

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

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Joint work with

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Viggo Andreasen & Lone Simonsen*

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Danmarks
Grundforskningsfond
Danish National
Research Foundation

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



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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.



Image from The New York Times article "*The Mask Slackers of 1918*", Aug. 3, 2020
<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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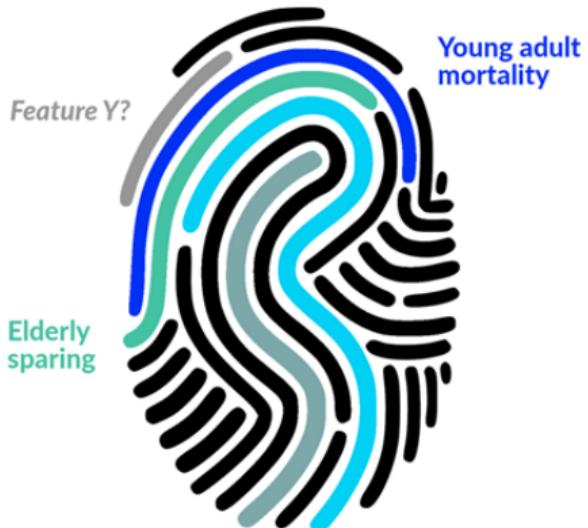
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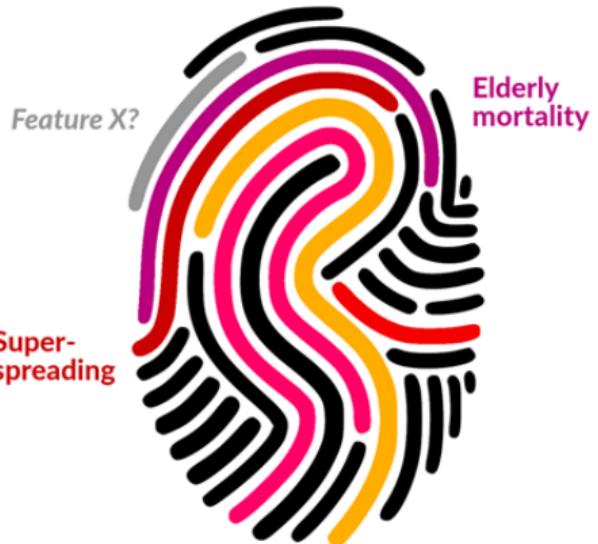
- ▶ Historical data provides us with more examples of epidemics than modern data alone.
- ▶ Our response to emerging diseases come from historical experience.
 - ▶ Quarantine - e.g. plague
 - ▶ Restriction of movement (*cordon sanitaire*) - e.g. cholera
 - ▶ Social distancing - e.g. 1918 influenza
 - ▶ Masks - e.g. 1918 influenza
- ▶ The pandemics of recent years may only be a subset of potential threats to consider for surveillance.



1918 Influenza



SARS-CoV-2



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In this talk, I will talk about:

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



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In this talk, I will talk about:

- ▶ Our recent study of epidemics in 19th century Denmark.
- ▶ Mortality baseline calculation.



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- ▶ Our recent study of epidemics in 19th century Denmark.
- ▶ Mortality baseline calculation.
- ▶ Age pattern analysis.



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In this talk, I will talk about:

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



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No.	Dødsdagen.	Begravelsedagen.	Den Dødes Navn og tilnavn.	Stand, Haandtering og Befolkningsd.	Ålder.	Hvad an- ført i det almindeligt ge. Den foretak Register.	Emner
35.	29. August	4. Sept.	Anders Jørgensen	Gjort i Fredericia	53 Års	692. 138	
36.	31. August	4. Sept.	Hans Carlsen	Først i Skælskør	63 Års	692. 139	
37.	30. August	3. Sept.	Ole Jensen	Møgelmose i Gladsaxe	39 Års	692. 140	
38.	3. Sept.	7. Sept.	Olger Larsen	Gjort i Fredericia	70 Års	692. 141	
39.	31. August	4. Sept.	Hans Olesen	Gjort og bort i Fredericia	42 Års	692. 142	
40.	4. Sept.	6. Sept.	Niels Pedersen	Først i Fredericia	61 Års	692. 143	
41.	5. Sept.	9. Sept.	Ole Hansen	Møgelmose i Fredericia	63 Års	692. 144	
42.	4. Sept.	9. Sept.	Niels Christensen	Gjort i Fredericia	57 Års	692. 145	
43.	7. Sept.	12. Sept.	Niels Larsen	Gjort i Fredericia	80 Års	692. 146	
44.	6. Sept.	12. Sept.	Jens Andersen	Gjort i Fredericia	70 Års	692. 147	
45.	8. Sept.	13. Sept.	Hans Lethsen	Gjort i Fredericia	42 Års	692. 148	
46.	5. Sept.	9. Sept.	Lars Christoffersen	Møgelmose i Fredericia	9.3. Års	692. 149	
47.	12. Sept.	16. Sept.	Anders Hansen	Gjort i Fredericia	78 Års	692. 150	
48.	11. Sept.	14. Sept.	Thorkil Hansen	Gjort i Fredericia	49 Års	692. 151	



Data source

- Parish registers for Danish church parishes between 1815-1915

MS 1831

Døde.

Ramfjord.

Sn.	Baptistes.	Bartidestedsen.	Barnets navn og tilnavn.	Faderens navn.	Moderens navn.	Tænkningerne.
25	18. Februar	Johannes	Lindore Brondsen	Johannes Lindore		Bladslagt 34
26	31. Januar	Auguste	Hans Carlsten	Hans Carlsten		Bladslagt 154
27	30. Januar	3. marts	Ole Jensen	Ole Jensen		Bladslagt 167
28	3. Februar	7. marts	Hager Larsen	Hager Larsen		Bladslagt 140
29	31. Januar	4. marts	Hans Olsen	Hans Olsen		Bladslagt 195
30	1. Februar	6. marts	Niels Andersen	Niels Andersen		Bladslagt 188
31	3. Februar	9. marts	Ole Hansen	Ole Hansen		Bladslagt 180
32	4. Februar	9. marts	Niels Carlsten	Niels Carlsten		Bladslagt 180
33	7. Februar	11. marts	Ole Larsen	Ole Larsen		Bladslagt 167
34	10. Februar	1. april	Jens Andersen	Jens Andersen		Bladslagt 167
35	13. Februar	1. april	Jens Andersen	Jens Andersen		Bladslagt 167
36	16. Februar	1. april	Hans Leth	Hans Leth		Bladslagt 167
37	19. Februar	1. april	Jens Andersen	Jens Andersen		Bladslagt 167
38	22. Februar	1. april	Hans Leth	Hans Leth		Bladslagt 167
39	25. Februar	1. april	Jens Andersen	Jens Andersen		Bladslagt 167
40	1. Marts	1. april	Jens Andersen	Jens Andersen		Bladslagt 167
41	4. Marts	1. april	Jens Andersen	Jens Andersen		Bladslagt 167
42	7. Marts	1. april	Jens Andersen	Jens Andersen		Bladslagt 167
43	10. Marts	1. april	Jens Andersen	Jens Andersen		Bladslagt 167
44	13. Marts	1. april	Jens Andersen	Jens Andersen		Bladslagt 167
45	16. Marts	1. april	Jens Andersen	Jens Andersen		Bladslagt 167
46	19. Marts	1. april	Jens Andersen	Jens Andersen		Bladslagt 167

Scan of parish register for "Fakse" parish.

Data source

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

MS 1831

Døde.

Ramfjord.

nr.	Eddato.	Navn	Dødested	Dødsårsak	Ålder	Bemærk.
25.	1. Februar	Jørgen Lindner	Lindner	Avd i Hjelteby	58	Udskrift fra 1860
26.	3. Februar	Hans Carlsten		Avd i Hjelteby	59	Udskrift fra 1860
27.	30. Januar	3. jætte	Ø. Jensen	Udskrivne i Hjelteby	94	Udskrift fra 1860
28.	3. Februar	7. jætte	Hans Larsen	gæst i Hjelteby	100	Udskrift fra 1860
29.	31. Januar	4. jætte	Hans Olof	gæst og døde i Hjelteby	100	Udskrift fra 1860
30.	1. Februar	Ø. Jætte	Niels Andersen	Avd i Hjelteby	66	Udskrift fra 1860
31.	3. Februar	9. jætte	Ø. Hansen	Udskrivne i Hjelteby	66	Udskrift fra 1860
32.	4. Februar	9. jætte	Niels Carlsten	Avd i Hjelteby	66	Udskrift fra 1860
33.	7. Februar	B. Jætte	Ø. Niels Larsen	gæst i Hjelteby	66	Udskrift fra 1860
34.	10. Februar	B. Jætte	Jens Andersen	Udskrivne i Hjelteby	66	Udskrift fra 1860
35.	8. Februar	3. jætte	Hans Løgten	Avd i Hjelteby	66	Udskrift fra 1860
36.	3. marts	9. jætte	Niels Christensen	Udskrivne i Hjelteby	66	Udskrift fra 1860
37.	11. marts	11. jætte	M. Hansen	Udskrivne i Hjelteby	66	Udskrift fra 1860
38.	11. marts	14. jætte	Hans Larsen	gæst i Hjelteby	66	Udskrift fra 1860

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.	Navn	Bartidpladsen	Døds dato og tilhører	Døds årsak og dødsform	Begravelsessted	Begravelses dato
25.	Jørgen	S. Jørgen	Larsen, Christensen	Avd i 30. alder	Bur i Fakse Kirke	1831. Sept. 24
26.	31. Søgård	Ø. Søgård	Hans Christensen	Bur i Fakse Kirke	Begravelsestid 1831. Sept. 24	1831. Sept. 24
27.	30. Søgård	3. Søgård	Ø. Søgård	Begravelsestid 1831. Sept. 24	Begravelsestid 1831. Sept. 24	1831. Sept. 24
28.	3. Søgård	7. Søgård	Hans Christensen	Avd i 30. alder	Bur i Fakse Kirke	1831. Sept. 24
29.	31. Søgård	4. Søgård	Hans Christensen	Avd i 30. alder	Bur i Fakse Kirke	1831. Sept. 24
30.	Ø. Søgård	Ø. Søgård	Vilh. Andersen	Bur i Fakse Kirke	Begravelsestid 1831. Sept. 24	1831. Sept. 24
31.	3. Søgård	9. Søgård	Ø. Søgård	Begravelsestid 1831. Sept. 24	Begravelsestid 1831. Sept. 24	1831. Sept. 24
32.	4. Søgård	4. Søgård	Ø. Søgård	Avd i 30. alder	Bur i Fakse Kirke	1831. Sept. 24
33.	Z. Søgård	B. Søgård	Ø. Søgård	Avd i 30. alder	Bur i Fakse Kirke	1831. Sept. 24
34.	6. Søgård	B. Søgård	Jens. Christensen	Begravelsestid 1831. Sept. 24	Begravelsestid 1831. Sept. 24	1831. Sept. 24
35.	8. Søgård	3. Søgård	Hans. Christensen	Avd i 30. alder	Bur i Fakse Kirke	1831. Sept. 24
36.	3. Søgård	9. Søgård	Jens. Christensen	Begravelsestid 1831. Sept. 24	Begravelsestid 1831. Sept. 24	1831. Sept. 24
37.	11. Søgård	11. Søgård	Hans. Christensen	Avd i 30. alder	Bur i Fakse Kirke	1831. Sept. 24
38.	11. Søgård	14. Søgård	Hans. Christensen	Avd i 30. alder	Bur i Fakse Kirke	1831. Sept. 24

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*

Sn.	Fødesteds-	Dødssteds-	Døds-	Begravelses-	Gren. om-	Tændrings-
	Nævne.	Nævne.	Års.	Års.	Års.	Års.
25.	1. J. L. H. W. S. -	Lindore. Sørensen	Jens i. 1815. -	Skæring. -	Skæring. 1815.	
26.	3. S. E. S. -	Hans. Carsten	Pur i. Skæring. -	Skæring. 1815.		
27.	3. S. E. S. -	3. J. L. -	Ol. Jensen	Skæringen i. Skæring. -	Skæring. 1815.	
28.	3. S. E. S. -	7. J. L. -	Hager. Larsen	gives i. Skæring. -	Skæring. 1815.	
29.	3. S. E. S. -	4. J. L. -	Hans. Olof	gives og dødes i. Skæring. -	Skæring. 1815.	
30.	3. S. E. S. -	6. J. L. -	Vilh. Andersen	Pur i. Skæring. -	Skæring. 1815.	
31.	3. S. E. S. -	9. J. L. -	Ol. Hansen	Skæringen i. Skæring. -	Skæring. 1815.	
32.	4. S. E. S. -	Gr. S. -	W. Niels. Christensen	Jens i. Skæring. -	Skæring. 1815.	
33.	5. S. E. S. -	B. S. -	W. Niels. Larsen	gives i. Skæring. -	Skæring. 1815.	
34.	6. S. E. S. -	B. S. -	Jens. Andersen	Skæringen i. Skæring. -	Skæring. 1815.	
35.	8. S. E. S. -	3. J. L. -	Hans. Lethsen	Jens i. Skæring. -	Skæring. 1815.	
36.	9. S. E. S. -	4. J. L. -	W. Niels. Christensen	Skæringen i. Skæring. -	Skæring. 1815.	
37.	10. S. E. S. -	6. J. L. -	W. Niels. Hansen	gives i. Skæring. -	Skæring. 1815.	
38.	11. S. E. S. -	14. J. L. -	Hans. Larsen	Jens i. Skæring. -	Skæring. 1815.	

