Marine Heatwaves analyzed using Extreme Value Theory

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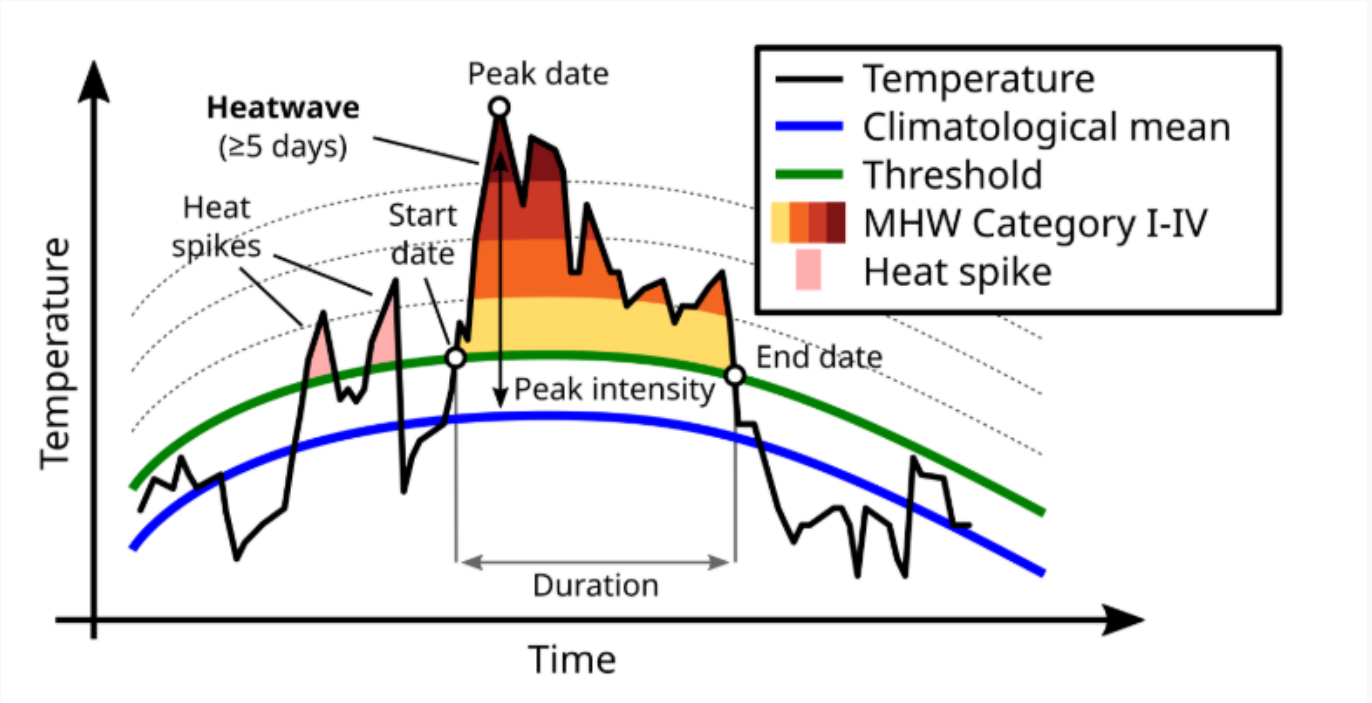
Site E01


Bering Sea
ALASKA
UNITED
STATES
CANADA
ROCKY MOUNTAINS
Gulf of Alaska
Pacific Basin
British Columbia
Port Hardy
Vancouver Island
Where you are now!
Vancouver
E01
Tofino
Victoria
Seattle
Pacific Ocean
51°N
50°
49°
48°
130°W
128°
126°
124°
122°

