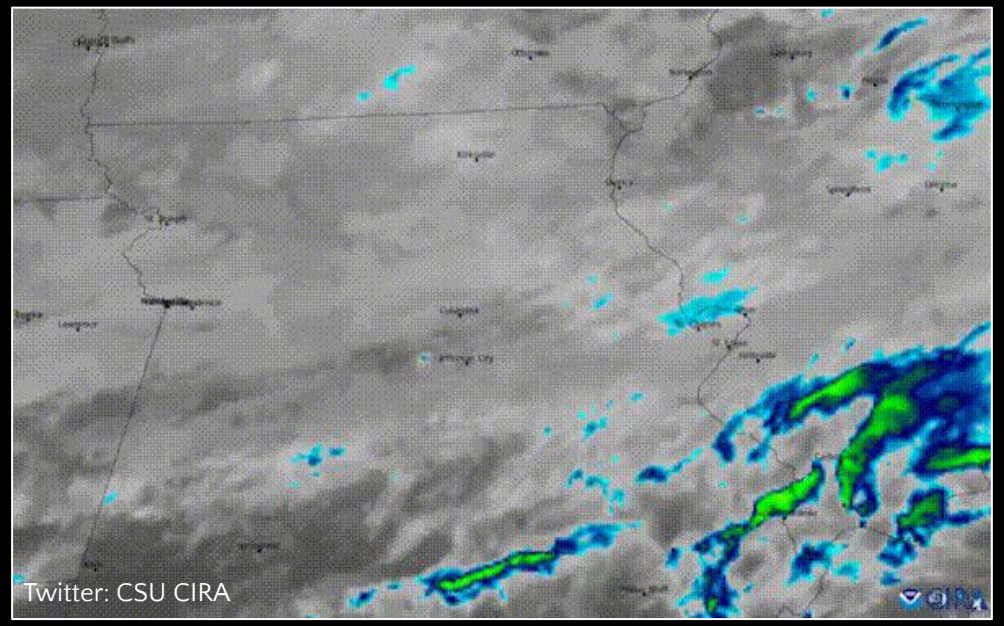
Blending observations with CESM to assess the historical context of lower Midwest extreme precipitation



Alexander Thompson, Bronwen Konecky, & Jack Hutchings

CESM Workshop

June 14, 2023

the David & Lucile Packard FOUNDATION

July 2022

1-in-1,000-year event?

FORBES > BUSINESS

Forbes

BREAKING

U.S. Has Seen Four 1-In-1,000 Year Rainfall Events This Summer

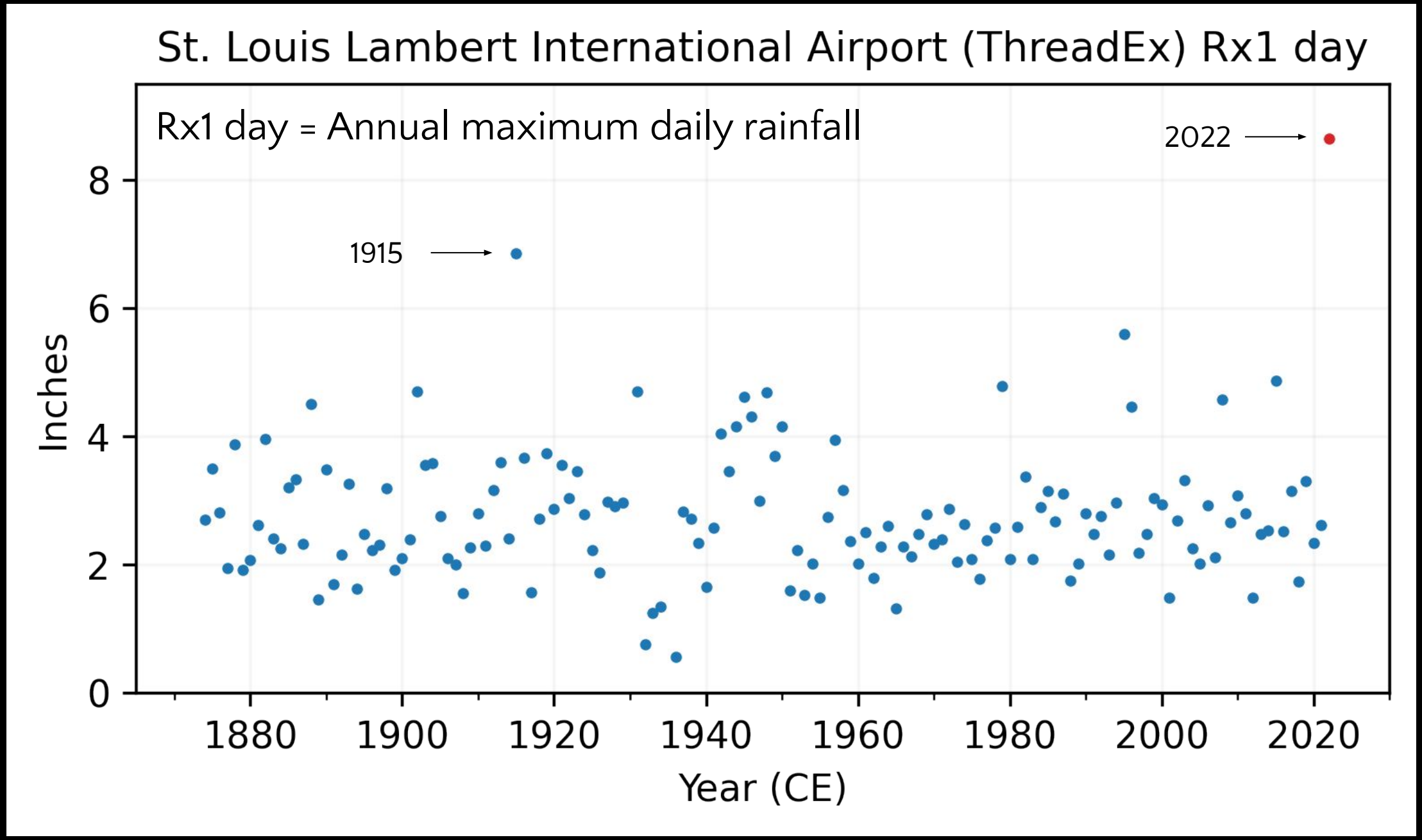
less than a 1 in 1,000 chance of happening

CNN

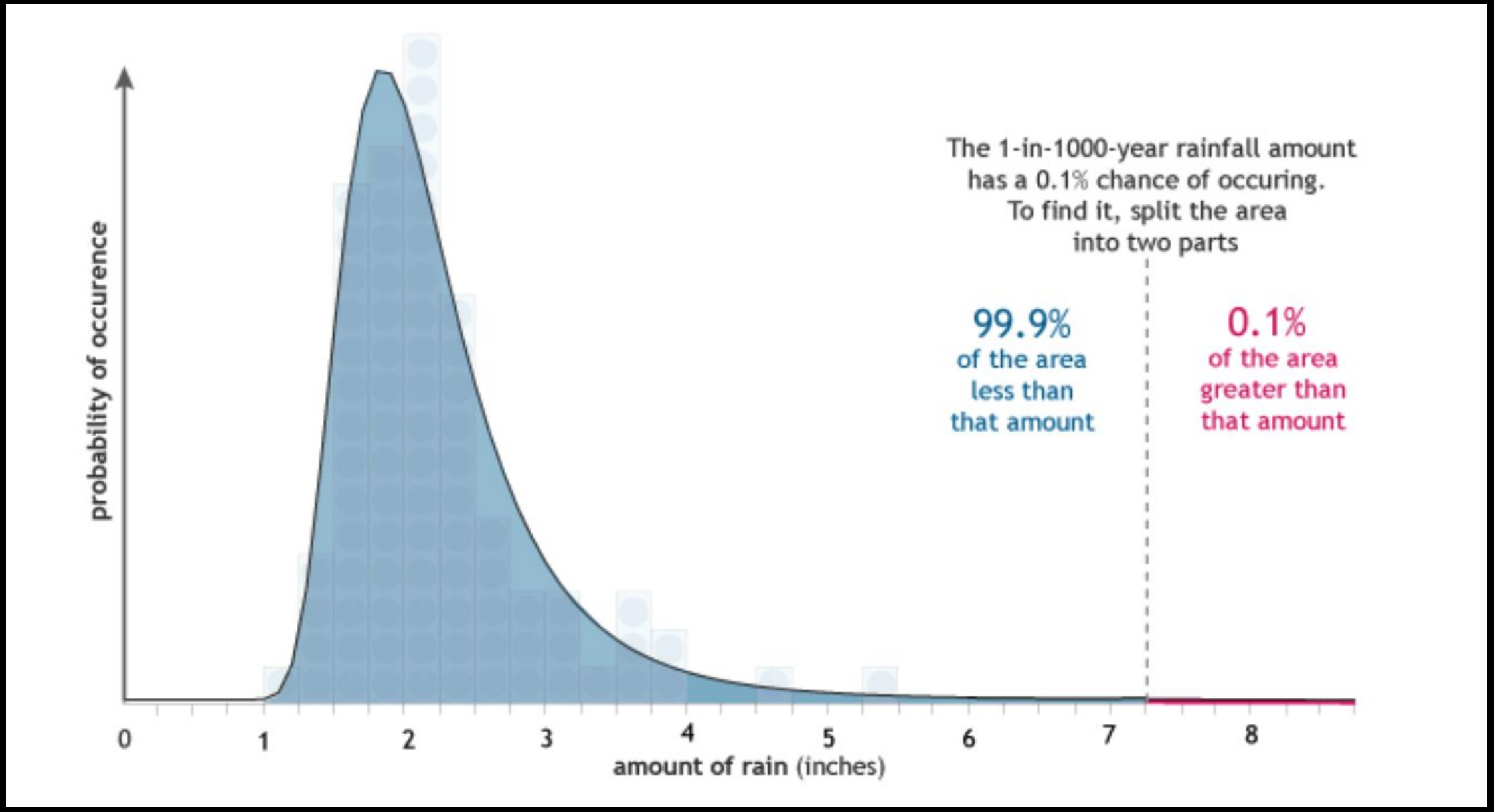
EXTREME WEATHER | Published August 24, 2022 7:59pm EDT

6 rare '1,000-year' rain events within a month? Climate change may force NOAA to update criteria

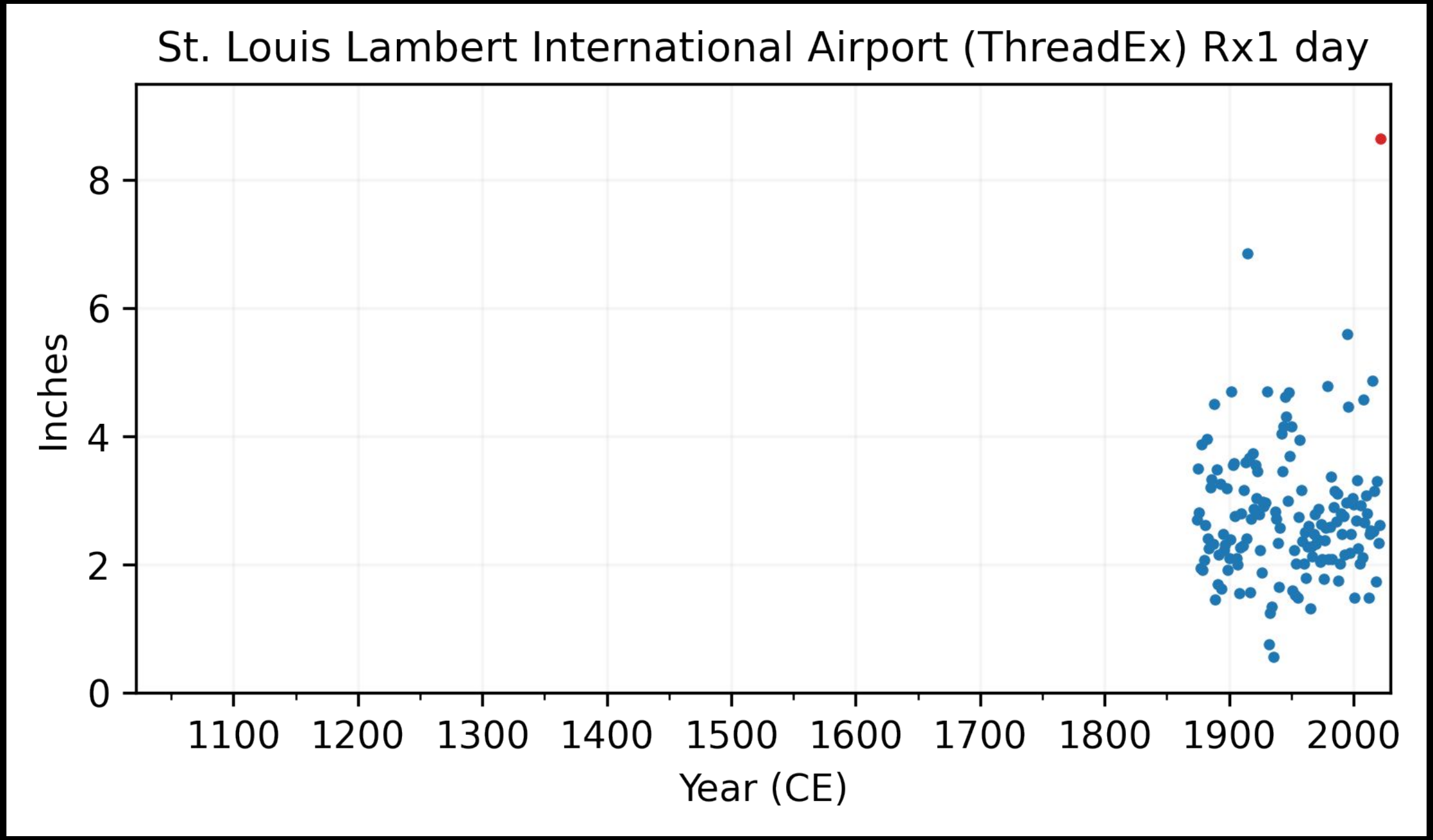
FOX Weather



Data from NOAA Applied Climate Information System


probability of occurence
The 1-in-1000-year rainfall amount has a 0.1% chance of occuring. To find it, split the area into two parts
99.9% of the area less than that amount
0.1% of the area greater than that amount
0
1
2
3
4
5
6
7
8
amount of rain (inches)