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)



Data cleaning and managing

Date of burial	Name	Age	Gender	Amt	Sogn
1857-01-02	Anne Kirstine Christensen	2	Female	Thisted Amt	Jannerup Sogn (Thisted Amt)
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1857-01-02	Gjertrud Jensdatter	82	Female	Thisted Amt	Thisted Sogn
1857-01-02	Karen Christensdatter Wilbøll	52	Female	Thisted Amt	Vester Vandet Sogn
1857-01-02	Karen Marie Jensen	21	Female	Thisted Amt	Sennels Sogn
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1857-01-03	Anders Hansen Tøylfang	79	Male	Thisted Amt	Gettrup Sogn
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1857-01-04	Maren Jensen	0	Female	Thisted Amt	Hillerslev Sogn (Thisted Amt)
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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)

- ▶ Temporal resolution:
- ▶ Daily

- ▶ Geographical resolution:
- ▶ Individual parishes



Data cleaning and managing

Date of burial	Name	Age	Gender	Amt	Sogn
1857-01-02	Anne Kirstine Christensen	2	Female	Thisted Amt	Jannerup Sogn (Thisted Amt)
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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 Wilbøll	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 Tøylfang	79	Male	Thisted Amt	Gettrup 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 Thystrup	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)

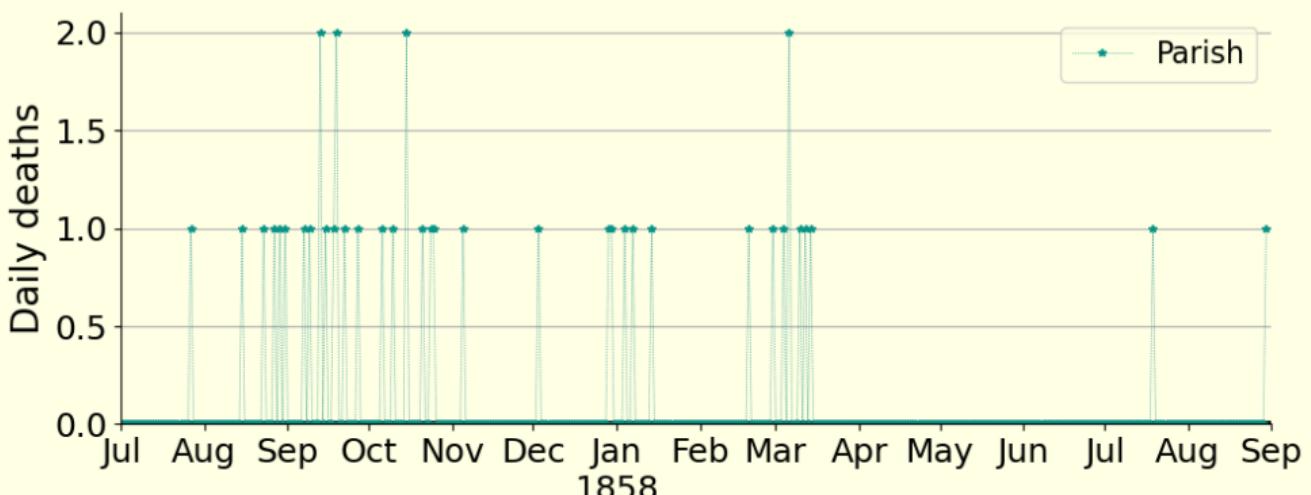
► Temporal resolution:

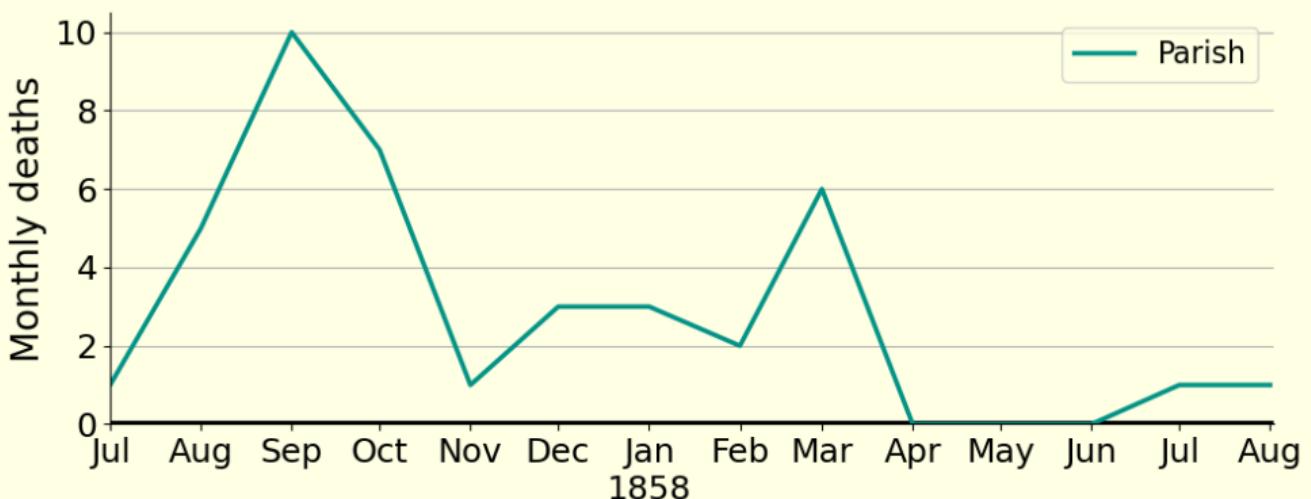
- Daily
- Weekly
- Monthly
- Yearly

► Geographical resolution:

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







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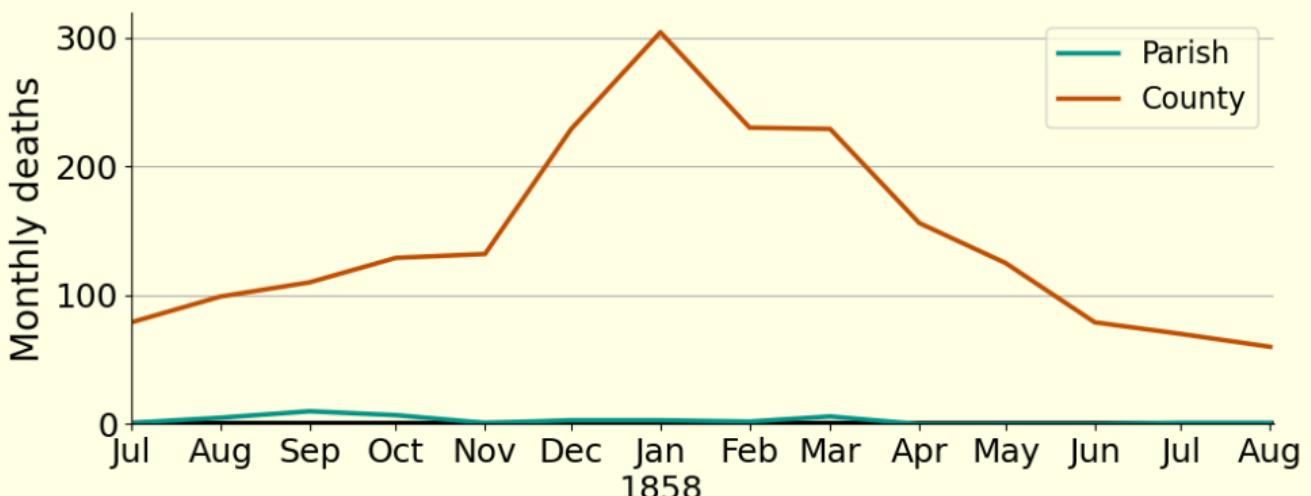
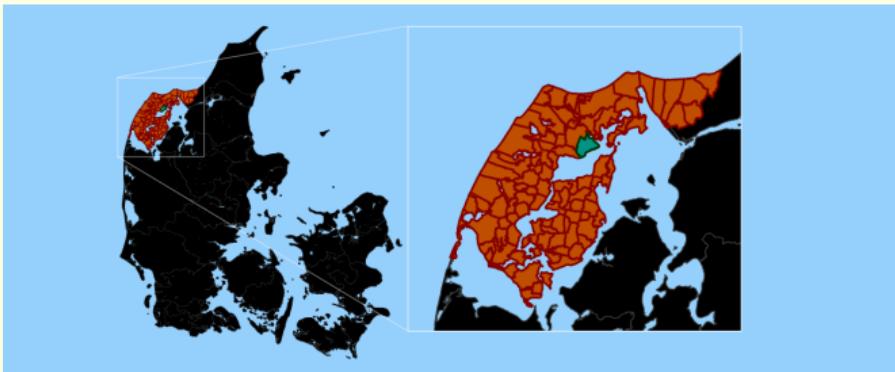
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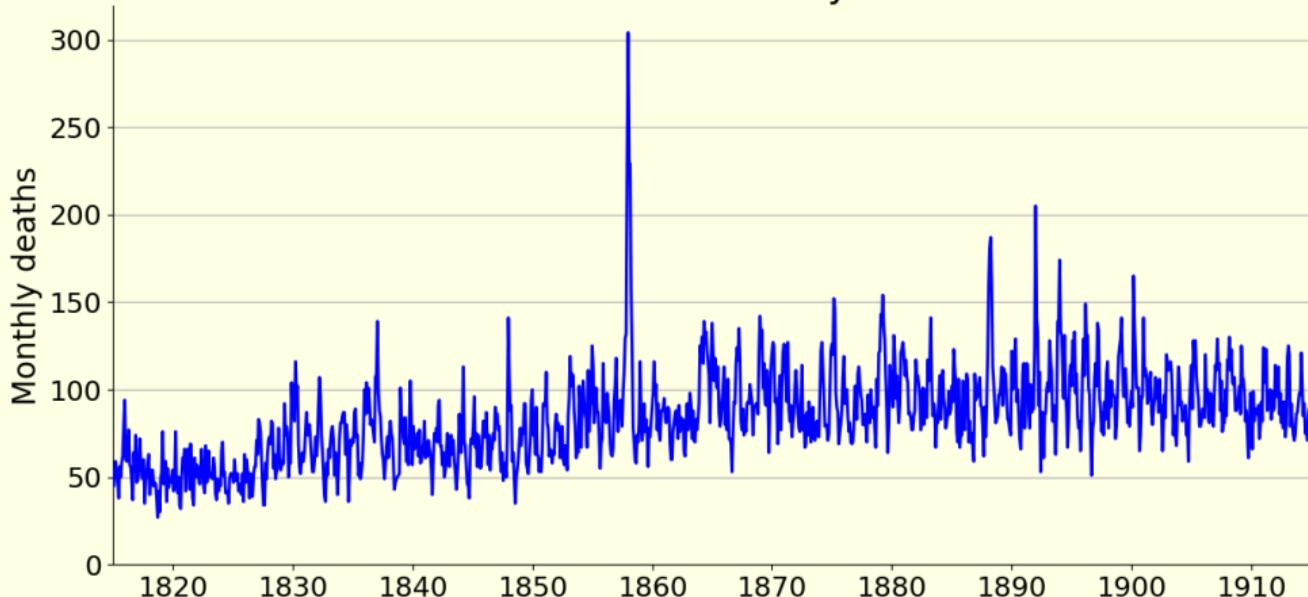
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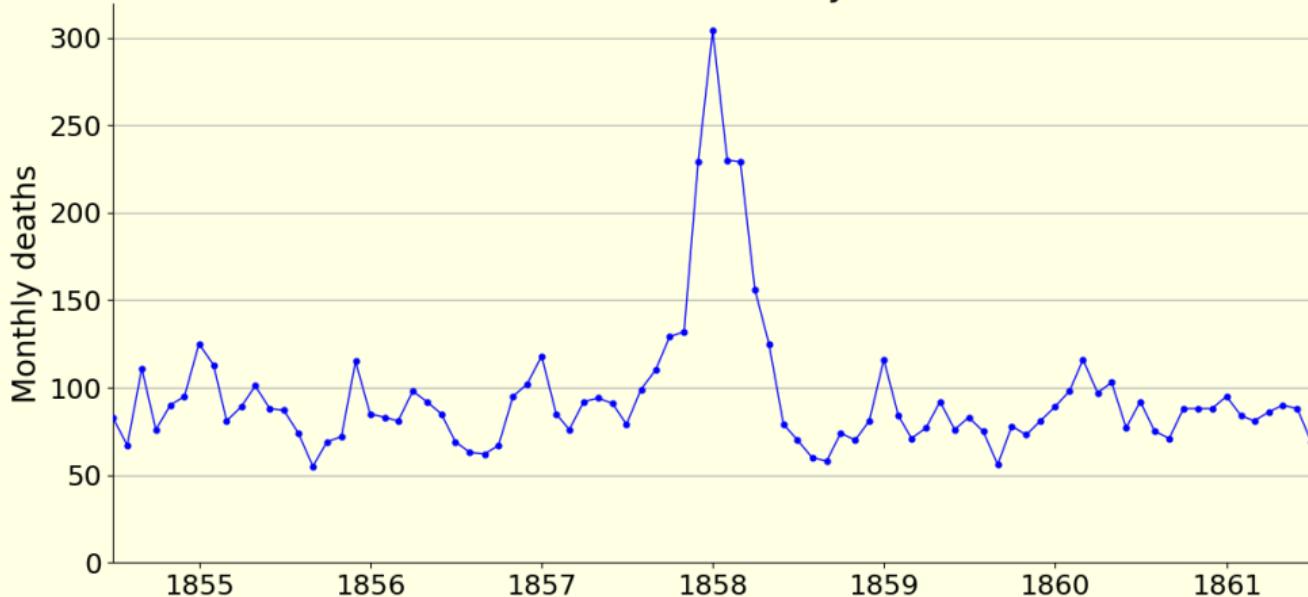
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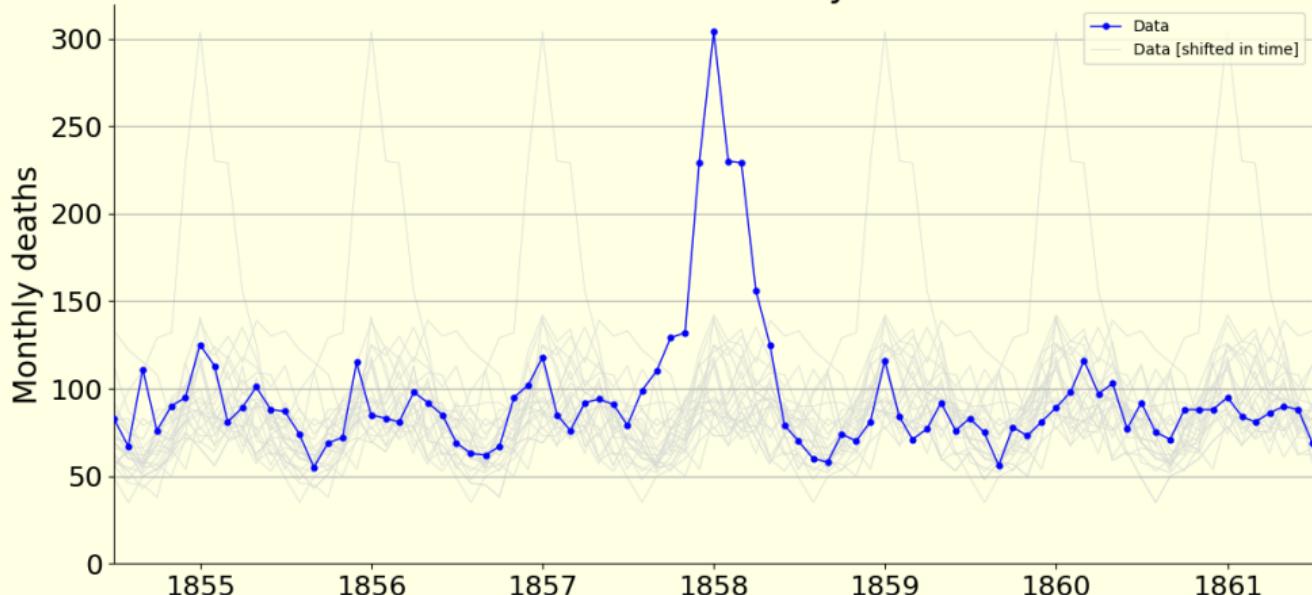
Calculating the mortality baseline

