

Identifying Excess Mortality Patterns in 19th Century Denmark

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Joint work with
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Viggo Andreasen & Lone Simonsen*

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Universität
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Danmarks
Grundforskningsfond
Danish National
Research Foundation

Why study historical epidemics?

Identifying Excess Mortality

RK Pedersen

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- ▶ Historical data provides us with more examples of epidemics than modern data alone.

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- ▶ Our response to emerging diseases come from historical experience.

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Image from The New York Times article "*The Mask Slackers of 1918*", Aug. 3, 2020
[nytimes.com/2020/08/03/us/mask-protests-1918.html](https://www.nytimes.com/2020/08/03/us/mask-protests-1918.html)

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- ▶ Historical data provides us with more examples of epidemics than modern data alone.
- ▶ Our response to emerging diseases come from historical experience.
 - ▶ Quarantine - e.g. plague
 - ▶ Restriction of movement (*cordon sanitaire*) - e.g. cholera
 - ▶ Social distancing - e.g. 1918 influenza
 - ▶ Masks - e.g. 1918 influenza

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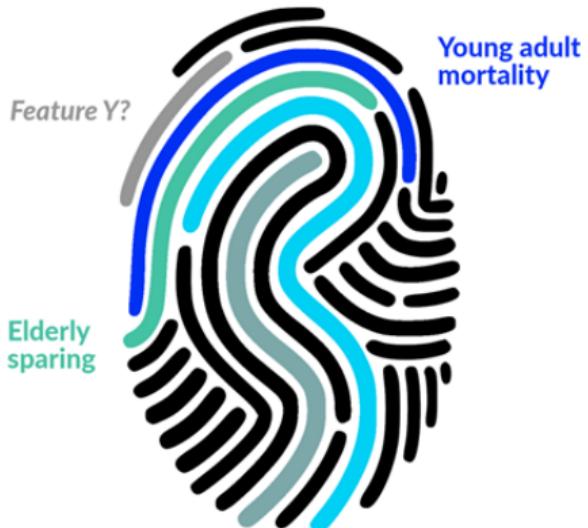
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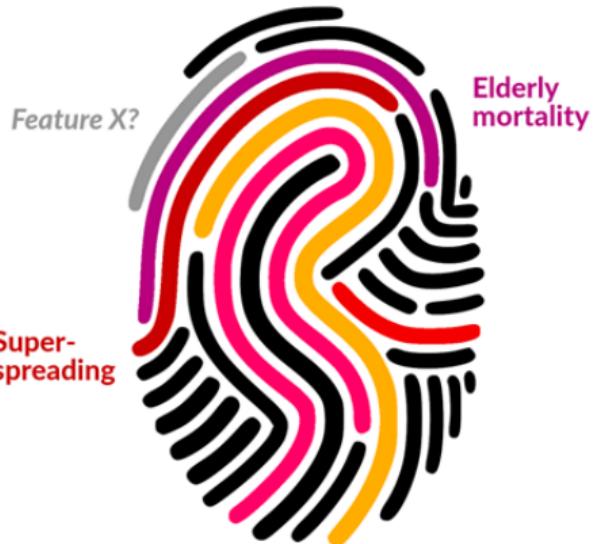
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 - ▶ Masks - e.g. 1918 influenza
- ▶ The pandemics of recent years may only be a subset of potential threats to consider for surveillance.
- ▶ It's interesting!

1918 Influenza



SARS-CoV-2



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- Our recent study of epidemics in 19th century Denmark.

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- ▶ Mortality baseline calculation.

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- ▶ Our recent study of epidemics in 19th century Denmark.
- ▶ Mortality baseline calculation.
- ▶ Age pattern analysis.
- ▶ Reflect on what we learned.



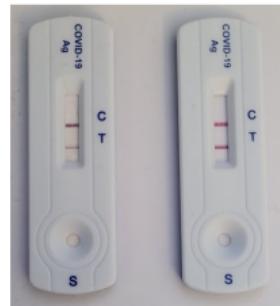
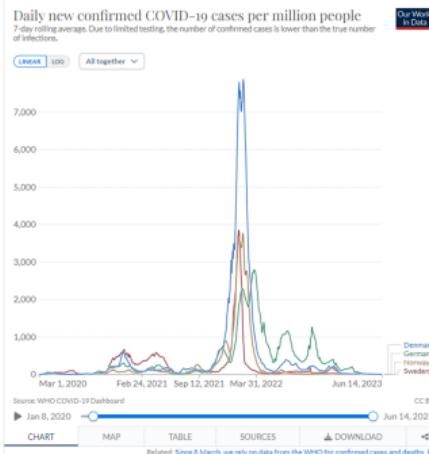
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Download covid-19-opgørelser

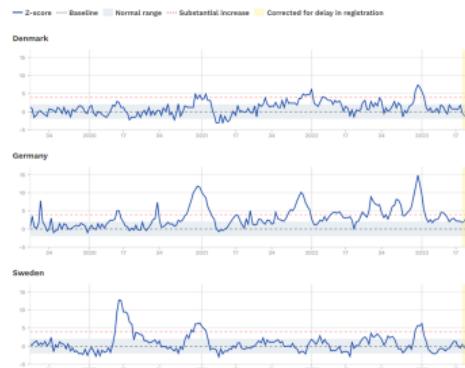
Filer med covid-19-opgørelser fra dashboardet (zip-csv),
den 8. marts 2021 og frem

- [COVID-19-dashboard 14062023 \(zip\)](#) 0.44 MB
- [Covid-19-dashboard 07062023 \(zip\)](#) 0.44 MB
- [Covid-19-dashboard 31052023 \(zip\)](#) 0.44 MB
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- [Covid-19-dashboard 10052023 \(zip\)](#) 0.43 MB
- [Covid-19-dashboard 03052023 \(zip\)](#) 0.49 MB

Our World
in Data



EUROMOMO



No.	Døbdagen.	Begravelsedagen.	Den Dødes Navn og tilnavn.	Stand, Haandtering og Opholdsted.	Alder.	Hvor an- ført i det almindelis- ge Leon- torske Registre.	Emærkninger.
35.	29. August	1. Septbr.	Anders Jørgensen	Sjæl i Hørbygå	53 Æar	692. 138	
36.	31. August	4. Septbr.	Hans Carlsson	Tørst i Skælskør	65 Æar	692. 139	
37.	30. August	3. Septbr.	Ole Jensen	Blodgårdsmann i Skælskør	89 Æar	692. 140	
38.	3. Septbr.	7. Septbr.	Holger Larsen	Sjæl i Hørbygå	70 Æar	692. 141	
39.	31. August	4. Septbr.	Hans Olsen	Gud og Guds i Hørbygå	42 Æar	692. 142	
40.	4. Septbr.	6. Septbr.	Niels Pedersen	Tørst i Espeværsø	66 Æar	692. 143	
41.	5. Septbr.	9. Septbr.	Ole Hansen	Blodgårdsmann i Tønsberg	66 Æar	693. 144	
42.	4. Septbr.	9. Septbr.	Niels Christensen	Sjæl i Tyslevig	57 Æar	693. 145	
43.	7. Septbr.	12. Septbr.	Niels Larsen	Sjæl i Saager	80 Æar	693. 146	
44.	6. Septbr.	12. Septbr.	Jens Andersen	Blodgårdsgård i Tønsberg	72 Æar	693. 147	
45.	8. Septbr.	13. Septbr.	Hans Knudsen	Sjæl i Tyslevig	42 Æar	693. 148	
46.	5. Septbr.	9. Septbr.	Lars ChristopherSEN	Blodgårdsmann i Hørbygå	93 Æar	693. 149	
47.	12. Septbr.	16. Septbr.	Peder Hansen	Sjæl i Skælskør	78 Æar	693. 150	
48.	11. Septbr.	14. Septbr.	Hans Larsen	Sjæl i Hørbygå	49 Æar	693. 151	

Data source

- Parish registers for Danish church parishes between 1815-1915

No.	Født	Middelnavn	Efternavn	Dato	Død	Ålder	Dødsårsak	Begravelse
35	Jørgen	A.	Sørensen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
36	Jørgen	A.	Carlsen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
37	Jørgen	A.	Jensen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
38	Jørgen	A.	Høyer-Larsen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
39	Jørgen	A.	Larsen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
40	Jørgen	A.	Nielsen-Jørgensen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
41	Jørgen	A.	Olsen-Hansen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
42	Jørgen	A.	Olsen-Hansen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
43	Jørgen	A.	Niels Carstensen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
44	Jørgen	A.	Pedersen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
45	Jørgen	A.	Pedersen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
46	Jørgen	A.	Pedersen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
47	Jørgen	A.	Pedersen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
48	Jørgen	A.	Pedersen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
49	Jørgen	A.	Pedersen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
50	Jørgen	A.	Pedersen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
51	Jørgen	A.	Pedersen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
52	Jørgen	A.	Pedersen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
53	Jørgen	A.	Pedersen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
54	Jørgen	A.	Pedersen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34
55	Jørgen	A.	Pedersen	1831-01-01		31	Udbrud af sygdom	Kirkegård nr. 34

Scan of parish register for "Fakse" parish.

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Data source

- Parish registers for Danish church parishes between 1815-1915
- Approximately 4 million burials



Scan of parish register for "Fakse" parish.

Data source

- ▶ Parish registers for Danish church parishes between 1815-1915
- ▶ Approximately 4 million burials
- ▶ Individual level information
Includes date of death, date of burial, gender, age and parish

Nr.	Dødsdag.	Begravelsedag.	Den Døde Navn og tilnavn.	Størst, bemanding og døbfestdag.	Dødsdag.		Tilhørsomme.
					År.	Måned.	
15	for 1. Januar.	1. Januar.	Ambrose Brorson	Jesu Christus	1831	Jan.	
26	3. Februar.	4. Februar.	Hans Carlsten	Jesus Christus	1831	Feb.	
27	30. Februar.	3. Marts.	Ole Jørgen	Bjergmanns Jørgen	1831	Mar.	
28	3. Marts.	7. Marts.	Hugo Larsen	Jesus i Kristus	1831	Mar.	
29	31. Desember.	4. Januar.	Hans Olsen	Jesus Christus	1831	Jan.	
30	4. Januar.	8. Januar.	Niels Andersen	Jesus Christus	1831	Jan.	
31	4. Januar.	8. Januar.	Ole Hansen	Jesus Christus	1831	Jan.	
41	5. Februar.	9. Februar.	Niels Carlsten	Jesus Christus	1831	Feb.	
42	4. Februar.	9. Februar.	Niels Carlsten	Jesus Christus	1831	Feb.	
43	7. Februar.	12. Februar.	R. Vilh. Larsen	Jesus Christus	1831	Feb.	
44	6. Februar.	12. Februar.	Jens. Andersen	Bjergmanns Jørgen	1831	Feb.	
45	8. Februar.	13. Februar.	Hans Larsen	Jesus Christus	1831	Feb.	
46	5. Februar.	9. Februar.	Niels Christensen	Bjergmanns Jørgen	1831	Feb.	
47	12. Februar.	16. Februar.	Andreas Hansen	Jesus Christus	1831	Feb.	
48	11. Februar.	15. Februar.	Hans Larsen	Jesus Christus	1831	Feb.	

Scan of parish register for "Fakse" parish.

Data source

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

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Nr.	Født dage.	Begravelsesdage.	Den Døde Den og tilhører.	Stedt, Begravelse og Døbfestid.	Døde.	
					Begravelsestid.	Døde.
15	for 1. Februar.	1. Februar.	Johannes Christensen	Yderst i Kirkebygning	1831. febr. 1. 100	
26	... 3. Februar.	3. Februar.	Hans Carlsten	Yderst i Kirkebygning	1831. febr. 3. 100	
27	... 30. Februar.	3. Marts.	Ol. Jensen	Ringemose i Kirkebygning	1831. marts 3. 100	
28	... 3. April.	7. April.	Hugo Larsen	Yderst i Kirkebygning	1831. april 7. 100	
29	... 31. April.	8. April.	Hans Olsen	Yderst i Kirkebygning	1831. april 8. 100	
30	... 1. Maj.	8. Maj.	Niels Andersen	Yderst i Kirkebygning	1831. maj 8. 100	
31	... 5. Maj.	9. Maj.	Ol. Hansen	Ringemose i Kirkebygning	1831. maj 9. 100	
42	... 4. Jun.	9. Jun.	Niels Christensen	Yderst i Kirkebygning	1831. juni 9. 100	
43	... 7. Jun.	12. Jun.	K. Vilh. Larsen	Yderst i Kirkebygning	1831. juni 12. 100	
44	... 8. Jun.	12. Jun.	Jens. Christensen	Ringemose i Kirkebygning	1831. juni 12. 100	
45	... 8. Jun.	13. Jun.	Hans Larsen	Yderst i Kirkebygning	1831. juni 13. 100	
46	... 5. Jul.	10. Jul.	Niels Christensen	Yderst i Kirkebygning	1831. juli 10. 100	
47	... 12. Jul.	16. Jul.	Andreas Hansen	Yderst i Kirkebygning	1831. juli 16. 100	
48	... 11. Aug.	14. Aug.	Hans Larsen	Yderst i Kirkebygning	1831. august 14. 100	

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 Tüylfang	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)
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► Temporal resolution:

► Daily

► Geographical resolution:

► Individual parishes

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► Temporal resolution:

- Daily
- Weekly
- Monthly
- Yearly

► Geographical resolution:

- Individual parishes
- Shire
(groups of 5 to 10 parishes)
- Counties
(groups of 5 to 10 shires)