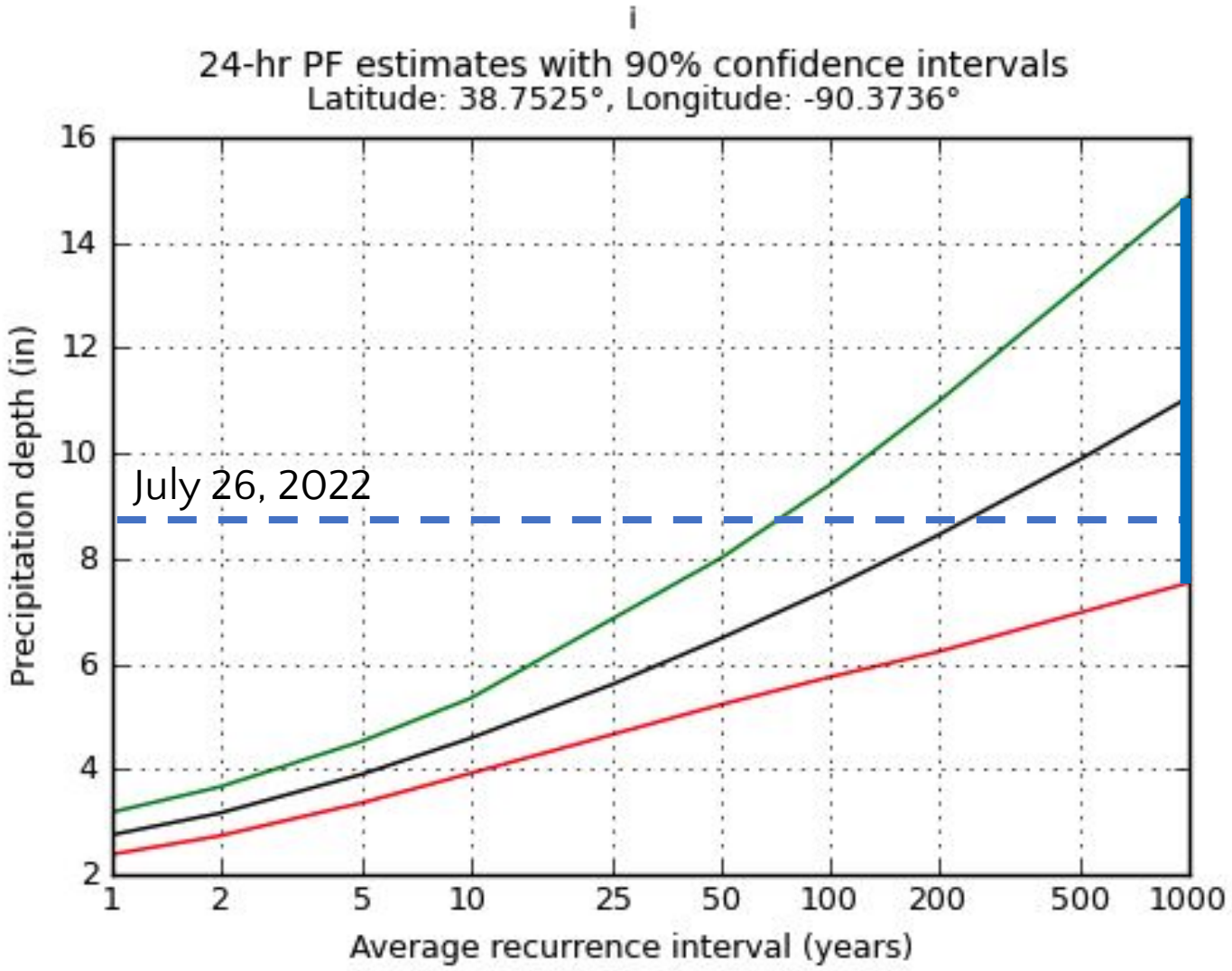
Climate.gov



Data from NOAA Applied Climate Information System

Duration:

- 5-min
- 10-min
- 15-min
- 30-min
- 60-min
- 2-hr
- 3-hr
- 6-hr
- 12-hr
- (•) 24-hr
- 2-day
- 3-day
- 4-day
- 7-day
- 10-day
- 20-day
- 30-day
- 45-day
- 60-day



Upper bound of the 90% confidence interval
Precipitation frequency estimates
Lower bound of the 90% confidence interval

NOAA Atlas 14, Volume 8, Version 2

Created (GMT): Thu Sep 15 20:01:43 2022

St. Louis Lambert International Airport

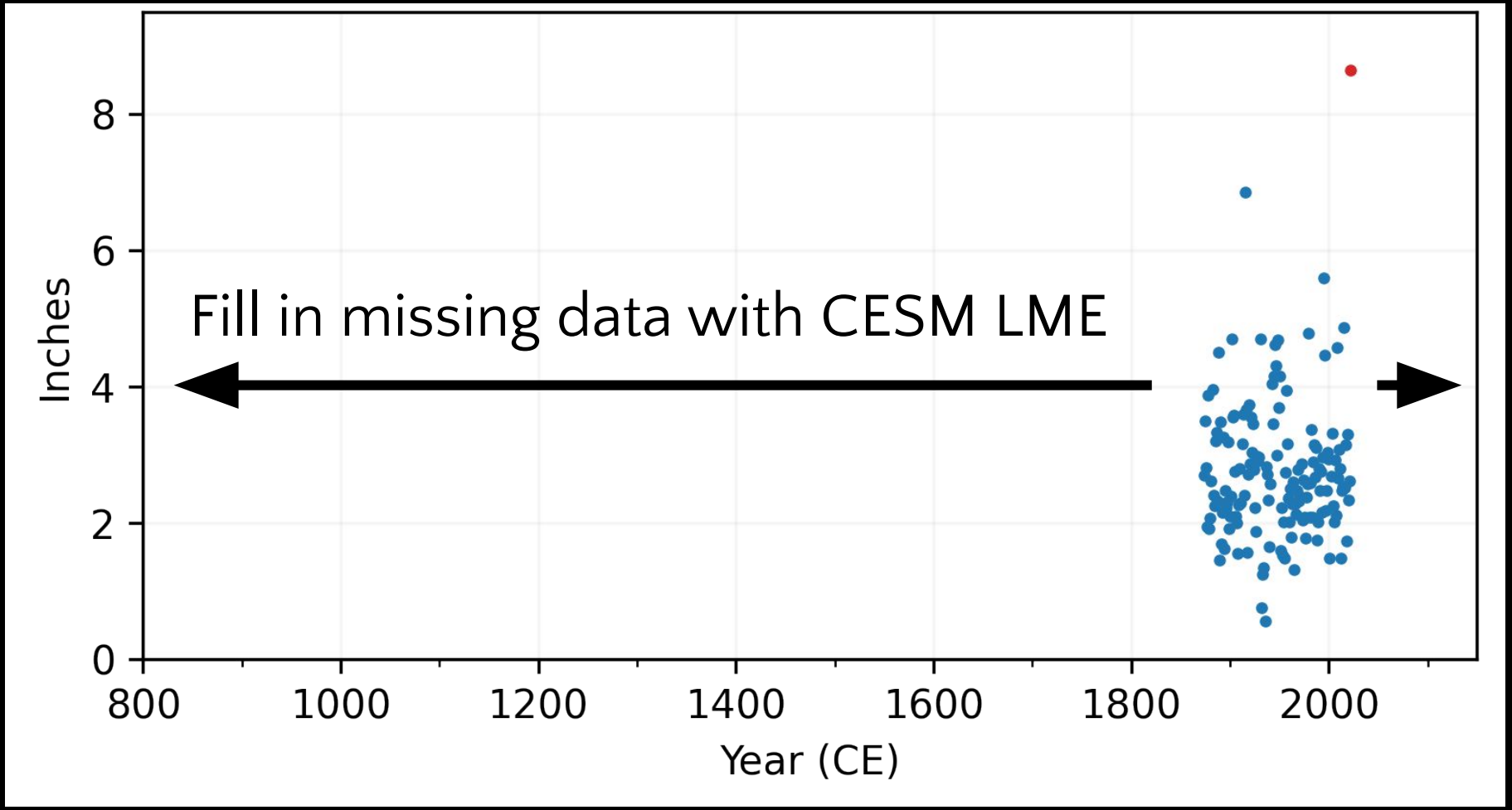
90% CI range: 7.36 inches (~18.7 cm)