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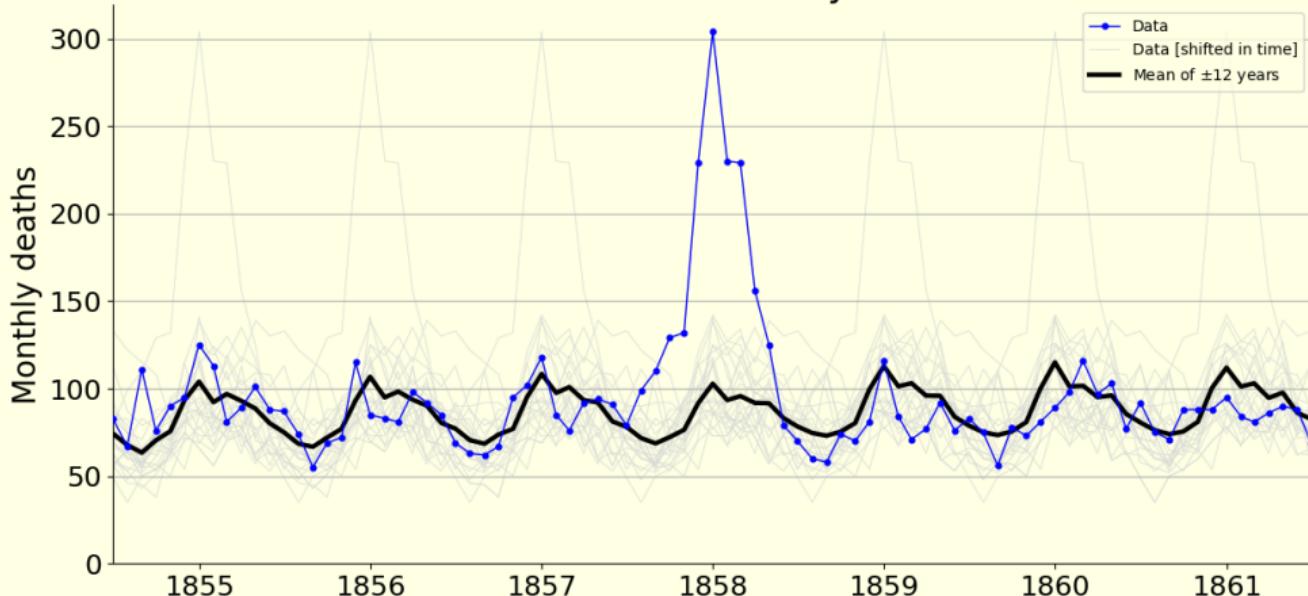
Calculating the mortality baseline

Thisted county



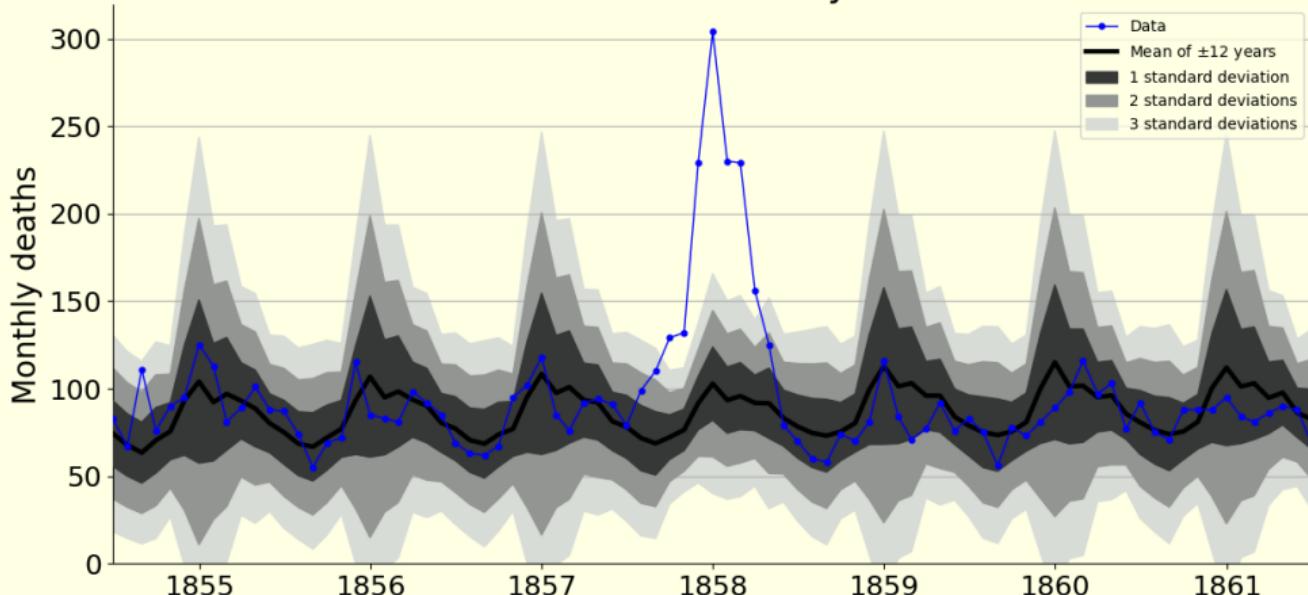
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Thisted county



Calculating the mortality baseline

Thisted county



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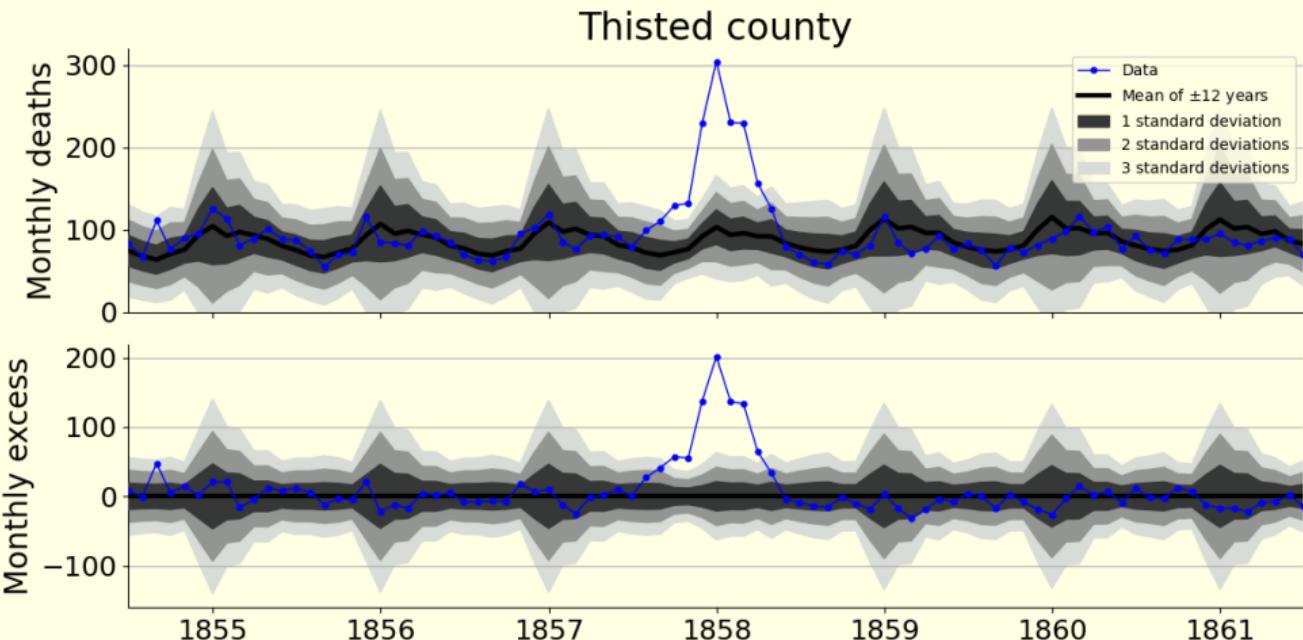
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Age-specific mortality

Comparing age patterns

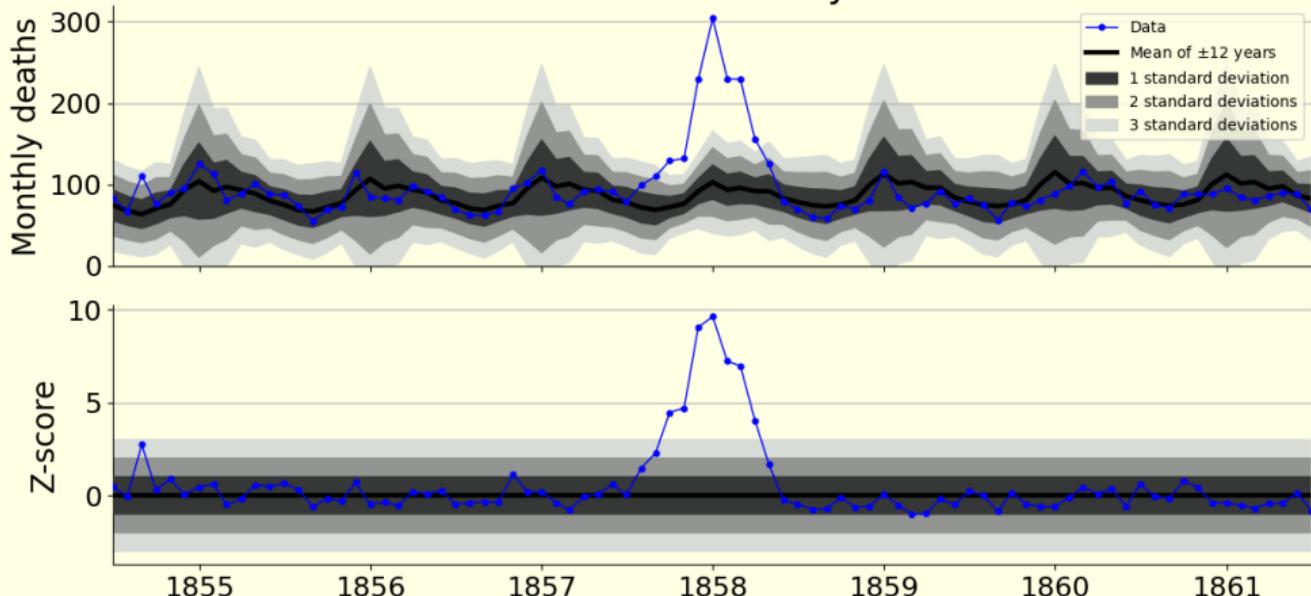
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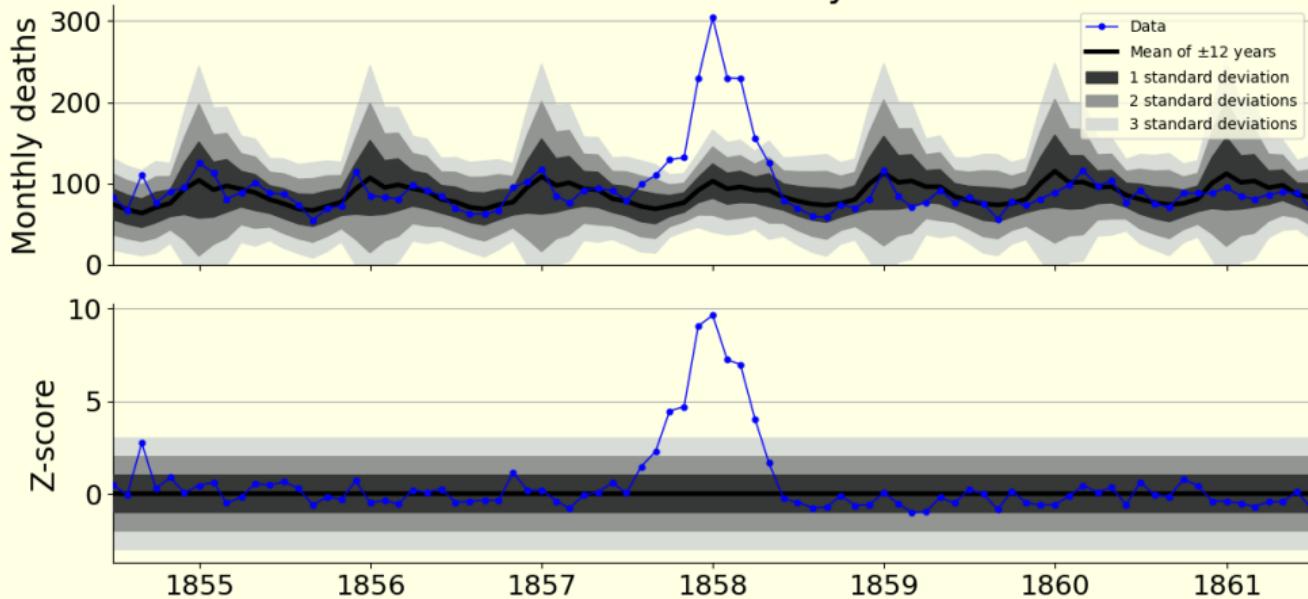
Calculating the mortality baseline

