Finding Earth System Processes in Ancient Papyri and Medieval Chronicles, and Human History in Tree-Rings and Ice-Cores

How the Planet Shapes History: Geosciences, Human Society and Civilization

European Geosciences Union

vGIFT 2022

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Climate History

Aims: (1) Use historical sources to reconstruct past climate conditions and (2) to examine interactions between climate and society, including social vulnerability and responses to extreme weather…

Works best when combining written archives and natural proxies…

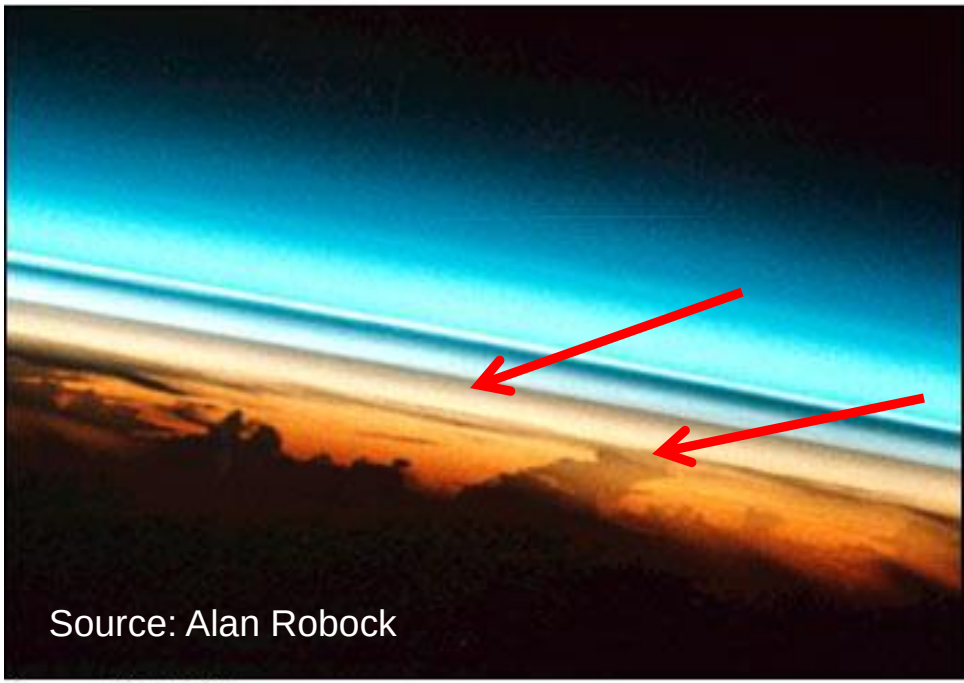
Woodcut, 'The Great and Terrible Flood', January 1651, Bavaria State Library

Part 1: History Informing Climate Science?

Lithograph depicting the 1631AD eruption of Vesuvius, with Saint Januarius (San Gennaro) interceding to stop the eruption.

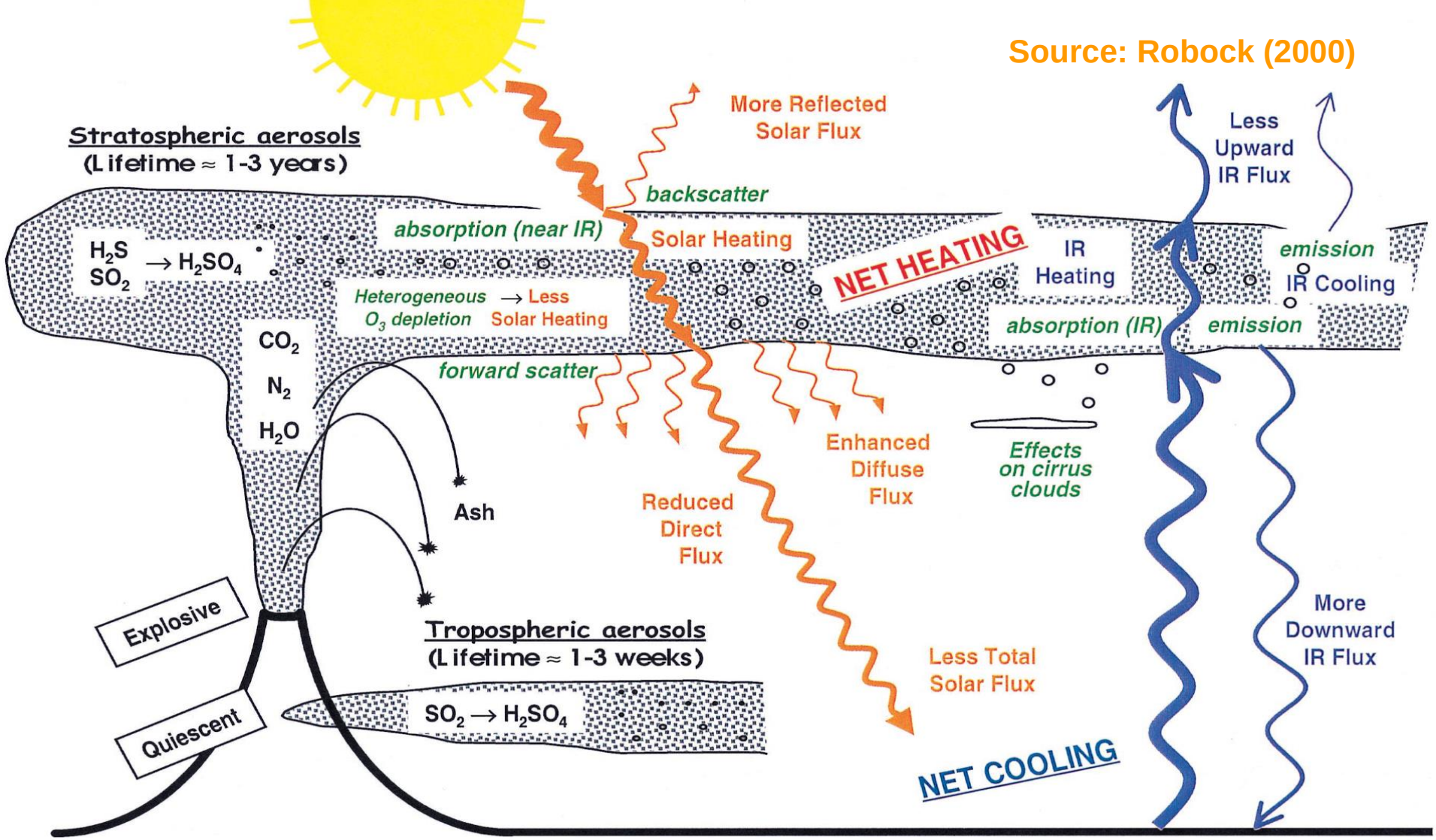
Eruptions can also have significant impacts much further afield, through influence on climate.

August 30, 1984



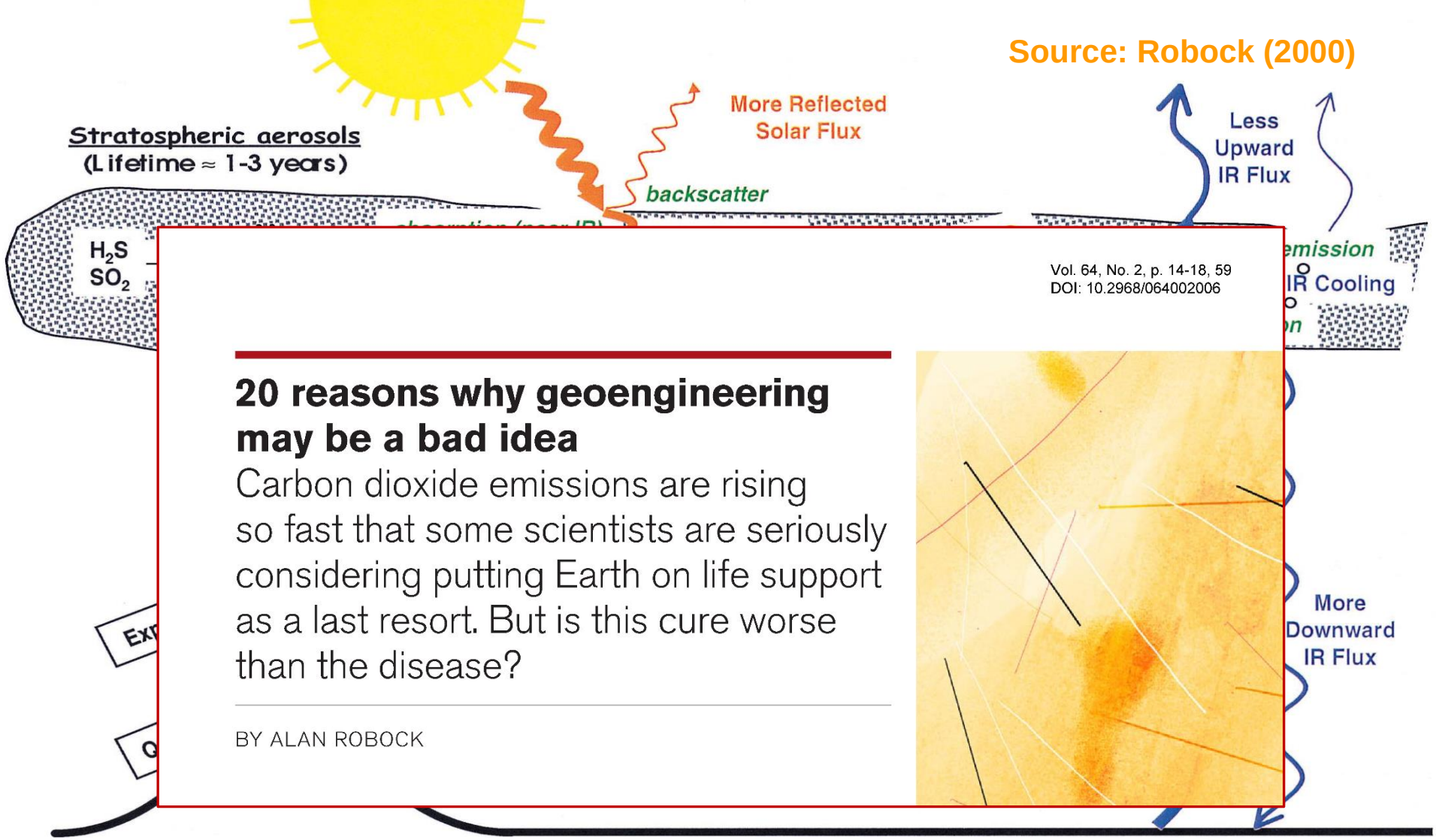
August 8, 1991

Source: Robock (2000)



The main point? There's serious complexity here! Many unknowns.

Source: Robock (2000)



Vol. 64, No. 2, p. 14-18, 59
DOI: 10.2968/064002006

20 reasons why geoengineering may be a bad idea

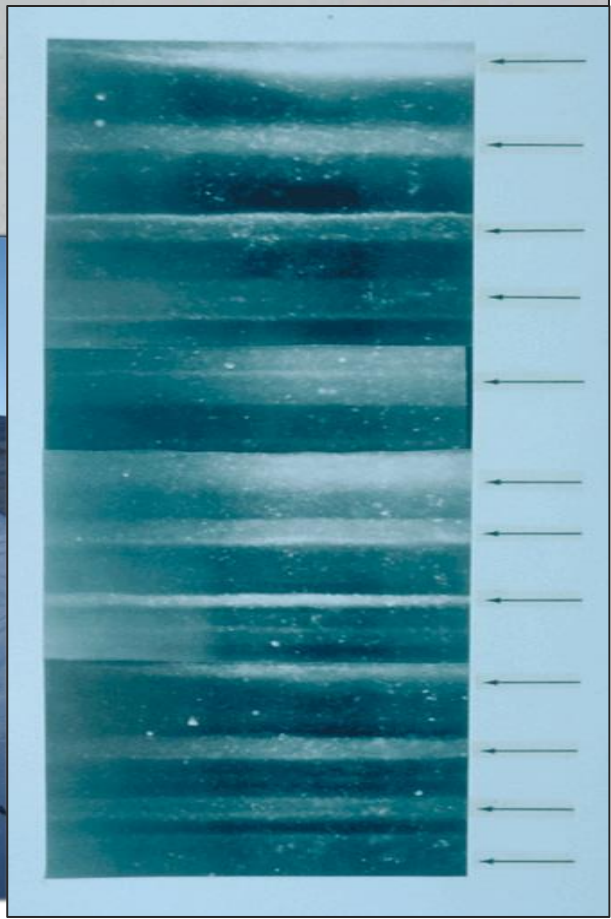
Carbon dioxide emissions are rising so fast that some scientists are seriously considering putting Earth on life support as a last resort. But is this cure worse than the disease?

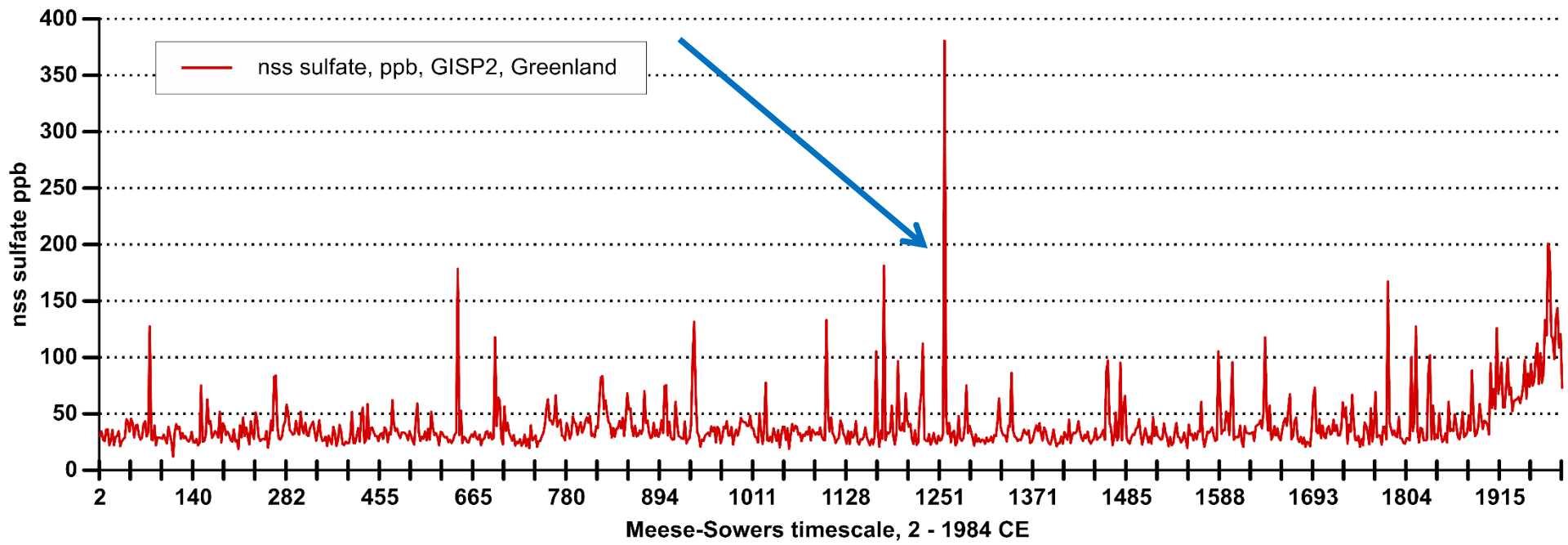
BY ALAN ROBOCK

The main point? There's serious complexity here! Many unknowns.

This is not a good thing…

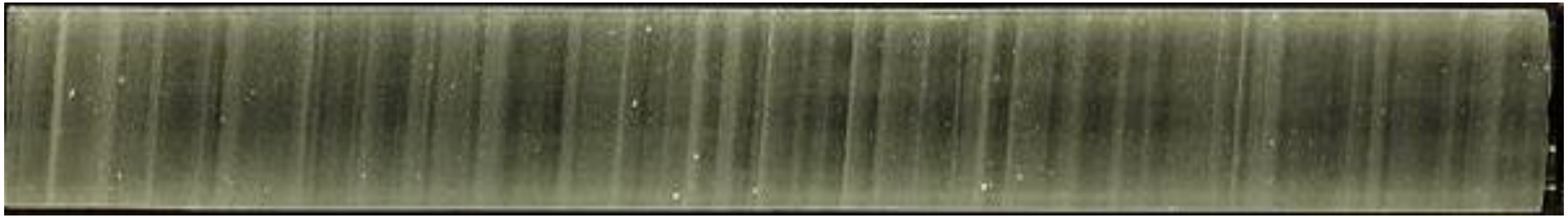
Images courtesy M. Sigl & D. Meese.





Large "spikes" in sulphate deposition above background levels identify major explosive eruptions prior to the modern period…

… before which we have *only limited observational records of eruptions and climate impact*.



Annual layers in the GISP2 ice-core (Greenland) at a depth of 1837m. Photo: Deb Meese.