Definition of MHWs



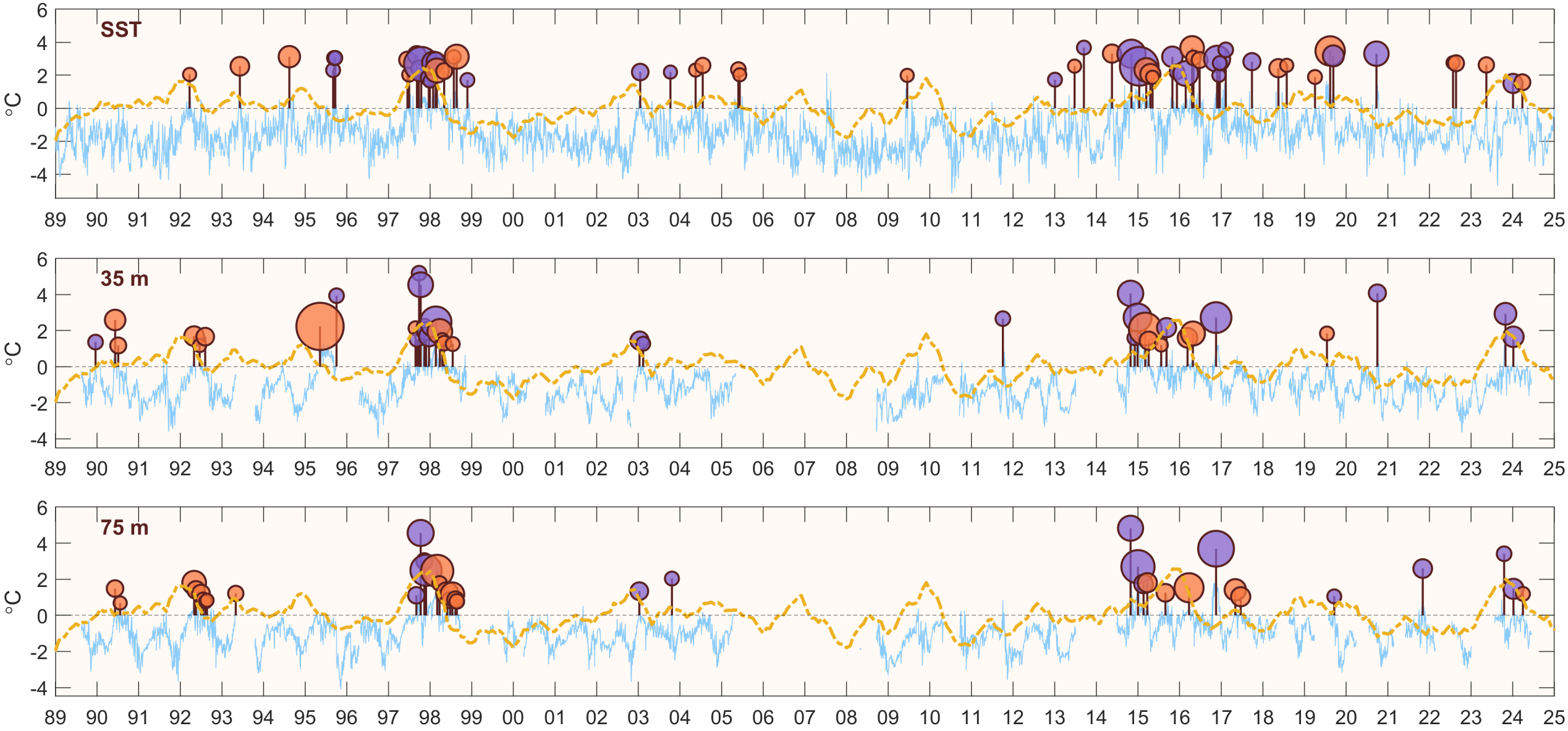
MHW definition is based on 5 consecutive days above 90th percentile for each day. With some latitude for 1 or 2-day gaps (Hobday et al., 2016).

Two Metrics: Intensity and Duration.

E01 MHW Time Series

Height is Intensity, Area of circle is Duration.

Orange is spring/summer; purple is fall/winter



Year: 1989 to 2025.

Extreme Value Theory

- Mathematical formalism for using existing data to extract information about events that have not been observed.
- Return Levels
  - For a given time interval, what is the expected value of the largest

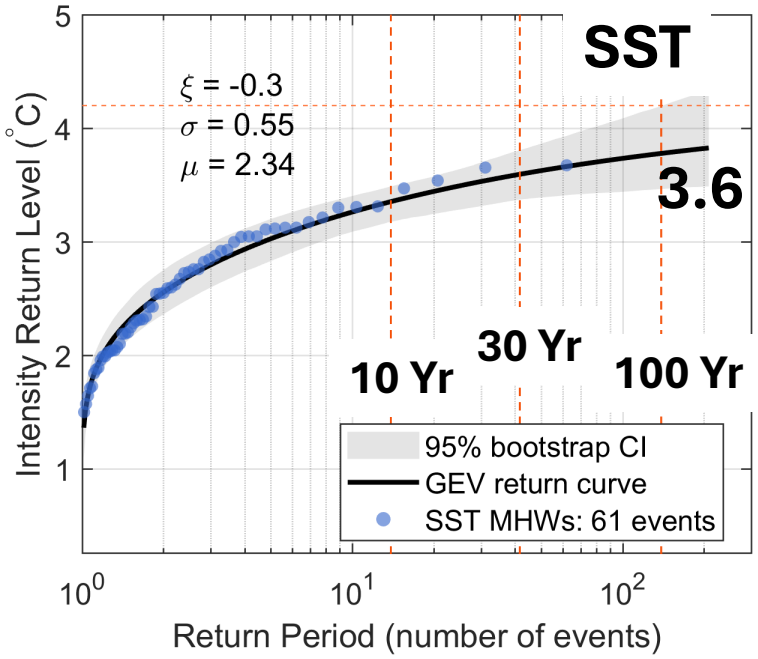
Questions

1) What is the 100-year MHW – Intensity, Duration.
2) How likely to observe the 100-year MHW Duration with 30 years of observation?

