A simulation study
to assess performance
# of Mahalanobis distance
based metrics for dimension reduction and change-point detection
in animal behavior time-series

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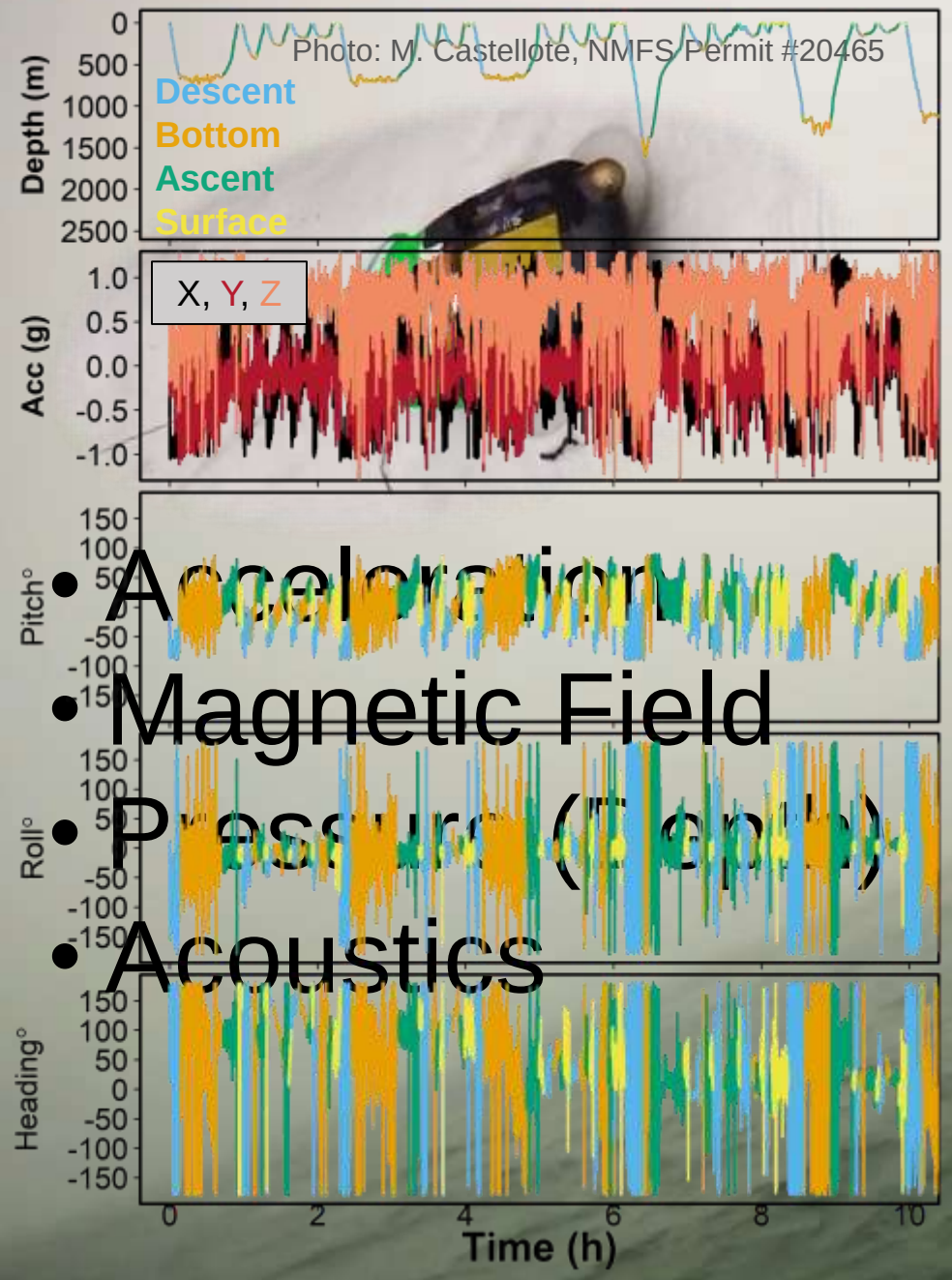