CESM Last Millennium Ensemble

4 members

002
003
008
009

850–2100 CE



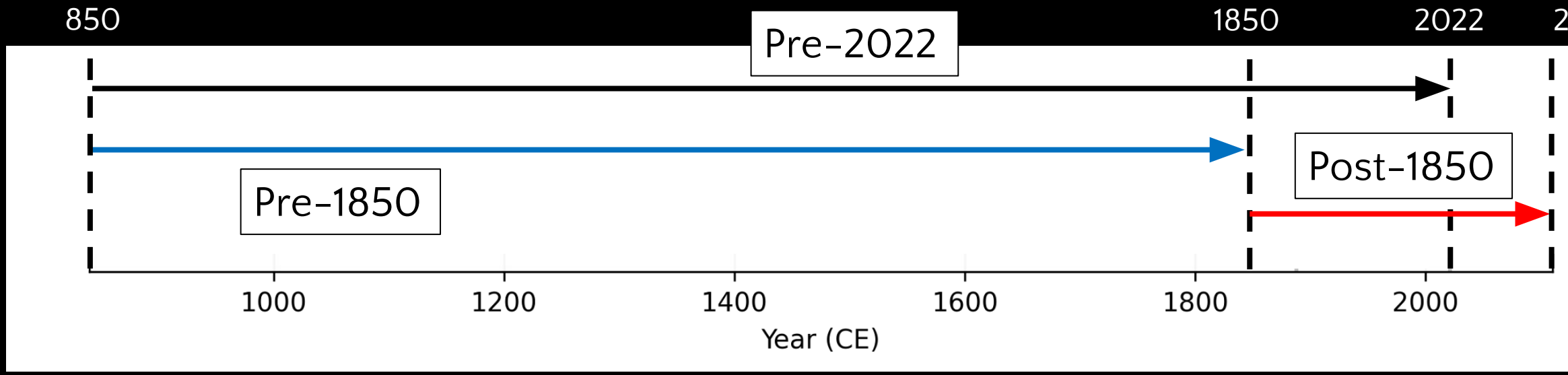
Research Questions

1. What is the “updated” 1,000-year rainfall amount for STL and EKY?

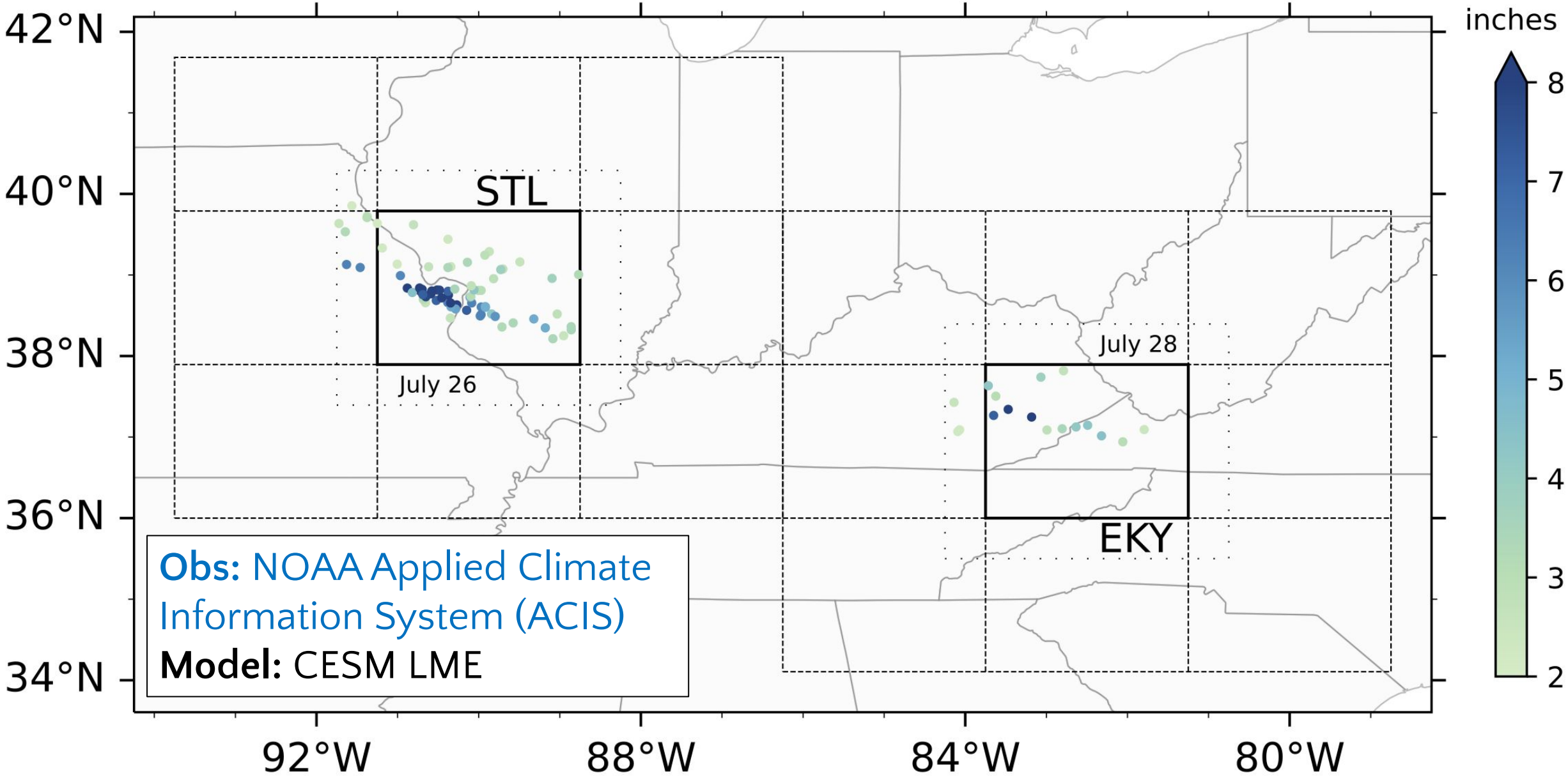
2. What was the return period for the rainfall from the July 2022 storm?

Research Questions

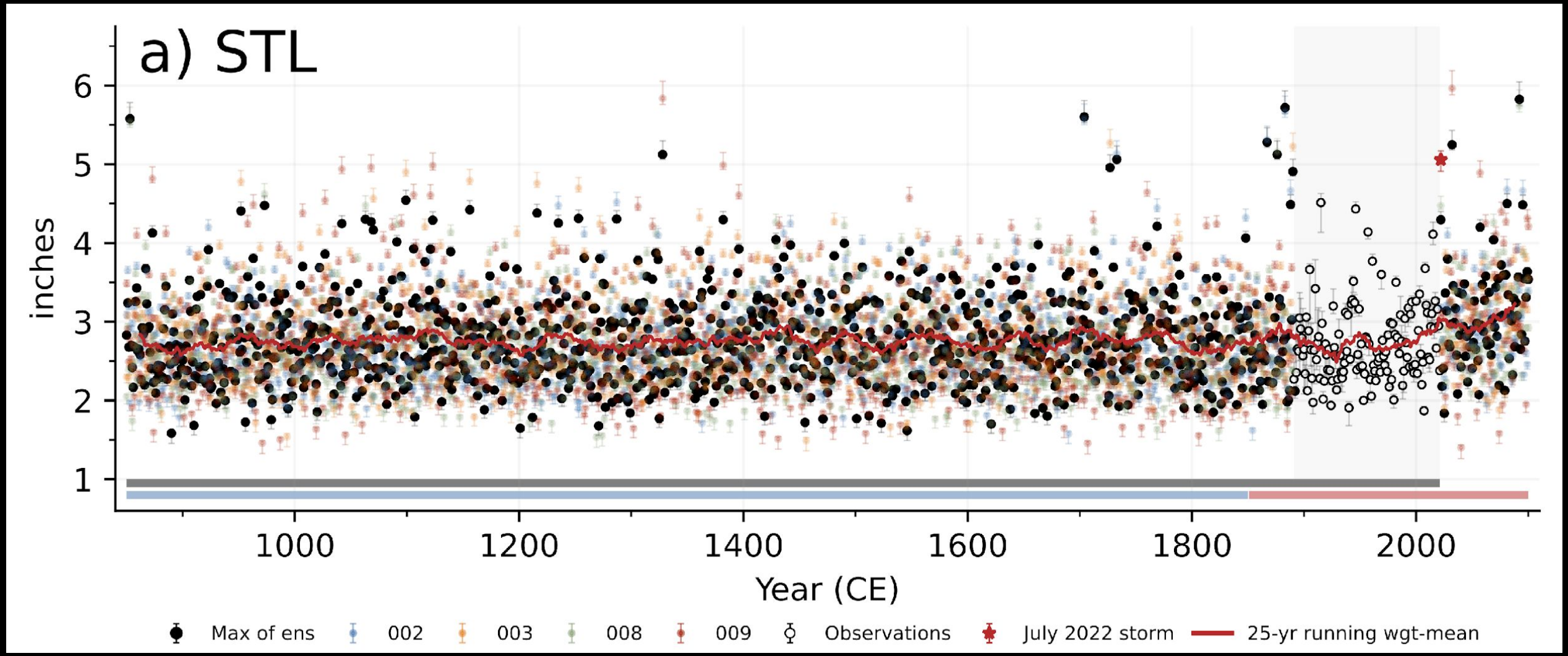
3. How does the return period change under different temporal scenarios?



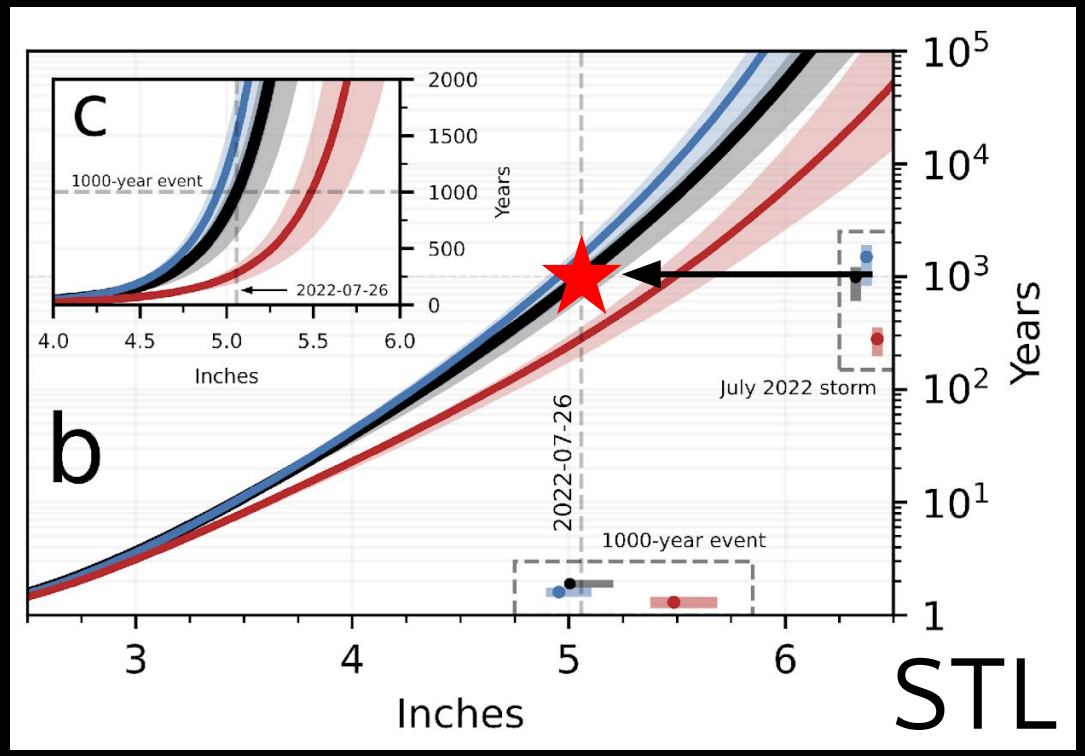
Blended dataset: obs + model

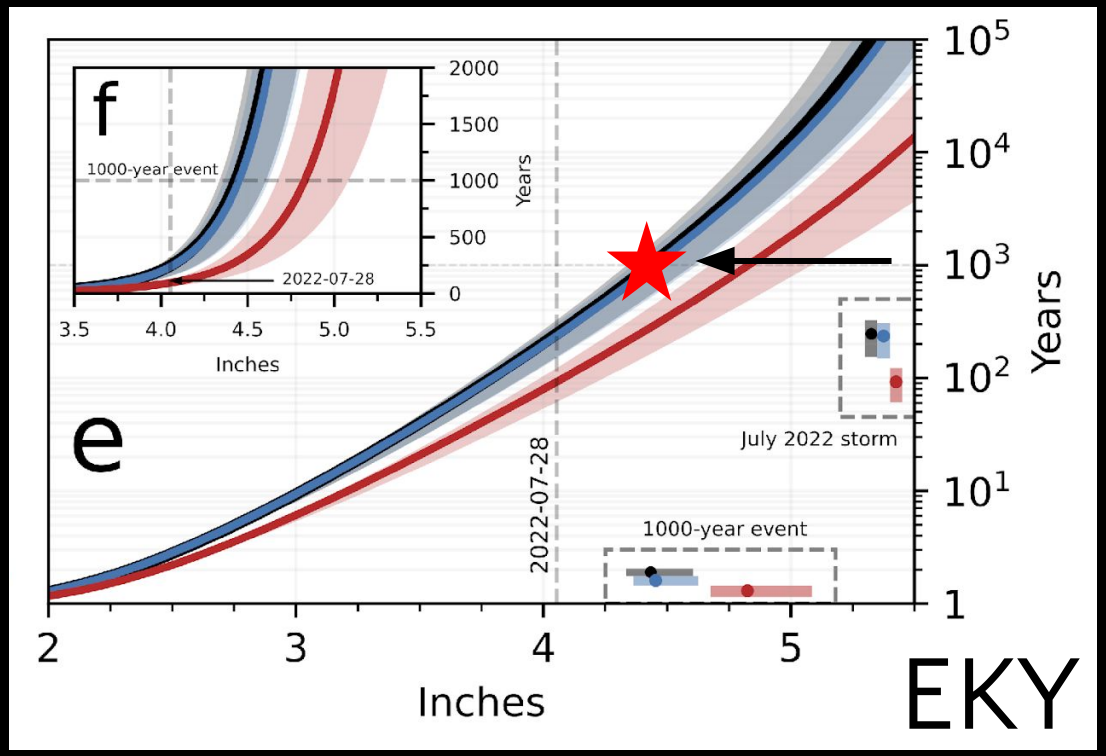


Blended Dataset of Rx1 day



Q1. 1000-year rainfall amount



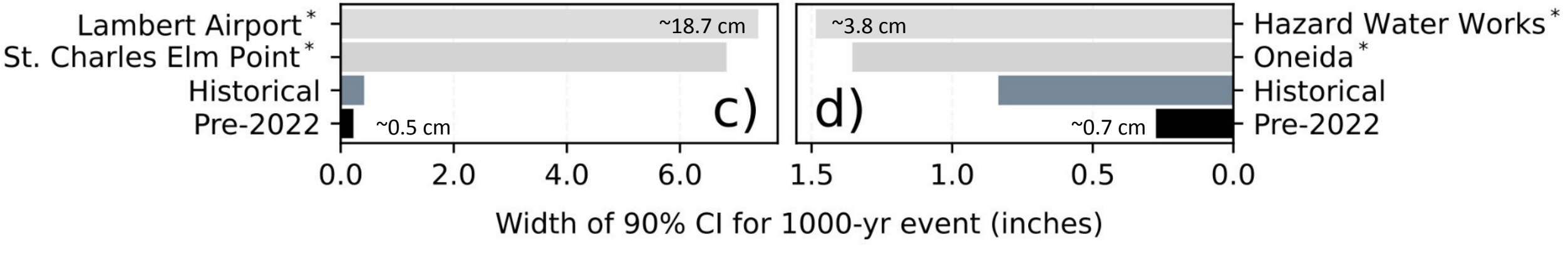


5.06 inches
(90% CI: 5.01–5.21 inches)

4.43 inches
(90% CI: 4.33–4.61 inches)

