The impact of the Little Ice Age on Danish warfare in the 17th century

A historical climatological analysis of the impact of the Little Ice Age on the wartime economy of Denmark from 1550-1750

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Remarks

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Resumé & Abstract

English

The goal of this thesis is to analyze in what way the Little Ice Age, a colder climatic period between around 1300-1850, affected the development of the modern Danish state. This is though too large a scope for a single thesis and the wars between 1550-1750 have been chosen as an area of focus. These wars changed the geopolitical position of Denmark in the Nordic area, from a strong nation to a minor player. The worst outcome came, as Denmark lost all processions east of the Sound Strait to its rival Sweden in 1658, of which Bornholm was the only land area to return. These wars correlate to the Maunder Minimum, a period from 1645-1715, which was the coldest part of the Little Ice Age. In order to understand if there is a causation following this correlation, the main focus of the thesis will be the structural integrity of the Danish economy in pre-war and wartime periods. Two different economic spheres will be analyzed, the first being the Sound Toll income and the second the agricultural output. The Sound Toll do not seem to have a strong correlation to the cooling climate, and it does not seem that the colder winters decreased the income from the Toll. However, the agricultural output does seem to have a moderate correlation to the harsher winters of the Maunder Minimum, with a lower total output, thereby decreasing the ability of the State to increase taxation during wartime. It is also possible that the harsher winters increased the susceptibility of the society to epidemics. This master's thesis argues that there is a possible connection between the changing climate and warfare, especially in the period before 1660. After the change in government, from an aristocratic monarchy to an absolutist monarchy in 1660, the following wars were more manageable for the State, possibly due to better harvests.

Dansk

Dette speciale kaster lys over, hvilke måder at den Lille Istid, en koldere klimatisk periode fra ca. 1300-1850, påvirkede udviklingen af den moderne danske stat. For at afgrænse emnet, vil dette speciale særligt fokusere på den danske krigsførelse mellem år 1550-1750. Krigene i denne periode, typisk betegnet som svenskekrigene og Trediveårskrigen, ændrede Danmarks geopolitiske position i Norden. Fra at være et vigtigt land, som man i Europa inddragede i beslutninger, blev Danmark en andenrangs stat. Disse krige foregik lige før og under den periode, som kaldes *Maunder Minimum*, den koldeste del af den Lille Istid fra ca. år 1645 til 1715. Specialet analyserer om dette er et tilfældigt sammenfald, eller om de kolde, barske vintre, som var en del af *Maunder Minimum*, påvirkede krigenes gang gennem en påvirkning af Danmarks økonomiske fundament. To dele af økonomien er udvalgt, nemlig Øresundstolden og foldudbyttet fra de danske marker, og derigennem mulighederne for beskatning af landet. Gennem en analyse af Øresundstolden, bliver det tydeligt, at der ikke var en stærk korrelation mellem temperaturudviklingen og indtægterne fra tolden. Til gengæld ses der en moderat korrelation mellem temperaturudviklingen og høstudbyttet, især i forhold til midten af tidsperioden, og senere dele af perioden. Det er muligt at dette er grundet sammenfaldende udviklinger, så som epidemier. Specialet argumenterer for, at der er en mulig sammenhæng mellem det ændrede klima, og udfaldet af krigene, især i perioden op til år 1660. Med indførelsen af enevælden i år 1660, blev krigene mere overskuelige for staten, muligvis i kombination med stigende vintertemperaturer og øget høstudbytte.

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Part I

A climatic introduction

1. A world with a changing climate

The year started with the harshest and coldest winter, that any man in Denmark could remember

(*the start of 1608*)[1]

Denmark is not blessed with either beautifully cold winters, nor extremely warm summers. We live in an area which seems to have found a stability around lukewarm, even though we Danes love to talk about changes in the weather. However, this assumption of climatic stability seems unfounded on a larger time scale. For although anthropogenic mechanisms on climatic stability have played a role in the general development of the climate during the last 150 years, the climate changed greatly before that. Oscillating between very warm periods and much cooler periods, the landmass on which the nation of Denmark today is founded has been through many changes. This is seen in the deep chalk deposits at Stevns Klint (created when Denmark was under a tropical ocean) and the gentle rolling hills in the landscape (created when parts of Denmark were hidden under glaciers), to highlight a few of numerous examples.

However, geomorphology does not explain the history of human societies. Through history, Denmark has gone from the Vikings, to the Middle Ages to modern time, with great changes along the way. We are no longer the fur wearing, sword wielding, barbarians from the year 1000, ready to attack with our long boats (to point to an overused stereotype for pre-modern times). Nor are we the builders of great cathedrals, one of which, Roskilde Domkirke, always brings me back in time, to days long gone when on my way to classes at the university.

But what if climate and history could go hand in hand, and changes in the natural world around us meant changes in our society? This master's thesis will attempt to uncover the effects of the changing climate on the development of Denmark in present day. It will try to add one more dimension to our understanding of how history develops and why history changes. In order to do so, this thesis will analyze a period of great social and climatic change, the period from 1550-1750, focusing on one of the most defining parts of human society, warfare.

2. Problem statement

How did climate changes affect Denmark's ability to wage warfare in the period from 1550-1750?

[1] Speerschneider, C. J. H., & Institut, M. (1915). Om Isforholdene i danske Farvande i ældre og nyere Tid : Aarene 690-1860. Gad, p. 75

3. Motivation

The motivation for this thesis originates from many different experiences in my journey through the life of a student. Starting as a Bachelor, one of my greatest longings was to find out what drives history. Why is today not the same as yesterday, and why is it that I can be sure that tomorrow will be different from now? It became clear to me that history was not as neat and clean as one might hope. There is no simple device that drives history forward. At times the grand stories of development, as with the classical Marxist view of history, seemed plausible. And at other times it seemed as if life was random, with one event affecting the other by chance.

I have been fortunate in my quest for an understanding of time to be able to study my two passions; the history of people and the history of nature. Through my studies of history, I have met Vikings and Soviet soldiers, and much in between. I have been given the chance to see the many different peoples and societies before me and learned the marvels of reading a source for the first time and hearing voices from the past describe their thoughts and dreams. It is an experience I hope many others after me also receive.

Through by master's studies in geography I have learned the complexities and wonders of the natural world. Here, history became clay sediments and pond snails, some as old as 6000 years. Time received a new dimension, where thousands of years was the blink of an eye and a couple of million years was an acceptable margin of error. With this understanding of time, the borders of history were greatly expanded.

The natural world captured my imagination, with all its complexities and uniqueness. It is hard to describe the wonder of being the first person to hold clay that was deposited during the warming of the last Ice Age or measuring gytje from a former lake and imagining how the waters were full of post glacial biology. Although the methods of geography and the methods of history are different, the magic of science was, and is, the same. With my new historical and geographic glasses, the world around me changed. What once was an ordinary field in a classical Danish landscape, changed to being a question of which paths the water in the soil chose and how people in the Middle Ages must have been affected by the very same flooding that was making my boots sink into the clay rich soil. The gift of being able to study these two academic areas that both excite my academic mind, will never be forgotten.

The combination of the human and the natural sciences has balanced my core understanding of history and is the springboard for this thesis. I became, and still am, interested in how the natural world, which so often is forgotten when not in its extremes, creates a framework for our lives.

The main idea for this thesis came to me on the way home from work one day, after discussing with my students the importance of water management. An interesting programme came on to the radio station to which I was listening. What if the horrible war in Syria was partly due to a harsh drought in the region, brought on by modern climate change? What if the climate of the region played a noticeable role in the development of its history? The radio presenter made sure that this was not to negate the importance of the developments in the political sphere, with Al-Assad, the rebels, and ISIS; it was rather a way to deepen our understanding of which elements we as a community focus on in a conflict[2]. With this in mind, I wanted to go back in time and study how former communities dealt with change. The clear spatial choice was Denmark, as it is here most of my experience is, both historically and geographically, and the clear chronological choice was the Little Ice Age, as this seems to be the largest occurring modern change in the climate, before the changes of recent times.

[2] Kelley, C. P., Mohtadi, S., Cane, M. a, Seager, R., & Kushnir, Y. (2015). Climate change in the Fertile Crescent and implications of the recent Syrian drought. *Proceedings of the National Academy of Sciences*, *112*(11), 3241–3246.

4. Scale and scope

4.1 Historical time period

Historically the Little Ice Age (LIA) stretches from ca. 1300 to ca. 1850 A.D.[3], however this time period includes too much information to be properly dealt with in this thesis. This is especially true as the focus of this thesis is an understanding of the scope of the LIA, rather than a single event. Alone a single century in this period, with all its complexities and problems, could constitute an academic's life's work. My goal is therefore to do justice to the material, by choosing a smaller time frame stretching from ca. 1550 to ca. 1750, with a heavy focus on the period from 1600-1660, one of the coldest in the LIA and one with many changes to the state of Danish warfare. Three main aspects have laid the foundation for my choice.

The first is a heavy inspiration from Geoffrey Parker's theory in his groundbreaking 2013 book *Global crisis*: *war, climate change and catastrophe in the seventeenth century*. Parker argues, in an almost unjust simplification of his work, that "The fatal synergy that developed between natural and human factors created a demographic, social, economic and political catastrophe that lasted for two generations …"[4]. Part of Parker's goal is to study the instability with which the contemporary States answered the changing climate in the 17th century. This means focusing on internal dynamics within the States and discovering how they coped with the challenges presented to them. This fits well with the general history of Denmark, as the 17th century saw many Danish wars, including a number of catastrophic losses, a possible reaction to climatic pressure.

However, stopping at the shift to the 18th century can seem illogical when studying Danish military history and could give an ahistorical timeframe. Militarily, the 17th century is dominated by wars with Sweden. Continuing past Parkers timeframe is important in order to include the dynamics of the causation between the different wars and for finding the weight, if any, of the Maunder Minimum. In order to subjectively scale an event, other events must be found that can be used as a baseline. Not doing so could undermine an understanding of the events that laid the foundation for a particular war or series of wars. This could reduce possible explanations from other parts of scholarly history, thereby increasing a possible climatic determinism.

The final aspect in defining the relevant time scale for this thesis is the changing climate in Europe itself. The Maunder Minimum, from 1645-1715, is the coldest period in the LIA and therefore interesting when analyzing the

[3] White, S. (2014). The Real Little Ice Age. *Journal of Interdisciplinary History*, *XLIV*(3), 327–352.

[4] Parker, G. (2013). *Global crisis* : *war, climate change and catastrophe in the seventeenth century*. New Haven: Yale University Press, p. xxv

impact of climate on historical development, as it is possible that the most dramatic consequences are found here[5]. Caused by a reduction in solar activity, the period may have had large consequences on the early modern history of Denmark and presents an ultimately interesting dynamic. For example, only 15 years after the onset of the Maunder Minimum, Denmark changed its form of government from an aristocratic monarchy to an absolute monarchy. This could be purely coincidental, but should not be assumed as such. If climatic changes had an impact on warfare, and thereby the Danish state, this period of large climatic change should be visible. After finding when to look, the next step was defining where to look.

4.2 Geography

This thesis will focus spatially on the extent of the Danish kingdom in the 17th century, with a heavy focus on modern Denmark, however it will not focus on the lands formerly in the Duchy of Holstein nor the formerly Danish, now Swedish, provinces of Skåne (Scania), Halland, and Blekinge. The choice here is twofold. For the first, a lot of previous scholarly work exists for the spatial area of Denmark, however without a climatic focus. The northern part of the Duchy of Schleswig was not part of Denmark at this point and whereas Skåne, Halland and Blekinge were, scholarly work seems to have set its focus on the 3 large land masses of modern Denmark, Sjælland, Fyn and Jylland. Secondly, on a much more practical scale, much of the scholarly work on Denmark is in Danish, my native language, or English, and therefore accessible to me for purposes of study.

4.3 Terminology

While writing this thesis, it has at times been difficult to translate from the Danish historical material to English, while still retaining an understanding of the historical terminology. This becomes prevalent with both the administrative titles for Danish offices in the 17th century and the wars throughout the period. Partially, this is due to the specific system of the Danish state, as with many national administrations during the period and partially it is due to historiographical literature which has Danish as its main language. In order to give the English reader an understanding while still retaining an understanding for the Danish reader, Danish titles will be used when an English title would prove problematic. In order to show this system, Danish words will be set in italics with a rough English translation following in parenthesis. For example, when naming the war from 1563-1570 the title *Syvårskrigen* will be used with a following translation of (The Seven Years War). Although somewhat problematic and lacking in

[5] Mayhew, S. (2015). Maunder minimum. In *A Dictionary of Geography*. Oxford University

aesthetics, this system seems best at retaining one foot in the classical Danish historiography and one foot in the English language.

5. Methodology

5. 1 Works and sources

In order to understand the developments within this time period both academic works and historical sources will be used. However, the academic works will weigh heavily, as it is my goal to gain a greater understanding of the Little Ice Age, through many different aspects. It is therefore not within my timeframe to study each separate part of this thesis with primary sources alone. Simply said, it is my goal to have a great breadth of knowledge in my thesis, while leaving the depth to other scholarly works. This leaves a heavy focus on other academic studies, where luckily, there is a rich and thorough historiography to work from.

This thesis will also lean towards a more quantitative, rather than qualitative, approach to the subject matter. This may be a result of former geographic works, but it is also applied to help find normality in the time period. By applying a greater amount of numeric data, it is my goal to find tendencies which may be masked by the multiple human experiences within my time frame. An example may clarify:

I remember the winter of 2008-2009 as being very cold. As I biked along in Copenhagen, I was always freezing and as I studied in my apartment on Amager I had to wear a sweater to keep warm. However, the winter of 2010-2011 I remember as a mild and comfortable. This is most likely due to moving to a better insulated home and the imminent arrival of my first child. Using the qualitative data from my memory, 2008-2009 should be a colder winter than 2010-2011. However, the opposite is true. 2008-2009 had an average winter temperature of 1,5°C whereas the 2010-2011 had an average winter temperature of -1,3°C[6]. My recollection of the quantitative data is obscured by time and memories. However, this does not free quantitative data from problems. Firstly, the data may be wrong, which is always a problem. Secondly, the data may seem to correlate, however the causation may be assumed. The classic example of this is the fall in the stork population in Denmark and birth rates in the 20th and 21st century. From the start of the 20th century the amount of storks in Denmark collapsed from 222 in 1952 to 2 in 2004[7]. In the same period the birth rate in Denmark went from 77,251 to 63,465[8]. As both numbers are decreasing, well be it that the

[6] DMI. *Vejret i Danmark - vinteren 2012-2013*. Retrieved December 12, 2015, from http://www.dmi.dk/vejr/arkiver/maanedsaesonaar/vejret-i-danmark-vinteren-2012-2013/

[7] *Præsentation af den hvide stork*.. Retrieved December 12, 2015, from http://storkene.dk/default.asp?mainmenu=20

[8] *FOD8*: *Enkelt- og flerfødsler efter fødselstype*. DMI. Retrieved January 19, 2016, from http://www.statistikbanken.dk/10018

stork population decreases quicker, it could be concluded that a rise in the stork population would help the demographic future of Denmark by increasing the birth rate. What the numbers mask is the general rise of industrialization, increased agriculture, women's rights, the modern society's role on childbirth, and numerous other factors which are the real cause of changes in both data sets. This examples shows that although numbers fit together, their connection may be very different. Other than having an assumed mathematical correlation between two data sets, it helps if a correlation can be proven to be qualitative. Historian Dagomar Degroot notes as an example that there may be a graph that shows stronger easterly winds, and a graph that shows a decrease of sailing times in an easterly direction, however a true link can only be said to exist then there is a source that connects a stronger wind with a shorter travel time[9]. Sources will be included in this work to build these bridges between the data sets, when this is possible.

The question of scale also appears to be problematic. For much of the quantitative data is set to finding tendencies within large blocks of time, using smoothing to reduce awkward data points. However, a change in the historical data may need much shorter time. It is possible that the quantitative focus on tendencies, in order to reduce outliers, makes an annual viewpoint, used later in this thesis, challenging. However, a comparison between the quantitative and qualitative data seems to verify the usability of the quantitative data. Though it should be noted that it may be problematic making conclusions from the quantitative data set on an annual level.

[9] Oosthoek, J. (2012). *Podcast 46: Explorations in Historical Climatology*. ca. 13:30 into the podcast

6. Historiography of the Little Ice Age

6.1 The development of the Little Ice Age and environmental history

In 1939, Francois Matthes used the phrase "The Little Ice Age" to explain a period of glacial growth in modern times[10]. From there, the term changed to referring mostly to the period between the 16th and 19th century, though dating the period is difficult, in which winter temperatures decreased. Jean M. Grove aided in this understanding in 1988, by studying the changes in glaciers and pointed to some of the issues between climatology and history. Grove noted that "One wonders how many historians appreciate the cumulative and progressive nature of scientific research!"[11]. He also noted that research in this area was expanding greatly, but that historians did not always understand the complexities of the natural sciences, with the same phenomena giving different local variations, and that historians could end up being deterministic when understanding natural processes. Much has changed since then, and environmental history has grown to include many different areas, with many different academic backgrounds.

This thesis rests on the shoulders of these giants and its creation is in many ways only possible because of the many preceding years of solid historical work, of which this study trifles in comparison. Already in the 1970s-1980s, research was being done on the connection between climate and economy, even finding that there was no connection for certain areas[12]. However, these were not even the first of their kind. Fernand Braudel's grand work *La Méditerranée et le Monde Méditerranéen à l'Epoque de Philippe II* from 1949 started with "Part One: The Role of the Environment" and stated "Geography, like history, can answer many questions. Here it helps us to discover the almost imperceptible movement of history, if only we are prepared to follow its lessons and accept its categories and divisions[13]". This focus on nature and people has developed through time and still produces interesting results today. In 2015, Alan Mikhail wrote an enlightening article that linked the Icelandic Laki volcano's eruption in 1783 with the structural changes in Ottoman Egypt, and the slow loss of Ottoman Egypt to autonomy[14]. A combination that points to our continued connection with the natural elements we cannot control.

From the start of the academic study of history in Denmark, focus was on the kings and the Danish realm, with high quality analysis of the historical sources. These studies became an important part of the base work for an

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[10] Mann, M. E. (2002). Little Ice Age. *Encyclopedia of Global Environmental Change*, *1*, 504–509.
[11] Grove, J. M. (1990). *The Little Ice Age*. London: Routledge. p.416
[12] Grove, J. M. (1990). *The Little Ice Age*. London: Routledge. p. 416
[13] Braudel, F. (1995). *The Mediterranean and the Mediterranean world in the Age of Philip III*. New York: University of California Press, Ltd., p.23
[14] Mikhail, A. (2015). *Ottoman Iceland: A Climate History*. Environmental History, *20*(2), 262–284.

understanding of the developments of the state through time. It is thanks to these studies that it is possible to find a short but informative and thorough overview of the 17th century in Denmark. This was aided by a focus, starting early in the 20th century and stretching up to present day, on the agricultural background of the nation of Denmark. Techniques, outputs and administrative structures were important and discussed. In many ways, this form of environmental history seems to reflect the older Marxist tradition of a backdrop to history, with a focus on structure and systems. This is both wonderful and problematic, but it may be that the swing towards environmental histories neo-structural focus represents a challenge to the discourse based studies of my early university years. This will be an interesting development to study, though it should be noted that environmental historians do not lie in the majority.

Unfortunately, not all areas of history receive the respect they deserve and military history in Denmark has not always been seen as a legitimate area of study for a historian. Personal experience exemplifies this. When presenting my Bachelor thesis, I was advised not to focus on the military aspect of the Soviet war in Afghanistan. At times it has seemed that wartime history is a populist form of history, which should be left to armchair generals and former soldiers. Thanks in part to a small number of talented historians, the history of warfare in Denmark is gaining the respect and understanding that it deserves.

With the many years of academic research as a foundation, this thesis now will analyze the different ways the Little Ice Age has been studied.

6.2 Four different views of climate and society

In order to better understand the multi-disciplinary nature of historical climatology, the scholarly work can be divided up into four categories, with caution for the multitude of grey areas. These different views reflect the different approaches used to understand a similar subject.

The first method is a natural science approach to the LIA, using methods and theories from the world of the natural sciences. In this category, one can find climatic reports and model studies of the environment within the LIA (as used in chapter 7 *What Caused the LIA*). Literature in this category can be of a more global scale, rather than regional, and serves to examine the period as a whole. This category can be useful when trying to determine what happened, how it happened, and how extreme an event was. However, the category focuses on inhuman aspects of the period, and there is not a large focus on the mechanisms used (or not used) by early modern societies to counteract possible changes. Roughly stated, this approach poses the following questions: has the climate changed, and if so by how much? The arguments within the articles are based on the natural sciences and focus on the credibility of the models and data used, rather than historical sources. Therefore, this approach is not always concerned with if a change had an effect on human society. It is quite plausible that a changing climate can be discovered, without it having an impact. However, this approach is very important when understanding the LIA and its dynamics.

This approach can have its shortcomings when it does try to explain social events. In a form of fall back to the days of mathematical history, where correlations and numbers could explain developments, some of the articles on climate change and social development, in this case war, can be questioned from a historical viewpoint. In the article *Positive correlation between the North Atlantic Oscillation and violent conflicts in Europe* Harry F. Lee, David D. Zhang, Peter Brecke and Jie Fei note the correlation between the cycles of the North Atlantic Oscillation, explained later in this thesis, and wars in Europe. They conclude that the two seem to correlate somewhat for the southern European and the Mediterranean region[15]. They note that wars have many social causes and note the deterministic notion of their work, however it does appear that in this form of mathematical/correlation history, social history becomes a byproduct. This viewpoint may cause a couple of problems, seen from a historical viewpoint. Firstly, it should be remembered that the human understanding of an event is just as important as the objective truth. In other words, even if a period of time is objectively the coldest period, if the narrative of the period does not include the "poor" weather, if may be unimportant. Secondly, as always with correlations, we may be seeing two different cycles that oscillate in unison, but unaffected by each other. Thirdly, some of these reports use the past to predict the future, in a form of "the past will repeat itself" understanding. This can be problematic as it assumes a circular pattern in historical time, whereas history may not always be as simple as this. In the broader historical timelines there may be comparisons, however when applying a closer look the importance of individual events become clear.

The second method to the LIA is a historical approach that involves an acceptance of the LIA as a cooler climatic period and makes a connection between the cooler climate and a negative period of development. Here the human response is included in the argument and the scholarly works of the first category, the natural science category, are used as a base for the conclusions of the human response. The climate receives a more subjective dimension, as certain events are connected to, or removed from, data. The book *The Little Ice Age*: *How Climate Made History 1300-1850* from 2000, by Brian Fagan, includes an example of this type of argument, though instead of linking a colder climate to destruction, he links a warmer climate to growth. Fagan attributes the building of cathedrals to the

[15] Lee, H., Zhang, D., Brecke, P., & Fei, J. (2013). Positive correlation between the North Atlantic Oscillation and violent conflicts in Europe. *Climate Research*, *56*(1), 1–10.

