

Identifying Signature Features of Epidemic Diseases in 19th Century All-cause Mortality Data

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Joint work with
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Roskilde University



Danmarks
Grundforskningsfond
Danish National
Research Foundation

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- ▶ Lack of data is a challenge for surveillance of emerging diseases.

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- ▶ Lack of data is a challenge for surveillance of emerging diseases.
- ▶ The epidemics and pandemics of recent years may only be a subset of potential threats to consider.

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- ▶ Our response to threats depend on our experience with past threats.

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 - ▶ SARS-CoV-2 - Experiences from Pandemic Influenza, Spanish Flu, SARS-CoV-1.

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 - ▶ MPox - Experiences from small pox.



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- ▶ The epidemics and pandemics of recent years may only be a subset of potential threats to consider.
- ▶ Our response to threats depend on our experience with past threats.
 - ▶ SARS-CoV-2 - Experiences from Pandemic Influenza, Spanish Flu, SARS-CoV-1.
 - ▶ MPox - Experiences from small pox.
 - ▶ Scarlet fever - Experiences from historical scarlet fever.
- ▶ Analyzing historical pandemics is a way to study infectious diseases in more details than the study of modern pandemics alone allow for.



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In this talk, I will talk about:

- Our recent study of a unique dataset of all-cause mortality.

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- ▶ Mortality baseline calculations.

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- ▶ Mortality baseline calculations.
- ▶ Analyzing age patterns to classify epidemics.



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- ▶ Our recent study of a unique dataset of all-cause mortality.
- ▶ Mortality baseline calculations.
- ▶ Analyzing age patterns to classify epidemics.
- ▶ Reflect on what we can learn through historical epidemiology.



1918 Influenza



SARS-CoV-2



Data source

- Parish registers for Danish church parishes between 1815-1915

Scan of parish register for "Fakse" parish.

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Data source

- Parish registers for Danish church parishes between 1815-1915
 - Individual level information
Includes date, age, sex and parish



Scan of parish register for "Fakse" parish.

Data source

- Parish registers for Danish church parishes between 1815-1915
 - Individual level information Includes date, age, sex and parish
 - Approximately 4 million burials



Scan of parish register for "Fakse" parish.

Data source

- Parish registers for Danish church parishes between 1815-1915
 - Individual level information Includes date, age, sex and parish
 - Approximately 4 million burials
 - Property of the Danish National Archives, digitized by *Ancestry*



Scan of parish register for "Fakse" parish.

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Date of burial	Name	Age	Gender	Amt	Sogn
1857-01-02	Ane Kirstine Christensen	2	Female	Thisted Amt	Jannerup Sogn (Thisted Amt)
1857-01-02	Birthe Marie Christensen.	0	Female	Thisted Amt	Hundborg Sogn
1857-01-02	Ane Marie Mortensdatter	81	Female	Thisted Amt	Vejerslev Sogn (Mors)
1857-01-02	Gjertrud Jensdatter	82	Female	Thisted Amt	Thisted Sogn
1857-01-02	Karen Christensdatter Wiilsbøll	52	Female	Thisted Amt	Vester Vandet Sogn
1857-01-02	Karen Marie Jensen	21	Female	Thisted Amt	Sennels Sogn
1857-01-02	Ane Christensdatter Krogh	76	Female	Thisted Amt	Vester Vandet Sogn
1857-01-03	Anders Hansen Tülfang	79	Male	Thisted Amt	Gøttrup Sogn
1857-01-03	Marcus Christensen	6	Male	Thisted Amt	Hunstrup Sogn
1857-01-04	Maren Jensen	0	Female	Thisted Amt	Hillerslev Sogn (Thisted Amt)
1857-01-04	Thomas Jensen	0	Male	Thisted Amt	Flade Sogn (Thisted Amt)
1857-01-04	Niels Madsen Thÿstrup	74	Male	Thisted Amt	Skjoldborg Sogn
1857-01-04	Poul Pedersen	72	Male	Thisted Amt	Villerslev Sogn
1857-01-04	Oline Christine Christensen	1	Female	Thisted Amt	Kollerup Sogn (Thisted Amt)
1857-01-04	Maren Cathrine Nielsen	2	Female	Thisted Amt	Kollerup Sogn (Thisted Amt)