Thisted county



Calculating the mortality baseline

Thisted county



From historical demography¹: "Mortality crisis" when Z-score above two.

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



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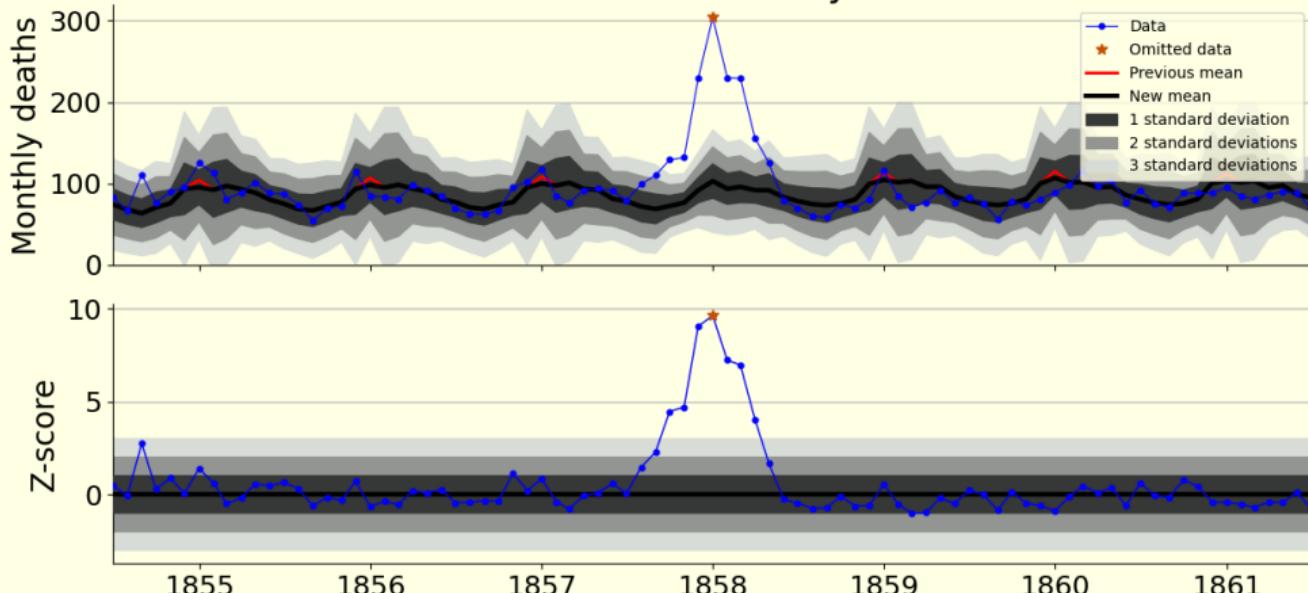
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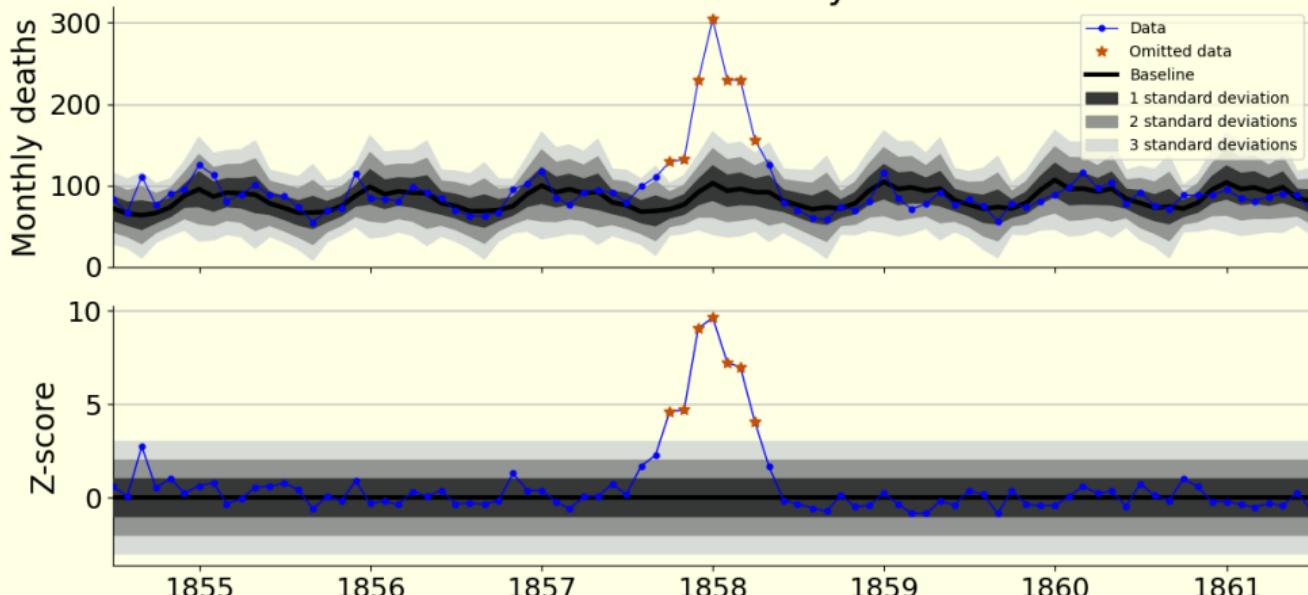
Calculating the mortality baseline

Thisted county



Calculating the mortality baseline

Thisted county



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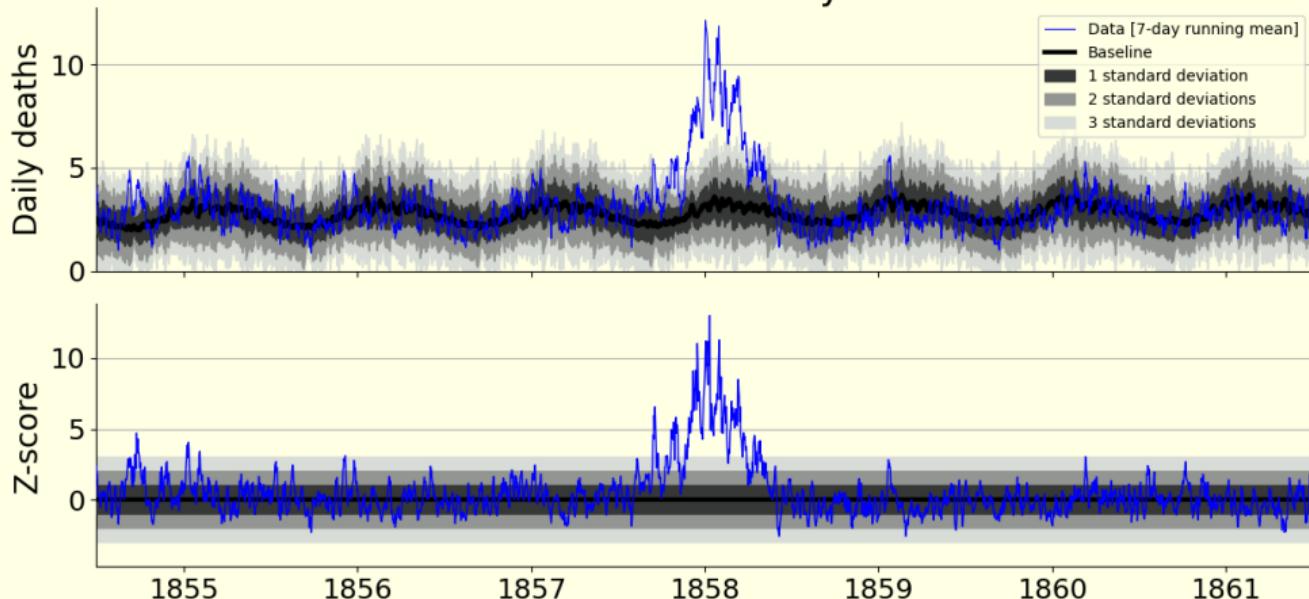
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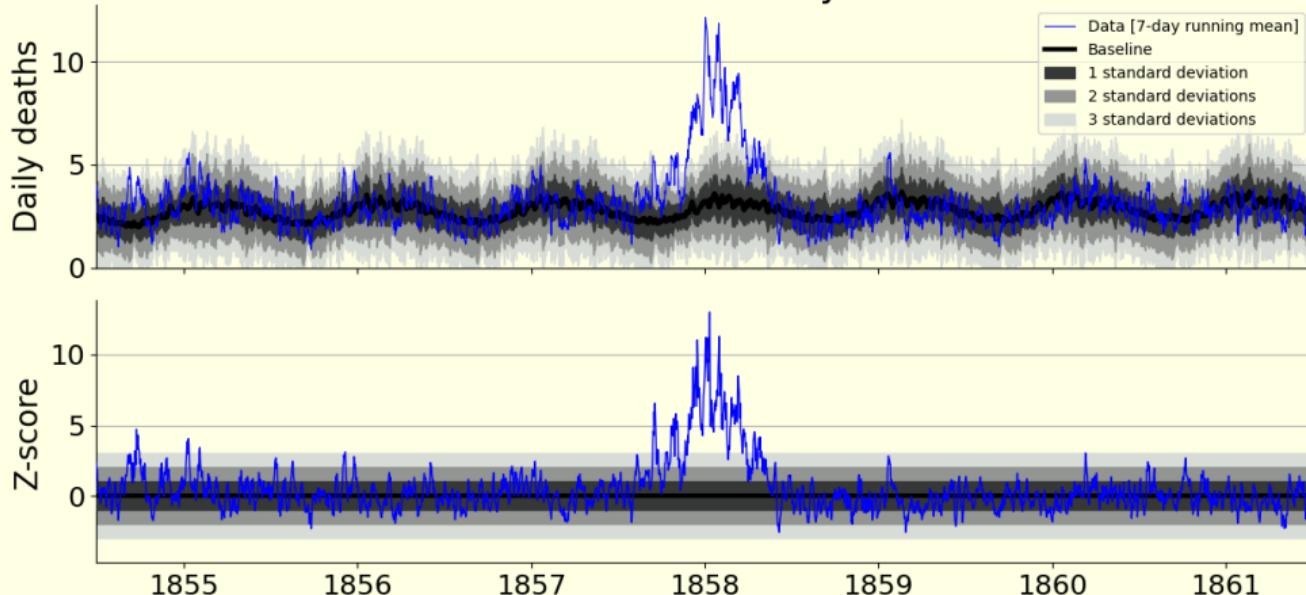
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Identification of "mortality crises"

Thisted county



We wish to identify continuous periods of excess mortality.