The Irish Annals

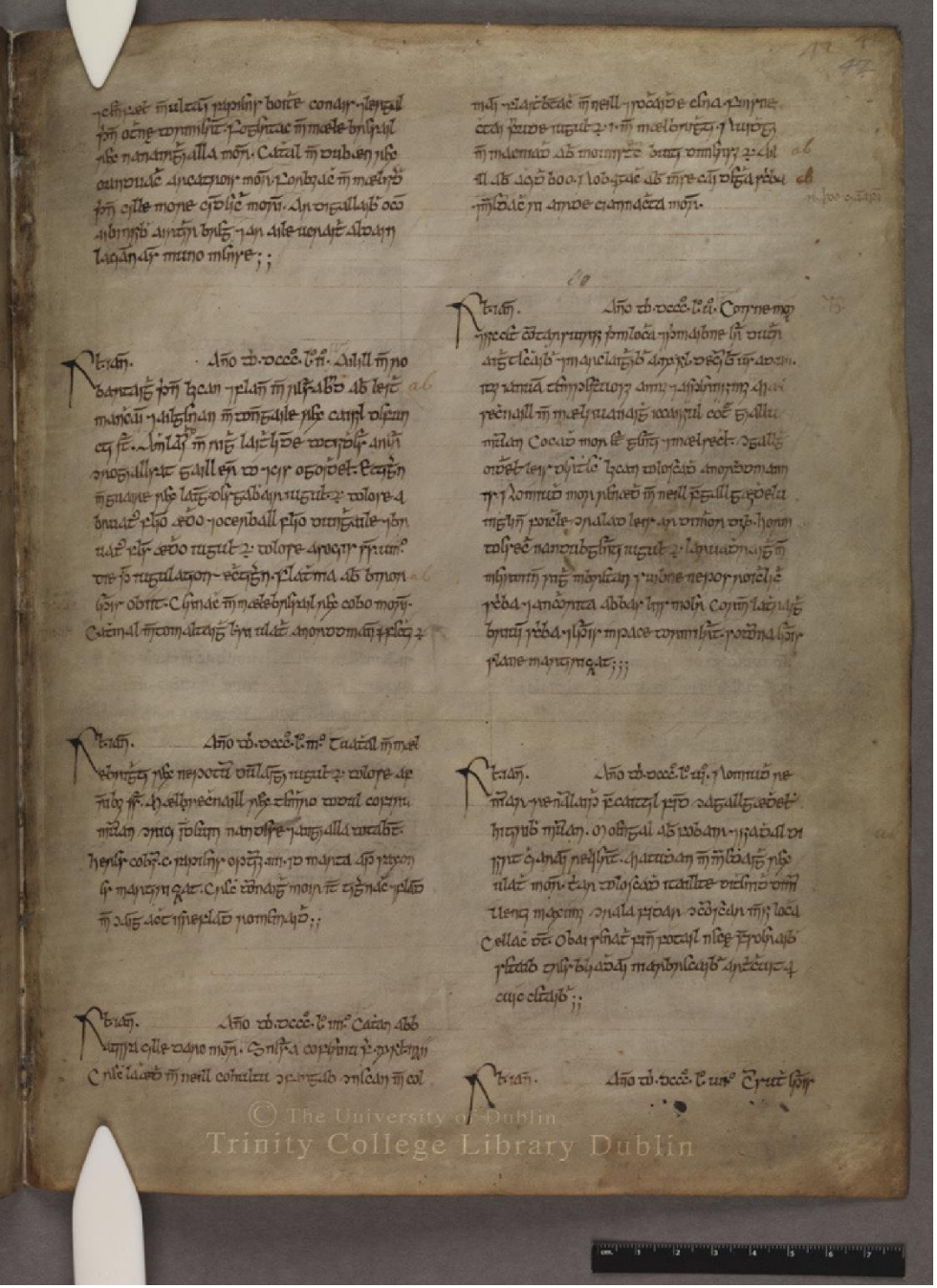
Yearly listings of important events maintained originally in monastic communities across Ireland, running reliably from, c.500-1600 CE.

https://stairnaheireann.net/2016/01/21/clonmacnoise-monastery-cluain-mhic-nois-meadow-of-the-sons-of-nos/

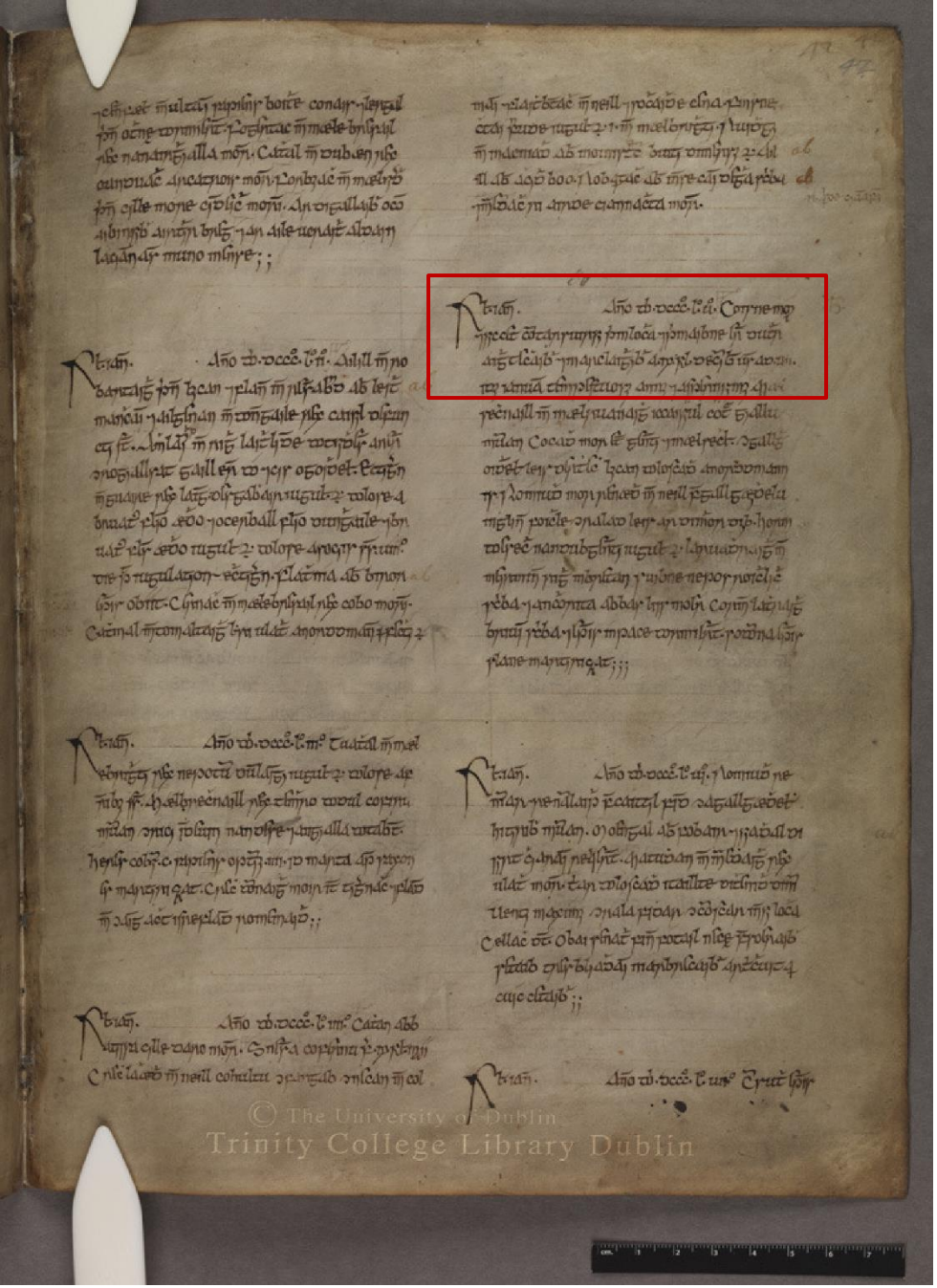
Report the founding of religious settlements, obituaries of elites, conflict, extreme weather & major societal stresses.

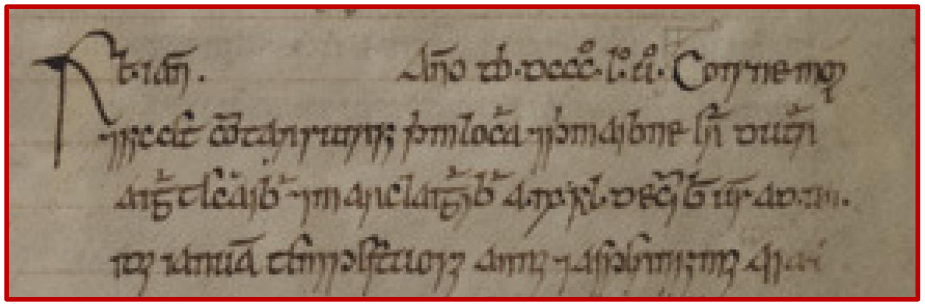
Survive in 22 texts and 1.1 million words.

https://heritageireland.ie/visit/places-to-visit/clonmacnoise/highlights/



Vellum page from TCD MS1282, the *Annals of Ulster*, covering 852 to 858 CE.





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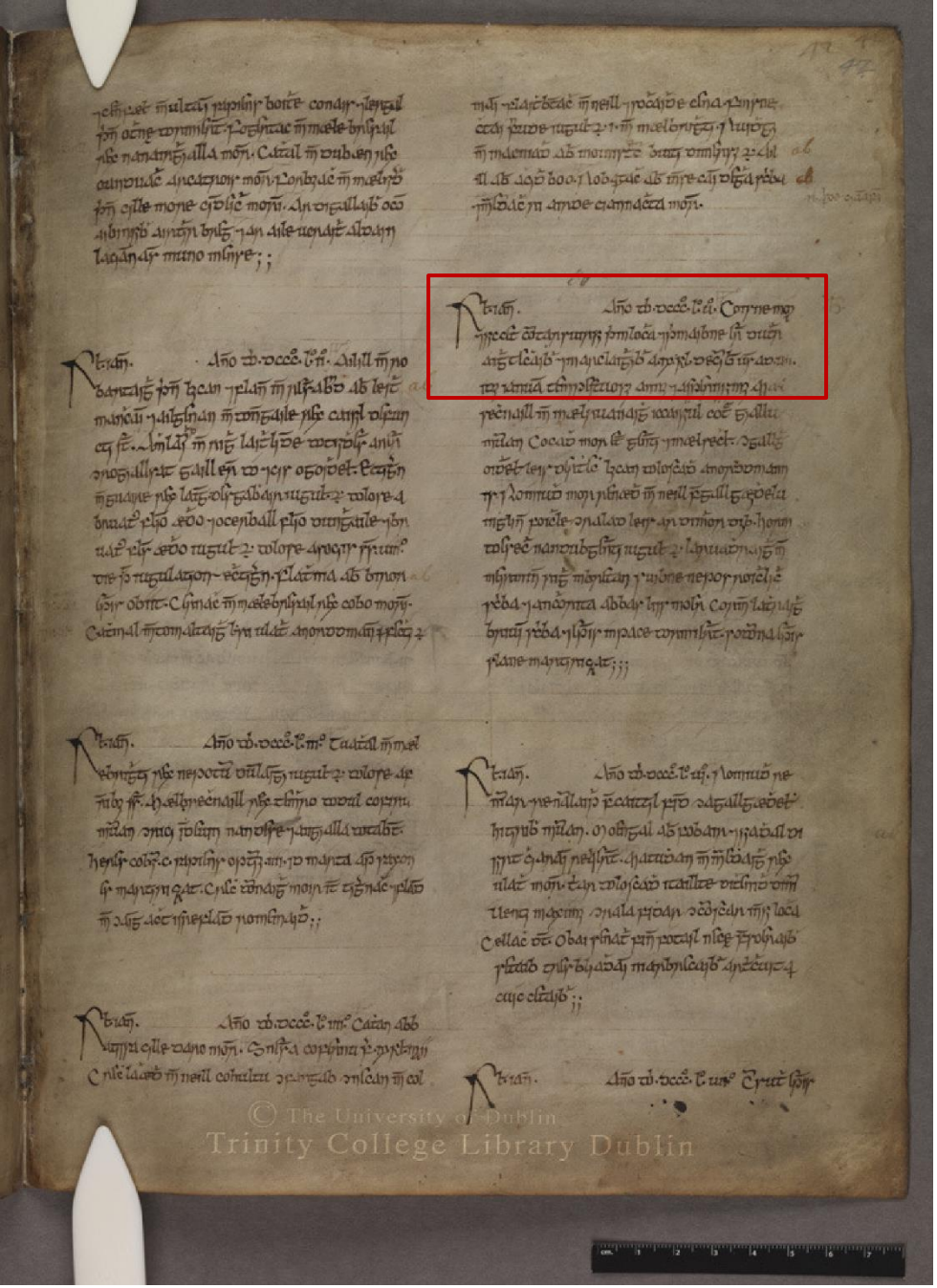

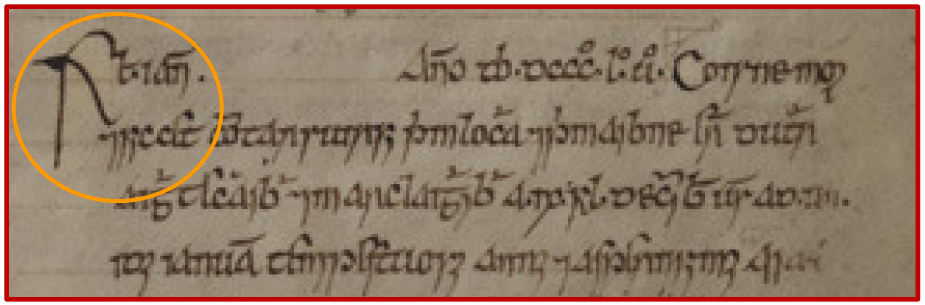

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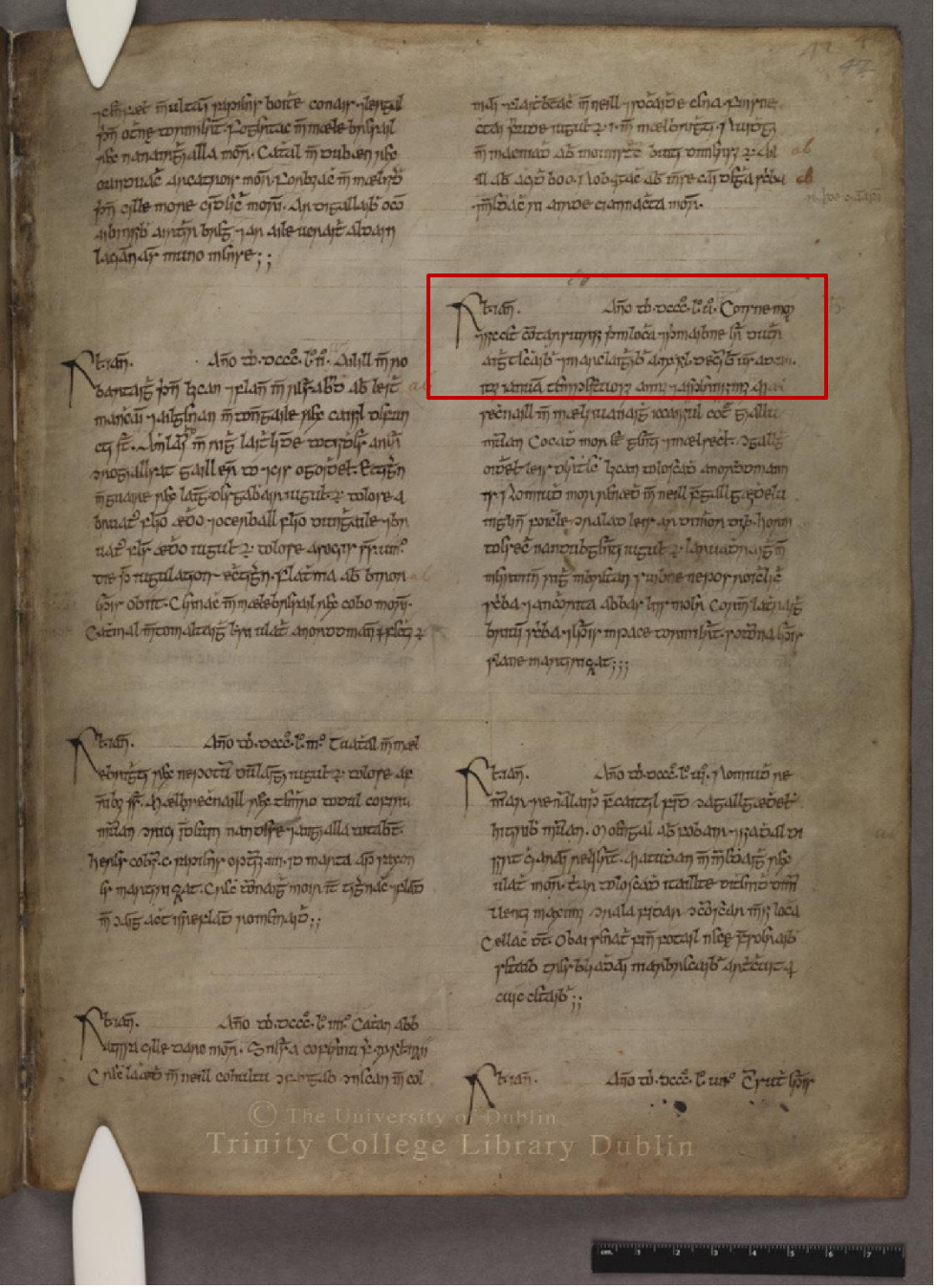
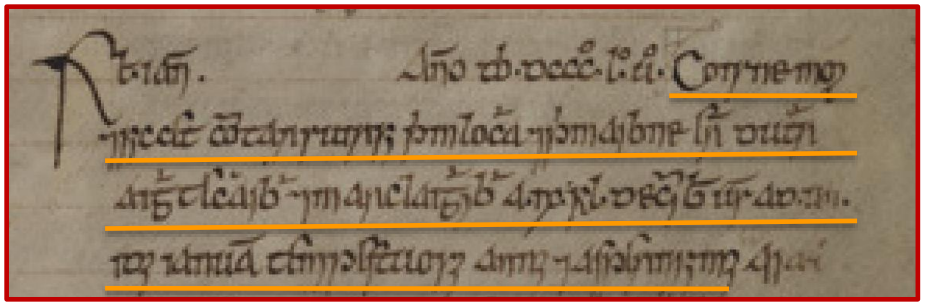




"Much ice and frost so that the principal lakes & rivers of Ireland could be crossed by people on foot & horseback from… 23 November [855] to 7 January [856]."