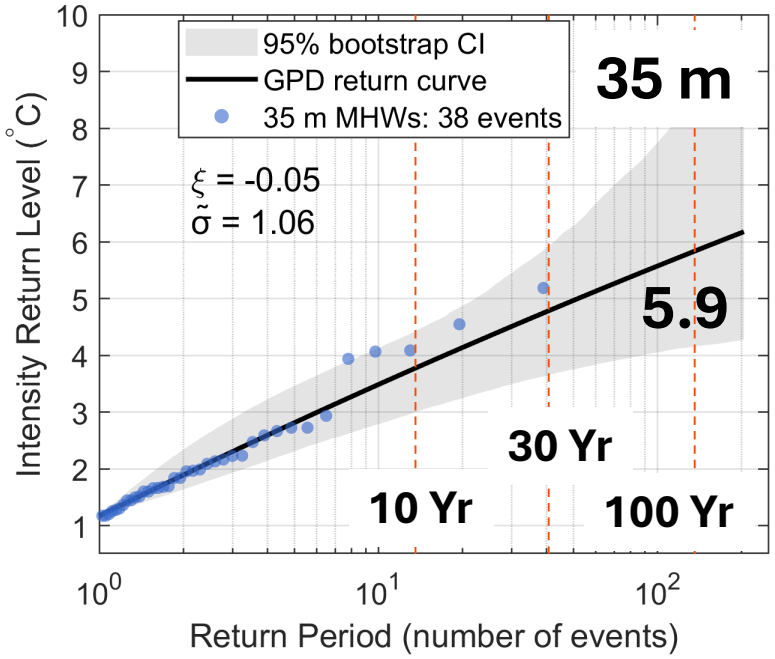
- **EVT is the branch of statistics created to make these types of estimates.**
- **Return levels and Poisson Point Process use the same math framework and require estimating the same free parameters.**
- **They provide different views of the event statistics, but they are not independent.**

- **Coles. 2001. *An introduction to statistical modeling of extreme values***
- **Thomson and Emery. 2024. *Data analysis methods in physical oceanography*.**