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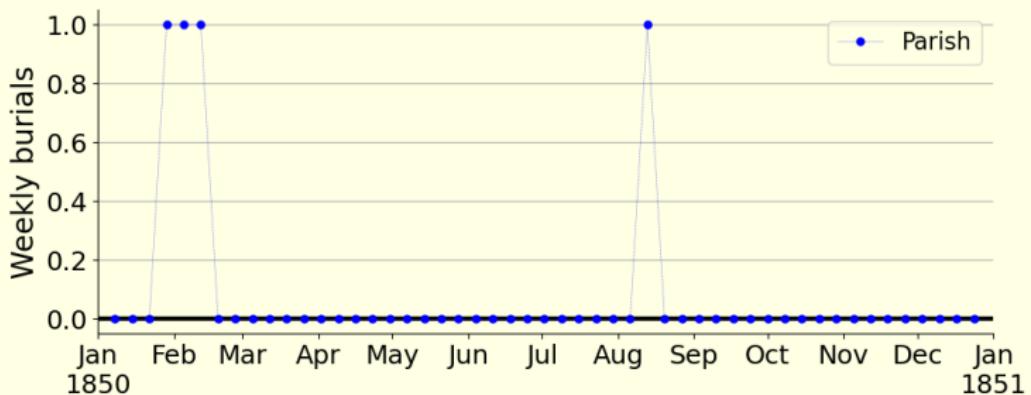
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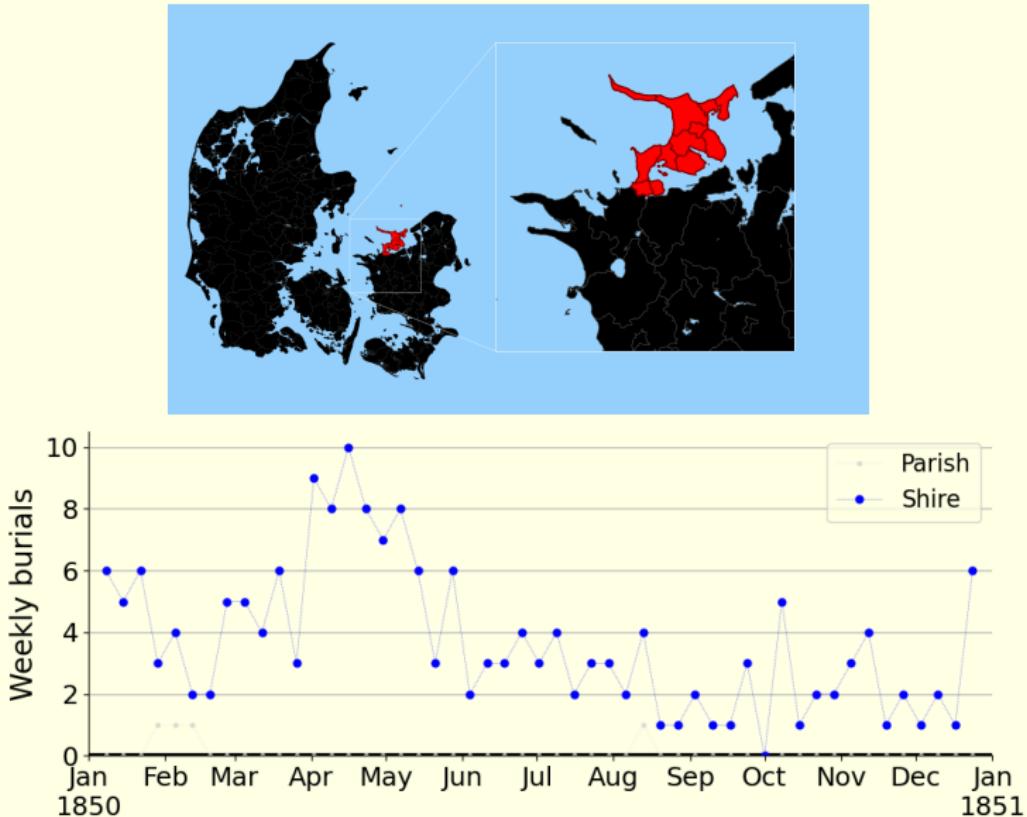
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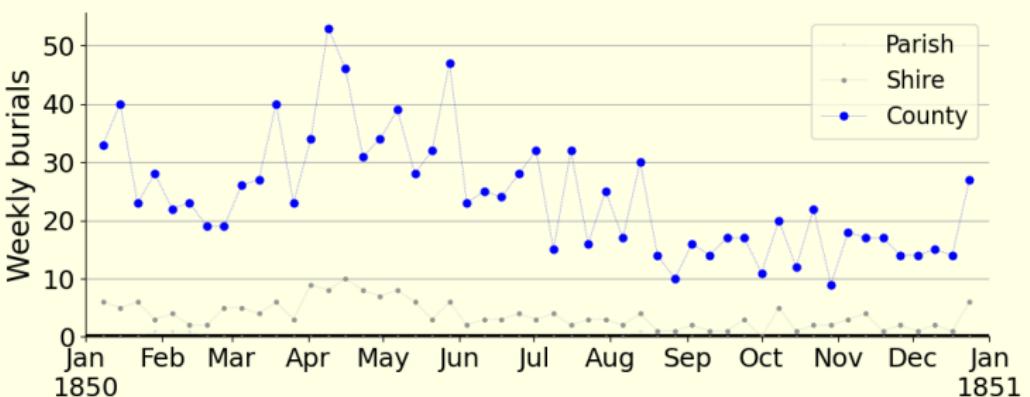
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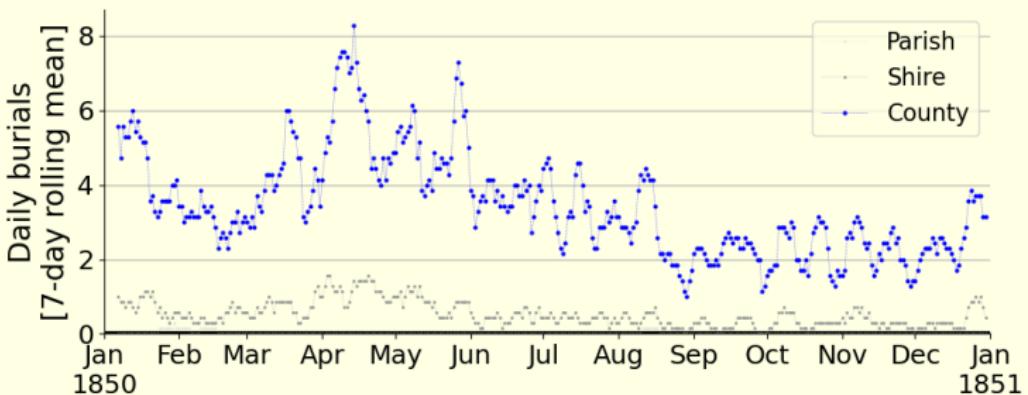
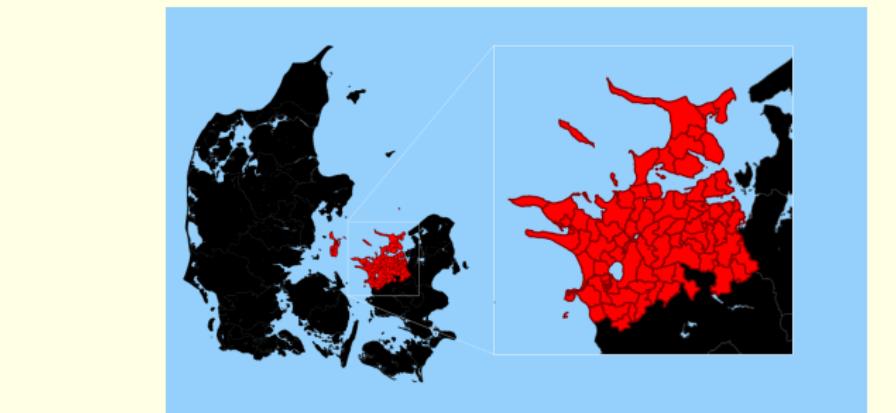
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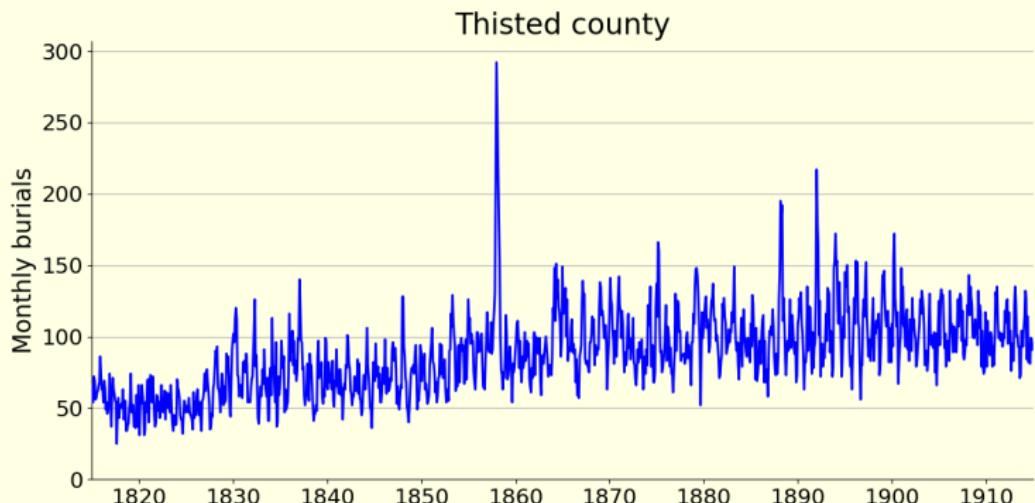
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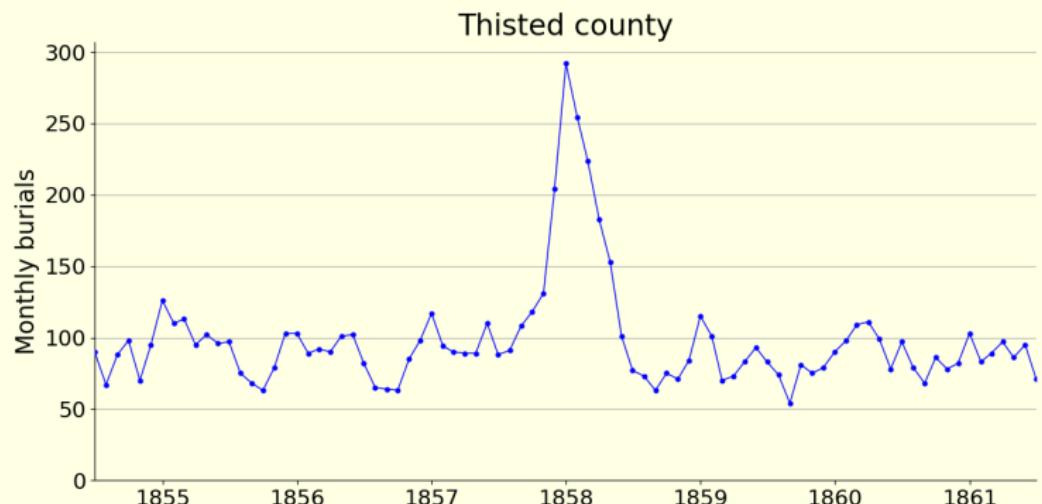
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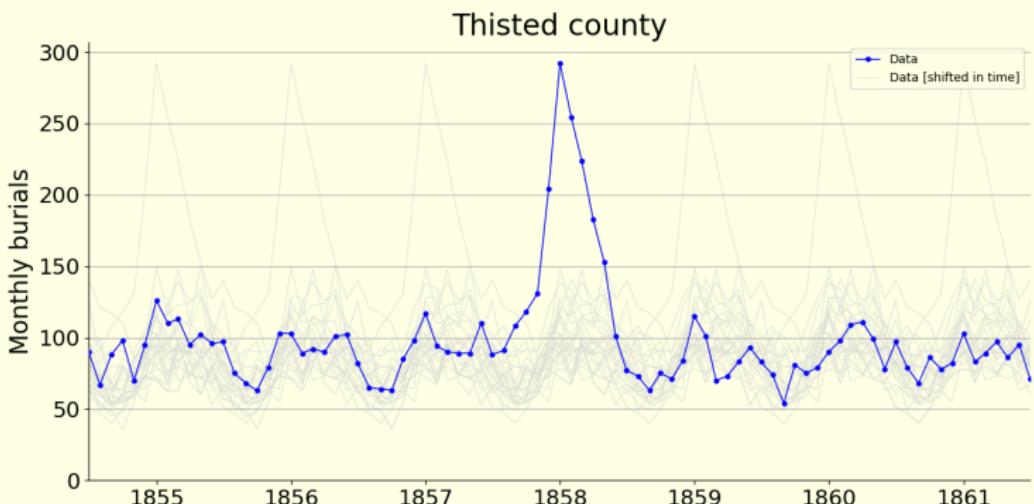
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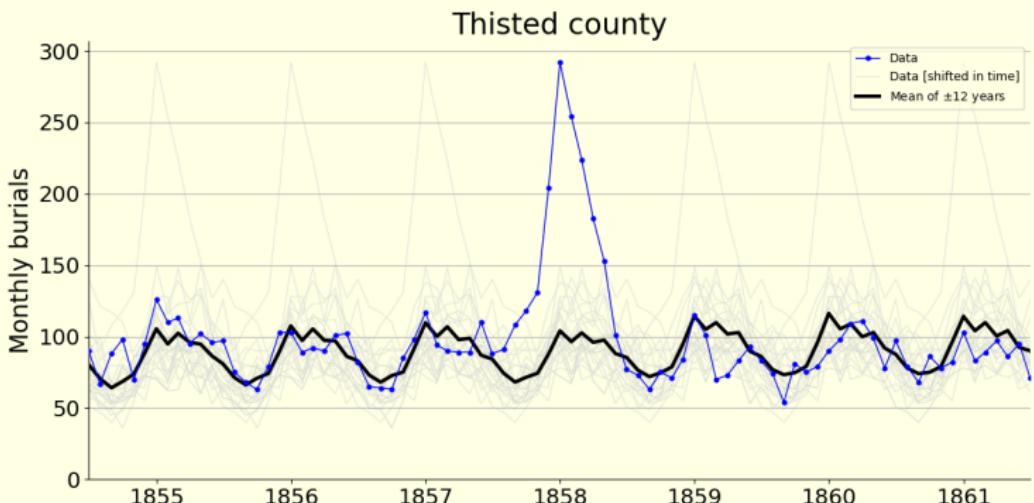