Medieval Warm Period, a view that is not without its problems. Stating "Despite wars, Crusades, schism and other strife, the Medieval Warm Period was a bountiful time for Europe[16]" and "Like the Norse conquests, cathedrals too are a consequence of a global climatic phenomenon, an enduring legacy of the Medieval Warm Period."[17] Brian Fagan draws a strong correlation between the great architectural works of the medieval period and the warmer climate. This view overlooks the independence of the many other historical timelines of the period, such as religion, politics, technology and economics. Fagan received critique for this simplified correlation, one that may be shared by other parts of environmental history. In a review of Fagan's book it was noted that "… long stretches risk becoming little more than potted social histories of northwest Europe with a weather report added on" and that "The phenomenon that the less well-documented a period is, the greater ease "environmental" explanations have in coming into play, is familiar[18]". Although the critique can seem harsh and somewhat exaggerated, the problem of drawing a direct correlation between warm weather and societal growth, or cold weather and societal failure, is worth contemplating. This should not detract from Fagan's work, which is an otherwise interesting read, but it does point to a necessary caution. This leads to the next of the four categories.

The third method is a continuation of the second, including an acceptance of the LIA as a climatically colder period, however it includes a problematization of the second category's determinism towards the negative impact of the LIA. This view does not deny that climate and history can affect each other, however it does understand that many variables are included in history and that climate may very well not be the most important. In the article *Testing the Limits of Climate History: The Quest for a Northeast Passage during the Little Ice Age, 1594–1597* climatic historian Dagomar Degroot discusses the relationship between history and climate through the Dutch expeditions to the artic in the Grindelwald Fluctuation (a cooler climatic period like the Maunder Minimum). After discussing the three different journeys, in 1594, 1595 and 1596-97, of which pack ice played an important role, Degroot concludes that "If the course of three expeditions across four years cannot be tied to the manifestations of a climatic regime, it is difficult to understand how that climatic regime can be linked to broader trends in human history[19]". As if to make an active defense against future attacks on historical climatology, Degroot notes that the disconnection of a direct

[16] Fagan, B. M. (2000). *The Little Ice Age: How Climate Made History 1300-1850*. New York: Basic Books. p. 16

[17] Fagan, *The Little Ice Age: How Climate Made History 1300-1850*. p. 21

[18] Warde, P. (2002). The Little Ice Age. How Climate Made History 1300-1850. *Environmental History*, *7*(1), 133–134.

[19] Degroot, D. (2015). Testing the Limits of Climate History: The Quest for a Northeast Passage during the Little Ice Age, 1594–1597. *Journal of Interdisciplinary History*, *45*(4), 483

link between history and climate should not be a complete disregard of climate as a factor, but rather an acceptance of the plurality of historical explanations[20].

It is also important in this third category to differentiate between weather and climate, as the two are often mistaken as one in the same. On a smaller scale, as with Degroot's article, weather may dominate over climate and this may also be the case with many historical studies, as Degroot himself notes many times. When searching for historical events, one may focus on such a short time span, in a geographic sense, that weather will naturally dominate. For example, when discussing a colder climatic period, a warm summer may create examples that differ from the norm of the period, but which fit with the scale of the historical work. Weather also naturally has the rapidity to be seen on such a small scale. If one thinks of a historical battle, rain from the night before may have created a muddy battlefield, aiding one force and giving another a disadvantage. This would naturally be noted in sources of the time and be observable in a historical work. However, the hydrological report for the battlefield over a 30-year span (the minimum for climate), requires other sources that may not be available or may not be as direct. This does not detract from the effects of climate, but it does obscure them.

Lastly, Degroot notes that historians, as with all other scholars, are products of their time. Climate change is an everyday discussion in our society and this may lead historians to explanations which are logical in our time and in our mind frame, but which ultimately could result in an understanding of the past through the present, rather than an understanding of the past through itself, a form of presentism.

Continuing with a deeper understanding of the LIA, the fourth and last view is a problematization of the concept of the LIA and therefore a problematization of the concept of long-term climatic impacts on the development of the early modern to modern European societies. As this is an atypical but rather interesting view, the following chapter will discuss some of the critiques of the historical evidence for the LIA included in this category.

6.3 Probelmatizations of the historical evidence for the LIA

Scholarly literature on the LIA is not in complete agreement on the effects of the LIA. In a somewhat unique attack on the otherwise almost unanimous scholarly sentiment, Professor of Economics at University College Dublin, Morgen Kelly, and Professor Emeritus of Economics at University College Dublin, Cormac Ó Gráda, argue that the LIA is in reality a statistical creation of continuity, arguing against many of the main works on the LIA. They state

[20] Degroot, D, *Testing the Limits of Climate History: The Quest for a Northeast Passage during the Little Ice Age*, 1594–1597. p. 482-483

that "We find no statistical evidence of any major breaks, trends, or cycles in European weather of the sort that one could associate with an LIA[21]" Their article is an interesting opportunity to examine the many different forms of data on which the LIA is built and the weaving together of the many different types of information.

Kelly and O Gráda start by distancing history from climate, stating that "… the implicit view of human beings as passive victims of meteorological circumstance, bereft of any capability to adapt to changing conditions … has led many mainstream historians to be skeptical of such climatic stories[22]". In a latter rebuttal to their article they comment on Sam White's, Assistant Professor of History at Ohio State University, division of the LIA in three time scales, the last two focusing on the human experience, commenting that they "… are intended to capture the "human dimension" and the "human experience" of the LIA, respectively, but they serve only to allow the historian's tail to wag the climatologist's dog "[23]. This argument seems to be a classical attempt to distance oneself from other scholarly works within an academic field and create a caricature of the opponent, a strawman argument. Most environmental historians seem very cautious in making deterministic connections between history and climate, and the idea that "climate made an event possible but did not cause the event" seems to dominate the field. If for no other reason than that determinism in any historical work will always cause other historians to become cautious, no matter what the subject area.

Kelly and Ó Gráda continue to argue against the literature on the LIA, stating that although poor weather periods may exist, there is no long term continuity between these "bad weather periods[24]". When trying to find an explanation for why historians, and others, find the LIA when none has existed, they point to climatologists practice of smoothing out data, when the data in reality is random, as noted above[25]. This practice leads to, according to Kelly and Ó Gráda, random high and low figures creating oscillating averages that do not exist. This argument seems problematic, as many different proxies give similar answers. If all these different proxies had the same tendency to oscillate within a given period, it would seem that something is oscillating them, thereby reducing the random nature of the results. In a rebuttal to Kelly and Ó Gráda, Sam White states that "The evidence for this trend [the LIA] is by no means limited to a couple of contested studies, as Kelly and Ó Gráda imply, nor only to tree rings in Europe. A wide variety

[21] Morgan, K., & Grada, C. O. (2014). The Waning of the Little Ice Age: Climate Change in Early Modern Europe. *Journal of Interdisciplinary History*, *XLIV*(3), p. 301.

[22]Morgan, K., & Grada, C. O. (2014). The Waning of the Little Ice Age: Climate Change in Early Modern Europe, p. 302

[23] Morgan, K., & Grada, C. O. (2014). Debating the Little Ice Age. *Journal of Interdisciplinary History*, *XLIV*(1),p. 62.

[24] Morgan, K., & Grada, C. O. (2014). The Waning of the Little Ice Age: Climate Change in Early Modern Europe, p. 303-304

[25] Morgan, K., & Grada, C. O. (2014). The Waning of the Little Ice Age: Climate Change in Early Modern Europe. P. 302.

of regional proxies, ranging from Greenland ice cores to South African speleothems, point in the same direction."[26] Most interestingly in Kelly and Ó Gráda's article is not their attack of the LIA as a concept but their questioning of some of the core works on the historical LIA, such as Lamb and Fagan. They argue that climatological explanations could also be substituted by social and economic explanations in the historical examples of the LIA. It is a tour de force through the backbone of the environmental history of the era.

One the classical examples of the human effects of the LIA is the end of Norse colony on Greenland. According to the theory, explorers from Scandinavia arrived in Greenland around the year 1000 and lived there for approximately 400 years. The settlement then ended around the 1300s-1400s. This would seem to fit with the idea of a warm period for settlement, an idea that Fagan supports[27], and an abandonment around the start of the LIA. Kelly and Ó Gráda argue that many other factors could have played a role and that climate changes do not have to have a dominant position on the discussion. Although this is still a very open discussion, a Ph.D. report from 2014 by Christian Koch Madsen concludes that "… while climatic deterioration and a marginal environment were serious challenges to Norse settlement in Greenland, there is no reason to assume that they were so much more aggravating than elsewhere in the North Atlantic that they should have caused a complete collapse.[28]" This points to the continual need for reflection on climatic determinism and raises the question of source material for the LIA.

The question then becomes: can historical proxy data, such as the collapse of the Norse settlement in Greenland, be used to as evidence for or against the LIA? White argues that Kelly and Ó Gráda are using the wrong form of data in their discussion, thereby undermining the whole concept. This points to one of the key elements in environmental history, that being, which sources can be used to answer which questions. White argues that scientific proxy data (from the natural sciences), as will be used in chapter 7 *What cause the LIA*? in this thesis, has already laid a foundation for an understanding of the climate in the period and that historical reconstructions point to the human element[29]. This thereby opens up subjectivity and multiple explanations in the climatic reconstructions, rather than directly connecting historical reconstructions and climate as, White argues, Kelly and Ó Gráda do. In other words, historical events can point to the effects of climate, but are often too complex to connect directly to climate. Using the example of the Norse in Greenland, it may have been a collapse in trade, relations with the Inuit people, or a

[26] White, S. (2014). The Real Little Ice Age. *Journal of Interdisciplinary History*, *XLIV*(3), p. 328
[27] Fagan, B. M. (2000). The Little Ice Age: How Climate Made History, 1300-1850. p. 7.
[28] Madsen, C. K. (2014). *Pastoral Settlement, Farming, and Hierarchy in Norse Vatnahverfi, South Greenland*. University of Copenhagen, p. 255
[29] White, S. (2014). The Real Little Ice Age. p. 327–352.

completely different event that ended the settlement, and not climate alone. The difference, and distance, between historical events and climatic changes will remain an important element in this thesis.

In conclusion, the four viewpoints on the LIA are different in source material and focus, however all can be used to understand the period if used with caution. Kelly and Ó Gráda's argument against the LIA gives historical climatologists the possibility to re-valuate their usage of historical anecdotes as examples of tendencies.

7. What caused the LIA?

Although it is not the focus of this thesis to discuss the causation of the LIA, the argument for a possible connection between history and climate would be weaker without an understanding of the LIA as a climatic phenomenon. It would also be against the multidisciplinary nature of environmental history not to include the other scholarly disciplines to which this historical work owes much of its foundation.

7.1 The Total Solar Irradiance (TSI) and climate change

There is not a complete understanding of the processes which created the LIA, however a few different mechanisms have been suggested. These include a decreased solar irradiance, changes in the North Atlantic Oscillation (NAO), volcanic eruptions, changes in the North Atlantic Current (NCA) and the Atlantic meridional overturning circulation (AMOC), and high-pressure blocks over the Atlantic Ocean[30]. Using ^{10}Be, an isotope of beryllium, deposits in ice cores and computer modeling, F. Steinhilber and J.Beer, of the Swiss Federal Institute of Aquatic Science and Technology, and C. Frohlich, of the Physikalisch-Meteorologisches Observatorium Davos, created a solar irradiance time line for most of the Holocene. This timeline shows many dips in the total solar irradiance (TSI) throughout the Holocene time period. A noteworthy dip for this thesis is the well-known Maunder Minimum, from between 1645 and 1715 and named after the English astronomer Edward Walter Maunder who discovered that few sunspots were observed between 1645 and 1715[31]. Steinhilber, Beer and Frohlich note a fall in the TSI, compared to the observed mean value between 1986-1996, of 0.9 ± 0.4 Wm^{-2} (Watts per meter squared) [32]. Together, this points to a reduction in the amount of energy delivered to the Earth and a possible cooling of the climate. However, connecting lower solar inputs of energy and the possible climatic responses is not as easy as it may seem.

In an article in Nature Geoscience from 2014, Paola Moffa-Sánchez, Andreas Born, Ian R. Hall, David J. R. Thornalley and Stephen Barker discuss how a decline in the TSI would affect the climate of northern Europe, and thereby Denmark, by affecting the oceanic waters in the North Atlantic. In a simplified version, warm water is transported up the coast of North America, where it sinks off the coast of Greenland, defining the end of the Gulf Stream[33]. This sinking action is caused by a difference in density between the arriving warm salty water and the cold fresh water. As the water freezes in the colder climate the excess salt increases the salinity of the remaining water. The remaining water becomes denser and sinks downwards, starting a pumping action in the Northern Atlantic, and

[30] Mo, P., Born, A., Hall, I. R., Thornalley, D. J. R., & Barker, S. (2014). Solar forcing of North Atlantic surface temperature and salinity over the past millennium. *Nature Geoscience*, *7*(April), 275–278.
[31] Mayhew, S. (2015). Maunder minimum. In *A Dictionary of Geography*. Oxford University
[32] Steinhilber, F., Beer, J., & Fröhlich, C. (2009). Total solar irradiance during the Holocene. *Geophysical Research Letters*, *36*(19),
[33] "Saltpumpen" Pilegaard Hansen, B., Sestoft, A., Brøndum, P., & Andersen f. 1933, T. (1999). *Geografihåndbogen* (2nd ed.). Kbh.: Gad. p. 177

creating deep water formations. This “pump” in turn pulls more warm water into the area, which freezes and sinks, creating a self-renewing loop[34].

Moffa-Sánchez, Born, Hall, Thornalley and Barker discuss how changes in this process can be caused and which effects they may have. Through core samples of the sea floor off the coast of Iceland and Greenland, they find that in periods of solar minima (such as the Maunder Minimum), the water in the NAC area (the area of the “pump”) is cold and fresh, with a strong correlation to the TSI values[35]. This points to a reduction in the amount of warm water arriving in the Northern Atlantic and thereby a reduction in the creation of warm winds to Europe.

This can also be linked to changes in the North Atlantic Oscillation (NAO). A positive NAO can be linked to stronger westerly winds, which would affect the climate in Europe with warmer weather. This is due to the winds pulling warmer water northwards and thereby strengthening the “deep water pump”. A prolonged period of a positive NAO situation may be the cause of the Medieval Climate Anomaly, from ca. 800- ca. 1300, which is defined as a period of generally warmer climate in Europe[36]. The direct consequence of the warmer climate is however not agreed upon[37].

In a negative NAO period, high pressure blocks (areas of high pressure systems) can develop. These systems can, as their name implies, block the westerly winds and replace them with northeasterly winds, which are colder. Periods of solar minima, as the Maunder Minimum, have been linked to periods of increased high pressure blocking, with weaker circulations in the ocean area around Greenland and Iceland and a colder, fresher NAC[38]. All in all, this would result in colder temperatures in Europe. Thereby, a decrease in the TSI, can lead to changes in the weather patterns in the North Atlantic, which may lead to short, cold changes in the climate of Europe.

7.2 Volcanic forcing

As with all science, however, the answer is never that simple. Although a lowering of the TSI may have caused the LIA, it is not the only explanation. Volcanic explosions may have started a positive feedback system (where one process aids another process, which in turn aids the first process) and caused a cooling of the climate. In the article *Abrupt onset of the Little Ice Age triggered by volcanism and sustained by sea-ice/ocean feedbacks*, from 2012, it is

[34] “Saltpumpen” Pilegaard, *Geografihåndbogen*, p. 177
[35] Mo, *Solar forcing of North Atlantic surface temperature and salinity over the past millennium.*
[36] Trouet, V., Esper, J., Graham, N. E., Baker, A., Scourse, J. D., & Frank, D. C. (2009). Persistent positive North Atlantic oscillation mode dominated the Medieval Climate Anomaly. *Science* (*New York*, *N.Y.*), *324*(5923), 78–80.
[37] Hybel, N. (2002). Klima og hungersnod i middelalderen. *Historisk Tidsskrift* (*København*), *102*(2), 265–280.
[38] Mo, *Solar forcing of North Atlantic surface temperature and salinity over the past millennium.*

discussed how a relative short geological event, such as a volcanic eruption, could affect the climate on a longer scale [39].

In the article, the authors chose to use glaciers as their climatic proxy, rather than biological proxy such as trees, because glaciers have no survival strategy. A survival strategy could weaken a climatic proxy by lowering the impact of a climatic event, as the strategy would be used to decrease loses. In many ways, this is what makes historical sources problematic as climatic proxies. Through the glacial proxy, the authors find a cold period starting around ca. 1430 - 1450 and stretching to the 20th century[40]. The authors find that this may correspond to a large volcanic eruption in 1452, possibly the eruption of Kuwae in the Pacific Ocean[41]. A large, high altitude volcanic eruption would negatively affect the weather in a limited to global geographic area, for a short time span. However, the authors find that it may also have had a longer effect. By cooling the pole-ward areas of the northern hemisphere (above 60ºC) a greater amount of ice would form. This ice formation would thereby increase the albedo of the area (the amount of sun light directly reflected) and therefore again cool the area. This would expand sea ice and lower oceanic temperatures, and could weaken the AMOC, thereby decreasing the amount of warm winds reaching Europe, resulting in a cooling of the climate of Europe[42]. This theory is supported by an increase in sea ice around Iceland, an area that only receives excess sea ice from the Arctic Ocean.

In general, both theories point to the complex nature of climatic changes and to the ongoing research in the field of former climatic events.

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[39] Miller, G. H., Geirsdóttir, Á., Zhong, Y., Larsen, D. J., Otto-Bliesner, B. L., Holland, M. M., … Thordarson, T. (2012). Abrupt onset of the Little Ice Age triggered by volcanism and sustained by sea-ice/ocean feedbacks. *Geophysical Research Letters*, *39*(2),

[40] Miller, *Abrupt onset of the Little Ice Age triggered by volcanism and sustained by sea-ice/ocean feedbacks*.

[41] Gao C., Robock A., Self S., Witter J. B., Steffenson J. P., Clausen H. B., Siggaard-Andersen M. L., Johnsen S., Mayewski P. A., Ammann C. (2006). The 1452 or 1453 AD Kuwae eruption signal derived from multiple ice core records: Greatest volcanic sulfate event of the past 700 years. *Journal of Geophysical Research*, *111*, 1–11

[42] Miller, *Abrupt onset of the Little Ice Age triggered by volcanism and sustained by sea-ice/ocean feedbacks*.

8. Temperatures in Denmark and the LIA

In order to better understand the importance, or lack of thereof, of the LIA on warfare in Denmark during the 17th century, it is essential to develop a baseline for the LIA in Denmark.

8.1 Converting historical sources

Nearly 100 years ago Captain C.I.H. Speerschneider reported to *Det Danske Meteorologiske Institut* (The Danish Meteorological Society) on the historical ice conditions in the waters around Denmark, aiding in the search for a better understanding of the climate around 1914 and indirectly supporting the development of a better understanding of historical climatology. Using a wide array of sources, Speerschneider tried to piece together a year-by-year development in the severity of the winters in Denmark. Not having modern scientific tools, Speerschneider used historical sources which discussed the ice conditions in the belts and tolls around Denmark. It should be noted that Speerschneider did a remarkable job of finding a path through all the historical sources. In a very thorough fashion Speerchneider critically studied the sources and came to a few conclusions about the available source material.

Firstly, not all the historical sources could and should be trusted. This is not a new conclusion with regards to historical information, however it is always important to problematize the source materials' development process.

Speerschneirder comments on two different forms of historical errors that he found in his sources. The first involves misquotations of information. For example, in a passage from 1296 it is stated that it was possible to ride "de Opslo ad Jutiam"[43]. This later becomes, in other sources, that the whole of Skagerak was frozen (see map 14.3). However, a complete icing of Skagerak seems extreme. Speerschneirder discusses if the original sources in reality meant that one could ride from the diocese of Oslo, instead of the city of Oslo, as it would seem logical to find the shortest route to Denmark when crossing the ice. As the diocese of Oslo included the city of Gøteborg, this would shorten the route to Denmark. This is a classic example of the importance of finding the original source.

Speerschneider's second form of historical error is also a classic one in Danish sources from the middle ages, the issue of dates. The same trip between Oslo and Denmark can be dated to 1269 (a possible reversal of the date), 1292,1294 and 1296[44]. This could represent three very close, very cold winters and therefore a possible start to changes

[43] Speerschneider, *Om Isforholdene i danske Farvande i ældre og nyere Tid : Aarene 690-1860, p.*10
[44] Speerschneider, *Om Isforholdene i danske Farvande i ældre og nyere Tid : Aarene 690-1860, p.*10

in the climatic conditions, or it could represent the imprecision of dates and quantities in the middle ages. The difference is of course important and Speeschneider concludes that it is most likely the latter rather than the former.

Speerschneirder also comments on another aspect of using human interpretations as sources, the difference time creates. The human notion of time is different from a geographic understanding of time, and events can quickly be forgotten or lowered in hierarchy within a human life, as with the example used in the start of this thesis of the feeling of cold in winter. This difference is important when trying to weigh the severity of an event, in this case a specific winter. Speerschneirder writes "Paa den anden Sider mener jeg, at man ikke kan tage Udtrykket >det var uden Eksempel< som et afgørende Bevis, fordi Folk saa hurtigt glemmer, hvad der er sket"[45].Speerschneiders critique can be summed up in the notion that modern events, within the framework of human memory, have greater meaning than earlier events, especially in a time without precise measurements. The winters of recent past may seem more extreme than the winters of the distant past. This is not very different from most historical methodology, as the historian is taught to always look for a description of an event, as close to the event as possible. When using historical sources the historian must analyses for a repetition of "worst-winter-ever"s, for else it is hard to judge the conditions against each other. Does, for example, a long list of "worst-winter-ever"s mean an annual decrease in winter temperature? Or does it rather indicate that the author of the historical source has a tendency to forget the past?

An assumption that the author of a source is "lying" by simple forgetfulness is of course a problematic methodological assumption, as the historian becomes better knowing than the source. By assuming this, there is a risk of downplaying an otherwise important data source in order to minimize exaggerations. This is also noted in a review of Speerschneiders book for the magazine *Geografisk Tidsskrift* in 1916. Johan Gehrke writes that other authors seem to have "større Tiltro til de middelalderlige Beretninger, end Kaptajn Speerschneider har [a larger confidence in sources from the middle ages than Captain Speerscheider [*trans. author*]"[46].