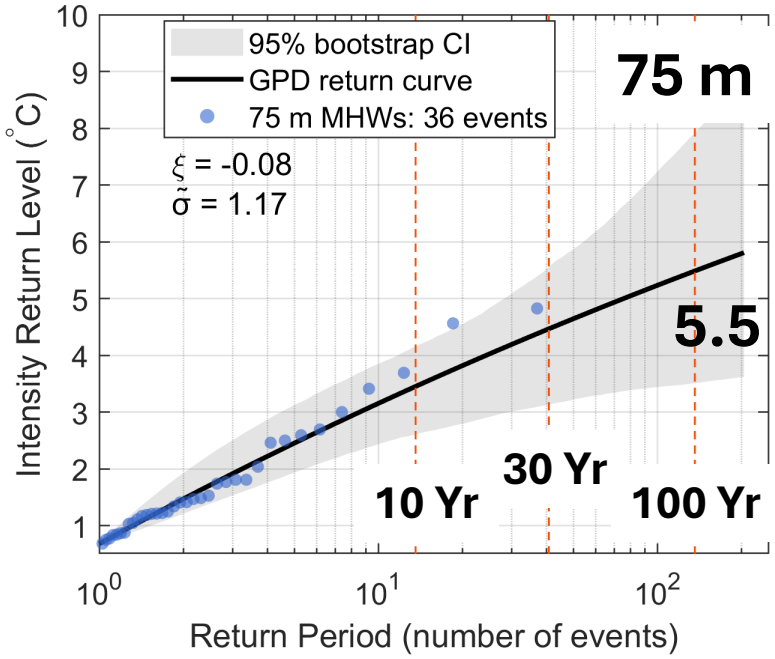
Return Levels for Intensity



Return Period



Return Period

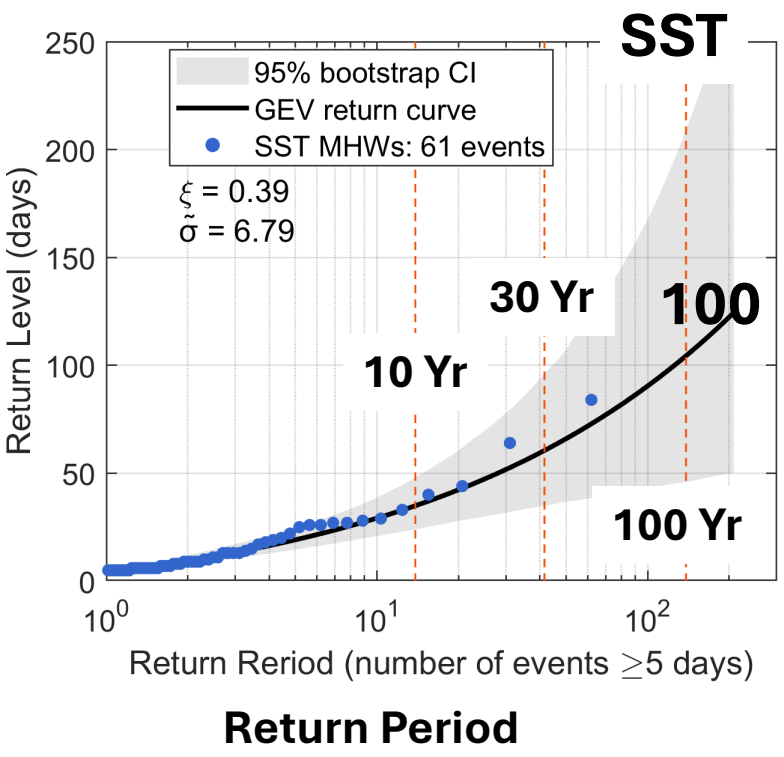


Return Period

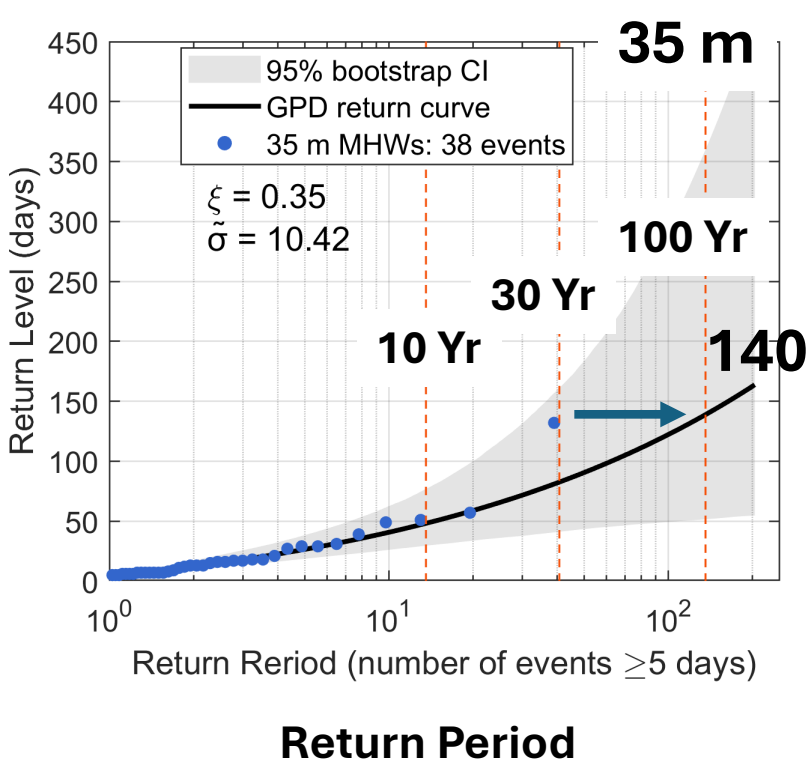
Notice that vertical axis scale change between SST and the other two.