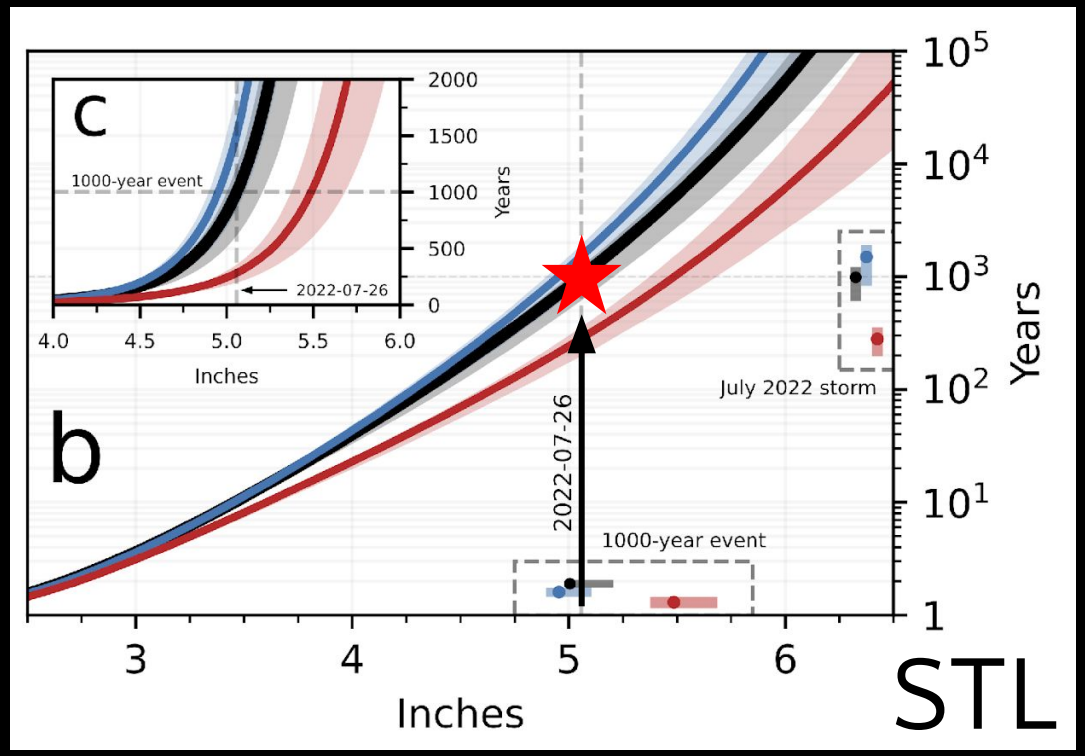
Q1. 1000-year rainfall amount

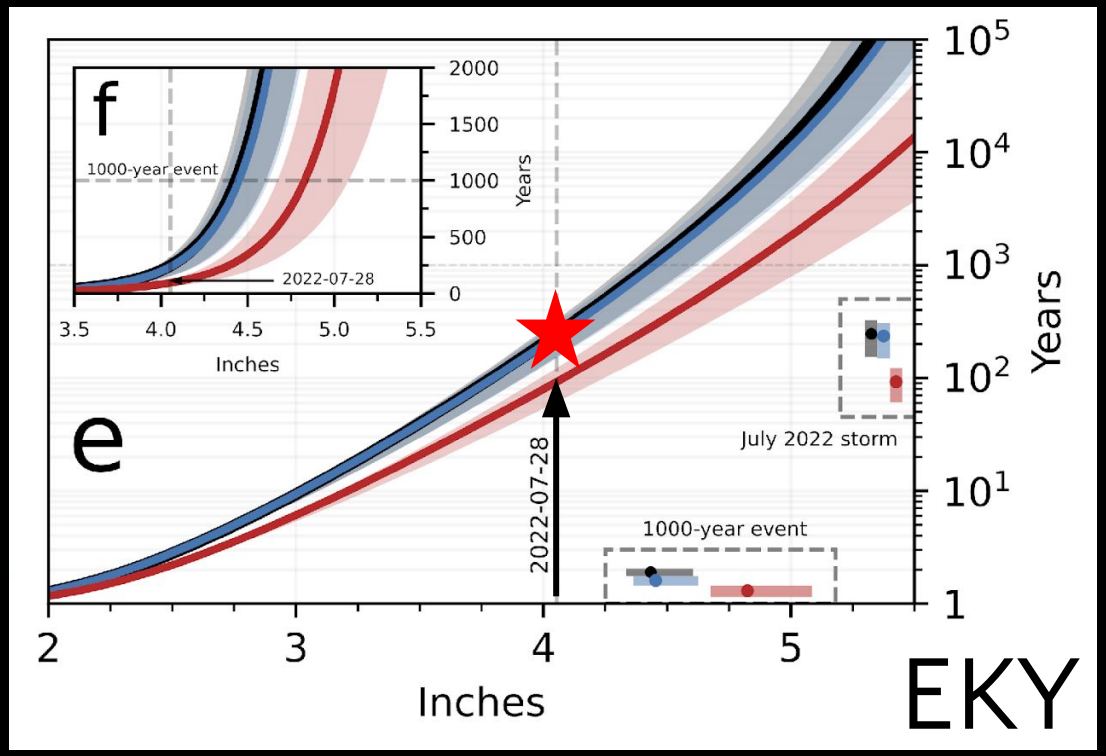
STL EKY



Much less uncertainty with our approach

Q2. July 2022 storm return period

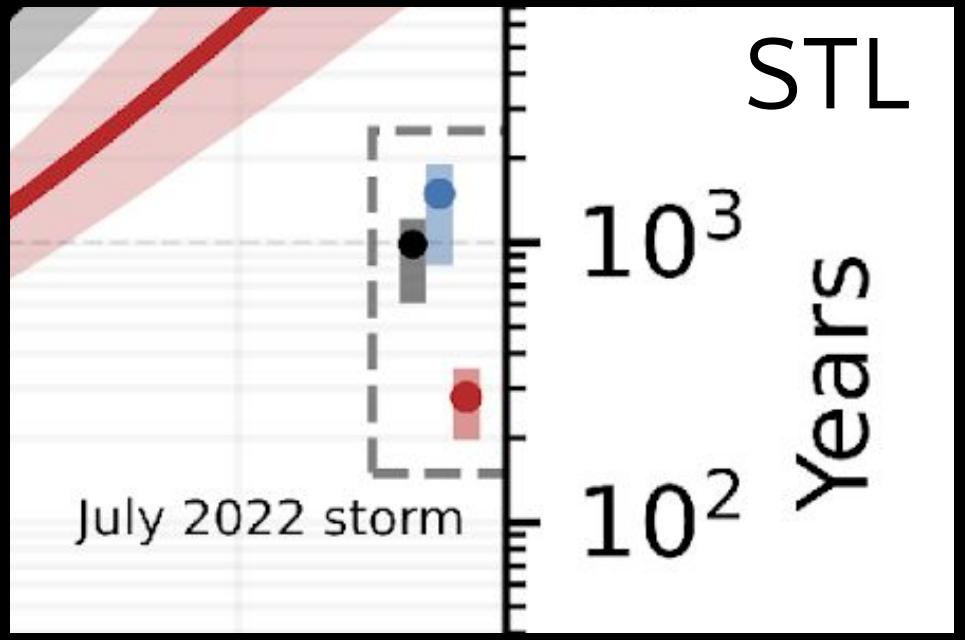


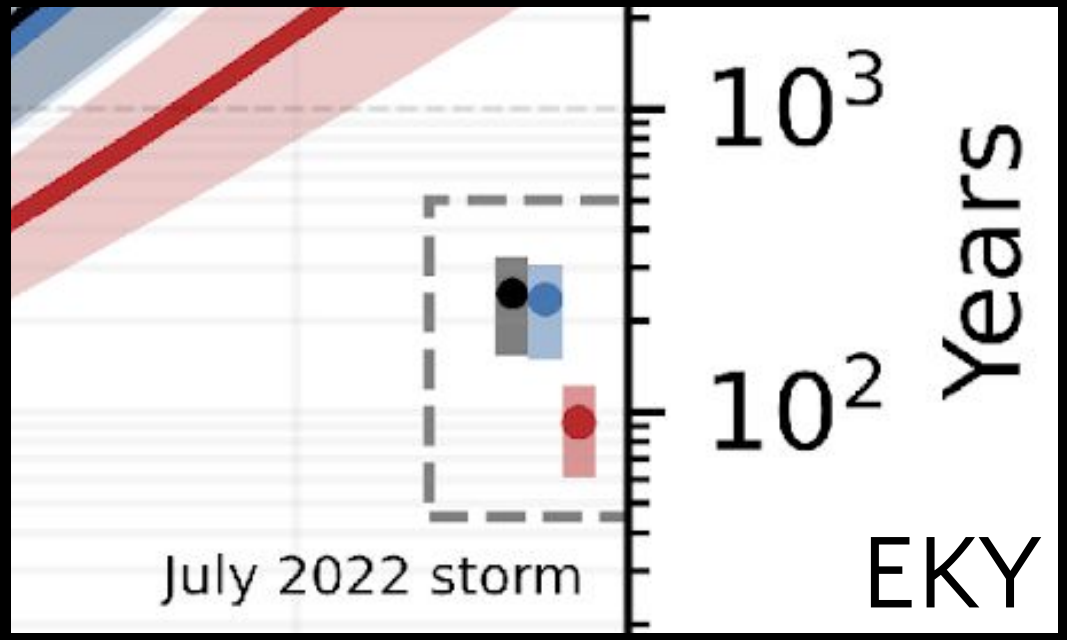


1-in-989-year event
(90% CI: 610–1,219 years)

1-in-246-year event
(90% CI: 153–327 years)

Q3. Impact of warmer world?
July 2022 storm return period





~5 times more likely

~2.5 times more likely

Conclusions

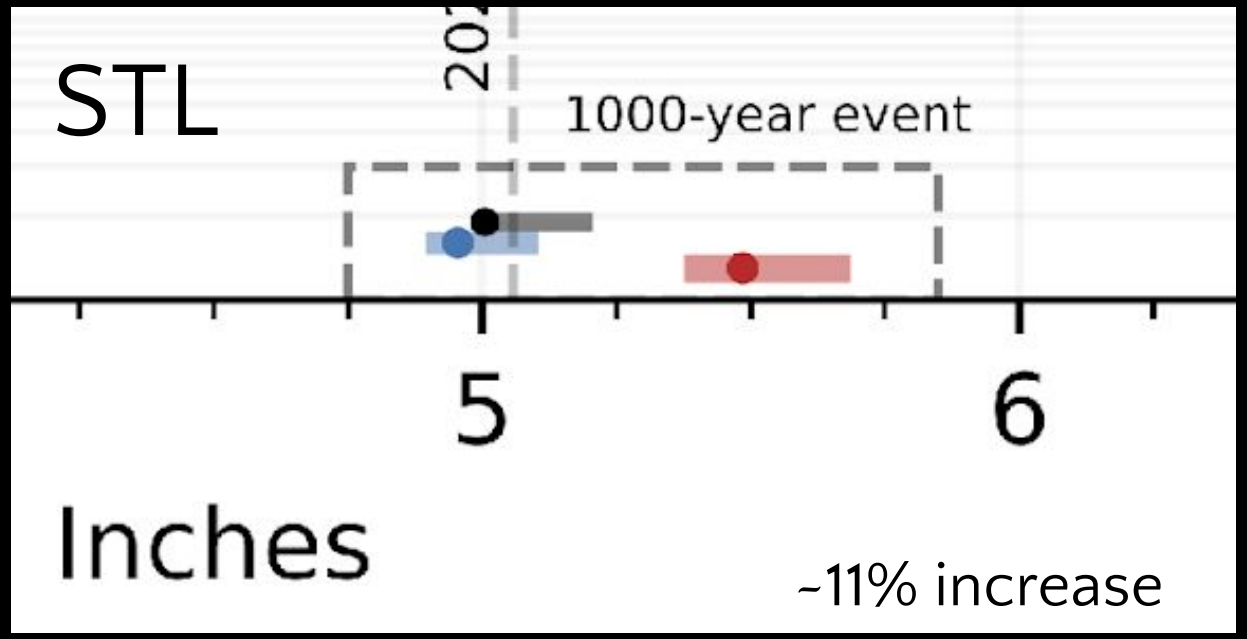
- Novel approach to modern extreme rainfall using paleoclimate modeling!
- July 2022 extreme rainfall
  - STL: ~1000-year event, EKY: ~250-year event
- July 2022 storm is ~2.5 to 5 times more likely in post-industrial era