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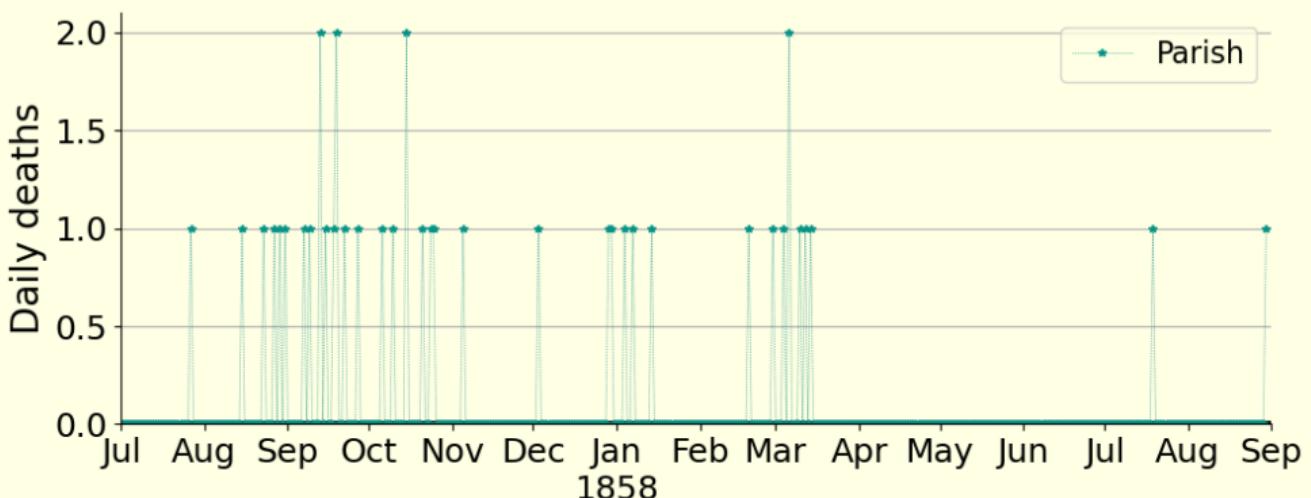
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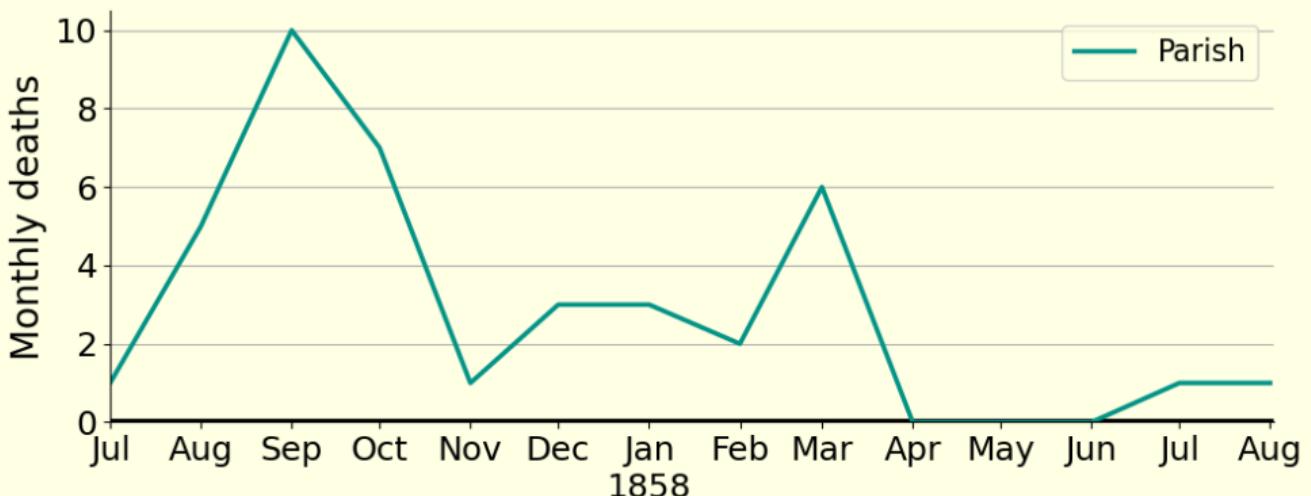
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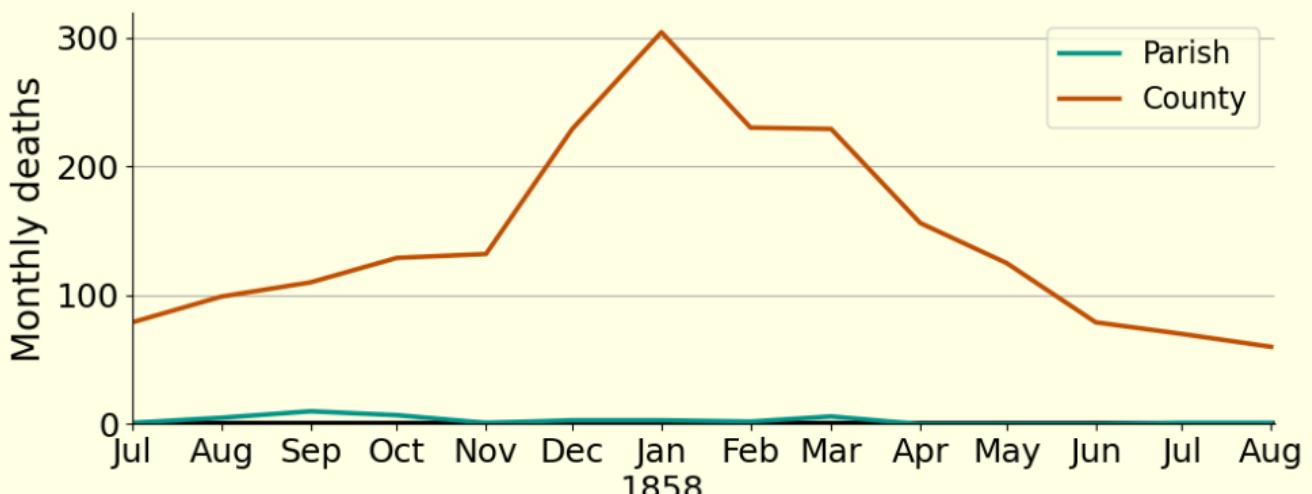
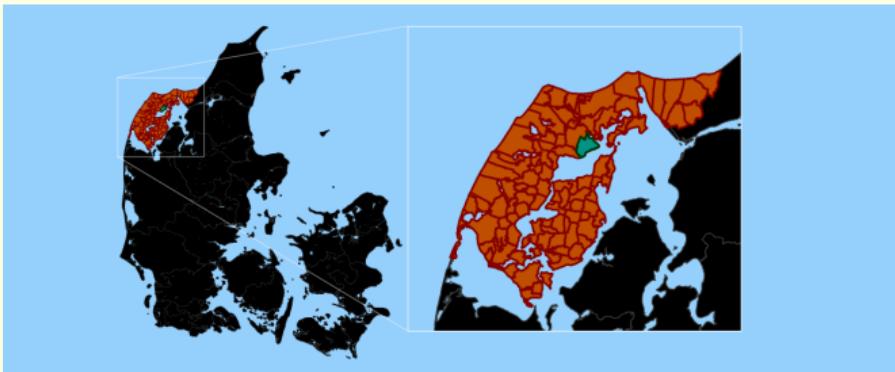
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Calculating the mortality baseline