- **44 years of SST data**
- **26-28 years at 35 m and 75 m.**

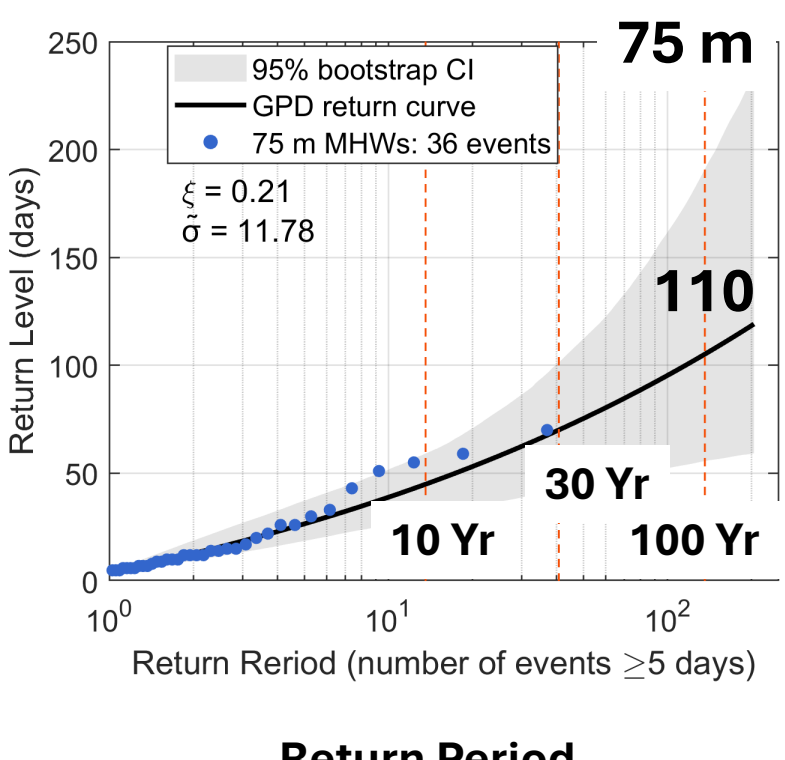
Return Levels for Duration



Return Period



Return Period



Return Period

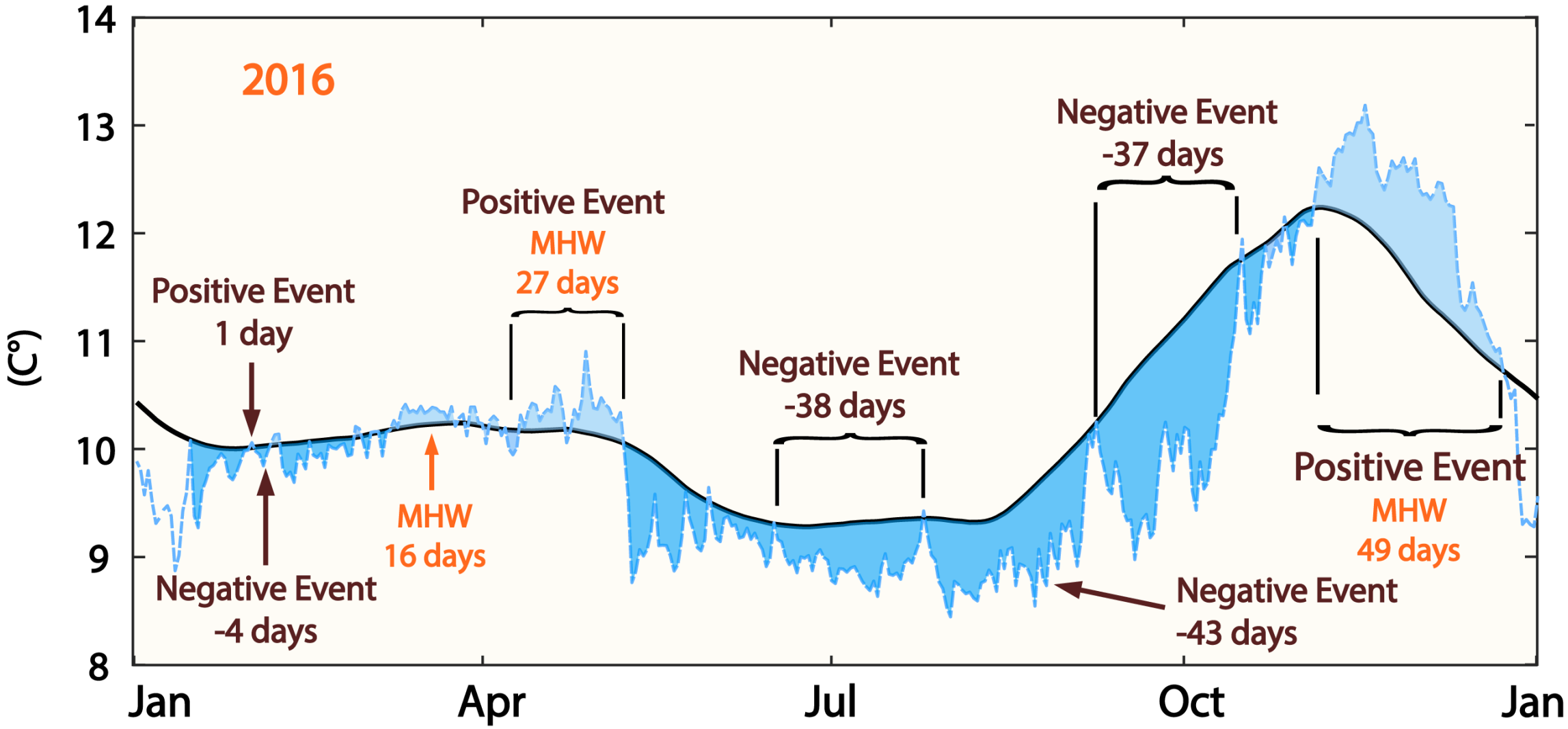
Notice that vertical axis scale change between 35 m and the other two.