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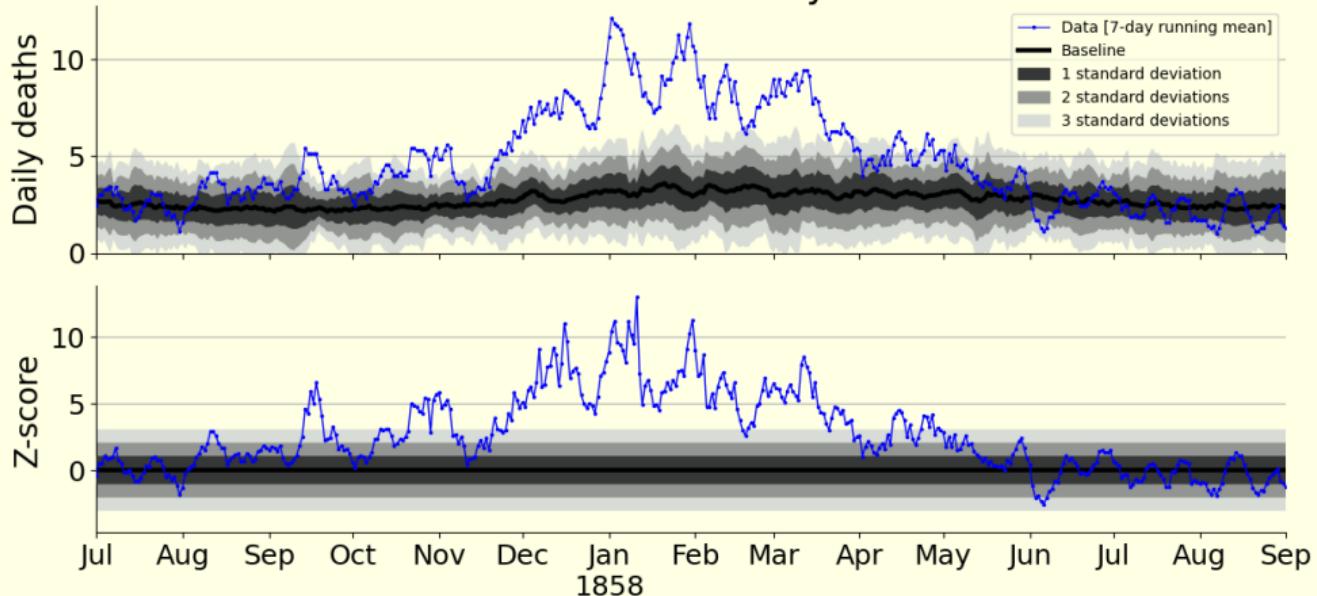
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Zooming in...



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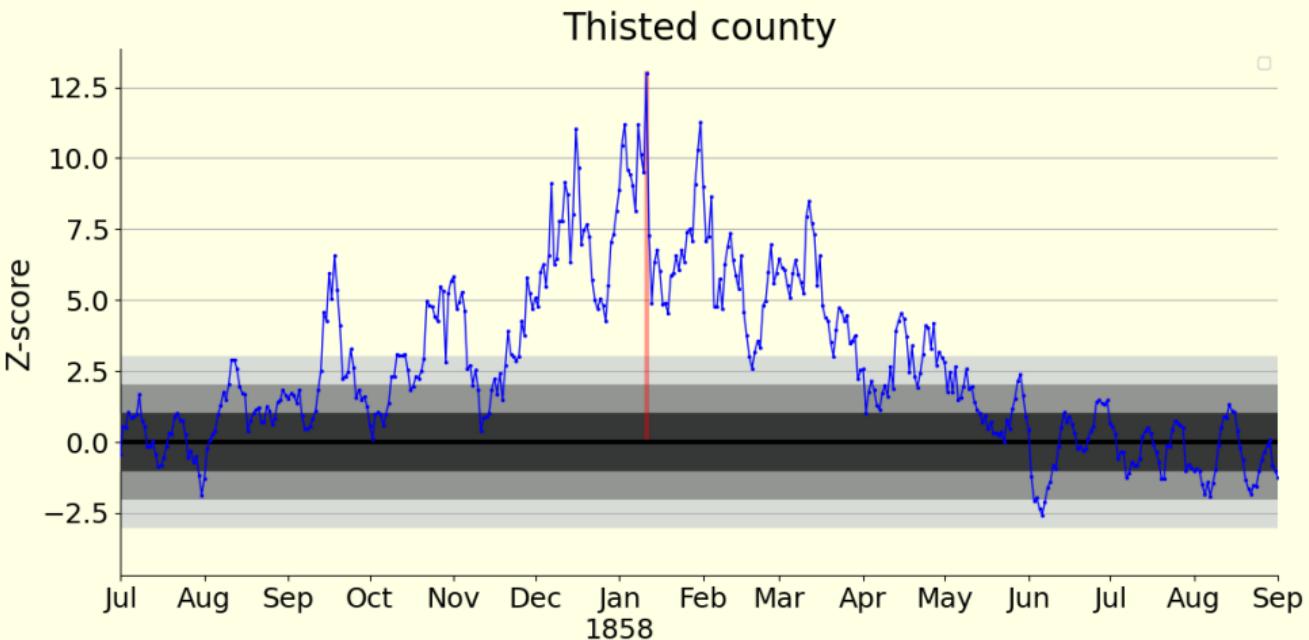
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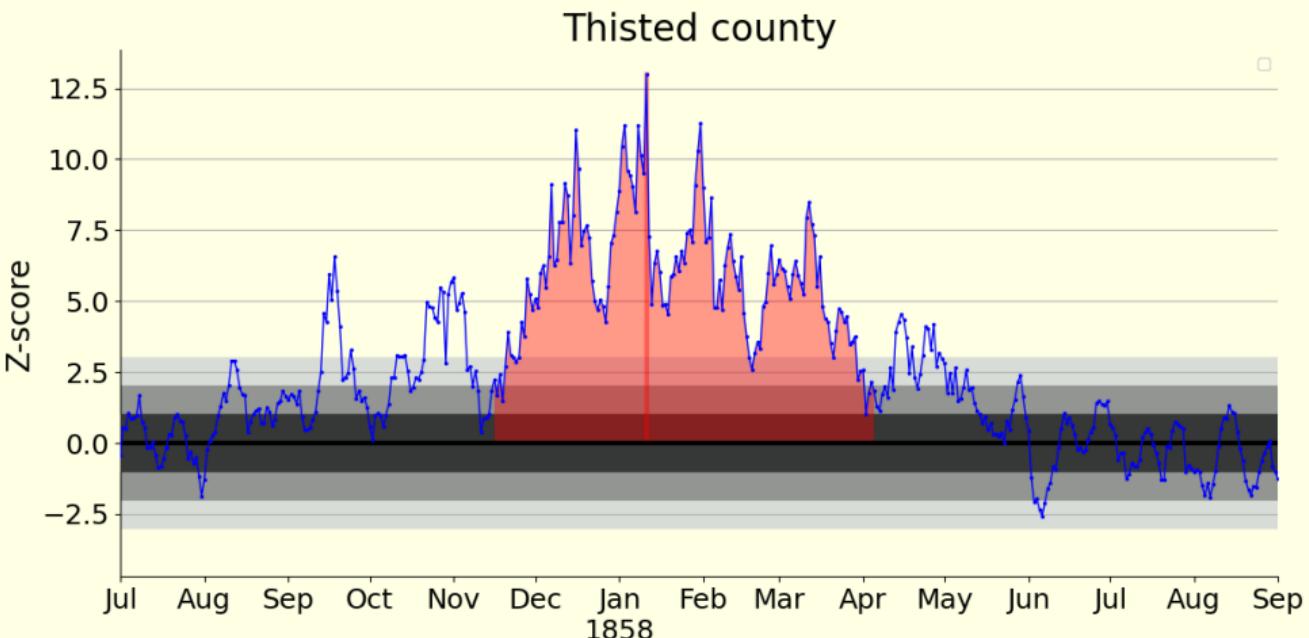
Identification of “mortality crises”



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



Identification of “mortality crises”

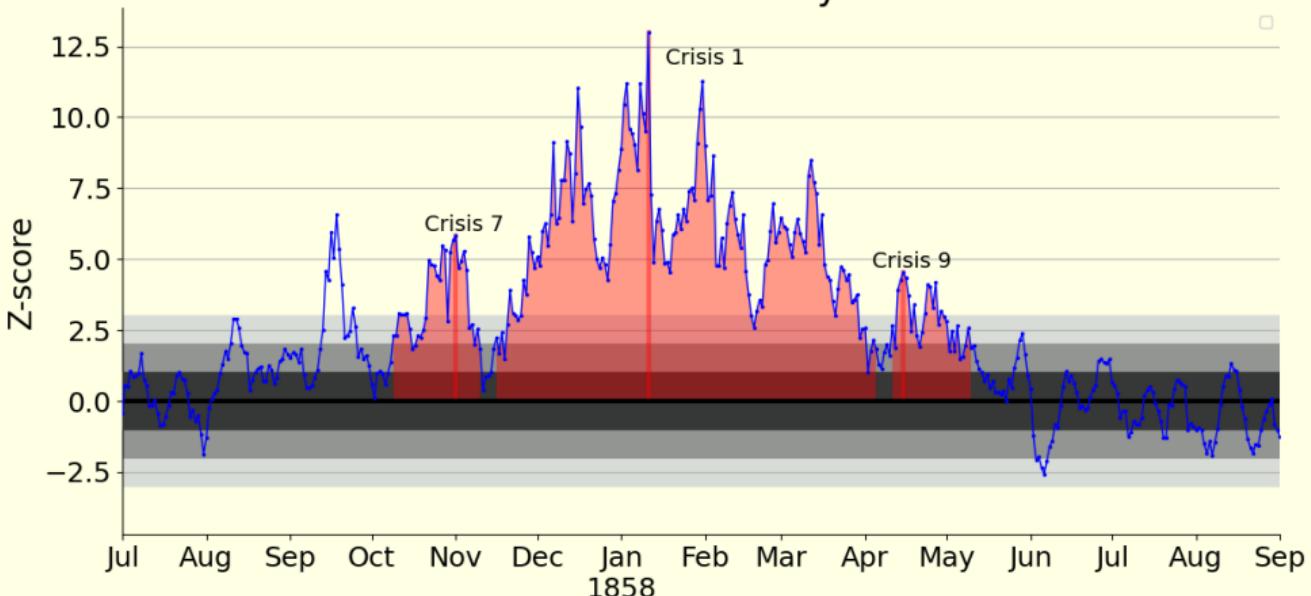


... we group all days with Z-score above three, until the Z-score drops below two for four days or more.



Identification of “mortality crises”

Thisted county



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



Identifying main "signature features"

Using this methodology, we identify 319 mortality crises.

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



Identifying main "signature features"

Using this methodology, we identify 319 mortality crises.

For each crisis,

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



Identifying main "signature features"

Using this methodology, we identify 319 mortality crises.

For each crisis,

- ▶ Peak-date.

County	#	Peak-date		
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		
⋮	⋮	⋮		



Identifying main "signature features"

Using this methodology, we identify 319 mortality crises.

For each crisis,

- ▶ Peak-date.
- ▶ Excess deaths.

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

County	#	Peak-date	Total excess	
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 319 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 319 mortality crises.

For each crisis,

- ▶ Peak-date.
Significant on a county level
(Population-sizes $\approx 100,000$).
- ▶ Excess deaths.
- ▶ 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
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⋮	⋮	⋮	⋮	⋮



Identifying main "signature features"

Using this methodology, we identify 319 mortality crises.

For each crisis,

- ▶ Peak-date.
- ▶ Excess deaths.
Significant on a county level
(Population-sizes $\approx 100,000$).
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e.g. "lasting two months"
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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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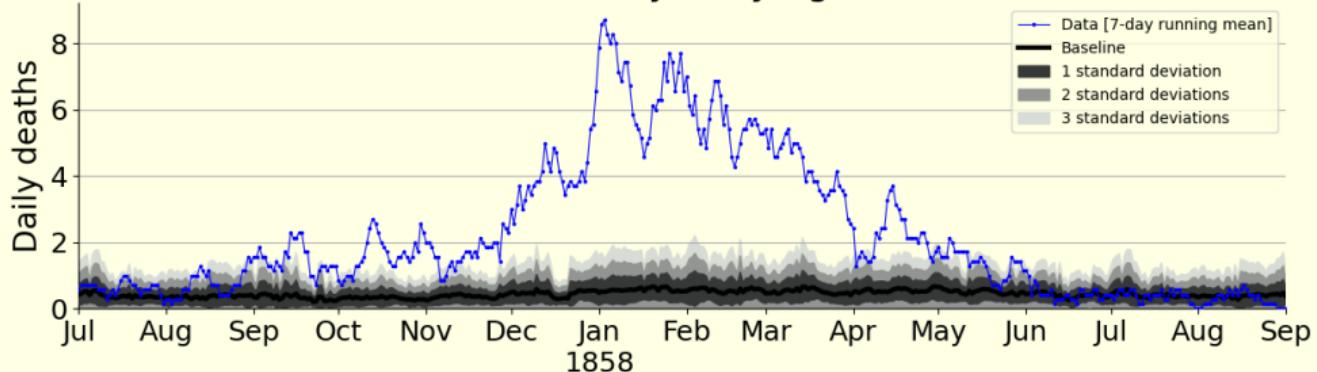
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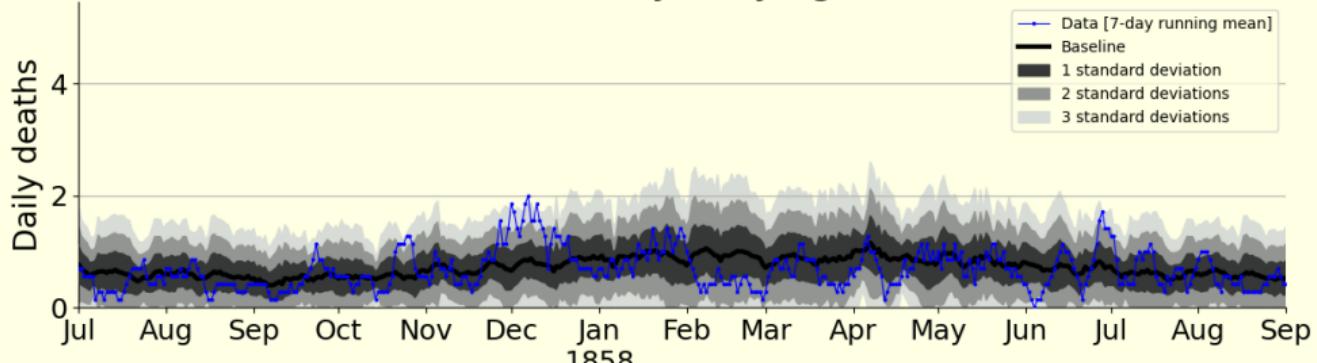
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Thisted county, only ages 1-14



