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Prof. Stefan Grab
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Leipzig, 15.09.2020
Betreff:
Author's response

Dear Stefan,

please find attached our responses to the Referee comments and a marked-up version of our document. We haven't changed the figures, but apart from that, large parts of the manuscript structure have been revised according to RC2 and our own critical review of our first manuscript. And of course we integrated the feedback of RC1 (Christian Rohr), which required only minor formal changes. Furthermore, we had a thorough language copy-editing by a native speaker with a professional background in academic research in history. As linguistic quality was a key critique to our paper, well deserved, we hope to have changed it and present an article in much better quality now.

Supplementary Information is attached as a zip file of one PDF and one Excel file.

Finally, we present our submission as a zipped LaTeX-package, including the images (as jpgs and pngs) and their captions in a separate folder (/images). If resolution does not suffice, please let us know and we'll see that we can do

The revised article can be found named as template.pdf or template.tex respectively in the main folder. To provide a possibility to countercheck, we attached the PDF of our revised Word-File including the images in the zip file of the LaTeX version:
Bauch Labbé Engel Seifert – A prequel to the Dantean anomal.pdf

I hope that's sufficient. Please come back to me if any questions are still open.

Thanks for all your efforts with our article,

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Clim. Past Discuss.,
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Climate of the Past Discussions

Interactive comment on "A Prequel to the Dantean Anomaly: The Water Seesaw and Droughts of 1302–1307 in Europe" *by* Martin Bauch et al.

Martin Bauch et al.

martin.bauch@uni-leipzig.de

Received and published: 5 August 2020

Thank you very much for this constructive and informative review. We could easily agree upon all your revision proposals with regard to terminology (weather vs. climate, MCA, LIA) and the research literature we could still add (Kiss 2019).

We agreed that it is better to describe the drought event as "supra-regional event, maybe even of transcontinental scale", as data ertainly covers mainly Central Europe, France and Italy, with some indications from England, but - and this we added newly - also from the Middle East: 1304-06 CE are drought years in Syria and Egypt, with rogation processions for rain from Damascus (see on this Vogt et al. 2016, p. 91; Raphael 2013, 96-96)) and low-water levels of the Nile (Chalyan-Daffner 2013, pp. 565, 668;

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Vogt et al. 2016, p. 91). While documentary data for the Byzantine area in between Italy and the Middle East remains silent on drought between 1302-07 (Telelis 2004, vol. 2, No. 626-627), proxy data from the Aegean can help: An annual precipitation reconstruction from North Aegean tree rings (Griggs et al. 2007) demonstrates that the years 1302-04 are among the five driest periods in the 13th and 14th century in this region.

Raphael, Sarah Kate (2013): Climate and Political Climate. Environmental Disasters in the Medieval Levant. Leiden, Boston: Brill.

Chalyan-Daffner, Kristine (2013): Natural disasters in MamlÅńk Egypt (1250 - 1517). perceptions, interpretations and human responses. Ruprecht-Karls-Universität, Heidelberg.

Vogt, Steffen; Glaser, Rüdiger; Kahle, Michael; Hologa, Rafael; Münch, L.; Erfurt, M. et al. (2016): The Grotzfeld Data Set - Coded Environmental, Climatological and Societal data for the Near and Middle East from AD 801 to 1821. In: Rüdiger Glaser, Michael Kahle und Rafael Hologa (Hg.): tambora.org data series. vol. I. Online verfügbar unter doi:10.6094/tambora.org/2016/c156/serie.pdf.

Telelis, Ioannis G. (2004): ÎlJετεωÎ£λÎ£γικÎň φαινÏŇμενα και κλÎŕμα στÎ£ ÎŠυζÎňντι Î£. 2 vols, Athens: Akademia Athinon.

Griggs, Carol; DeGaetano, Arthur; Kuniholm, Peter; Newton, Maryanne (2007): A regional high-frequency reconstruction of May-June precipitation in the north Aegean from oak tree rings,A.D. 1089-1989. In: Int. J. Climatol. 27 (8), S. 1075-1089. DOI: 10.1002/joc.1459.

With this further information and bibliography added, we'd like to adapt our formulation and speak of a supra-regional, maybe trans-continental drought event in 1302-04.

We couldn't find evidence if low water levels led to an increased use of ship mills, but the hypothesis seems plausible and wort further research in the future, but probably on

periods with a denser record on mill construction.

Furthermore, we fully agree with the more technical corrections on language, style and formal requirements. We'll change the text accordingly and have it proof-read by a professional native speaker.

Interactive comment on Clim. Past Discuss., https://doi.org/10.5194/cp-2020-34, 2020.

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Discussion paper

Clim. Past Discuss.,
https://doi.org/10.5194/cp-2020-34-AC2, 2020

Climate of the Past Discussions

Interactive comment on "A Prequel to the Dantean Anomaly: The Water Seesaw and Droughts of 1302–1307 in Europe" *by* Martin Bauch et al.

Martin Bauch et al.

martin.bauch@uni-leipzig.de

Received and published: 6 August 2020

Dear colleague,

we discussed your valuable review among us authors and agreed that we can integrate almost all of your proposals to improve our text. Thank you very much for your effort and the important input.

So we will clarify key questions and provide a better outline in the introduction. We'll split up chapter 3 in methods and a new chapter 4 (results) and move the already present text blocks accordingly. Still, we would like to keep the comparisons of our results with OWDA and Campbell 2007 in the results section, as the accordance of our results and those of other colleagues is a key finding of our manuscript. Yet, we will add

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a paragraph on chapter 5 (discussions) arguing for a systematic counter-check of (at times relativcely scarce) dendrochronological reconstructions with dense documentary data (whereever possible). As proposed, we'll move societal drought responses mostly to chapter 4.

We were also convinced that is is usefula to add more bibliographical information on where from we took the data for the long series of blazes from and how we collected it (chapter 3).

And we found it very reasonable to put our comparative section on the 1361-62 event with examples from within and beyond Europe in the Discussion chapter 5.

With regard to the work of Manuel Barriendos (Vallvé), he is main or co-author of three titles in our bibliography and in the state of the art section, as he's a main contributor to Brázdil et al 2019, which provides the best overview on his important work on droughts, but also on the general history of drought. As rogation ceremonies are not at the core of our paper, we hope it is justified not to quote further of his certainly key publications in this part of historiography of droughts.

We hope that the paper will gain by these modifications a better, more logical structure, more adapted to publication habits in the sciences and particularly in Climate of the Past.

Interactive comment on Clim. Past Discuss., https://doi.org/10.5194/cp-2020-34, 2020.

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Discussion paper

A Prequel to the Dantean Anomaly: The ~~Water~~Precipitation Seesaw and Droughts of 1302~~–~~ to 1307 in Europe

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Abstract. The cold/wet anomaly of the 1310s ~~(«~~(“Dantean ~~anomaly»)~~Anomaly”) has attracted a lot of attention from scholars, as it is commonly interpreted as a signal of the transition between the Medieval Climate Anomaly (MCA) and the Little Ice Age (LIA~~.~~). The huge variability that can be observed during this decade, ~~similarly with~~like the high interannual variability observed in the 1340s, has been highlighted as a side~~-~~ effect of this rapid climatic transition. In this paper, we demonstrate that a multi-seasonal drought of almost two years occurred in the Mediterranean between 1302 and 1304, ~~and respectively~~followed by a series of hot ~~and~~ dry summers north of the Alps from 1304 to 1306. We ~~propose to interpret~~suggest that this outstanding dry anomaly, unique in the ~~13th/14th century, combined~~thirteenth and fourteenth centuries, together with cold anomalies of the 1310s and the 1340s ~~cold anomalies, as,~~ is part of the climatic shift from the ~~Medieval Climate Anomaly~~MCA to the ~~Little Ice Age~~LIA. Our reconstruction of the predominant weather patterns of the first decade of the ~~14th~~fourteenth century ~~from —~~ based on both documentary and proxy data ~~lead to the identification of —~~identifies multiple European ~~water~~precipitation seesaw events ~~in~~between 1302~~–~~ and 1307, with similarities to the seesaw conditions which prevailed ~~in 2018~~ over continental Europe in 2018. It can be debated to ~~which~~what extent the 1302–1307 period can be compared to what is currently discussed regarding the influence of the phenomenon of Arctic amplification ~~phenomenon~~ on the increasing frequency of ~~long-lasting~~persistent stable weather patterns that have occurred since the late 1980s. Additionally, this paper deals with ~~socio-economic~~socioeconomic and cultural responses to drought risks in the Middle Ages ~~from~~as outlined in contemporary sources and provides evidence that there is a significant correlation between pronounced dry seasons and blazes that devastated cities ~~and pronounced dry seasons~~.

1 Introduction & State of the Art

~~While Medieval~~In recent decades, scholars of medieval studies ~~analyzed since decades the reconstruction~~have produced considerable research reconstructing the Little Ice Age (Pfister, Schwarz-Zanetti, Wegmann 1996) and appraising the ~~impact~~impacts of cold events on premodern societies ~~in~~, but, except for the ~~context of the Little Ice Age~~notable exception of economic historians, few ~~papers focused on~~ scholars have addressed the issue of droughts~~, notably from economic history~~ (Stone 2014). ~~The~~ Almost two decades ago, Brown (2001) has highlighted the so-called ~~“~~“Dantean

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~~Anomaly' has been highlighted since the 2000s by Brown (2001)~~ Anomaly" as a wet and ~~fresh~~cold anomaly lasting from 1315 to 1321~~, and leading~~ that led to famine over ~~NW~~northwestern Europe (Jordan 1996). This climatic anomaly has been recently described more neutrally as ~~"~~"the 1310s ~~event'~~event" (Slavin 2018). A distinctive ~~"~~"1300 ~~event'~~event" has been found in proxy data even around the Pacific rim (Nunn 2007). ~~But~~ Historians have consistently focused on the ~~focus was always on the~~ cold ~~and~~, wet character of this decade ~~and historians have clearly been~~, seemingly fascinated by continuous rains and their ~~impact~~often detrimental impacts on food security~~, often leading to widespread famines.~~. A lot has been written, for example, about ~~the deficit of crops and thus of food supply induced by the rainy years~~ how excessive rain in 1315 and 1316~~, leading to~~ caused harvests to fail and ultimately resulted in a famine in northern Europe (Campbell 2016; Jordan 1996).