- **44 years of SST data**
- **26-28 years at 35 m and 75 m.**

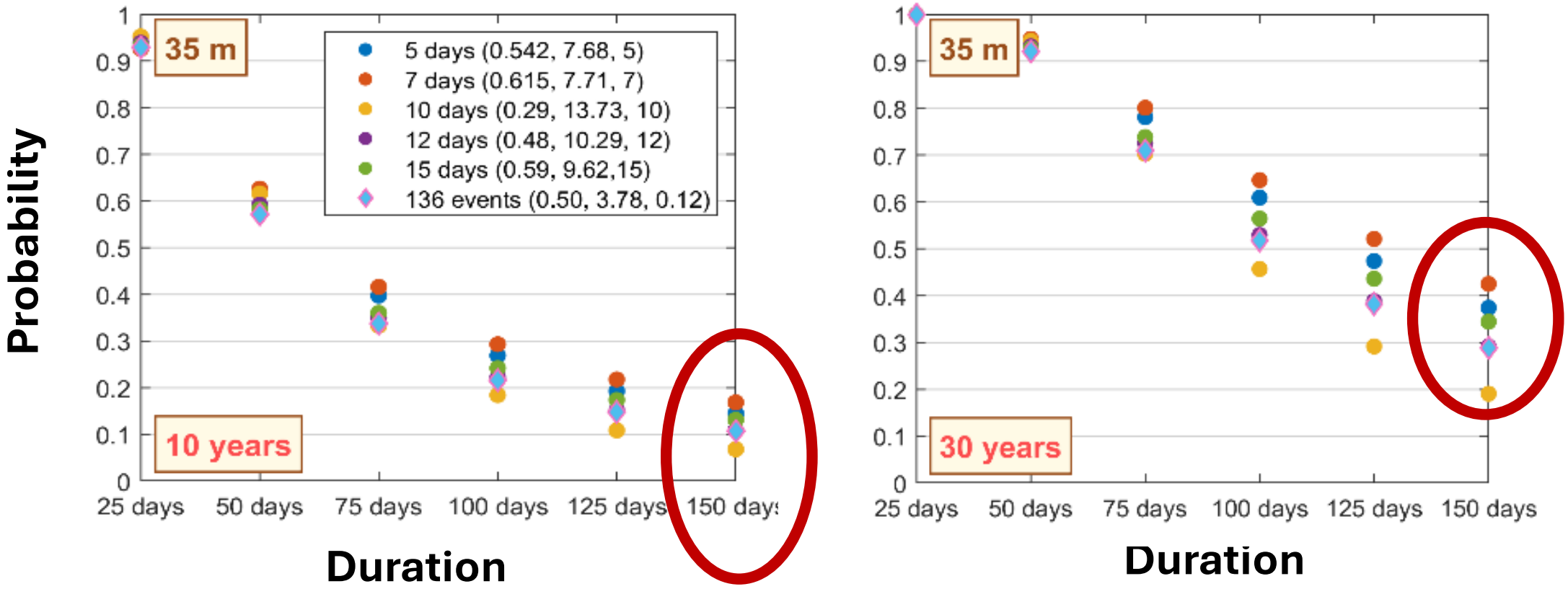
Poisson Point Process (PPP)

- **Different question than Return Levels.**
- **It is about the likelihood of a particular magnitude of event.**
- **For example, what is the likelihood of a 100-day MHW in the next 10 years or 30 years?**
- **We will focus on Duration.**
- **We need to define a more general sampling space for Duration (called Ω)**