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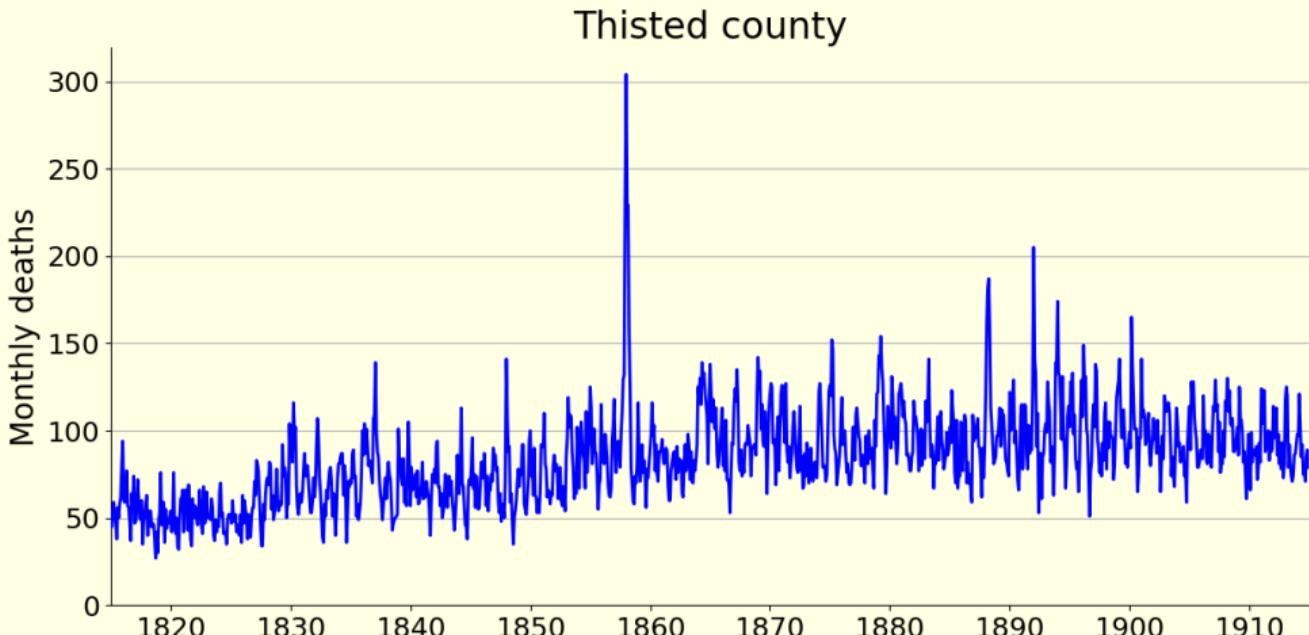
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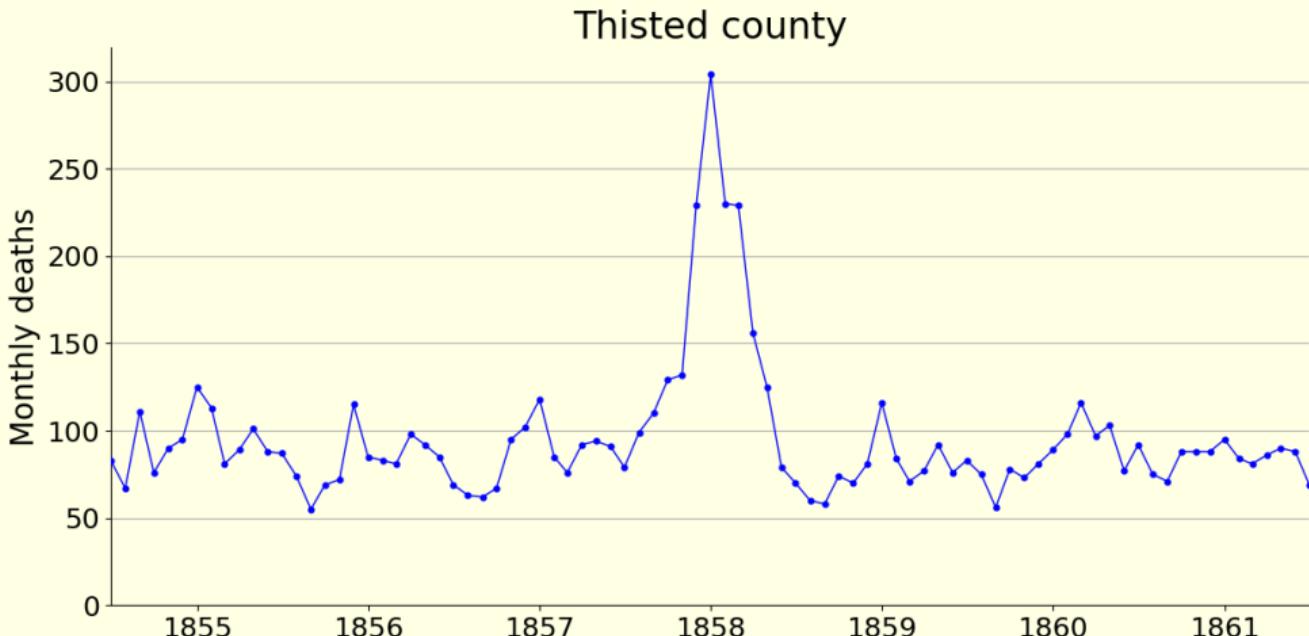
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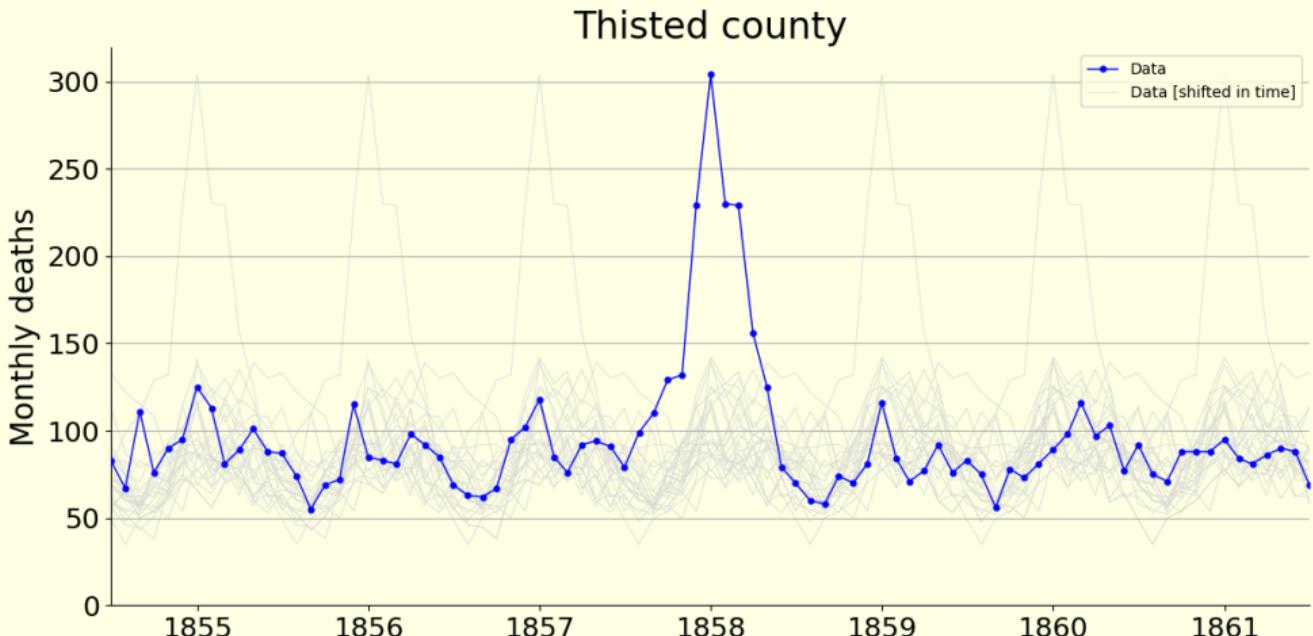
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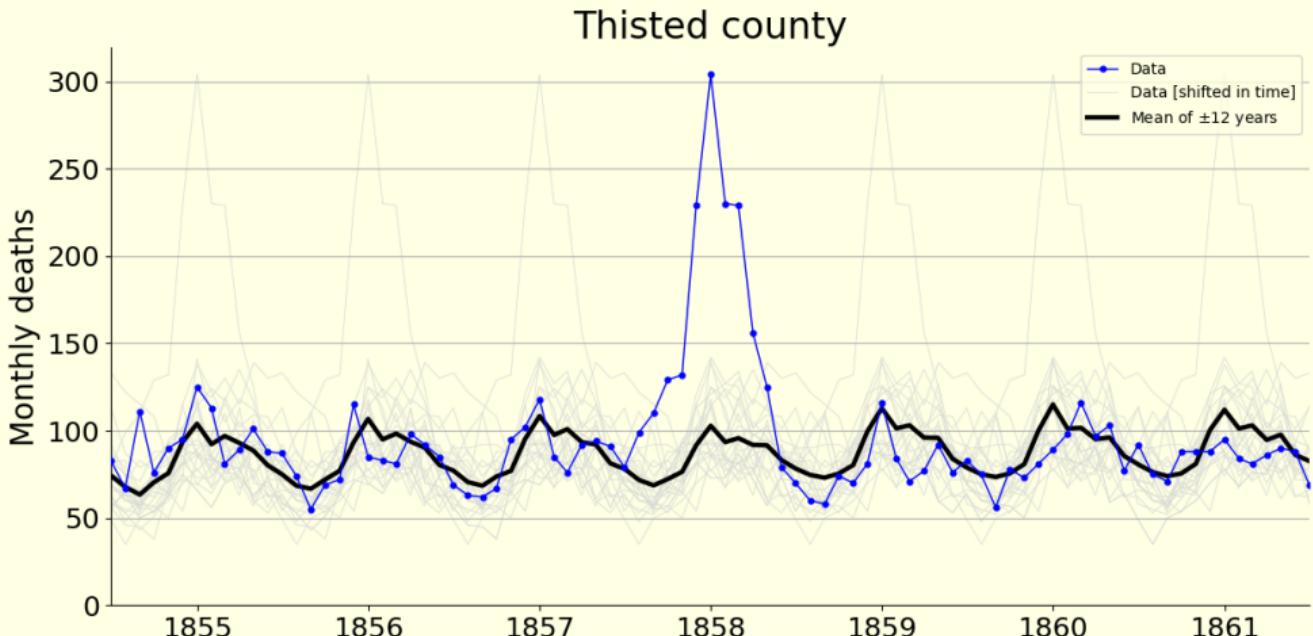
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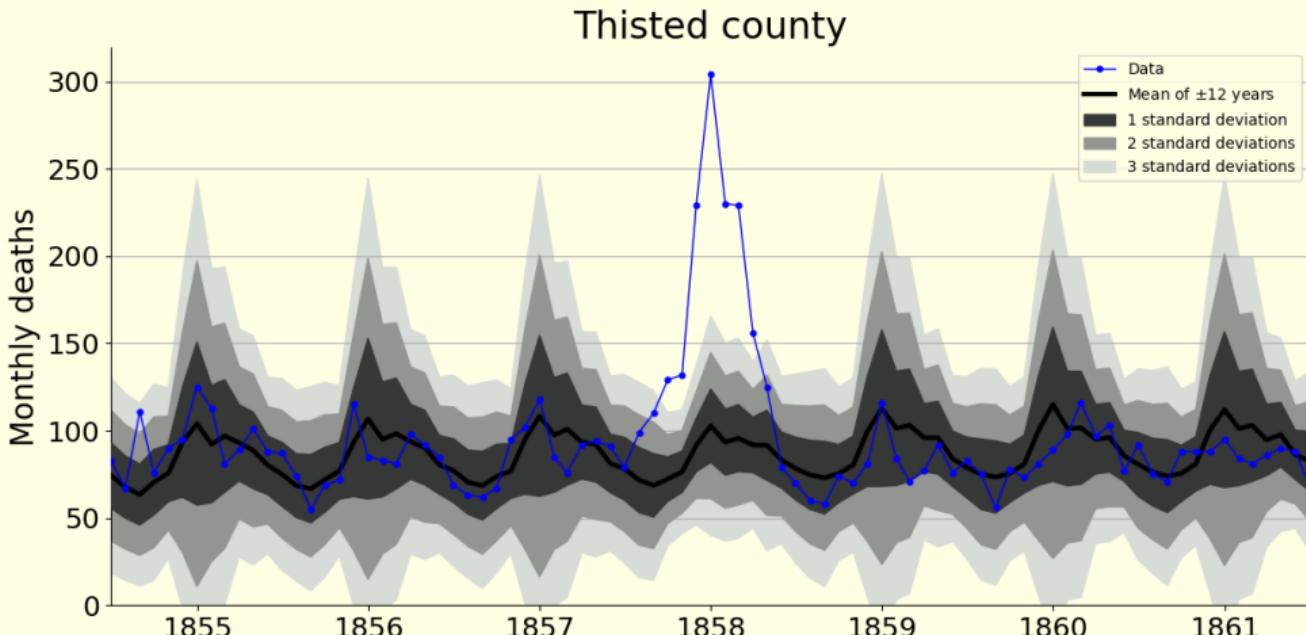
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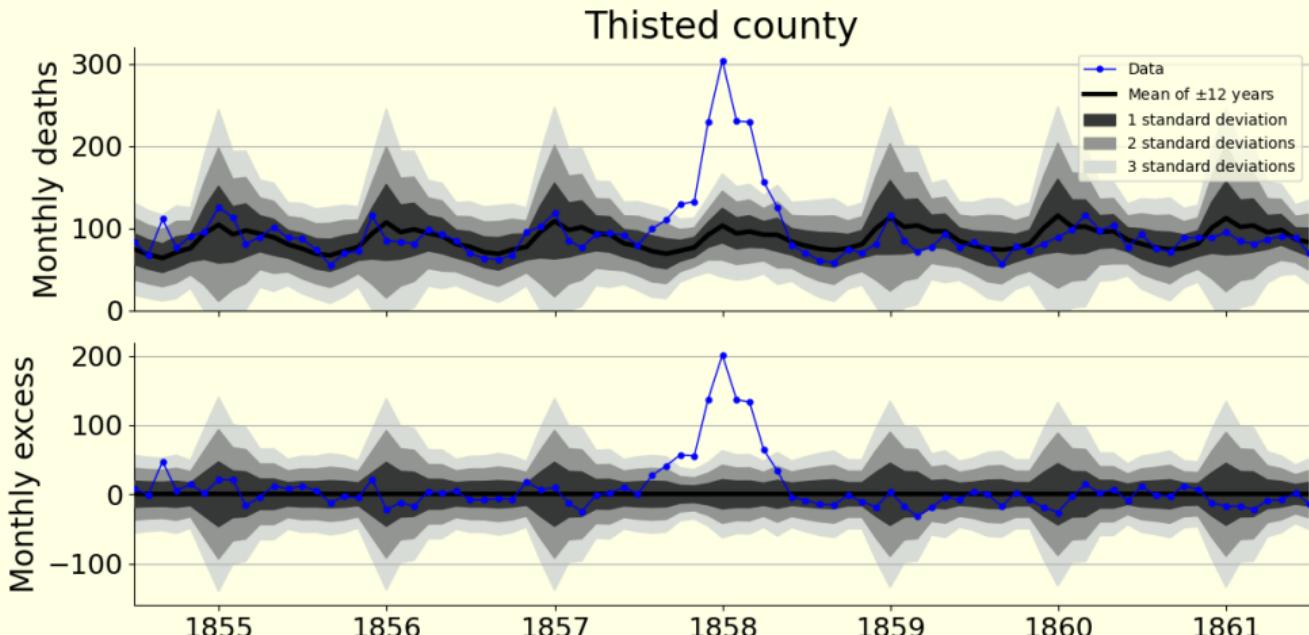
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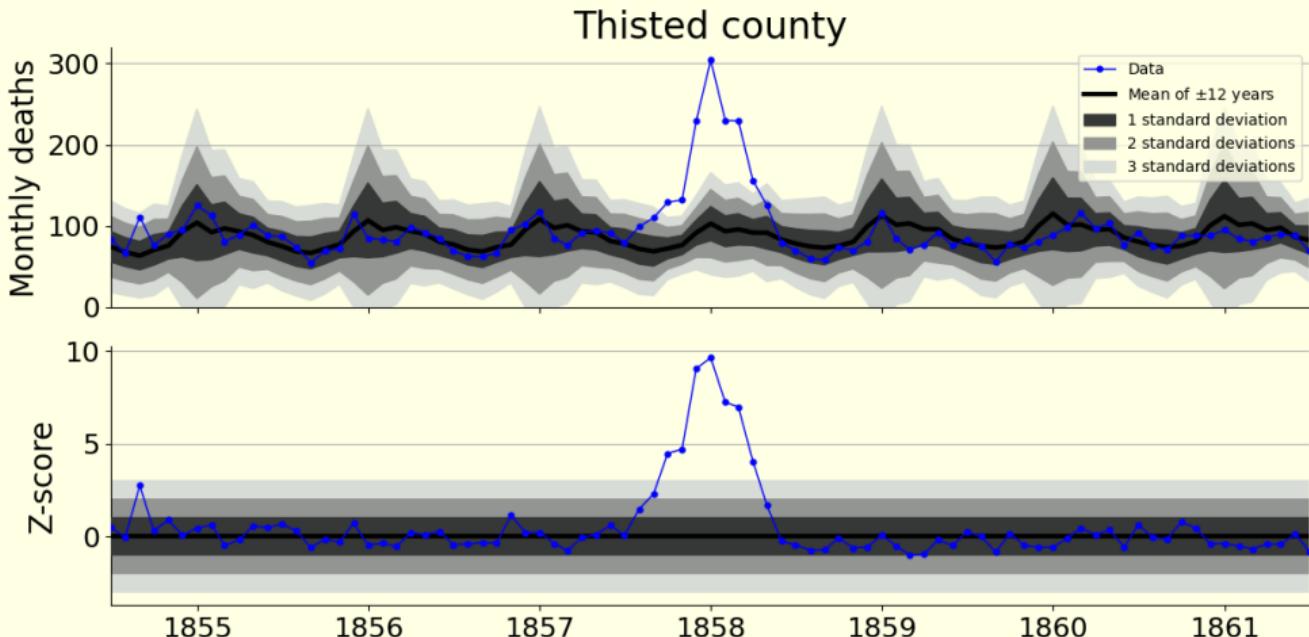
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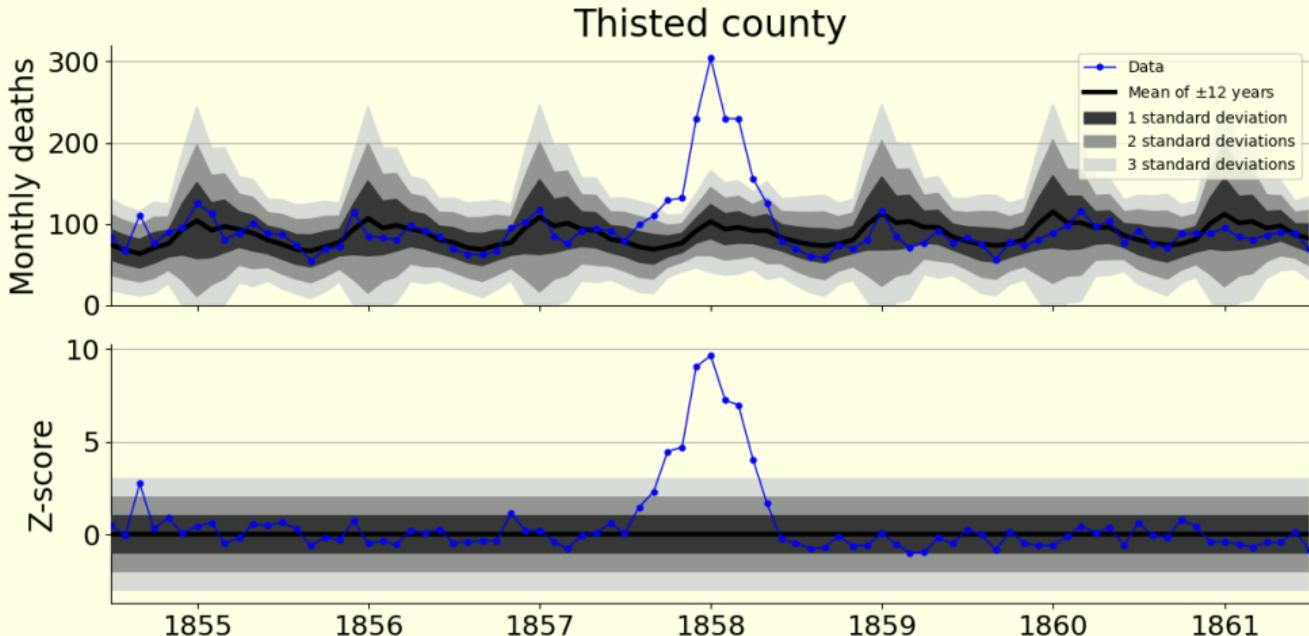
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From historical demography*: "Mortality crisis" when Z-score above two.