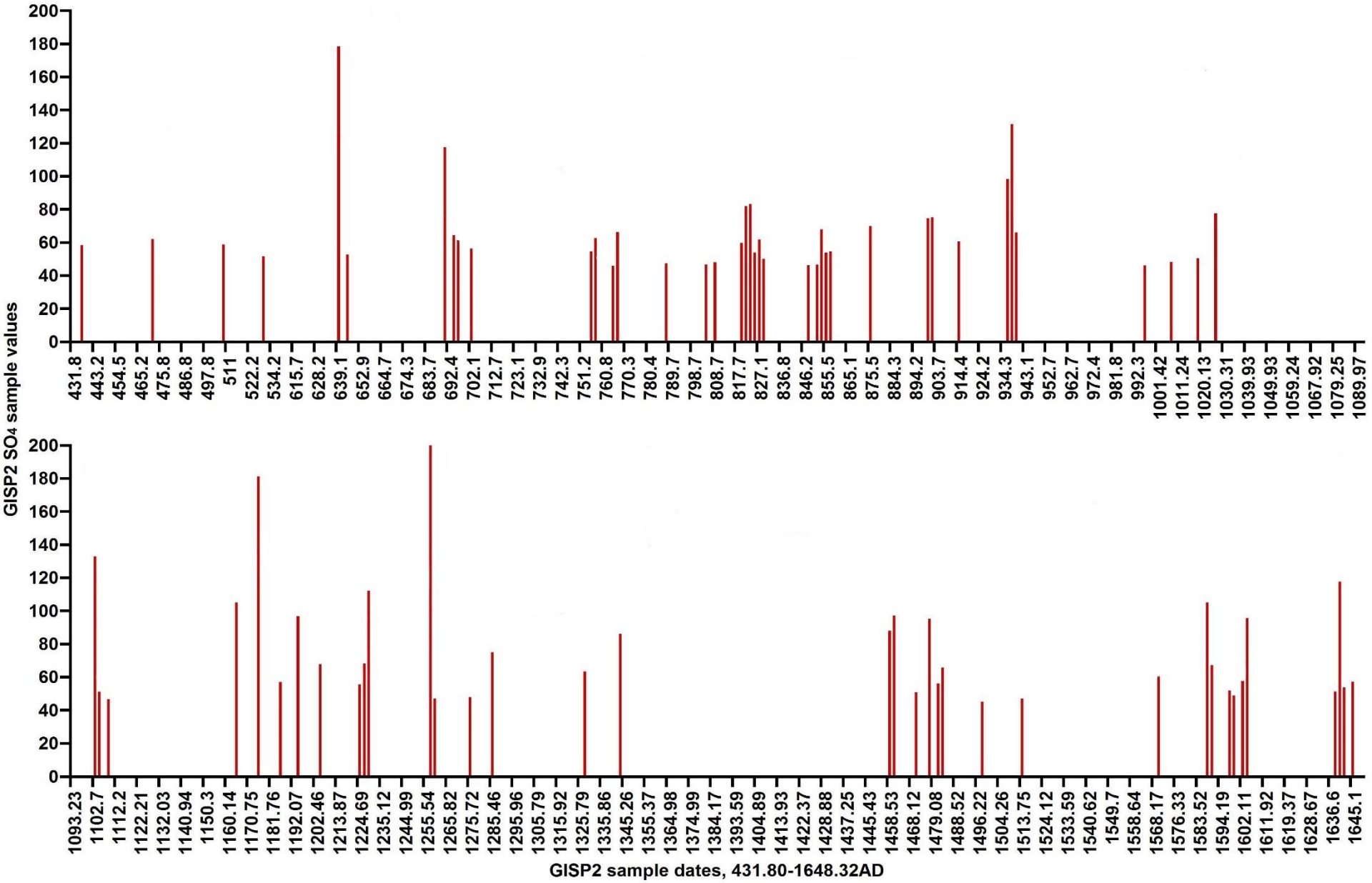
Vellum page from TCD MS1282, the *Annals of Ulster*, covering 852 to 858 CE.

“**A heavy and terrible shower fell in part of Connacht this year**, that is, in Tir Maine and in Sodain and in Ui Diarmata and in Clann Taidc, **which brought about disease and a very great sickness among the cows and beasts of those regions after they had eaten grass and leaves; and when men drank of the milk of these cattle and ate of their flesh, they suffered internal pains and various diseases**. Nor was it strange that these portentous things should happen in Connacht at that time, for a great affliction befell the country then, the loss of Cathal Crobderg son of Toirrdelbach O Conchobair, king of Connacht…”

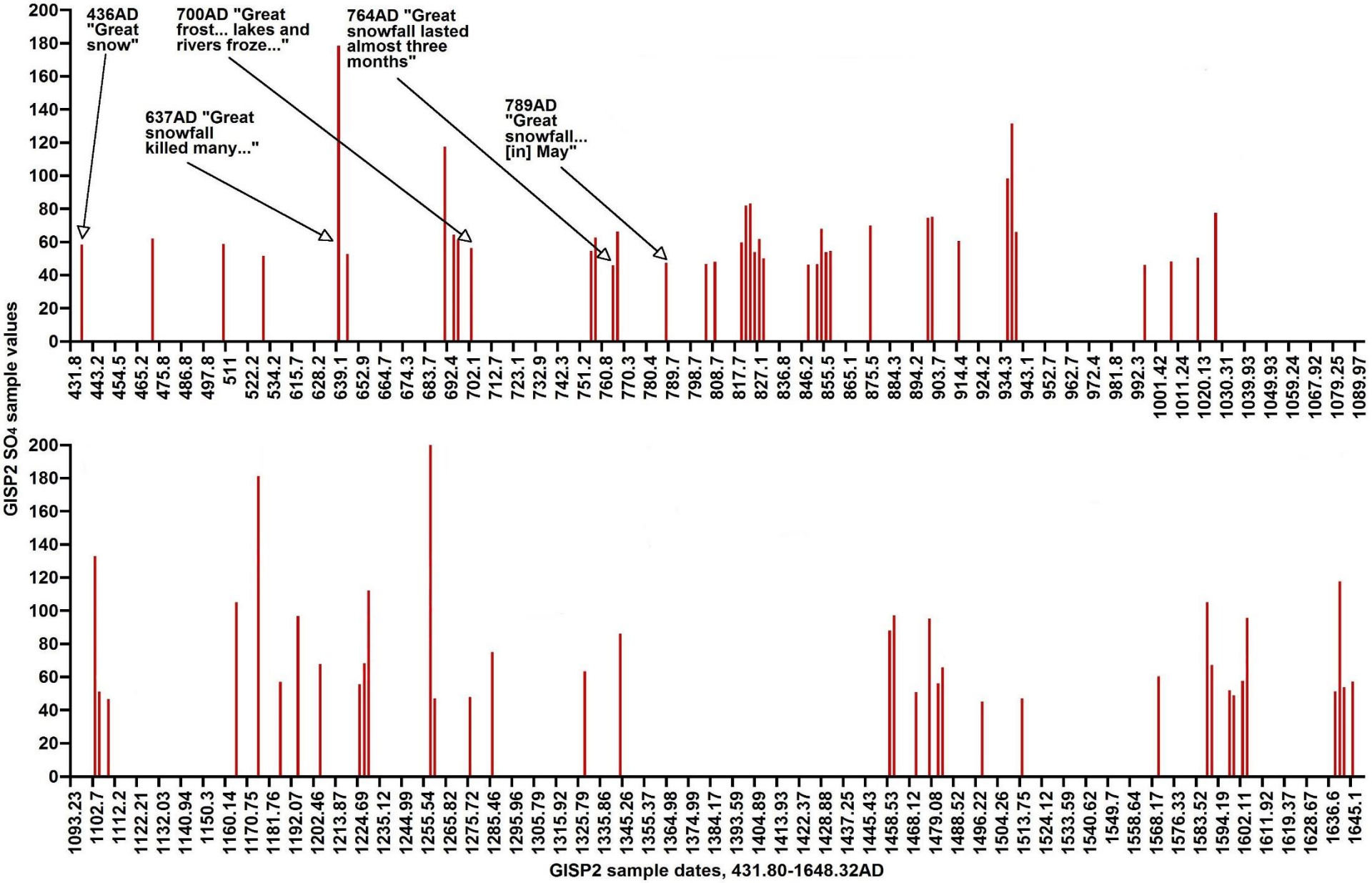
***Annals of Connacht*, 1224**.

Royal Irish Academy, MS C iii 2, f. 1 r.


All Human Mortality
All Animal Mortality
All Harvest Impacts
Agricultural Disturbance Index
All Famine & Scarcity Years
Low Precipitation Index
High Precipitation Index
Low Temperature Index
Windiness Index
Extremes and impacts
Years, AD431-1650



Volcanic events in GISP2 vs. severe cold events in Irish Annals, 431-1649 CE.



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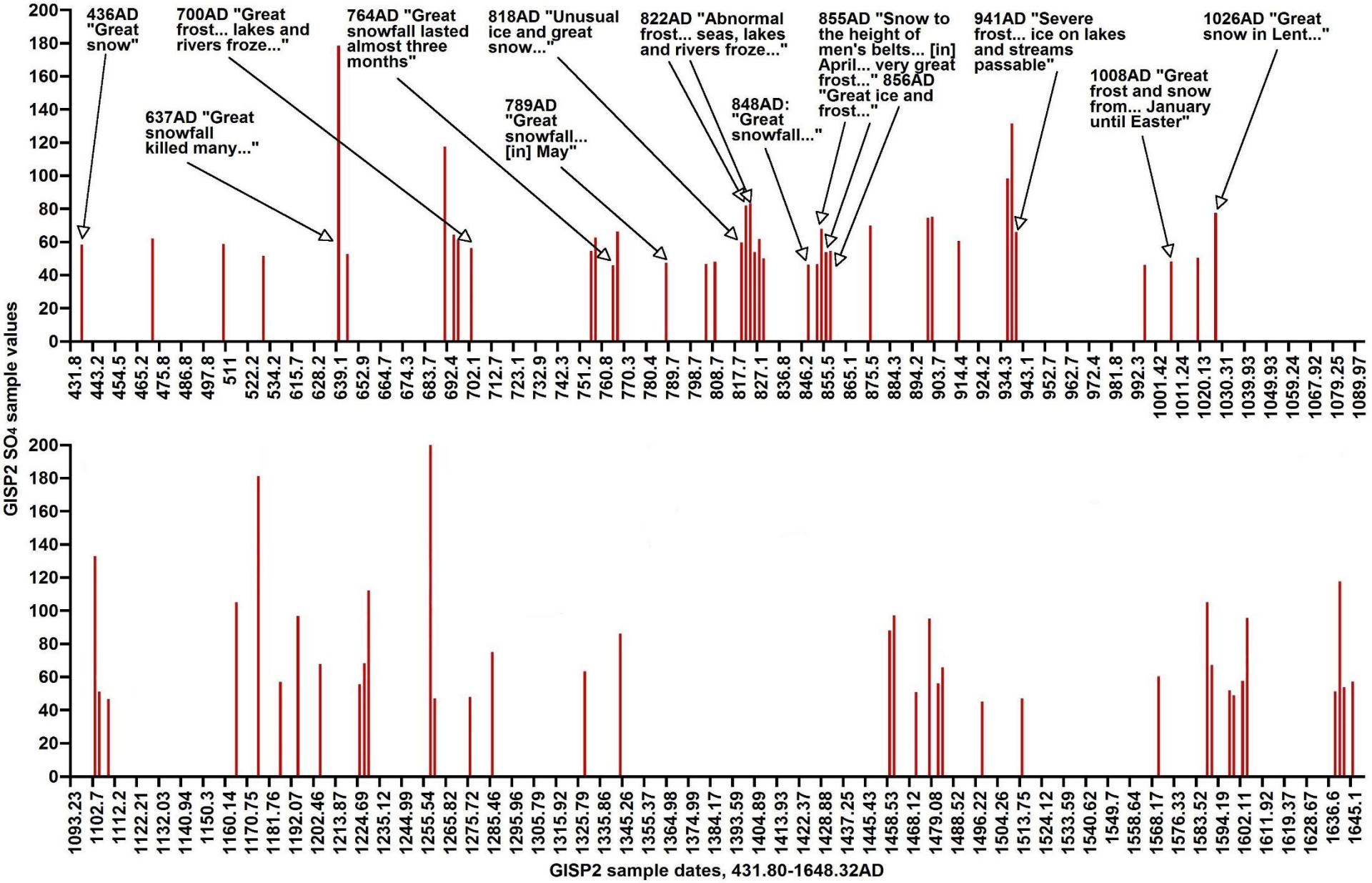

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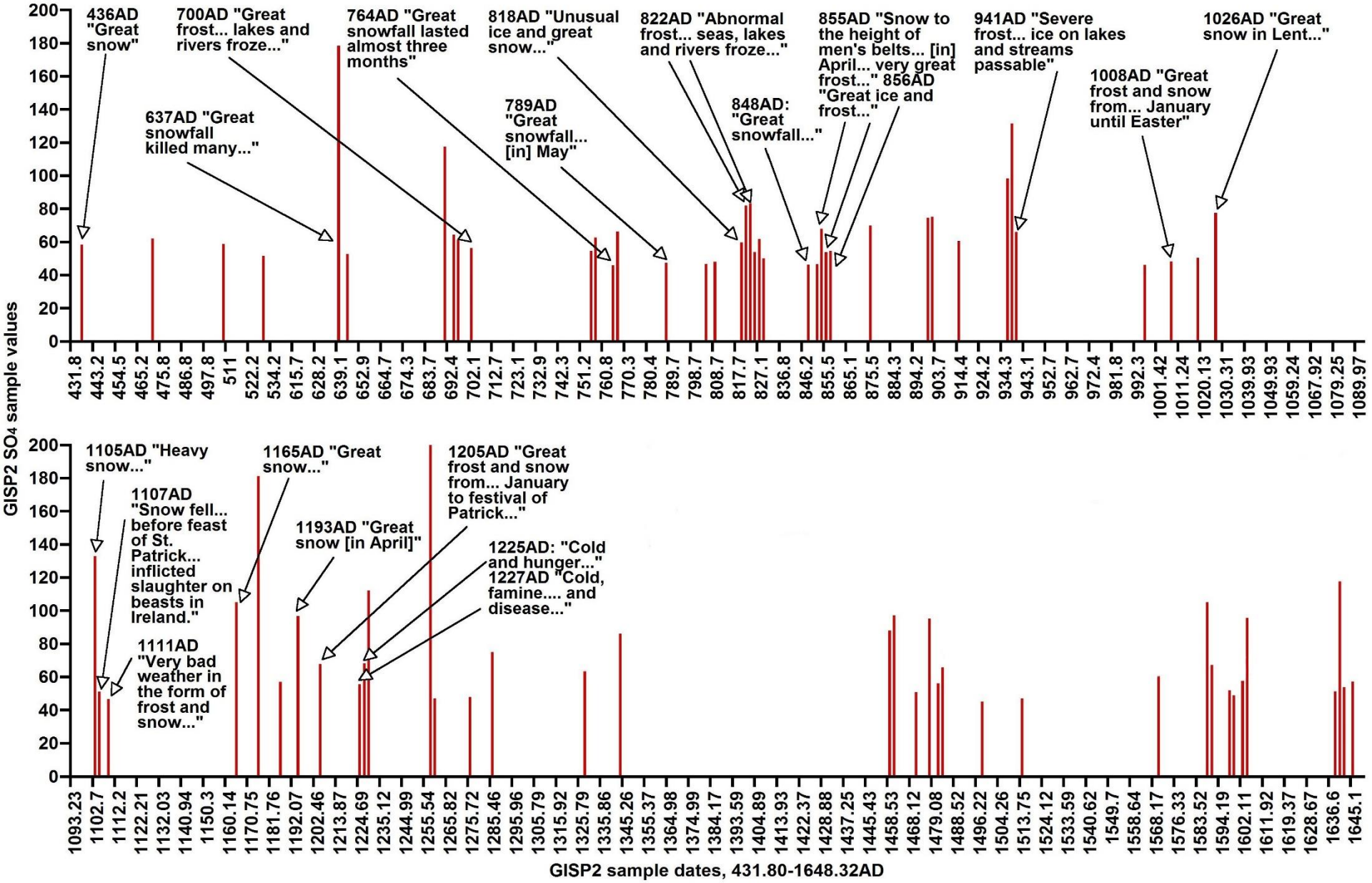