Thisted county, only ages 60+



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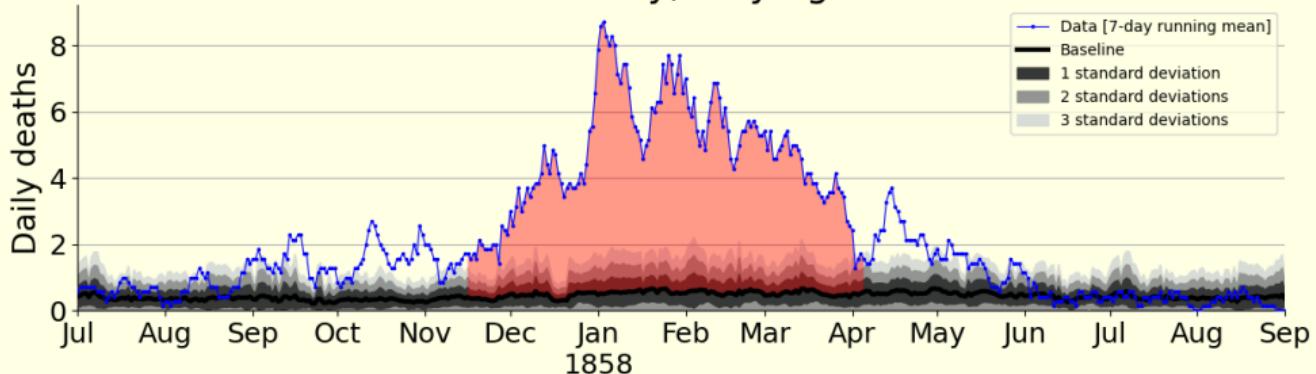
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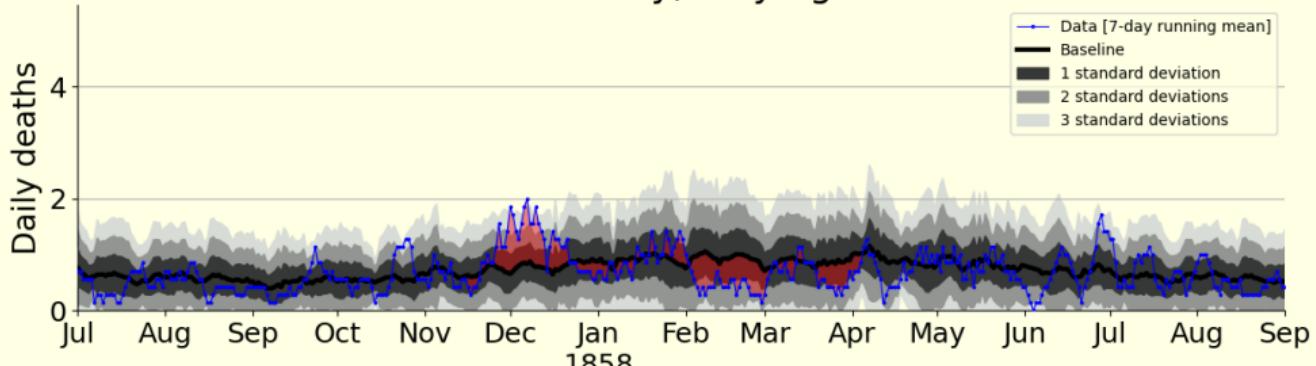
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Analyzing age-patterns

Thisted county, only ages 1-14



Thisted county, only ages 60+



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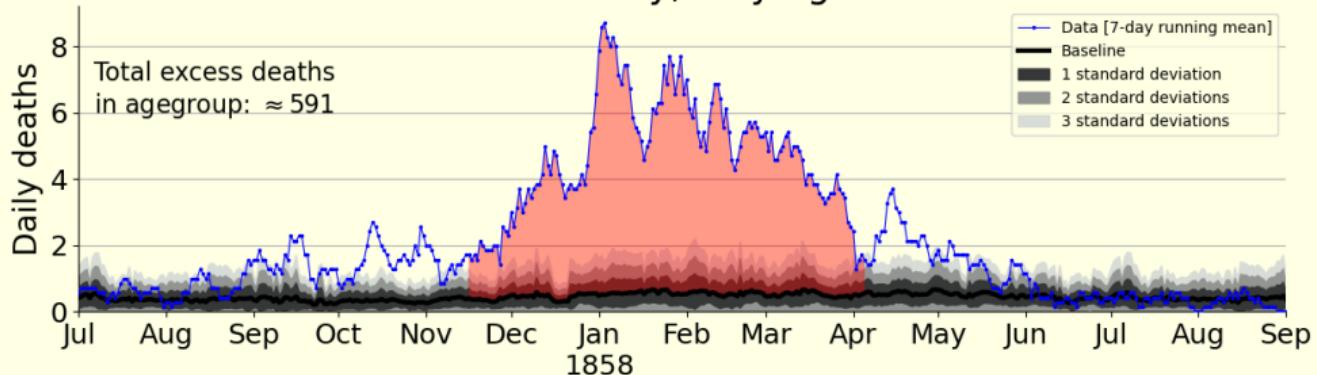
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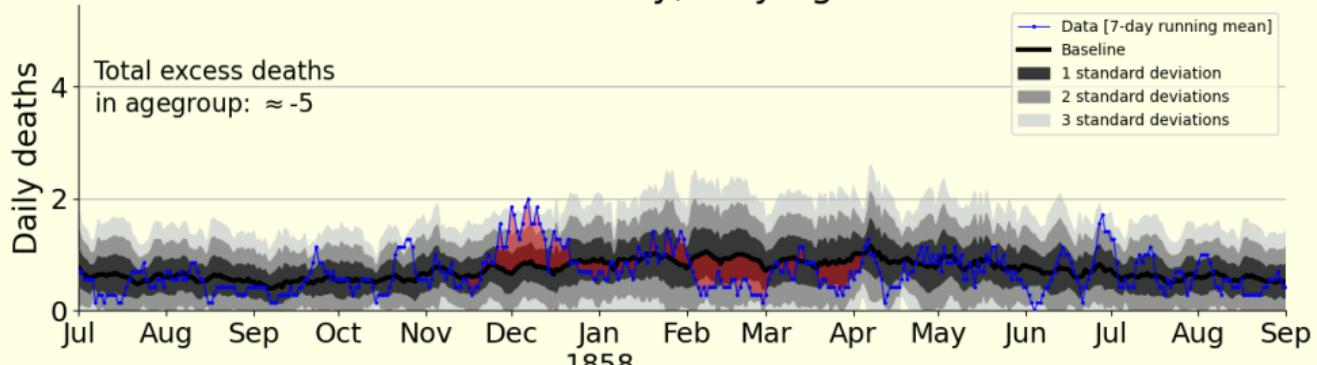
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Analyzing age-patterns

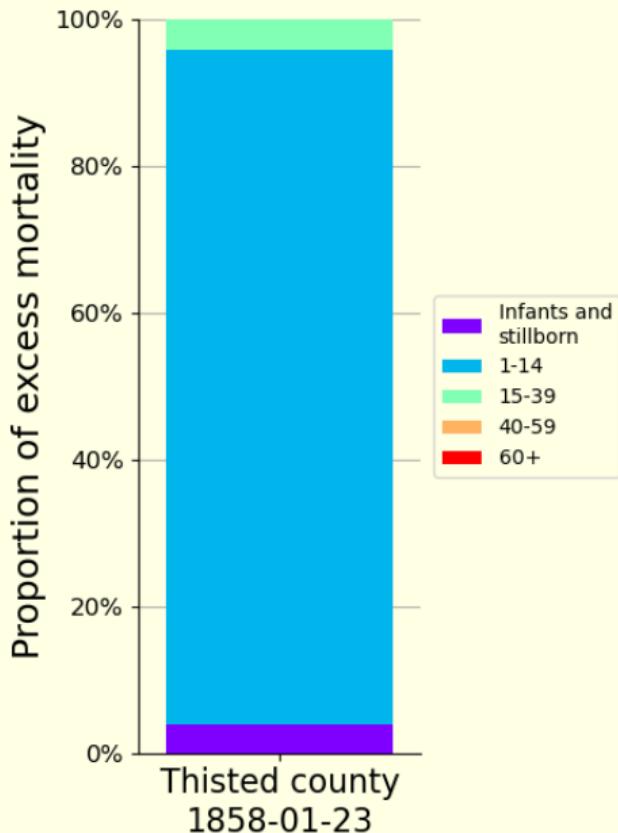
Thisted county, only ages 1-14



Thisted county, only ages 60+



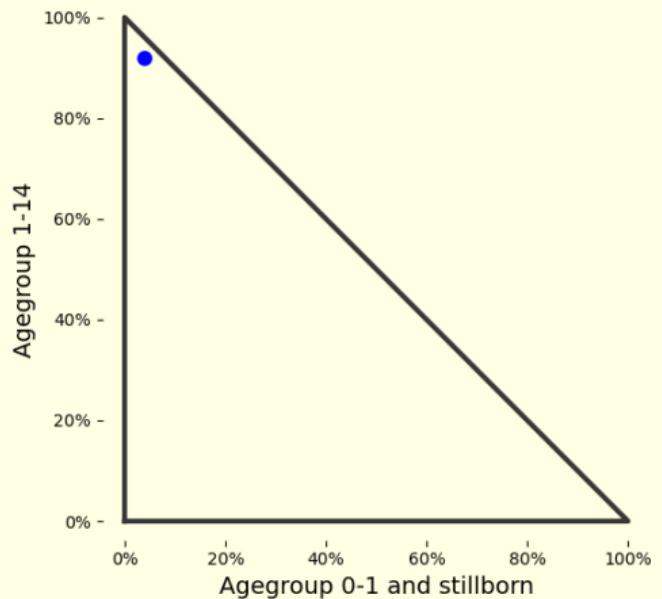
Analyzing age-patterns



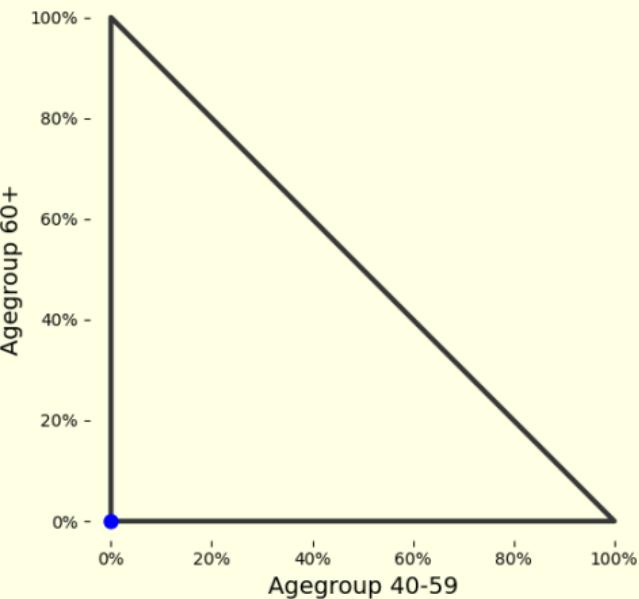
Age-specific excess mortality
in this period:

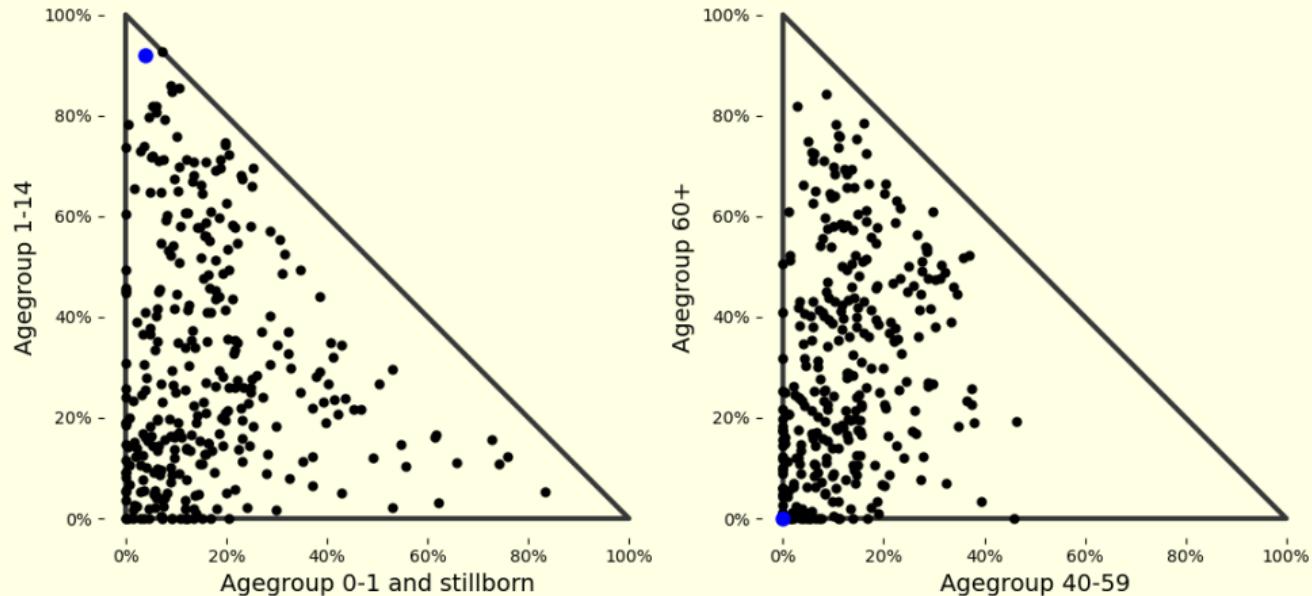
- ▶ Age group "60+": 0%
- ▶ Age group "40-59": <1%
- ▶ Age group "15-39": 3%
- ▶ Age group "1-14": 93%
- ▶ Age group "Below 1 year": 4%