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

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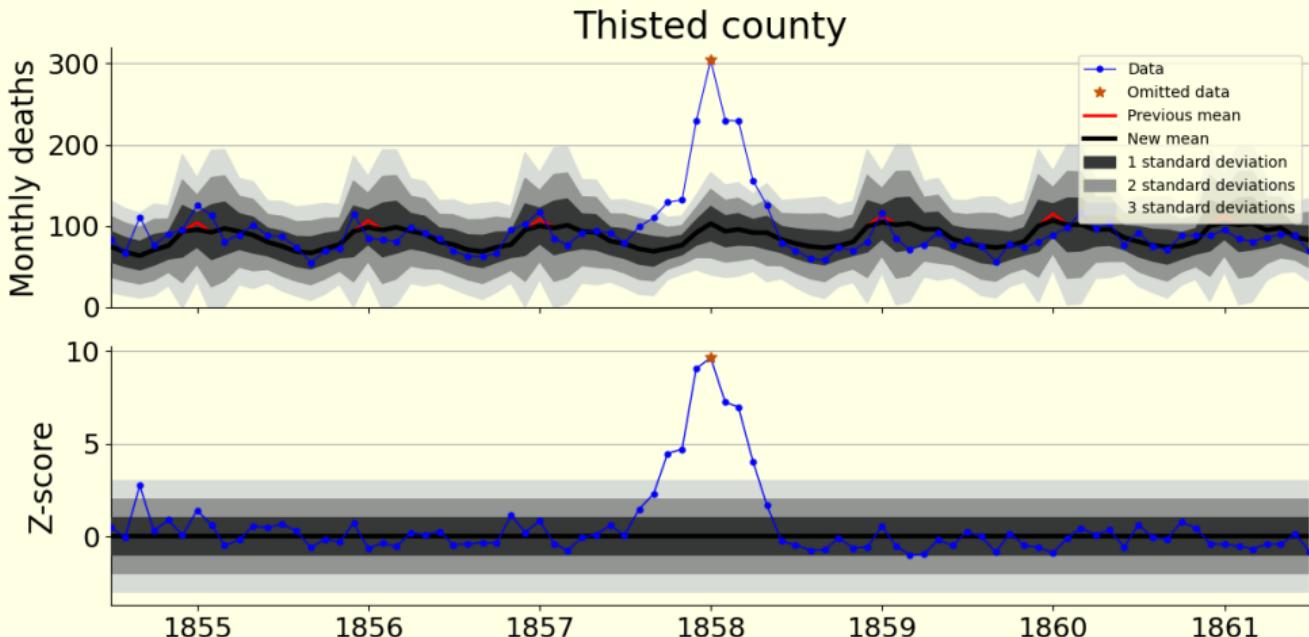
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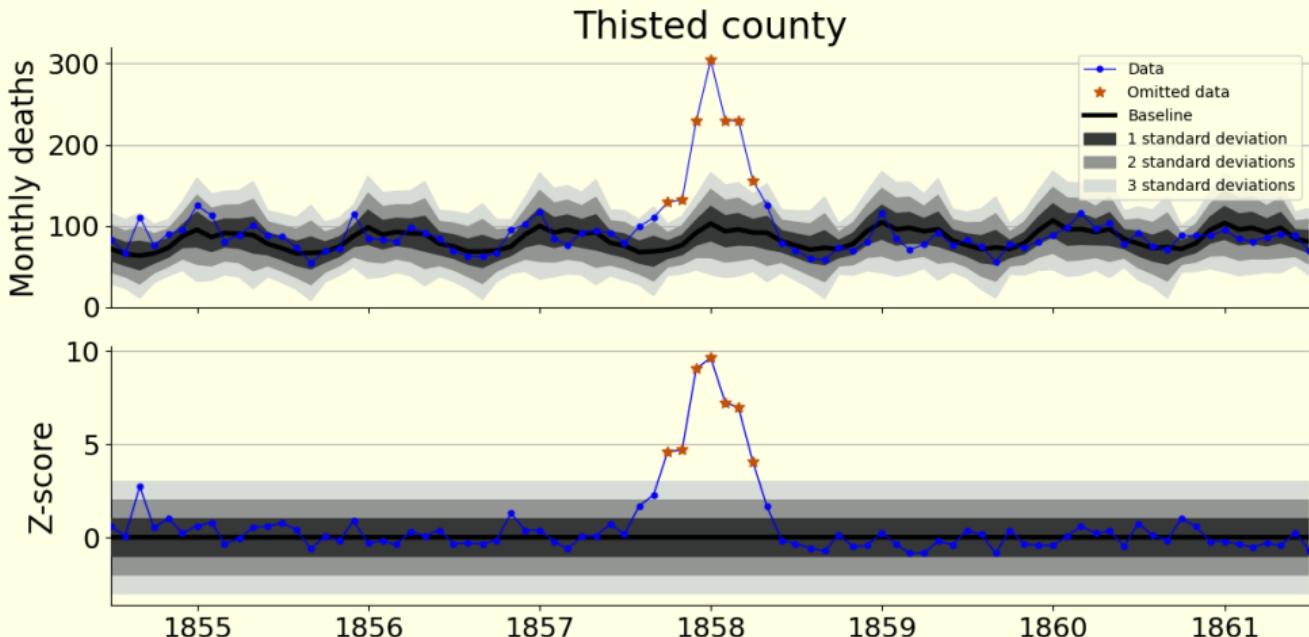
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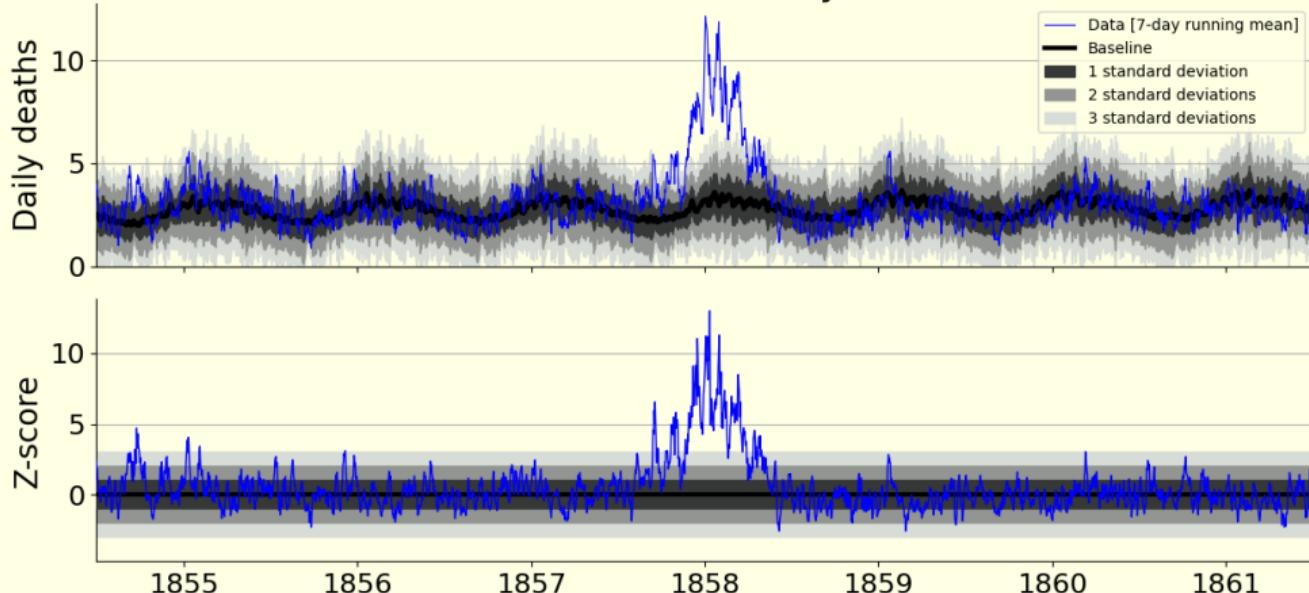
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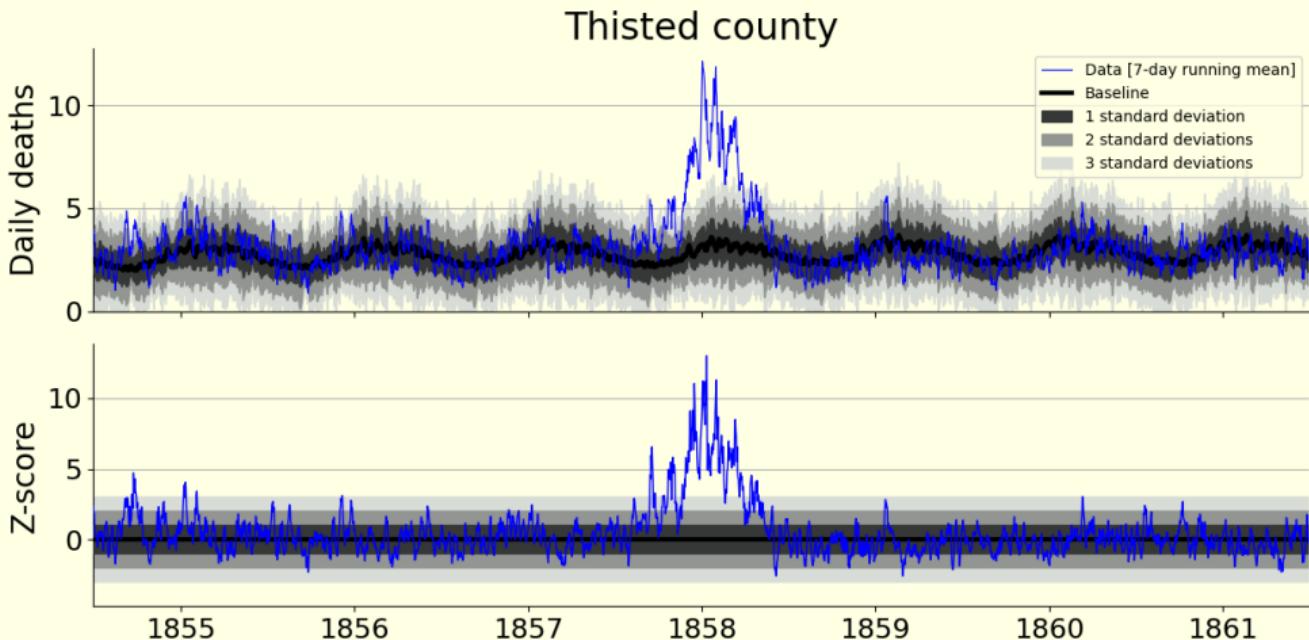
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We wish to identify continuous periods of excess mortality.

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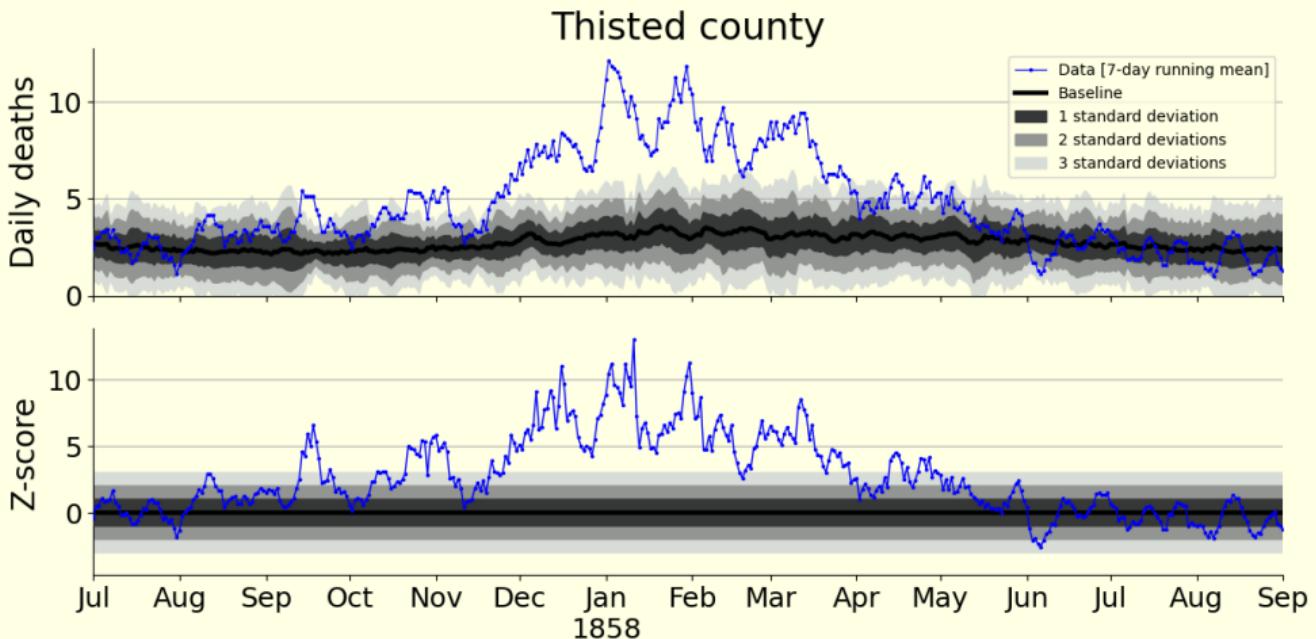
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Zooming in...

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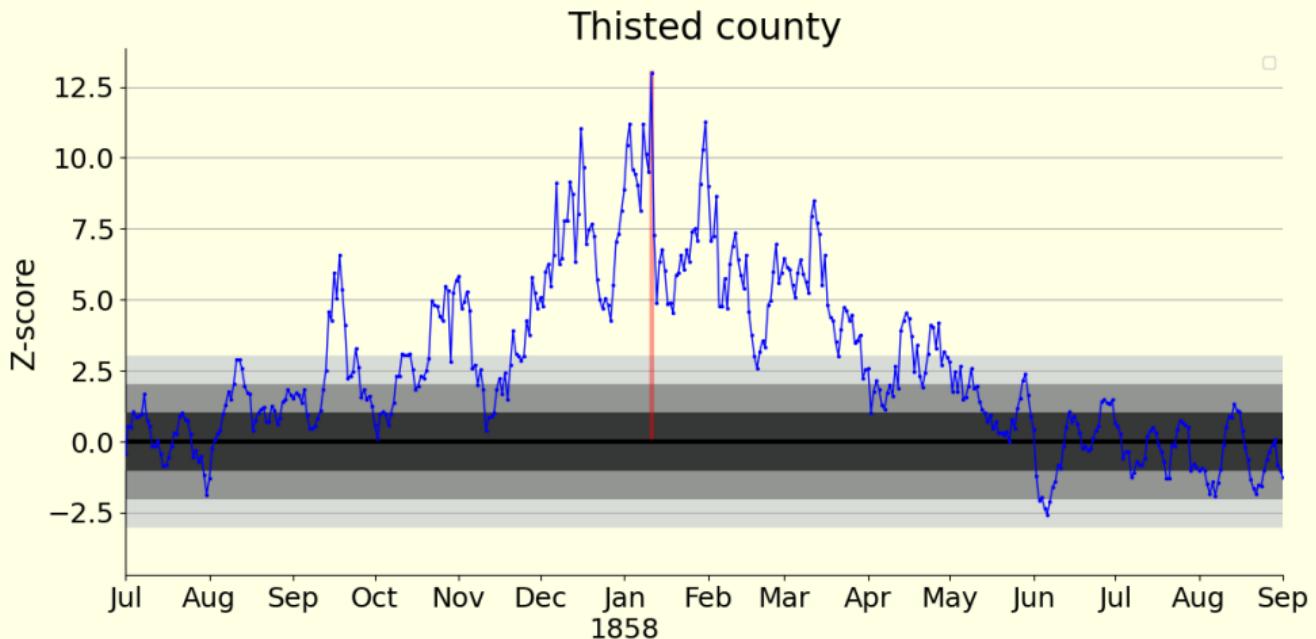
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Starting from the date with the highest Z-score...