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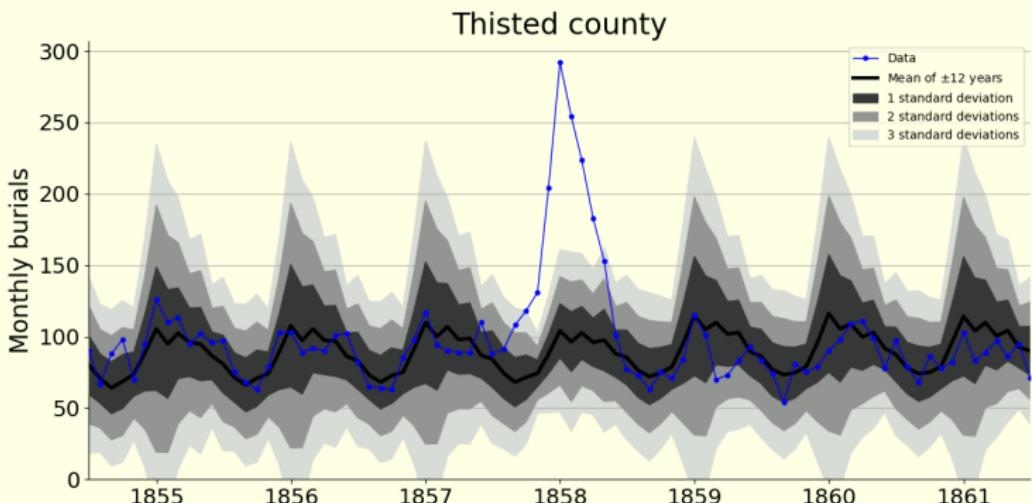
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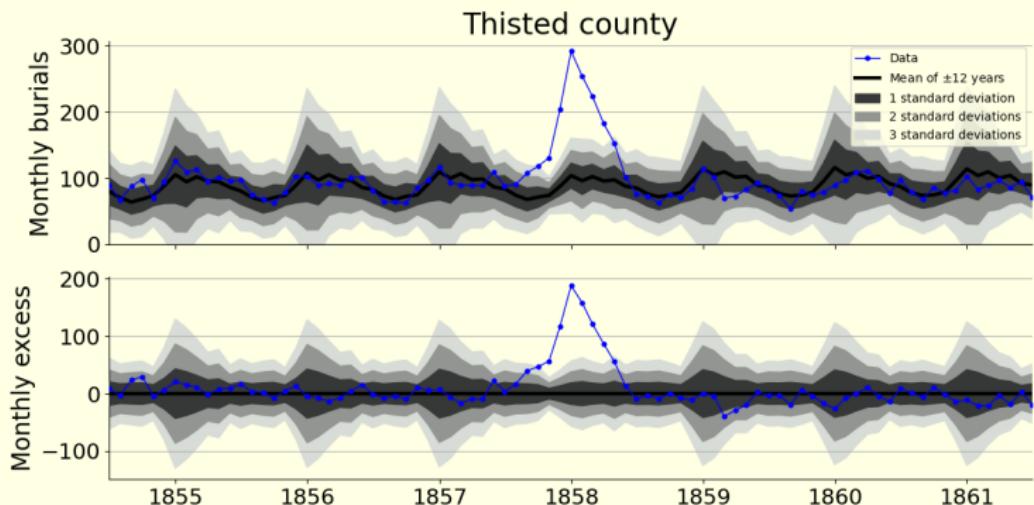
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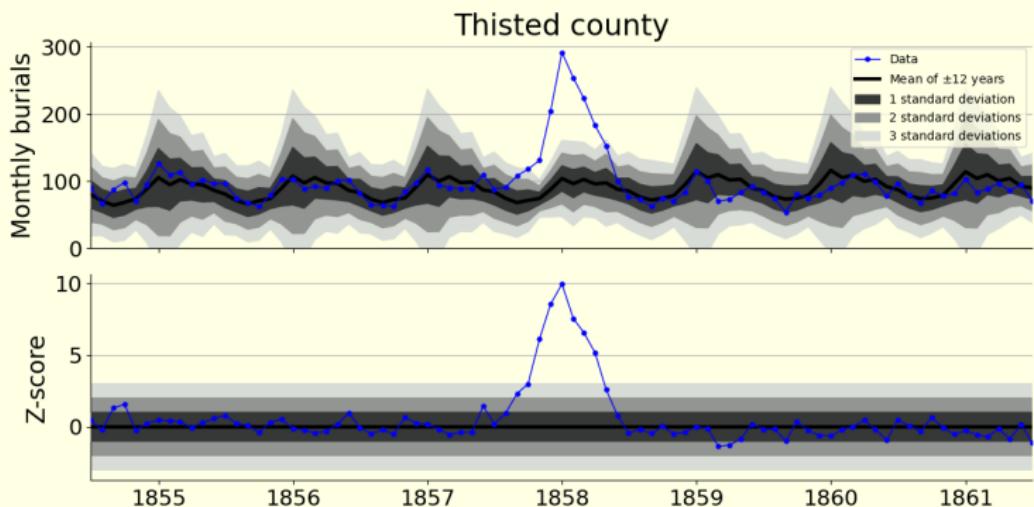
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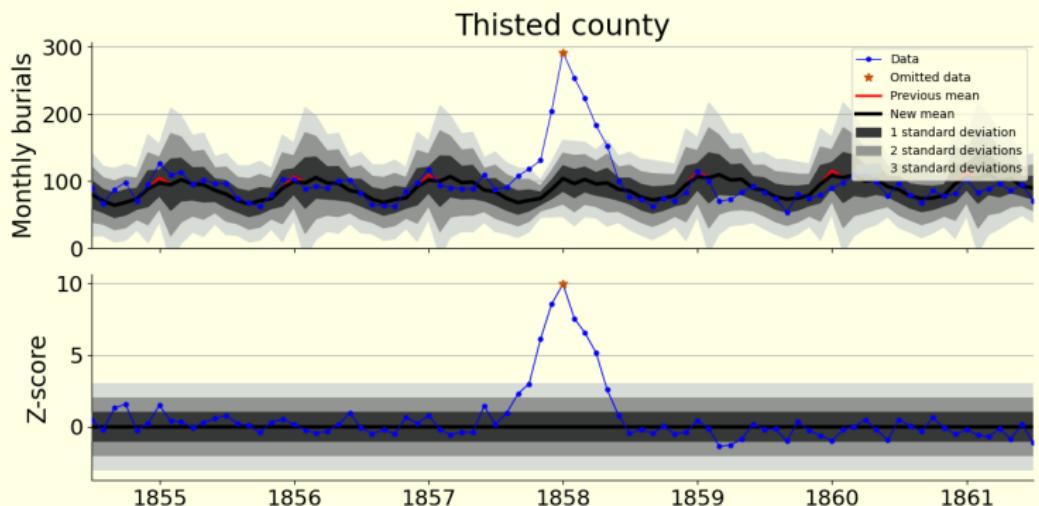
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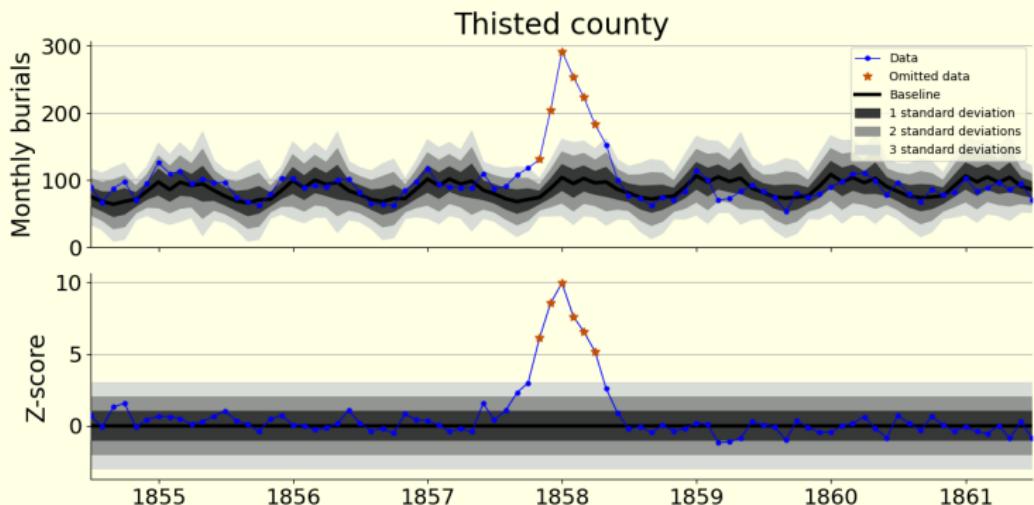
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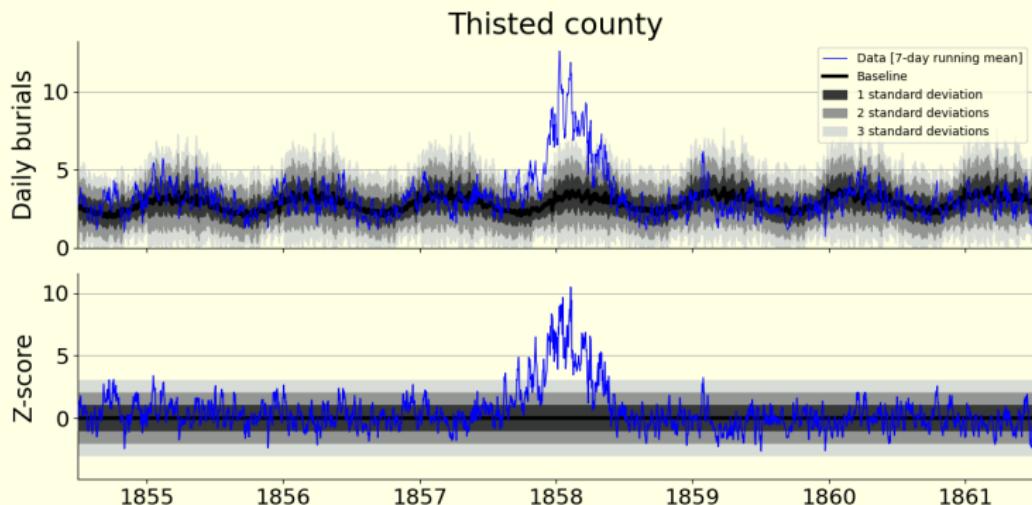
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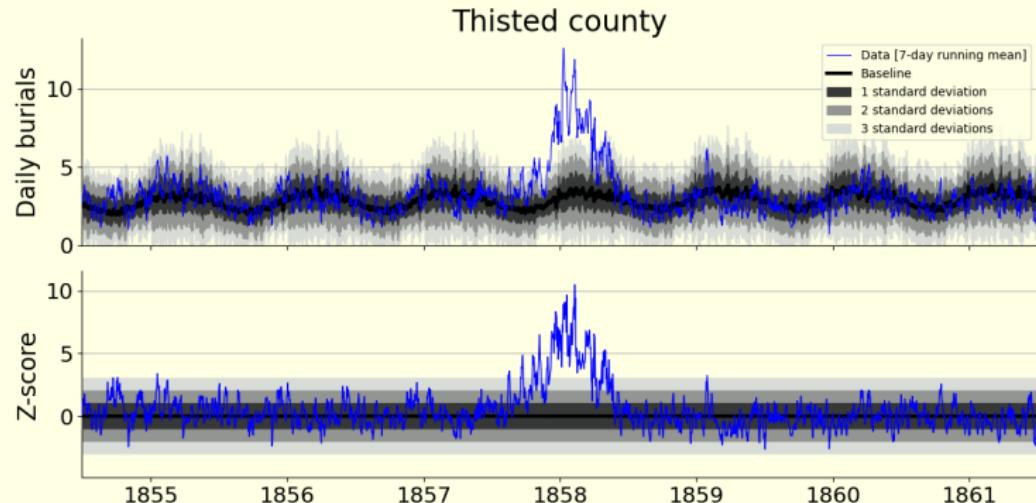
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Identification of "mortality crises"