~~Yet, in the context of current~~ As modern worries about global warming and ~~its link with a potential multiplication of 2003-like~~ the possibility of more frequent drought events like what occurred in 2003 have grown, however, dry periods have found more and more interest ~~from pre-modern~~ among climate ~~history~~historians (Brázdil et al. 2019; Brázdil et al. 2018; on the Middle Ages: Rohr et al. 2018). Most of this research, though, deals with the early modern period ~~though~~ (Garnier 2019; Munzar 2004; Martin-Vide, Barriendos Vallvé 1995; Weikinn 1965/66), ~~and~~especially with the ~~"~~"millennium ~~drought'~~drought" of 1540 ~~has been especially highlighted~~ (Pfister 2018; Wetter, Pfister 2013; Wetter et al. 2014). Concerning the medieval period, the very recent publication on the dry year 1473 (Camenisch et al. 2020) is still an exception, preceded only by case studies on medieval droughts in Hungary and modern-day Croatia (Kiss 2017; Kiss, Nicolić 2015). In fact, the ~~socio-economic~~socioeconomic impacts of droughts on medieval societies are more difficult to ~~conceptualize~~determine than those linked with cold~~-~~, wet weather. In most parts of western Europe, droughts were ~~basically~~largely benevolent, for agricultural production ~~based on~~in these areas centered around cereals and wine (Le Roy Ladurie 2004), which easily tolerate dry ~~weather~~ conditions ~~if excessive~~ as long as the hydric stress ~~doesn't~~does not block vegetation growth, as it did in extreme cases like ~~in~~ 1540. ~~Thus, droughts~~Droughts thus rarely induced ~~socio-economic~~socioeconomic disasters ~~similar to~~on par with those frequently associated with wet anomalies. As Pribyl (2017) states, for example, warm ~~and~~, dry summer half~~-~~years ~~were for example~~did not ~~dangerous to~~generally endanger crops in medieval England. ~~They only~~ Only after the introduction of *yersinia pestis* in 1348 do such summers—ideal conditions for flourishing rodent populations—show an indirect statistical correlation with epidemics~~,~~ occurring ~~with one~~the following year ~~lag, after the introduction of *yersinia pestis* in 1348, as rodent populations exploded under such conditions.~~. In Mediterranean regions, droughts must have ~~been more troublesome~~posed a graver danger for crops and had a ~~direct~~greater impact on the food~~-~~ supply and living standards, due to a higher vulnerability to lack of water. However, few studies have ~~been devoted to the~~addressed this topic.

~~The beginning of the 14th century is considered to be~~Many climate historians generally date the onset of the transition period from the Medieval Climate Anomaly (MCA) towards the Little Ice Age (LIA) to the turn of the fourteenth century, and the time around 1300 CE sees the nadir of the Wolf minimum in solar forcing (Steinhilber et al. 2009). Although these periods are highly disputed and maybe only regionally applicable (Andres, Peltier 2016; Grove 2001; Pfister,

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Schwarz-Zanetti, Wegmann 1996), this consensus has prompted researchers to emphasize mainly the cold ~~and,~~ wet conditions of the 1310s. ~~It is beyond the scope of our contribution~~This article does not intend to add to the discussion ~~about the question if there actually was an~~ over whether the MCA and ~~an~~ LIA ~~and~~actually occurred and, if so, when the LIA started (Bradley, Hughes, Diaz 2003; White 2014~~). Yet~~), but it ~~seems worthwhile to examine~~ does seem worth examining at least the consistently dry decade (at least during the summers) which directly ~~preceding~~preceded the wet~~/~~, cold period of the 1310s ~~anomaly. As~~ . In fact, in the first decade of the ~~14th~~fourteenth century ~~actually witnessed~~, two successive major drought events of at least supra-regional scale affected Europe, one striking Italian regions, another impacting regions north of the Alps~~, we aim with this~~. This article ~~at reconstructing its~~aims both to reconstruct their duration, ~~extension~~extent, and severity~~, look for~~ and to examine the related ~~socio-economic~~socioeconomic impacts and socio-cultural reactions. ~~Furthermore, we provide an estimate of the temporal evolution~~It also provides an an approximate timeline of the underlying meteorological patterns ~~underlying the observed anomalies~~and put and contextualizes these ~~into context with~~anomalies by comparing them to similar events reported ~~for the time range~~ between 1200~~–~~ and 1400 CE.

~~At~~

In 1304, in the ~~end~~conclusion of his annual report, the anonymous ~~writer~~author of the ~~'~~*Greater Annals of ~~Colmar~~'Colmar*, a Dominican monk most interested in weather phenomena, stated ~~astonished about the cold season~~with astonishment: "[This past] winter [i.e. 1303/04~~: "Winter~~] was cold in Rome, but in Alsace it was warm, and on the contrary, [the year before, i.e., 1302/03] it was warm in Rome ~~[the winter before, 1302/03],~~ but cold in Alsace" (Jaffé 1861, 229). It is not only winter ~~temperature~~temperatures that acted like a ~~North-South~~north-south seesaw at the beginning of the ~~14th~~fourteenth century all over Europe. As we will demonstrate, there was an even more pronounced ~~water~~precipitation seesaw ~~happened in~~from 1302~~–~~ to 1307, with extremely dry conditions in the Mediterranean from the end of 1302 to early 1304 while normal humidity levels prevailed north of the Alps, and pronounced drought periods ~~in~~from 1304~~-~~ to 1307 in most parts of ~~Western~~western and ~~Central~~central Europe. We will examine if this double event ~~could~~might have been ~~by far~~ the longest, multi-seasonal drought by far in three European regions ~~within~~during the ~~13th~~thirteenth and ~~14th century. We therefore want to focus our~~fourteenth centuries. Our reconstruction of this period ~~from~~is based on documentary and proxy data on ~~Northern~~northern and ~~Central~~central Italy (IT), ~~Eastern~~eastern France (FR) and ~~Central~~central Europe (CE) (Fig. 1). ~~Additionally, there are hardly any~~ There is a dearth of studies ~~that focus~~ on the ~~variety of~~ cultural impacts of drought on medieval societies~~. Especially regarding~~, but particular in regard to the Italian and French material, we can provide ~~first~~some initial insights into the economic ~~impact,~~impacts and stress these drought~~-stress~~ imposed on medieval societies and ~~adaptive~~how they adapted with measures like ~~fire-fighting~~firefighting and ~~infrastructures~~infrastructure to improve access to water and food~~, cultural implications of drought~~.

The article is structured as follow: ~~In~~ Section 2 ~~we provide a description~~describes and ~~critical evaluation of~~evaluates the ~~used~~ data sets taken from written and proxy records. Section 3 provides an overview ~~on~~of the applied methodologies of climate and drought indices and the reconstruction of agricultural production. In Section 4, we present our indices reconstruction and the ~~identified~~ meteorological patterns ~~of~~ identified in the period in question. Furthermore, we compare the

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chronology of ~~blazes~~major fires and droughts and identify the cultural and societal ~~drought~~ impacts~~. In~~ of droughts. Section 5 ~~we discuss~~discusses the reliability of narrative sources ~~in comparison~~compared to dendrochronological data, the impacts of drought on agriculture, the development of ~~fire fighting~~new institutional structures to prevent and fight fires, and the global context of ~~the 1302-07~~this period. We conclude that the 1302~~-07~~–1307 drought period ~~ressembles~~resembles the 2018/19 European ~~water~~precipitation seesaw and can be interpreted as ~~marker for~~an indicator of rapid climate change in the early ~~14th~~fourteenth century.

2 Data

2.1 Narrative ~~sources~~Sources

~~Narrative~~Climate historians have long regarded narrative texts ~~are commonly reckoned in the field of climate history as~~as most important sources of information~~,~~ and~~ historians have produced for~~ , over the course of decades ~~almost exhaustive catalogs of~~, have carefully cataloged relevant events ~~from~~ as described in chronicles and annals. ~~For this~~This paper~~, we draw~~ draws principally on these previous works. Alexandre (1987), Curschmann (1900) and Weikinn (1958, 2017) ~~provide~~each provided information, and mostly ~~with accurate source criticism~~also a reliable critical apparatus, for the territories of ~~nowadays~~present-day France, Italy, and ~~Central~~central Europe. ~~Additionally,~~ Brázdil and Kotyza (1995, Appendix I) gathered ~~the~~ material ~~for~~on the Czech Republic, as ~~well as~~did Malewicz (1980) for Poland. ~~Concerning~~For Italy, where more urban chronicles were produced than elsewhere in Europe, we collected material ourselves, but ~~analyzed~~ also ~~the~~incorporated some material from Emanuela Guidoboni's (Bologna) unpublished collection~~ of Emanuela Guidoboni (Bologna), covering~~, which covers the period 1000~~-~~–1500 ~~from~~CE with about ~~200~~two hundred edited narrative sources, some compilations and thematic articles, and ~~few~~some limited archival material. We ~~have limited ourselves~~chose to ~~the~~ use ~~of~~only those sources in the Guidoboni collection that were taken from critical editions of contemporary chroniclers~~ out of the Guidoboni collection. In~~. For France, there are few chronicles, which almost solely cover the regions of Paris and Alsace during this epoch~~.~~ (Alexandre 1987).

2.2 Administrative ~~sources~~Sources

~~Of major interest~~A central source for the history of climate are ~~cities' deliberation~~municipal protocol books and ~~accounting documentation. As far as~~financial records, which provide a wealth of information regarding extreme weather events ~~had an impact~~and their impacts on ~~the organization of the communities and/or on~~communal structures and agrarian production~~ alike, this kind~~. Such records of ~~documentation provides a bunch of information to the historians of climate. Cities' deliberation protocol books are~~ city officials' decisions and deliberations were kept in Italian archives ~~since~~beginning in the ~~middle of the 13th~~mid-thirteenth century. ~~All matters~~Matters of justice, economy, local policy, and the social order~~, etc.,~~ were systematically noted ~~down~~ after each meeting of the town council. Local governments ~~had~~ sometimes had to deal with situations created by climatic stress, ~~such as~~for example by organizing grain ~~trade~~imports in case of shortfalls, resolving

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potential social disorders that ~~came alongside~~such shortages caused, organizing processions together with ecclesiastical authorities, or dealing with the disruption of watermills in cases of floods or droughts. For the city of Siena, we used the unpublished protocols of the *consiglio generale* for the years 1302–1307 (Bowsky 1981).