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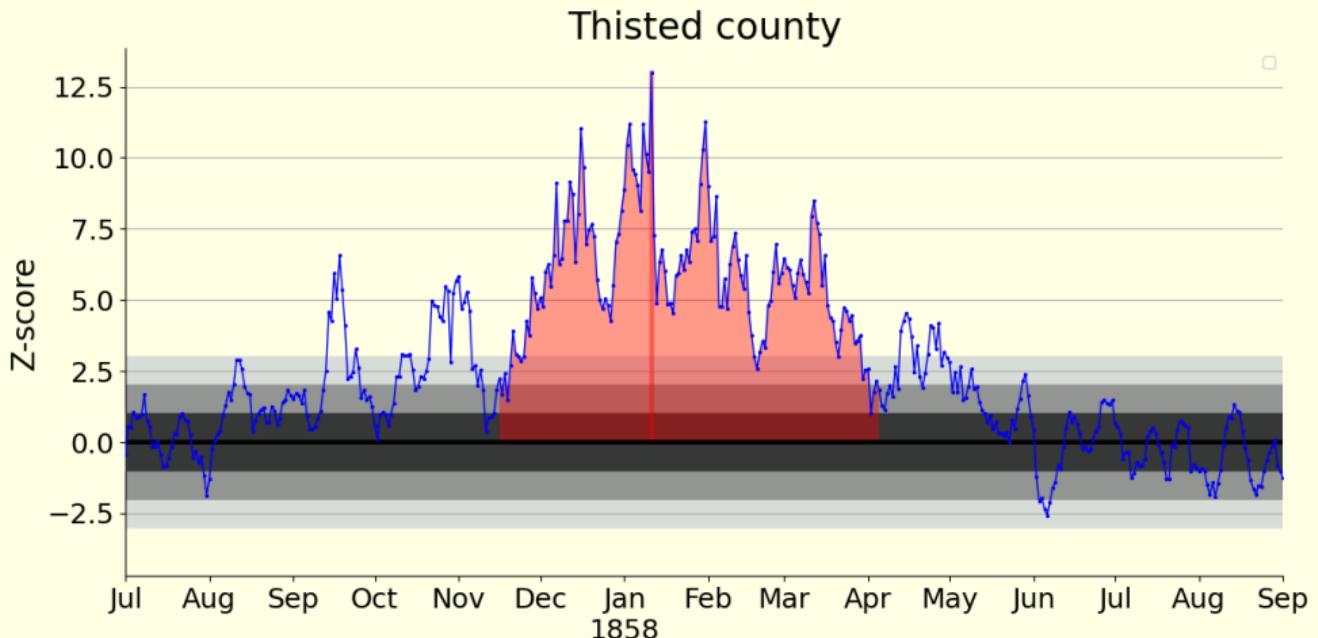
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... we group all days with Z-score above three, until the Z-score drops below two for four days or more.

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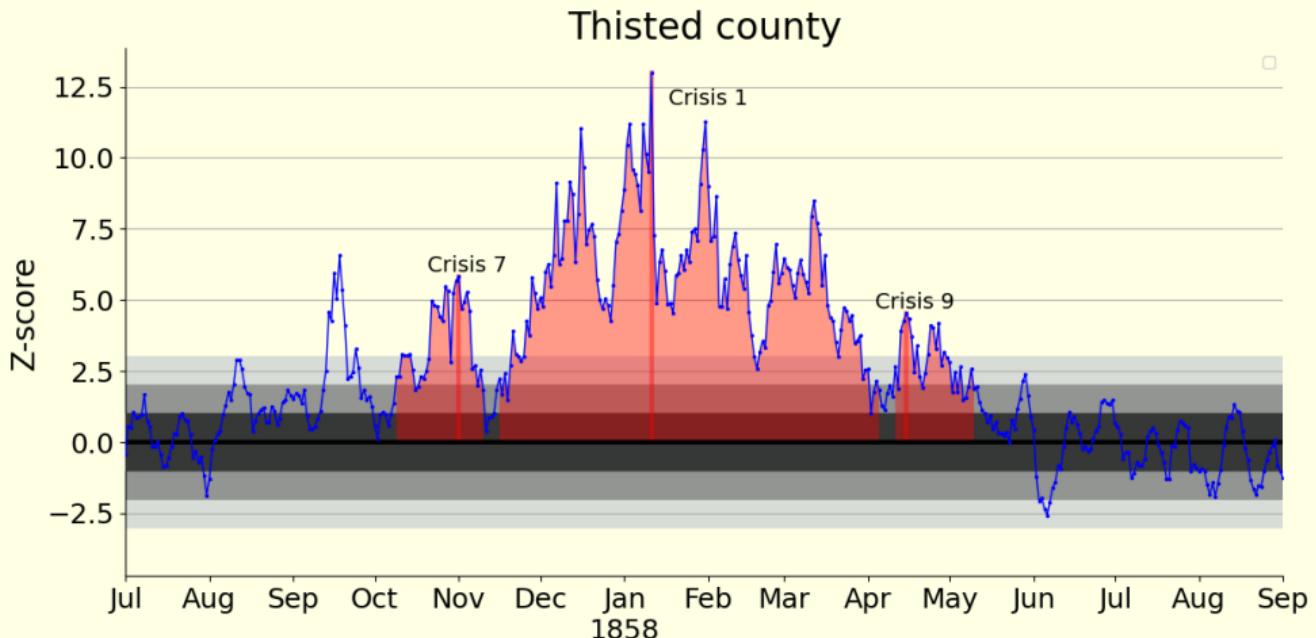
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All crises with at least seven days above the Z-score threshold of three are considered “mortality crises”.

Identifying main “signature features”

Identifying Excess Mortality

RK Pedersen

Using this methodology, we identify 418 mortality crises.

County	#			
Thisted	1			
Thisted	2			
Thisted	3			
:	:			
Copenhagen	1			
Copenhagen	2			
Copenhagen	3			
:	:			
Aarhus	1			
Aarhus	2			
:	:			

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Identifying main “signature features”

Identifying Excess Mortality

RK Pedersen

Using this methodology, we identify 418 mortality crises.

For each crisis,

County	#			
Thisted	1			
Thisted	2			
Thisted	3			
:	:			
Copenhagen	1			
Copenhagen	2			
Copenhagen	3			
:	:			
Aarhus	1			
Aarhus	2			
:	:			

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Identifying Excess Mortality

RK Pedersen

Using this methodology, we identify 418 mortality crises.

For each crisis,

- ▶ Peak-date.

<i>County</i>	#	<i>Peak-date</i>		
Thisted	1	1858-01-23		
Thisted	2	1892-01-23		
Thisted	3	1864-08-07		
:	:	:		
Copenhagen	1	1831-08-30		
Copenhagen	2	1891-12-13		
Copenhagen	3	1853-07-31		
:	:	:		
Aarhus	1	1892-01-06		
Aarhus	2	1853-08-24		
:	:	:		

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Identifying main "signature features"

Using this methodology, we identify 418 mortality crises.

For each crisis,

- ▶ Peak-date.
- ▶ Excess deaths.

Significant on a county level
(Population-sizes $\approx 100,000$).

<i>County</i>	<i>#</i>	<i>Peak-date</i>	<i>Total excess</i>	
Thisted	1	1858-01-23	655	
Thisted	2	1892-01-23	114	
Thisted	3	1864-08-07	105	
:	:	:	:	
Copenhagen	1	1831-08-30	592	
Copenhagen	2	1891-12-13	573	
Copenhagen	3	1853-07-31	552	
:	:	:	:	
Aarhus	1	1892-01-06	400	
Aarhus	2	1853-08-24	194	
:	:	:	:	

Identifying main "signature features"

Using this methodology, we identify 418 mortality crises.

For each crisis,

- ▶ Peak-date.
- ▶ Excess deaths.
Significant on a county level
(Population-sizes $\approx 100,000$).
- ▶ Duration.
e.g. "lasting two months"

<i>County</i>	<i>#</i>	<i>Peak-date</i>	<i>Total excess</i>	<i>Duration</i>
Thisted	1	1858-01-23	655	140 days
Thisted	2	1892-01-23	114	43 days
Thisted	3	1864-08-07	105	61 days
:	:	:	:	:
Copenhagen	1	1831-08-30	592	57 days
Copenhagen	2	1891-12-13	573	69 days
Copenhagen	3	1853-07-31	552	57 days
:	:	:	:	:
Aarhus	1	1892-01-06	400	61 days
Aarhus	2	1853-08-24	194	49 days
:	:	:	:	:

Identifying main "signature features"

Using this methodology, we identify 418 mortality crises.

For each crisis,

- ▶ Peak-date.
- ▶ Excess deaths.
Significant on a county level
(Population-sizes $\approx 100,000$).
- ▶ Duration.
e.g. "lasting two months"
- ▶ Timing and seasonality.
e.g. "peaking in winter" or
"late summer"

<i>County</i>	<i>#</i>	<i>Peak-date</i>	<i>Total excess</i>	<i>Duration</i>
Thisted	1	1858-01-23	655	140 days
Thisted	2	1892-01-23	114	43 days
Thisted	3	1864-08-07	105	61 days
:	:	:	:	:
Copenhagen	1	1831-08-30	592	57 days
Copenhagen	2	1891-12-13	573	69 days
Copenhagen	3	1853-07-31	552	57 days
:	:	:	:	:
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:	:	:	:	:

Identifying main "signature features"

Using this methodology, we identify 418 mortality crises.

For each crisis,

- ▶ Peak-date.
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Significant on a county level
(Population-sizes $\approx 100,000$).
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<i>County</i>	<i>#</i>	<i>Peak-date</i>	<i>Total excess</i>	<i>Duration</i>
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:	:	:	:	:
Aarhus	1	1892-01-06	400	61 days
Aarhus	2	1853-08-24	194	49 days
:	:	:	:	:

But we also have data on age.

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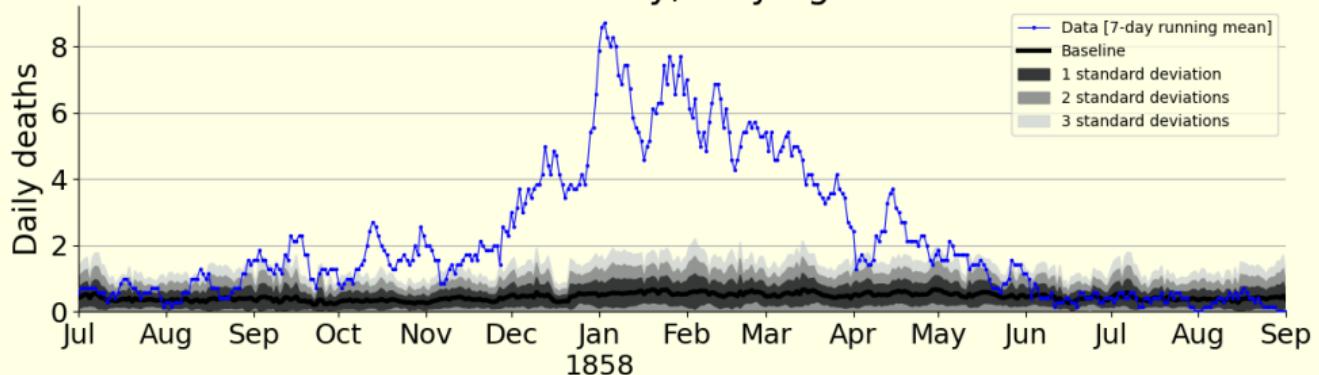
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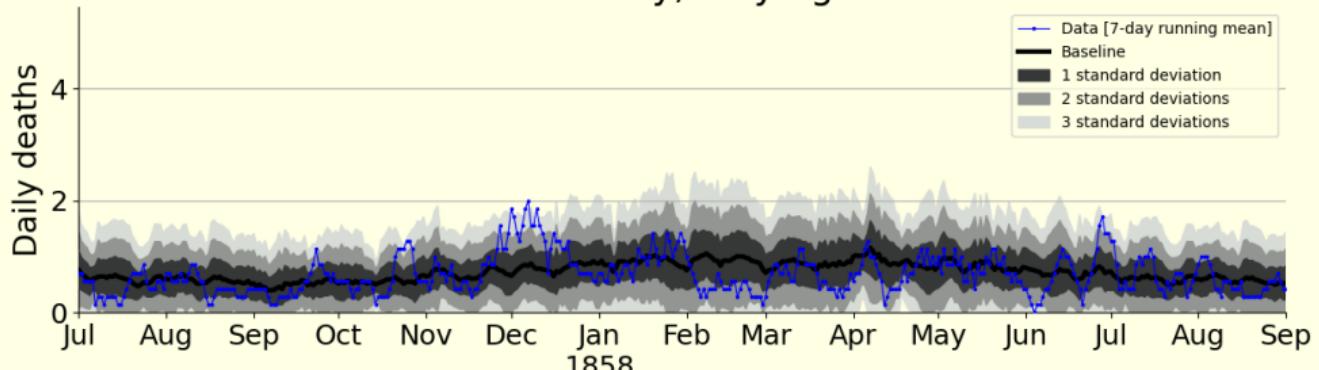
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Thisted county, only ages 1-14