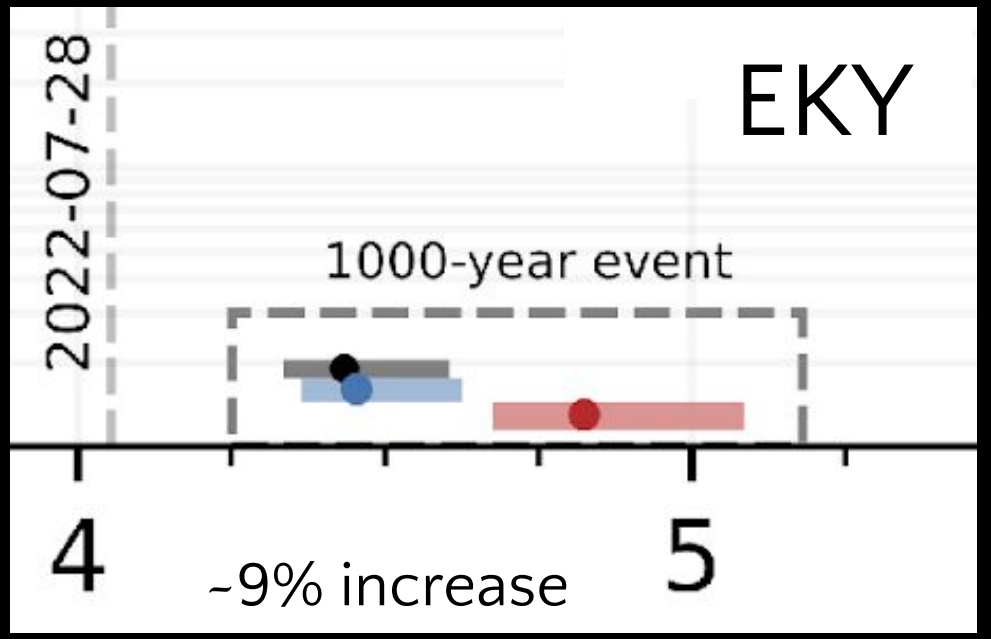
Thank you for listening

ajthompson@wustl.edu

the David & Lucile Packard FOUNDATION

Q3. Impact of warmer world?
1000-year rainfall amount





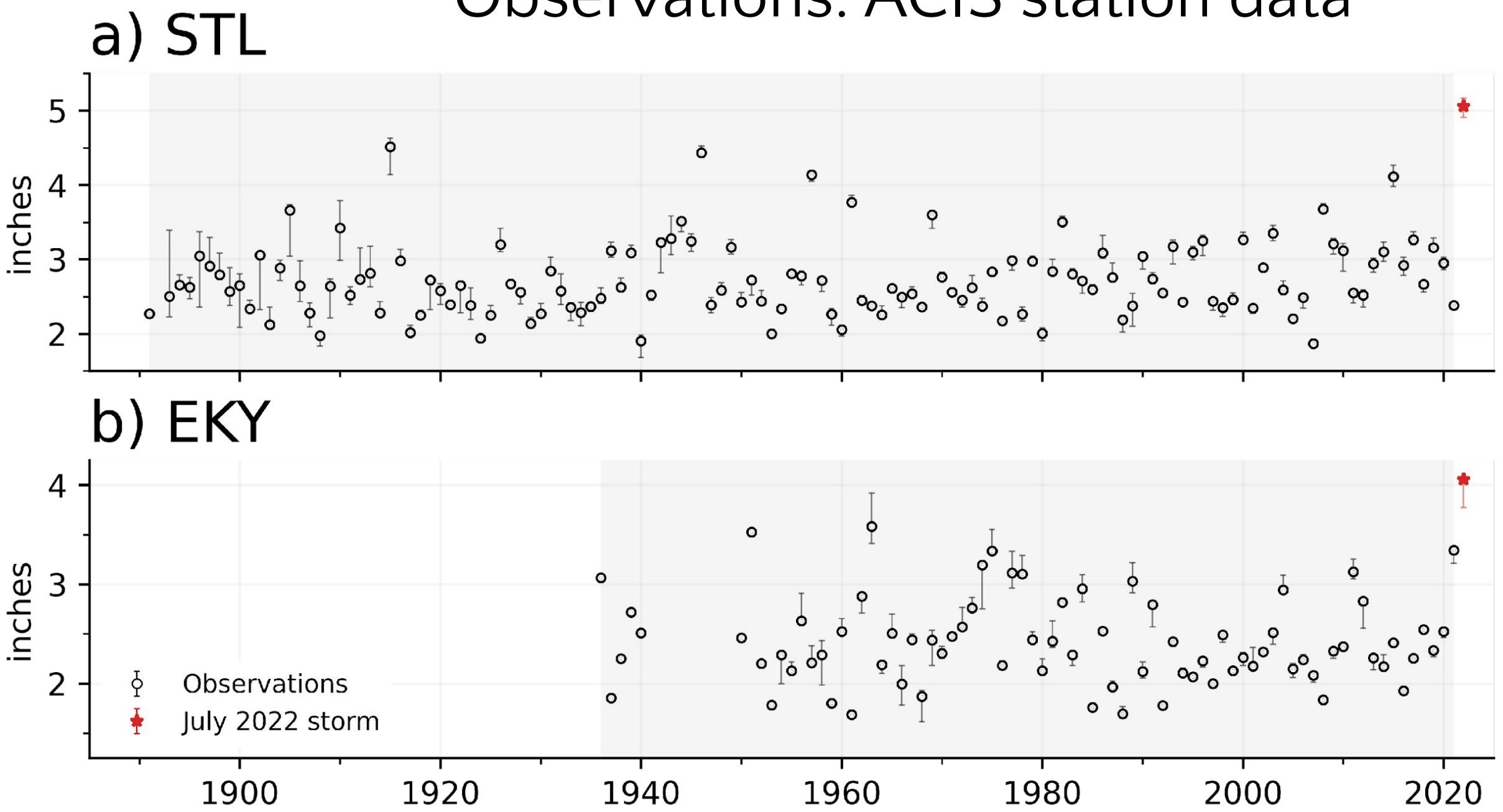
Pre-1850: 4.96 inches

Post-1850: 5.49 inches

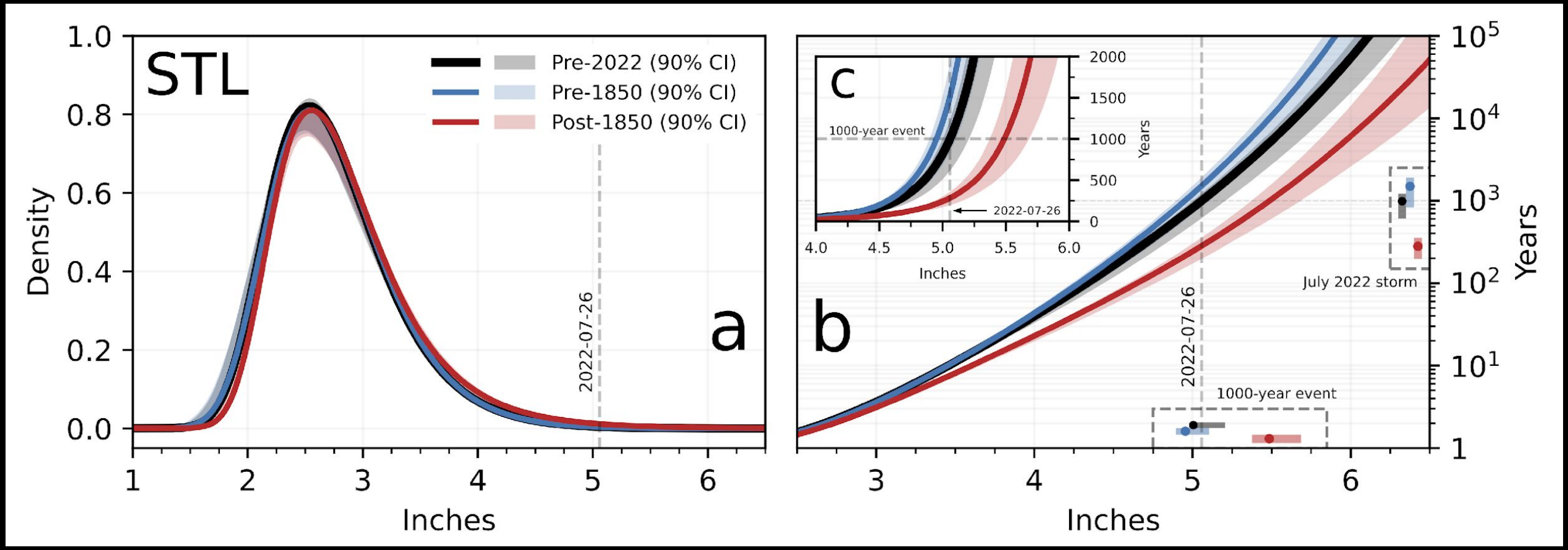
Pre-1850: 4.45 inches

Post-1850: 4.83 inches

Observations: ACIS station data

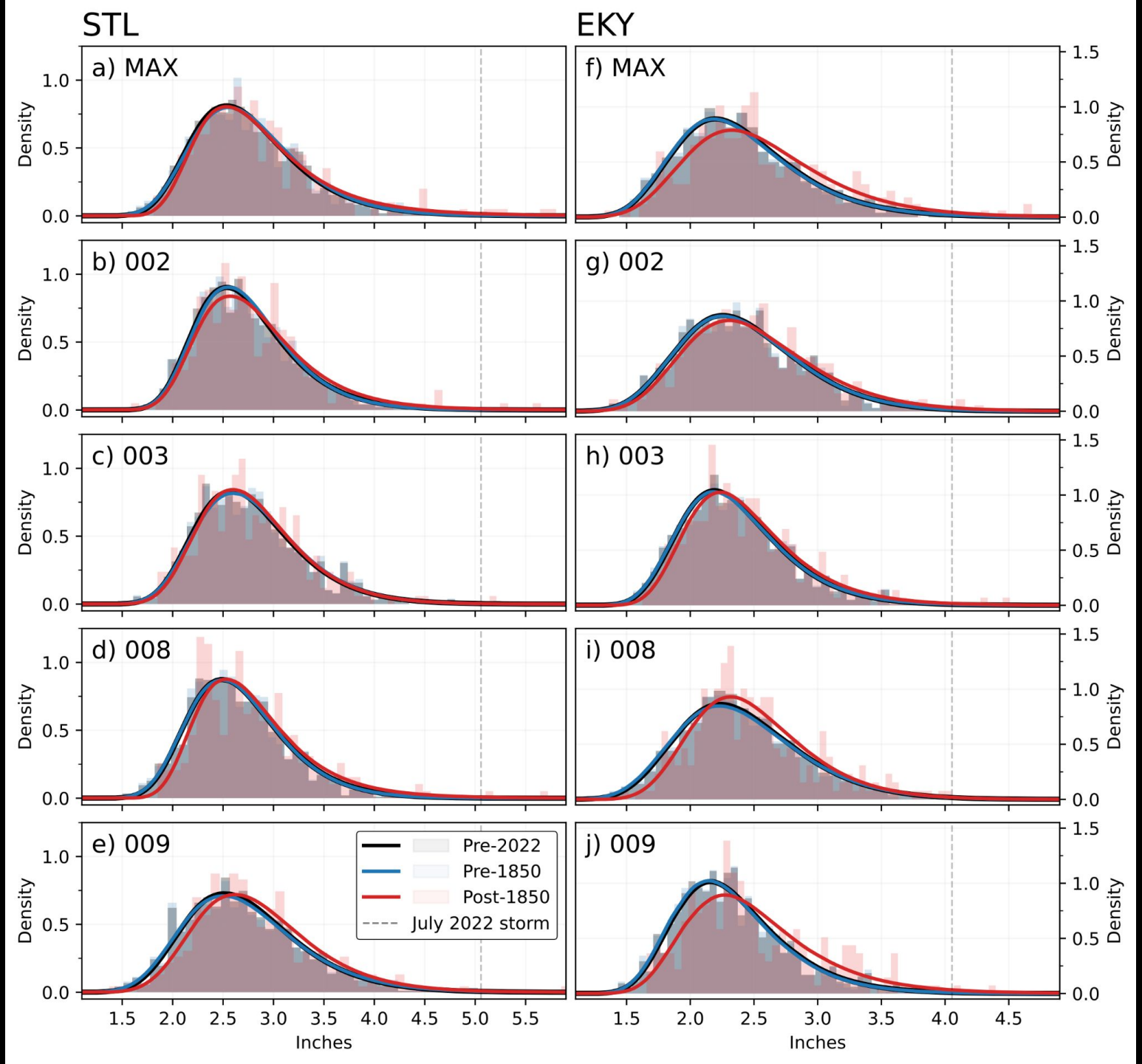


Historical context



GEV distribution

Average recurrence


STL
EKY
a) MAX
b) 002
c) 003
d) 008
e) 009
f) MAX
g) 002
h) 003
i) 008
j) 009
Density
Inches
Pre-2022
Pre-1850
Post-1850
July 2022 storm