In France and Germany, such documentation does not exist before the mid-~~14th~~fourteenth century. Nevertheless, archives contain a rich ~~and~~ assortment of unedited ~~accounting documentation~~financial documents for the territory of the County of Savoy, similar to ~~the one kept in English archives and repeatedly used by~~those that historians of climate have repeatedly used to reconstruct the situation England (Titow 1960; Pribyl et al. 2012 and Pribyl 2017~~), can be exhumed for the territory of the County of Savoy.~~). Roll accounts produced by the county administration ~~of the county~~ since the end of the ~~13th~~thirteenth century provide continuous information about the impact of extreme weather events on local ~~estates'~~estates' agrarian profits. Wine and cereal production, as well as food prices, ~~have been demonstrated to react to a large extent according~~fluctuated significantly in response to climatic stress in the medieval economy (Pribyl 2017; Camenisch 2015), and ~~thus~~ yields and annual variations in price ~~series give at~~thus serve as an ~~annual scale resolution an idea~~indicator of climatic trends. Moreover, the ~~accounters~~accountants who were responsible for the production of these rolls often referred explicitly to ~~weather~~climatic events to justify ~~any drops of~~declines in revenue ~~towards the administration. A close~~. As a result, such documents allow for a detailed chronology of events ~~can then be drawn from this documentation~~, which we have ~~been able to reconstruct~~ reconstructed in this case for the region of ~~the~~ Bresse (FR).

2.3 Charters

~~The value of charters as sources~~ Charters are an established source for reconstructing Hungarian climate history ~~has been demonstrated for Hungary~~ (e.g. Kiss 2019 and 2016; Vadas 2010). ~~While not revealing any clear evidence for drought, a~~A preliminary search within edited German charters ~~editions as well as~~ and the *Regesta Imperii* ~~unearthed~~does not reveal explicit evidence of drought conditions, but these sources do include several ~~accounts in the context of blazes: often~~instances related to major fires; indulgences ~~were granted~~, for example, helped finance the reconstruction of a number of buildings destroyed ~~by the fire. Unfortunately~~in such blazes. In such cases, unfortunately, the charters normally ~~don't give~~lack an exact date for the events and therefore only ~~provide~~ enable the determination of a *terminus ante quem*.

2.4 Information from ~~manuals~~Manuals

~~In addition to information drawn directly from historical sources, for the investigation of blazes~~In this research into fires and their connection to weather and climate, we ~~made use of existing collections in manual-like~~supplemented the information taken directly from chronological accounts by examining instructional literature, ~~as it has been done~~following the example set for early modern history by Zwierlein (2011~~) for Early Modern history, who evaluated the respective sections of the~~), whose research evaluates German and Austrian ~~„~~*Städtebücher*~~"~~ ((lit., "city books"; Keyser 1939–1974; Knittler et al. 1968–2001). For most of the cities included, there is a list of historical ~~blazes~~ fires unfortunately often without information about severity or causes, and always without references. Nonetheless, this huge database is a unique source of information,

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especially for the statistical evaluation of blazes and their potential connection to droughts. The ~~„~~*Städtebücher*~~“ are~~ provide a ~~widely trusted and highly used standard reference~~trove of sources for medieval urban history~~, making its use legitimate. Additionally,~~ that historians consider generally reliable. The present study also incorporates more detailed information about blazes ~~has been drawn~~ from manuals on historical monasteries ~~(„(~~*Klosterbücher*~~“, ~~e.g. Huschner et al. 2016).

3 Methodology

3.1 Reconstruction from ~~narrative sources~~Narrative Sources and ~~creation~~the Creation of ~~climate indices~~Climate Indices

~~We have created, basically according to the~~ Using well-established ~~methodology~~methodologies (Pfister 1999; Brázdil et al. 2013; Glaser 2013; general overview: Pfister et al. ~~2018),~~ 2018) as a general guide, we have compiled climate indices on precipitation and temperature for the period 1290–1320 ~~to~~that show the dry and hot episodes addressed in ~~the focus of~~ this ~~contribution~~study within ~~their climatical~~ the climatic context ~~over~~of the surrounding three decades. ~~We adapted~~The established indexing methodology was adapted mainly ~~on~~in regard to the temporal scale, as we chose a ~~semi-annual~~semiannual approach ~~(‘~~(“growing ~~season’~~season” vs. ~~’non~~“non-growing ~~season’), according~~season”) that corresponds to the ~~focus~~structure of medieval documentary records ~~from medieval societies~~based on ~~the~~ agricultural ~~year~~cycles. Derived from these well-established climate indices (see SI 1), we closely followed Camenisch~~,~~ and Salvisberg (2020) and created seasonal drought indices from the ~~above mentioned~~ aforementioned narrative sources over the longer period 1200–1400 for all three regions (IT, FR, CE) (see SI 1). As the ~~aforementioned~~ sources and climate historical repositories focus on extreme events, we gave values of -3 (extremely dry) and -2 (very dry) if we had actual indicators ~~for~~of agricultural and meteorological drought (Brázdil et al. 2019, 75) or a lack of precipitation over ~~2~~two months. We have, however, not applied the category of ~~‘socio-economic drought’ (Ibid~~“socioeconomic drought” (ibid., 75–76), as not all of its indicators are in our opinion specifically related to dry periods. To identify long-term droughts, these drought index values have been ~~accumulated~~calculated for single years (figs. 8–10~~); they have~~) over the ~~potential to confirm~~course of two centuries, which provides the context in which the extraordinary character of the 1302–1307 drought events~~. Wherever~~ becomes particularly apparent. Whenever possible, ~~we want to compare~~ these indices have been compared with a tree-ring–based precipitation reconstruction to reassess ~~either~~ the quality of the index reconstruction ~~or~~and the reliability of the available dendrochronological data for FR, IT, and CE. Beyond these core regions~~ and with the important exception of England and Pribyl’s (2017) dense reconstruction from written records, only a qualitative assessment of documentary data is planned, if possible contrasted or combined~~, however, the historical record does not generally permit for more than a comparison of isolated cases with scientific proxy data. England is a notable exception, as Kathleen Pribyl (2017) shows in her research on the situation there.

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3.2 Agricultural ~~production~~Production in France and England from ~~administrative documentation~~Administrative Documentation

~~From the accounting documentation of the~~ Based on financial documents for the Bresse region (~~Eastern~~eastern France), we have reconstructed wheat and wine yields for the period 1300–1330. For each of these reconstructions, the raw data of ~~different~~individual castellanies~~,~~ —i.e. administrative units under the control of a steward~~,~~ —have been extracted and then compiled in aggregate series indexed on the year 1307. ~~Cereal~~Grain yields have been estimated from the revenue ~~perceived~~generated on seignorial lands located in the territories of the two castellanies~~, i.e.~~ Jasseron and Treffort. ~~This information is indirect, as it refers~~Although these accounts refer only to the taxes ~~perceived on these lands which were~~paid by the tenants who cultivated ~~by tenants, and not to direct indication of cereal~~these lands rather than directly indicating the quantity of grain harvested each year~~. Being said, if that induces a limit in the interpretation,~~, there is no reason to discount the reliability of the reconstructed series ~~is not to dismiss~~ entirely. Wine yield series are much less ~~critical, as the accounters referred directly to~~problematic, as these accounts do list the exact ~~amount~~volume of wine ~~collected~~produced in seignorial vineyards located in four castellanies. Thus, roll accounts allow for ~~a~~the reconstruction of a ~~relevantly~~ detailed chronology ~~of the reaction of the~~how local ~~vineyard toward climatic variations. We~~vineyards fared under varying climatic conditions. This reconstruction can then ~~will compare this reconstruction with well-studied and accessible~~be compared with existing research on English wheat yields (Campbell 2007) and East ~~Anglia~~ Anglian (July–September) precipitation as reconstructed by Pribyl (2017).

3.3 Drought ~~periods~~Periods and ~~city fires~~City Fires

~~Medieval city fires are a topic touched upon mainly by~~Thus far, it is scholars of medieval cultural history who have primarily addressed urban fires in the Middle Ages (Jankrift 2003, 83–100; Riegg 2003; Wolf 2015; Wozniak 2011, 2015~~). But a close~~), but some have pointed to a likely connection between drought and fire ~~has been made plausible~~ for extreme years like 1540 (Pfister 2018; Wetter et al. 2014; Mauelshagen 2010, 127–129). ~~Nevertheless, as a general phenomenon this has been put into question (~~Although Zwierlein (2011, 102–110~~), although~~) has questioned the connection, the latent fire risk of ~~wood-based pre-modern~~timber frame buildings with open fires to heat, cook, and provide light is more than obvious (Bitterli 2015; Contessa 2000, 16–18). ~~Already~~Even contemporaries ~~saw a close~~made the connection between drought and ~~blaze~~fires: “Many cities were consumed by domestic blazes because of the drought and “sterility” (*sterilitas*) that prevailed in this year” (Wattenbach 1851b, 641). We have been comparing accumulated drought indices, ~~yet~~ distinguishable by seasons, with the number of ~~blazes~~fires we could ~~take from the archives of societies~~determine based on archival records (see sections 2.1, 2.3 and 2.4). These are taken for FR from Alexandre (1987), for IT from the unpublished Guidoboni collection, and for CE mainly from charters (see 2.3), chronicles, and the ~~„Deutsche~~German *Städtebücher*“ and comparable manuals (see 2.4~~.).~~).

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3.4 Socio-cultural ~~reactions~~Reactions

Finally, we want to highlight ~~aspects of societal impacts~~how medieval societies dealt with and ~~adaptation measures~~adapted to drought beyond the classical rogation ceremonies and other religious processions (overview Brázdil et al. 2019), especially as we have only one example ~~for them from~~of such rituals in IT: In May 1303 there were processions for rain in Parma, that indeed ~~'provoked' a~~"provoked" one~~-~~ rainy day ~~rain~~ (Bonazzi 1902, 84). ~~But there~~There is, however, considerably more to ~~find~~be considered about how droughts impacted medieval societies, and about how ~~they were~~those societies perceived and ~~how contemporaries~~ reacted~~.~~ to their situation. This qualitative analysis ~~applies~~progresses on three ~~fields – the development of infrastructures~~fronts: developments in infrastructure as a reaction to drought ~~periods~~, cultural artifacts related to the experience of drought, and ~~societal~~social responses to dry periods.