Thisted county, only ages 60+



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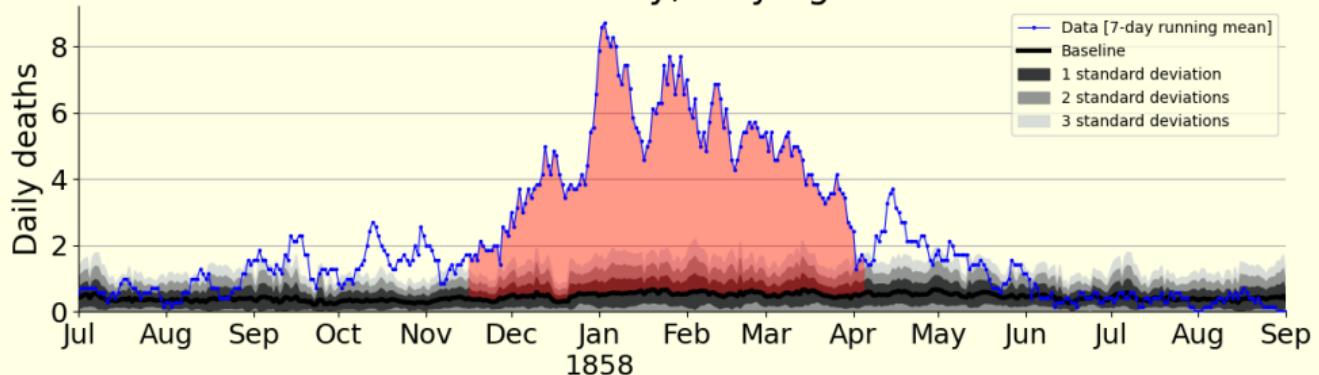
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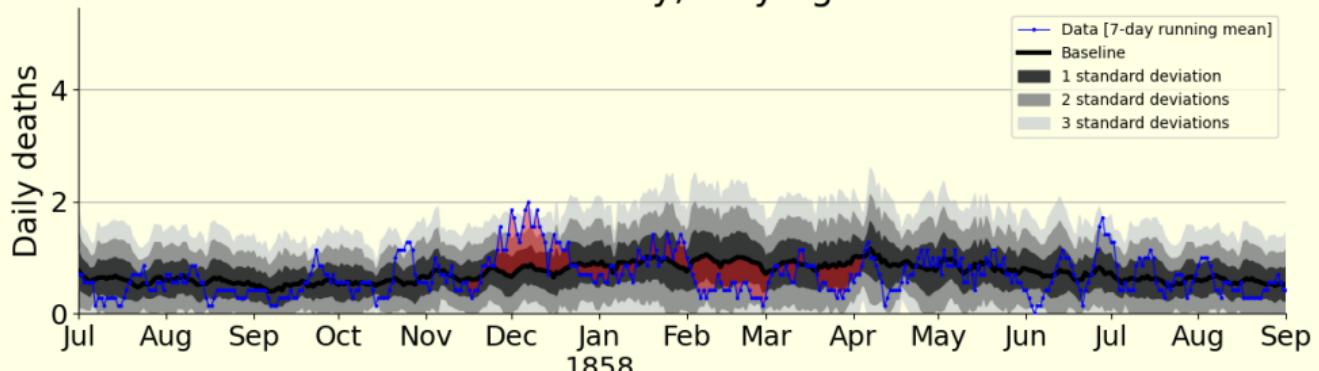
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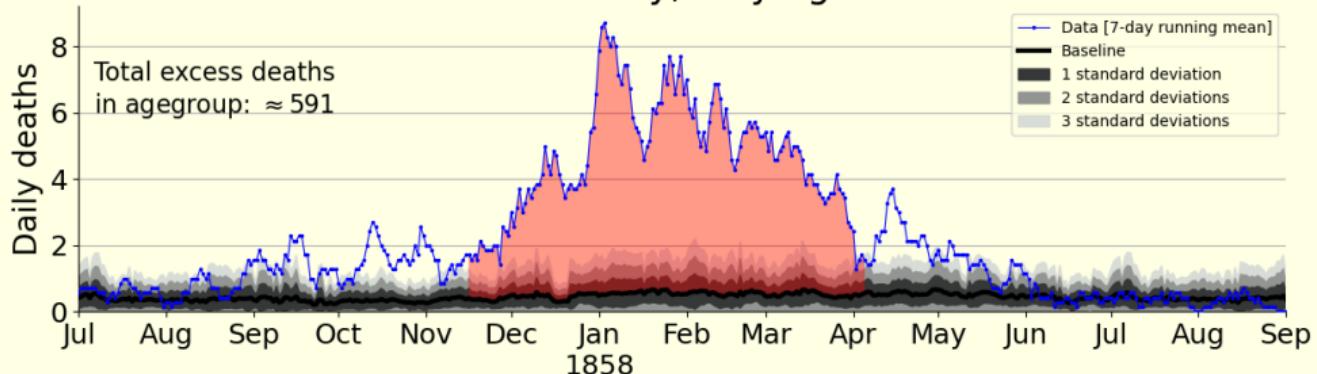
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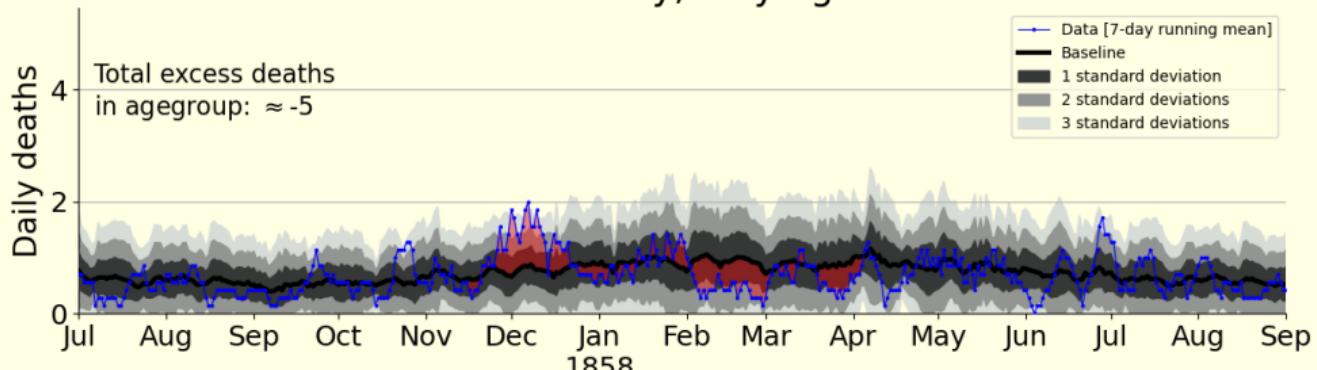
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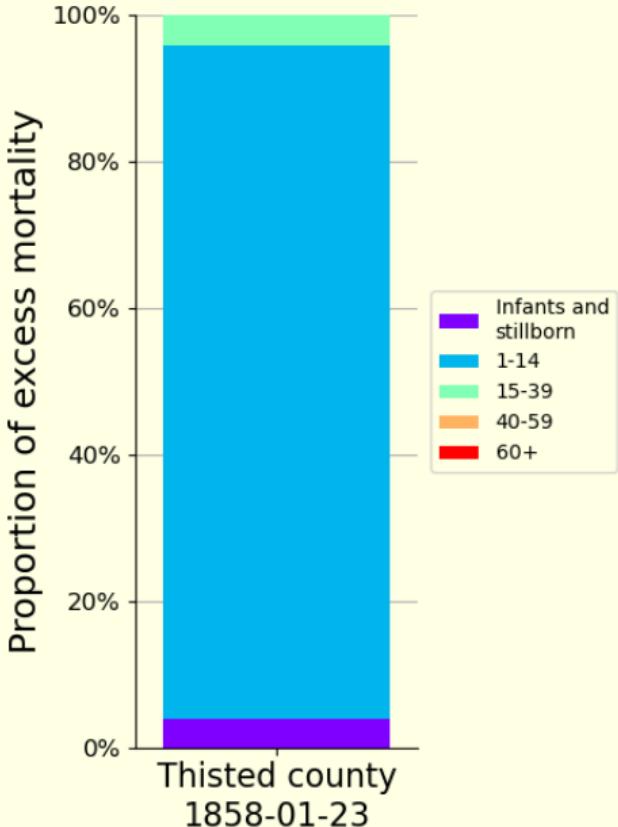
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Age-specific excess mortality in this period:

- ▶ Age group "60+": 0%
- ▶ 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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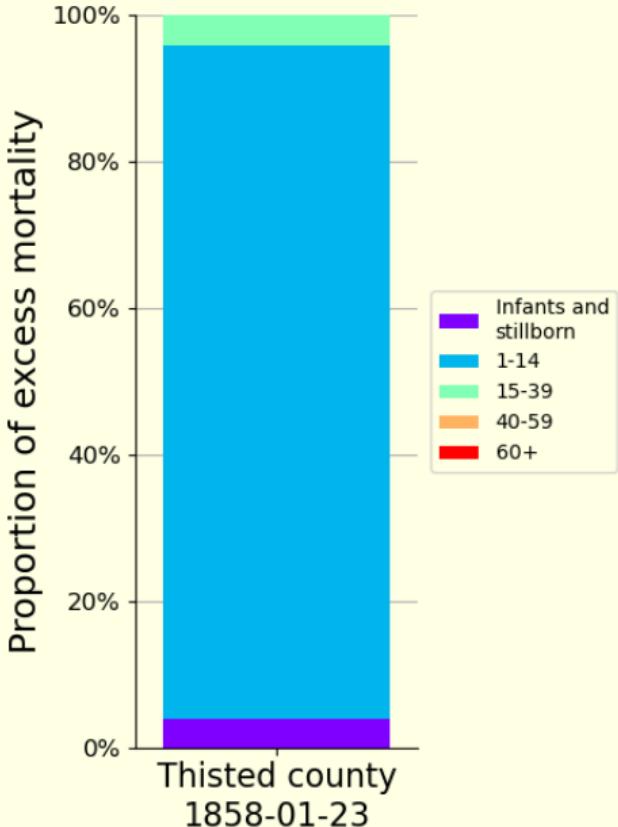
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- ▶ Age group "Below 1 year": 4%

Consider this a five-dimensional vector:

$$(0, 0, 0.03, 0.93, 0.04)$$

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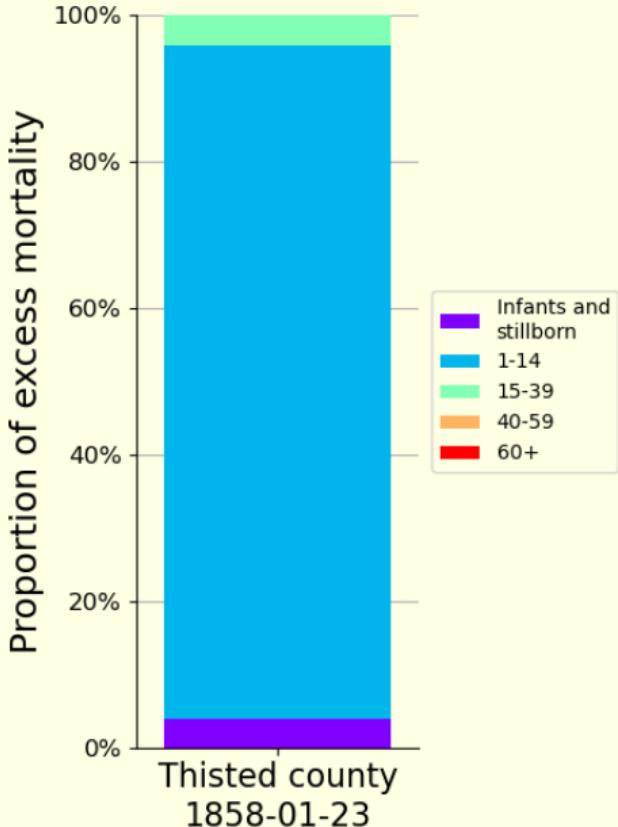
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- ▶ Age group "15-39": 3%
- ▶ Age group "1-14": 93%
- ▶ Age group "Below 1 year": 4%

Consider this a five-dimensional vector:

$$(0, 0, 0.03, 0.93, 0.04)$$

In terms of age groups "Below 1 year" and "1-14":

$$(0.04, 0.93)$$

In terms of age groups "40-59" and "60+":

$$(0, 0)$$

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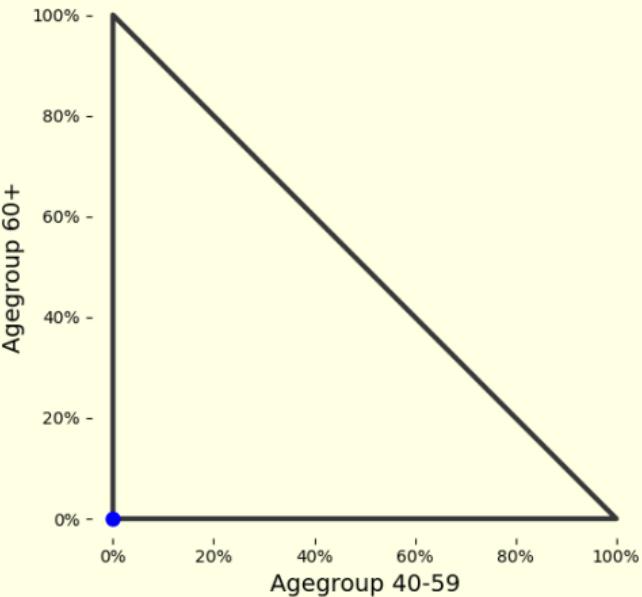
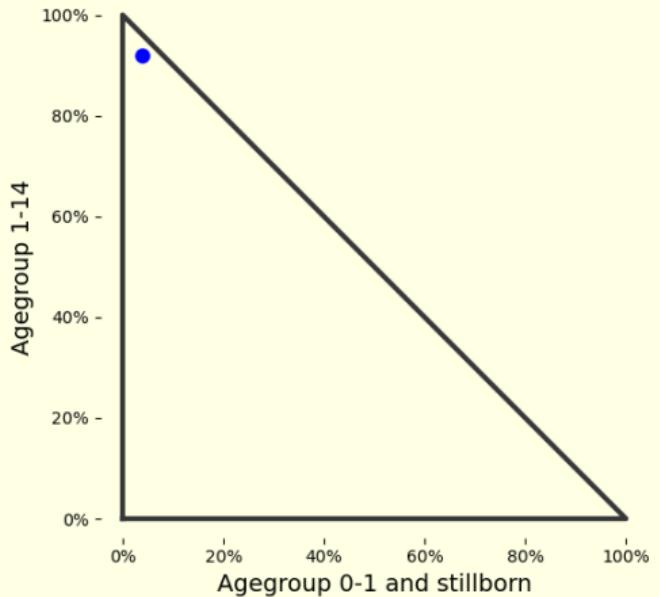
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(Age group "15-39" not shown here)