What makes Speerschneider's work so interesting is that he, after looking at all the data from the historical sources, concludes that "… there is no reason to believe in any marked difference in the amount of ice in Danish waters during the winters of former periods and of the present day"[47]. In other words, before an understanding of the climate as a changing entity in our modern world, Speerschneider concludes that nothing has changed in the past

[45] Speerschneider, *Om Isforholdene i danske Farvande i ældre og nyere Tid : Aarene 690-1860, p.*.9

[46] Gehrke, J. (1915-1916.). C. I. H. Speerschneider: Om Isforholdene i danske Farvande i ældre og nyere Tid, Aarene 690 —1860. Publikationer fra det Danske Meteorologiske Institut ved C. Ryder, Direktør. Meddelelser Nr. 2. København 1915. *Geografisk Tidsskrift*, *23*.

[47] Speerschneider, *Om Isforholdene i danske Farvande i ældre og nyere Tid : Aarene 690-1860, p.*141

ca. 1300 years. This points to the same fact that Dagomer Degroot notes, that modern historians are products of their time.

Speerschneider's conclusion is both interesting and problematic. Speerschneider might show a modern reader an understanding of the world before the ever-present climatic change, and therefore be able to reduce climatic determinism when studying climatic history. However, it is also a possibility that Speerschneider, rather than being in opposition to modern thoughts, is in reality just a reflection of an understanding of climate in which the climate is a stable, rather than a dynamic, entity. Therefore, he might be just as affected by his perception of stability as we are about change. To make Speerscheider's conclusion even more interesting, Speerschneider wrote his conclusion in the Gleissberg Minimum, a solar minimum like the Maunder Minimum, close to its total solar minimum in ca. 1910[48][49]. It is possible that the conditions of the environment around Speerschneider seemed similar to the conditions he read about, thereby creating a sense of stability.

8.2 The climatic data for Denmark

In order to better understand the effect of the LIA, and hereby the Maunder Minimum, it is important to construct an estimate for the temperature conditions in Denmark.

There does not seem to be a large amount of scholarly research on the reconstruction of temperature developments in Denmark and therefore the temperature reconstruction baseline for this thesis is based on summer calculations from northern Europe in general[50], and winter/spring calculations from Stockholm[51] in particular. By using tree ring data Jan Esper, Elisabeth Düthorn, Paul J. Krusic, Mauri Timonen, and Ulf Büntgen have reconstructed the summer temperatures in northern Europe dating back to 17BC (see graph 8.3). Both the summer and winter temperatures are important when understanding the effects of climate and short-term weather patterns on historical events, however this thesis will focus on the changes in the winter conditions, as these define the LIA. Additionally, their consequences seem to appear more often in the scholarly material, making their correlation to developments in the 17th century compelling.

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[48] Steinhilber, *Total solar irradiance during the Holocene*.

[49] Summerhayes, C. P. (2015). *Earth's climate evolution*. Chichester, West Sussex, UK: Wiley Blackwell, p.341

[50] Esper, J., Düthorn, E., Krusic, P. J., Timonen, M., & Büntgen, U. (2014). Northern European summer temperature variations over the Common Era from integrated tree-ring density records. Journal of Quaternary Science, 29, 487–494.

[51] Leijonhufvud, L., Wilson, R., Moberg, A., Söderberg, J., Retsö, D., & Söderlind, U. (2010). Five centuries of Stockholm winter/spring temperatures reconstructed from documentary evidence and instrumental observations. *Climatic Change*, *101*(1-2), 109–141.

In order to better understand the winter/ spring conditions the study *Five centuries of Stockholm winter/spring temperatures reconstructed from documentary evidence and instrumental observations* will be used. Using a combination of many different qualitative historical documents, such as toll data noting the first arrival and first departure to a port, Lotta Leijonhufvud, Rob Wilson, Anders Moberg, Johan Söderberg, Dag Retsö and Ulrica Söderlind have reconstructed the possible winter temperatures, in regards to the reference period of 1961-1990, around Stockholm. However, the authors note that, as described above, historical documents can tell many different truths. The authors note the year 1569 as being a noteworthy cold winter, however the very low value based on trade data given to this year could also be due to a war between Denmark and Sweden as much as it could be due to the winter conditions[52]. In order to reduce an overwhelming amount of references later in this thesis, all stated temperature data, unless otherwise noted, derive from this study.

Interestingly, thanks to Speerschneider's work, the winter/spring temperatures from Stockholm can be qualitatively compared to Danish sources during the same time period. Two systems of comparison have been chosen, the first being a random selection of 10 different years, in order to better understand the general comparisons of the two data sets, and the second being an analysis of the three warmest and three coldest years, to better understand the extremes.

Randomly selecting 10 years, of the 200-year period, can give at better understanding of the relationship between the two sources. The 10 randomly selected years were 1561, 1581, 1585, 1594, 1616, 1630, 1660, 1678, 1697, 1715[53]. Starting chronologically with 1561, there is a decrease in the winter temperature, in relation to the reference period, of 2.08 degrees. This is a relatively large decrease. Although Speerschneider does not cite Danish sources it is noted that this was a harsh winter in Switzerland, demonstrating the possibility that is was a continentally cold winter. The next year in the series, the year 1581, sees a decrease of 0.53 degrees. Denoting a somewhat mild winter in Stockholm. Speerschneider notes that this was an icy winter in the Baltic Sea, with a Swedish army crossing the Gulf of Finland. The next year, 1585, sees a mild winter in comparison to some of the much colder winters of the period, with a decrease in temperatures of only 0.09 degrees. The winter is noted for being mild in France and Germany by Speerschneider, most likely denoting a mild winter in Denmark also. 1594, the next year on the list, sees a temperature decreases of 0.02 degrees and is therefore a close fit to the reference period. Speerschneider notes this as being a mild winter with no ice in the Sound Strait. However, his description of the year hints at the regional

[52] Leijonhufvud, I, *Five centuries of Stockholm winter/spring temperatures reconstructed from documentary evidence and instrumental observations*, p. 138

[53] The 10 years are selected using random.org *True Random Number Generator* with the limitations: min=1550, max=1750. Years where there is no data have been removed and replaced by a new random year.

effects of the LIA, as the mild Danish winter of 1594 was a harsh winter in Iceland, and it is noted that the lagoons of Venice froze in the same year.

The next year on the list is 1616. This is again a mild winter with a decrease of “only” 0.95 degrees. Speerschneider notes that Christian IV travelled between Kronborg in Denmark and Helsingborg in Sweden on the 16th of January and had to break the ice along the way, which does not seem atypical for the winters of the period. Speerschnieder notes that “the cold” arrived around the 9th of January, which again seems typical. It is hard to determine if 1616 is an average year, however many of the more extreme winters are noted for their cold conditions, whereas 1616 leaves no mark. This may point to 1616 having no extreme effects.

Moving forward to the next year, 1630, the data from Stockholm points to a cold winter in the city with a decrease of 3.04 degrees. No sources are found in Denmark, however it is noted that this was a very cold winter in Iceland, with icebergs forming. 1660, the next year noted, is a mild winter, with a decrease in temperatures of 0.46 degrees, and the first of the randomly chosen dates within the Maunder Minimum. In Denmark there seems to have been ice around Copenhagen from the middle of December to the middle of February. This does not seem to be a noteworthy extreme. However, it is noted that the conditions in France were very harsh that year. Starting the final three years is 1678. This is a warmer winter, with an increase to the reference period of 1.67 degrees. Speerschneider is ambiguous in his description of the year, noting both that the ice pack broke up already in December 1677, and that there was a harsh frost in the start of 1678. As a conclusion, he notes that in December 1677 there must have been some icing of the Danish straits, however the main transport waterways must later have been free of ice. The lacking icepack does fit with a warmer winter, where colder periods existed but did not dominate for a longer period of time. The next year is 1697, which again is a milder winter with a decrease of 0.57 degrees, is noted as being a very cold winter by Speerschneider. This seems to show a misfit between the two sources. Interestingly the years surrounding 1697 seem to fit very well. 1696, which saw an increase in temperatures by 2.96 degrees is noted as having a mild start to the winter and 1698, which saw a decrease of 1.54 degrees is noted for being a long and harsh winter. It is even stated that travelers from Nyborg had to wait five weeks for a sailing passage to be made between the Danish islands during that year. The last year on the list is 1715, which happens also to be the last year of the Maunder Minimum, was again a relatively mild winter with a decrease of “only” 0.20 degrees. Speerschneider notes that there was ship traffic from Copenhagen in January, but that there must have been ice in January/February. This late icing could be connected to the recorded milder temperatures during the year.[54]

The 10 randomly selected years are a good way to study general movements in the data, however it is also important to study the ability of both sources to find extremes. Using the data from Stockholm as a reference, the three warmest winters during the period occurred in 1750, 1605 and 1743 with temperature increases of 3.64ºC, 4.08 ºC and 4.57 ºC, respectively. The coldest winters occurred in 1557, 1573 and 1569 with temperature decreases of -5.87 ºC, -6.47 ºC and -7.26 ºC, respectively. Starting with the three warmest winters, Speerschneider's remarks are not conclusive. 1750 is noted for being a very mild winter with ship traffic all winter and trees budding during the winter. However, both 1605 and 1750 are noted for being harsh in other parts of Europe (Iceland and France, respectively) with no note of Denmark. As seen before, cold winters in other parts of Europe do not mean cold winters in Denmark and may, in some cases, even mean warmer winters locally.

As for the colder winters, 1557, 1573, and 1569, these seem to fit better. 1557 is noted for being a very harsh winter in Germany, lasting from 19th of November to the 5th of April. 1573 is noted for having very harsh weather in the start of January and that the ice remained well into the spring. 1569 has a very curious story of Frederik the 2nd trying to travel over *Storbaeltet* (The Great Belt) during the Christmas season with great danger. It seems that breaking ice was an issue. It is not noted if this represents a warming or a general cooling, however it is noted that there must have been ice from at least December to January[55].

In general, it seems that the temperature calculations from Stockholm can be transferred to Denmark, if one mostly looks at movements and not at exact values. There seems to be a match between when the data from Stockholm swings toward or above the reference temperature, and milder winters in Denmark and opposite when the temperatures swing down. As both works, the data from Stockholm and Speerschneiders book, involve many sources, the match between the two seems to support the usability of both sources.

[54] All historical data was found in: Speerschneider, *Om Isforholdene i danske Farvande i ældre og nyere Tid : Aarene 690-1860, p.* 73-87

[55] Speerschneider, *Om Isforholdene i danske Farvande i ældre og nyere Tid : Aarene 690-1860, p.* 73,75,90

8.3 Developments in the average temperature from 1550-1750

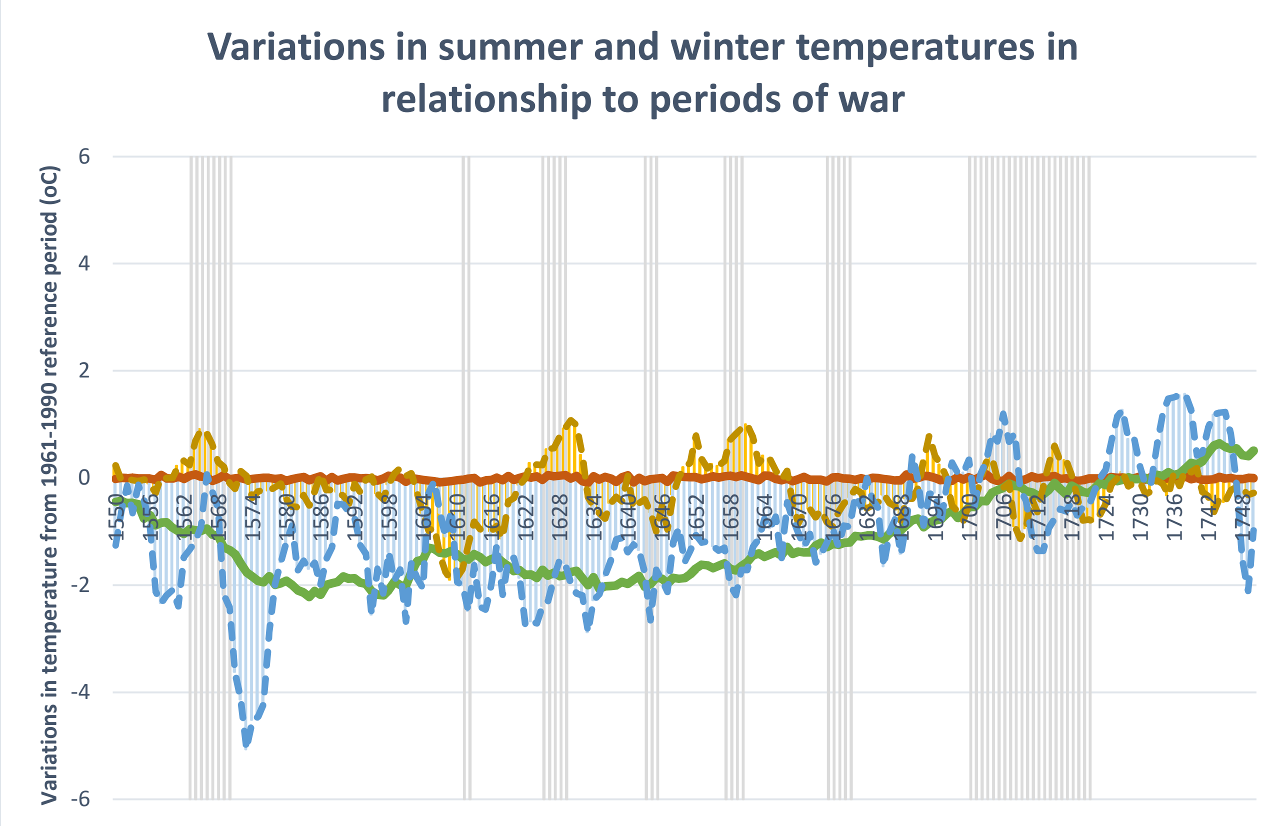

Figure 8.3 shows the variations in summer and winter temperatures, in relation to the 1961-1990 reference, with a 5 year moving average (yellow bars for summer and blue bars for winter), a 30 year moving average (a red line for summer and a green line for winter) and occurrences of war (grey areas). While some of the wars seem to fit areas of lower summer and winter temperatures, for example the Kalmar War in 1611-1612, others fit with warmer summer and colder temperatures, for example the Karl Gustav Wars in 1657-1660[56][57].

Figure 8.3 shows an estimate of the summer and winter temperature variations from a 1961-1990 reference period using a five-year trailing moving average to show tendencies and to clarify the data. A five-year period has been chosen to represent a time of successively bad or good conditions, of which the buffering capacity of the society is spent or restored[58]. A five-year trailing average is used, instead of an equal moving average, to better represent the nature of history. A five-year equal moving average, where the mean value is determined by the value of the given year plus 2 years on either side, divided by the total number of years, could be useful in some scientific studies. For example, when studying the onset of an ice age it could be useful to gather averages that represent cooler periods, where close annual rises in the temperature would not cause melting. By combining pre and post values into the

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[56] Esper, J., Düthorn, E., Krusic, P. J., Timonen, M., & Büntgen, U. (2014). Northern European summer temperature variations over the Common Era from integrated tree-ring density records. *Journal of Quaternary Science*, *29*, 487–494.

[57] Leijonhufvud, I, *Five centuries of Stockholm winter/spring temperatures reconstructed from documentary evidence and instrumental observations.*

[58] Zhang, D. D., Zhang, J., Lee, H. F., & He, Y. (2007). Climate Change and War Frequency in Eastern China over the Last Millennium. *Human Ecology*, *35*(4), 403–414.

average, the moving average would represent time periods with a generally cooler weather, and therefore a reduction in ice melting. However, this would be illogical when discussing the effect of a small scale climatological impact on history. For example, if a period of cooling caused famine before the onset of a war, the 2 years after the start of the war, would play no part in the buildup of the war. Even if the two years after the famine were very productive, they were in the future in relation to the observed time specific event. Therefore, a trailing moving average, with the 5 years previous to the observed event defining the moving average, is a more historically accurate tool when trying to understand the impact of climate on history.

Figure 8.3 also includes a 30 year moving average which better represents the data in a climatological understanding and can therefore better show long term trends. However, a difference in scale between climatology and history is vital when understanding the importance of scale. Although a 30-year scale in geography may help to remove short-term tendencies, a 30-year scale in a historical time period may be too large and may include too many important events and thereby make the scale insignificant. A wide 30-year scale covers large changes in the condition of the state during 17th century, such as the change in government in 1660. The 30-year moving average for this period could thereby include an all-important event, but at a scale so large that it would seem difficult to correlate between an event and the temperature data. This could cause the general developments in temperature to seem insignificant as a contributing factor to change.

8.3.1 Root mean squared (RMS)– a data test

A root mean squared (RMS) value has been calculated for both the five year and 30 year moving average and will applied to the data in order to understand the smoothing effects of the moving average, when this is important ltaer in this thesis. This is also meant to incorporate Kelly and Ó Gráda critique of finding a low average where a single outlier defines the data set. A high RMS value will show that the average distance between the moving average trend line and the modeled temperature is large and that there therefore is a large possibility of noteworthy annual differences or outliers. This could mean, that a five-year period with a very low moving average temperature is in reality a period of four mild years and one extremely cold year. The RMS value for this period would show this discrepancy. The opposite would be true for low RMS values.

After this short, but concise, introduction to the climatic developments and problematizations, the next step is to apply human history.

Part II

Connecting climate and history

9. Climate, warfare and economy

There are many ways to study the connection between climate, warfare and the economic situation in Denmark during the LIA. On a micro scale, it is possible to study the events of a single battle and contemplate if specific climatic conditions played a part in the outcome. A classic example would be the invasion of Denmark during the Karl Gustav Wars, between 1657-1660, were the Swedish army was able to cross the Danish belts and attack Copenhagen. An event that today seems unimaginable due to the lack of freezing of the Sound Strait was made possible in part due to colder winter temperatures.

On a much larger scale, climate and the economic situation in Denmark may have played a part in the course of the many wars during the 1600s and their outcome. If, for example, the state was hard hit by stable or falling income, due to poor climatic conditions, and growing expenses, due to the many wars, it might have been impossible for the state to correct its budget, leading to a possible military failure.

In the article *Climate Change and War Frequency in Eastern China over the Last Millennium*, this theory is applied to the history of China. Much like Europe, China was also effected by the LIA resulting in warmer and colder periods. Dividing China into a northern and southern region, the authors find that the southern part of China was heavily affected by the changing climate. This might be due to a population push from the cooling northern regions to the warmer southern regions, resulting in tensions in cooler climatic periods. By correlating the relationship between periods of war and periods of cooler climate the authors conclude that there is a "… near perfect match between high war frequencies and the cold phases, [and] doubled war ratios in cold periods…[59]". The mechanism behind these wars is a climatic push on agricultural outputs resulting in periods of reduced harvest, thereby affecting the population. This is also evident by the lag between climatic cooling and social tensions, a lag that might be explained by "the buffering capacity of stored food resources which might sustain individuals for some time as well as maintain the power of the state"[60].

The authors use the Ming dynasty as an example and link the fall of the Ming dynasty (1348-1644[61]) to a period of cooling from around 1538- 1717, with a severe period from 1620-1660. According to the authors, this cold period resulted in times of famine and a two front war between a rebellion and the Manchu invasion. It is implied that the

[59] Zhang,, *Climate Change and War Frequency in Eastern China over the Last Millennium*.
[60] Zhang,, *Climate Change and War Frequency in Eastern China over the Last Millennium*.
[61] ""Ming" - Bekker-Nielsen, T. (2009). *Gads historieleksikon* (4th ed.). Kbh.: Gad.

Manchu invasion, an invasion from the north, might have also been caused by poorer conditions in their home region. The result is the collapse of the Ming dynasty and the start of the Qing dynasty.

It should be noted that this theory relies heavily on a form of determinism between poor climate and destruction. Following in the path of earlier correlations between climate and collapse, the article is quick to assume that a cooler climate heavily affected the governments in China. Although this very well may be the case, it is important to note other factors may have had a large influence on a declaration of war and the course of the war. If, for example, one assumes that a poorer climatic condition in the northern parts of China lead to the collapse of the Ming dynasty by making the government unstable, why did its successor also come from the north? It seems that a climatically affected northern region should also have caused large problems for the invading Manchu warriors. This, and other questions, should not reduce the importance of climate as a background for war, but remind one, that human history is never as straightforward as it may seem.

Richard S.J. Tol and Sebastian Wagner take the correlation between war and climate one step closer to home. In their article *Climate Change and Violent Conflict in Europe over the Last Millennium* from 2008, they find that violence and cooling conditions or lack of precipitation may be connected. By correlating periods of warfare and climatic information through the past 1000 years, they conclude "some evidence that periods with lower temperatures in the pre-industrial era are accompanied by violent conflicts, as do Zhang et al. (2006). However, we also show that this evidence is not particularly robust[62]." In order to better understand why, they identify economic stress as a reason, using drought as an example. Tol and Wagner note that the changing climate may not start a conflict, but may make it worse. This leads to an overall analyzes that points to the pressures on structural elements of climate change, like in China, but not how the underlying structures would make themselves shown in a daily or yearly context. To be fair to Tol and Wagner, this was not the goal of their article, and is more a critique of the general nature of quantitative data, where the uniqueness of history becomes washed out.

Geoffrey Parker, in his book *Global Crisis*: *War*, *Climate Change*, *& Catastrophe in the Seventh Century*, also links colder climate with an increase in warfare, noting however that this should not be seen as a deterministic link, but rather a forgotten variable. For Parker the problems during the LIA were caused by a decrease in food production, combined with an increase in population and poor leadership in the global community[63]. He writes "… early modern

[62] Tol, R. S. J., & Wagner, S. (2008). Climate change and violent conflict in Europe over the last millennium. *Climatic Change*, *99*, p, 77.

[63] Parker, G. (2013). *Global crisis* : *war, climate change and catastrophe in the seventeenth century*. New Haven: Yale University Press., p.19-25

rulers who followed the Pharaoh's example, and ignored the 'appeal' of their people, soon faced more rebellions and revolutions"[64]. According to Parker this led to upwards of one-third of the world's population dying. Tokugawa Japan is the exemption to the rule for Parker. In Japan, the state cut down on wars and built granaries that help overcome this period of need. And although Japan suffered, it demonstrated a population growth during the 17th century, in contrast to the population reduction in the rest of the world[65]. This leads back to Denmark, and a better understanding of the conditions the state faced during the 17th century and which issues were on the horizon.

9.1 The correlation between war and climate in Denmark

From 1550-1750 the kingdom of Denmark went to war eight times, totaling 43 years or around 20% of the period and with an average war length of 5 years (however with great differences between the wars). Most of the wars involved the balance of power in northern Europe, and the Baltic region, between Sweden and Denmark. In this sense, the Danish wars in this time period, were arguably different from the wars of rebellion and revolution noted by Parker and Zhang et.al. The Danish wars were interstate wars and not internal affairs. However, it is possible that internal stress in the state caused an external show of force, thereby reducing a problem within the state to a physical battle with an international enemy.