Reconstruct Sample Space Ω

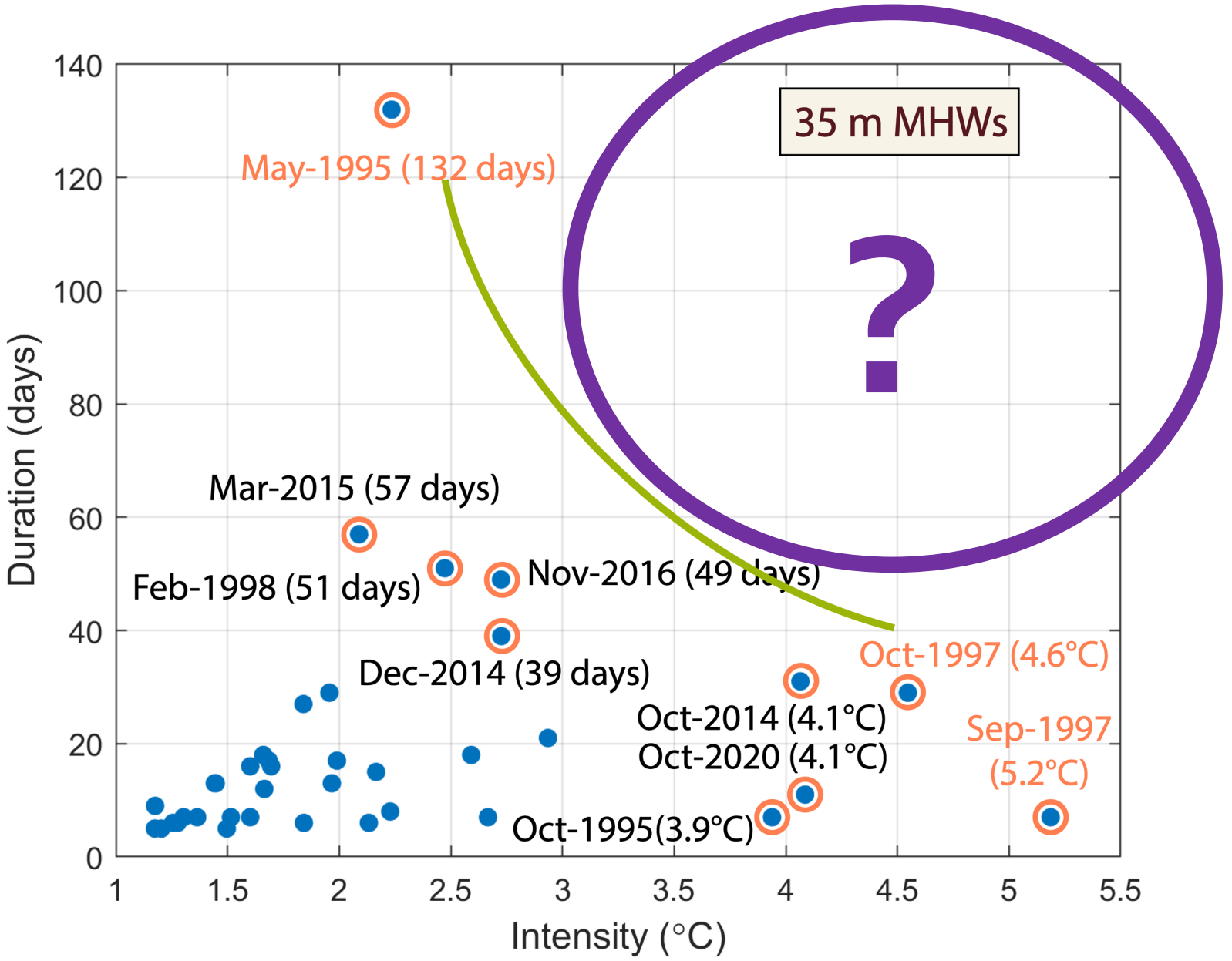


Poisson Likelihood for 10 and 30 years

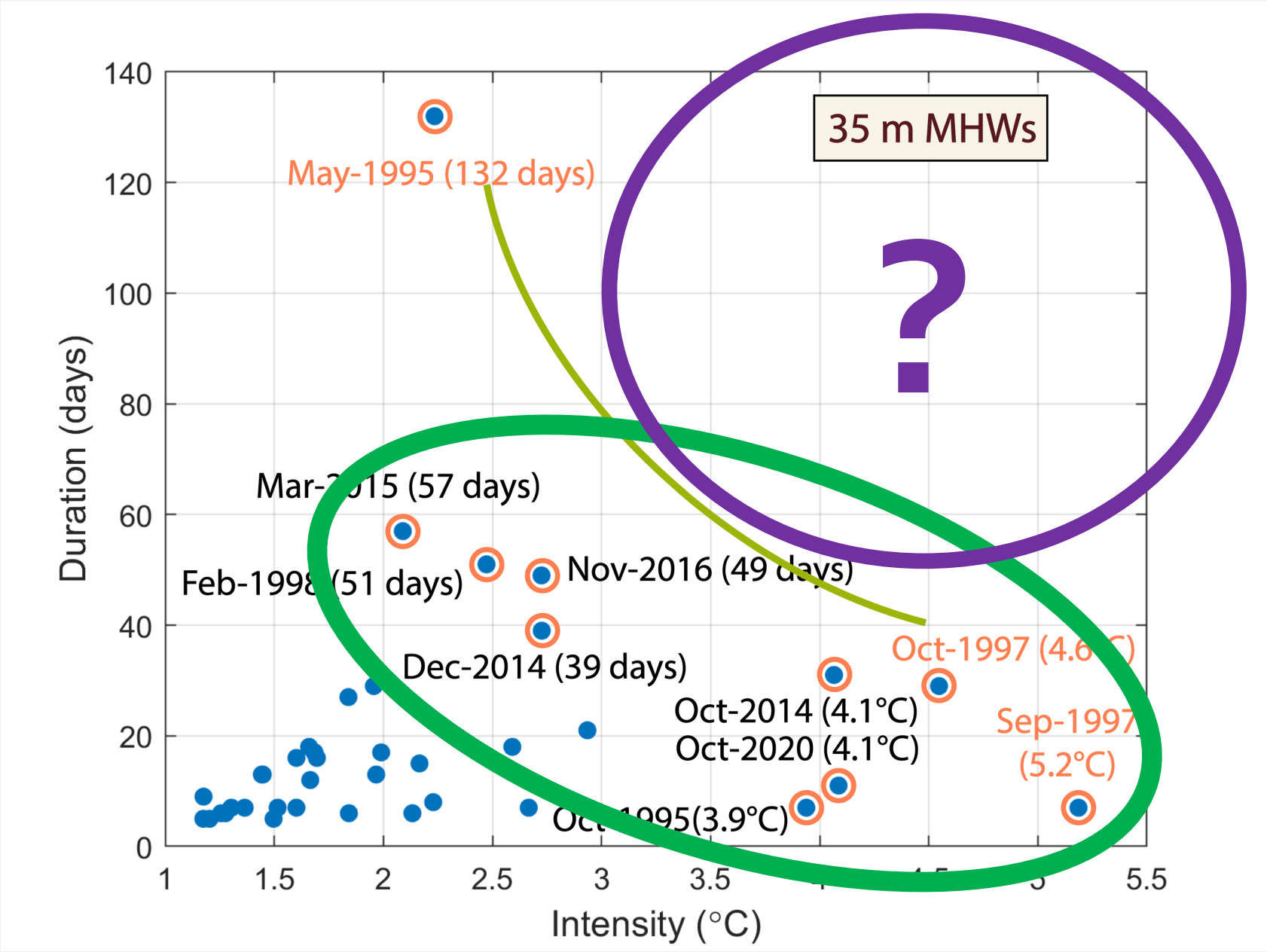


- At 35 m, the 100 year return level is 140 days.
- The probability of a 150 day MHW in the next 10 years is 10-20%.
- The probability in the next 30 year is 30-40%.