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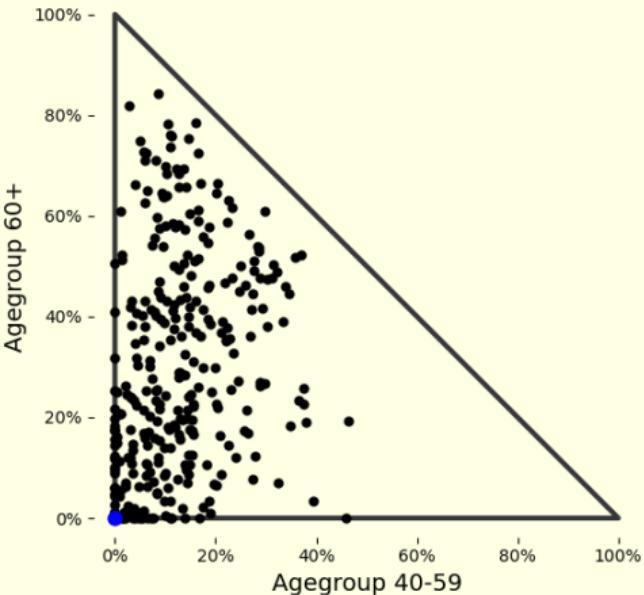
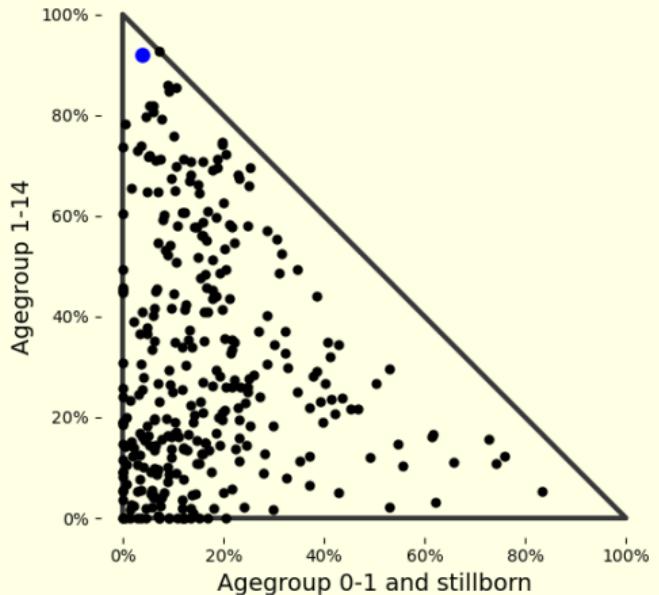
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Adding the other 417 mortality crises identified.

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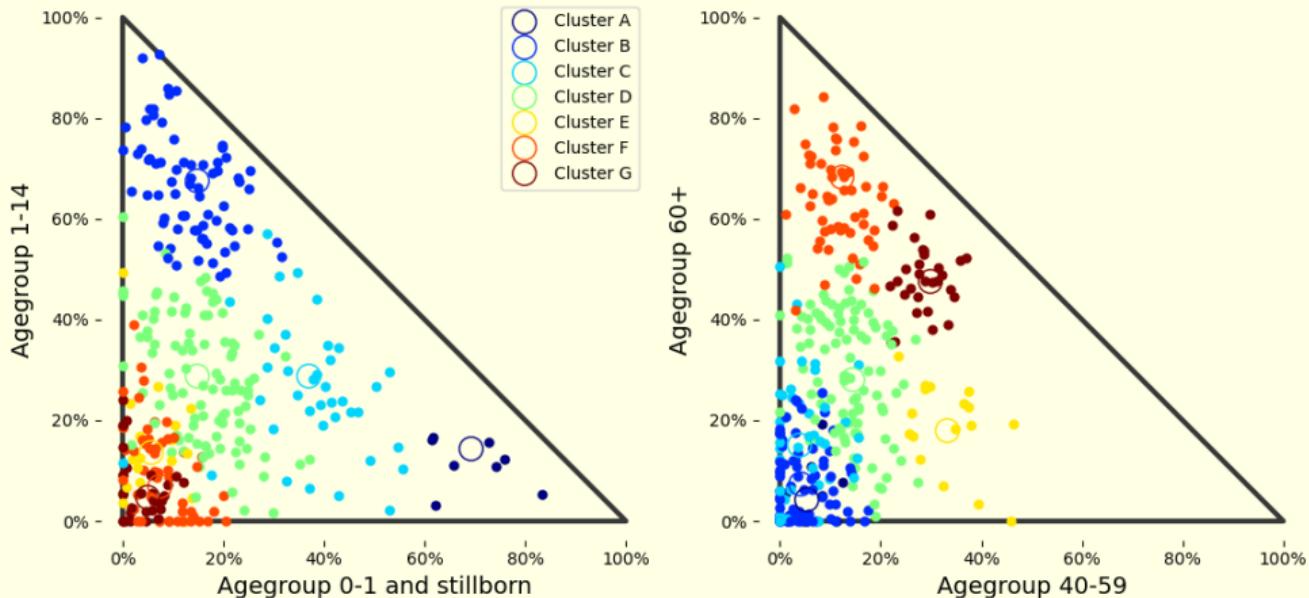
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Gaussian mixture modelling on full five-dimensional data.

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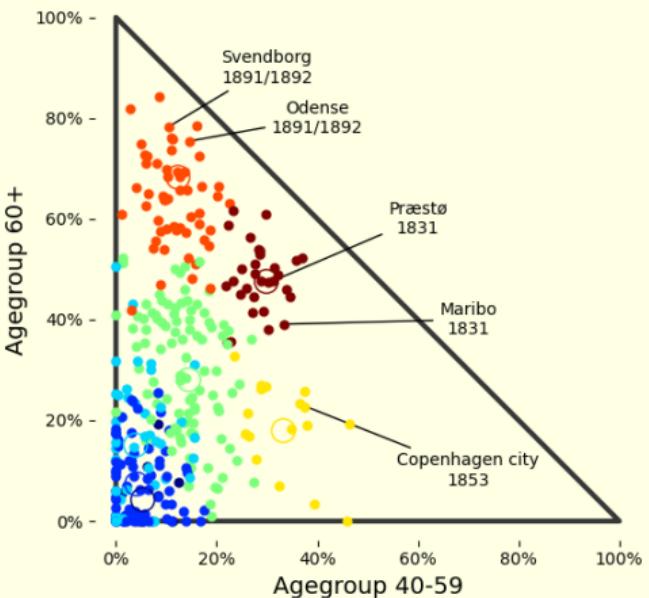
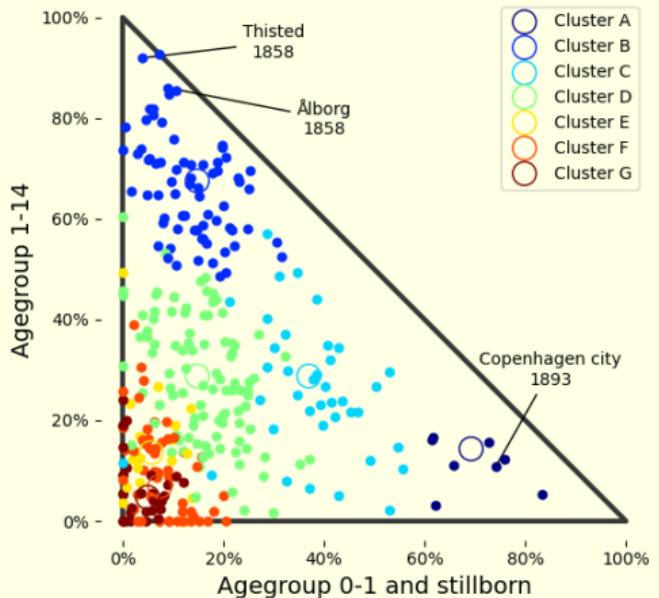
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Gaussian mixture modelling on full five-dimensional data.

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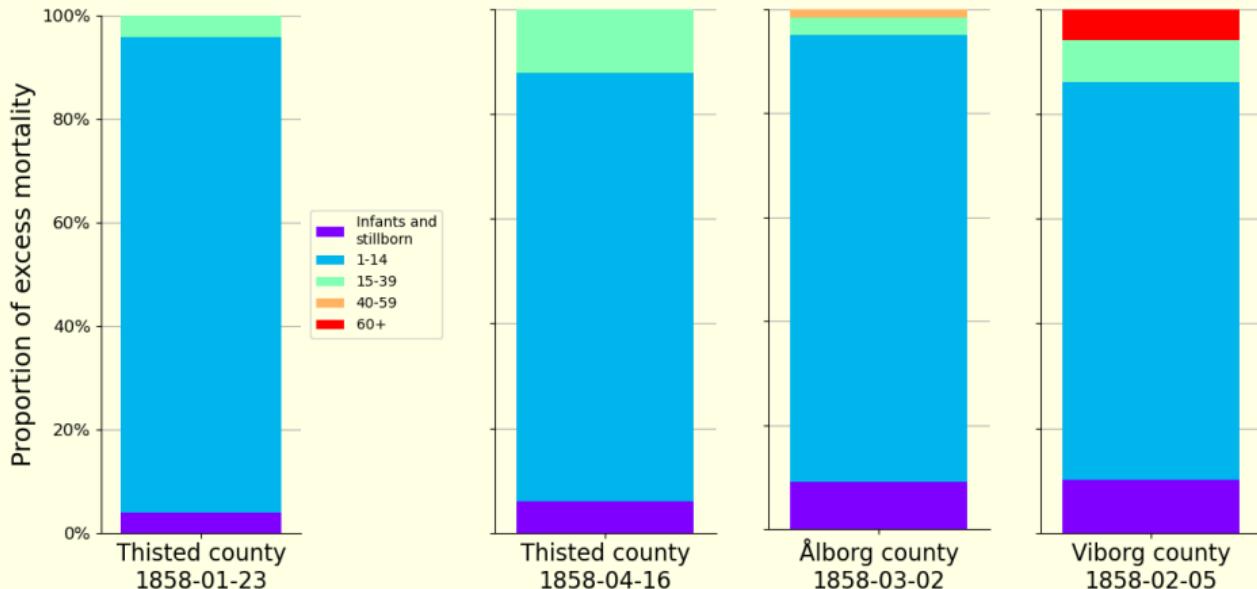
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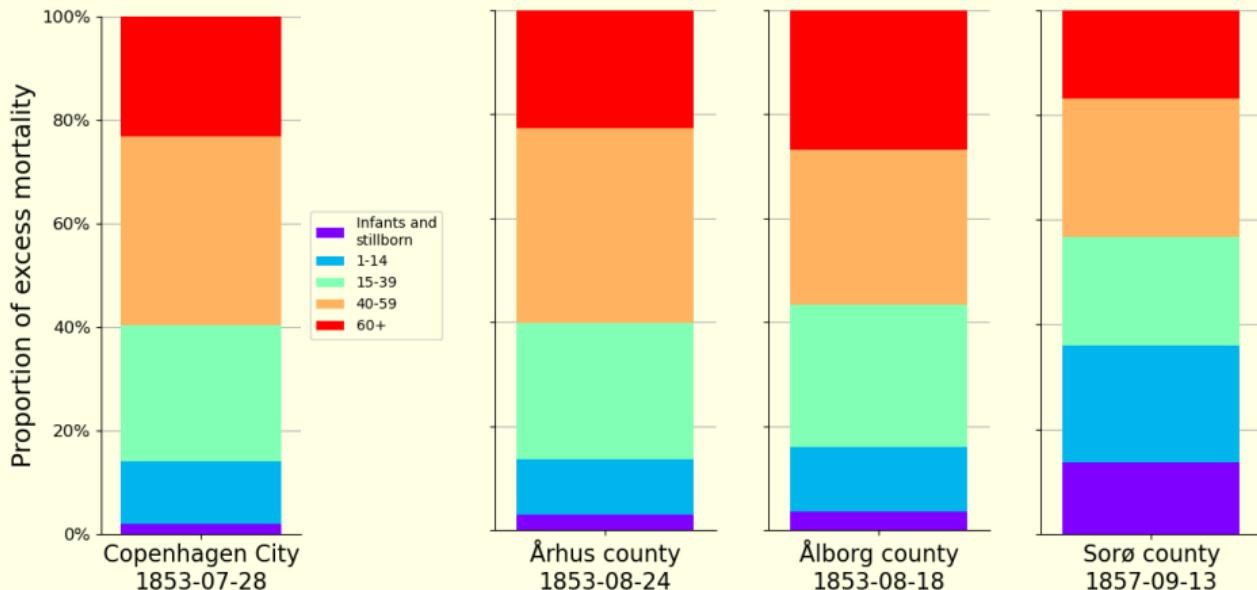
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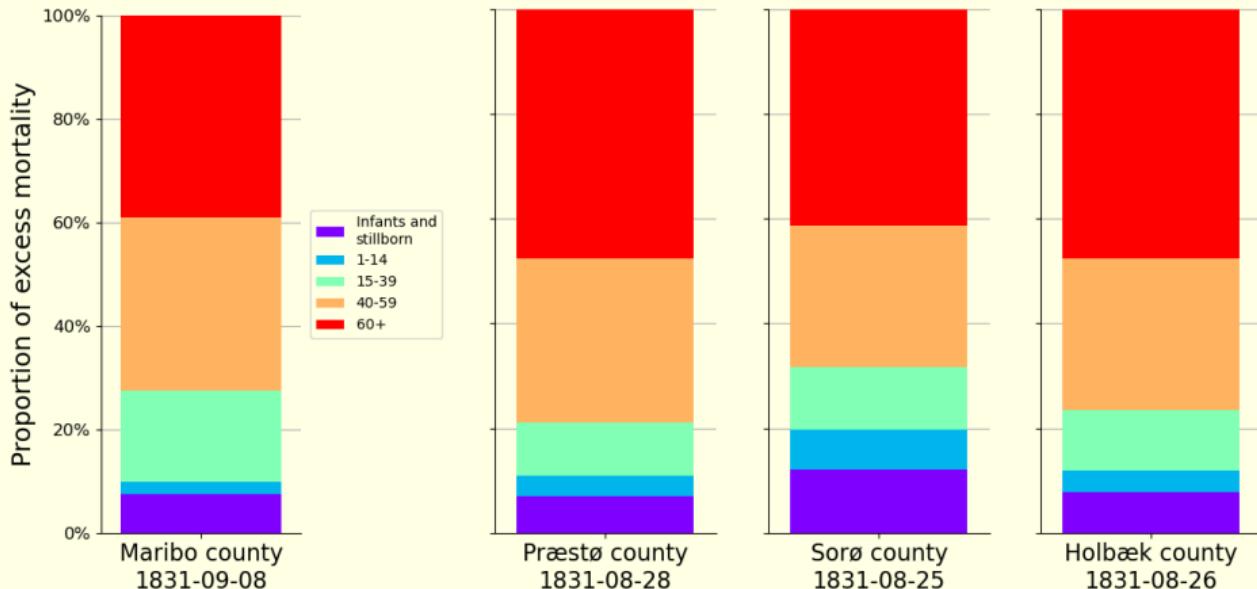
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The signature features of certain diseases