We wish to identify periods continuous excess mortality. Hinde¹ uses the definition of months with a Z-score above two and three as "mortality crisis" and "severe mortality crisis", respectively

¹A. Hinde (2010) "A review of methods for identifying mortality 'crises' using parish record data" - Local Population Studies



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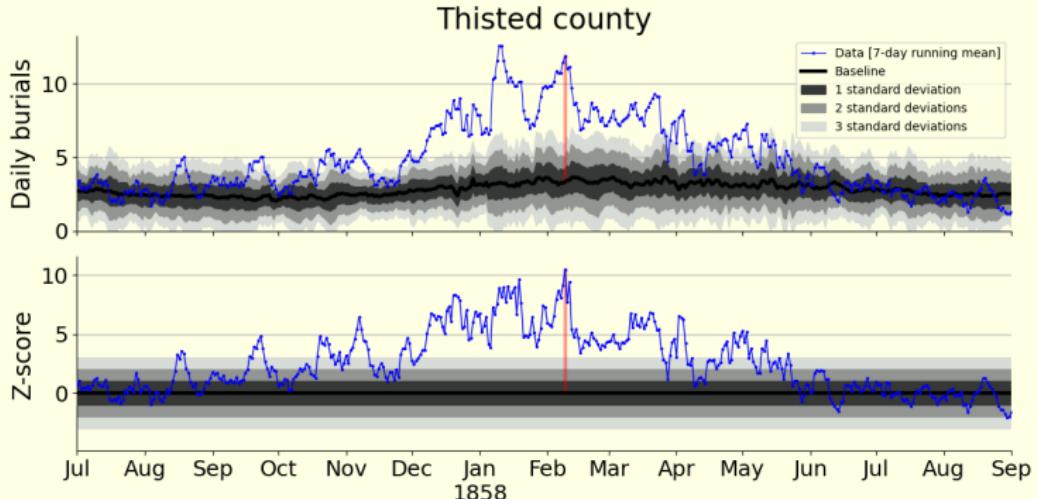
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Starting from the date with most burials...