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

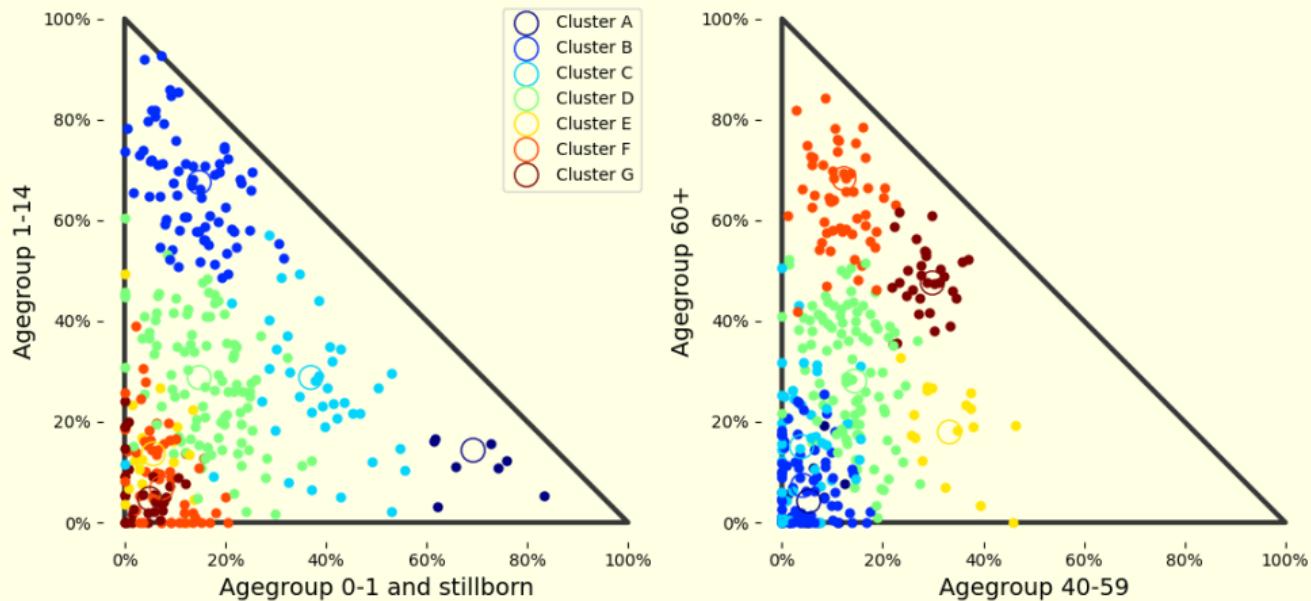




Adding the other 318 mortality crises identified.



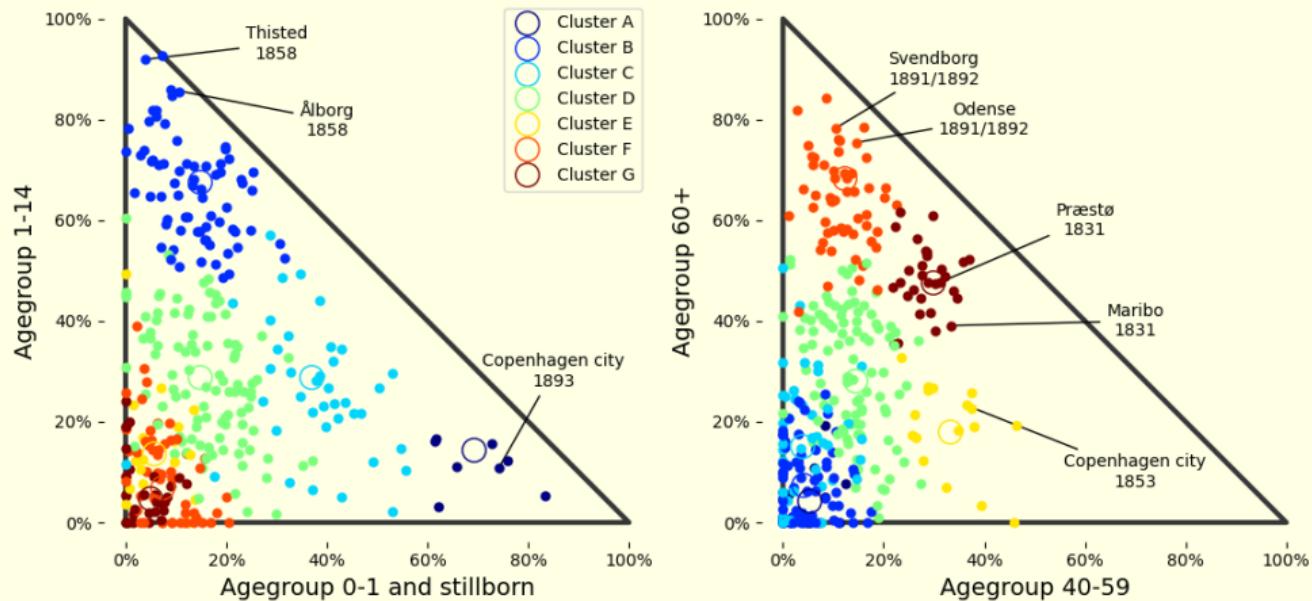
Mortality crises with comparable age patterns



Gaussian mixture modelling on full five-dimensional data.



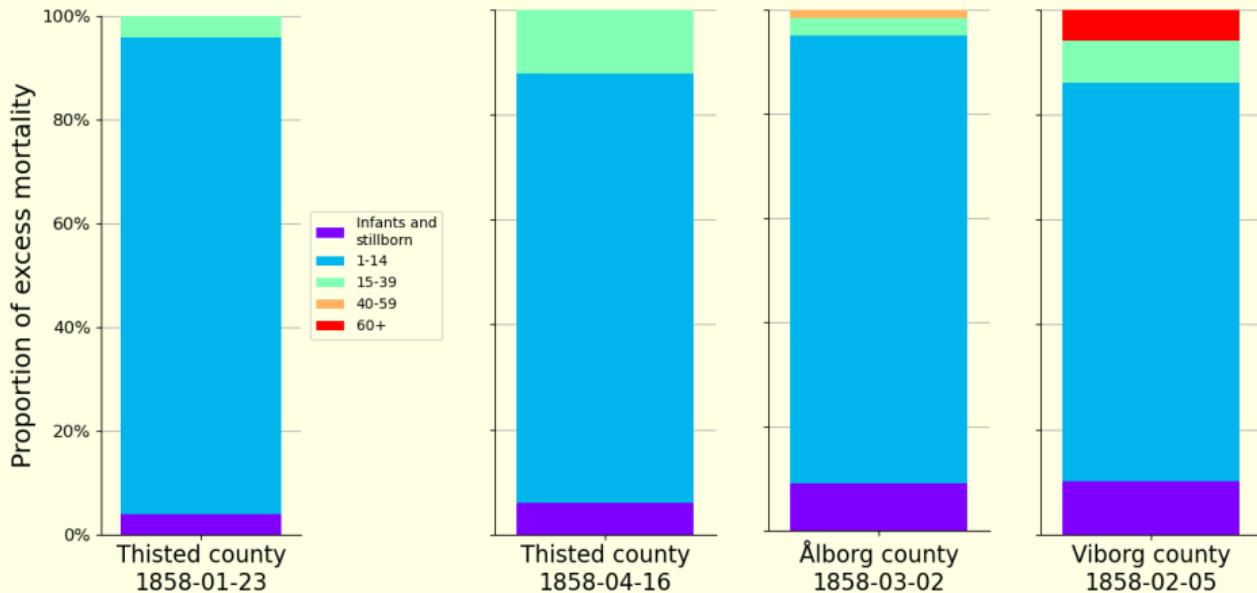
Mortality crises with comparable age patterns



Gaussian mixture modelling on full five-dimensional data.

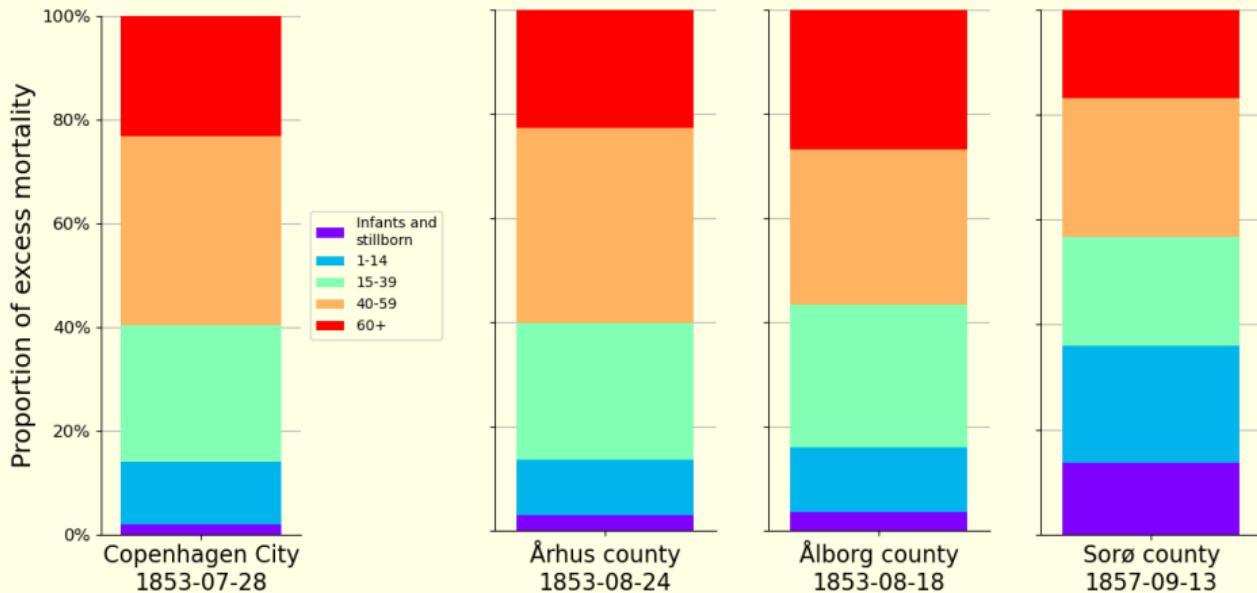
Mortality crises with comparable age patterns

Examples from "Cluster A"



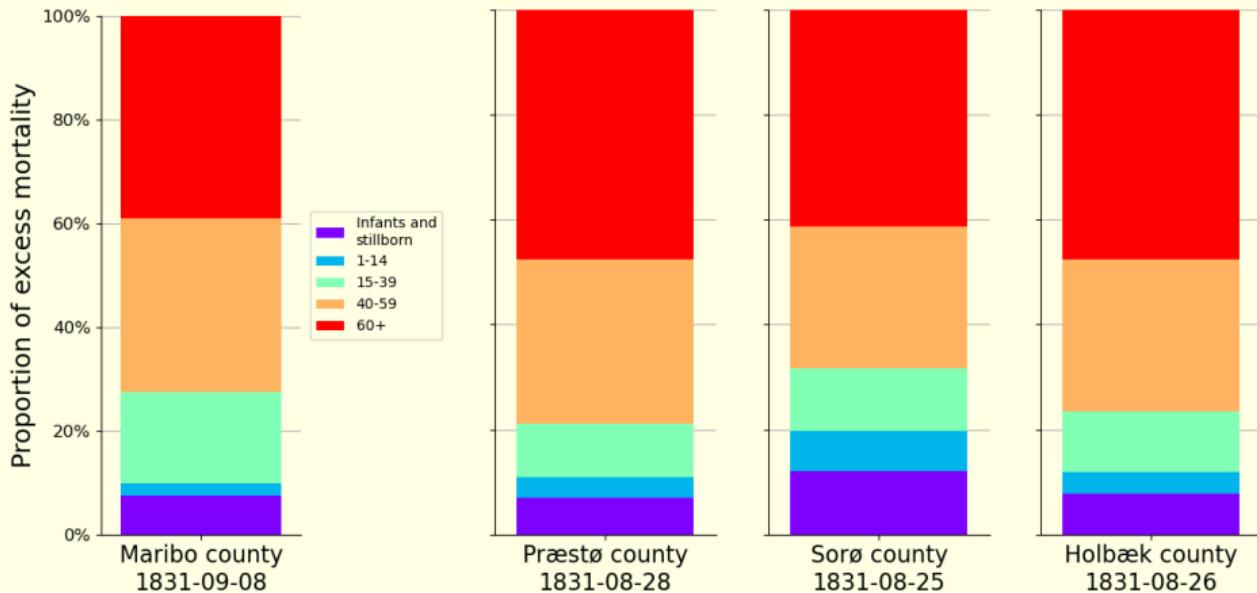
Mortality crises with comparable age patterns