4 Results

4.1. Indices ~~reconstruction~~Reconstruction and ~~qualititative analysis~~Qualitative Analysis in ~~combination~~Combination with ~~proxy data~~Proxy Data

~~If we focus on the~~The precipitation indices ~~only, we get for IT~~taken by themselves (Fig. 2) ~~a dense picture demonstrating~~suggest a sustained~~, almost 24 months long~~ dry period in Italy that lasted nearly two years but is not at all represented by the Palmer Drought Severity (PDSI) values from the Old World Drought Atlas (OWDA, Cook et al. 2015). The case of Italian OWDA data is special, as only a handful of dendrochronological series from the Alps and Calabria are available for the period in question. This ~~nourishes previously formulated~~reinforces existing doubts about the reliability of the simulated precipitation values (Bothe et al. 2019), ~~as the OWDA is~~which were calculated for large parts of Italy for the OWDA on the basis of only a few tree-ring series.

The precipitation indices for FR (Fig. 3) are scarce, and yet they show a pronounced drought pattern in the growing seasons of 1304~~–06~~1306. In regard to IT, we lack information on the continuity of this drought over the non-growing seasons (1303/04~~ to –~~1306/7~~). But~~), but the general tendency ~~is fitting~~agrees with available OWDA data, except for the summers of 1293 and 1311.

The most interesting results are the precipitation indices for CE (Fig. 4~~).~~): They have to be stacked, as CE ~~covers~~includes a ~~row~~number of quite different ~~sub-regions, yet the tendency is the same in~~subregions, but all of ~~those~~these regions~~.~~ ~~Furthermore, they~~ display similar trends, which, moreover, are mostly consistent with OWDA data points~~, and if~~. Where the indices do seem to differ (e.g.~~.~~, 1291/92, 1294/95, 1305/06), they provide precipitation data on the non-growing season which is not covered by tree~~-~~ rings.

~~If we aim for a~~Regarding the qualitative description of weather patterns, documentary data provides a clear, reliable, and very dense picture (see SI 2) of meteorological conditions over the period in question. ~~It all started with a rainy~~ The summer ~~in~~of 1302 ~~with floods~~was extraordinarily rainy in CE and FR, ~~while~~ which experienced floods, but Italy

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received very little precipitation in the second half of 1302 ~~was already without precipitation in IT.~~. This was followed by a cold winter ~~with freezing~~in CE, FR, and IT, in which major rivers (Rhine, Doubs, Adige) froze and ~~low~~ water levels ~~in CE, FR and IT~~dropped unusually low, while ~~more to the East~~areas further east (Silesia, Russia~~), the winter was~~) experienced a mild and snowless~~. Spring~~ winter. The spring of 1303 proved cold in CE— —and while we have no information on this summer from north of the Alps, IT ~~was hit by continued~~ endured a meteorological, agricultural, and hydrological drought ~~the whole year~~ for all of 1303. The following winter (1303/04) was particularly warm in FR ~~and split~~, while conditions in CE~~:~~ varied from warm in its ~~Western part,~~ western regions to cold in Bohemia. ~~A~~Meanwhile, IT is reported to have had a very chilly winter with freezing rivers ~~is reported for IT.~~. Spring and summer 1304 were extremely dry and hot in FR and CE, with all signs of hydrological drought. IT saw ~~strong~~significant, yet short, precipitation events in late spring, interrupting the 13 months of drought, and then ~~again a~~another dry summer until September 1304. Once more, a pronouncedly cold winter in 1304/05 followed in FR and CE, with strong precipitation in IT in early 1305 ~~in IT~~ that continued into summer ~~and a~~, while FR faced another dry period in summer 1305 ~~in FR~~. The winter of 1305/06 was so chilly that the Baltic ~~sea~~Sea froze over ~~and so~~, as did rivers in FR ~~and~~, CE, and IT. In FR, drought continued into spring 1306, and, in both CE ~~as in~~and IT, the winter of 1306/07 was again very ~~frosty,~~cold, followed later ~~changing to flood conditions.~~by flooding. In ~~Eastern~~eastern CE, drought set in in summer 1307, ~~and~~as a heatwave ~~in~~swept across FR and IT.

If we ~~leave aside~~look beyond the core regions of this study ~~and look as far as~~ to the Middle East, ~~,~~ we see that ~~1304-06 CE are drought years in~~ Syria and Egypt also experienced drought conditions in 1304–1306 CE, with rogation processions for rain ~~from~~in Damascus (Vogt et al. 2016, 91; Raphael 2013, 96-96) and low- water levels ~~of~~along the Nile (Chalyan-Daffner 2013, 565, 668; Vogt et al. 2016, 91). While documentary data for the Byzantine area in regions between Italy and the Middle East ~~remains silent on~~ does not mention drought between 1302 ~~-07~~ and 1307 (Telelis 2004, vol. 2, No. 626– 627), proxy data from the Aegean basin can help: ~~An~~a reconstruction of annual precipitation ~~reconstruction from~~ based on North Aegean tree rings (Griggs et al. 2007) ~~demonstrates~~suggests that the years 1302 ~~-04~~ –1304 are among the five driest periods ~~in~~of the ~~13th~~thirteenth and ~~14th~~fourteenth century in this region.

~~Hence we~~ We might thus describe the drought event not only as supra-regional~~,~~ but ~~maybe~~ even perhaps as an ~~phenomeno~~phenomenon of transcontinental scale.

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4.2 Agricultural ~~production~~Production in France and England

Figure 5 plots the reconstruction of mean wheat and wine yields in ~~the~~ Bresse from 1300 to 1320. ~~The results~~Both lines show a similar pattern, namely a trend to relatively high yields before 1310 and then a downward trend reflecting the deteriorating weather conditions of the ~~1310's~~1310s' anomaly. Good harvests, especially for wine, clearly stand out in 1304 and 1305, in response to the successive droughts locally described in both Parisian ~~as in~~and Alsatian chronicles (see SI 2). ~~Besides, the plentiful wine harvest of 1304 is confirmed by~~In addition, a contemporary chronicle (Jaffé 1861, 231~~).~~) confirms the plentiful wine harvest of 1304. In the years 1306~~/07 vineyard~~ and 1307, vineyards' production ~~met~~was fairly average ~~values~~, even ~~if the~~though historical accounts mention ~~in both years~~ heatwaves in June and/or July~~. In this case,~~

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though of both years—i.e., generally favorable conditions for vineyards. In these years, however, temperatures were so high that it prevented peasants from properly plowingcould not plow the vineyard on time, which canmight explain why production iswas lower than inthe previous years. In any case, it can be inferred from the accounting documentation of the financial documents from Bresse that fromfor 1304 to 1307, suggest above-average summer temperatures certainly reached above-average values. Additionally, the . Such a link existing between good wine harvestproduction and warm summer half-year stands out ingrowing seasons exists for 1313 too. Accounts, as well, when account records mention in that year a summer dryness, which has been benevolent for the vineyard had benefitted from a dry summer.

Figure 6 plots the relationship between cerealgrain production in Southernsouthern England (Campbell 2007) and the Bresse region (FR), in comparison with) against East AngliaAnglian July–September precipitation indices as reconstructed from local archival sources (Pribyl et al. 2012; Pribyl 2017). From 1300 to 1320, English and French yields correlate significantly (Pearson coefficient r = 0,61). General trends are similar in the two regions, with average or above-average harvests in the 1300s. Moreover, we find a synchronous movement between 1304 and 1306 (Fig. 6), reflecting the precipitation trend. The low level of precipitation reconstructed in East- Anglia for these three specific years thenis most probably applies similarlylikely similar for the Bresse region, which means that this multi-annualmultiannual 1304–1306 drought occurred inprobably affected a large part of NWnorthwestern Europe.

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4.3 Identification of meteorological patternsMeteorological Patterns

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The proxy and documentary data presented in sections 4.1 and 4.2 provide evidence for the occurrence of an alternating series of large-scale weather patterns over large parts of Europe between 1300– and 1310. The found features found are similar to the phenomenon of a water seesaw, as it was recently discussed bywhich Toreti et al. (2019) concerninghave recently discussed in relation to the drought events of 2018 and others ofover the last 500 yearsfive centuries. A water seesaw describes a remarkable dipole of negative water (precipitation) anomalies in one part of Europe and positive ones in another part of Europe. Toreti et al. (2019) associated the 2018 drought towith pronounced positive anomalies in the geopotential height of the 500-hPa level of atmospheric pressure over the continental European landmass north of the Alps. This blocking situation led to the formation of low-pressure anomalies over Northern as well as Southernboth northern and southern Europe, with precipitation patterns associated in such as a way, that Centralresult central Europe suffered a severe lack of precipitation whereas Northernnorthern and Southernsouthern Europe experienced an excess ofexcessive precipitation. Thus, inIn the 2018 case, the water seesaw was thus positive over Southernsouthern Europe and negative over Centralcentral Europe.

Similar to what was reported by Toreti et al. (2019),) reported, the predominant weather patterns found for the period from 1302- to 1307 also must have originatedresulted from certain seesaw constellations and associated patterns in the geopotential height fields. A possible meteorological interpretation of the We used the reported weather conditions collected for this study (see SI 2), to establish the large-scale meteorological patterns (see SI 2) was found, as is illustratedby means of

the 500-hPa geopotential anomalies for the period under study, which are depicted in Fig. 7a–k and described in the following:

In summer 1302 (Fig. 7a), wet conditions in FR and CE and dry conditions in IT correspond to a water seesaw which was negative over IT and positive over FR and CE. Geopotential anomalies were thus positive over IT and negative over FR and CE. WinterThe winter of 1302/130303 (Fig. 7b) was reported to have beenreportedly dry and cold over IT, FR, and CE, but warm over Westernwestern Russia. This situation can be explained by the presence of a blocking large-scale positive anomaly in the 500-hPa geopotential that covered wholeall of IT, FR, and Southernsouthern CE. A negative anomaly over Northernnorthern Europe would have provided such a constellation that generally correspond to the arrival of warm (conditions and – not reported – likely moist air) would have arrivedmoisture in Silesia/ and Russia, as was reported for this season. Thus, a; in fact reports confirm above-average temperatures but neglect any mention of precipitation. While the evidence suggests that the potential seesaw was tipping from the region CE, IT, and FR (negative) towards Easterneastern Europe, —i.e. heretowards Silesia toand Russia (positive). Due to the lack of), there are insufficient precipitation proxies for Silesia/ and Russia for theduring this period, meaning that this likely constellation can however be hypothesized but not currently not be proven.