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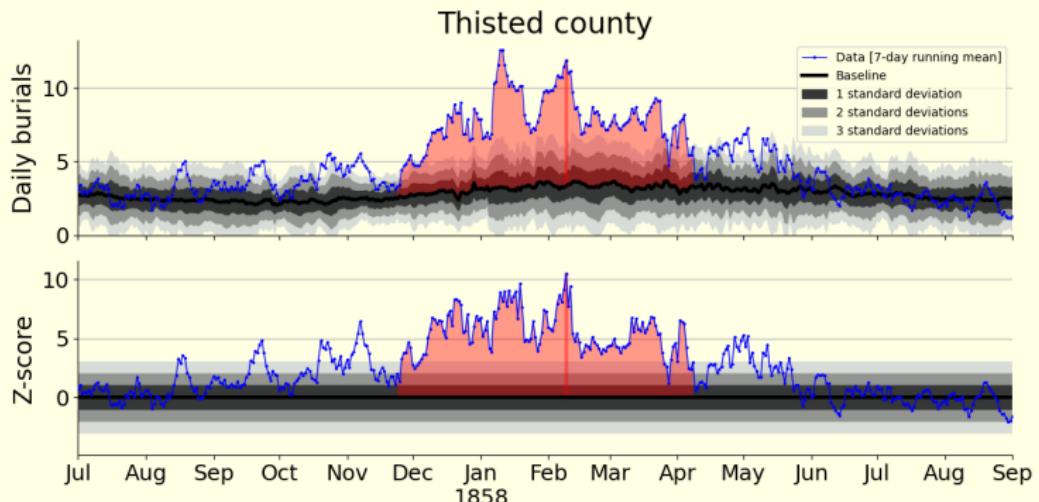
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... we group all days with Z-score above three, until the Z-score drops below two for *four* days or more.



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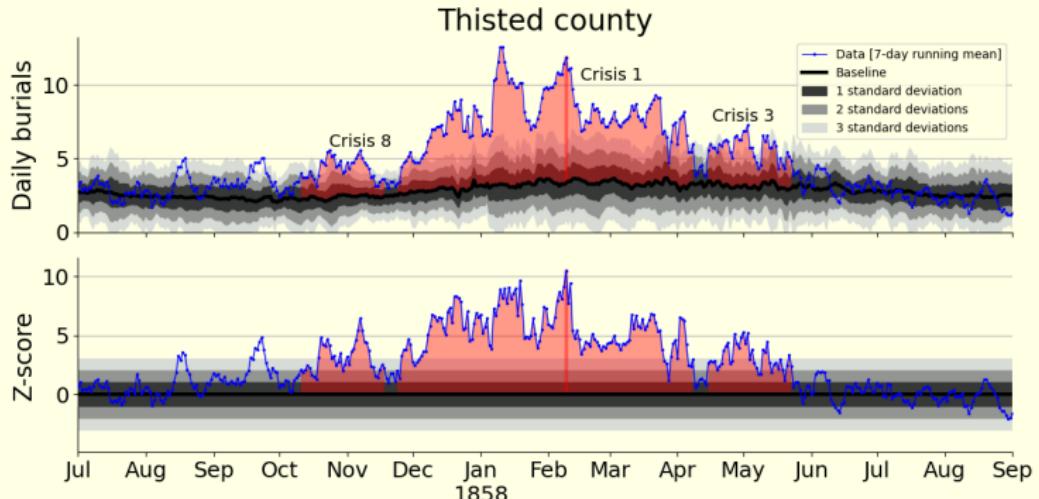
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Identification of "mortality crises"



All crises with at least seven days above the Z-score threshold of three are considered "mortality crises".



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Using this methodology, we identify 320 mortality crises in Denmark between 1820 and 1910.

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Using this methodology, we identify 320 mortality crises in Denmark between 1820 and 1910.

For each crisis, we can determine:

- ▶ Significant excess mortality.
Enough to cause excess burials on a county level
(Population-sizes \approx 100,000).



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- ▶ Timing and seasonality.
e.g. “peaking in winter” or “late summer”



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e.g. “peaking in winter” or “late summer”
- ▶ Duration
e.g. “lasting two months”



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- ▶ Timing and seasonality.
e.g. “peaking in winter” or “late summer”
- ▶ Duration
e.g. “lasting two months”

But we also have data on age.



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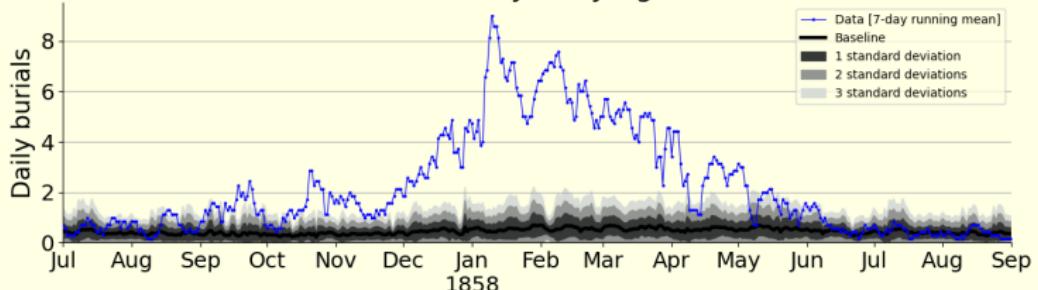
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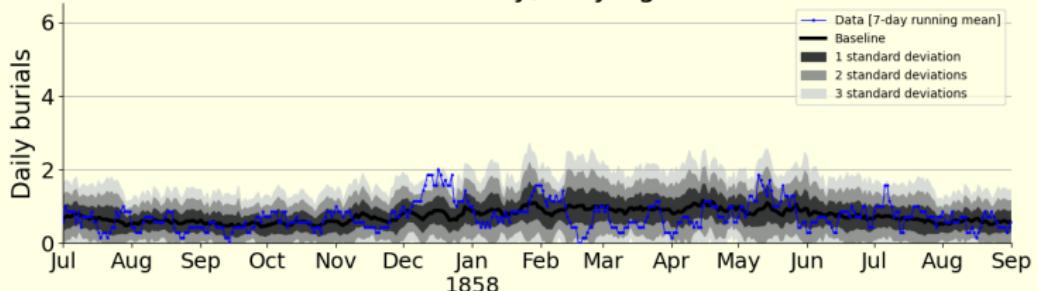
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Analyzing age-patterns

Thisted county, only ages 1-14



Thisted county, only ages 60+



Calculations for specific age groups...



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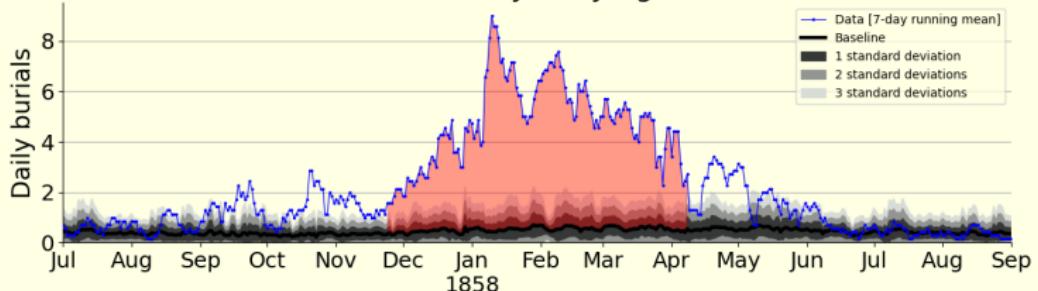
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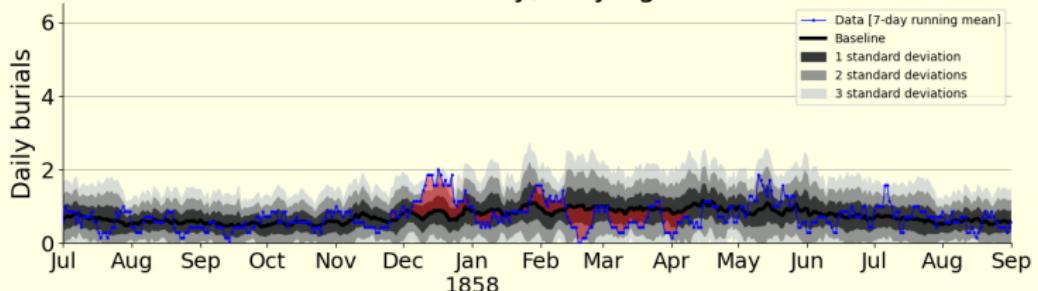
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Analyzing age-patterns

Thisted county, only ages 1-14



Thisted county, only ages 60+



... within the "mortality crisis period" found.