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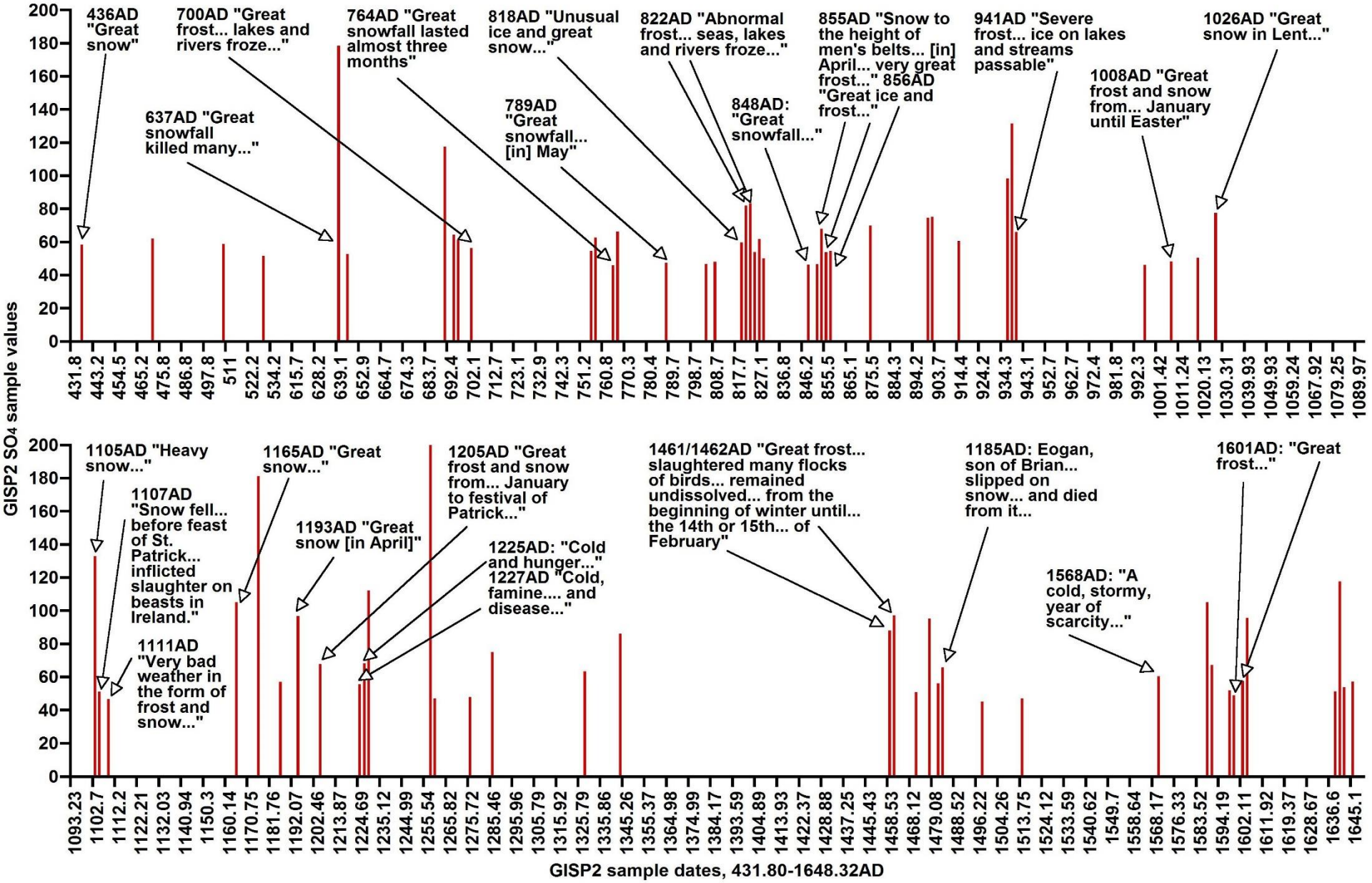


Volcanic events in GISP2 vs. severe cold events in Irish Annals, 431-1649 CE.

What to Take Away from This?

1. Historical records frequently untapped and often dismissed by climate scientists, e.g.:

"*There are. . .weather records preserved in Irish and Norse annals back to the middle of the first millennium. . .but their dating is imprecise and descriptions of weather and climate are often exaggerated.*" U.S. National Research Council (2006), *Surface Temperature Reconstructions for the Last 2,000 Years.*

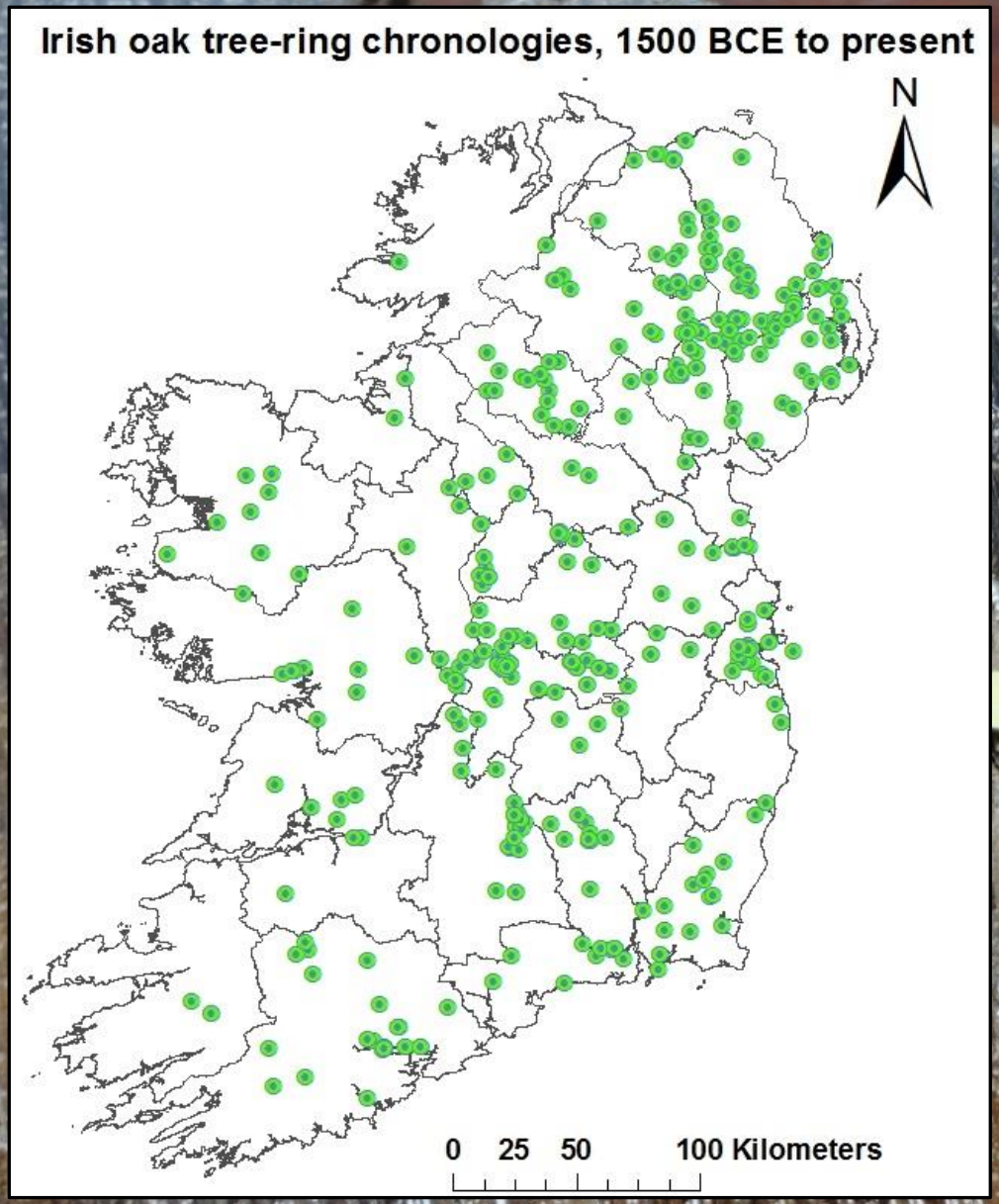
2. Yes, human records require careful assessment by historians… but huge potential when done properly (e.g. other sources such as tree-rings *only* cover the growing season)

3. Recall: This is just ONE type of source from ONE region applied to ONE problem…

Part 2: Climate Science Informing History?

“Failure of bread.”
Annals of Ulster, 538

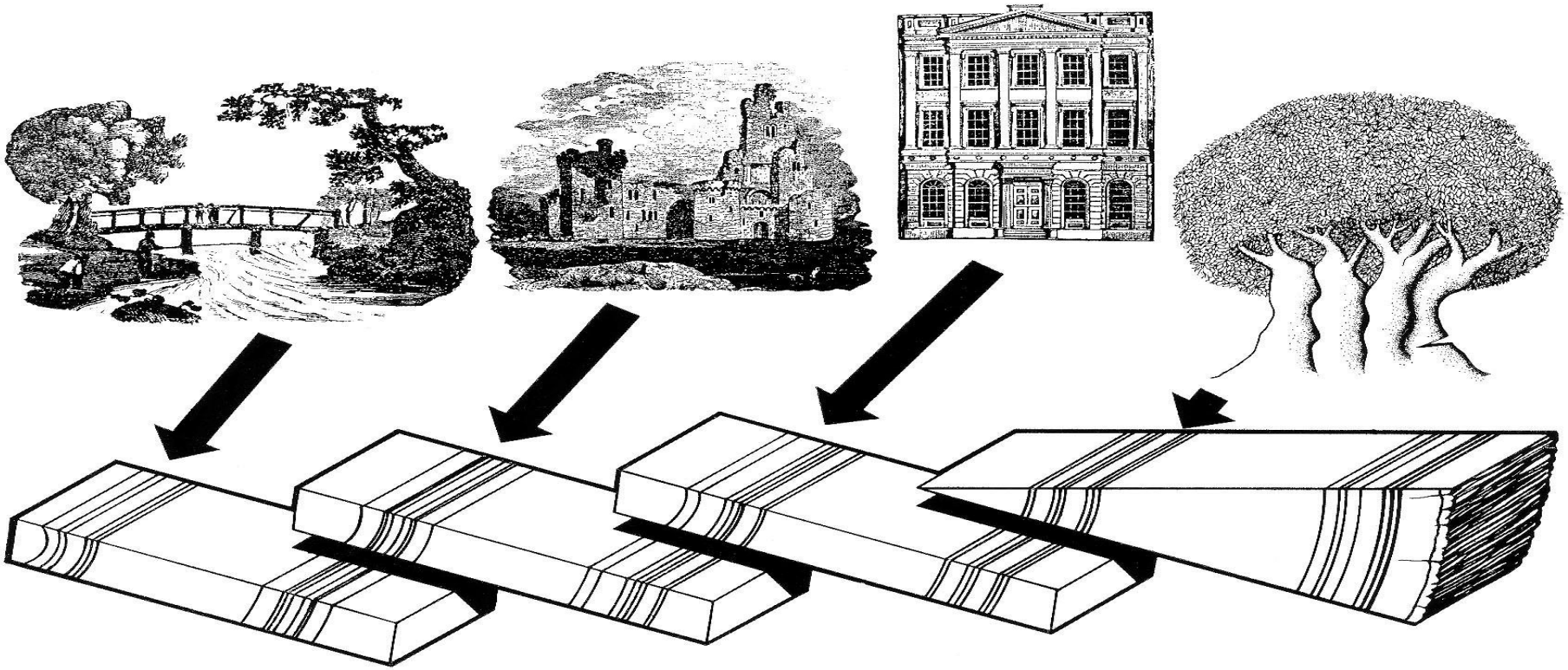
Deer Park, Q9807A
Courtesy of David Brown



Deer Park, Q9807A
Courtesy of David Brown

Part of Belfast Dendrochronological Laboratory archives; accessed courtesy M. Baillie and D. Brown.

Figure courtesy Mike Baillie.

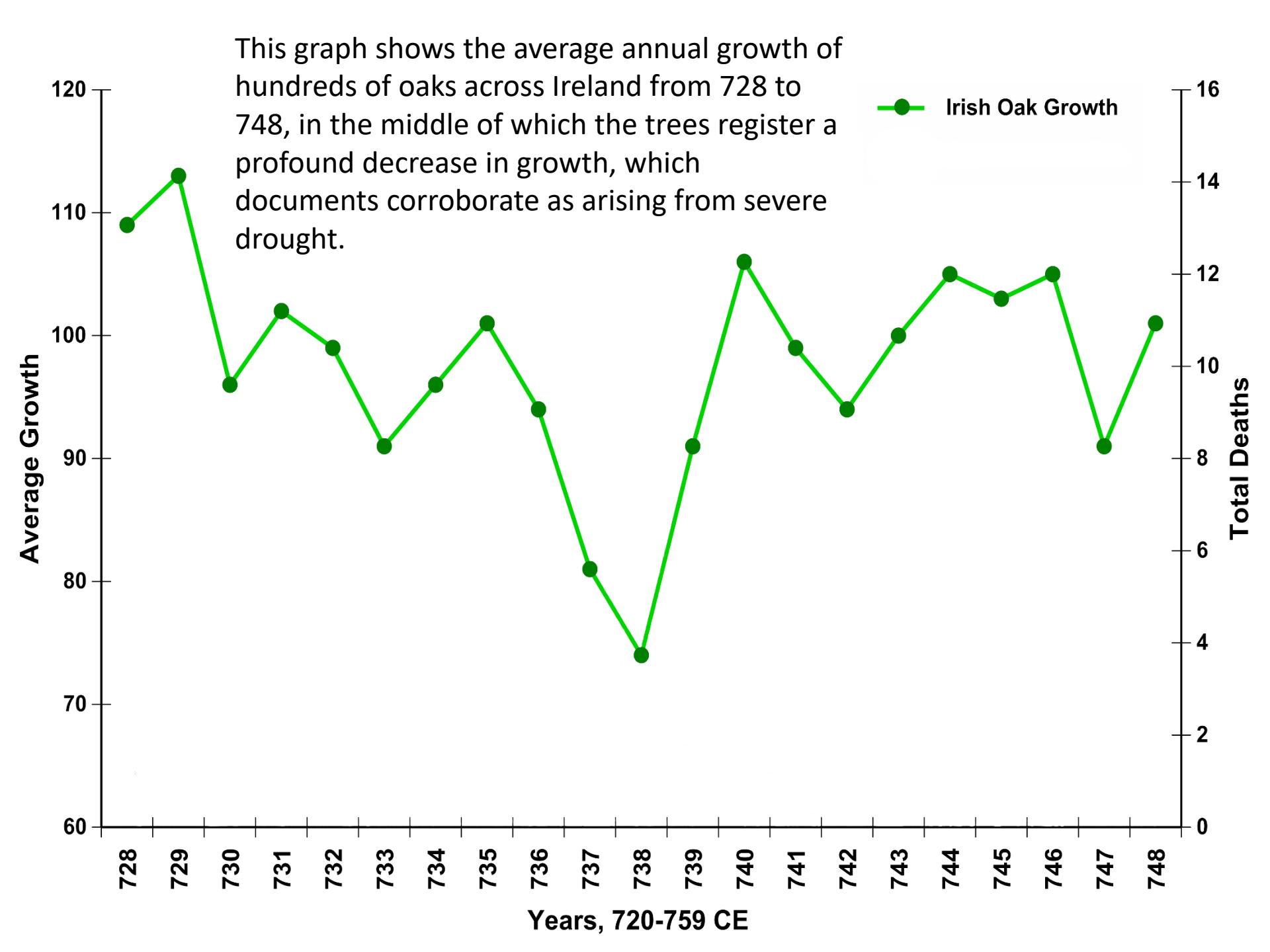


But any given tree can only grow for so long…

…how can we extend our tree-ring records further into the past?