The 1302/130303 winter constellation likely continued throughout the whole of 1303 (Fig. 7c). ContinuedIn the spring, continued positive 500-hPa geopotential anomalies over IT, FR, and CE caused a long-lastingbrought an enduring cold period in spring north of the alpsAlps, while the blockage led to a continued lack of precipitation over IT. Also in the following winter of 1303/130404 (Fig. 7d), the positive 500-hPa geopotential anomaly must have persisted over IT. However, the reported warm conditions reported in FR and Westernwestern CE indicate that the positive anomaly did not extend less towardas far to the north compared to as it had the previous winter 1302/1303. .

Spring The spring of 1304 seems to behave been a turning point for the water seesaw constellation (Fig. 7e). The combination of dryness ofin FR and CE and the wetness reported for IT let it appear likelysuggests that the positive 500-hPa geopotential anomaly had moved towardtowards FR and CE (similar to what was reported by Toreti et al. 2019 forfound in the case of the 2018 drought), enabling precipitation systems to reach IT from the southwest via the Westernwestern Mediterranean. The dry summer reported for IT following the wet spring could have been caused by a slight positive 500-hPa geopotential anomaly over IT during this time (Fig. 7f), but in this case, given the subtropical climate, summertime precipitation is rather unlikely anyway in its subtropical climate.

The weather reported for winter 1304/1305 gives a clear indication for05 clearly indicates the presence of a large-scale positive 500-hPa geopotential anomaly over Northernnorthern Europe and a negative 500-hPa geopotential anomaly over Southernsouthern Europe (Fig. 7g). Cold air masses from Easterneastern Europe were reported for the whole of CE and FR, while IT wasItalian sources reported to be wet conditions. This constellation likely continued likely during summer 1305, with a slightly increased negative anomaly over eastern CE that allowed normal temperaturetemperatures and precipitation conditions over this region (Fig. 7h).

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Cold air masses ~~from Eastern Europe~~ were reported ~~for the whole of~~throughout CE, FR, and IT in the winter 1305/~~1306~~06, which must have been caused by yet another large-scale positive 500-hPa geopotential anomaly over ~~Northern~~northern Europe (Fig. 7i~~).~~) and the associated cold, easterly winds along its southern boundary. A negative 500-hPa geopotential anomaly can thus be expected ~~to have been present~~ over ~~Northern~~northern Africa. The ~~dry air from Eastern~~resulting westerly flow of eastern European air masses over CE consequently led to the ~~reported~~ dry conditions ~~over~~reported for FR. That situation likely continued until the winter of 1306/1307, when drought and low temperatures were once again reported ~~again~~ for CE and IT (Fig. 7j). The ~~reported~~ increasing flood conditions reported in IT in spring 1307 can be explained either by ~~melting snow~~snowmelt or by a slight ~~movements~~shift of the positive 500-hPa geopotential anomaly towards the north, allowing precipitation systems to reach IT via the Mediterranean.

Finally, the ~~CE~~ drought in CE and heatwave in FR and IT ~~is~~are likely a result of a continuing positive 500-hPa geopotential anomaly over CE (Fig. 7k). ~~In~~Dryness prevailed in its center, ~~dryness prevailed~~ while on the western (FR) and southern (IT) borders hot air was advected from Africa.

4.4 Blazes – ~~correlation~~Correlation with ~~drought periods~~Drought Periods and ~~cultural aspects~~Cultural Aspects

A peak in ~~blazes around~~urban fires during the 1302~~–05~~–1305 drought is visible for IT (Fig. 8), with a significant correlation of droughts and blazes (r = 0,346) ~~over the whole period. The same~~in the thirteenth and fourteenth centuries. A similar peak is visible for FR in 1306 (Fig. 9) with an even higher correlation of fires and droughts (r = 0,657) over ~~the two centuries.~~this time period. The correlation of drought years and blazes in CE (Fig. 10) is less obvious but still significant (r = 0,379). Furthermore, ~~we have suspected~~suspecting from these results (Figs. 8–10) that the probability of a ~~blaze~~fire might lag ~~by~~ one year ~~the~~behind drought ~~event, as~~events because wooden structures that had dried over long periods ~~and~~ might ignite more easily even ~~with a temporal distance to~~ after the drought~~. We have then tested in a~~ had ended, we cross-~~correlation if this assumed connection existed in our~~ correlated the data ~~and we~~to test this assumption and found a very significant correlation regarding a one year lag for FR (r = 0,83) and a ~~significant~~significant one for IT (r = 0,59), but none for CE (r = -0,167). The differing results in the case of CE can probably be explained by discrepancies in the ~~non-critical use of~~ documentary data in the ~~‚~~*Deutsche Städtebücher*‘~~,~~ while the relevant ~~blaze~~ information ~~was~~on fires in IT and FR could be more carefully validated by historical source-criticism ~~for IT and FR~~.

As the OWDA information for CE (~~here~~ broadly defined here as a rectangle ~~from~~ naturally delineated by the Rhine ~~to~~and the Alps to the west and south, and stretching to Novgorod in the ~~East~~east and including all of Denmark plus ~~Southern~~southern Scandinavia to the ~~North~~north, i.e. 47~~,~~–34° N – 58.69° N, 7.52 ° E – 30.88°E) is relatively dense and reliable, it has been combined with available information on ~~blazes~~fires from documentary data. ~~Yet~~Nevertheless, the correlation of low PDSI values (i.e., drought) and ~~blazes in the same years~~fires (Fig. 11) is very weak in this case, if not nonexistent (r = -0,06).

The best documented of all ~~blazes~~fires during the 1302–1307 period is the infamous city fire of Florence on 10 June 1304 ~~that~~in which 1,700 homes burned ~~1700 houses. It was interpreted by contemporaries as~~. Contemporaries suspected a

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conspiracy of the political opposition, the Florentine White Guelfs, ~~which~~who were driven out of the city in the aftermath of the blaze. The detailed ~~available~~ documentation available on ~~14th~~fourteenth-century fires in Florence (Contessa 2000, 89–107) makes clear how unusual a ~~large blaze~~fire of this ~~kind~~magnitude was, even for a populous city like the Tuscan metropolis. One week after the fire, and again in early August 1304, the blaze was even ~~a~~the topic ~~for~~of homilies ~~of~~ delivered by the Dominican Giordano da Pisa, who reminded his fellow citizens that the fire had only ~~did what it should do according to~~done God's will: ~~bring~~with fire came warmth~~-~~, and, when it burned the city's houses, this was ~~no sin, but God's will~~product of divine volition (Varanini, Baldassari 1993, 314). Another strategy to cope with the fire threat was to oblige citizens, in case of ~~droughts~~drought or strong winds, to ~~arrange full water~~ place buckets ~~at~~of water by the doors of their houses, ready to be used immediately ~~used~~ by anyone in case of fire emergency. A Parisian chronicler described ~~this~~such a coping ~~strategy already~~mechanism in 1305, when high temperatures combined with strong wind made authorities worry about a potential disaster (Buchon 1827, 116–117). ~~This is a shared~~Other sources share this concern ~~of other sources, too~~, as well (Wattenbach 1851a, 676). That wind ~~was~~played a crucial role can ~~also~~ be ~~derived~~deduced from the fact that ~~the fire was~~fires were able to cross water bodies like rivers (Wozniak 2015).

4.5 Drought and ~~infrastructural responses~~Infrastructural Responses

~~Italy provides a~~A number of infrastructural responses to the drought experience of 1302~~-04.~~–1304 are evident in Italy. In 1303, the city of Parma built ~~-~~a new fountain, larger and deeper ~~fountain~~than before (Bonazzi 1902, 86). ~~Something comparable happened in the~~ The Tuscan city of Siena, ~~settled away~~situated far from any larger ~~watercourses~~ bodies of water and ~~traditionally struggling~~frequently confronted with water scarcity~~. Not surprisingly, the century~~, took similar measures. Based on a centuries-old myth of an underground river below the city~~,~~ (the so-called "Diana~~, was still alive in Siena. In~~"), city councillors apparently authorized digging in a local church in an attempt to find this underground waterway in April 1305, one year after the end of the drought~~, documentary evidence reveals that the city council actively searched for this underground river by digging in a local church~~ (Bargagli Petrucci 1903, II, 20). ~~An even more real-time response can be found for 1303: In~~ This was not their first attempt to alleviate the drought's effects. In the spring of 1303, when a dearth of grain was already ~~strangled~~affecting Siena, the city council decided to import grain via the small port of Talamone, 100 km ~~South-West~~southwest of Siena (ASS, CG 62, 1303 March 26, c. 99~~). They~~) as they had done ~~so already~~ the previous year ~~before. But in~~. In September 1303~~—~~, however, after the ~~successful~~ grain imports ~~that even~~ had ~~created an abundance of~~made food once again abundant in the city~~—~~, the city council decided to buy the port for the Republic and ~~to invest~~invested heavily in its refurbishment and expansion in the following years (Sordini 2000, 73–112). Sienese citizens were ~~settled in~~relocated to the newly designed city~~,~~ complete with ~~infrastructures~~ infrastructure and military fortifications (Fig. 12). Although ~~Siena~~the Sienese had discussed buying the port years before, it was the drought experience and ~~connected~~the associated food scarcity that ~~let the~~finally sparked the realization of these plans ~~become real~~ and lead to a long-term ~~infrastructure~~ investment~~,~~ in infrastructure, which was quite possibly the most expensive project the Republic of Siena ever financed outside the capital's walls.

