to increased storminess, intense rain/snow could be responsible for an increased sedimentation along river valleys, creating the so-called "younger fill"(Grove, 2001). Downstream and inside the estuaries, a sea level drop will allow the sediments to migrate towards the sea, contributing to beach nourishment. The same reason should allow the rivers to cut its own deposits: close to river mouth, the river channels may be narrower and incised upon the abundant sediments that characterise that climate situation, forming river terraces, a reverse

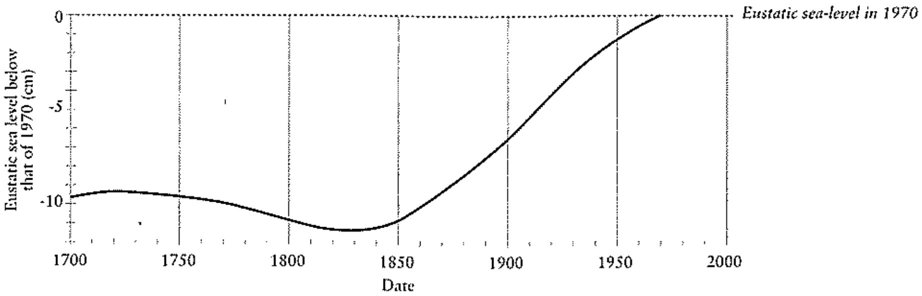


Fig. 4: Eustatic sea level changes from 1700 to 1970. According to Mörner 1973. Source: Pethick 1985.

of upstream situation, where "younger fill" sedimentation should be the norm.

2 – The sediment transported to the coastline should be deposited in the coastal areas where they should construct wide beaches that strong winds could use as sources for building extended coastal dunes.

3 – Sea level should be a little lower than present. This could result into a sea retreat, abandoning older beach ridges, and reinforcing the sandy supply for dune building.

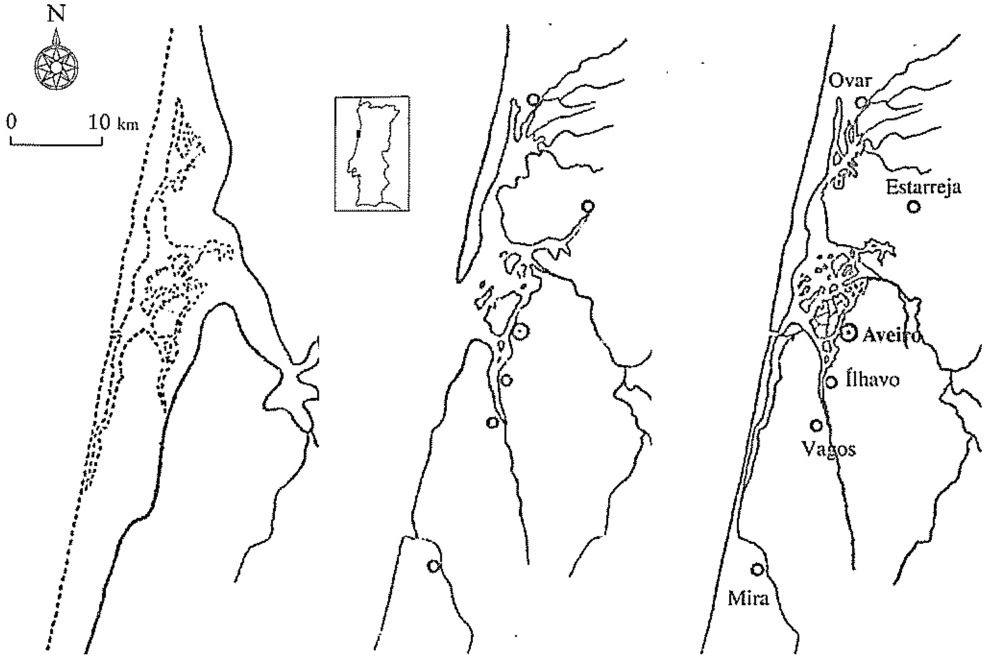
On the contrary, during MWP and the recent warm period:

1 – The rivers carry less sediment than during LIA. Consequently, having less sediment charge they will have the strength to cut older sedimentation areas, transforming them into river terraces, at least in the intermediate part of river channel.

2 – A sea level rise produces some infilling of estuaries because the rivers have not enough strength to carry their sediments into the sea. This also contributes to a coastal retreat because of lack in sediments available to littoral drift.

3 – The sea level rise produces a retreat of the coastline end the erosion of previous beaches and dunes.

The history of Aveiro lagoon shows a very fast (fig. 5) advance of the sand spit that encloses the lagoon. At 922 Ovar was still a sea harbour. At the end of XV century the sand spit was located at the latitude of Aveiro. At 1756 the sand spit stayed at Mira latitude and Aveiro port entrance was ca 28 km to the south of the city. Aveiro was dying because of a precarious connection to the sea and the lagoon, filled with non-renewed waters had serious sanity problems. The new port entrance was finally opened in 1808.



A: At the end of Flandrian transgression (ca. 5000. BP): the sea invaded lower Vouga valey, transforming it inta a "Ria".

B: At the end of XIV century: the spit was near Aveiro latitude.

C: Nowadays: the cutting of advancing spit was made by man action in 1808.

Fig. 5: The sand spit progression and Aveiro lagoon evolution. Adapted from Martins, 1949.

This means that from ca 1500 to 1756 (about 250 years) the sand spit moved about 28 km: a little more than 1 km each decade. It is important to underline that the sand spit fast movement happened during Little Ice Age when the increased storminess and rainfall could have brought a greater amount of sediments to the coastline. These sediments contributed to a rectification of the coastline that was presumably more irregular during high sea level periods (around 5000-6000 BP, Dias et. al, 1997), and also during MWP.

6. Some conclusions:

The more we move towards the past, the more difficult are the reconstructions of physical environment, and the more information and team work is necessary.

More than the deductions we presented it is important to know if the model really apply to the reality. The use of Hisportos database, with its rich cartographic fund can be a very important issue in order to analyse the real situations and finding out the possible connections between climate change, sea level change, coastal and port evolution.

That's one of the more important issues about Hisportos: the possibility of working together exchanging information and methodology between earth sciences and history sciences.:::

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