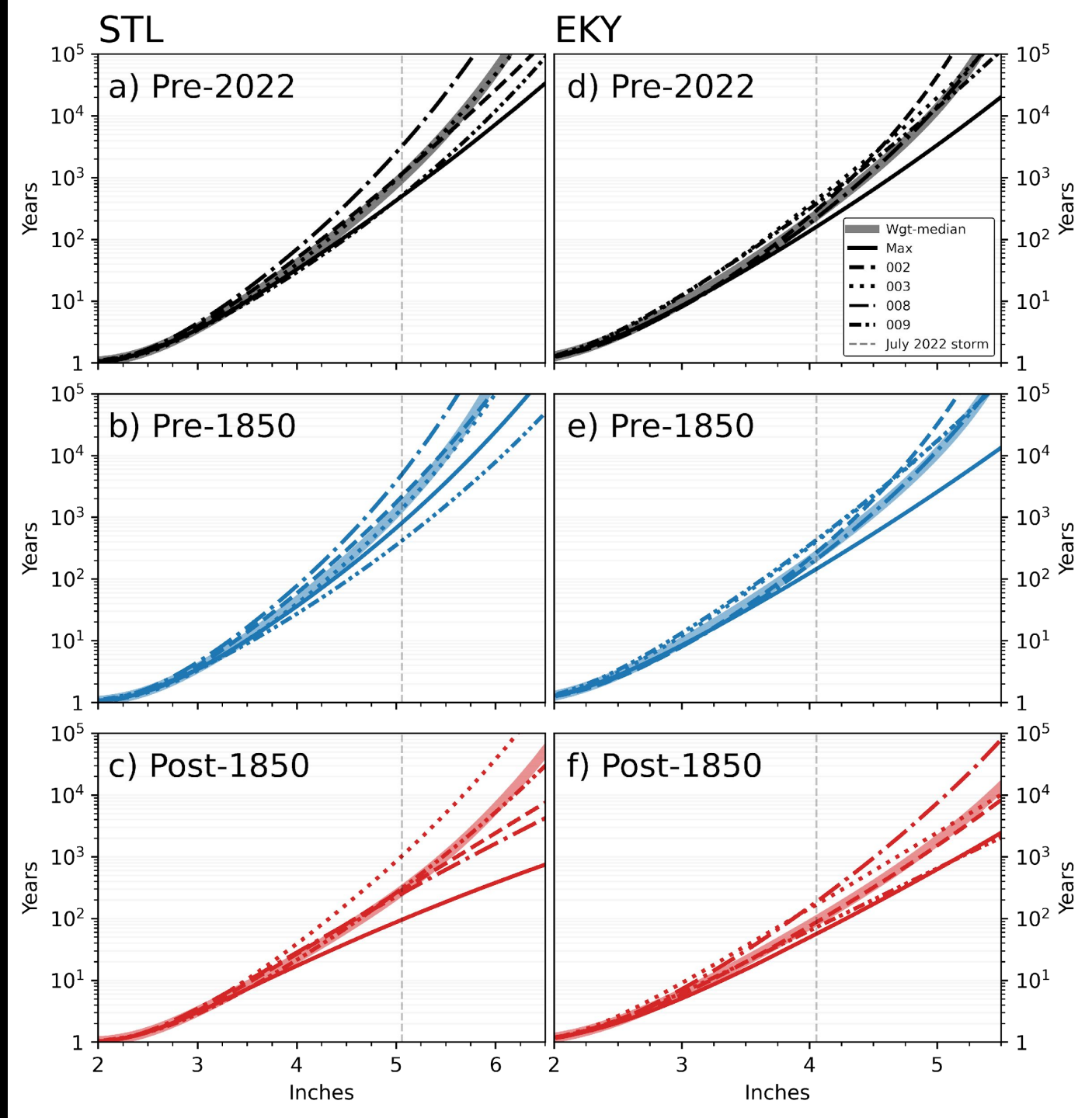
Weighted median:

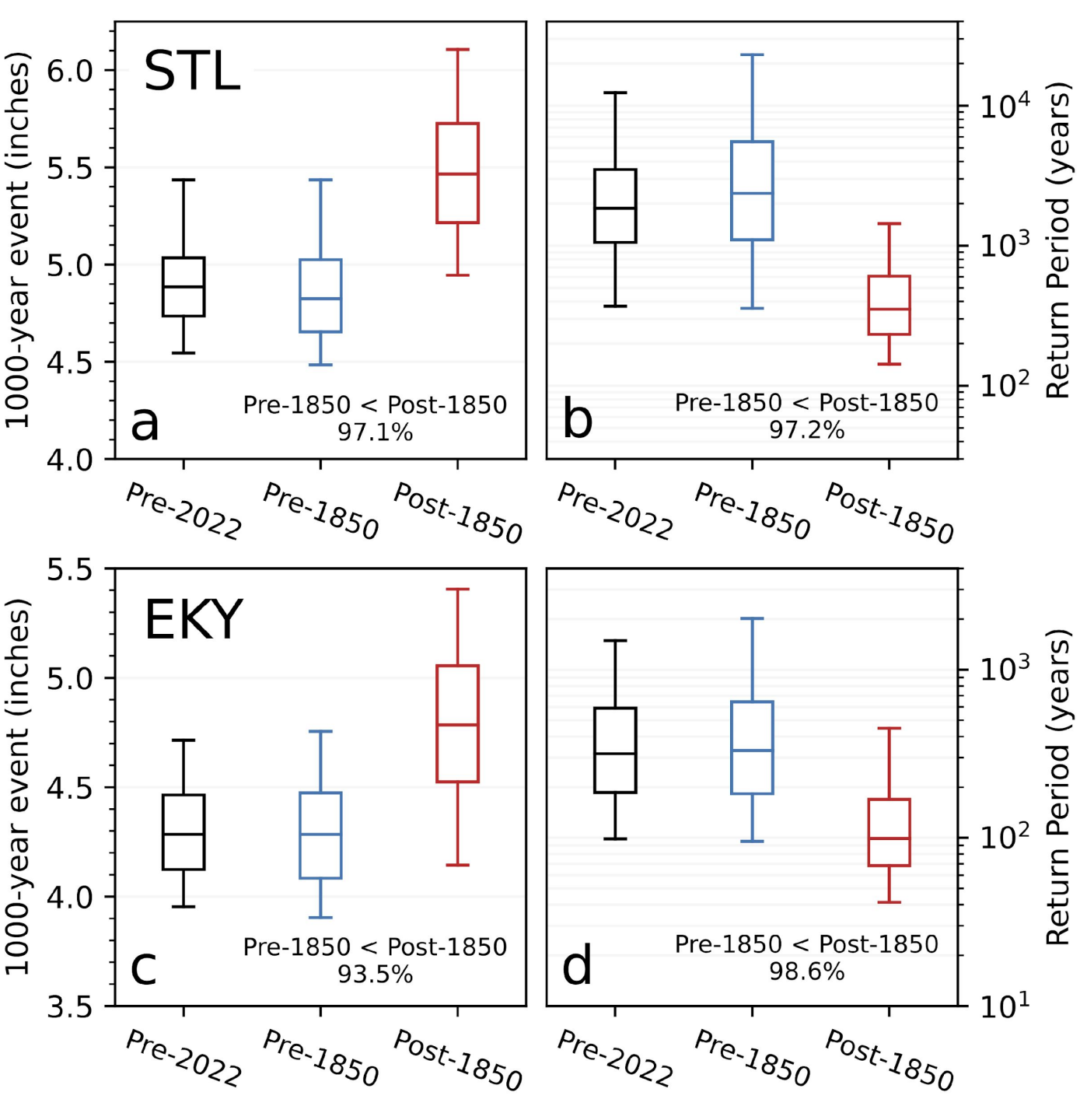
0.5*max

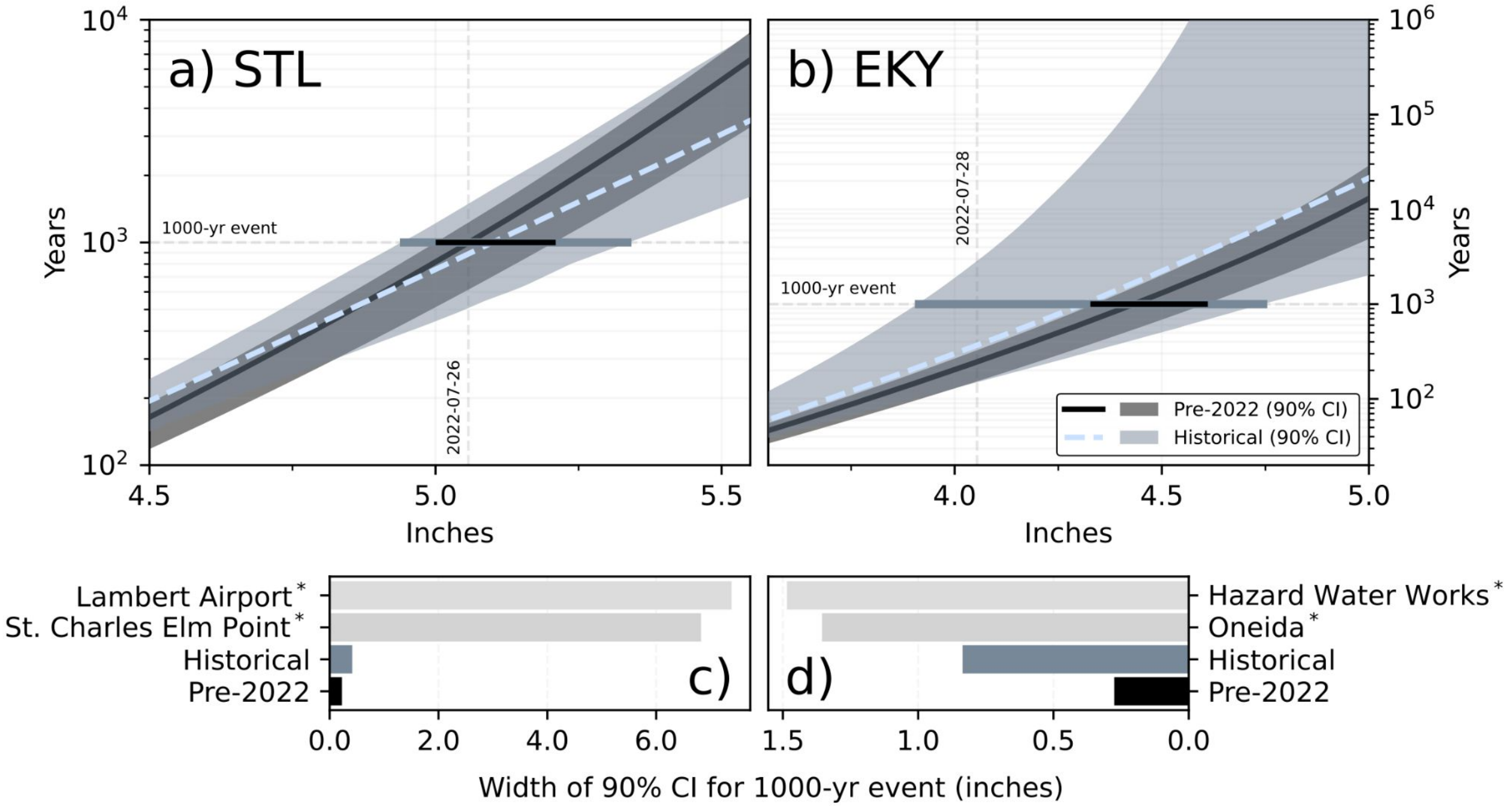
+

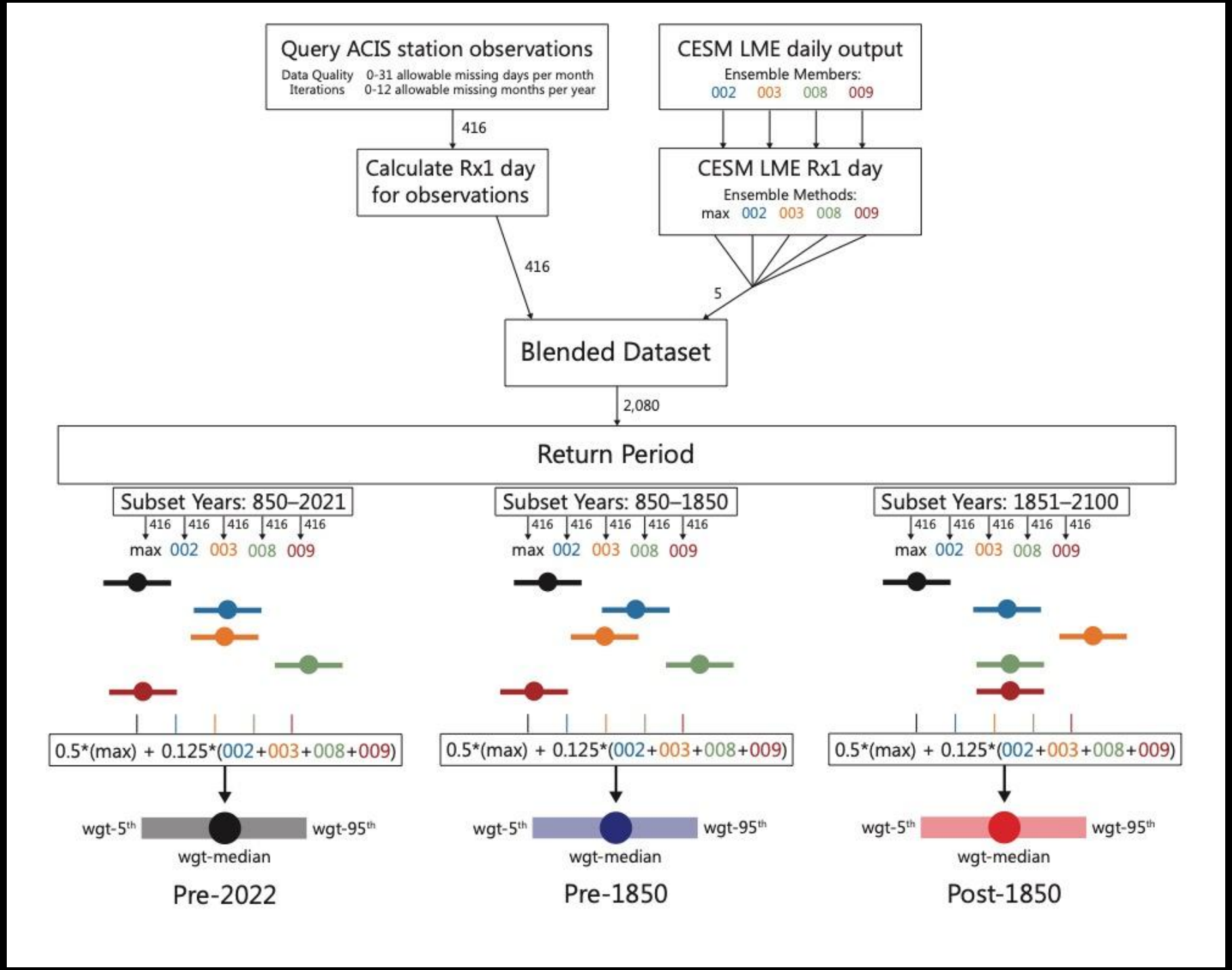
0.125 *

(002+003+008+009)




STL
a
Pre-1850 < Post-1850
97.1%
b
Pre-1850 < Post-1850
97.2%
EKY
c
Pre-1850 < Post-1850
93.5%
d
Pre-1850 < Post-1850
98.6%
1000-year event (inches)
Return Period (years)
Pre-2022
Pre-1850
Post-1850


a) STL
b) EKY
Years
Inches
1000-yr event
2022-07-26
2022-07-28
Pre-2022 (90% CI)
Historical (90% CI)
Lambert Airport*
St. Charles Elm Point*
Historical
Pre-2022
c)
d)
Hazard Water Works*
Oneida*
Historical
Pre-2022
Width of 90% CI for 1000-yr event (inches)


Query ACIS station observations
Data Quality 0-31 allowable missing days per month
Iterations 0-12 allowable missing months per year
CESM LME daily output
Ensemble Members:
002 003 008 009
416
Calculate Rx1 day for observations
CESM LME Rx1 day
Ensemble Methods:
max 002 003 008 009
416
5
Blended Dataset
2,080
Return Period
Subset Years: 850–2021
Subset Years: 850–1850
Subset Years: 1851–2100
416 416 416 416 416
max 002 003 008 009
0.5*(max) + 0.125*(002+003+008+009)
wgt-5th
wgt-95th
wgt-median
Pre-2022
Pre-1850
Post-1850

Data Quality Iteration: 10 allowable missing days per month
5 allowable missing months per year

Selected year from Queried Station #1

J:	15 values,	16 NaN	✗	≥ 10 NaN
F:	20 values,	8 NaN	✓	< 10 NaN
M:	30 values,	1 NaN	✓	< 10 NaN
A:	28 values,	2 NaN	✓	< 10 NaN
M:	11 values,	20 NaN	✗	≥ 10 NaN
J:	12 values,	18 NaN	✗	≥ 10 NaN
J:	30 values,	1 NaN	✓	< 10 NaN
A:	31 values,	0 NaN	✓	< 10 NaN
S:	29 values,	1 NaN	✓	< 10 NaN
O:	15 values,	16 NaN	✗	≥ 10 NaN
N:	30 values,	0 NaN	✓	< 10 NaN
D:	25 values,	6 NaN	✓	< 10 NaN

4 months with ≥ 10 NaN days ✓

Year has < 5 NaN months

Queried Station #1

Included in data query

Selected year from Queried Station #2

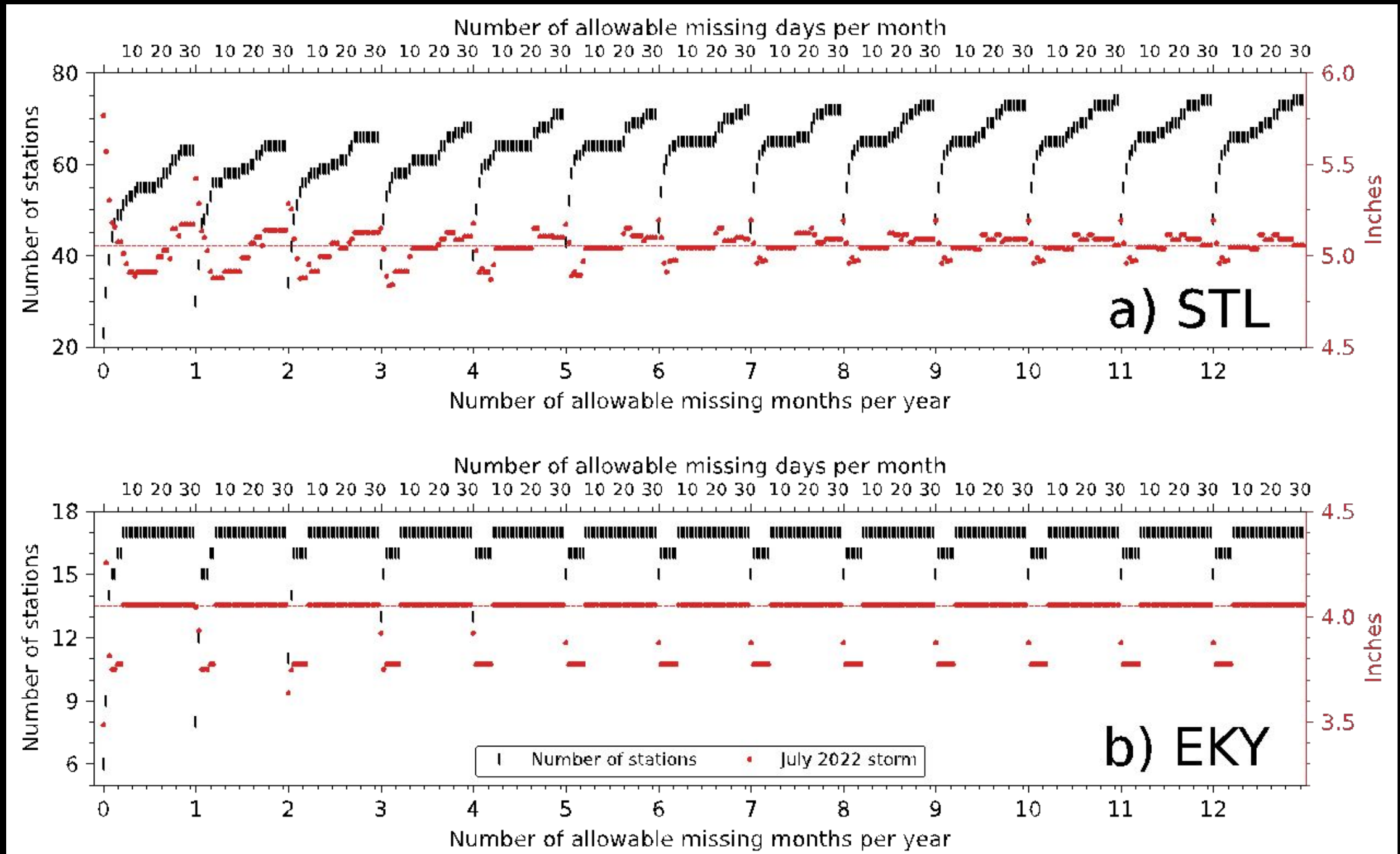
J:	15 values,	16 NaN	✗	≥ 10 NaN
F:	10 values,	10 NaN	✗	≥ 10 NaN
M:	30 values,	1 NaN	✓	< 10 NaN
A:	28 values,	2 NaN	✓	< 10 NaN
M:	11 values,	20 NaN	✗	≥ 10 NaN
J:	12 values,	18 NaN	✗	≥ 10 NaN
J:	30 values,	1 NaN	✓	< 10 NaN
A:	21 values,	10 NaN	✗	≥ 10 NaN
S:	29 values,	1 NaN	✓	< 10 NaN
O:	15 values,	16 NaN	✗	≥ 10 NaN
N:	30 values,	0 NaN	✓	< 10 NaN
D:	25 values,	6 NaN	✓	< 10 NaN