4.6 Cultural ~~aspects~~Aspects of Drought

Siena's attempts to develop infrastructure in response to the drought

~~The aforementioned infrastructural responses by the city of Siena to the drought experience provoked a satirical response by Dante Alighieri. In his 'Divine comedy'.~~ caught the attention of the Florentine poet Dante Alighieri, who mocked ~~his~~the Sienese ~~neighbors with a famous verse~~in his *Divine Comedy*: "You will ~~find~~see them [some Florentines] ~~amongst the foolish crowd~~among that vain people [the Sienese] who ~~put~~place their ~~trust~~hopes in Talamone~~,~~ and will lose more hope ~~there~~in it than in ~~their search for~~seeking the Diana" (Dante, *Divine Comedy*, *Purgatory*, canto XIII~~).~~, transl. Durling 2003, 213). The *Purgatory*, finished during the early 1310s, makes clear that the futile ~~Sienese~~ efforts of the Sienese to search for their underground river did not go unnoticed by their neighbors. Nor did the Florentines ignore the acquisition of Talamone~~ they had~~, having themselves experienced in 1303/04 how vital the port was for their own food security, too. ~~So it was just consequent to sign~~They negotiated a trade agreement with Siena, signed in August 1311, that guaranteed Florentine access to the maritime grain trade via Talamone, although under conditions very beneficial for Siena (Banchi 1871, 126–127). -

In another famous medieval text, the *De regimine principum*, a kind of manual on good governance~~—~~or so-called "mirror of princes"—by Thomas Aquinas and Ptolemy of Lucca, the latter starts writing from 1302 onwards and reflects on the importance of food security: "Food that is sold is not as effective for nourishment as it should be, since it is often adulterated. As Solomon says in Proverbs ~~(Prov. 2,5):~~: 'Drink water from your own cistern~~',~~' which includes all nourishment, but especially drink, because it can more easily be adulterated. […] There is greater security in using one's own food, since outsiders can easily poison something not kept in its proper storehouse or pantry, and it is more likely to be harmful.~~"~~," (Blythe 1997, 114). ~~The whole reflection about safe access to food and drink is framed with a most striking biblical proverb, traditionally attributed to Solomon himself: "Drink waters out of thine own cistern, and running waters out of thine own well. Let thy fountains be dispersed abroad, and rivers of waters in the streets." (Prov. 5, 14–16).~~ That Ptolemy of Lucca wrote about the drought in his chronicle (Clavuot 2009, 652~~) exactly the time)~~, while he ~~worked~~was also working on the mirror of princes, makes a connection between the two texts even more plausible.

4.7 Societal ~~responses~~Responses to ~~water scarcity~~Water Scarcity

~~This worry about access to water, theoretically~~While the concerns expressed in ~~the~~ *De regimine principum*~~, meets social reality in~~ were theoretical, medieval ~~civilization.~~civilizations had a very real stake in the matter. In times of drought, ~~one of the major problem~~ communities ~~affected had to cope with, in absence of~~ that lacked any efficient water system~~, was actually entitlement to healthy drinkable resources. In another context,~~ were confronted with the issue of how to acquire and distribute potable water. According to chronicles, some French rural communities faced severe hardships during ~~the~~an extreme drought ~~of~~in 1137, ~~some chroniclers fully described the hardships met by some French rural communities to access water, as~~ when people ~~had~~were forced to walk for miles in ~~order to seek for non-dried sources~~ search of water (Labbé 2018).

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~~This aspect is complemented~~The problem was further complicated by the fact that water sources were frequently ~~polluted with dangerous gastrointestinal pathogens, a situation eventually worsened by high~~contaminated, especially when temperatures soared and ~~low~~water levels ~~of almost stagnant waters~~fell and stagnated in summertime. ~~Thus, in~~It is thus hardly surprising that, according to the account of a chronicler in Paris, an epidemic broke out in the summer of 1307, after three years of drought, ~~a chronicler of Paris explained that,~~ because the vineyard ~~being burnt by~~had suffered a late frost in April~~, citizens had~~ of the previous year, forcing the city's residents to drink water instead of wine~~, and that an epidemic subsequently broke out during the summer~~ (Buchon 1827, 130). ~~The~~ Pribyl (2017) has suggested that the outbreak of ~~epidemic~~such epidemics one year after a warm ~~half~~ summer half-year, as the summer of 1306 likely was, may ~~have been, has been emphasized by Pribyl (2017) as~~be one of the most typical consequences of such ~~kind of~~ climatic conditions. The epidemic in Paris in 1307, ~~due to~~caused by warm conditions ~~during the summer combined with a lack of ersatz drink like~~ paired with a wine shortage, can ~~then most~~thus probably be interpreted as a result of the ~~back-to-back dry vintages~~successive years of drought from 1304 to 1306.

Another side~~-~~ effect of major droughts in the ~~14th~~fourteenth century was ~~eventually~~ the temporary ~~blockage~~interruptions of production and sometimes even ~~of communication systems. If crops were~~ shipping routes. Although drought did not generally ~~not heavily endangered~~imperil the harvest itself, at least in the regions north of the Alps, the lack of water ~~induced nevertheless~~sometimes indirectly ~~in some occasions a disruption of~~disrupted the entire food supply system~~. Difficulties to transform cereals~~ in that mills could not turn grain into flour~~,~~ and ~~to sustain the~~ transportation ~~of food supply~~ from production regions to city markets ~~could have some~~ was more difficult. These complications had economic consequences~~. This inconvenience was precisely exposed~~ , as described by the Dominican monk of Colmar in 1304: ~~If~~Although wheat that year was quite affordable ~~this year~~ because of benevolent harvests, ~~nevertheless~~ bread was ~~very~~ simultaneously quite expensive and scarce ~~at the same time, just,~~ because mills ~~settled~~ along ~~dried~~dry rivers could not work anymore. ~~Likewise, if~~Similarly, while winegrowers were able to produce wine of very good quality, ~~as~~because the ~~berries~~grapes contained a lot of sugar, they could not benefit from it. ~~Actually, wine~~Wine prices actually remained very low ~~as~~since shipments ~~were unable to go~~could not be sent down the Rhine river ~~and attain~~to the usual city markets of Strasbourg, ~~Köln~~Cologne, and Trier (Jaffé 1861, 231).

5 Discussion

5.1 Reassessing ~~dendrochronological data~~Dendrochronological Data with ~~dense documentary information~~Dense Documentary Information

~~What is surprising, is the totally different~~Surprisingly, the outcome of the correlation between droughts and blazes for CE~~, calculated~~ varies depending on which source one ~~time from~~uses for the ~~OWDA~~ drought data ~~with a very bad~~. The correlation ~~and~~according to the ~~other time from the drought indices~~data contained in the OWDA is quite insignificant (r = -

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0.06), while a correction based on drought indices in written sources, ~~where the correlation~~ is much better (~~respectively r = -0,06 and~~ r = 0,379). The data ~~for blazes stayed~~on the ~~same~~fires was constant in both calculations. ~~Here,~~The difference can be explained by the discrepancy between the reconstruction from the OWDA ~~on the one hand~~ and the drought indices, ~~on the other hand, comes into play~~; The OWDA (even more so the maps ~~provided with~~ it provides) shows ~~a lot~~considerably more dry periods than the documentary data, ~~that mirror mainly outstanding ones~~which emphasize the extraordinary events. Regarding the misleading picture the OWDA gives for Italy (in comparison with a reconstruction on the basis of written sources, see 4.1~~.).~~), a general comparison with reconstructions from written sources would be advisable, especially for those regions and periods ~~where~~for which there is a ~~good basis~~wealth of written sources and ~~where the amount~~lack of ~~dendrological~~dendroclimatological data ~~is at the same time rather low~~ (like for Italy).

5.2 Drought ~~impacts~~Impacts on ~~agricultural production~~Agricultural Production

Experimental archeology has demonstrated the impacts of drought on medieval ~~style agriculture~~ agricultural techniques (Kropp 2019): considerable damage ~~on~~to summer crops, but stable harvests from winter crops. A mixture of different crops taken together guaranteed ~~altogether~~ a sufficient harvest. This can explain the average cereal yields in figure 5, especially in 1304. In contrast, excessive humidity in 1310 and ~~from~~ 1314 ~~to~~ –1316 clearly had a negative impact on the harvest (cereals -20/-40% and wine -80/-60% respectively). Methodologically, it is worth noting that cold episodes are ~~mirrored~~reflected more ~~faithfully through~~reliably in agricultural proxy- data than dry periods.

5.3 Drought, ~~blazes~~Blazes, and the ~~development~~Development of ~~fire-fighting~~Firefighting

There is no clear connection between the experiences of the ~~blazes~~urban fires in the first decade of the ~~14th~~fourteenth century and the development of organized ~~fire-fighting.~~firefighting. The first~~,~~ (yet very limited) fire prevention policies are known from 1325 (~~Ibid.,~~ Contessa 2000, 21–27) and consisted of the introduction of brick ~~built~~ chimneys and stoves. As early as ~~from~~ 1296 onwards, ~~in Siena,~~ the city of Siena reimbursed citizens ~~that~~who ruined their tools ~~when~~ fighting fires (Bellissima 1922), and when ~~two blazes hit~~ the city experienced two fires in November 1302, more than ~~200~~two hundred people fought the fire in an organized way and used more than ~~1800~~ 1,800 buckets of water ~~charges~~ (Di Tura del Grasso, 265). These are strong indicators of a proto fire-guard system in Italian city-states around 1300, ~~before~~ even prior to the establishment of official fire guards ~~were established, e.g.~~, for example, between 1344 ~~48~~ and 1348 in Florence (Contessa 2000, 31–48).

5.4 Putting the 1302 ~~07 drought period in a global perspective~~ –1307 Drought Period in Global Perspective for the 13th~~/~~ and 14th ~~centuries~~Centuries

~~Following~~According to our ~~indices~~ reconstruction of indices from narrative sources, no such multi-seasonal ~~and supraregional scale~~ droughts or comparable events on a supra-regional scale did ~~not~~ occur during the ~~13th~~thirteenth century ~~and do not find any similar case before~~, and after the drought in the first decade of the century, there is no comparable event

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until the 1360~~-~~–1362 drought ~~that struck all~~, which stretched across Europe, ~~more specifically in 1360-61 in Central~~affecting central Europe (Brázdil et al. 2019, 82-83; Kiss 2017, 44–45; Bauch 2017, 1102–1104) and England (Pribyl 2017, 102–104~~), while~~) in ~~1362 on~~1360–1361, and the Balkan peninsula~~,~~ and areas around the Black Sea and the Aegean ~~drought conditions prevailed~~ (Kiss, Nicolić 2015, 13–14~~). As~~) in 1362. Given the administrative data ~~gives indicators of drought~~ suggesting abnormally dry conditions in Catalonia in 1361/62 (Fynn-Paul 2016, 137), ~~one might even connect~~ it seems plausible that a major city fire in Urgell (Battle 1999, 79–82) ~~with this~~ was linked to a continuous lack of precipitation. There are even indicators ~~for~~that this event had a global dimension ~~of:~~ the ~~event: The~~ years 1360 and 1362 were characterized in Japan by major droughts ~~causing~~that caused famines there (Farris 2006, 109~~), also on~~); the Korean peninsula (Robinson 2009, 163) and ~~also 1362/63 in Western~~western Rajasthan (Rao 2009, 19~~), which is a considerable difference to the~~) have been shown to have experienced similar conditions during this period. There are, however, no traces of the drought of 1302~~–07 event that is not traceable outside of~~ 1307 evident beyond Europe.