Through “cross dating”, i.e. matching the common ring-width patterns from successively older oak samples.

And these patterns are “common” (not perfectly matching, but often very similar) because each tree generally experiences the same annual weather conditions in a given area.


This graph shows the average annual growth of hundreds of oaks across Ireland from 728 to 748, in the middle of which the trees register a profound decrease in growth, which documents corroborate as arising from severe drought.
Irish Oak Growth
Average Growth
Total Deaths
Years, 720-759 CE
120
110
100
90
80
70
60
16
14
12
10
8
6
4
2
0
728
729
730
731
732
733
734
735
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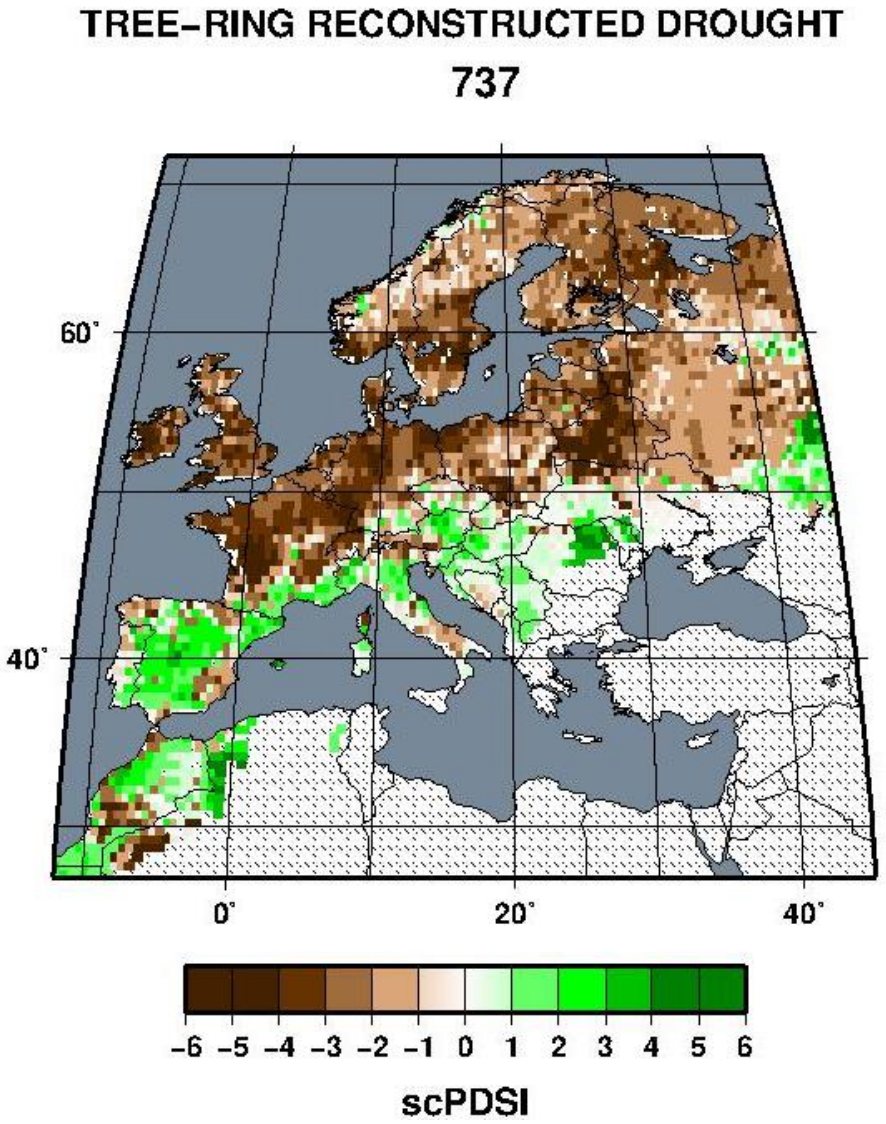
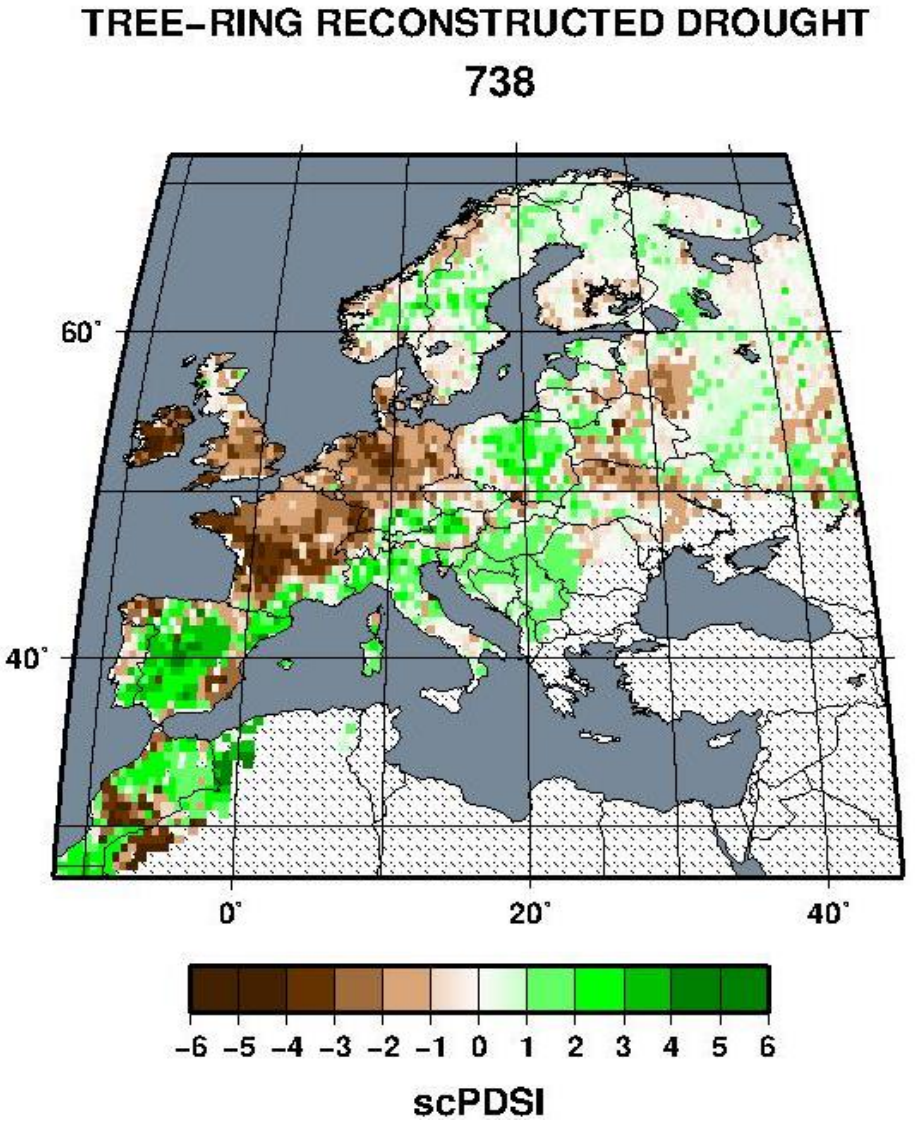
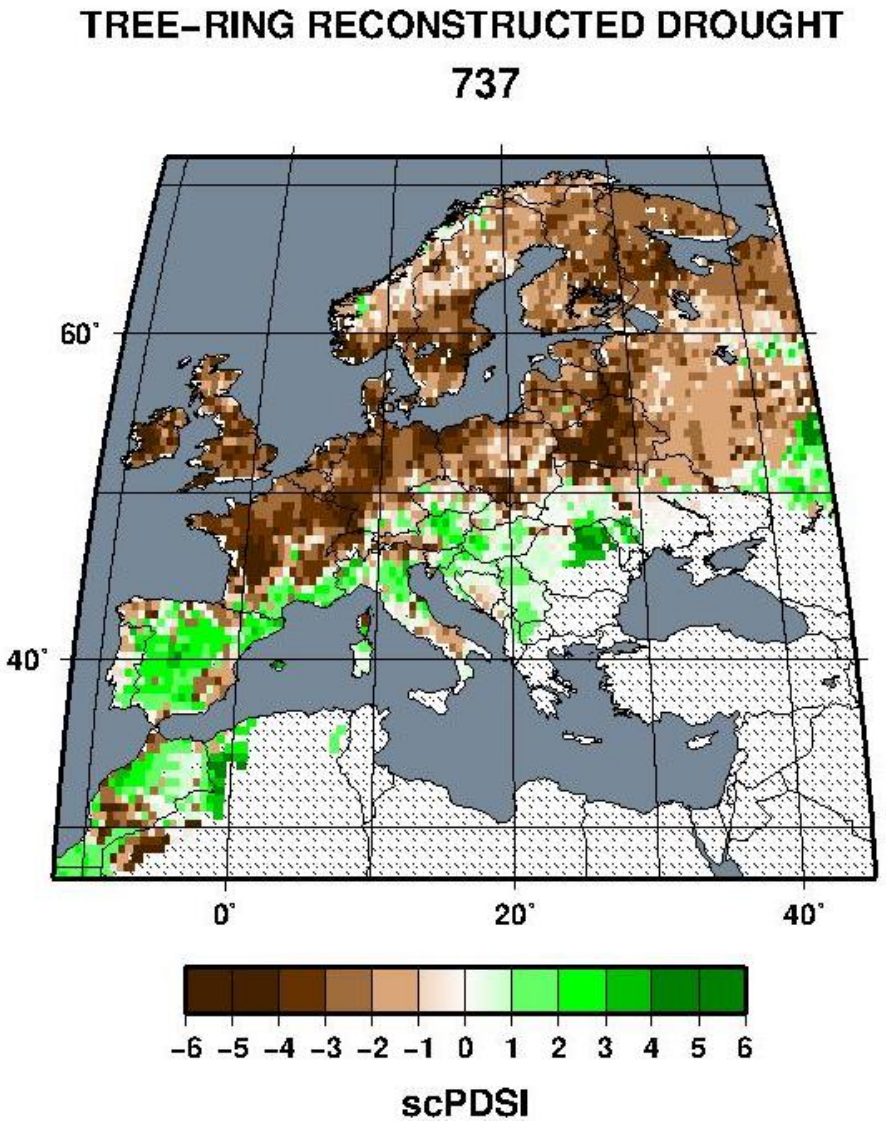
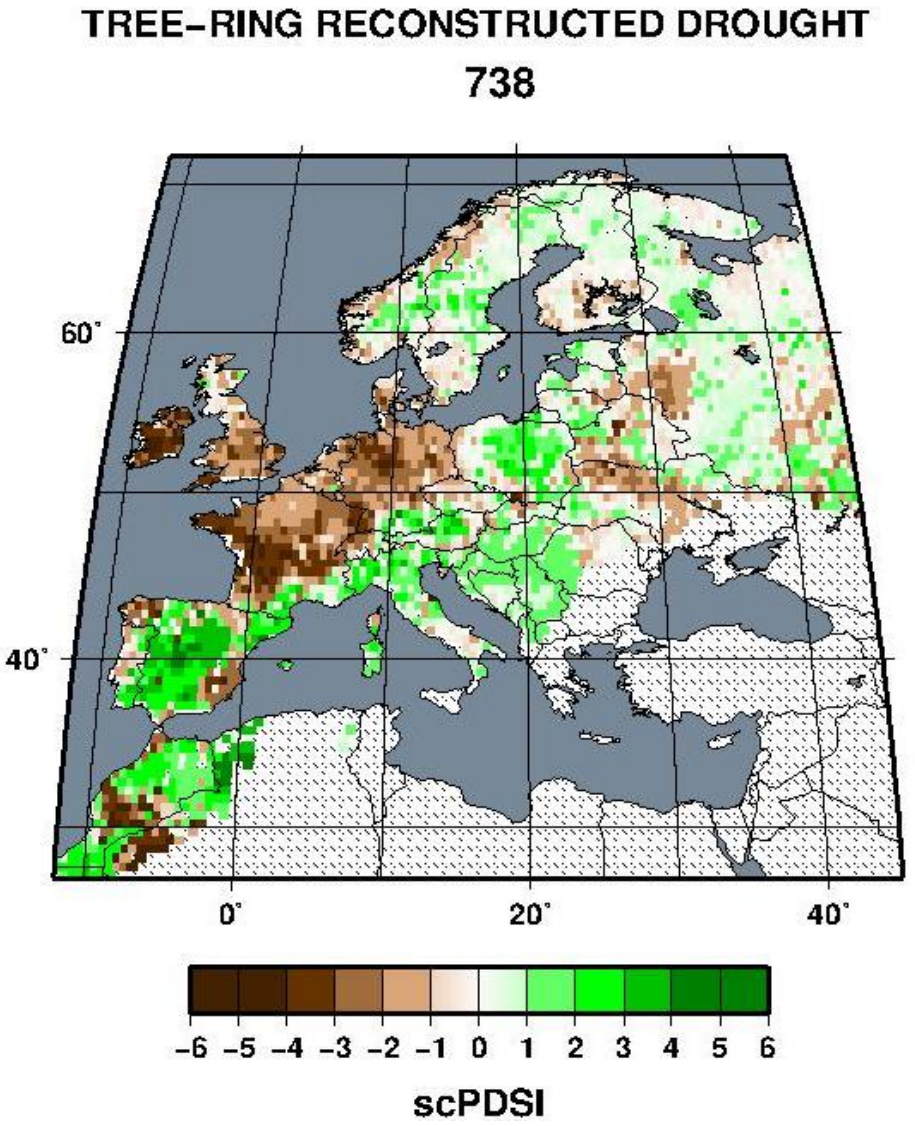
744
745
746
747
748





Cook et al, 2015, Old World Drought Atlas, *Science Advances*.





We now have a highly reliable reconstruction of past drought…

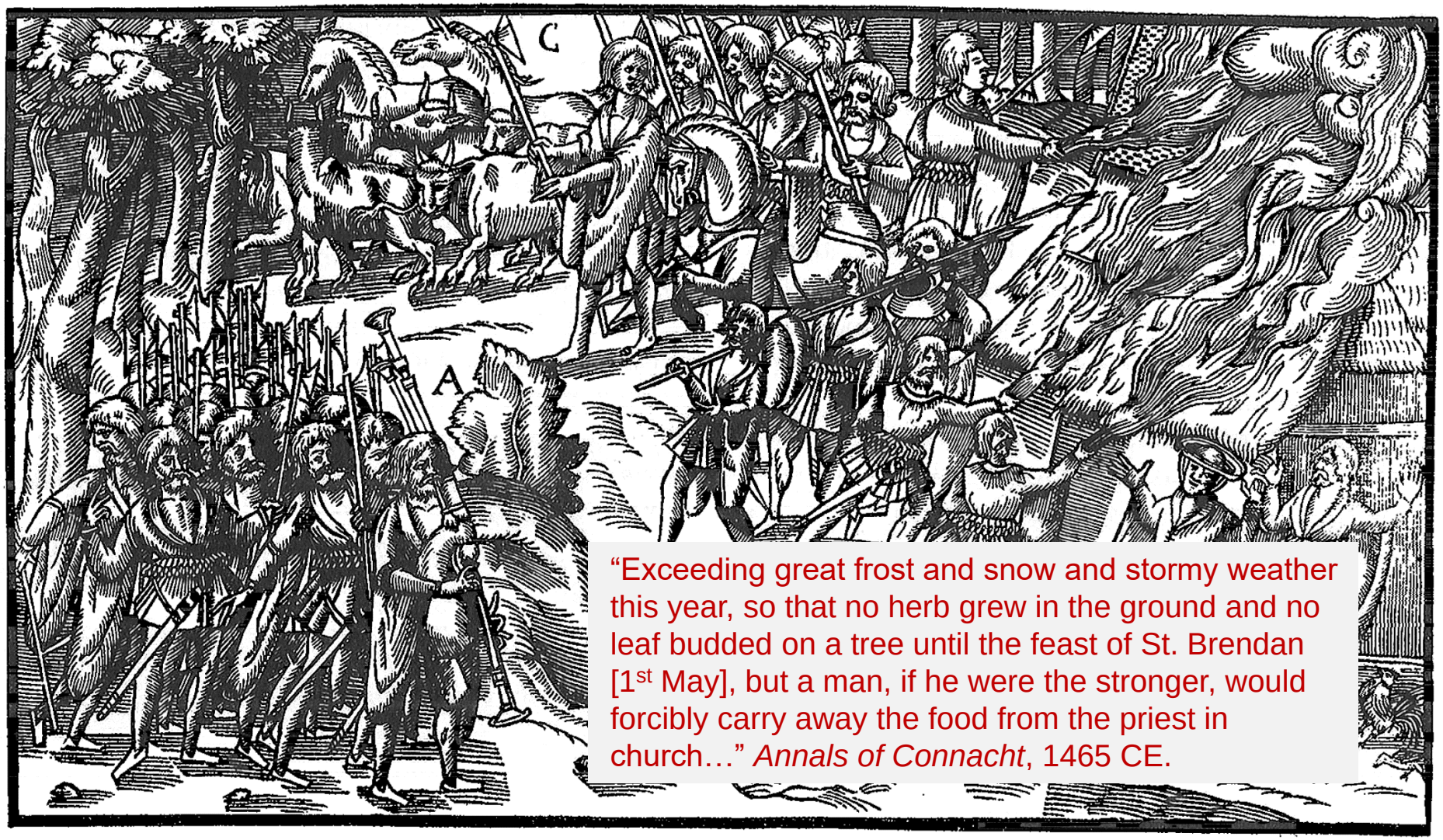
But for Historians, So What?