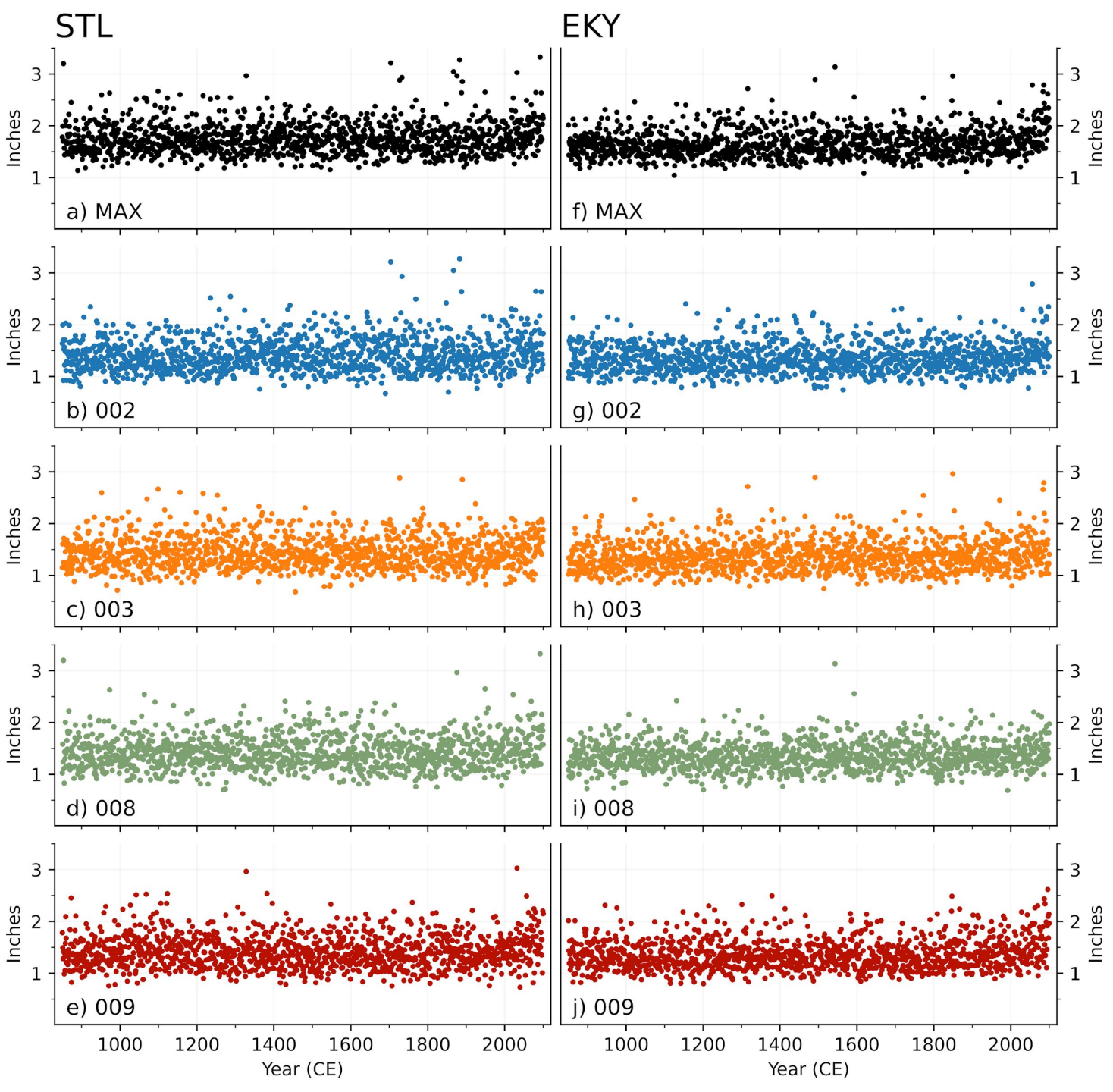
6 months with ≥ 10 NaN days ✗

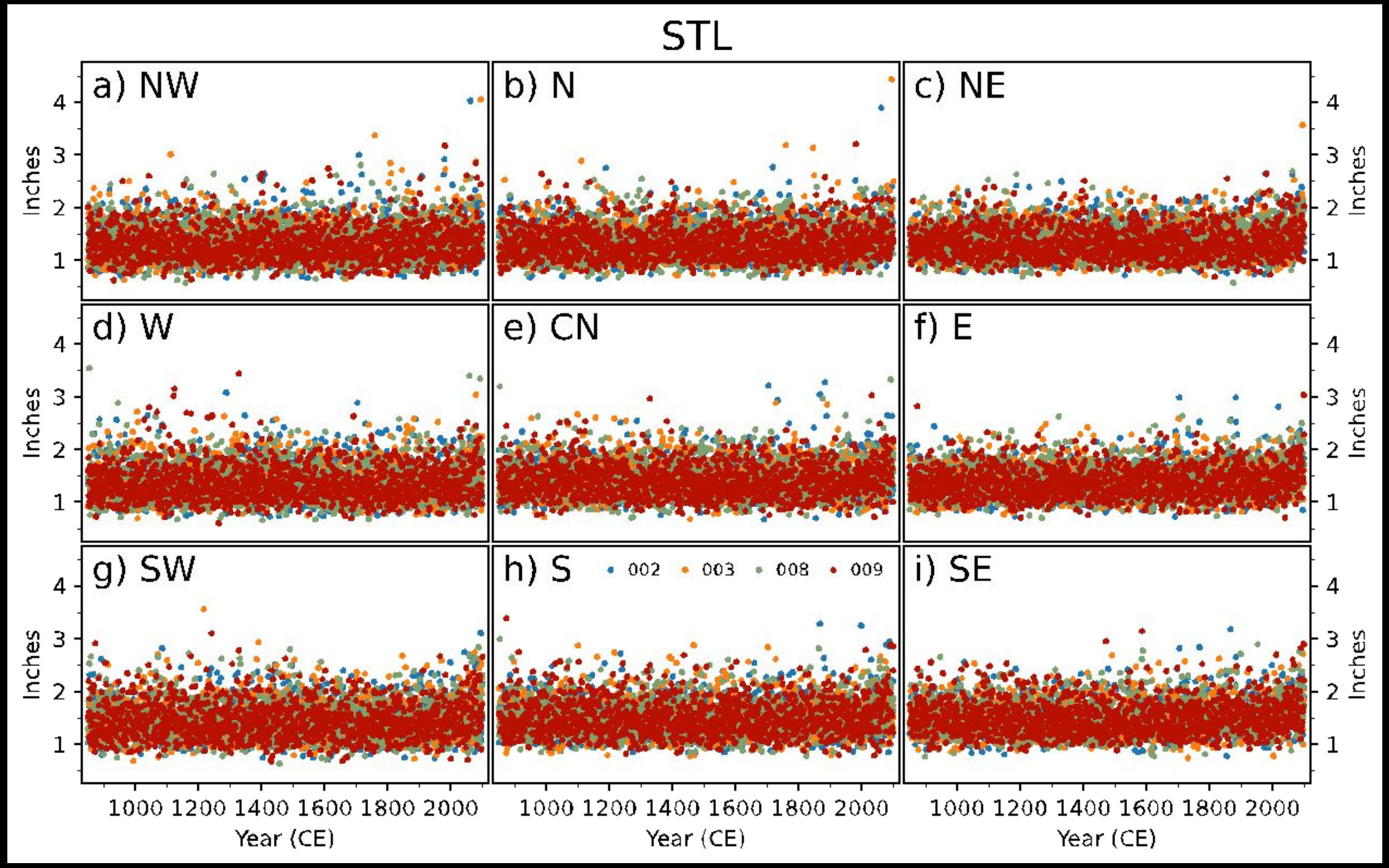
Year has > 5 NaN months

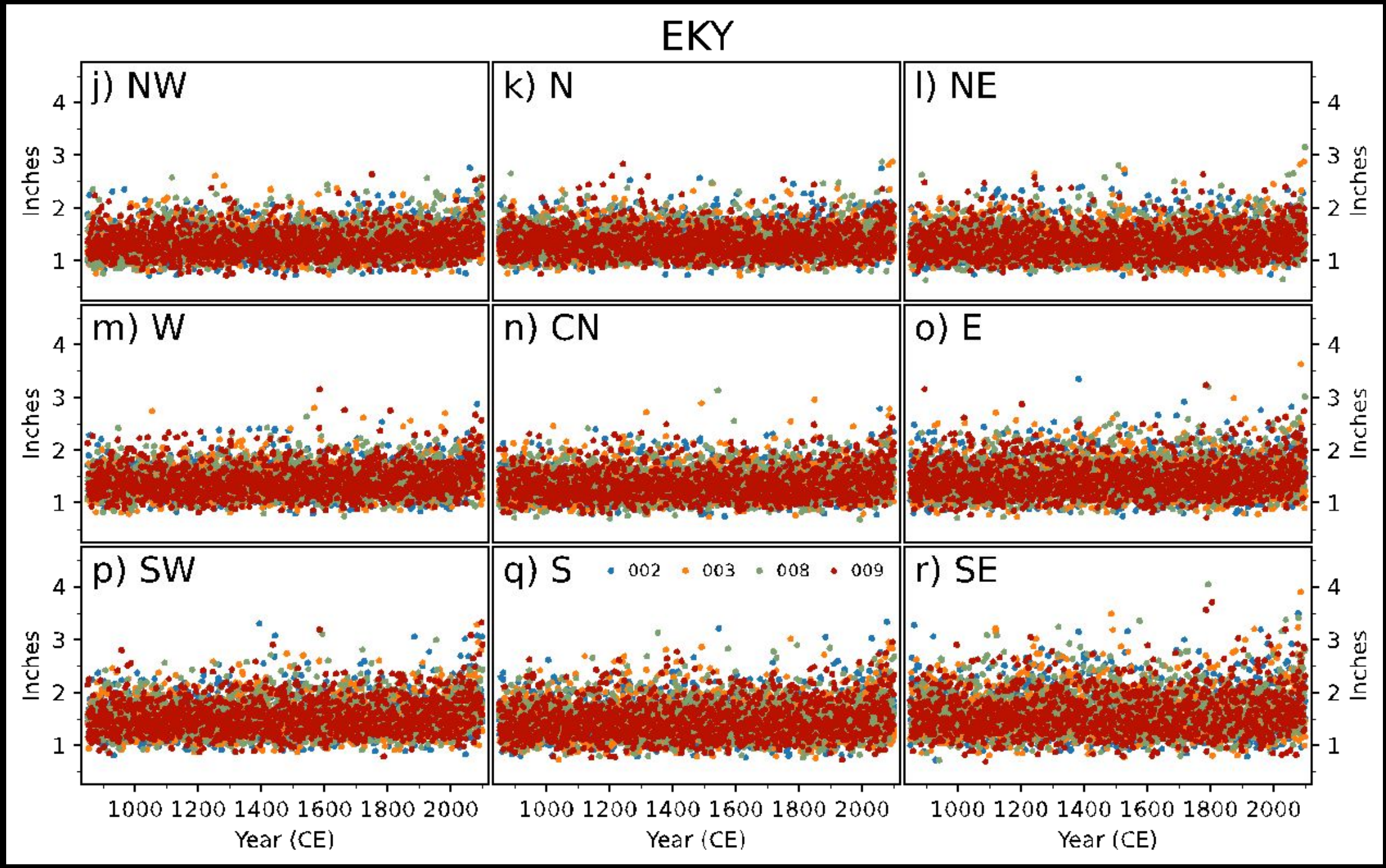
Queried Station #2

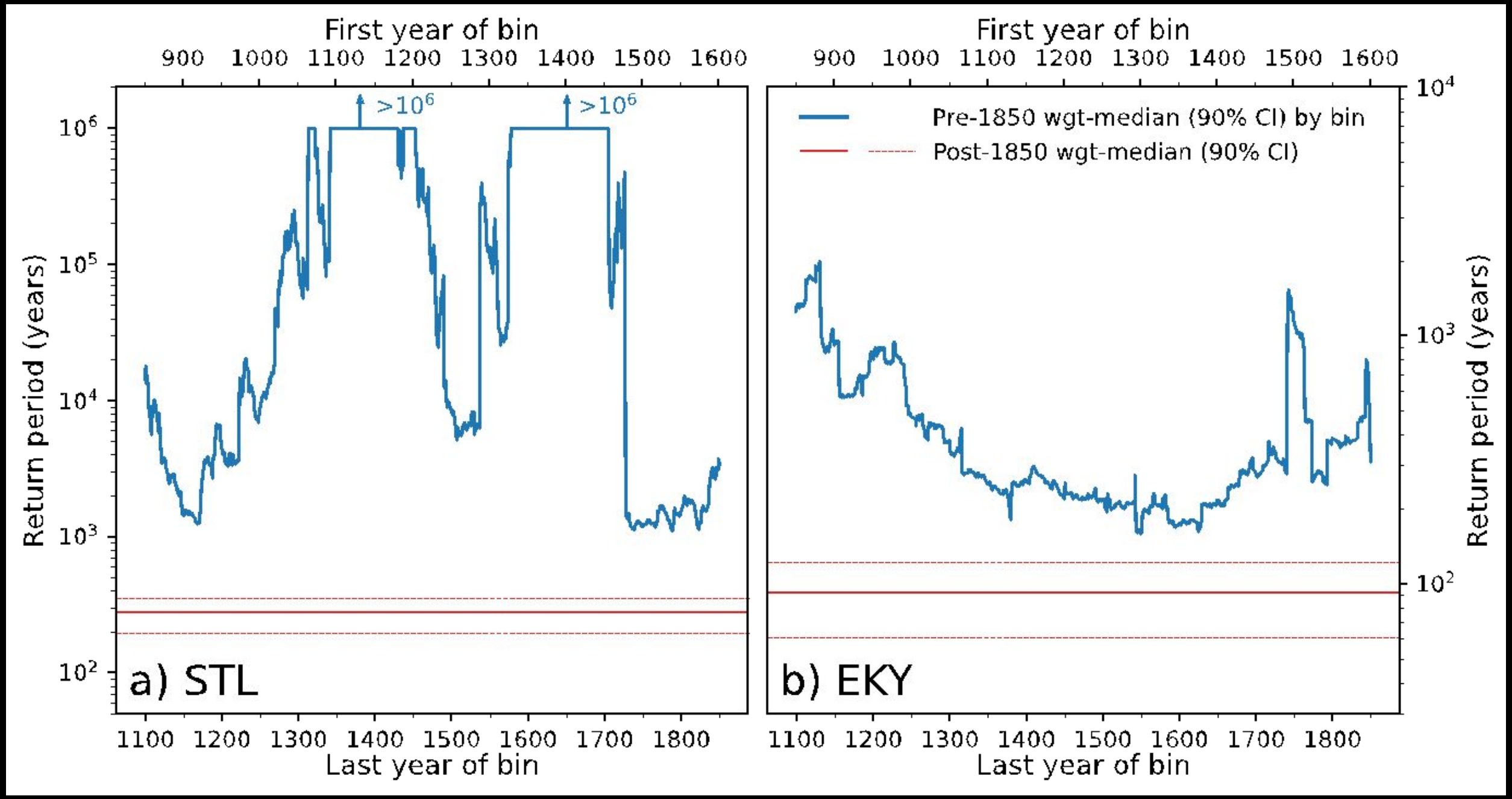
Excluded from data query


Number of allowable missing days per month
10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30
Number of stations
Inches
80
60
40
20
6.0
5.5
5.0
4.5
0 1 2 3 4 5 6 7 8 9 10 11 12
Number of allowable missing months per year
a) STL
Number of allowable missing days per month
10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30
Number of stations
Inches
18
15
12
9
6
4.5
4.0
3.5
Number of stations
July 2022 storm
0 1 2 3 4 5 6 7 8 9 10 11 12
Number of allowable missing months per year
b) EKY


STL
EKY
Inches
a) MAX
f) MAX
b) 002
g) 002
c) 003
h) 003
d) 008
i) 008
e) 009
j) 009
1000
1200
1400
1600
1800
2000
Year (CE)


STL
a) NW
b) N
c) NE
d) W
e) CN
f) E
g) SW
h) S
i) SE
002
003
008
009
Inches
1
2
3
4
1000 1200 1400 1600 1800 2000
Year (CE)


EKY
j) NW
k) N
l) NE
m) W
n) CN
o) E
p) SW
q) S
r) SE
002
003
008
009
Inches
Year (CE)
1000 1200 1400 1600 1800 2000
1
2
3
4


First year of bin
900 1000 1100 1200 1300 1400 1500 1600
>10^6
>10^6
Return period (years)
10^6
10^5
10^4
10^3
10^2
a) STL
1100 1200 1300 1400 1500 1600 1700 1800
Last year of bin
First year of bin
900 1000 1100 1200 1300 1400 1500 1600
Pre-1850 wgt-median (90% CI) by bin
Post-1850 wgt-median (90% CI)
10^4
10^3
10^2
Return period (years)
b) EKY
1100 1200 1300 1400 1500 1600 1700 1800
Last year of bin