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Conclusion

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~~The~~In recent years, the wet anomaly of the 1310s has attracted a lot of attention from scholars ~~these last years~~ (Slavin 2019), ~~as it is~~who commonly ~~interpreted~~interpret it as a signal of the transition between the MCA and the LIA (Campbell 2016). The huge variability that can be observed during this decade, ~~similarly with~~like the high interannual variability observed in the 1340s, ~~have~~has been highlighted as a side~~-effects~~ effect of this rapid climate change. In the context of global warming, specialists now agree that periods of rapid climate change are accompanied by a ~~probabilistic~~ higher probability and frequency of extreme events (Sippel and Otto 2014). To date, in the field of ~~Medieval~~medieval climate history, no efforts have been made to ~~underline~~examine the ~~outstanding~~remarkable period of drought ~~of~~in the first decade of the ~~14th~~fourteenth century. However, we have demonstrated that two exceptional series of warm ~~and,~~ dry summer half-~~year~~years occurred ~~respectively~~ during this period—in the ~~mediterranean~~Mediterranean Italian region between 1302 and 1304, and north of the Alps from 1304 to 1306.

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~~We propose then to interpret~~Might the remarkable drought conditions of 1302~~–07 CE~~–1307, combined with the cold anomalies of the 1310s and the 1340s ~~cold anomalies,~~, be viewed as part of the climatic transition from the MCA to the LIA~~. More~~ , as well? The dry anomaly of the 1300s was more than a last glow of the MCA~~, the dry anomaly of the 1300s combined~~. Together with the wet-cold anomaly of the 1310s ~~allow us to~~one might speak of a ~~'long'~~"long" Dantean Anomaly~~: Not a new, but now~~, which provides a much more ~~substantiated~~ substantial, if not entirely new, starting point for the changing climatic ~~pattern~~patterns of this period. Our reconstruction of the predominant weather patterns for the first decade of the ~~14th~~fourteenth century ~~from~~ —based on both documentary and proxy data ~~likely lead to the identification of~~

—points to multiple European water seesaw events ~~of~~from 1302– to 1307, ~~maybe~~which may have even ~~reaching~~affected the ~~Eastern~~eastern Mediterranean.

The series of reported meteorological conditions for this period show similarities to the seesaw conditions which prevailed in 2018 over continental Europe (Toreli et al. 2019). The period under study was characterized by a series of ~~long-lasting~~enduring, steady precipitation dipoles which ~~lead~~led regionally to ~~strongly contrasting~~stark contrasts of extreme precipitation and drought ~~extremes~~. It can be debated to which extent the 1302–1307 period can be compared to what is currently discussed regarding the influence of the Arctic amplification phenomenon (Cohen et al. 2014) on the increasing frequency of ~~long-lasting~~persistent, stable weather patterns that have occurred since the late 1980s. Arctic amplification describes the decrease of the latitudinal temperature gradient between the midlatitudes and the Arctic, which was found to weaken the storm tracks, shift the jet streams, and amplify quasi-stationary synoptic-scale atmospheric waves (Coumou et al. 2018). Future studies should investigate whether such a scenario was also present in the early ~~14th~~fourteenth century ~~when~~during the transition from the MCA ~~and~~to the LIA ~~occurred~~. It appears plausible that such a climatological transition ~~is~~could be temporally associated with a reduced latitudinal temperature gradient and have consequences similar to the ~~currently ongoing~~current phase of Arctic amplification.

~~Historical~~Careful critical analysis of written historical sources~~, coupled with acute source criticism, are deemed to be useful~~ provide a useful mechanism to refine the chronology of extreme events in combination with natural proxy~~-~~ data. As we have demonstrated, the OWDA tree-ring reconstruction ~~sometimes missed~~has gaps in the information due to scarce raw data, especially for southern Europe. ~~An in-depth analysis of~~ Using narrative and administrative sources, which are sufficiently numerous from the ~~14th~~fourteenth century onward, ~~permits to draw a~~ historians can more ~~accurate picture of~~accurately discern this epoch's climate, including the winter conditions that must be taken into consideration to get a full image of the droughts' extent.

Finally, droughts ~~are phenomena that offer~~deserve more ~~for a~~attention from cultural ~~history~~historians of climate than just the analysis of religious mitigation strategies. ~~They show both in~~Both contemporary ~~perception as in historical~~ perceptions and analysis of the historical data suggest a connection to ~~blazes,~~fires, which were a major threat to medieval cities. ~~We could demonstrate~~Our analysis shows, for the first time, a correlation ~~of~~between droughts and blazes over ~~200~~the course of two hundred years, ~~including a one-~~and suggests that the increased fire danger lagged a year ~~lag in these phenomena. Furthermore, drought provokes~~behind the climatic phenomenon. In addition, droughts provoked unusual reflections on thirst and the use of water that ~~we~~is otherwise ~~hardly ever find~~rare in medieval texts.

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~~**Author contribution**~~

Contributing Authors

Martin Bauch provided the general conceptualization, curation ~~&~~, and analysis of the Italian historical sources, in addition to the creation, evaluation, and visualization of drought indices and city ~~blazes, writing of~~fires; he also wrote the ~~original~~initial draft and led the funding acquisition. Thomas Labbé provided conceptual input, curation ~~&~~, and analysis of the French historical sources and the visualization of other agricultural proxies. Annabell Engel provided curation ~~&~~and analysis of the ~~Central~~central European material and conceptual input on data presentation. Patric Seifert provided conceptual input on climatological backgrounds, meteorological analysis, and the interpretation of documentary data ~~for~~on weather patterns and geopotential maps.

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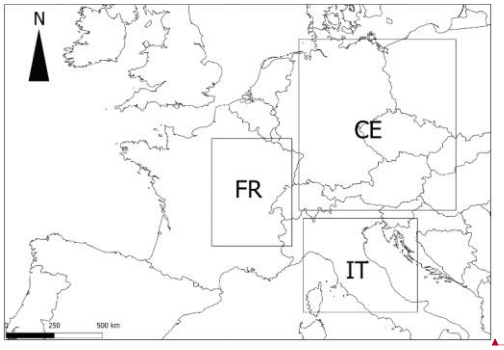

Figure 1: Geographical zones delimited for documentary researches (Map: Thomas Labbé).

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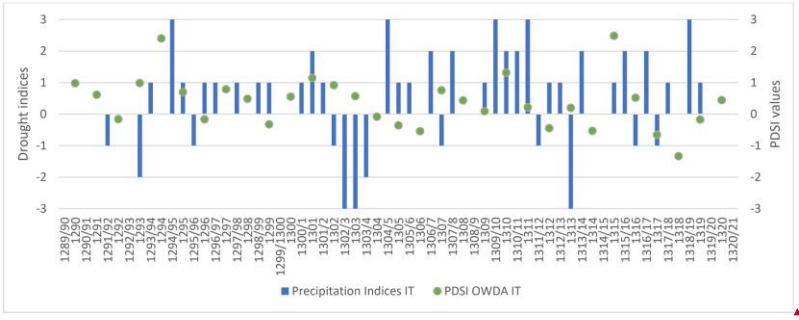

Figure 2: Reconstructed semi-annual drought indices and OWDA PDSI data for JJA from tree-rings (Cook et al. 2015) for IT, 1290–1320.

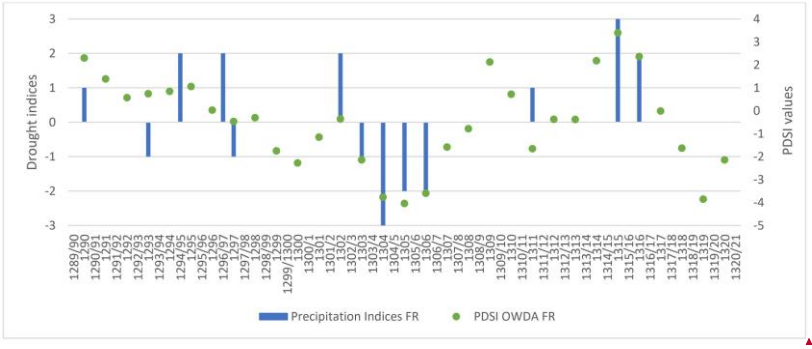

Figure 3: Reconstructed semi-annual drought indices and OWDA PDSI data for JJA from tree-rings (Cook et al. 2015) for FR, 1290–1320.

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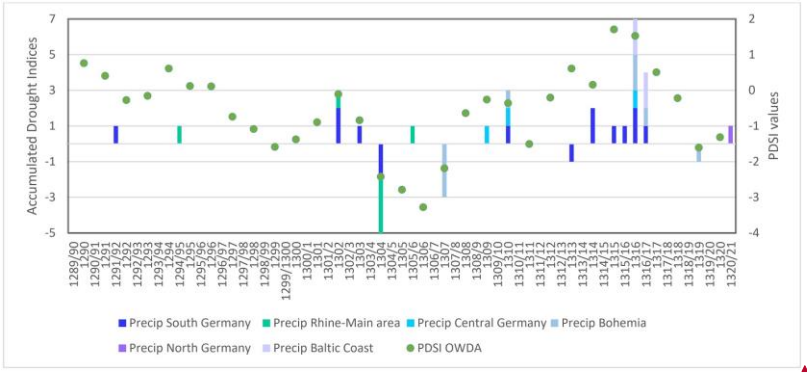

Figure 4: Reconstructed semi-annual drought indices and OWDA PDSI data for JJA from tree-rings (Cook et al. 2015) for CE, 1290–1320.