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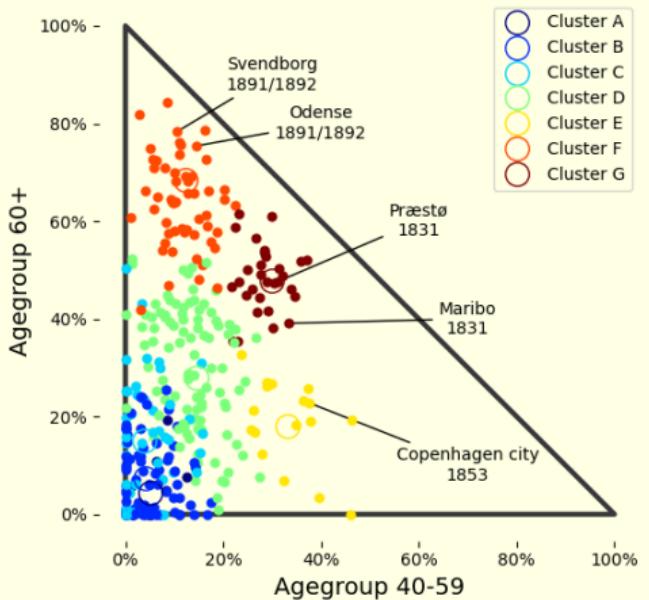
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Comparing age patterns

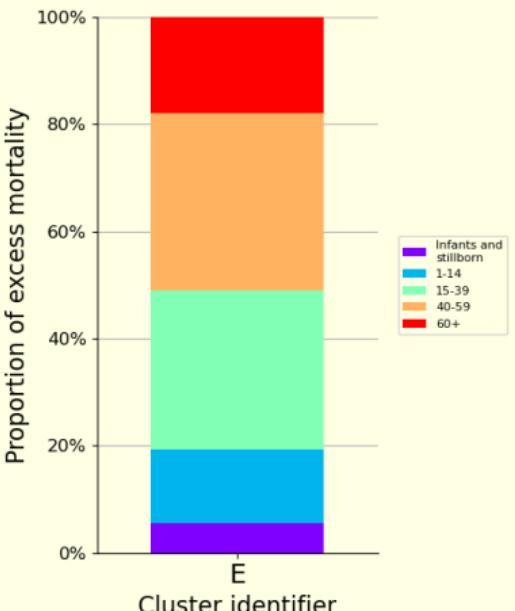
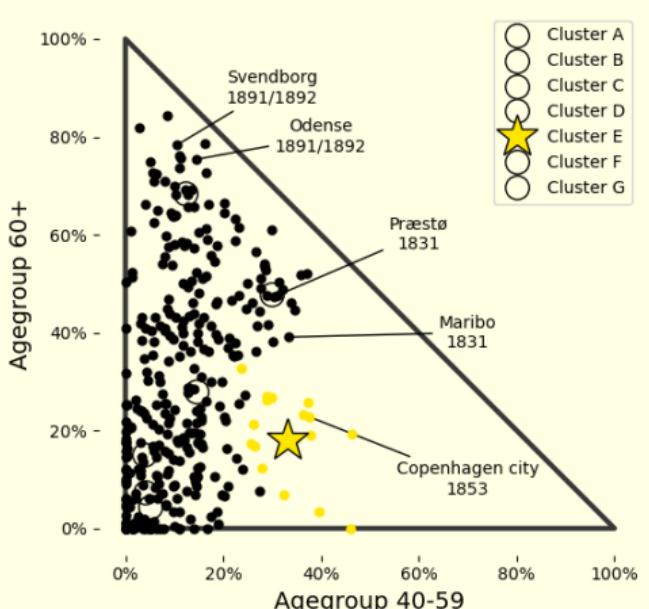
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Multiple of the mortality crises in cluster E appear to be related to **cholera**.

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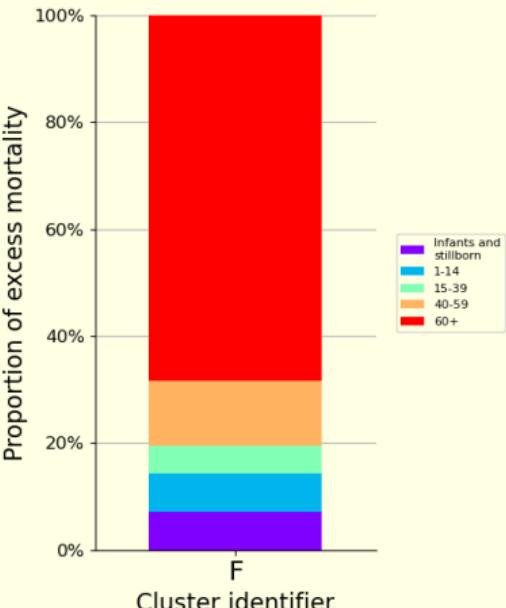
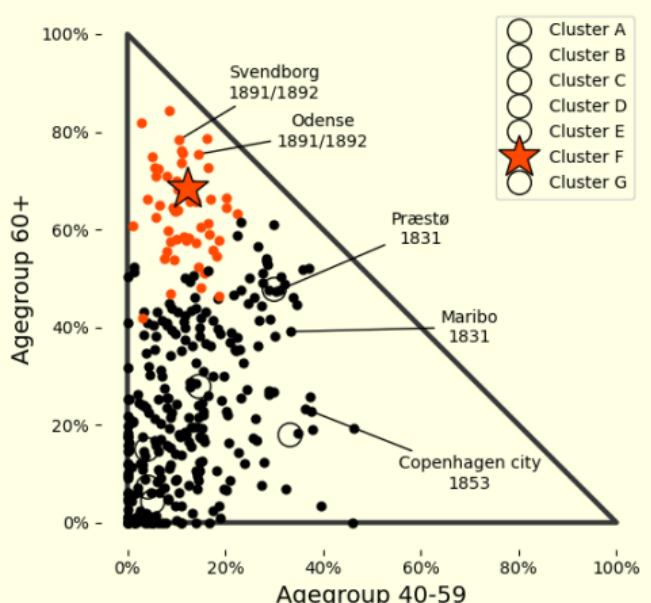
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Multiple of the mortality crises in cluster F appear to be related to **pandemic influenza**.

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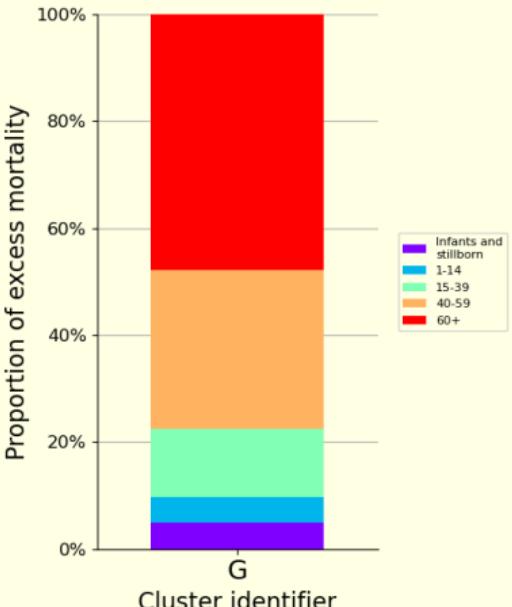
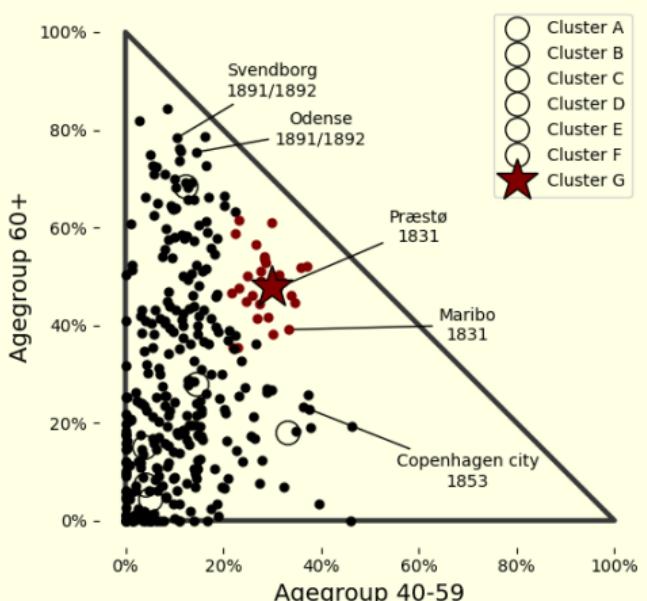
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Multiple of the mortality crises in cluster G appear to be related to “**the Harvest epidemics of 1826-1832**”.

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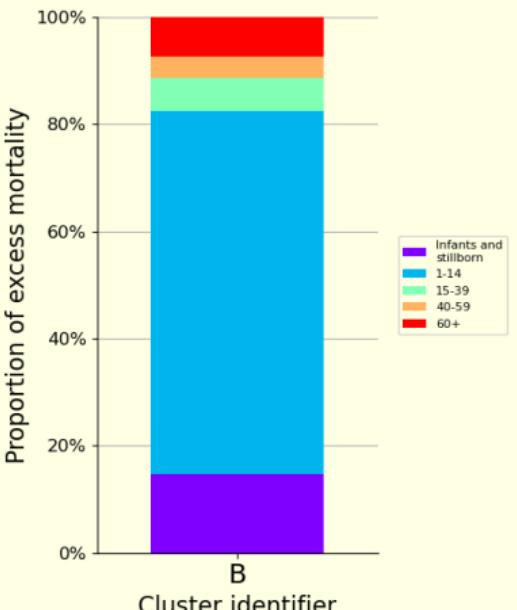
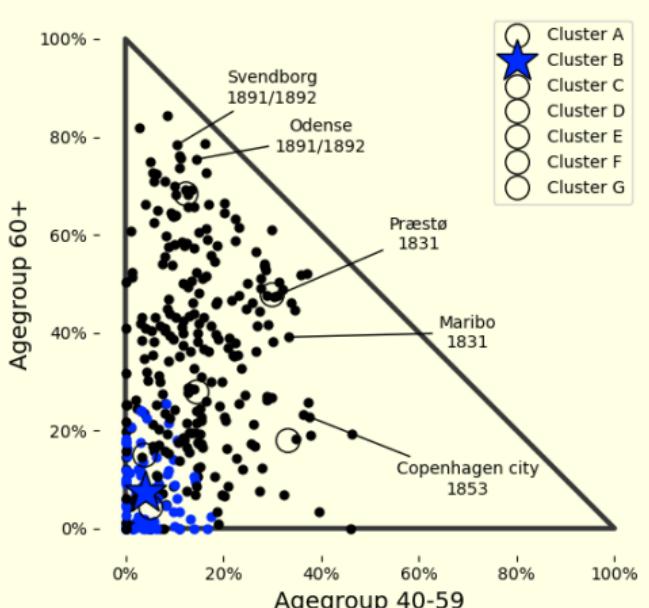
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Multiple of the mortality crises in cluster B appear to be related to **scarlet fever**.

All epidemics and pandemics in 19th century Denmark

Identifying Excess Mortality

RK Pedersen

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Disease	Timing	Total excess	Age structure
Cholera	Late summer, 1853 and 1857	5381	Adults Cluster "E"
Scarlet fever	Winter 1857/1858	2451	Children (1-15) Cluster "B"
"Harvest epidemics"¹	Late summer, 1826-1832	10818	Adults Cluster "G"
Pandemic influenza	1892 and 1900	8201	Elderly Cluster "F"

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

¹ Various diseases, aggravated by a subsistence crisis. Discussed in detail by Ingholt (2022) *Scandinavian Journal of History*

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- We determine mortality baselines on county-level, using an iterative process to omit outliers and estimate excess mortality.

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- ▶ We determine mortality baselines on county-level, using an iterative process to omit outliers and estimate excess mortality.
- ▶ We identify 418 major mortality crises in 19th century Denmark.

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- ▶ We determine mortality baselines on county-level, using an iterative process to omit outliers and estimate excess mortality.
- ▶ We identify 418 major mortality crises in 19th century Denmark.
- ▶ For each crisis, we determine signature features:

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- ▶ For each crisis, we determine signature features:
 - ▶ Age-patterns.

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 - ▶ Timing and seasonality.

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- ▶ We determine mortality baselines on county-level, using an iterative process to omit outliers and estimate excess mortality.
- ▶ We identify 418 major mortality crises in 19th century Denmark.
- ▶ For each crisis, we determine signature features:
 - ▶ Age-patterns.
 - ▶ Timing and seasonality.
 - ▶ Duration.
 - ▶ Geography.
- ▶ 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.

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- Similar methods could be applied to modern data.

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- ▶ Similar methods could be applied to modern data.
 - ▶ Clustering of age-patterns in modern all-cause mortality data.
A wide range of methods for clustering exists, see e.g. `scikit-learn` for python.

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 - ▶ Excess mortality calculation.
Python library, available on GitHub: github.com/PandemiXCenter/ExcessMortality

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Python library, available on GitHub: github.com/PandemiXCenter/ExcessMortality
- ▶ Despite demographic differences between 19th century Denmark and modern times, the age patterns in the 19th century may be similar for modern epidemics.

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 - ▶ Excess mortality calculation.
Python library, available on GitHub: github.com/PandemiXCenter/ExcessMortality
- ▶ Despite demographic differences between 19th century Denmark and modern times, the age patterns in the 19th century may be similar for modern epidemics.
- ▶ As more historical data are transcribed, e.g. using computer vision technology, similar studies of other countries will become possible.



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.

DOI: 10.1093/aje/kwae187



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