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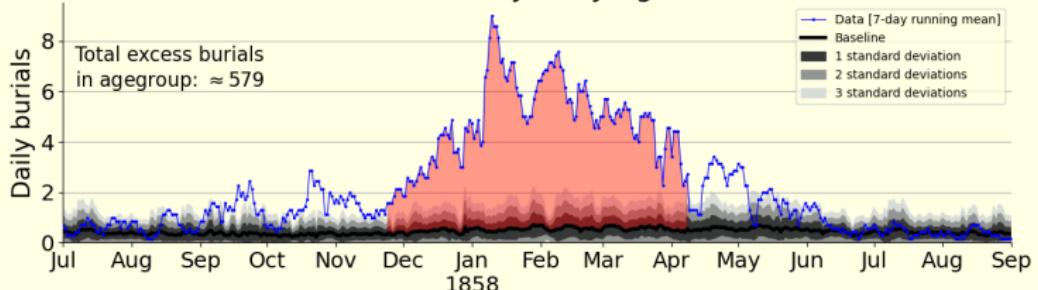
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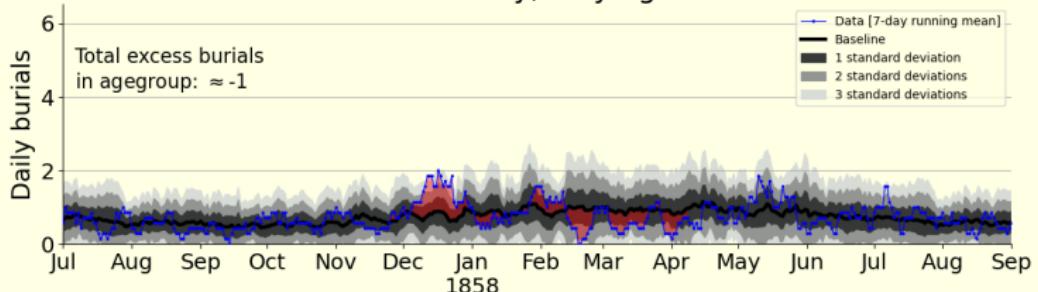
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Thisted county, only ages 1-14



Thisted county, only ages 60+



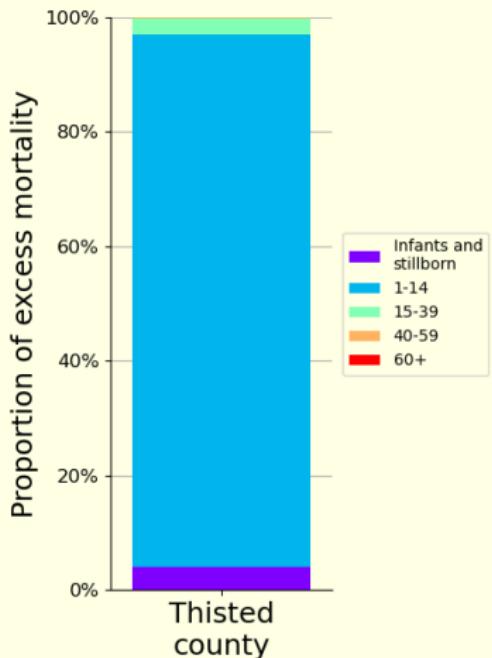
... within the "mortality crisis period" found.



Analyzing age-patterns

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Age-specific excess mortality in this period:

- ▶ Age group "60+": <1%
- ▶ Age group "40-59": <1%
- ▶ Age group "15-39": 3%
- ▶ Age group "1-14": 93%
- ▶ Age group "Below 1 year": 4%

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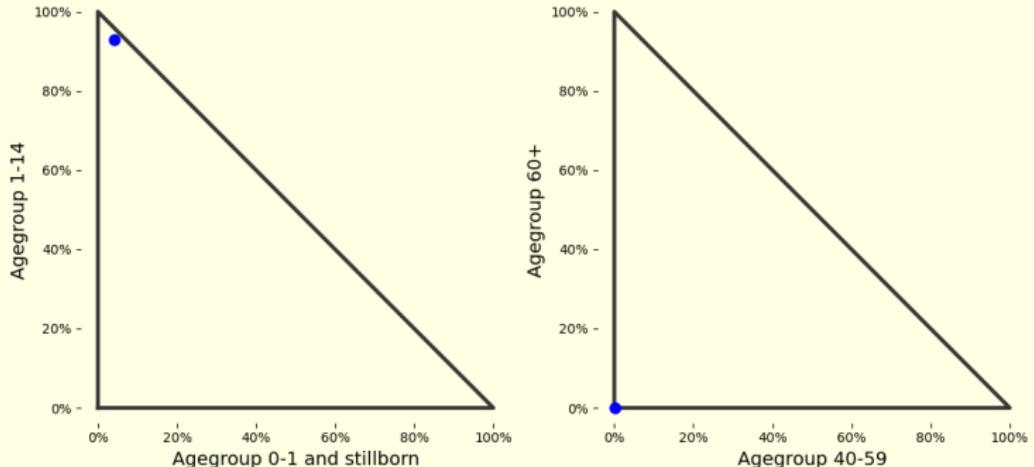
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(Age group "15-39" not shown here)



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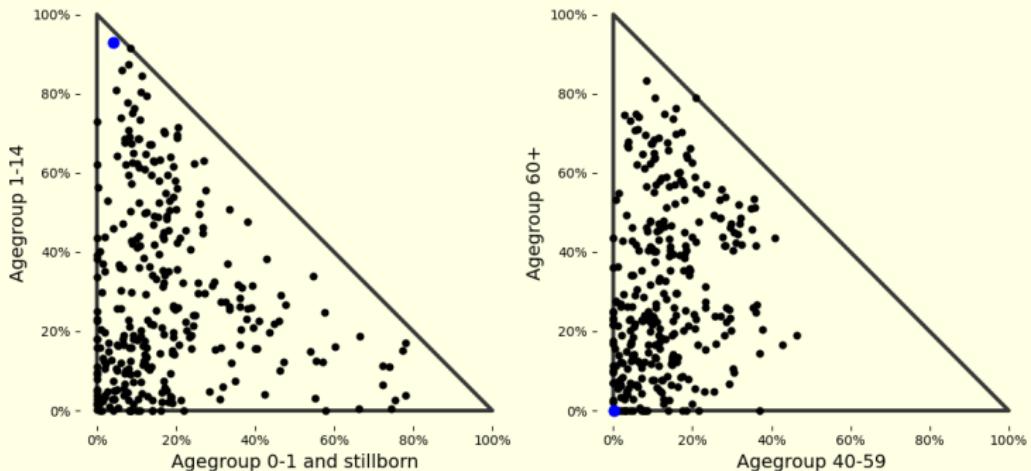
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Adding the other 319 mortality crises identified.



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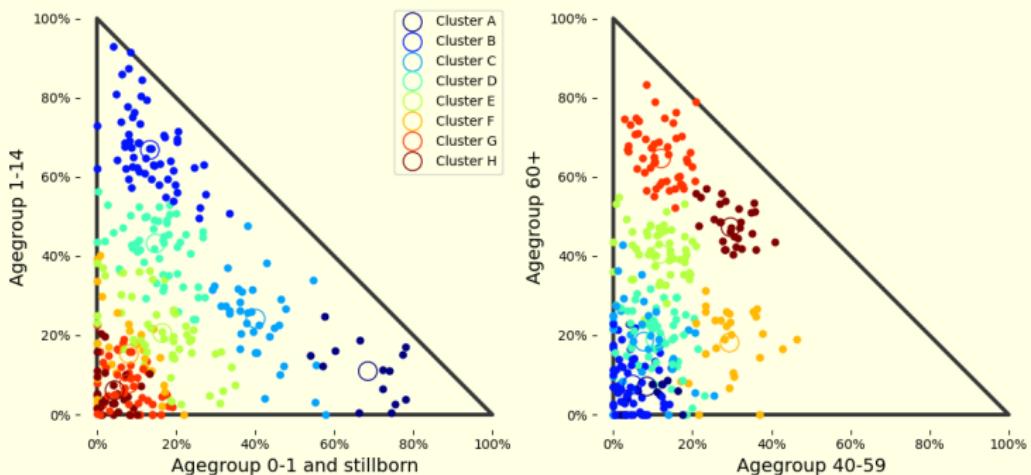
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Gaussian mixture modelling on full five-dimensional data.