It seems difficult to draw a direct connection between climate and warfare during this time period. This is though not unreasonable, as such a connection would require a large amount of determinism. Figure 8.3 showed the occurrences of war combined with summer and winter temperature variations. Starting with summer temperatures, some of the many wars fit with the generally cooler summer temperature periods, while others seem to be free from a connection with climate. *Syvårskrigen* (The Nordic Seven Years' War) from 1563-1570 occurred in a period of generally milder summers, whereas *Torstenssonsfejden* (Torstenssons War) (1643-1645) occurred in a period of cooler summer temperatures. Looking at winter temperatures *Syvårskrigen* occurs in a period of falling winter temperatures, however the following period of 1570-1611 saw very cold winter temperatures without any occurrences of war. This leaves, that climatic changes may have played a role by changing other economic or social variables rather than in a direct correlation, a development with was not unexpected. In order to better understand the role of the climate, it is interesting to look at a possible correlation between climate and the funding of warfare, when war did occur.

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[64] Parker, *Global crisis : war, climate change and catastrophe in the seventeenth century*. p.109

[65] Dagomar, D. (2015). *Climate Change and Crisis: Lessons from the Past*. Retrieved from http://www.historicalclimatology.com/interviews/a-conversation-with-dr-geoffrey-parker

9.2 The economic situation in Denmark

The economic history of the 17th century in Denmark has been divided into two different themes by the historian Ole Feldbæk, with a period of growth from 1550-1650 and a period of stagnation from 1650-1750[66]. This seems to mostly to be based on the occurrence of very harsh wars during the period of 1650 - 1750, that caused serious damage to the economic system in Denmark, and a change in the economic condition of the country.

9.2.1 Periods of growth and stagnation

The period of growth between 1550-1650 is attributed to a general population expansion in northern Europe shortly before and under this time period. This expansion started a period of economic growth within the Kingdom of Denmark also known as the price revolution[67]. Denmark saw an increased demand for agriculture which supported growth in the society. Although this period also saw its share of wars, Feldbæk notes that these were distant wars for the general population of Denmark, whereas the letter wars, with for example Swedish invasions of Jylland, hit much closer to home. Feldbæk points directly at the Danish involvement in the Thirty Years Wars and *Torstensfejden* in 1643-1645 as the start of the end for what seems to be a golden period from 1550-1650. Although Feldbæk uses 1650 as an end date for the period of growth, he notes that already in 1625, the sun was setting on the Danish state as a period of serious wars was starting[68]. Interestingly, the period from 1625-1700 was characterized by colder average temperatures in winter and the onset of the Maunder Minimum, opening up for a possible climatic connection.

9.2.2 Funding for the army and navy

The economic situation in Denmark reflected on the conditions of the armed forces. Historian Martin Bellamy notes that, "There really is little positive that can be said of the navy's financial administration"[69] from 1596-1648. According to Bellamy, the *len* system that supplied the navy, was not able to develop at the same rate as the expenses for the navy, partly due to the system being outdated and partly due to corruption. Feldbæk is not quite as harsh on the *len* system, at least not in the period between 1559-1602, noting that there was a doubling of the intake from the *len* and that the Danish kings were much better at administrating the system[70]. However, Feldbæk, as Bellamy, points to an increased militarization of the society during the period. The state expenses grew from 2-2.5 million rigsdaler around 1600 to 9-10 million in 1646[71]. This leaded to a shift in the state from a domain state, with intakes from

[66] Feldbæk, O. (1993). *Danmarks økonomiske historie 1500-1840*. Herning: Systime.

[67] Feldbæk, *Danmarks økonomiske historie* 1500-1840. p.28

[68] Feldbæk, *Danmarks økonomiske historie* 1500-1840. p.29

[69] Bellamy, M. J. (2006). *Christian IV and his Navy : A Political and Administrative History of the Danish Navy, 1596-1648*. Boston, MA, USA: Brill Academic Publishers. p. 97

[70] Feldbæk, *Danmarks økonomiske historie* 1500-1840. p.50

[71] Feldbæk, *Danmarks økonomiske historie* 1500-1840. p.51

owned land, to a tax state. However, the shift was not easy. Part of the problem was that the state did not have a central treasury from which to pay for the expenses of the state. The treasury was divided between the *rentekammer*, which was administrated by the rigsraad and the king, with the *Kongens eget Kammer*, which was the kings alone. According to Bellamy, there were no formal boundaries between the two bodies[72].

During the rule of Christian IV, the *Kongens eget Kammer* was used to partially to pay for the navy. Bellamy notes that although it is a very rough division, the *rentekammer* paid for the upkeep of the navy, whereas the king paid for capital investments. This is a rough division, as at times the king paid for the upkeep and the *rentekammer* paid for building materials[73]. However, it is interesting as the *Kongens eget Kammer* received a large amount of its intakes from the Sound Tolls. Christian IV even managed to maneuver large amounts of the Sound Tolls away from the *rentekammer* and over to the *Kongens eget Kammer*. Historian E. Ladewig Petersen notes that the amount of the Sound Tolls that the *rentekammer* reviewed annually fell from 50-55% in 1596-1603 to 1-2% from 1607-1623[74].

Ladewig Petersen also focuses on the financial situation of the Danish military and its involvement in the Kalmar war in 1611-1612 and the involvement of the Christian IV in the Thirty Years War. Petersen's conclusion mirrors that of Bellamy, noting that the Danish military's financial system was not up to date. Ladwig Petersen notes "In comparison with the violent rationalization of war finance on the continent … Danish war finance seems archaic during this phase of internationalization."[75]. Christian IV was able to finance the start of the wars, however as the involvement increased he could no longer pay the military costs and required the help of the rigsraad (council of the realm). In the end, this lead to a strengthening of the *rigsraad* in regards to the kings, and a stronger control over the finances of the state.

However, noting that the financial system could not keep up with the war effort is not a complete answer. There are many reasons why the financial foundation of a state could be reduced, including enemy occupation, poor management, organization problems, societal norms and agriculture issues, to name a few. The question becomes; was the system underdeveloped or was the *foundation* for the system underdeveloped? Ladewig Petersen notes many of the issues that faced Christian IV and the *rigsraad* in the early 17th century when related to warfare, including issues of payments. One way of circumventing these issues, especially with regards to the Thirty Years War, was if

[72] Bellamy, *Christian IV and his Navy : A Political and Administrative History of the Danish Navy, 1596-1648*. p.73
[73] Bellamy, *Christian IV and his Navy : A Political and Administrative History of the Danish Navy, 1596-1648* p.78
[74] Ladewig Petersen, E. (1982). Defence, War and Finance: Christian IV and the Council of the Realm 1596-1629. *Scandinavian Journal of History*, *7*(4), p.288.
[75] Ladewig, *Defence, War and Finance*: *Christian IV and the Council of the Realm 1596-1629*. p. 312.

the Danish war contribution was financed by international donations rather that internal revenue sources. This would largely complicate a connection between climatic occurrences and warfare, as the local conditions would therefore not affect the financial system of the war. However, although promised large amounts from other countries, it does not seem that international support had a large impact on the Danish financial system. Although Ladewig Petersen notes it is a rough estimate, out of combined revenue of 942.5 thousand rigsdaler in 1626, 150 thousand came from foreign subsides and 80.3 thousand from The Lower Saxon Circle[76]. In comparison, taxes from Denmark and Holstein gave 261.3 thousand rigsdaler in revenue, leading the war to be largely funded locally. This leaves the issue of local and internal revenue which was receptive to climatic change, such as the Sound Tolls and agricultural output from the time period.

Firstly, the Sound Tolls must be addressed. When studying the foundation for financing the wars, the Sound Tolls are interesting for two reasons. In the period from 1625-1627 they represent, as a rough estimate, around 5% of the revenue for funding the Danish contribution to the Thirty Years War and grew from a revenue of 232,959 rigsdaler in 1635 to 499,980 rigsdaler in 1641[77]. Also, as noted before, they were in the hands of the king. Using the Thirty Years War as an example, Christian IV joined the war with his own finances, making income from the Sound Tolls an important aspect of Danish war and diplomacy. It is possible that a large income from the Sound Toll would increase the king's wealth, making war a possibility and conversely a great change in the Sound Tolls could leave the king in the hands of the *rigsraad*.

The second area of interest is how the change climate affected the agricultural output during the period. As noted with the developments in China, agricultural pressure could lead to increased pressures in the society. It could also lead to a much more direct economic consequence. If the harvests continued to fail in a period, this could lead to a greatly weakened tax base for the state to finance its war. Outside of social and economic consequences, failing harvests could also lower the general health of the population, making it more susceptible to disease during periods of war. All these connections between climatic change and warfare are interesting when understanding Denmark's many wars.

However, before jumping to a direct connection between a lack of financing and climate change, it is always relevant to remember that economies are built by human beings. For example, in 1621 when the council of the realm argued

[76] Ladewig, *Defence, War and Finance: Christian IV and the Council of the Realm 1596-1629*. p.306.

[77] Ladewig, *Defence, War and Finance: Christian IV and the Council of the Realm 1596-1629*. p. 306 and Degn, O. (2010). *Tolden i Sundet: toldopkrævning, politik og skibsfart i Øresund 1429-1857*. Kbh.: Told- og Skattehistorisk Selskab. p.166

against an annual defense tax, with the argument that it would be too expensive. This might very well have been true, however it is also possible that the council, in reality, was more concerned with controlling its own wealth rather than a lack of income[78]. This shows that economics is not always based on objective values. However, in order to better understand how, if at all, climate effected the financing of the state, the income from the Sound Toll and the corn prices between 1552-1750 will be analyzed.

9.3 The Sound Toll and the LIA

The Sound Toll was collected as a tax on all ships crossing through *Øresund* (The Sound Strait) starting as far back as 1497 and ending in 1857. As noted before, the tax went increasingly to the king and was important for the king's economic mobility. For example, when Christian the 4th needed more revenue in 1630s, and the council of the realm was not willing to provide this aid, an increased taxing of the Sound Toll was initiated[79]. Around 1600 half of the state's finances came from tolls and taxes, making this revenue important[80]. This policy of increased taxation led to many problems for the nation, such as a lack of international assistance during some of the wars with Sweden. Using a calculation of the average tax in rigsdaler per ship from 1550-1750, the top five years were 1639, 1638, 1640, 1641 and 1644 with values 204.2, 145.1, 130.6, 122.1, and 104.6 respectively. This increased tax burden has part of the reason for the *Torstenssonfejden* (1643-1645) and to Denmark's weak position in the peace agreement of the Thirty Years War[81]. A changing climate could affect the Sound Toll in multiple ways, including blockage from ice, increased storm occurrence and decreased travel times due to wind changes. However, in order to better understand the connection between a changing climate and the Sound Toll, it is important to compare revenue from the tolls and the temperature changes during the LIA. Table 1 shows the average yearly revenue, the average tax per ship, the average winter temperatures and their RMSE value, noted to show any "hiding" deviations in the average, in the Sound Toll divided up in 10 year blocks.

[78] Ladewig, *Defence, War and Finance*: *Christian IV and the Council of the Realm 1596-1629*. p. 292.
[79] Degn, O. (2010). *Tolden i Sundet*: *toldopkrævning, politik og skibsfart i Øresund 1429-1857*. p.131
[80] Feldbæk, *Danmarks økonomiske historie 1500-1840*. p.51
[81] Degn, *Tolden i Sundet*: *toldopkrævning, politik og skibsfart i Øresund 1429-1857*. p.132, 166

Table 9.3 – Travel in the Sound Toll

YEAR	AVERAGE YEARLY INCOME (*RIGSDALER*)[82]	AVERAGE TAX PER SHIP (*RIGSDALER*)[83]	AVERAGE ANOMOLY TO REFERENCEN TEMPERATURE[84]	RMS VALUE (TEMPERATURE DATA)
1550-1559	*	*	-1,2	2.1
1560-1569	43491.8	13.8	-1.7	2.5
1570-1579	82690.3	19.2	-3.0	2.0
1580-1589	104107.1	12.8	-1.1	1.3
1590-1599	131689.0	24.3	-1.7	2.1
1600-1609	134882.5	33.0	-1.3	2.7
1610-1619	170720.8	40.2	-2.0	1.9
1620-1629	184659.4	51.2	-2.2	0.9
1630-1639	298625.3	97.1	-1.7	1.8
1640-1649	271706.7	78.0	-1.0	1.8
1650-1659	53642.3	23.6	-1.7	1.2
1660-1669	62836.4	35.6	-1.7	1.9
1670-1679	88462.3	33.9	-1.2	1.3
1680-1689	123388.5	30.6	-0.7	2.0
1690-1699	90381.8	29.7	-2.8	3.2
1700-1709	72248.3	26.2	0.3	1.5
1710-1719	89328.4	20.7	-0.8	1.0
1720-1729	145757.5	42.3	0.4	1.4
1730-1739	162685.0	21.9	1.2	1.3
1740-1750	187481.2	45.5	-0.1	2.6

Table 9.3 shows the average yearly income in 10 year blocks from 1550-1750, with the average tax per ship added to show the level of taxation. Included is the average winter temperature for each of the 10-year block and an RMS value to show outliers to the average. The RMS values are relatively constant, between 0,9 and 3,2.

It seems, noting table 9.3, that the Sound Tolls were in general not strongly affected by the cooling climate, at least not in a direct way visible in the table. Again, this is not a surprising lack of correlation, but rather a direct connection would have been obvious to the past and would most likely have been corrected for. A disconnect between the colder winter/spring temperatures and income from the Sound Toll can be seen in the coldest of the winter periods. During the 10-year block with the coldest average temperatures, 1570-1579 (with an average winter/spring temperature of -3 degrees to the reference period), the average yearly income increased, though importantly this was partially due to an increase in the tax paid per ship. This increase might come from a new *lastetold*, cargo tax, which was imposed

[82] Degn, *Tolden i Sundet: toldopkrævning, politik og skibsfart i Øresund 1429-1857.* p. 142

[83] Degn, *Tolden i Sundet: toldopkrævning, politik og skibsfart i Øresund 1429-1857.* p. 142

[84] Leijonhufvud, I, *Five centuries of Stockholm winter/spring temperatures reconstructed from documentary evidence and instrumental observations.*

on the 25 February 1567 and included a new system of taxation for cargo and ballast. Originally, the tax was an even tax of one rigsdaler per cargo item and ½ rigsdaler per ballast, however it became a differentiated tax, with different items having a different tax value. For example, the tax for wax was 12 rigsdaler, whereas the tax for salt was one rigsdaler[85]. This tax did not include ships from Denmark, Norway, Sweden, Lübeck or Gdansk and was suspended for the Dutch in June 1568 but was re-imposed on the 30th of March 1571. As Dutch ships accounted for 44% of passage travel in 1574 and 48% of the passenger travel between 1575-1579[86], their inclusion in the tax most likely increased the income of the state.

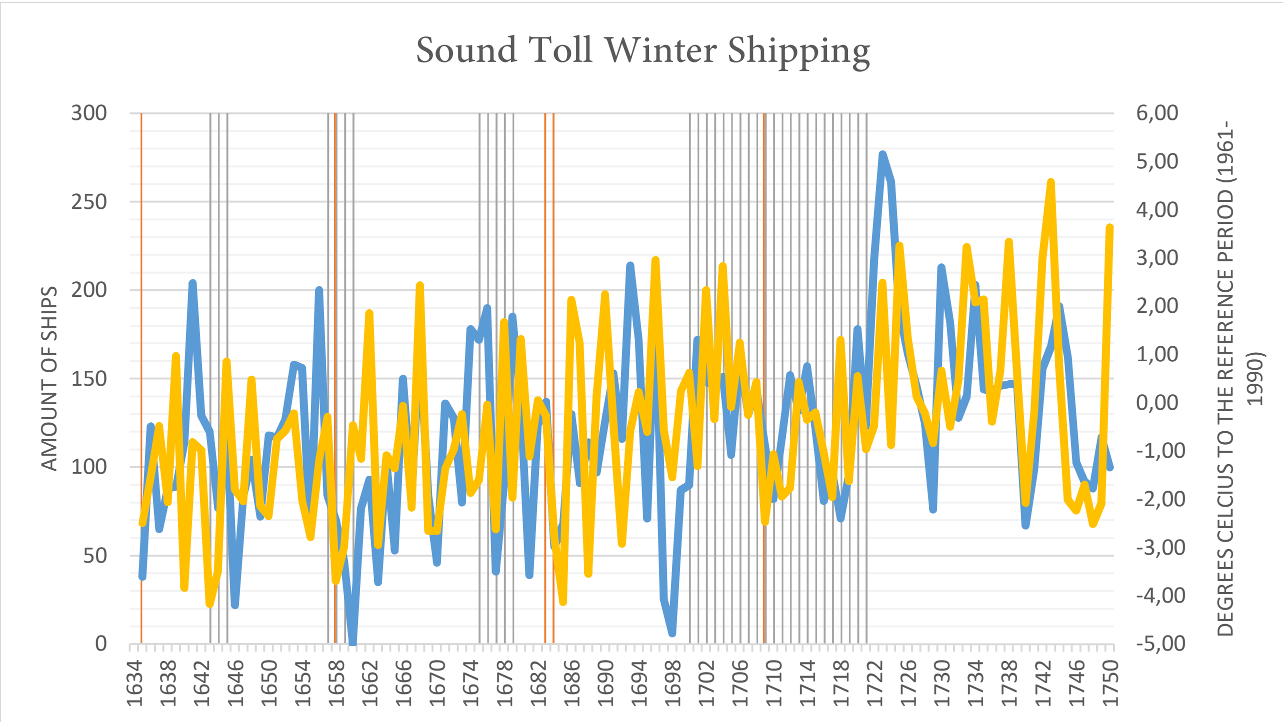
Erik Gøbel, from The Danish National Archives, notes one of the ways that the colder winter temperatures could have affected the Sound Toll revenue. Gøbel argues that the Sound Tolls total amount of ship travel was not evenly divided between the months and that travel during the winter months was heavily reduced. Using data from the Sound Tolls, he notes that even as late as the winter of 1837/1838, during January and February, 17% of the total year, only 13 ships were registered out of a yearly total of 13,983 ships or 0,09 percent[87]. This opens for an interesting possible connection between colder periods and less winter ship traffic and conversely, warmer periods and more ship traffic.

At this point, it should be noted that this is only possible thanks to the groundbreaking work done by the Sound Toll Registers Online project, led by the University of Groningen (RUG) and Tresoar, Frisian Historical and Literary Centre at Leeuwarden with help from the Danish National Archives, Copenhagen and the Fryske Akademy, Leeuwarden. This project has digitalized the Sound Tolls registry and made it possible to search for specific data at the blink of an eye, rather than months of reading and compiling. The project shows the true importance of making historical documents available online for easy access and easy computations. Much of the following analysis is only possible because the Sound Toll Registers Online project has made it time efficient to search for important and relevant information. It should also be noted that in general the time period for Sound Tolls Register Online starts at 1634. This is the earliest available date when using the organized Sound Toll Registers Online (as of late 2015, early 2016) and therefore defines the start date of this analyzes. In general, this does not largely effect this thesis as 1634 is an early enough start date to properly analyze the period.

[85] Degn, *Tolden i Sundet: toldopkrævning, politik og skibsfart i Øresund 1429-1857.* p. 128-129
[86] Degn, *Tolden i Sundet: toldopkrævning, politik og skibsfart i Øresund 1429-1857.* p. 149
[87] Gobel, E. (2010). The Sound Toll Registers Online Project, 1497-1857. *International Journal of Maritime History*, *1660*(2), p.315.

Following Gøbel's argument, that the icepack stopped travel through the Sound Strait during the winter, and noting that the temperature data from Stockholm represents qualitative values for the Danish winters, it is possible to compare the two. The hypothesis being, that when the temperature decreased, an increase of icepack reign would decrease the amount of winter shipping (December to February). Graph 3 shows the relationship between the temperature fluctuations, ship travel, qualitatively harsh winters (noted by Speerschneider) and periods of war. Periods of war are noted as these seem to have a large impact on the ship travel and not including them could lead to misunderstandings. Visually the two data sets seem very close, however closer inspection is necessary.

Graph 9.3: *Sound Toll Winter Shipping*



Graph 9.3 shows the amount of recorded winter shipping (December, January and February) in the Sound Toll (blue line) in relation to periods of war (grey areas), periods of cold winter as observed by Speerschneider (orange areas) and calculated winter temperatures (yellow line). Some periods show correlation, for example the drop around 1658, however other periods show inverse correlation, for example 1674.[88]

Correlation

Running a correlation test between the amount of winter shipping and the change in winter temperatures gives a correlation value of P=0.416, which can be defined as a moderate correlation[89]. Roughly, that means that changes in

[88]Ship data found using the Sound Toll Registers Online. Temperature data from: Leijonhufvud, I, *Five centuries of Stockholm winter/spring temperatures reconstructed from documentary evidence and instrumental observations*. Severe winters found from: Speerschneider, Om Isforholdene i danske Farvande i ældre og nyere Tid : Aarene 690-1860. Wars found from: Jensen, *Danmarks krigshistorie*, p. 458-459

[89] Hyldtoft, O. (1999). *Statistik : en introduktion for historikere*. Kbh.: Institut for Historie, Københavns Universitet. p.128-134

the amount of shipping from 1550-1750 during the winter was 40% affected by the developments in the temperature, most likely caused by icing. Taking the period of 1645-1715, again this period being the Maunder Minimum, the correlation is set at 0.3781, again around the 40% and a moderate correlation. This is an interesting relationship, as it shows that travel in the Sound Strait was effected by decreases in the winter temperatures in a notable degree. However, it is important to understand how much of the general revenue from the Sound Toll the winter period represents. For, as Gøbel correctly notes, the winter months represented a much larger time period than its revenue accounted for. If the general winter intakes were so low that even "good" years made marginal changes in the annual revenue, then the Sound Toll might be seen as generally free from the negative effects of worsening icepack with decreasing temperatures.

Winter revenue versus yearly revenue

In order to measure the impact of decreasing winter temperatures on the general annual revenue from the Sound Toll, it is possible to compare the monthly shipping traffic to the yearly shipping traffic. Table 9.3.2 shows the average percentage of ship traffic that occurred during the winter (December to February) out of a total year (in this case December to November so that no ships are counted twice). 5 year periods were chosen to show the relative importance of Sound Tolls on the income to the state.