Examples from "Cluster E"



Mortality crises with comparable age patterns

Examples from "Cluster G"



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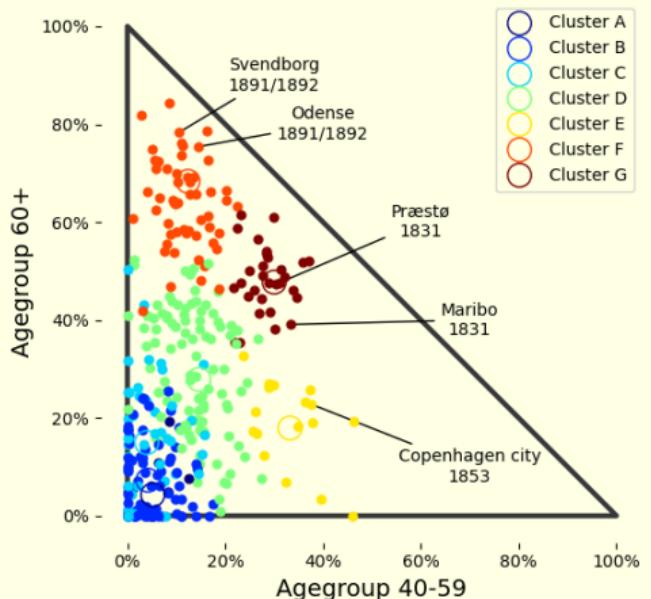
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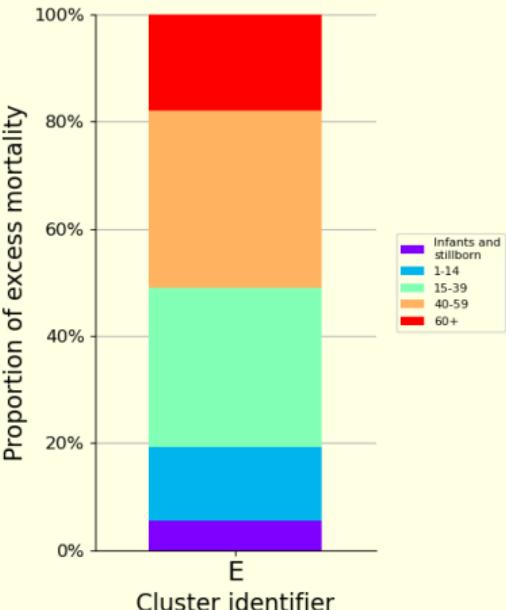
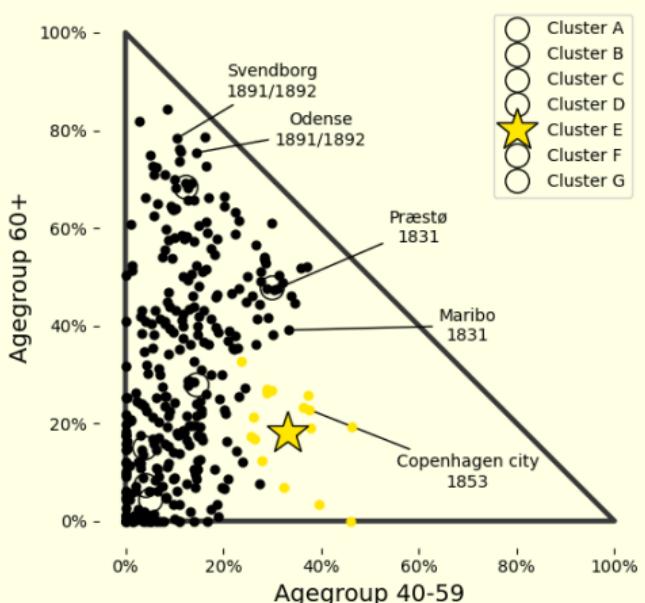
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The signature features of certain diseases



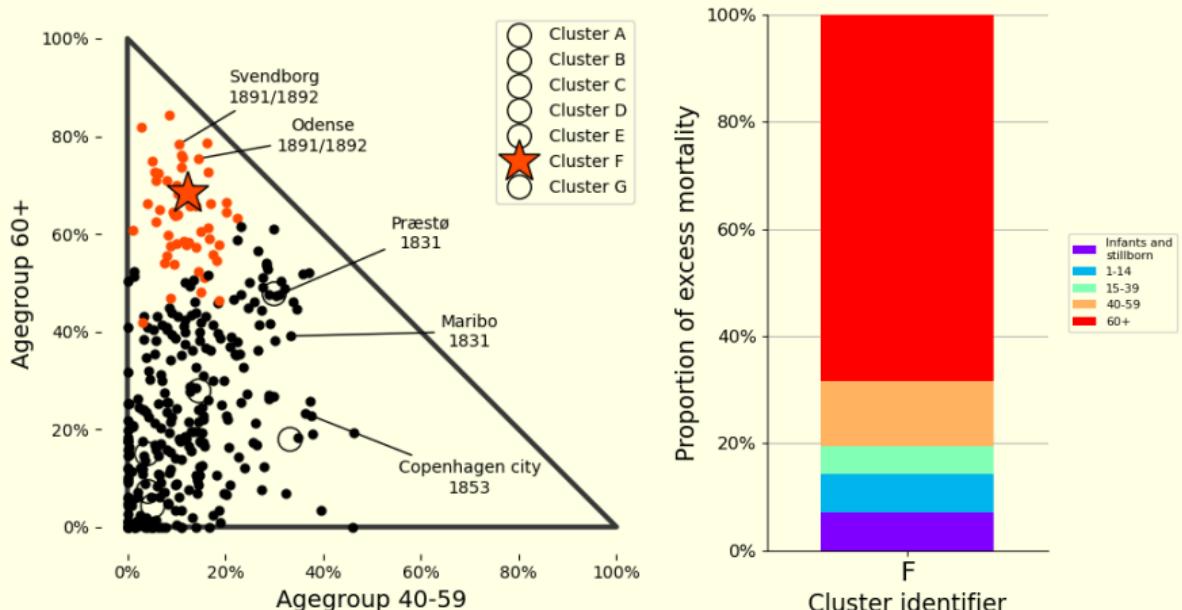
The signature features of certain diseases



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



The signature features of certain diseases



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



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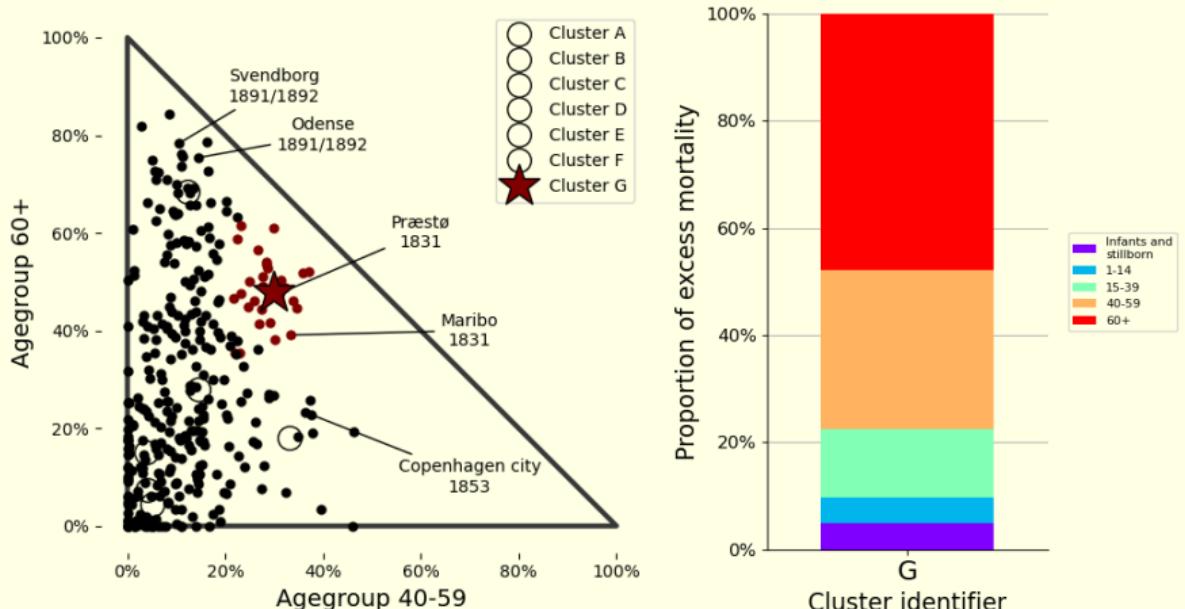
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Multiple of the mortality crises in cluster G appear to be related to “**the Harvest epidemics of 1826-1832**”.



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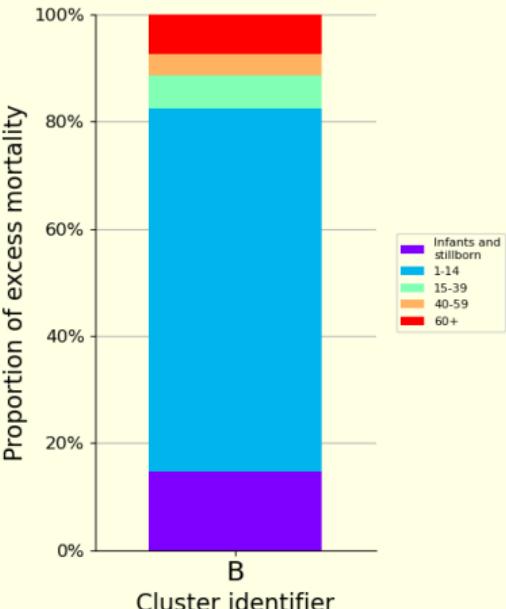
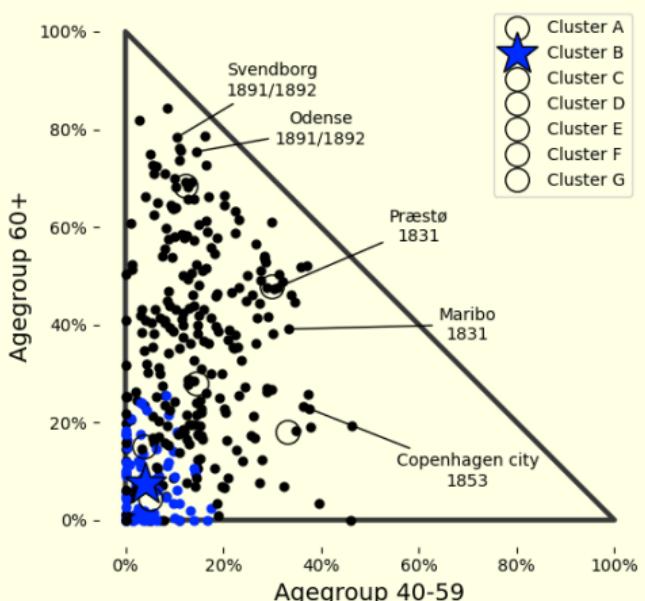
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The signature features of certain diseases



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



All epidemics and pandemics in 19th century Denmark

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

<i>Disease</i>	<i>Timing</i>	<i>Total excess</i>	<i>Age structure</i>
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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Summary

- ▶ We determine mortality baselines on county-level, using an iterative process to omit outliers and estimate excess mortality.
- ▶ We identify 319 major mortality crises in 19th century Denmark.

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Summary

- ▶ We determine mortality baselines on county-level, using an iterative process to omit outliers and estimate excess mortality.
- ▶ We identify 319 major mortality crises in 19th century Denmark.
- ▶ For each crisis, we determine signature features:



Summary

- ▶ We determine mortality baselines on county-level, using an iterative process to omit outliers and estimate excess mortality.
- ▶ We identify 319 major mortality crises in 19th century Denmark.
- ▶ For each crisis, we determine signature features:
 - ▶ Age-patterns.



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- ▶ We determine mortality baselines on county-level, using an iterative process to omit outliers and estimate excess mortality.
- ▶ We identify 319 major mortality crises in 19th century Denmark.
- ▶ For each crisis, we determine signature features:
 - ▶ Age-patterns.
 - ▶ Timing and seasonality.



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 - ▶ Duration.



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 - ▶ Duration.
 - ▶ Geography.



Summary

- ▶ We determine mortality baselines on county-level, using an iterative process to omit outliers and estimate excess mortality.
- ▶ We identify 319 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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- ▶ Similar methods could be applied to modern data.
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A wide range of methods for clustering exists, see e.g. `scikit-learn` for python.
 - ▶ Excess mortality calculation.
Available online soon, as both Python and R package.



Final comments and reflections

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A wide range of methods for clustering exists, see e.g. `scikit-learn` for python.
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Available online soon, as both Python and R package.
- ▶ 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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Available online soon, as both Python and R package.
- ▶ 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 becomes transcribed, e.g. thanks to improved computer vision, similar studies of other countries will become possible.





Feel free to email me with
questions or comments

Website: rasmuspedersen.com
Email: rakrpe@ruc.dk

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



Danmarks
Grundforskningsfond
Danish National
Research Foundation

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