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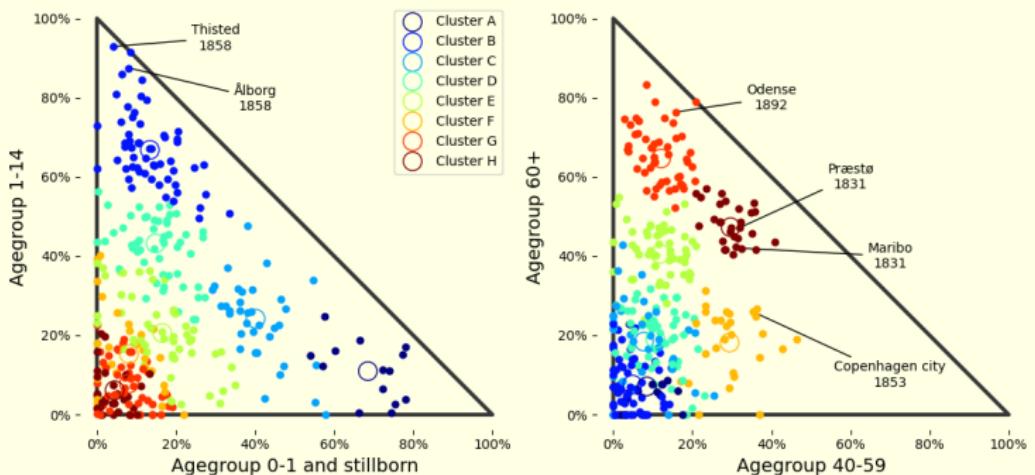
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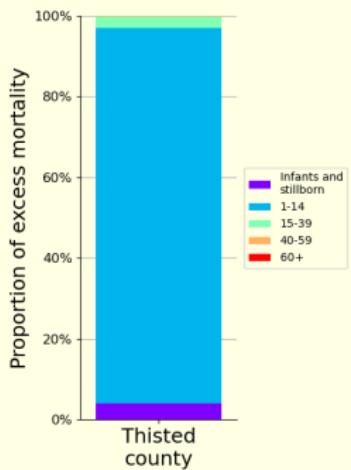
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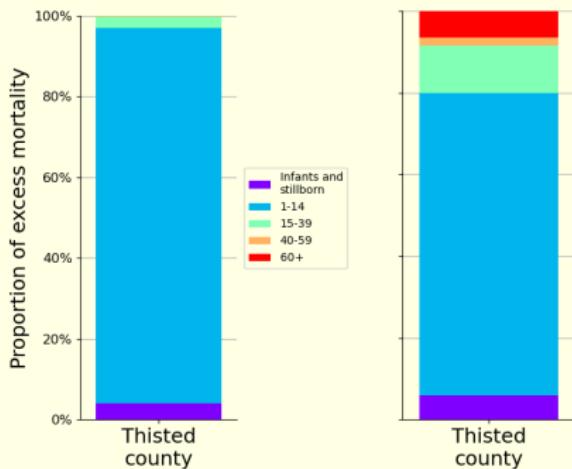
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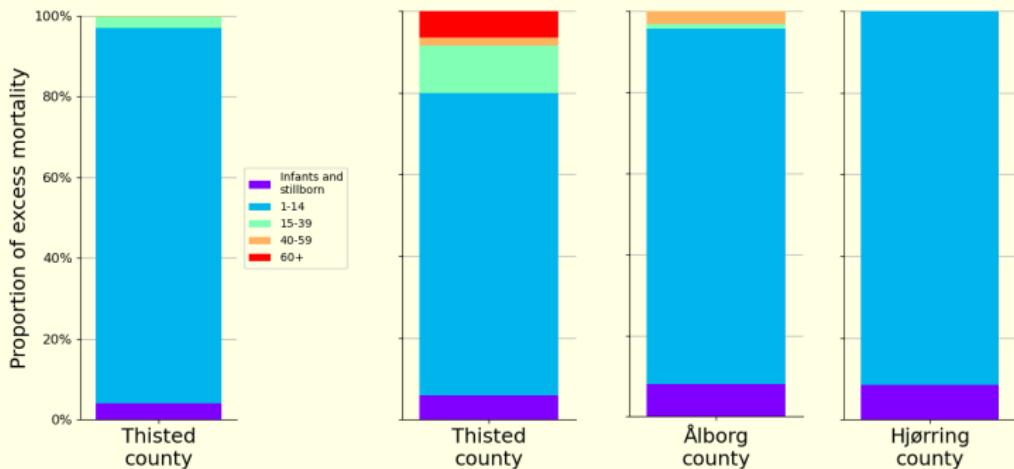
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Mortality crises with comparable signature features



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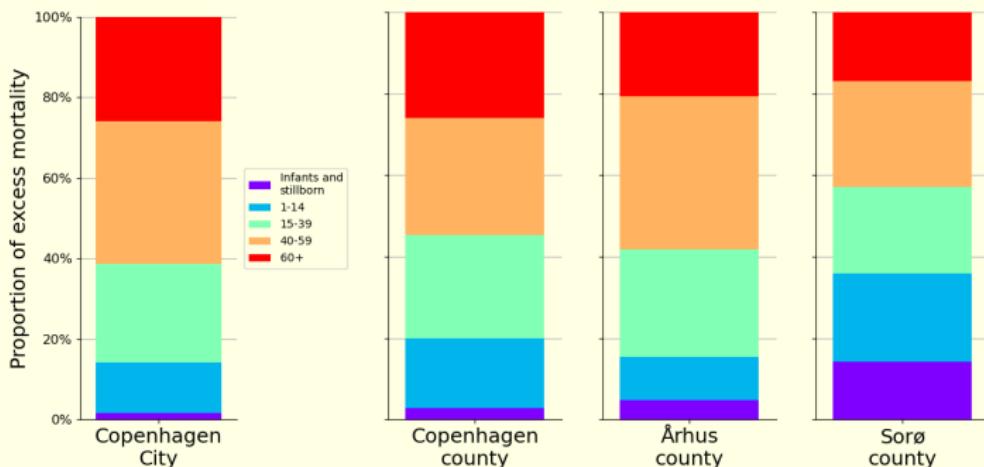
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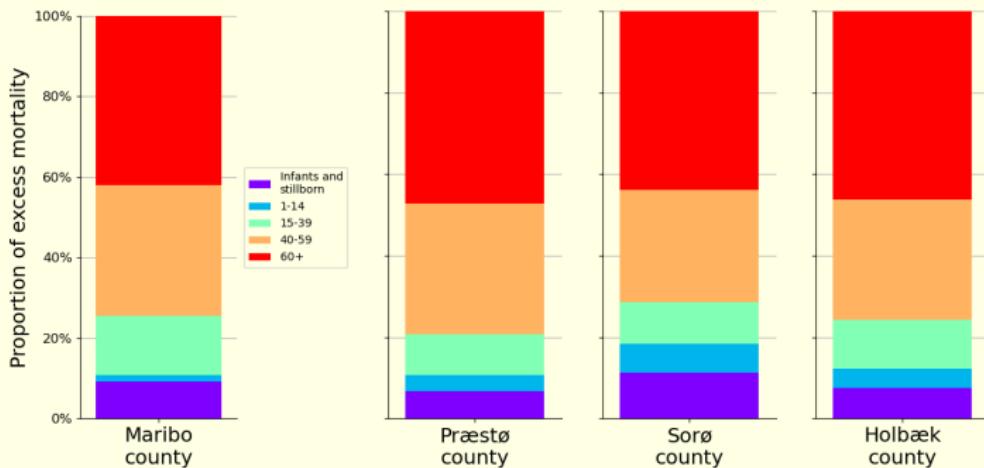
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All epidemics and pandemics in 19th century Denmark

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Going through all major mortality crises, and
crossreferencing with historical records of epidemics:

Disease	Timing	Total excess	Age structure
Cholera	Late summer, 1853 and 1857	4588	Adults Cluster "F"
Scarlet fever	Winter 1857/1858	2323	Children (1-15) Cluster "B"
"Harvest" epidemic ¹	Late summer, 1825-1831	11539	Adults Cluster "H" and "F"
Pandemic influenza	1892 and 1900	9532	Elderly Cluster "G"

And other epidemics as well as mortality crises unrelated to disease, e.g. war.