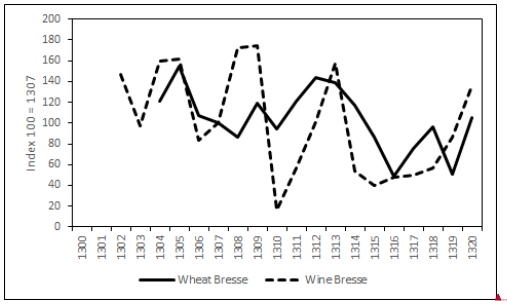

Figure 5: Mean wheat and wine ~~yield~~yields in the region of ~~the~~ Bresse (FR), 1300–1320.

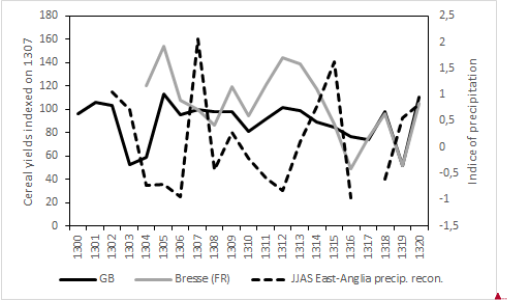

Figure 6: Comparison of cereal production in ~~Southern~~southern England and ~~in~~ the Bresse region (FR). Data: Southern England wheat yields (Campbell 2007); Bresse wheat yields (this article); East-Anglia JJAS precipitation reconstruction (Pribyl 2017).

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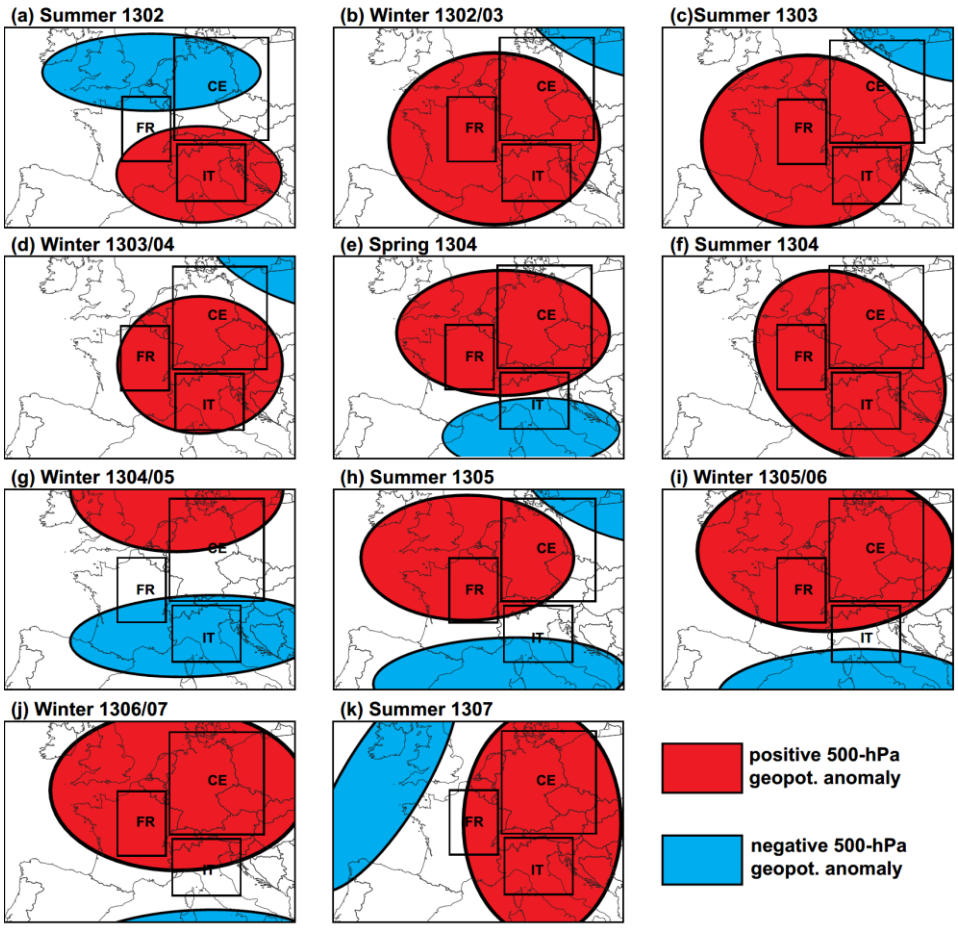

Figure 7: Illustration of the possible constellations of 500-hPa geopotential anomaly that can explain the weather patterns retrieved from the proxy and documentary sources for the years 1302—1307.

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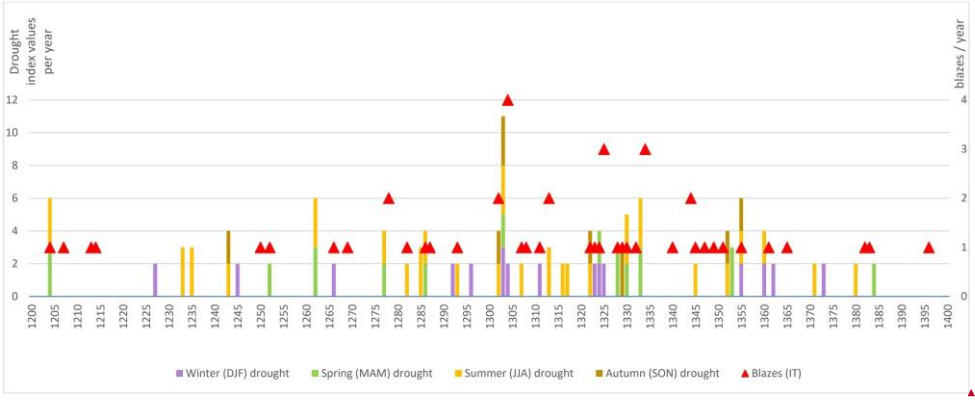

Figure 8: Reconstruction of drought indices compared with a chronology of ~~blazes~~fires for IT, 1200–1400. Data is available for 64 years out of 200 (32% coverage).

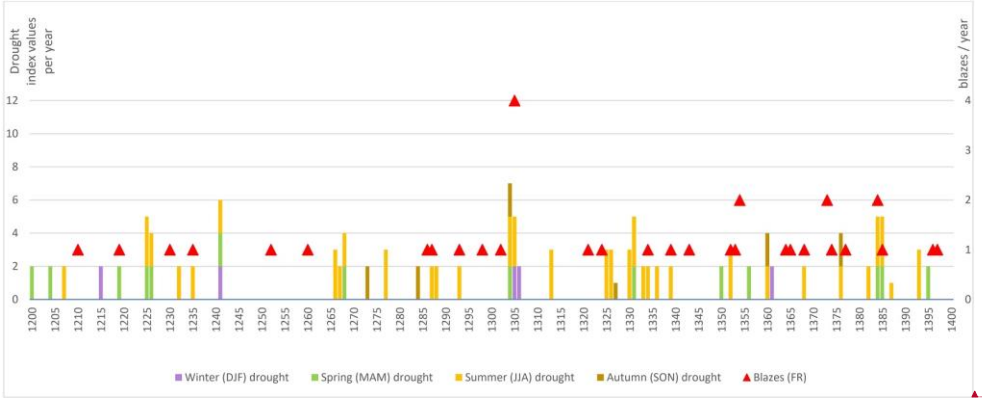

Figure 9: Reconstruction of drought indices compared with a chronology of blazes for FR, 1200–1400. Data is available for 67 years out of 200 (33,5% coverage).

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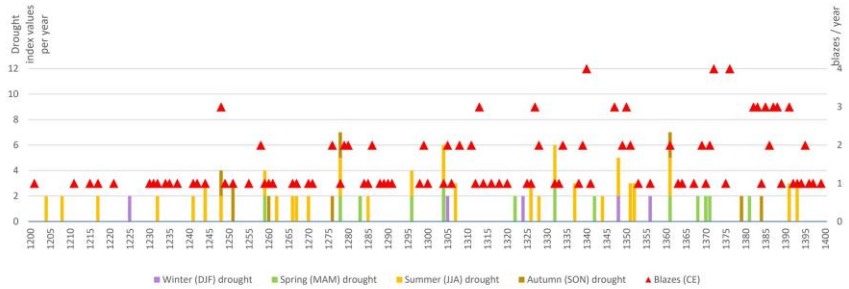

Figure 10: Reconstruction of drought indices compared with a chronology of blazes for CE, 1200–1400. Data is available for 125 years out of 200 (62,5% coverage).

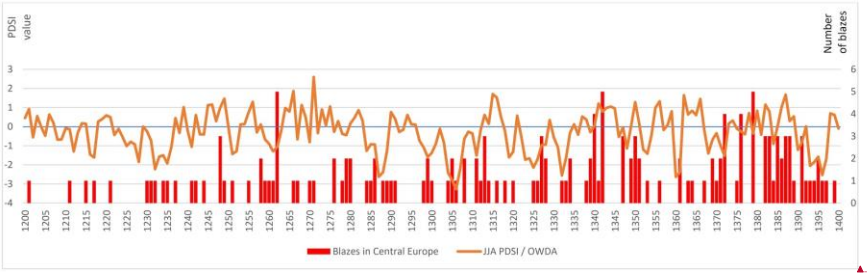

Figure 11: Reconstruction of JJA precipitation in tree-rings for CE and information on blazes from documentary data for the same region.

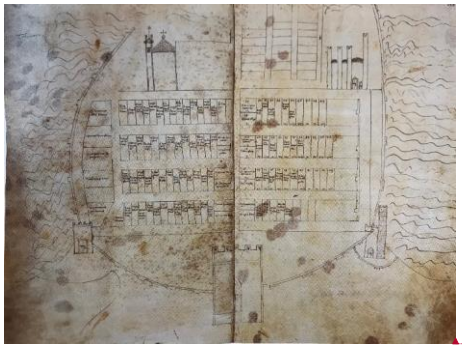

Figure 12: New city layout of Talamone with plots for new settlers from the mother city. Source: Archivio di Stato di Siena, Caleffo Nero, cap 3, 21 December 1306.

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