Cook et al, 2015, Old World Drought Atlas, *Science Advances*.

Extreme Weather, Conflict & Violence

Cattle raid in C16th century Ireland – endemic form of violence, but also associated with resource scarcity?

Extreme Weather, Conflict & Violence



"Exceeding great frost and snow and stormy weather this year, so that no herb grew in the ground and no leaf budded on a tree until the feast of St. Brendan [1st May], but a man, if he were the stronger, would forcibly carry away the food from the priest in church…" *Annals of Connacht*, 1465 CE.

Cattle raid in C16th century Ireland – endemic form of violence, but also associated with resource scarcity?


Irish Oak Growth
Average Growth
Total Deaths
120
110
100
90
80
70
60
16
14
12
10
8
6
4
2
0
728
729
730
731
732
733
734
735
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744
745
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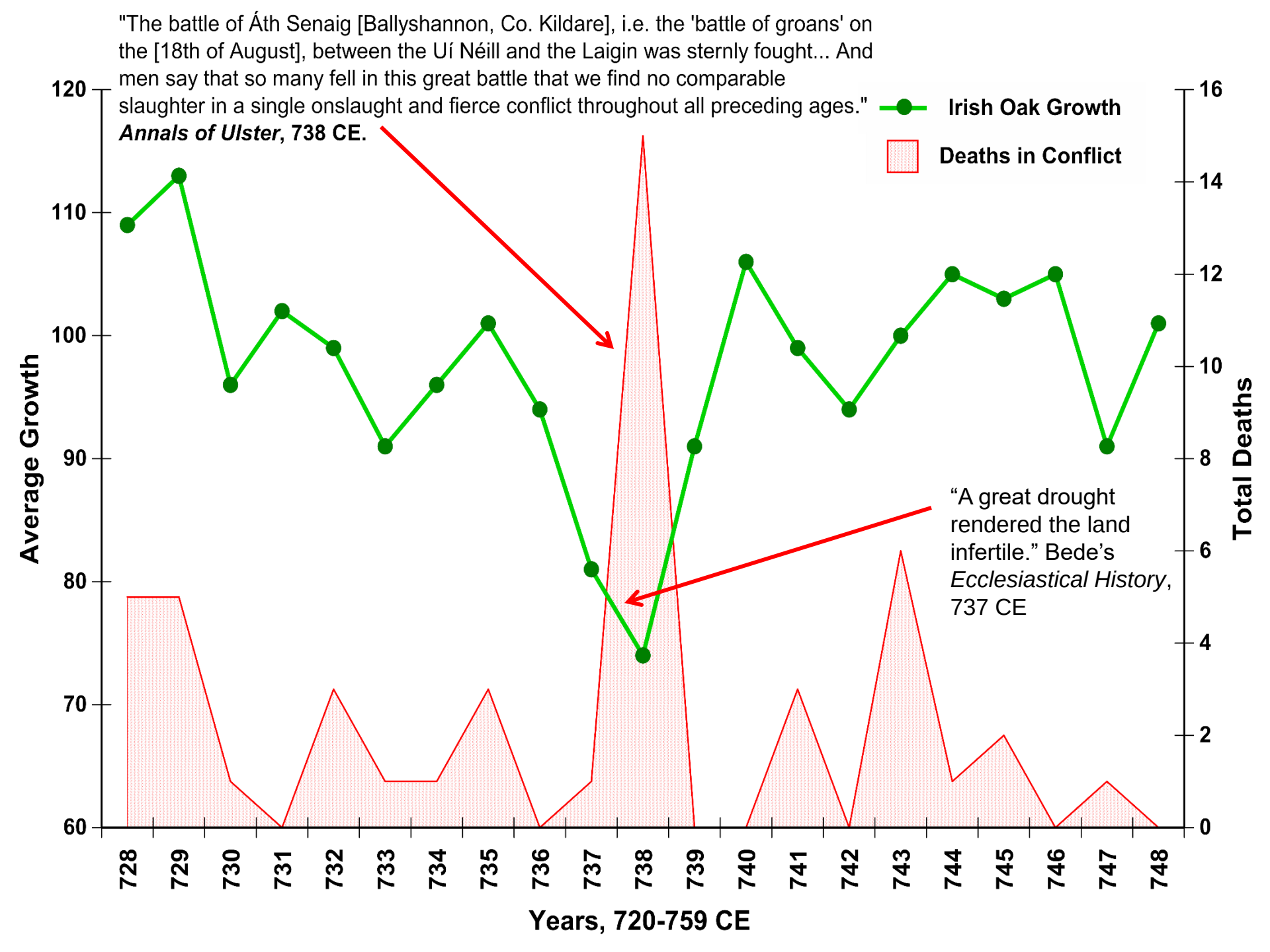
748
Years, 720-759 CE


"The battle of Áth Senaig [Ballyshannon, Co. Kildare], i.e. the 'battle of groans' on the [18th of August], between the Uí Néill and the Laigin was sternly fought... And men say that so many fell in this great battle that we find no comparable slaughter in a single onslaught and fierce conflict throughout all preceding ages."
Annals of Ulster, 738 CE.
Irish Oak Growth
Deaths in Conflict
"A great drought rendered the land infertile." Bede's *Ecclesiastical History*, 737 CE
Average Growth
Total Deaths
Years, 720-759 CE
120
110
100
90
80
70
60
16
14
12
10
8
6
4
2
0
728
729
730
731
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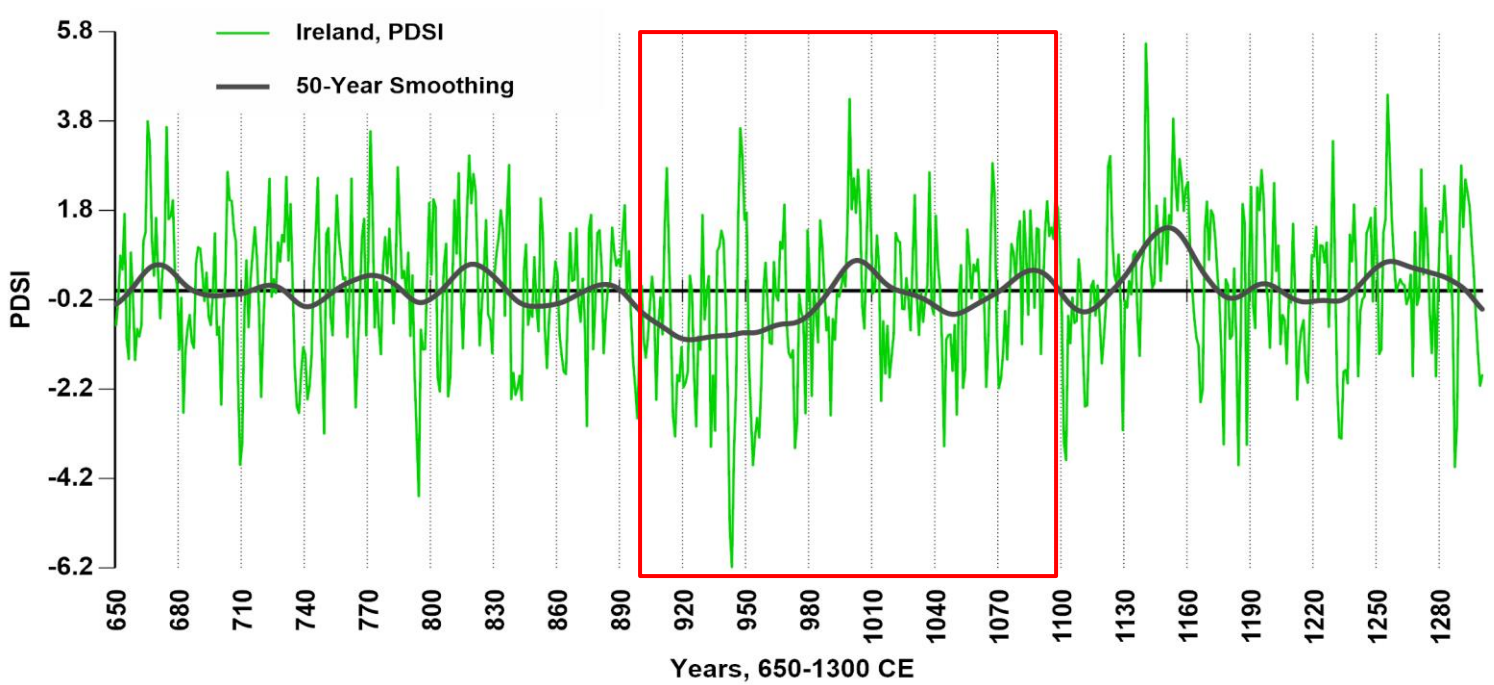
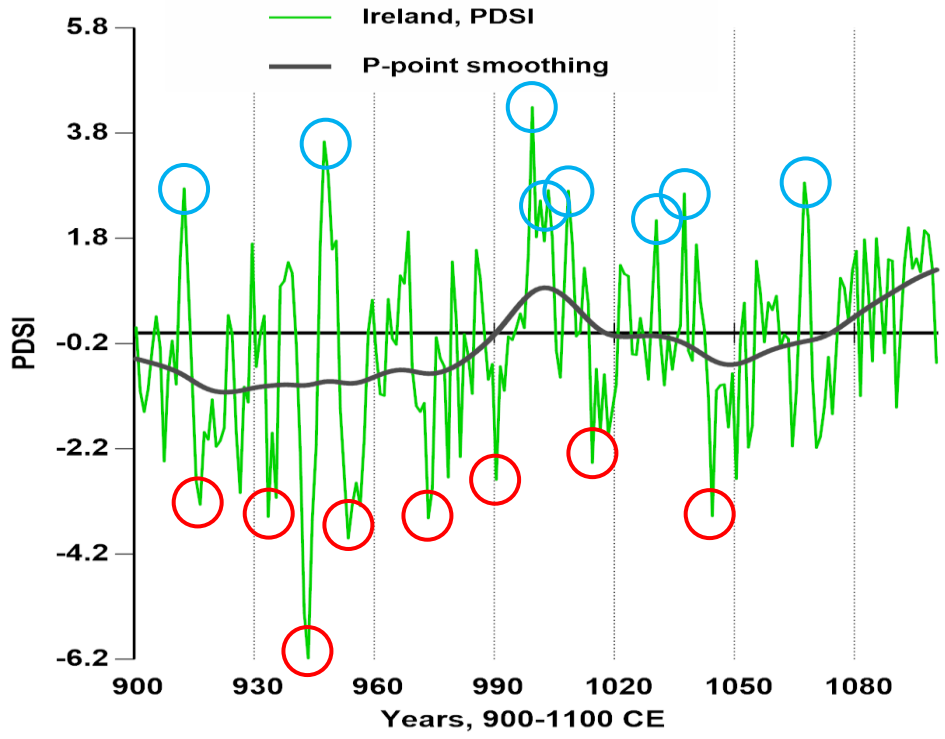


Cook et al, 2015, Old World Drought Atlas, *Science Advances*.



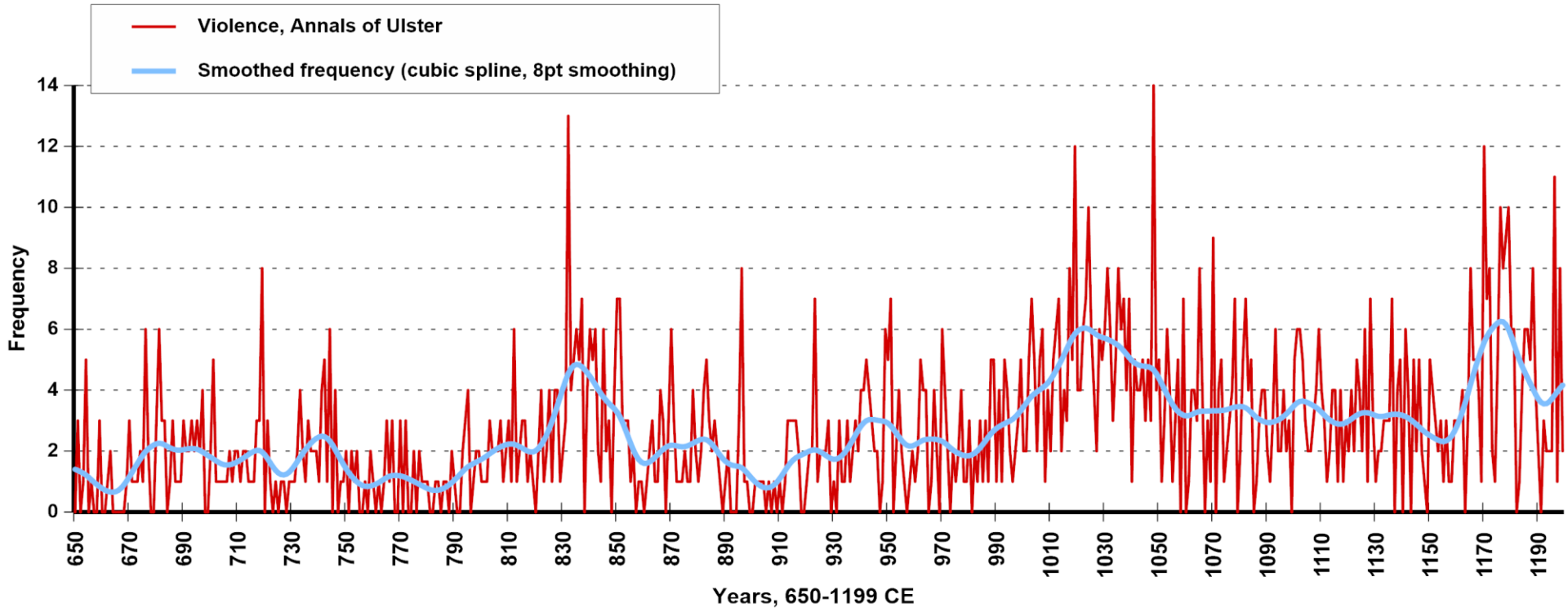
Changes in averages also accompanied by changes in the frequency and severity of extreme weather.

"Much wet and bad weather in this year, and it ruined the corn." Annals of Ulster, 1107.

"A windy, wet summer, with famine and wars." MacCarthaigh's Books, 1203.