Table 9.3.2 – Winter travel percent

5 YEAR PERIOD	AVERAGE PERCENT OF WINTER TRAVEL TO TOTAL ANNUAL TRAVEL[90]	AVERAGE TEMPERATURE (TO REFERENCE)[91]
1635-1639	2,2	-1.1
1640-1644	3.5	-2.7
1645-1649	4.1	-0.9
1650-1654	4.4	-1.2
1655-1659	18.9 (4.7)	-2.2
1660-1664	2.6	-0.8
1665-1669	4.4	-0.8
1670-1674	4.5	-1.4
1675-1679	5.5	-0.9
1680-1684	2.5	-0.6

[90] Found by using the Sound Toll Registers Online Project, at http://www.soundtoll.nl/index.php/en/over-het-project/sonttol-registers

[91] Leijonhufvud, I, *Five centuries of Stockholm winter/spring temperatures reconstructed from documentary evidence and instrumental observations.*

1685-1689	2.5	-0.8
1690-1694	4.0	-0.3
1695-1699	2.4	0.1
1700-1704	5.0	0.8
1705-1709	4.9	-0.2
1710-1714	7.0	-0.9
1715-1719	6.8	-0.7
1720-1724	7.0	0.1
1725-1729	3.5	0.7
1730-1734	4.0	1.2
1735-1739	3.6	1.3
1740-1744	3.2	1.2
1745-1750	2.8	-1.1
AVERAGE	4.8 (4.1)	

Table 9.3.2 shows the relationship between winter temperatures and the average amount of travel through the Sound Strait during December, February and January (winter). There is not a simple correlation between the two data sets.

Table 9.3.2 shows that there again is no easy connection between the two data sets. The Maunder Minimum, ca.1645-1715, does see a period of lower than average temperatures with 12 out of the 14 5-year periods being under the reference period of 1961-1990. However, only six out of the 14 5-year periods show a below average winter transport (4,8% with 1655-1659 included, 4.1% without). The period of 1655-1659 deserves a special note, as it has a much higher average value than all the other periods. This is due to a very high winter travel percent (76%) in the year 1659, most likely a result of the Karl Gustav Wars during this period problematizing proper registration. Removing 1659 from the average leaves a much more uniform result of 4.7% of the yearly travel.

Part of the problematic correlation between harsh winters and annual revenue can be exemplified by the difference between 1697 and 1698. During both years, the first ship of the year was late to come. January and February were quiet in Helsingør in 1697, with no ships at all. On the 14th of March, Reyer Pietersen Vliegop from Vlieland, an island in the northern part of the modern Netherlands, broke the silence. On his way from Amsterdam to Copenhagen he was traveling with tobacco, cheese, honey and wine, among other items, and had to pay 103 daalder in tax to the Danish realm/king[92]. Likewise, in 1698, the winter was quiet and was first broken by Cornelis Roelofsen from Stockholm, on the 14th of March, on his way from Newcastle upon Tyne in England to Copenhagen and thereafter "siider ad Østersøen[93]". Roelofsen was most likely on a tax-free travel as there is not noted any paid tax for his trip. In this sense, the two years seem similar. Comparing the two years according to the data from Stockholm,

[92] *The Sound Toll Registers Online Project*, Retrieved January 19, 2015, from http://dietrich.soundtoll.nl/public/?periode=. Search for passage id=663884

[93] *The Sound Toll Registers Online Project*,.Retrieved January 19, 2015, from http://dietrich.soundtoll.nl/public/?periode=. Search for passage id=646993

1697 had a temperature of -0.57 degrees to the reference and 1698 had a temperature of -1.54 degrees to the reference. In other words, both years were under reference and could be described as somewhat harsh. Looking at the notes from Speerschneider 1697 is categorized as an "ualmindelig streng Vinter[94]"(an abnormally cold winter) and 1698 is noted for being "streng og lang[95]" (harsh and long). Again the two years seem similar to one other. However, when looking at the yearly revenue, 1697 had a revenue of 59007 rigsdaler, with an average of 22 rigsdaler per ship, and 1698 had a revenue of 110382 rigsdaler, with an average of 27,1 rigsdaler per ship[96]. In other words, even though 1698 had a harsh winter it still was more profitable than 1697, which also had a harsh winter. This can also be seen in the ship travel. Where 1697 saw 2701 ships in the periods of December 1696-december 1697, 1698 saw 4015 ships from December to December. Evening the average rigsdaler per ship out between the two years, does not help bring 1697 up to the same level as 1698. Using an average of 27.1 rigsdaler per ship (the average from 1698), and 2701 ships in total (the total ships from 1697), and annual revenue would be around 73,000 rigsdaler, well short of the 110382 rigsdaler from 1698. In other words, although two succeeding harsh winters had similar winter travel patterns, down to the first day of recorded transit in the Sound Strait, 1697 remained a quiet year, whereas 1698 was a much more lucrative year. This shows that harsh winters may play a role in lowering the yearly revenue, but other factors dominate during the rest of the year and have a larger contribution to the annual revenue.

In general, it seems that although the winter shipping was moderately affected by the decreasing temperatures, the winter revenue was not large, ranging from 2.2 to 7.0 percent of the yearly travel. This cannot be directly converted into revenue, as some taxes were based on the cargo type and not a straight tax on all ships, however it does point to the relatively minor importance of winter travel. In other words, the Sound Tolls revenue seems to see relatively little impact from the increased icepack during the winter, as the ice related time period is of generally low importance for the annual revenue. This does not mean that other issues could not arise from the decreased winter temperatures, however in many ways it mirrors Degroot's somewhat cautious approach to the effects of the cooling climate on societies. This leads to the second of the two areas of analysis, the agricultural output.

9.4 Agricultural output and the LIA

In our modern world with global shipping and international markets, it is possible to forget the importance of seasons and decadal changes on agriculture. It may be that buying a watermelon in the middle of December at 55.5

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[94] Speerschneider, Om Isforholdene i danske Farvande i ældre og nyere Tid : Aarene 690-1860, p.84

[95] Speerschneider, Om Isforholdene i danske Farvande i ældre og nyere Tid : Aarene 690-1860, p.84

[96] Degn, *Tolden i Sundet: toldopkrævning, politik og skibsfart i Øresund 1429-1857*. p. 167

degrees' north latitude (the location of Roskilde, Denmark) is expensive, however it is possible. We are not used to the idea of a lack of food due to harvest failure, but in the 17th century this was a possibility, even the norm, in Denmark. The following chapter will analyze the availability and output of the annual harvest seen in relation to the climatic developments in the LIA. This is an attempt to find the economic backbone of the Danish state during the Swedish Wars and discover if the annual harvests were negatively affected by changes in the climate, in a degree that would seem significant.

9.4.1 The importance of agriculture.

Other than the Sound Tolls, agricultural output played a large role in the condition of the state, not only fiscally but also socially. Fiscally, the importance of corn can be hard to find in market values, as some parts of the economy during the 17th century were still moneyless and therefore disappear in the record books as the market price was not always noted. However, it is still possible to get a general idea of the importance of corn. Although not a part of the Kingdom of Denmark, in Haderslev amt (part of the Duchy of Holstein), corn represented around 46% of the revenue between 1595-1600, with money as the second largest income, and on the heavily barley-dominated island of Ærø corn was the largest source of income in 1627/1628 representing ca. 61% of the annual revenue[97]. Both examples show an economic system, much like the Danish system, which was heavily based on corn and agricultural products.

The many wars in the 17th century did affect the agricultural parts of the country greatly; however, it may be possible to determine the climatic impact of the period also. Agriculture can be affected by many different aspects of the climate, such as heavier precipitation, shorter growth seasons, harsher and earlier or later frost events and even a lack of frost, leading to increased disease and rodent infestation. The following will analyze the correlation between the NAO, a climatic shift, and the agricultural outputs.

9.4.2 Agricultural output and negative North Atlantic Oscillation (NAO) events

As noted above, the winter weather in Scandinavia is affected by fluctuations in the North Atlantic Oscillation (NAO). If the NAO is negative and there is a weak high pressure around the Azores and Lisbon, the warm, humid air from North America will flow into the middle of the European Continent, leaving Scandinavia with cold, dry winters[98]. Oppositely, high NAO values will cause mild winters in Denmark with large amounts of precipitation.

[97] Porskrog Rasmussen, C., & Grænseregionsforskning, I. for. (2003). *Rentegods og hovedgårdsdrift : godsstrukturer og godsøkonomi i hertugdømmet Slesvig 1524-1770. Del 1. Fremstilling*. Aabenraa: Institut for Grænseregionsforskning, p183 and 302

[98] Koslowski, G., & Glaser, R. (1999). Variations In Reconstructed Icewinter Severity In The Western Baltic From 1501 To 1995, And Their Implications For The North Atlantic Oscillation. *Climatic Change*, (1995),

Both conditions would seem to affect agriculture. Cold, harsh winters could affect the growth season and the winter crops, mild winters could lead to stormy weather destroying the harvest or accelerating disease and rodent infestation. Figure 9.4.2 shows the variation in the North Atlantic wind currents during a positive and a negative NAO variation.

Figure 9.4.2 – The North Atlantic Oscillation[99]

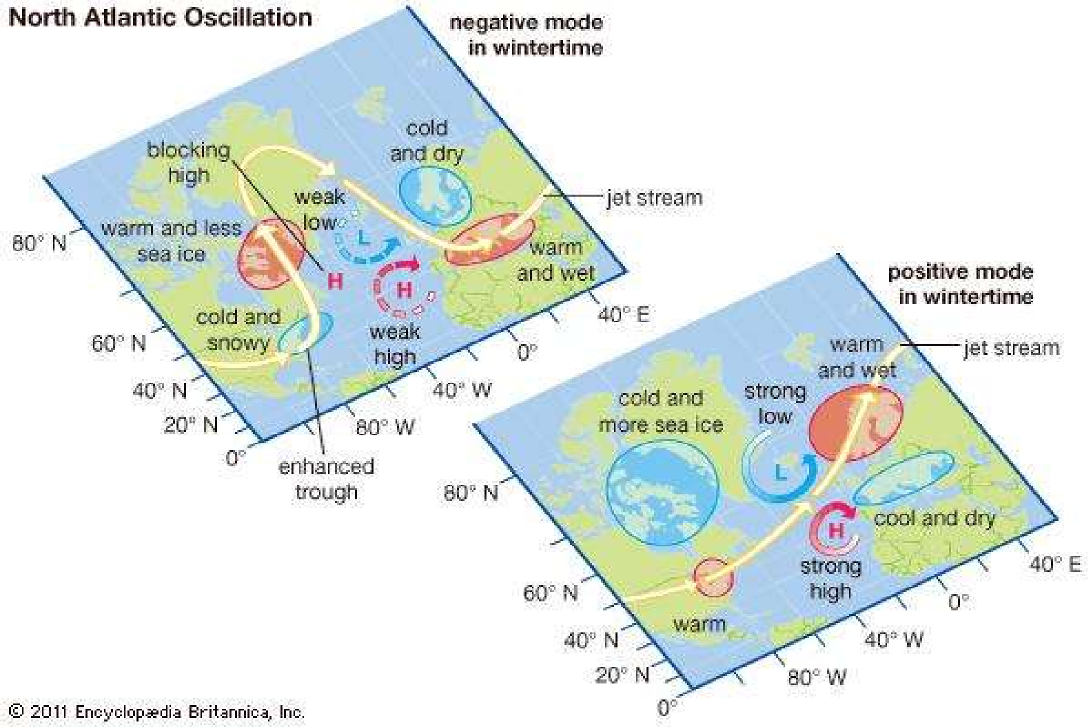


Figure 9.4.2 shows the variations in the Northern European wind conditions during a positive NAO and a negative NAO. During a positive NAO warm and wet air masses cover Scandinavia, whereas during negative NAO periods cold and dry air masses during Scandinavia.

Due to the lack of instrumental data before the 19th century, other proxies must be used when determining the NAO variations in the 17th century. In the article *Variations in Reconstructed Ice Winter Severity in The Western Baltic from 1501 To 1995, And Their Implications for The North Atlantic Oscillation* Gerhard Koslowski and Rudiger Glaser compare winter ice conditions in the Baltic Sea to the NAO variations, with the hypothesis that growing ice regimes in the Baltic would be comparable to negative NAO conditions due to the decrease in temperature and decrease in warm westerly winds, increasing icing. Although a multitude of very precise and high quality reconstructions of the

[99]"North Atlantic Oscillation". In *Encyclopædia Britannica, Inc.*

NAO variation have been created within the past 20 years of scholarly work, this study is chosen because of its geographic comparability to Denmark. Figure 9.4.2.1 shows the ports used by Koslowski and Rudiger.

Figure 9.4.2.1 – Map of western Baltic reconstructions stations

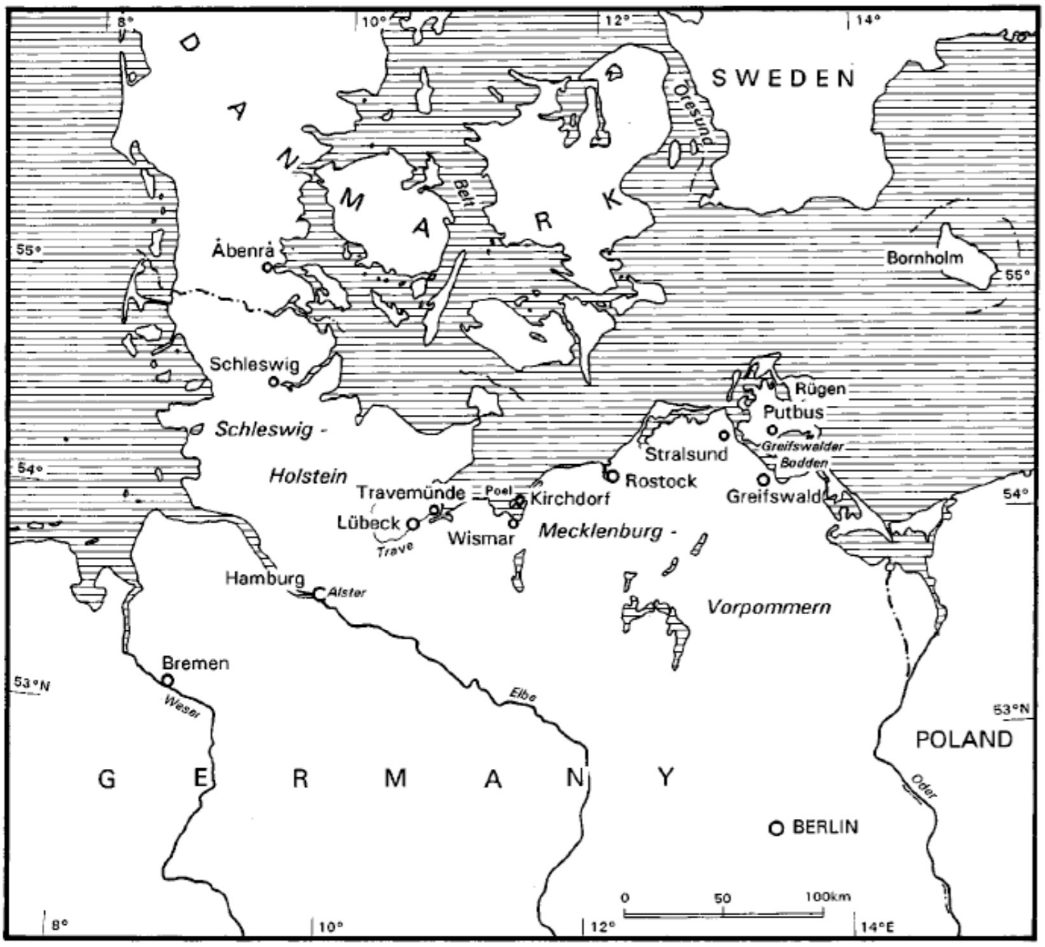


Figure 9.4.2.1 shows the ports used by Koslowski and Glaser when reconstructing the NAO variations between 1501-1995. Important for this thesis, this their relative proximity to Denmark.[100]

As visible in figure 9.4.2.1, the stations lie just south of the Danish area, giving a correlation between the results in the article and the conditions in Denmark more credibility.

Koslowski and Glaser use the winter ice conditions to estimate periods of low westerly winds, or NAO negative conditions. It can be somewhat difficult to receive an annual answer, partially due to the over decadal variances of the NAO. Therefore, Koslowski and Glaser reconstruct decadal blocks with few weak-westerly events and decadal

[100] Koslowski, *Variations In Reconstructed Icewinter Severity In The Western Baltic From 1501 To 1995, And Their Implications For The North Atlantic Oscillation.* p. 177.

blocks where there were more weak-westerly events[101]. They conclude that periods of increased zonal atmospheric circulation, which seem to fit with positive NAO periods and few weak-westerly events, occurred between 1521-1553, 1577-1592, 1631-1654 and 1711-1762. Periods with low zonal atmospheric circulation, which seem to fit with negative NAO periods and more weak-westerly events, occurred between 1554-1576, 1593-1630, 1655-1710, and 1763-1860, with harsh periods in the 1620s and 1690s[102]. This seems to correspond well with the increased atmospheric high pressure zonal blocking descripted in chapter 7, which may have occurred more frequently during the LIA. However, colder, drier winters do not per se have to include reductions in the agricultural output, and before making the classical correlation between colder climates and destruction, it is important to understand how NAO conditions affect agriculture.

9.4.3 The North Atlantic Oscillation and agricultural output

In a study from Spain, Luis Gimeno, Pedro Ribera, Raqual Iglesias, Laura de la Torre, Ricardo Garcia and Emiliano Hernandez analyze the effect of the NAO on Spanish agriculture by studying the relationship between NAO events and crop/price developments. It is important to remember that Spain has the opposite NAO conditions from Denmark. In other words, when high pressure blocking decreases the westerly winds in Denmark, they increase in Spain. In the study, 1963, 1977, 1985, 1986, 1991, 1992, 1994 and 1997 were identified as NAO positive years, whereas 1965, 1967, 1971, 1979 and 1981 were identified as NAO negative years[103]. This correlates well with Denmark. The coldest December in instrumental history occurred in 1981, an NAO negative year, and the wettest December occurred in 1985, an NAO positive year[104]. Interestingly, the study concludes that higher yields of wheat, rye, oats and citrus can be excepted during positive NAO periods than during negative periods. In other words, during dry and colder winter periods in Spain the agricultural outputs increased, whereas during periods of increased westerly winds, the output decreased. An explanation can be found when studying durum wheat output in Italy. A study found that a decreased NAO, or a negative NAO event, lead to increased rain in Northern Italy, which increased

[101] Koslowski, *Variations In Reconstructed Icewinter Severity In The Western Baltic From 1501 To 1995, And Their Implications For The North Atlantic Oscillation*. p. 188.
[102] Koslowski, *Variations In Reconstructed Icewinter Severity In The Western Baltic From 1501 To 1995, And Their Implications For The North Atlantic Oscillation*. p. 189-190
[103] Gimeno, L., Ribera, P., Iglesias, R., Torre, L. D. La, Garca, R., & Hernndez, E. (2002). Identification of empirical relationships between indices of ENSO and NAO and agricultural yields in Spain. *Climate Research*, *21*(2), p 167
[104] "Sådan er vinteren i tal (mange tal)". *DMI*. Retrieved December 22, 2015, from http://www.dmi.dk/nyheder/arkiv/nyheder-2015/12/saadan-er-vinteren-i-tal-mange-tal/

nitrogen leaching (the out washing of fertilizer thereby reducing the amount of fertilizer for the crop to use) and decreased crop quality.[105]

In Denmark, the crops may have been affected by lower winter temperatures during NAO negative variations or early or late frosts during the same period. Oats are the least resilient to frost, followed by barley, wheat and rye[106]. As noted above, the temperature alone does not determine the output, the timing is also important. If spring frosts coincided with flowering in winter varieties, the plant could have been damaged. In addition, when the winters were too cold (between -4^{oC} and +3^{oC}) or too warm (+10^{oC} to +17^{oC}), optimal flowering would not occur[107]. If the winters were very severe, as may have happened in an NAO negative situation, only spring variations of different sorts may have been possible, lower the total annual output from the fields. And lastly, if the plants lacked water during flowering, a possible side effect of the reduction in wet westerly winds over Denmark, the total output may have been reduced[108].

In other words, both studies from the Mediterranean and the general characteristics of agriculture in the temperate zone (of which Denmark is a part) show that the expected crop output of a given year, can be affected by an NAO variation event. In the cases from Spain and Italy, negative NAO periods reduced the crop output. Looking historically at the LIA, it becomes interesting if the increased amount and length of negative NAO periods saw a similar crop reduction in Denmark, thereby adding a possible source of pressure to the society.

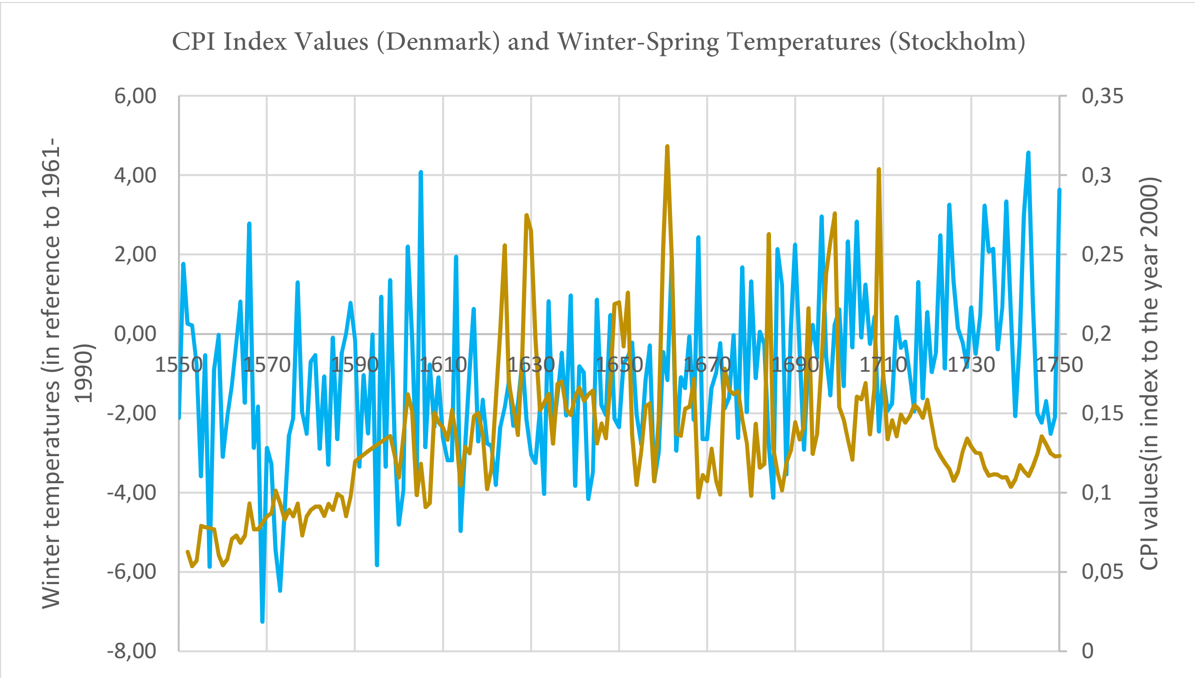
9.4.4 Danish agricultural output and negative NAO events

The following chapter will examine a possible correlation between NAO negative events and agricultural output during the period from 1550-1750 in Denmark. The first step on this path is to find fluctuations in the corn price during this period. This is possible thanks to Kim Abildgren, from the Danish National Bank, who has created a consumer price index (CPI) from between 1502-2007, thereby including the large parts of the LIA. Abildgren notes, to his dismay, but to the interest of this thesis, that the calculations of the CPI from 1502-1712 are based solely on corn prices[109]. Using these corn prices as a baseline Abildgren explains what a CPI reconstruction can tell us. He explains that the CPI values are ". . . index numbers that measure changes in the prices of goods and services

[105] Marta, A. D., Grifoni, D., Mancini, M., Zipoli, G., & Orlandini, S. (2011). The influence of climate on durum wheat quality in Tuscany, Central Italy. *International Journal of Biometeorology*, *55*(1), 87–96.
[106] Griffiths, J. F. (1994). *Handbook of agricultural meteorology*. New York: Oxford University Press. p. 180
[107] Mirschel, W., Wenkel, K. O., Schultz, a, Pommerening, J., & Verch, G. (2005). Dynamic phenological model for winter rye and winter barley. *European Journal of Agronomy*, *23*, 123–135.
[108] Griffiths, J. F. (1994). *Handbook of agricultural meteorology*. New York: Oxford University Press., p.178, 180
[109] Ahmed, M., Anchukaitis, K. J., Asrat, A., Borgaonkar, H. P., Braida, M., Buckley, B. M., … Zorita, E. (2013). Continental-scale temperature variability during the past two millennia. *Nature Geoscience*, *6*(6), 503–503.

purchased or otherwise acquired by households, which households use directly, or indirectly, to satisfy their own needs and wants[110]". Thereby the information from Abildgren not only gives the annual corn prices but sets them in relation to each other through index numbers, making them comparable by setting the year 2000 as the index=100. As a historian, the CPI values give the ability to see how much the cost of necessary daily needs effected the lives of the inhabitants of a time period. For example, with the CPI values one can find how expensive bread was (a necessary item) in relation to income and thereby, if the worker had a large disposable income to use in his or her free time. These kinds of analyses help us better understand the daily life of different historian periods.