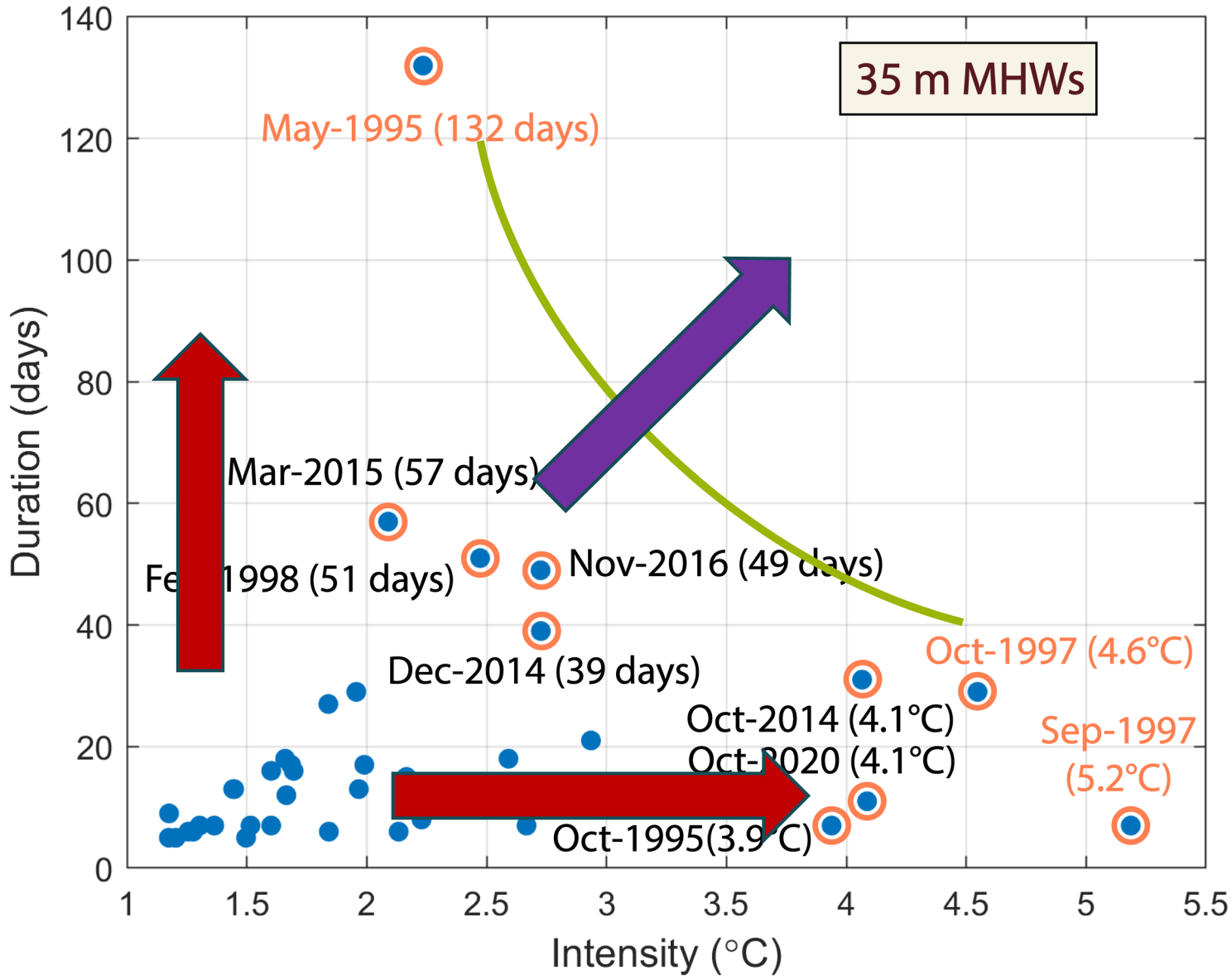
Duration vs Intensity



Duration vs Intensity



Duration vs Intensity



Summary

- **The return level calculation returns sensible results for the MHW metrics Intensity and Duration.**
- **MHW Durations is approximately a Poisson Process for *high enough* threshold**
  - **This means we can estimate the likelihood of a given Duration MHW (say 100 days) over a particular time frame (say next 10 years).**
  - **This is an alternative view for talking about the likelihood of extreme events.**
- **The Intensity – Duration phase space may contain additional information**
  - **35 m does not show MHWs of both high Intensity and prolonged Duration.**


Thank you