Quantifying Violence & Conflict

* *Annals of Ulster*, 650-1200 CE
* Frequency of violent killings of individuals [elites], mass killings, raiding, burnings
* Approach: Duplicates removed, chronological corrections of Daniel McCarthy (TCD) applied and assessed (e.g., by examining solar/lunar eclipse dates)
* Cons: Reductive, lose context // Pros: Bird's eye view, systematically examine whether repeating patterns or influences exist

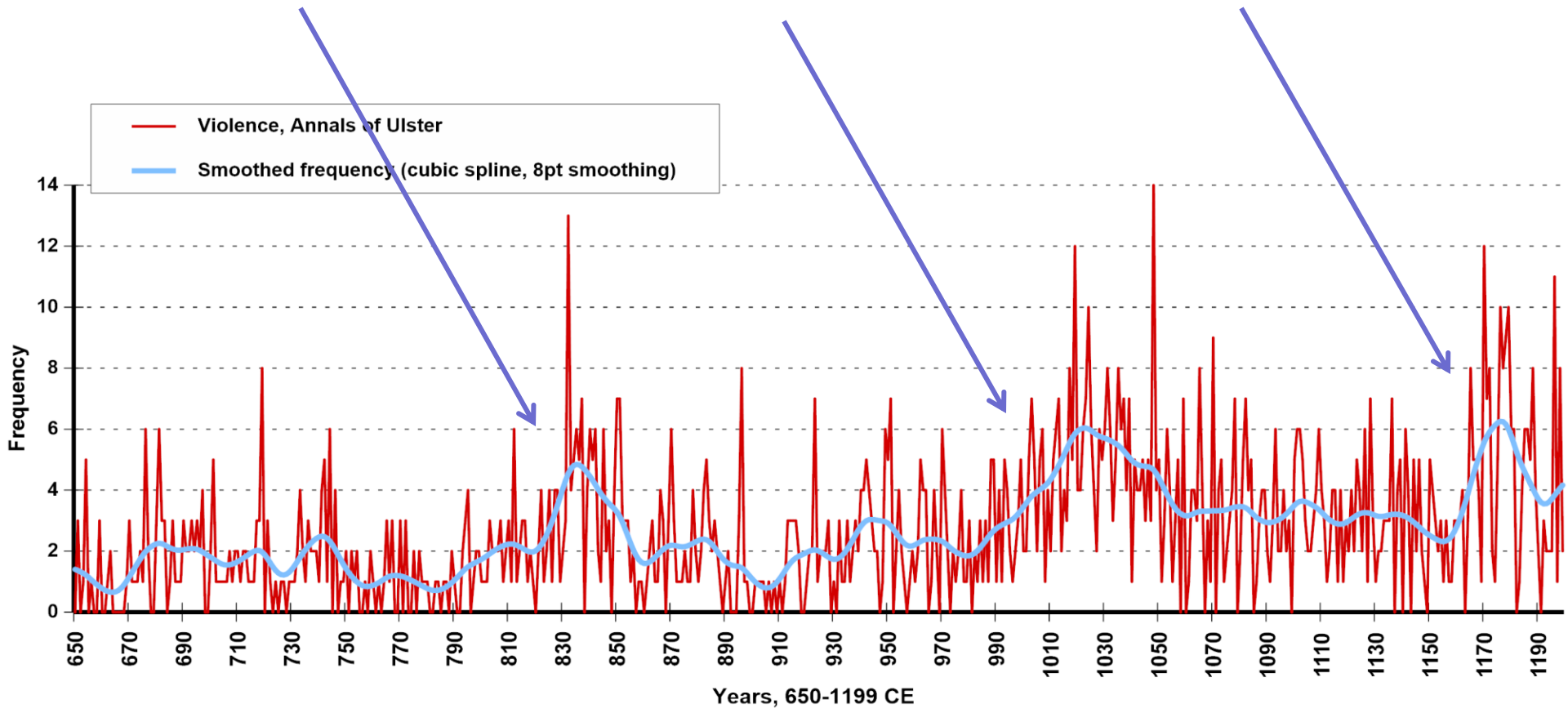


Quantifying Violence & Conflict

Viking contribution

Brian Boru & Aftermath

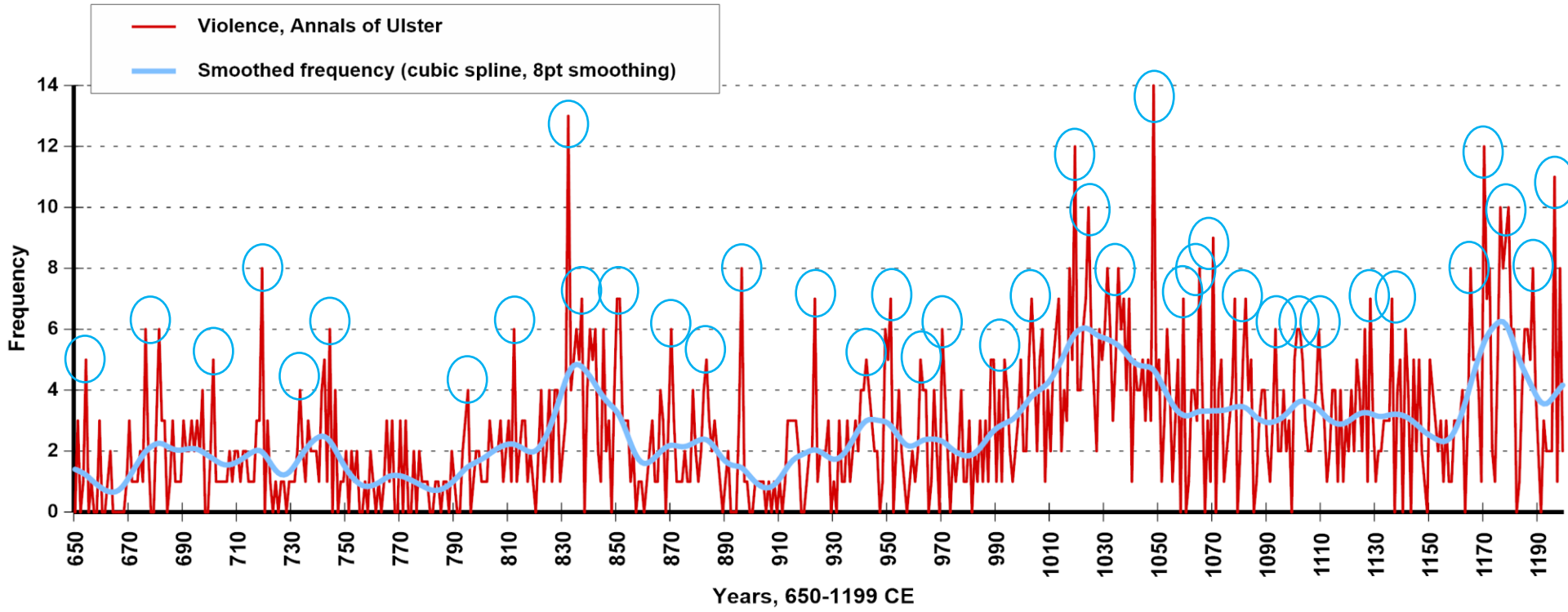
Anglo-Norman contribution

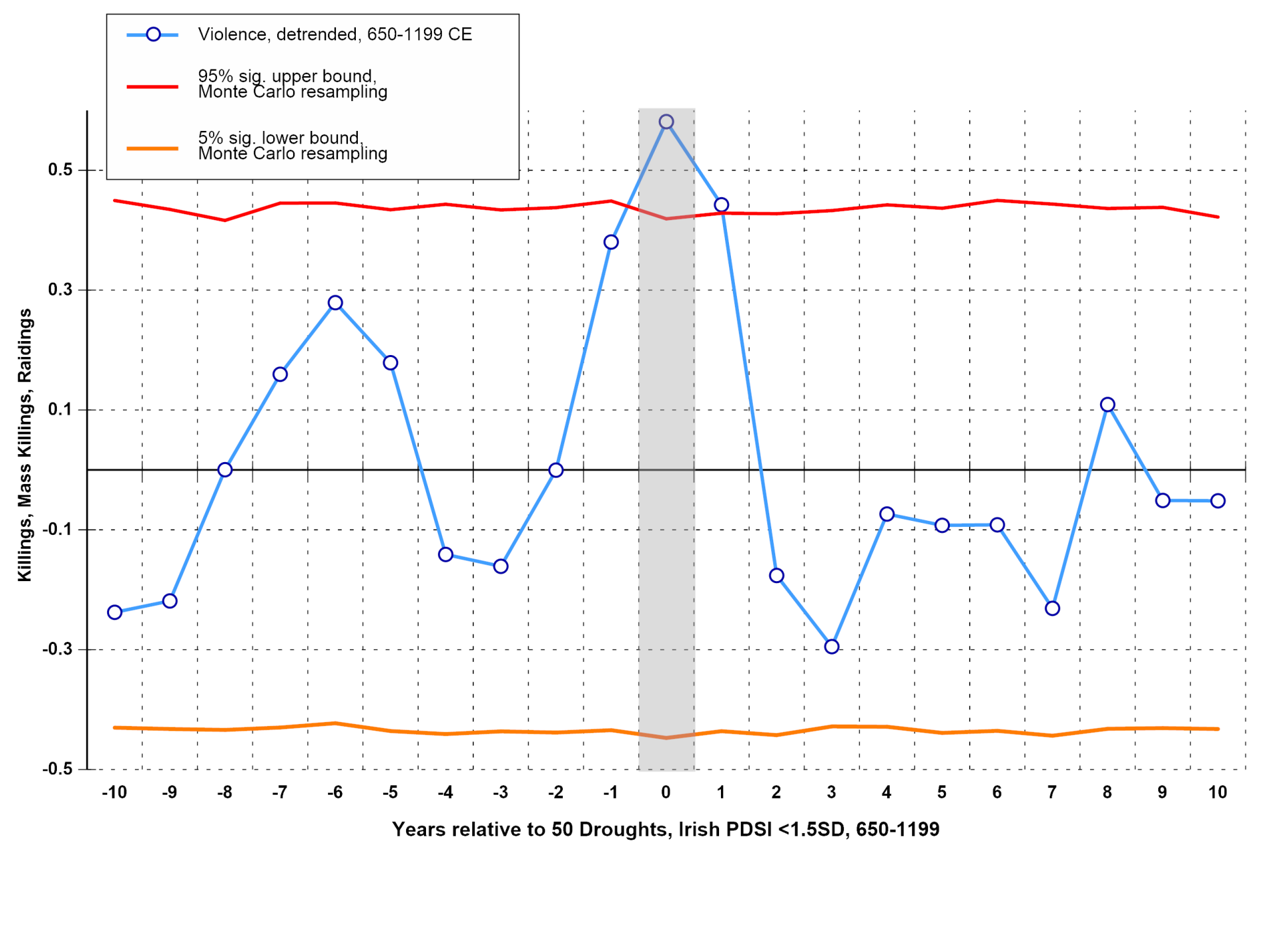


Quantifying Violence & Conflict

But: Also multiple years of notably elevated violence (above the average in any given period).

Interested here in any *climatic contribution* to these years.




Violence, detrended, 650-1199 CE
95% sig. upper bound, Monte Carlo resampling
5% sig. lower bound, Monte Carlo resampling
Killings, Mass Killings, Raidings
0.5
0.3
0.1
-0.1
-0.3
-0.5
-10
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-8
-7
-6
-5
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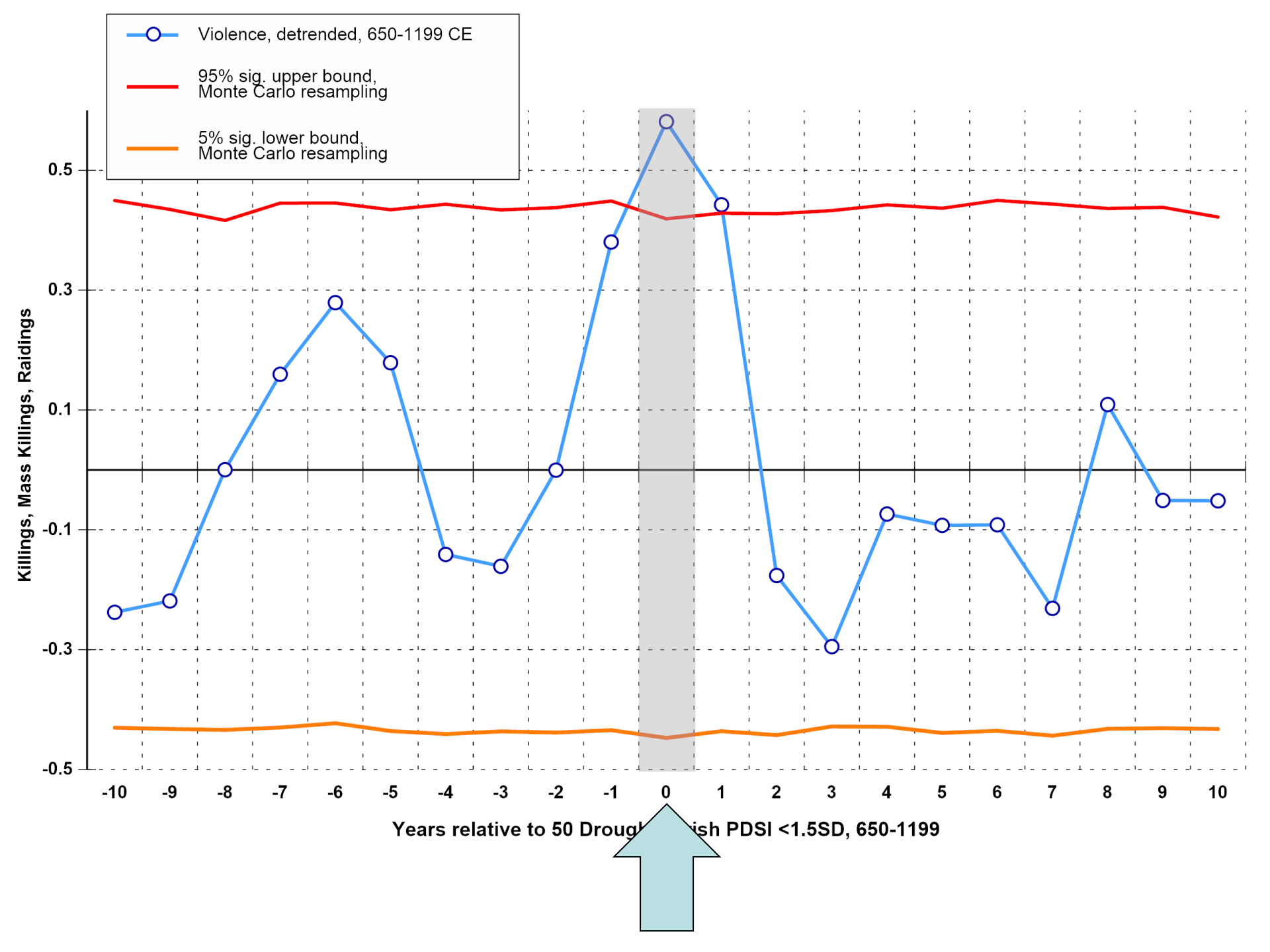
Years relative to 50 Droughts, Irish PDSI <1.5SD, 650-1199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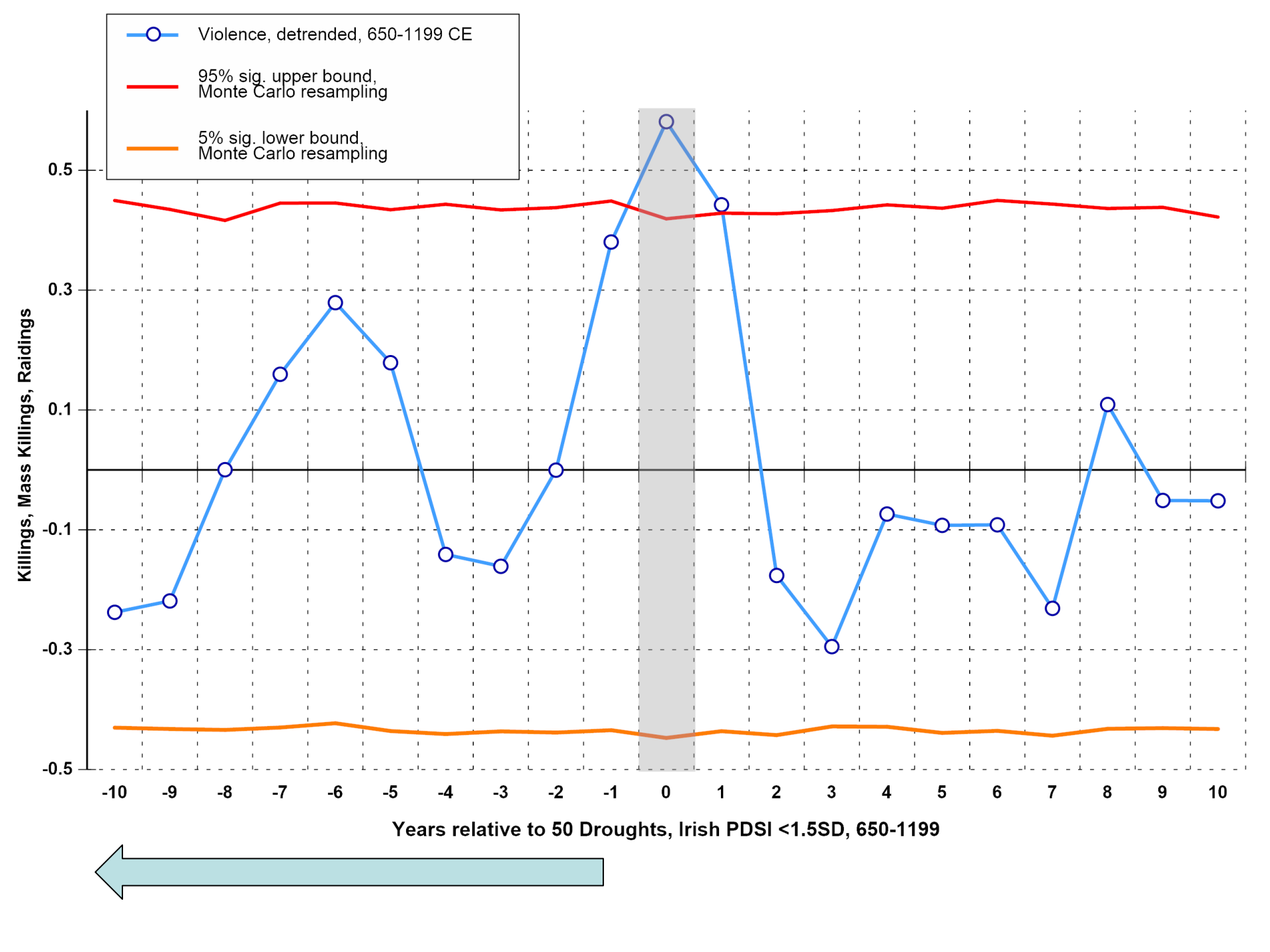
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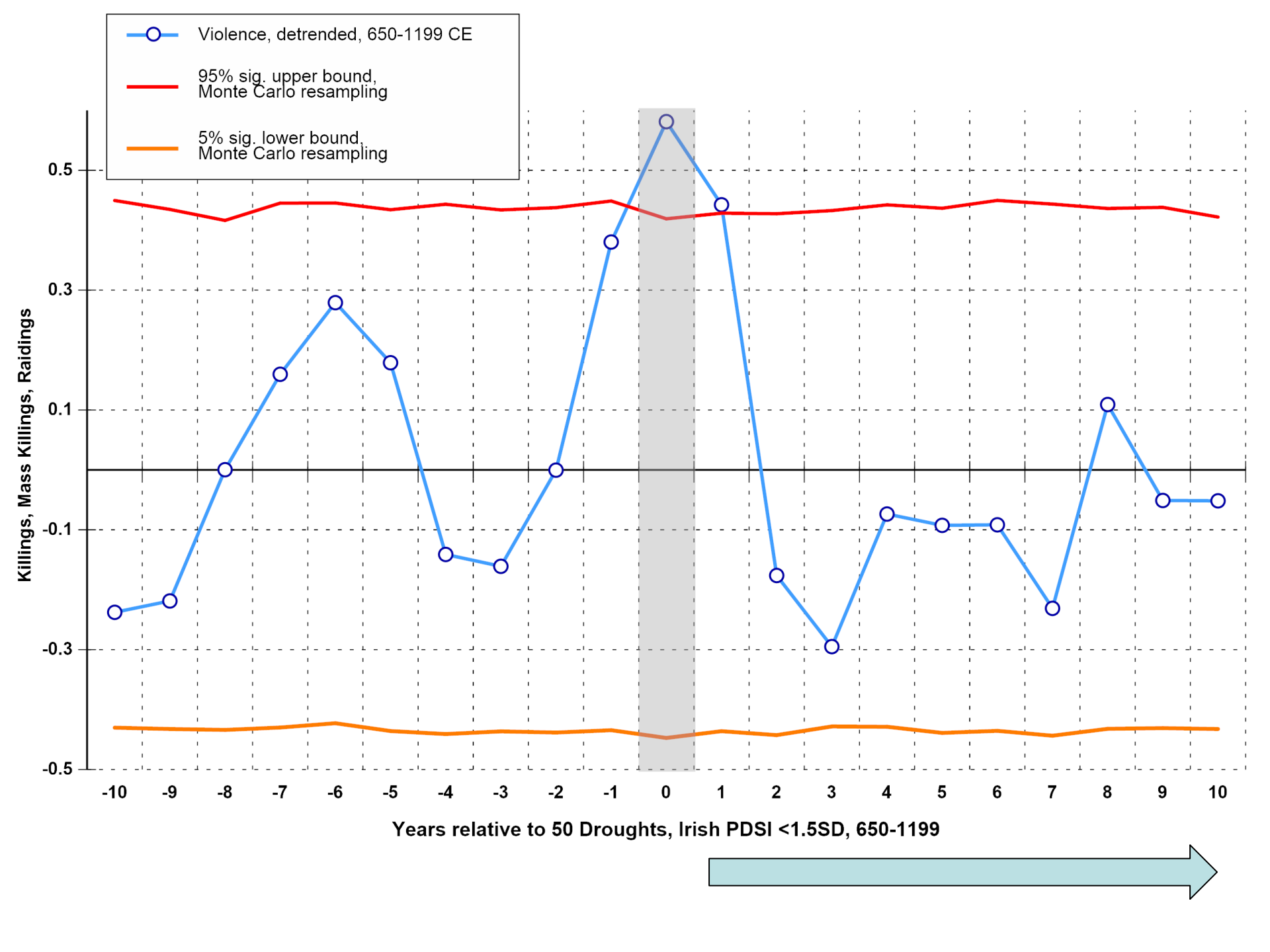
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Years relative to 50 Droughts, Irish PDSI <1.5SD, 650-1199