Graph 9.4.4 CPI Index Values and Winter Temperatures



Graph 9.4.4. shows a casual graph of the connection between the CPI values (the orange line) from 1550 to 1750, compared with the winter temperatures (in reference to the period from 1961-1990) (the blue line). An ideal correlation should show a growth in the CPI values as the winter temperatures decrease[111].

CPI values, and thereby corn prices, can be used to analyze annual harvests, under the assumption that higher corn prices are the result of a poor harvest and conversely for lower corn prices. Ole Feldbæk notes that there was a connection during the period from 1650-1750 between corn prices and the harvest; a bad harvest would increase the corn prices. However, Feldbæk notes that political developments could also affect the prices[112]. Increased corn prices,

[110] Abildgren, K. (2010). Consumer prices in Denmark 1502–2007. Scandinavian Economic History Review, 58(1), p..3

[111] CPI values: Abildgren, K. (2010). Consumer prices in Denmark 1502–2007. Scandinavian Economic History Review, 58(1). Temperature data: Leijonhufvud, I, *Five centuries of Stockholm winter/spring temperatures reconstructed from documentary evidence and instrumental observations.*

[112] Feldbæk, *Danmarks økonomiske historie 1500-1840*, p 74

due to a bad harvest, would increase the CPI values as corn prices were seen as a baseline items. This assumption is not unproblematic, as it does not include an understanding of the importance of export to the international community. In other words, the corn prices may have been high in Denmark due to a large international demand, rather than an internal collapse of the harvest. This will be examined later. Firstly, however, it is important to quantify the correlation between the CPI and the harvest output, in order to better understand the usability of the CPI to find bad harvests. In order to reduce an overwhelming number of citations to Abildgren's article on the CPI values, it should be noted that from now on references to the CPI values, unless otherwise noted, are references to Abildgren's work.

9.4.5 CPI values and harvest output

In order to use the CPI values to discover the NAO's effect on corn output, it is possible to correlate different studies of harvest outputs with CPI values of the same year. As noted before, it is possible that other factors played into the corn prices, like export demands or politically motivated reductions or increases in prices. It is therefore relevant to try to find the relationship between the CPI values and the harvest output. However, the harvest output, seen in relation to the amount of seed used and grain harvested, can be hard to find. Historian Karl-Erik Frandsen noted this in 1977, when he pointed out that some of the source material used to find the relationship between seed and harvest may result in low harvest values[113]. In addition to this the backbone of the Danish agricultural system was the peasant farmer, however sources that directly describe the output of their farms, in relation to seed amounts, can be difficult to discover. Instead one must use the farmlands under control of the king. The question becomes; do the results for the estates correlate with the local production? It may be possible that the peasant farmers were more effective in their production, as it, for them, was not a question of profit but survival. However, even with all of these important problematizations of the CPI values, and therefore corn prices, it still seems to be the best possible way of quantitatively understanding corn production during the time period. In other words, it may not be possible with this data set to know how bad a "bad" year was, but it may be possible to find the "bad" years during the period.

Using historian Bo Fritzbøger's analysis of the estate of Skinnerup, on the north-easterly part of the island of Fyn, it is possible to compare seed and harvest amounts for the period of 1637-1646 with the CPI values. Noting Frandsen's caution on finding seed amounts, Fritzbøger uses the amount of seed withdrawn from the previous year's total harvest to estimate the amount of seed for the next year[114]. Although this may be problematic, it is a pragmatic

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[113] Frandsen, K.-E. (n.d.). Udsæd og foldudbytte i det 17 . århundrede. *Fortid Og Nutid*, *44*, 21–36.

[114] Fritzbøger, B. (1984). Hovedgårdsdrift og godsøkonomi: Skinnerup 1616-1660. *Landbohistorisk Tidsskrift* (*Bol Og By 2.rk. bd.6*). p. 202

solution. Table 9.4.5.1 shows the CPI values (in relation to the index year, 2000=100), the percent of change from the year before (an easy way of finding raising or falling prices), the barley seed and harvest relationship for Skinnerup and the rye seed and harvest relationship for Skinnerup. Under the each of the corn sorts the linear correlation between the seed/harvest relationship and CPI is noted.

Table 9.4.5.1: The relationship between the CPI and seed/harvest results at Skinnerup Estate

YEAR	CPI VALUE[115]	PROCENT CHANGE IN CPI FROM YEAR BEFORE	BARLEY SEED/HARVEST RELATIONSHIP[116]	RYE SEED/HARVEST RELATIONSHIP[117]
1638	0.1525	-10.3	2.9	3.2
1639	0.1491	-2.2	2.2	1.3
1640	0.1607	7.8	2.5	1.1
1641	0.1661	3.4	2.9	0.9
1642	0.1579	-4.9	3.9	0.9
1643*	0.1619	2.5	1.9	1.7
1644*	0.1644	1.5	2.4	2.0
1645*	0.1311	-20.3	5.7	1.6
1646	0.1435	9.5	2.8	0.8
CORRELATION	-	-	-0.7	0.1

Table 9.4.5.1 shows the correlation between the CPI values and the harvest outputs for a Danish farm. The correlation proves moderate when referring to barley, where as it is almost random when referring to rye

Table 9.4.5.1 shows that the barley prices have a strong negative correlation to the CPI values. In other words, when the barley harvest increased, the CPI values decreased, showing a fall in corn prices. This seems to show that for barley the CPI values are usable to understand the harvest results. Rye does not seem to have the same correlation, and is close to random with a value of 0.1. Most likely, the rye prices are either not included in the CPI values or rye represented a small amount of the general corn prices, making its fluctuations of minimal importance. It should be noted that, although it does not seem to effect the analysis, the period from 1643-1645 (denoted with a star) represents the *Torstenssonsfejde* (Torstensson War).

Although the analysis from Skinnerup seems usable, as with most historical work it is important to verify the results as much as possible. Even more so, as the goal of this thesis is to discover change, if any, and therefore this thesis is dependent on finding usable reference values for a longer time period. Using the seed and harvest relationship from Christen Lauritsen from Kullerup, close to Nyborg on the island of Fyn, from 1678-1703 it is again possible to

[115] Abildgren, K. (2010). Consumer prices in Denmark 1502–2007. Scandinavian Economic History Review, 58(1),

[116] Fritzbøger, *Hovedgårdsdrift og godsøkonomi: Skinnerup 1616-1660*. p. 182

[117] Fritzbøger, *Hovedgårdsdrift og godsøkonomi: Skinnerup 1616-1660*. p. 182

correlate the data. This is possible thanks to the work done by the ethnologist Karen Schousboe in the article *Foldudbytte og bondeøkonomi* from 1979-1980. Table 9.4.5.2 shows the results.

Table 9.4.5.2: The relationship between the CPI and seed/harvest results from Christen Lauritsen

YEAR	CPI VALUE[118]	PROCENT CHANGE IN CPI FROM YEAR BEFORE	BARLEY SEED/HARVEST RELATIONSHIP[119]	RYE SEED/HARVEST RELATIONSHIP[120]
1678	0.1461	-10.9	4.0	4.5
1679	0.1311	-10.3	6.0	5.0
1680	0.0981	-25.2	4.5	1.6
1681	0.1434	46.2	6.0	0.9
1682	0.1158	-19.2	7.0	3.0
1683	0.1181	2.0	4.0	4.0
1684	0.2629	122.6	5.0	2.5
CORRELATION			**-0.1 (0.0)**	**-0.3 (0.2)**
1687	0.1014	-10.0	6.0	5.0
1688	0.1191	17.5	5.0	3.0
1689	0.1268	6.5	5.5	2.6
1690	0.1443	13.8	5.0	3.3
1691	0.1335	-7.5	5.2	3.8
1692	0.1423	6.6	7.0	3.2
1693	0.2162	51.9	3.5	3.2
1694	0.1244	-42.5	9.0	5.5
1695	0.1375	10.5	6.0	3.0
1696	0.1814	31.9	5.0	3.2
1697	0.2379	31.1	6.0	3.0
1698	0.2582	8.5	5.0	3.0
1699	0.276	6.9	5.2	2.5
1700	0.1538	-44.3	4.0	4.6
1701	0.1458	-5.2	5.0	4.0
1702	0.133	-8.8	5.5	5.5
1703	0.1207	-9.2	8.0	6.2
CORRELATION			**-0.4**	**-0.4**

Table 9.4.5.2 shows the correlation between the CPI values and the barley seed/ harvest relationship and the rye seed/harvest relationship for a farm in Kullerup between 1678-1703. Between 1678-1684 the correlation is weak for barley and a weak/moderate inverse correlation for rye. Removing the high value from 1684, the correlation in parenthesis, does not change the relationship. Between 1687-1703 the inverse correlation is moderate.

[118] Abildgren, K. (2010). Consumer prices in Denmark 1502–2007. Scandinavian Economic History Review, 58(1),

[119] Schousboe, K. (n.d.). Foldudbytte og bondeøkonomi. *Fortid Og Nutid*, 35–49.

[120] Schousboe, Foldudbytte og bondeøkonomi. 35–49.

The data from Kullerup proves to be a conundrum. Whereas the period from 1678 to 1684 shows little to no correlation, especially if the high value from 1684 is removed, the period from 1687-1703 shows a moderate inverse correlation for both barley and rye. A linear inverse correlation of -0.4 shows that 40% of the change in the corn prices match with the barley and rye harvest outputs. In general, this correlation seems strong, as other farms in the country may have had larger or smaller harvests that affected the general corn prices. It is also possible that the corn prices are based on the regulation corn prices for Sjælland, as this seems to be an often used source in the scholarly work, and as noted before Kellerup lies on the island of Fyn. This makes it possible to compare the two sides of the Great Belt, and it is worth noting that although two different land areas the corn prices seem to have moderate correlation.

The data from Kellerup shows that some periods correlate well, in this case with both types of corn, while other periods seem random, maybe due to political actions or from the lacking of the harvest from Kellerup being representative of the nation as a whole. It strengthens the use of corn prices when examining harvest output, but leaves a caution towards direct correlation. Thanks to the outstanding work of earlier historians, it is possible to expand the search for a correlation and causation between the seed to harvest ratio and the price of corn. Using the regulation corn prices from Sjælland, the average seed to harvest ratios from the Sjællanske ladegaarde (large farms without nobility[121]) and the amount of corn export between 1610-1660, it is possible to analyze the correlation during this period. Gunnar Olsen, the historian who compiled this work in 1942, notes that the corn export numbers should be read carefully, as they most likely are lacking information. The export values should be used to show trends rather than exact values[122]. Table 9.4.5.3 shows the results of Olsen's work and the correlation between the regulation price and the corn output.

Table 9.4.5.3: *corn prices, seed/harvest ratios and yearly export on Sjælland*

	RYE			**BARLEY**		
	Fold	Pris Kr.	Transport amounts	Fold	Pris Kr.	Transport amounts
1610	1.90	5.54	3.00	2.30	5.13	1224.50
1611	1.90	4.92	138.50	3.40	4.88	3012.50
1612	2.80	7.38	223.50	2.80	6.15	3803.00
1613	2.20	6.15	182.00	2.80	5.38	2543.50
1614	2.20	5.13	1.00	2.70	5.13	1787.00
1615	1.70	6.77	9.00	2.20	6.68	1996.50

121 Porskrog, *Rentegods og hovedgårdsdrift: godsstrukturer og godsøkonomi i hertugdømmet Slesvig 1524-1770*, p 39

122 Olsen, G. (1943). Studier i Danmarks Kornavl og Kornhandelspolitik i tiden 1610-60. *Historisk Tidsskrift*, *10*(6), p. 458

1616	2.00	6.15	20.00	2.50	6.40	888.00
1617	1.40	6.15	6.00	2.50	5.13	1694.50
1618	2.10	5.82	35.00	2.20	6.15	2578.50
1619	1.90	4.90	4.00	2.00	5.02	1220.50
1620	2.20	3.21	9.00	2.80	3.11	2869.50
1621	1.50	5.12	230.00	3.60	3.83	3559.00
1622	1.10	8.20	549.10	3.10	6.16	3459.50
1623	1.50	11.83	24.00	3.10	6.89	2760.50
1624	1.60	13.87		1.90	10.08	649.00
1625	2.20	8.41		3.10	6.16	1131.00
1626	2.20	7.50	18.00	3.20	5.12	1497.00
1627	2.50	6.16	8.00	3.90	4.62	3068.00
1628	0.90	11.25	391.00	2.00	7.68	3119.00
1629	1.70	16.41	126.00	1.80	10.25	1843.00
1630	2.30	15.41	390.00	1.30	9.75	724.00
1631	2.00	9.60	558.00	1.80	8.00	1038.00
1632	2.10	7.00	*	2.90	5.50	*
1633	1.80	7.00	909.00	2.30	6.00	3894.00
1634	2.10	8.00	*	3.10	6.78	*
1635	1.90	6.00	714.50	2.80	5.00	3294.50
1636	1.70	8.00	987.00	2.10	6.00	3350.00
1637	3.20	8.00	319.00	3.00	6.16	5044.00
1638	3.30	7.50	1044.00	3.20	6.33	4420.00
1639	3.80	7.00	834.00	3.20	6.00	2614.00
1640	2.80	8.00	900.00	3.40	6.24	2597.00
1641	2.50	8.00	942.00	3.80	6.33	3203.00
1642	2.20	7.50	999.00	2.90	6.29	4316.00
1643	2.20	8.00	681.00	2.30	6.00	2943.00
1644	2.20	8.00	426.00	2.60	6.00	788.00
1645	1.90	6.25	592.00	2.60	5.33	621.00
1646	1.70	6.58	364.00	3.40	5.20	1316.00
1647	1.70	6.58	417.00	4.30	5.00	1737.00
1648	1.50	8.00	743.00	3.30	6.00	1716.00
1649	1.10	12.00	365.00	1.60	8.66	1172.00

1650	1.60	12.00	419.00	2.70	8.66	200.00
1651	1.40	13.00	89.00	2.40	8.00	350.00
1652	2.20	11.66	168.00	1.50	9.66	90.00
1653	3.20	4.89	374.00	3.60	4.89	1000.00
1654	3.00	2.94	215.00	2.60	3.66	1104.00
1655	2.60	4.25	42.00	1.60	4.41	874.00
1656	2.80	5.88	268.00	2.20	5.88	469.00
1657	2.80	5.88	126.00	1.50	5.23	87.00
1658	3.30	3.92		2.00	3.92	
1659	2.30	5.88		3.60	4.90	
1660		11.76			9.80	
CORRELATION	-0.39			-0.47		

Table 9.4.5.3 shows the correlation between the corn prices and the harvest amount on the island of Sjælland, Denmark, as compiled by Gunnar Olsen[123]. The export values are show to add a better understanding of the importance of export on the corn prices. Olsen notes that these values are lacking in themselves and should be seen as trend markers rather than absolute values. The correlation between the corn prices and the harvest amounts seem moderate at -0.39 for rye and 0.47 for barley.

Olsen's data shows us that the corn prices were moderately effected by the harvest output at -0.39 and -0.47 for rye and barley respectively. In other words, around 40 and 50% of the corn regulation price was caused by the harvest size. This is much along the lines of the results from Christen Lauritsen in Kellerup, with values of -0.4, but under the results, -0.7, for barley in Skinnerup. It should be noted that the correlation in Olsen's data is between the Sjællandske regulation prices and the harvest value, rather than the CPI value and the harvest value for Kellerup and Skinnerup. In order to correct for this, it is possible to find the linear correlation between the CPI values and the regulation corn prices from 1610-1660. The correlation between the CPI values and the sjællandske rye prices is 0.95 and the correlation between the sjællanske barley prices and the CPI values is 0.94. In other words, the CPI values are strongly determined by the sjællanske regulation prices and therefore the results of Olsen's data are comparable to the results from Skinnerup and Kellerup.

After a rather lengthy comparison, it is possible to conclude that the CPI values show a moderate correlation to the harvest outputs. In other words, it is possible to use the CPI values to understand the harvest outputs during the LIA, adding a key step in the hunt to find the importance of the harvest to Danish warfare during the 17th century. Though, as always, this analysis should be done with caution as the correlations are moderate at best and leave an opening for other explanations.

[123] Olsen, *Studier i Danmarks Kornavl og Kornhandelspolitik i tiden 1610-60*, p.457-458

9.4.6 The NAO negative 1620s

In a somewhat rare gift, Gunnar Olsen chose in his article *Studier i Danmarks Kornavl og Kornhandelspolitik i tiden 1610-60* to analyze the harvest outputs for the 1620s, which as noted above was most likely a period of severe NAO negative conditions, with cold, dry winters in Denmark. This gives us the possibility to better understand the historical link between the farmers of the 17th century and the changing climate around them. Olsen himself did not see the weather as an issue, noting "Men Vejret var selvfølgelig ikke Skyld i, at Udbyttet som Helhed var saa lavt, da der ikke er paavist nogen væsentlig Klimaændring siden da[124]". Roughly translated, Olsen notes that weather was not the cause of decreased harvests, as there had not, in Olsen's time, been found any evidence of a changing climate since the 17th century. Of course, over 70 years after Olsen's article, the scholarly world view is different, with a growing focus on the importance of climate. Looking climatically back at the 1620s as a period, its winter temperatures were colder than modern winters and colder than average winters during the time scale of this thesis. The average for the period between 1550-1750 is -1.04 degrees from the reference, whereas the 1620s saw an average of -2.15 degrees to the reference period[125].

The period started off, in terms of the harvest, relatively well. A dip in the corn prices in 1620 seems to reflect a large harvest; so large indeed that it was too large, and the price of corn was falling too low. An import restriction was applied to stop the flow of foreign corn[126]. However, luck soon changed. 1622 saw a rise in the corn prices and a rise in the CPI value. This coincides with the start of the harsher negative NAO winter period. It seems to have hit rye very harshly and export restrictions and other survival mechanisms were enacted, including the buying of rye at the Sound Toll, to be sent to Copenhagen[127]. However, an export restriction on barley drew protest, as the barley harvest was not as strongly affected.

1623 did not bring relief. Again the rye harvest was badly affected and so was the oat harvest. It was decided that the import restrictions on rye should be lifted for the island of Sjælland and the Danish province of Skåne (now part of Sweden). However, Olsen notes that Jylland was not included, most likely because the nobility saw the restrictions as a good way of keeping prices high[128]. 1624 was also a bad year for corn prices. Starting from 1620, with the good harvest, the CPI values grew greatly. An index value of 0.1023 represented the year 1620, whereas 1625 had an index

124 Olsen, *Studier i Danmarks Kornavl og Kornhandelspolitik i tiden 1610-60*, p. 457-481
125 Leijonhufvud, I, *Five centuries of Stockholm winter/spring temperatures reconstructed from documentary evidence and instrumental observations.*
126 Olsen, *Studier i Danmarks Kornavl og Kornhandelspolitik i tiden 1610-60*, p. 460
127 Olsen, *Studier i Danmarks Kornavl og Kornhandelspolitik i tiden 1610-60*, p. 461
128 Olsen, *Studier i Danmarks Kornavl og Kornhandelspolitik i tiden 1610-60*, p. 462

value of 0.2559, a growth of ca.220%. The king decided that the export restrictions on corn should continue in 1624, however after meeting with the nobility, the export restriction were ended. This saw a rapid growth in corn prices, with a growth of almost 27% between 1623-1624 and must have been harsh on the parts of the population that bought corn. This seems to demonstrate a poor administration during bad harvests, leading to price increases rather than stability. This also demonstrates that this type of harvest failure may not have been normal, as the reaction of the state seems ad hoc and at times lacking a long term plan.

The rye and oats harvest failed again and it seems that 1624 was hit by drought. The start of the 1620s had not gone well and the export restrictions were again put in place. Olsen notes the human side of these events, describing an incident in Aalborg, a city in the northern part of Jylland, where local craftsmen accused boats in the fjord of illegally shipping corn, stating that it was difficult to buy corn for money in the city. The craftsmen went out to the boats with the local judge to investigate the case and even took the rudder from the Dutch captain. They accused the tolls men of taking bribes from the Dutch. Whether or not these accusations were founded is unknown, however a case was raised against them and the lead man behind the event lost both "Hals og Hovedlod" (neck and head)[129].

The next three years went better, with 1625, 1626, and 1627 seeing improved harvests and a fall in the CPI value from 0.2259 in 1624 to 0.1363 in 1627. However, the period was not unproblematic and 1628 again saw a terrible rye harvest and a lower than average barley harvest. This caused a spike in the corn prices, even with the often used mechanism of export restrictions. Looking at the CPI values, 1629 represents the highest of the period, with 0.275, and a growth of 46.7% from 1628. This seems like a rather large price increase. The question of the day became; should the state end the export restrictions or not? The merchants wanted freedom to trade, with import and export restrictions removed, and saw the nobility's attempts at regulation as a way of raising prices, and little else.