¹ The cause of this mortality crisis was probably a subsistence crisis as well as a range of diseases.
Discussed in detail in Ingholt (2022) *Scandinavian Journal of History*



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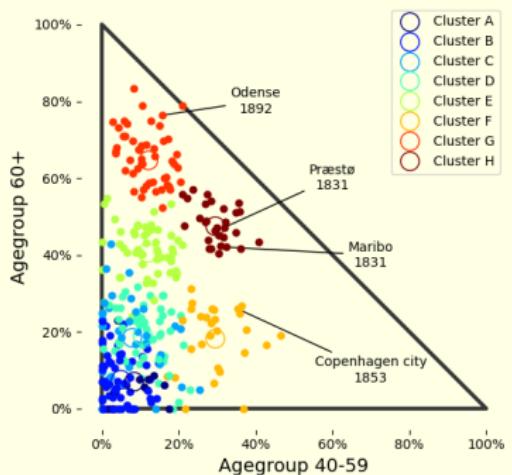
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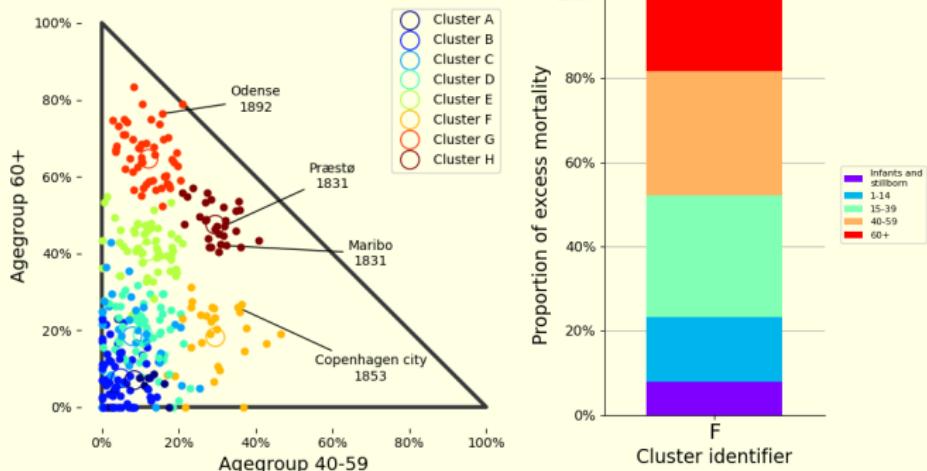
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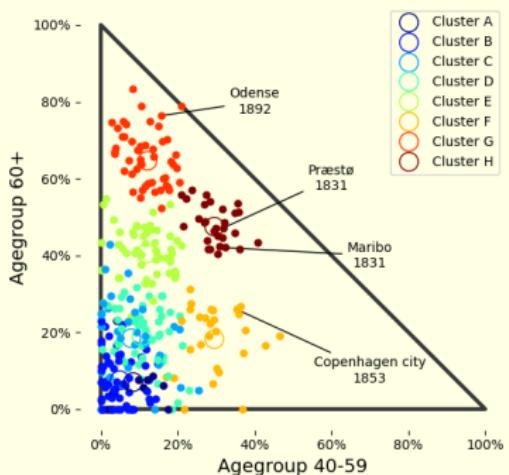
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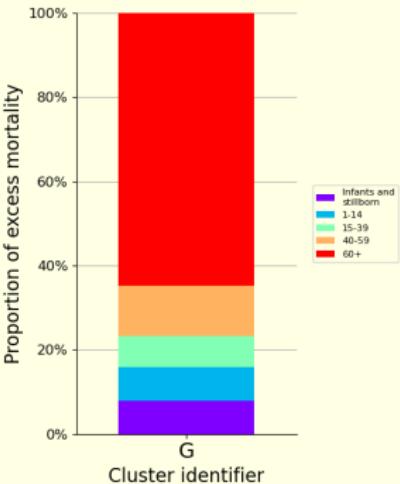
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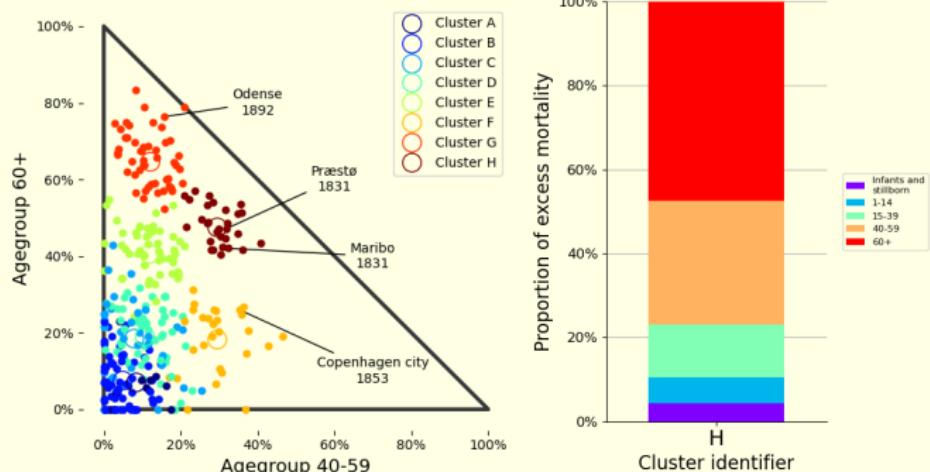
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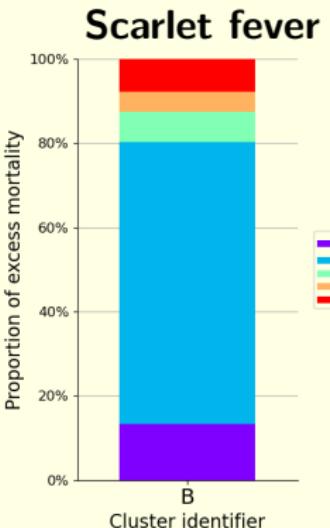
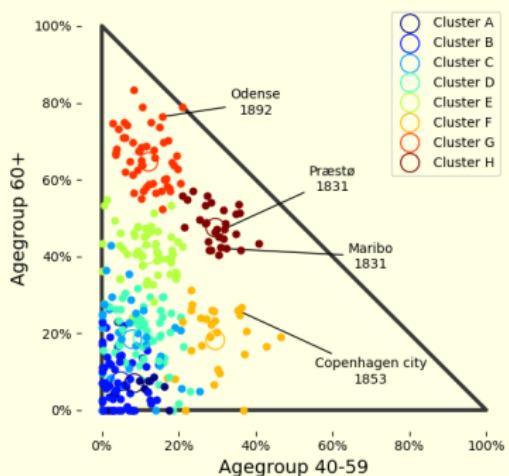
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- We calculate mortality on a county-level and estimate excess mortality for a 100-year lone period.

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- We calculate mortality on a county-level and estimate excess mortality for a 100-year lone period.
- We identify 320 major mortality crises in 19th century Denmark.

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- ▶ We calculate mortality on a county-level and estimate excess mortality for a 100-year lone period.
- ▶ We identify 320 major mortality crises in 19th century Denmark.
- ▶ We determine signature features of each crisis.

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 - ▶ Timing/Seasonality.

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- ▶ We calculate mortality on a county-level and estimate excess mortality for a 100-year lone period.
- ▶ We identify 320 major mortality crises in 19th century Denmark.
- ▶ We determine signature features of each crisis.
 - ▶ Timing/Seasonality.
 - ▶ Duration.
 - ▶ Geography.
 - ▶ Age-pattern.
- ▶ By comparing these features and validating with historical sources, we are able to determine groups of mortality crises with the same etiology, and estimate the total number of excess deaths during specific epidemics.



- ▶ Despite demographic differences between 19th century Denmark, the identified age patterns may still be relevant in modern data.

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Available online soon, as both Python and R package.

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- ▶ Understanding changes through history of the mortality of specific diseases may help us understand the disease today.



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Available online soon, as both Python and R package.
 - ▶ Quantitative comparison of age-patterns in modern all-cause mortality data.
- ▶ Understanding changes through history of the mortality of specific diseases may help us understand the disease today.
- ▶ As more historical data becomes transcribed, e.g. thanks to improved OCR, similar studies of other countries will become possible.



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Thank you for your attention.

Feel free to email me with
questions or comments

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"Identifying Signature Features of Epidemic Diseases in 19th Century All-cause Mortality Data" Pedersen RK, Ingholt MM, van Wijhe M,
Andreasen V & Simonsen L



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