Droughts are implicated in conflicts… and they are projected to become more frequent and extreme under future global warming

Middle Eastern Studies, 2014
Vol. 50, No. 4, 521–535, http://dx.doi.org/10.1080/00263206.2013.850076

Routledge
Taylor & Francis Group

The Role of Drought and Climate Change in the Syrian Uprising: Untangling the Triggers of the Revolution

FRANCESCA DE CHÂTEL*

More than two yea
what started as a p
Syria has degenera
estimated that mor
officially registered
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Is Syria really a 'climate war'? We examined the links between drought, migration and conflict

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PNAS

Climate change in the Fertile Crescent and implications of the recent Syrian drought

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Before the Syrian uprising that began in 2011, the greater Fertile Crescent experienced the most severe drought in the instrumental
ountry marked by poor governance and un-
al and environmental policies, the drought
, contributing to political unrest. We show
se in Syrian precipitation is a combination of
d a long-term drying trend, and the unusual
ed drought is here shown to be highly unlikely
cipitation changes in Syria are linked to rising
re in the Eastern Mediterranean, which also
nd. There has been also a long-term warming
editerranean, adding to the drawdown of soil
cause is apparent for these trends, whereas
nd warming are consistent with model studies
creases in greenhouse gases. Furthermore,
n increasingly drier and hotter future mean
Mediterranean. Analyses of observations and
ndicate that a drought of the severity and
t Syrian drought, which is implicated in the
become more than twice as likely as
man interference in the climate system.

change | unrest | conflict

winter of 2006/2007, Syria and the greater
(FC), where agriculture and animal herding
years ago (1), experienced the worst 3-year
mental record (2). The drought exacerbated
agricultural insecurity and caused massive
and livestock mortality. The most significant
e migration of as many as 1.5 million
farming areas to the peripheries of urban
cterizing risk as the product of vulnerability
we first analyze Syria's vulnerability to
al impacts of the recent drought leading to
an civil war. We then use observations and
sess how unusual the drought was within the
the reasons it was so severe. We also show
simulate a long-term drying trend for the
ence of human-induced climate change. If
eased the severity and frequency of occur-
ltiyear droughts such as the recent one. We
e that the circulation anomalies associated
ght are consistent with model projections of
ate change and aridification in the region
nt with patterns of natural variability.

bility and the Effects of the Drought

ural policy is prominent among the many
ria's vulnerability to drought. Despite growing
quent droughts, the government of President
–2000) initiated policies to further increase
n, including land redistribution and irrigation
projects, quota systems, and subsidies for diesel fuel to garner the support of rural constituents (5–9). These policies endangered Syria's water security by exploiting limited land and water resources without regard for sustainability (10).

One critical consequence of these unsustainable policies is the decline of groundwater. Nearly all rainfall in the FC occurs during the 6-month winter season, November through April, and this rainfall exhibits large year-to-year variability (Figs. 1*A* and 2*A*). In Syria, the rain falls along the country's Mediterranean Sea coast and in the north and northeast, the primary agricultural region. Farmers depend strongly on year-to-year rainfall, as two thirds of the cultivated land in Syria is rain fed, but the remainder relies upon irrigation and groundwater (11). For those farms without access to irrigation canals linked to river tributaries, pumped groundwater supplies over half (60%) of all water used for irrigation purposes, and this groundwater has become increasingly limited as extraction has been greatly overexploited (4). The government attempted to stem the rate of groundwater depletion by enacting a law in 2005 requiring a license to dig wells, but the legislation was not enforced (6). Overuse of groundwater has been blamed for the recent drying of the Khabur River in Syria's northeast (6). The depletion of groundwater during the recent drought is clearly evident from remotely sensed data by the NASA Gravity Recovery and Climate Experiment (GRACE) Tellus project (Fig. 2*C*) (12).

The reduced supply of groundwater dramatically increased Syria's vulnerability to drought. When a severe drought began in 2006/2007, the agricultural system in the northeastern "breadbasket" region, which typically produced over two-thirds of the country's crop yields, collapsed (13). In 2003, before the drought's onset, agriculture accounted for 25% of Syrian gross domestic product. In 2008, after the driest winter in Syria's observed record, wheat production failed and the agricultural share fell to 17% (14). Small- and medium-scale farmers and herders

Significance

There is evidence that the 2007–2010 drought contributed to the conflict in Syria. It was the worst drought in the instrumental record, causing widespread crop failure and a mass migration of farming families to urban centers. Century-long observed trends in precipitation, temperature, and sea-level pressure, supported by climate model results, strongly suggest that anthropogenic forcing has increased the probability of severe and persistent droughts in this region, and made the occurrence of a 3-year drought as severe as that of 2007–2010 2 to 3 times more likely than by natural variability alone. We conclude that human influences on the climate system are implicated in the current Syrian conflict.

Author contributions: C.P.K., S.M., M.A.C., R.S., and Y.K. designed research; C.P.K. performed research; C.P.K., S.M., M.A.C., R.S., and Y.K. analyzed data; and C.P.K., S.M., M.A.C., R.S., and Y.K. wrote the paper.

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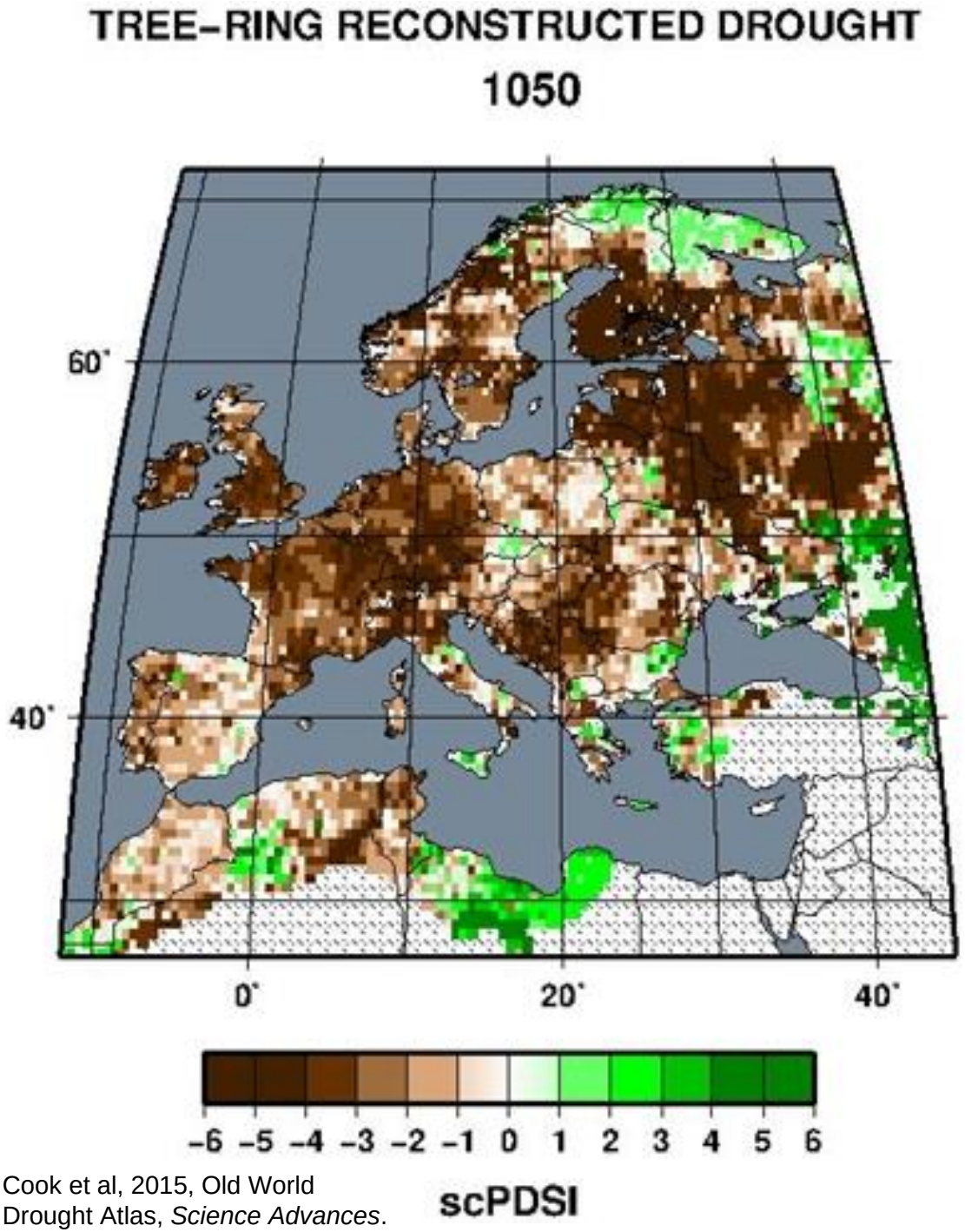

Cook et al, 2015, Old World Drought Atlas, *Science Advances*.

"Much inclement weather happened in the land of Ireland, which carried away corn, milk, fruit, and fish, from the people, so that there grew up dishonesty among all, that no protection was extended to church or fortress, gossipred or mutual oath, until the clergy and laity of Munster assembled, with their chieftains, under Donnchadh, son of Brian, i.e. the son of the King of Ireland, at Cill-Dalua [Killaloe], where they enacted a law and a restraint upon every injustice, from small to great. God gave peace and favourable weather in consequence of this law.." *Annals of the Four Masters*, 1050

Vulnerability to drought and hints at how food scarcity may promote conflict… But… coping strategies: Societies are not passive victims acting mechanistically under influence from weather…

Great benefits and potential of such work

Pursuing it helps overcome:

**** Overcoming disciplinary conservatism***

**** Overcoming disciplinary mistrust***

**** Overcoming different disciplinary "languages"***

**** Developing (and accepting legitimacy of) hybrid methodologies and hybrid research goals***

The Elusive Pursuit of Interdisciplinarity at the Human–Environment Interface

ERIC D. ROY, ANITA T. MORZILLO, FRANCISCO SEIJO, SHEILA M. W. REDDY, JEANINE M. RHEMTULLA, JEFFREY C. MILDER, TOBIAS KUEMMERLE, AND SHERRY L. MARTIN

Environmental challenges are complex and require expertise from multiple disciplines. Consequently, there is growing interest in interdisciplinary environmental research that integrates natural and social science, an often arduous undertaking. We surveyed researchers interested and experienced in research at the human–environment interface to assess perspectives on interdisciplinary research. Integrative interdisciplinary research has eluded many of our respondents, whose efforts are better described as additive multidisciplinary research. The respondents identified many advantages and rewards of interdisciplinary research, including the creation of more relevant knowledge. However, they also reported significant challenges and obstacles, including tension with departments (49%) or institutions (61%), communication difficulties, and differing disciplinary approaches, as well as institutional barriers (e.g., a lack of credit in promotion and tenure). Most (52%) believed that developing interdisciplinary breadth should begin as early as the undergraduate level. We apply our results to recommendations for successful interdisciplinary endeavors.

Keywords: interdisciplinary research, survey, coupled human and natural systems, social–ecological systems, sustainability

Environmental issues are characterized by dynamic interactions between humans and ecosystems. Humans now dominate the majority of Earth's ecosystems through land transformation, climate change, alterations in global biogeochemistry, and biodiversity loss (Vitousek et al. 1997, Ellis and Ramankutty 2008). Historically, researchers have addressed questions about environmental change and human well-being from within traditional academic disciplines (Redman 1999). The division in universities between the natural and social sciences has proven especially enduring (Heberlein 1988, Kinzig 2001). However, new approaches in which complex, interrelated human and natural systems are evaluated in an interdisciplinary manner are increasingly being acknowledged as an important part of addressing environmental issues (Liu et al. 2007a, 2007b, Ostrom 2008).

Interdisciplinarity has been defined in several ways and is often used to label research initiatives that may not actually deserve such a distinction (Klein 1990). We define *interdisciplinary environmental research* as research that involves scholars from different disciplines collaborating to develop terminology, research approaches, methodologies, or theories that are integrated across multiple disciplines in order to address environmental problems. This definition emphasizes a problem-driven approach, teamwork, and the integration of disciplines (Klein 1990). *Multidisciplinarity* is distinct from *interdisciplinarity* in that it is additive rather than integrative; that is, although a multidisciplinary research project includes perspectives or methods from several disciplines, the project's researchers still act within and preserve the exemplary concerns of their own discipline (Klein 1990).

The call for interdisciplinary environmental research has come from myriad scientific disciplines, including ecology, economics, urban planning, political science, geography, sociology, anthropology, and engineering (e.g., Liu et al. 2007a, 2007b). Major funding initiatives have been introduced in the United States to specifically promote interdisciplinary environmental research, including the National Science Foundation's (NSF) Dynamics of Coupled Natural and Human Systems program and the Integrative Graduate Education and Research Traineeship (IGERT). In addition, large international interdisciplinary research networks have been initiated (e.g., the Earth System Science Partnership, the International Geosphere–Biosphere Programme, the International Human Dimensions Programme on Global Environmental Change, Future Earth). Despite an increasing number of interdisciplinary graduate programs, research centers, departments, funding opportunities, and research networks, true integration of natural and social sciences

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