In the final decision, it is possible to see a connection between war, harvest and climate. The *Rigsraad* argued against the export restriction, noting that the commoners had no money and therefore could not pay taxes to the Thirty Years War and the debt from it[130]. Olsen notes that the commoner's ability to pay taxes was more important than their ability to eat. Again, an example of what seems to be poor administration in times of trouble, as Gregory Parker notes as one of the problems of the 17th century. At the end of the 1620s, it seems that the NAO negative conditions ended and an NAO positive variation dominated until ca. 1650-1660. The 1630s saw an average CPI value close to

[129] Olsen, *Studier i Danmarks Kornavl og Kornhandelspolitik i tiden 1610-60*, p 466
[130] Olsen, *Studier i Danmarks Kornavl og Kornhandelspolitik i tiden 1610-60*, p 470

the 1620s, 0.175 and 0.170 respectively, however whereas the 1620s started at 0.1023 and ended at 0.275, the 1630s started at 0.2649 and ended at 0.1491. It seems as if the prices were falling.

With the importance of the negative NAO and the agricultural problems in the 1620s in mind, the next step becomes finding the general importance of NAO on the CPI, and thereby corn prices, during the period. There are two possible ways of doing this. One would be to see the year to year differences in the corn prices, for example between 1600 and 1601 there was a 24.1% increase in the CPI value. However, this system has its draw backs, as the percent change value is subjective to the difference between the years. An example demonstrates this. The CPI value for 1601 is 0.1359, with the before noted 24.1% increase to the year before, however during 1631 the CPI value was 0.1971, with a 25.6% decrease. So the year to year difference tells a story of annual price fluctuations, but not the impact of the prices in general on the population, as 0.1971 (1631) is larger than 0.1359 (1601). The other way of looking at the data is by finding the highest CPI values in the period from 1550-1750. Doing this seems to get the best response. The following table shows the ten years with the highest CPI values from 1550-1750.

Table 9.4.6 CPI values during NAO negative conditions

YEAR	CPI INDEX VALUE[131]	NEGATIVE NAO[132]	PERIOD OF WAR
1661	0,3183	*	
1709	0,3038		
1699	0,276	¤	
1629	0,275	¤	*
1630	0,2649	*	
1684	0,2629	*	
1698	0,2582	¤	
1624	0,2559	¤	
1660	0,2539		*
1662	0,2467	*	

Table 9.4.6 shows the relationship between the CPI value, a negative NAO state and periods of war between 1550-1750. There is a differentiation between a negative NAO state (*) and a severe negative NAO state (¤) as large amounts of the time period had a possibly negative NAO state, making variations in severity important. Periods of war are included to show possible effects on the corn prices through warfare.

Table 9.4.6 shows that 4 out of the 10 years (40%) with highest CPI values were in severely negative NAO periods. In contrast to these, severe NAO negative conditions represent around 10% of the total time period. This

[131] Abildgren, K. (2010). Consumer prices in Denmark 1502–2007. Scandinavian Economic History Review, 58(1),

[132] Koslowski, *Variations In Reconstructed Icewinter Severity In The Western Baltic From 1501 To 1995, And Their Implications For The North Atlantic Oscillation*. p. 188-190

demonstrates that severe negative NAO periods, like those in 1620s, do seem to have a proportionally large negative effect on the harvest output during the time period.

The final step is to understand, if the 17th century was agriculturally worse than premodern harvests generally were, for example the 18th century. Geoffrey Parker notes that Finland suffered 11 harvest failures during the 17th century were as only one during the 18th century[133]. This would seem to show generally improved factors for agriculture during the 18th century, however it is worth noting that Finland is at the edge of agricultural production and therefore has a very short distance between success and destruction. Denmark is much better situated, climatically, for a more robust production, making a direct correlation between Finland and Denmark partially problematic. Studying the corn trade and corn prices in southwest Sjælland, between 1740-1807, Jørgen Mikkelsen notes that from around 1750 to 1760 corn prices increased and that during the 18th century a tripling to quadrupling of the harvest occurred[134]. The importance, if any, of the NAO on corn production also seems to be reduced as 1770-1800 saw a doubling of the harvest output during a period of increased ice severity, possibly denoting NAO negative variations[135]. It does therefore seem that the 18th century was agriculturally to be better off than the 17th century.

The general conclusion to the correlation between periods of negative NAO variations during the 17th century and the Danish corn prices is that the harvest was negatively affected by these conditions and that this moderately correlates with the CPI values, and thereby corn prices. This must then be analyzed in relation to periods of war, determining either an economic decrease before the war or a depleted war capacity during the war.

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[133] Parker, *Global crisis : war, climate change and catastrophe in the seventeenth century*, p. 18

[134] Mikkelsen, J. (1993). Korn, købmænd og kreditter : om kornhandel og kornpriser i Sydvestsjælland ca. 1740-1807. *Fortid Og Nutid*, *1993*(3), p.180.

[135] Koslowski, *Variations In Reconstructed Icewinter Severity In The Western Baltic From 1501 To 1995, And Their Implications For The North Atlantic Oscillation*, p.188

10. Warfare, economy and climate change in the 17th century Denmark

In a comprehensive overview of Danish military history Kurt Villads Jensen, Knud J.V. Jespersen and Gunner Lind divide the wars during the 17th Century into three different categories. The first of these consists of wars that were started by the Danish, the second contains wars fought when the strategic balance in the north had swung over to the Swedish and Denmark was left fighting for survival rather than gains, and the last category consists of wars fought after the 1660 peace agreement with Danish revenge as a goal, but with the situation locked by the great powers[136]. The ensuing analysis will follow these three categories as align with the developments of the period. Chronologically, the first category stretches from 1550-1612, which climatically fits with the start of the generally colder winter temperatures. Category two stretches from 1625 – 1660, a period with generally colder winters and the start of the Maunder Minimum in 1645, and the third category stretches from 1660-1720 (with the end of the *Store Nordisk Krig* – The Great Northern War), a period of warming winters, from around 1700-1710.

10.1 The wars of Danish attack

The wars early in this time period are especially interesting, as they are the result of the Danish initiative, rather than defensive wars. This leads to the possibility of a hypothetically climatically founded war enthusiasm due to "good" times. The first of these wars, *Syvårskrigen* (The Nordic Seven Years War), from 1563-1570, was part of the campaign for dominance over the Baltic region between Denmark and Sweden. This war is interesting, as it is a baseline to the later wars during the harsh winters of the Maunder Minimum period. In order to understand the correlation and causation between warfare and climate, it seems relevant to understand what the normality of warfare was during the period.

The war started with the capture and humiliation of a Danish admiral, and was continued as a way for Denmark to defeat the Swedish and stop their advance in the Baltic. However, as with many of the Danish/Swedish wars, the international community was not willing to let a local problem in the north stop their streams of income. The Netherlands and England would not accept a blockade of Sound Strait, which was part of the Danish war tactic against Sweden. The war continued for many years without a decisive victory for either part, ending in a slight Danish victory but at great cost[137].

The war was in many ways fought in the older fashion of large, expensive mercenary armies, which demanded a quick victory in order to be a viable economic option. Denmark could not pay for two grand campaigns within one

[136] Jensen, K. V., Jespersen, K. J. V., & Lind, G. (2010). Danmarks krigshistorie (1st ed.). Kbh.: Gad.p.175-177

[137] Jensen, *Danmarks krigshistorie*, .p.149-151

war[138]. This proved problematic for Denmark, as their mercenary army was delayed in Skåne at the start of the war. Already shortly after the start of the war, one third of the mercenary troops were dismissed (possibly due to economic difficulties), suggesting that from the start the war was difficult for the Danish state to handle[139]. However, the king did not rely solely on mercenary troops, as he also had the *rostjensten*. These were the noble cavalry, which unlike the mercenary troops were more loyal towards the king in harsh times[140]. Their role in the war shows how wars may have been fought during this time period, as they were typically, other than the winters of 1564-65 and 1567-68, sent home during the winter. This leaves the possibility that wars were temporarily stopped or paused during the winters, reducing the effect of harsh winters on battles, but increasing its effects on the winter camps for the troops.

In order to understand what effect, if any, the climate of the middle of the 16th century had on the war, it is important to understand the Danish state's condition. The data used earlier in this thesis reaches its limits when understanding this war. The CPI index numbers are available but the Sound Toll Online Project does not, as of yet, stretch this far back in an organized format. Both the period leading up to the war and the war itself were fought under an NAO negative situation, however not deemed severe by Koslowski and Glaser. This period included the coldest winter between 1550-1750, with a value of -7.26 to the reference, occurring in 1569. However, on an economic timescale this period is still noted for its general rise in prices, and some of the nobilities lack of discipline during the enrollment to the war may be found in their wish to earn money at home in these good times, rather than fighting the war[141].

In general, Speerschneiders source compilation shows an oscillation between very cold winters and mild winters throughout the war, though the winters do not seem to play a large role in the war, except for the campaign in the winter of 1567-68[142]. The war included a Danish national army as a counter part to the German mercenary troops, which were in or close to mutiny at certain times due to lack of payment. The national troops however did not have a high enough quality to be usable in the war and Frederik the 2nd chose instead to keep the peasants on the land and tax them, so he could pay for a professional army[143].

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[138] Lebahn,, *De danske nationale troppers deltagelse i syvaarskrigen 1563-70.* p 243–260.
[139] Lebahn,, *De danske nationale troppers deltagelse i syvaarskrigen 1563-70.* p 243–260.
[140] Lebahn,, *De danske nationale troppers deltagelse i syvaarskrigen 1563-70.* p 243–260.
[141] Lebahn,, *De danske nationale troppers deltagelse i syvaarskrigen 1563-70.* p 243–260.
[142] Speerschneider, *Om Isforholdene i danske Farvande i ældre og nyere Tid* : *Aarene 690-1860.* p. 73-74
[143] Lebahn,, *De danske nationale troppers deltagelse i syvaarskrigen 1563-70.* p 243–260.

It is hard to determine from the CPI values if the poor quality of the troops was due to famine or if the corn prices show signs of failed harvests. The data for the five years before the war shows a great variance in the prices with a reduction from 1558-1560 and increase again from 1561-1562. However, comparing 1558 and 1562, the 1562 prices are ca. 91% of the 1558 prices. This seems to show a certain amount of stability throughout the relatively short period, and therefore not an acute lack of food. Interestingly, 1566 saw a mild winter, with a value of 2.78 degrees over the reference and a spike in corn prices by 27.8%. A warm winter could lead to increased disease or rodent populations; however, it has not been possible to find evidence of either. The spike in prices does lead to a generally higher CPI value, however the average for the period before the war seems within normal limits. For the period of 1552-1557 the average index value is 0.068, whereas it is 0.064 leading up to the war, 0.078 during the war and 0.087 after the war. The prices seem to rise normally, and it is hard to find a generally negative structural consequence caused by the climatic conditions. In the end, the war was pushed to a conclusion by the fall of Erik the 14th in Sweden, the invasion of Swedish areas of the Baltic by Russia, the enormous cost of the war for the Danish state, and by international pressure to resume trade in the Sound Toll[144]. Some of these may have been affected by the climatic backdrop, but without better data, this is a problematic assumption.

The *Kalmarkrigen* (The Kalmar War), named after the city of Kalmar in Skåne, is the second war in this period. The duration of this war is short, lasting only from 1611-1613. Jensen, Jespersen and Lind note that this war may be seen as both an internal and an external conflict. Internally, the war was a way for the king to remove some of the power from the *rigsraad*, and externally it was a way of controlling the Swedish expansion. The war ended in favor of the Danes, however the war reacted the same stalemate situation as the *Syvårskrigen*, though this time the international powers were quicker to stop the war in order to mitigate the negative effects on trade in the area[145]. As with the *Syvårskrigen* this war was fought in a negative NAO variation and corn prices do greatly fluctuate during the pre-war period. The average CPI value for the five years preceding the war was ca 0.1240, however 1608 had a CPI value of 0.1504, ca. 60% rise from the year before. It seems here that an event has caused a sudden, dramatic rise in prices. This did not last and the prices fell again, though not to a pre-1608 level. It is possible that the economic structure of Denmark had affected the war, however its relatively short length, seen in comparison to the *Syvårskrigen*, makes the climatic consequences smaller.

[144] Jensen, *Danmarks krigshistorie*, p. 151

[145]Jensen, *Danmarks krigshistorie* p. 182,192-194, 199-201

In general, it seems wise not to correlate too strongly the *Syvårskrigen* and *Kalmarkrigen* and the climatic data, noting the critique of Fagan's book (that is, finding a causation between climate and society is easier with fewer sources). However, as a baseline, *Syvårskrigen* and *Kalmarkrigen* show that wars in the period were extraordinarily expensive for the Danish state, to a degree that there was little to no flexibility in the state budget. Militarily, we also see the usage of a national army for the first time during this period, however the Danish king notes that this force is mostly unsuitable to the battlefield. From this period onwards we see a transformation in the Danish state and military, in the form of a revolution. Starting around 1600, Denmark changed from a domain dominated state, where the king's income was based on his own land, to a tax-based system. In 1600, around half of the state's income was based on the king's land, whereas in 1642 29% of the state's income came from this source, the rest came almost exclusively from taxes and tolls. Ole Feldbæk notes that after the end of the *Kalmarkrigen*, the end of the wars of the Danish initiative, to the Thirty Years War, the Danish king had a large degree of economic freedom, with income from the war reimbursement from Sweden and the Sound Toll[146]. Ultimately this seems to show that the Danish state, although pressured by the costs of warfare, was not suffering greatly from the costs on a longer scale or from climatically challenging conditions.

10.2 The lost wars

The next set of wars occurred during the military revolution of the 17th century. Warfare was becoming more expensive and difficult, involving more men, artillery and forts. In this period, Denmark fought four wars, three if the Karl Gustav Wars are considered together as one, and the period resulted in a change in government to absolutism and a large loss of territory. This era starts badly for the Danish state. Christian the 4th involved Denmark in the Thirty Years Wars between 1625-1629, most likely to limit Sweden's expansion[147]. Militarily, the war did not go as planned for Denmark, leading to the general occupation of Jylland between1627-1629 and a rapid Danish exit from the war. As noted before, the Danish involvement happened during the severe NAO negative period of the 1620s, where there were six large corn price increases resulting from ten harvests. Outside of the quantitative data, Olsen found that these increases seem to fit with records of bad harvests throughout large parts of the 1620s, demonstrating a possible connection between warfare and climate.

In order to understand this, one must increase the scale of the Thirty Years War and study the international aspects of it. Parker notes that the two harvests leading up to the start of the conflict, 1617 and 1618, were ruined in central

[146] Feldbæk, *Danmarks økonomiske historie 1500-1840*, p.49-51

[147] Heiberg, S. (1976). De ti tønder guld : rigsråd, kongemagt og statsfinanser i 1630'erne. *Historisk Tidsskrift*, 25–58.

Europe, causing increased economic tensions[148]. In Denmark we see the CPI values of 1617 and 1618 as respectively 113 and 115 percent of the average of four years before and four years after the two years (averaging 10 years in total), denoting that the same troubles may have been evident in Denmark. This focus on the economic tensions should not detract from the well-studied political understandings of the war, however in much the same way as the conflict in Syria was pre-ambled by a harsh drought, the failed harvest could have added burden to an already pressurized society. One could conclude that the problematic harvests in Germany in 1616-1618 partially caused, greatly aided on their way by the complicated political systems and religious tensions, a strong military response in Denmark in the following period.

This was a militarization which Denmark struggled to finance. Historian Steffen Heiberg notes that the shock of the occupation of Jylland during the war had a large effect on the militarization of the nation. Before the war, Denmark did not seem to have a need for a standing army and wars could be financed with mercenary troops, although the *Syvårskrig* showed this to be expensive. Denmark-Norge's prestige seemed to save the country. However, the attack on Jylland showed the necessity for the kingdom to have an army ready, even in peacetime[149]. Heiberg notes that the Danish king had a difficult time securing funds for the new military situation brought on by the Thirty Years War. Economically the king could pay for the militarization through the Sound Toll. As noted before, it does not seem that the king's income from the Sound Tolls was greatly affected by the cooling climate of the period. The decadal intake from the Sound Toll increased from 1,846,594 *rigsdaller* between 1620-1629 to 2,986,253 between 1630-1639, following a growth period from ca. 1560[150]. With an increased income of more than 1,000,000 *rigsdaller* during the 1630s and a positive NAO variation, it would seem, hypothetically, that the Danish state would be able to militarize. The king saw his expenses grow, with debt repayments from the Thirty Years War, and the building of forts in the country, and looked to new taxes and a change of the *len* system as new possible incomes[151]. The increased costs to the state may have come at a climatically unfortunate time. The 1630s saw an average winter temperature of -1.7 to the reference and a CPI index value of 0.170, with a high of 0.265 in 1630 and a low of 0.131 in 1635. This shows fluctuations but nowhere near the growth necessary for the expansions of the state. Setting the tax level as index numbers, with 1600-1609 representing 100, the 1630s saw an index value of 324 and the 1640s saw a value of 548[152].

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[148] Parker, *Global crisis : war, climate change and catastrophe in the seventeenth century*. p.213

[149] Heiberg, *De ti tønder guld : rigsråd, kongemagt og statsfinanser i 1630'erne*. p.39

[150] Degn, O. (2010). *Tolden i Sundet : toldopkrævning, politik og skibsfart i Øresund 1429-1857*. Kbh.: Told- og Skattehistorisk Selskab.142

[151] Heiberg, *De ti tønder guld : rigsråd, kongemagt og statsfinanser i 1630'erne*. p. 26-27

[152] Feldbæk, *Danmarks økonomiske historie* 1500-1840. p.52

At the same time the average seed to harvest ratio was ca. 2 for 1610-1639, with an average winter temperature of ca. -1.9 to the reference, and the same for 1610-1649[153]. As a comparison, the period from 1700-1800 saw an average winter temperature of -0.11 to the reference, and a three to five time increase in the seed/harvest ratio[154] and the period from 1770-1800 saw a doubling of the harvest, with an average winter temperature of -0,63 to the reference[155]. Taking the winter temperatures as a proxy for poor conditions, the financial needs for the necessary militarization came at one of the hardest climatic times.

The changing climate did not stand alone. The king realized that the costs of the state could not be covered by the income from his resources alone, in the form of the Sound Toll and other incomes to the *Kongens Eget Kammer*, and that militarization was simply too expensive[156]. He attempted to reform the *len* system in Denmark, so that extra taxes did not become the norm. However, the *rigsraad* did not agree and Christian the 4th instead received permission for a new tax. However, Stefan Heiberg notes that this may all have been part of the nobility's plan to gain control over the king. After the Thirty Years War, the king had pressured the *rigsraad* to give him "10 barrels of gold", for which he would sign the peace treaty, giving Denmark an exit from the war. This gave the king an income that was outside of the *rigsraad's* control. However, in 1637 this extra tax was almost paid off and by not giving the king a *lens* reform, the king was then dependent on the *rigsraad* for taxes to pay for the increased militarization. This meant that the *rigsraad* could make demands to the necessary income of the king, weakening the king's ultimate power[157]. In general, the power battle between the *rigsraad* and the king may have occurred in a period of limited income, possibly due to the colder climate, leading the king to increase his resources from intake that he controlled alone, that is to say the Sound Toll.

This led to the *Torstenssonfejden* in 1643-1645,which resulted in Denmark losing the land areas of Gotland, Øsel, Jamtland and Harjedalen in Norge and Halland in Skåne for 30 years. The CPI values leading up to the war appear stabile, with an average of 0.157 and a high in 1641 of 0.1661 and a low of 0.1491 in 1639. Generally, there is not a large oscillation in the prices. The war can be seen in relation to the ending of the Thirty Years War, as Denmark was positioning itself as a negotiator of peace. Sweden saw this as a political threat and surprised Denmark with the war[158]. Most of the Danish forces were in winter camps, as the start of the war in late 1643 to early 1644 was cold

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153 Olsen, G. (1943). *Studier i Danmarks Kornavl og Kornhandelspolitik i tiden 1610-60*. Historisk Tidsskrift, 10(6), 457

154 Mikkelsen, J. (1993). Korn, købmænd og kreditter : om kornhandel og kornpriser i Sydvestsjælland ca. 1740-1807. Fortid Og Nutid, 1993(3), 43

155 Leijonhufvud, I, *Five centuries of Stockholm winter/spring temperatures reconstructed from documentary evidence and instrumental observations.*

156 Heiberg, *De ti tønder guld : rigsråd, kongemagt og statsfinanser i 1630'erne*. p.46

157 Heiberg, *De ti tønder guld : rigsråd, kongemagt og statsfinanser i 1630'erne*. p 48

158 Jensen, *Danmarks krigshistorie*, p. 238-241

with a temperature of 3.48ºC below the reference. Although an initial Swedish success, the war became stuck and was finally ended with a Swedish/Dutch naval destruction of the Danish navy. The Swedes were pressured by their allies to end the war, and in 1645 it ceased[159]. Climatically two different aspects are interesting. Firstly, the aforementioned dependence of the king on the Sound Toll, a climatically neutral income, meant great increases in the taxes per ship and greatly decreased the international sympathy for Denmark. Whereas the average tax per ship in 1610-1619 was 36,2 rigsdaaler, it rose to 96.3 in 1630-1693 and 77.9 in 1640-1649[160]. If we accept the argument that even in opportune times, the agricultural output could not keep up with the state's growth, then an increase in the Sound Toll must have seemed inviting. Feldbæk notes that while the extra taxes of 1638-1641 were paid in full, the 13 extra taxes between 1646-1648 only received around 55-60% of the budgeted income[161]. Generally, the low harvest outputs in the times of change may have added ill-timed pressure to the militarization of Denmark.

The second interesting climatic aspect of this period is the human cost, which would have affected the economic foundation of the state. Noting the effects of the *Torstenssonsfejde* on the population of Denmark, Jensen, Jespersen and Lind remark that the occupations of Jylland, the drafting of troops throughout the country and periods of epidemics reduced the Danish population[162]. The latter mechanism, periods of epidemics, may have occurred simultaneously with the cooling climate, although the two are not to be stated as exclusive partners. In her Ph.D. thesis from 2013, Leslie Lea Williams notes that a decrease in the available food sources creates physiological stress in the body, making it more susceptible to disease[163]. In addition to this, disease rates may increase in periods of large populations, as is the case in the period from 1550-1650[164].

Denmark was hit by widespread disease throughout the period, however Hans Christian Johansen notes that the late 1610s- 1620s and the 1650s were worse, whereas as the 1630s-1640s were better, in terms of epidemics[165]. As noted above, the 1620s saw a large amount of harvest failure, combined with an occupation of Jylland. An analysis of the demographic data shows that the death rates in Jylland were high during these periods, most likely from a combination of a brutal war and disease[166]. However, the death rates on Sjælland, which was not occupied, also rises.

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[159] Jensen, *Danmarks krigshistorie*, p. 250-251

[160] Degn, *Tolden i Sundet : toldopkrævning, politik og skibsfart i Øresund 1429-1857*. p 142

[161] Feldbæk, *Danmarks økonomiske historie* 1500-1840. p. 52

[162] Jensen, *Danmarks krigshistorie*, p 251-252

[163] Williams, L. L. (2013). *From Hot Summer Days to Cold Winter Nights* : *An Analysis of Health in Little Ice Age Germany and Austria*. The Ohio State University, p. 21

[164] Williams, *From Hot Summer Days to Cold Winter Nights* : *An Analysis of Health in Little Ice Age Germany and Austria*., p. 253

[165] Johansen f. 1935, H. C. (2002). Danish population history 1600-1939. Odense: University Press of Southern Denmark. P31

[166] Johansen f. 1935, H. C. (2002). Danish population history 1600-1939. Odense: University Press of Southern Denmark. P31 and Engberg, J. (2013). Det daglige brød : bønder og arbejdere 1650-1900. Kbh.p 33

In 1630, following what seems to be two bad harvests, almost 100 deaths were noted in Ottestrup-Sorterup sogn, a much higher value that the rest of the century and only topped by the death rate of ca.1620. This disease seemed most fatal in children, as 80 out of the 97 dead were under the age of 18[167]. Johansen notes that it was therefore unlikely to have been a form of plague, but rather typhus or dysentery. However, it is interesting that after a period of failed harvests, possibly caused by the harsher climatic conditions of the 1620s, disease broke out.

Similar to the 1620s, Johansen notes that the 1650s saw an increase in the death rate, but with very local variations. The islands east of the *Store Belt* (Great Belt) saw increased death rates between 1652-1657, except for 1653[168]. Sørbymagle in the southwestern part of Sjælland, saw an increase in the annual death rate from 10 to 89 in 1656, again impacting the younger age groups most[169]. *Fyn* (Funen) and Southern *Jylland* saw increases in the death rates around 1659-1660, possibly brought on by the waves of foreign troops entering the area under the *Karl Gustav Krigene*, bringing different diseases with them[170]. In order to understand the role of the harvest on disease rates, if any, it seems necessary to understand if the 1650s were an agriculturally harsher period. A study on famines in the Nordic countries between 536-1875, based partly on Abildgren's CPI values, found that 1650-1652 may have been famine years[171]. Analyzing the CPI values in the period from 1630-1649, three spikes, defined by annual rises of 10% or more, can be identified. This occurred in 1636 (28.7%), 1648 (26.0 %) and 1649 (29.4%). During the period of 1650-1660, five spikes can be identified. These occurred in 1652 (17.6%), 1655 (20.1%), 1656 (22.6%), 1659 (35.7%) and 1660 (74.7%). Interestingly, 1653(the year of lower death rates) sees a CPI value decrease of 39.4%. It does seem that the 1650s were more turbulent than the 1630s and 1640s. Though it should be noted that the CPI values of the period oscillated between 0.1048 (a low value) to 0.2539 (a very high value).

However, it is possible that instead of the CPI values denoting disease, the diseases are affecting the CPI values, possibly by decreasing the workforce. Here again, Olsen's work helps to clarify. The period from 1649-1653 is categorized as a period of supply crisis with failing harvests, whereas 1653-1657 is categorized as a period of demand crisis, where it was difficult to sell corn[172]. The former was a harsh period for the peasants, the latter a harsh period for the nobility. It is difficult to say what caused the failing harvests, be it too much or too little precipitation, disease

[167] Johansen f. 1935, H. C. (2002). Danish population history 1600-1939. Odense: University Press of Southern Denmark. P 25

[168] Johansen, H. C. (2002). *Danish population history 1600-1939*. Odense: University Press of Southern Denmark. P. 28

[169] Johansen, *Danish population history 1600-1939. Odense: University Press of Southern Denmark*. P 35

[170] Engberg, J. (2013). *Det daglige brød : bønder og arbejdere 1650-1900*. Kbh.: .p 55

[171] Dribe, M., Olsson, M., & Svensson, P. (2015). *Famines in the Nordic countries, AD 536-1875*.

[172] Olsen, *Studier i Danmarks Kornavl og Kornhandelspolitik i tiden 1610-60*, p 483

or another factor, but in 1654 it is noted that it had not rained for some time[173] and studying the winter precipitation reconstruction from southwestern Norway, it is possible that the start of the 1650s was drier, the mid-1650s wetter and the end of the 1650s drier again[174]. However, this is a very loose correlation and more work is needed to draw conclusions. It does though seem, that the outbreaks of disease could be related to periods of cooling, making warfare even more difficult for the state.

The *Karl Gustav Krigene*, including the first from 1657-1658 and the second from 1658-1660, were tipping points in Danish history, to use Gregory Parker's terminology. Thanks to a failed hope of Swedish stagnation in Poland, Denmark attempted to regain land and honor. In 1658, in the classic example of the Little Ice Age in Denmark, the Swedish army crossed the Danish belts and attacking Sjælland from "behind", forcing Denmark to the harsh peace of 1658. Jensen, Jespersen and Lind note that the freezing of the Danish straits only happened a small number of times every 100 years[175]. The temperature data does show 1658 as a cold winter (3.69 below the reference) however it is no colder than 1643 (with 4.13 below the reference) or 1633 (with 4.03 below the reference) and in 1652 Speerscheider notes that all Danish waterways had ice. It is questionable how surprising the icing of the belts was, but that does not change the most important fact[176]. The Danish army was no match for the war-tested Swedish army and Ander Bille, the architect behind the Danish war preparations, noted in 1655 that "Landsens defension er slet og ringe" (the countries defenses are very poor)[177]. In a much simplified analysis, the lacking economy, combined with hesitation from the nobility, forced otherwise strong reforms to become a paper tiger. It is possible that the harsher winters caused decreased harvests, thereby decreasing the tax foundation for the state and making the population more susceptible to disease, during a period of expensive military change in the Danish state. The rest is well documented and led to the loss of all Danish provinces east of the Sound Toll.

10.3 The wars of revenge

The following two wars, the *Skånske Krig* (Skånske War) from 1675-1679 and the *Store Nordiske Krig* (The Great Nordic War) from 1709-1720, were attempts at regaining the position and power that Denmark lost after 1660. After the defeat in 1660, the Danish political state changed form, as Frederick the 3rd used an opportune political situation to establish absolutism in Denmark. How he did this is outside the scope of this thesis, however this new system of

[173]Engberg, J. (2013). *Det daglige brød : bønder og arbejdere 1650-1900.* Kb, p 49

[174] Matti, C., Pauling, a, Kuttel, M., & Wanner, H. (2009). *Winter precipitation trends for two selected European regions over the last 500 years and their possible dynamical background.* Theoretical and Applied Climatology, 95(1-2), p. 15

[175] Jensen, *Danmarks krigshistorie*, p.273-274

[176] Speerschneider,. *Om Isforholdene i danske Farvande i ældre og nyere Tid : Aarene 690-1860.* p..79

[177] Jensen, *Danmarks krigshistorie*, 261-263

government may have been better able to cope with the economic situation of the times. Geoffrey Parker notes that, for Europe in general, "Although the 1690s and 1700s saw further bouts of extreme weather, famine and (in Europe and China) almost continuous war, unlike the 1640s and 1650s, no revolutions and relatively few revolts occurred" [178]. This could be due to a general lack of war enthusiasm or disillusion with the times and a longing for peace. In Denmark's case, it may have been aided by the reduction in the winter temperatures and better harvests. The average winter temperature from 1600-1660 was 1.78ºC below the reference, whereas it was 0.18 ºC below the reference for 1661-1750. This cannot be seen as an absolute value, however it does show that the period after the start of absolutism had milder winters, especially from around 1700 and afterwards. Ole Feldbæk also comments on this change. Although he still categorizes the period as an era of stagnation, he notes that the king was able to increase his income greatly through a heavier tax burden, without breaking the state[179]. Using index numbers Feldbæk sets 1663-69, after the before noted period of growing taxes, at 100 and finds that almost all taxes after that were over 100, denoting increased taxes. Only the rye harvest of 1800-1802 falls under this index value[180]. Feldbæk notes that although the ability to pay taxes was important for the state, the increased taxation did not come without costs for the general population. The increased tax burden forced the farming population to increase its output of agricultural products, something that must have been possible as the tax system did not collapse under both wars[181]. However, a growth in agricultural output is not always the same as economic growth. The increased taxation demanded a large corn sale, however too large a corn harvest would lower prices making the tax payment difficult to fulfil. Therefore, harvest output and demand must have increased together, something on which not all historians agree[182].Using the data from Christen Lauritzen from Kullerup, from 1678-84 and 87-1703, collected by Karen Schousboe, it is possible to note the average seed to harvest ratio for the era. Schousboe finds an average of 5.4 for barley and 3.5 for rye during the 20-year period[183]. In comparison, the data from Skinnerup, from 1638-1646, shows an average seed to harvest ratio of around 3 for barley and 1.5 for rye[184]. All this points towards that although the two wars were grand in scale, they were economically possible for a smaller Danish state to handle. Partially, this was aided by reforms in the

[178] Parker, *Global crisis : war, climate change and catastrophe in the seventeenth century*, p.. xxxi
[179] Feldbæk, *Danmarks økonomiske historie* 1500-1840. p.97
[180] Feldbæk, *Danmarks økonomiske historie* 1500-1840. p. 97
[181] Feldbæk, *Danmarks økonomiske historie* 1500-1840. p. 97
[182] Mikkelsen, J. (1993). *Korn, købmænd og kreditter : om kornhandel og kornpriser i Sydvestsjælland ca. 1740-1807.* Fortid Og Nutid, 1993(3), p. 186.
[183] Olsen, *Studier i Danmarks Kornavl og Kornhandelspolitik i tiden 1610-60*, p 38
[184] Fritzbøger, *Hovedgårdsdrift og godsøkonomi: Skinnerup 1616-1660.* p. 183

military system, that made the army larger but not more expensive and partly this may have been aided by better corn outputs, due to a milder climate[185].

Although this correlation seems rather direct, the period from 1660-1750 does challenge the somewhat linear understanding of the cooling climate's role on the structure of warfare. For, the period from 1660 to 1715 is still part of the traditional dating of the Maunder Minimum. However as noted above, this period does seem manageable, whereas the 1620s to 1660s saw strong challenges to the state's stability. It here becomes important to note, that although a democratically founded argument can be launched at the absolutist king, the reorganization of the political and military system seems to have aided in the stability of the state. For example, by controlling the taxation system and reducing the privileges of the nobility, the king was able to change the tax foundation of the state, making warfare possible[186].

However, stability did not come overnight. Analyzing the CPI values, there is still a tendency for 10% annual growth in the corn prices during this period. From 1661-1700, 15 years had increased prices of more than 10%. 1684 even saw an increase of 122.6% to the year before, possibly due to a very cold winter[187]. The 1690s were also a period of a severe NAO negative variations, of which the CPI values increased from 0.1443 in 1690 to 0.276 in 1699. However, this increase does not seem to create as large a problem for the state as the failing harvests in the 1620s had, possibly due to the lack of warfare. During the period from 1700 – 1750 there are only five years with a positive 10% spike in CPI values, possibility representing better harvests. However, Abildgren does note that from 1712, the CPI values are not based on corn alone, making it possible that a smooth effect to the values is added by other products.

Demographically, Johansen finds 16 years with increased death rates during the post *Karl Gustav Krigene* period, but none in the 1690s. The average death rate (deaths per 1000 inhabitants) is 31.1 between 1675-1684, 28.4 between 1685-1694, 27.6 between 1695-1704, 31.8 between 1705-1714, and 27.7 between 1715-1724[188]. The increase between 1705-1714 may be due to the plague in 1711[189]. He also notes that by 1700 many of the abandoned farms of the previous period were now inhabited, either due to population growth or migration from less affected areas[190]. The 1730s even saw an agricultural output crisis, sinking both corn prices and land prices[191].

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185 Jensen, *Danmarks krigshistorie*, 302

186 Feldbæk, *Danmarks økonomiske historie* 1500-1840. p. 64

187 Speerschneider,. *Om Isforholdene i danske Farvande i ældre og nyere Tid : Aarene 690-1860*. p. 83

188 Johansen, *Danish population history 1600-1939*. p. 44

189 Johansen, *Danish population history 1600-1939*. p. 60

190 Johansen, *Danish population history 1600-1939*. p. 61 and 46

191 Feldbæk, *Danmarks økonomiske historie* 1500-1840, p. 99-101

This generally varied picture, with some of the same climatic situations as the period from 1612-1660 but different warfare, social and economic effects, shows that although climate may play a role in the course of history, it by no means operates in isolation. It rather demonstrates that though the backdrop of history can change, the foreground may be more important.

11 Conclusion

Finding the importance of climate is never easy, especially not in the multitude of explanations that define history. This master's thesis has tried to undercover the relevance of the changing climate in one of the most important periods of Danish history. Many questions arose in the process. The first of these was: what was Little Ice Age, and where did it came from? Here, it seemed that a decrease in the amount of solar energy delivered to the earth may have, though a multitude of different atmospheric and oceanic systems, cooled the climate in Europe. But rather than coming from space, this change may have come from our own world. Volcanic eruptions may also have caused this period of colder climate. After studying where the climatic changes may have originated, the important next question became; what did this mean for the state of Denmark?

Noting the increase in militarization in Denmark during the time period and the increase in required funding, two different areas of the economy were analyzed. The first, the Sound Toll, showed a general correlation between a reduction in winter transport and the colder temperatures, however the income from the winter transport was marginal. Although few ships came through the toll, they did not greatly change the economic income on an annual level. The resulting conclusion was that the Sound Toll was a generally climatically independent income for the Danish king.

The second area of interest was the agricultural output, of which many correlations were needed in order to develop the usability of the sources. First, Kim Abildgren's Consumer Price Index was correlated to the harvest output of three different areas of the country in two different periods in order to understand the connection between harvest and prices. Here, the result was a generally moderate correlation, though a few samples showed no correlation, raising awareness of the problems of a direct correlation conclusion. Secondly, the CPI values were correlated to NAO negative conditions in Denmark, showing that although these conditions did not prove to be the only factor affecting prices, they played a proportionally large role. The changes in the variation in the 1620s were used as an example.

Lastly, the assembled and tested data was used to understand Danish warfare between 1550-1750. This period was divided into three blocks, the first being Danish wars of attack, the second being the power struggle in the north and the third being the wars of Danish revenge. During the first period, a correlation between climate and warfare seemed difficult, as the data was weak. In order to stay away from the trap of climatic determinism, the conclusion was one of possible importance, but lacking the necessary data to draw a strong conclusion. In the second period, the cooling winter temperatures did have a possible consequence for the Danish state. By reducing harvest output, the increased need for taxes was difficult to achieve. Included in this was a possible increase in the chance of epidemics. In general, in this period the colder climate may have had a negative effect. In the final period, the winter temperatures were rising as the state became more stable. An increased tax level by the absolutist king was achievable, although not without consequences for the population. The two wars in the period were difficult, financially, for the state, but not as problematic as warfare in the previous period.

In general, this thesis points to a possible, moderate impact of the Little Ice Age, especially the Maunder Minimum, on the warfare of the Danish state between 1550-1750. However, awareness of climatic determinism is always needed and climate should be viewed through the same lens as many other historical themes, such as great leaders, or technical developments. That is to say, at times its role may be larger, and at others time marginal, as with many of the driving forces of history.

12 Perspectives – The historical past and the future

In the following, I will address two meta questions which remain after my thesis. The first of these is modern climate changes and the second is the role of history within the discipline of environmental history. It has been my goal to skirt around the topic of modern climate change. This is choice is twofold. Firstly, it is hard to say that the reaction of the 17th century Danish society is applicable in understanding the societies of today. This draws into consideration the notion, that a similar question would be asked in other historical areas. Would one expect a social historian to explain the developments in the current modern, democratic Danish society by analyzing the agricultural, monarchical Danish society of the 17th century? Would it be seen as logical to understand the economic histories of the modern age through developments in the 1600s? The answers may be partly yes and partly no; however, it would seem important to remember the comparability of the different blocks of times. The second reason to shy away from a total comparison is the risk of a moralizing thesis, where the past is used to demonstrate the modern era's errors. Although there may be some truth in this argument, as a reader it quickly raises a cautionary flag, as history becomes a teaching assistant for the future, rather than being seen in its own right. This cautionary flag would reduce the utility and reputability of this thesis.

As for the role of history in the future of environmental history, Grada and O'Kelly colorfully noted that history may be there only to "… allow the historian's tail to wag the climatologist's dog "[192]. However, it seems that history is needed more than ever, seen through the subjective eyes of a lover of history. However, historians have the ability to know how different time periods were, in a depth beneath stereotypes. They can read the notions of a time period and understand the larger social picture. This is important when using a multidisciplinary approach, as people are not numbers, figures and models but rather products and creators of their world. As an example, historians can find the causation, or lack thereof, within a correlation by understanding what was occurring in the contemporary society. It may seem that the harvest failed during a period, numerically, however this may rather be a reflection of an administrative change rather than a natural causation. Here, the historian can add the missing piece to a deeper understanding between societies and the worlds around them, by understanding the uniqueness of each event. There is an important place for the modern historian in the future of environmental history and historical climatology.

[192] Morgan, K., & Grada, C. O. (2014). Debating the Little Ice Age. Journal of Interdisciplinary History, XLIV(1), 57–68.

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14. Appendix

14.1 Formildingsituation – presentation of knowelge

As a part of my master's thesis it is requested that I provide an example of how to present the knowledge I have gained in my thesis to an audience. My thesis may be deemed somewhat number heavy, and therefore not lend itself directly to an audience outside of a historically interested recipient, with the time and patience to discover the wonder of geography and history. However, that does not reduce from overall message of this thesis, but more to the communicative form of this thesis. In order to present the knowledge in this thesis in a readily available form, this thesis could be presented as an evening lecture or talk, of which a general audience would be the target. Judging by the reception of Geoffrey Parker's *Global Crisis*, there is an audience for this form of history.

This thesis revolves around a subject matter that would most likely interest some, that being the issue of climate change, and by presenting it to an audience of free will, the, at times heavy, analyses might seem easier to accept. That said, this thesis would not be presented in its entirety, as written and spoken history are two different disciplines. As a lecture, it would strive towards two different main points. The first being, that climate change and society can go hand in hand. Through examples of the changing climate and how peoples responded to it, this goal would hopefully show an audience, that the world around us changes. The second main goal, much along the lines of the first, would be to demonstrate that a changing climate has winners and losers, or as Dagomar Degroot once said, "losers and bigger losers". Here the goal would be to demonstrate, that the linear connection that is often wanted when simplifying complex developments does not help an understand, but makes it cloudier. Both main goals would seem to point to modern climatic developments, and although I have tried to reduce the impact of modern times in my thesis, the distance between past and present would most likely collapse, in order to make the material understandable for the audience.

Other than a softening of the scholarly moral guideline, the language of the presentation would also change. Where scholarly works require an academically controlled language in order to be excepted as science, a public presentation would require the opposite. During the presentation, the language used would be more free, with metaphors and anecdotes, that would open up for a renewed interest. Using a "15 minute" rule, I would attempt to change either subject matter or presentation form every 15 minutes, of the expected ca. 1-1 ½ hour total time. Through my work as a museum guide and gymnasium teacher, I have learned that around 15 minutes of focus is to be expected before change is needed. As the lecture is a one-sided communication, for the most part, there are limited options for change. However, this thesis is divided in three main areas, making at least 3 changes necessary, and changes in presentation form, such as a videos, graphs, pictures, source excerpts, jokes, physical objects…, would be natural to include. Also, this thesis included few accounts from the inhabitants of the 17th century Denmark, however it is my experience that finding faces and people in history, makes the subject matter more understandable for a general audience. Therefore, as a preparation for my lecture, I would find more "faces" that could be presented as examples from changing times.

Using these different tactics, I would make an interesting, historical presentation on how climate change has effected Denmark, and how it affected Denmark's ability to fight the Swedish wars.

14.2 Studieforløbsbeskrivelse – previous studies

In the following, I will present the acedemic work I have done, leading up to this thesis.

Københavns Universitetet

Before starting on my 3rd semester at Roskilde University, I studied history for two years at Københavns Universitet. While there, I studied Denmark's economic history between 1840-1910, historical methods and historiography, the Roman Empire around the year 0, South Africa's history, general Danish history, global history, and Danish colonial history.

Basis

While at Roskilde University I have studied 2 years on the Hum-Bas (Humanistisk Basis program) in Danish. There, I completed the following courses and projects:

3rd semester project: *Højrepopulisme i Europa* – a project which studied the growth of the right wing in Danish politics through an understanding of Norman Fairclough's discursive theory.

4th semester project: *Livet på et asylcenter* -a project which studied the daily life of an asylum seeker in Denmark and the effects of anxiety.

5th semester (geography): *Kalibrering af RUCs vejrstation* – a project that attempted to calibrate RUCs weather station to the actual evaporation (compared with the calculated evaporation) of a field using soil samples.

Bachelor project: *Den sovjetiske krig i Afghanistan - en undersøgelse af tre forskellige sammenhænge mellem krigen og Sovjetunionen* – A project that studied the soviet invasion of Afghanistan and the lasting effects the war had on the Soviet Union

Courses:

Humantistisk Basisstudie – History course – Christian history
Physical and biogeography
Basis course in Educational Studies
Basis course in Cultural Encounters

Overbygning:

7th semester: *Vikingernes krigstaktik* – a project about, how Vikings went to war and the historical usage of Viking warfare in modern Denmark.

8th semester (geography): *Nitrat i det sekundære grundvandsspejl på RUCs mark* – A field project that involved measuring the nitrate concentrations on a sloping field and determining the movement of nitrate during the autumn of 2014.

9th semester (geography): *Kortlægning af Kildemosen* – a field project that involved determining the development of the Kildemose swamp through the layering of the bog, in correlation to the climatic developments in the pre-Holocene, Holocene period.

Courses:

Historical method
European/ World history after 1750
Cultural geography
Social geography
Physical geography
Danish history before 1750
GIS course

Field work (geography)
Geology for geographers
Historical theory and historiography

Note:
In general, both my courses in history and geography have built up to this master's thesis. Starting all the way back at København Universitet, I studied economic history and received an understanding of the dimensions of this discipline. Both my bachelor project and my 7th semester project have involved military history, and have added to my understanding of the complexities of this scholarly area. My courses and projects in geography have taught me both the language of the natural sciences and the wonders of geological time, including the changing climate. By combining all these areas, this thesis is the result.

14.3 Map of Denmark from 1872