- Acceleration
- Magnetic Field
- Pressure (Temp)
- Acoustics

Video: SOCAL BRS Project, NMFS permit #14534

Whales & Naval Sonar

Photo:
https://www.sinodefenceforum.com/plan-type-052-052b-class-destroyers.t5571/page-370

Photo: Eirik Grønningsæter/WildNature.no/FFI/3S Project

The problem:
Detecting Behavior Change

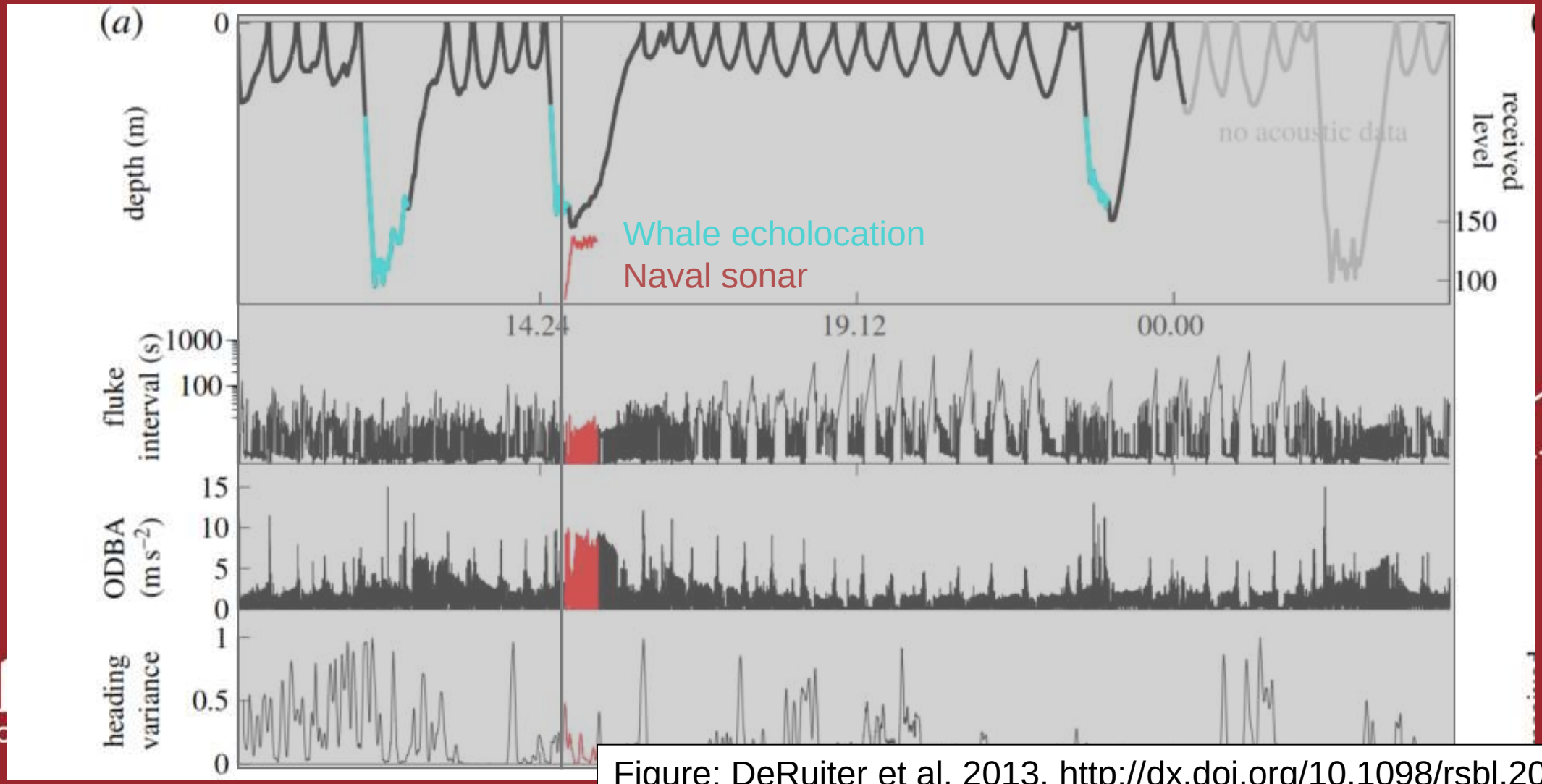
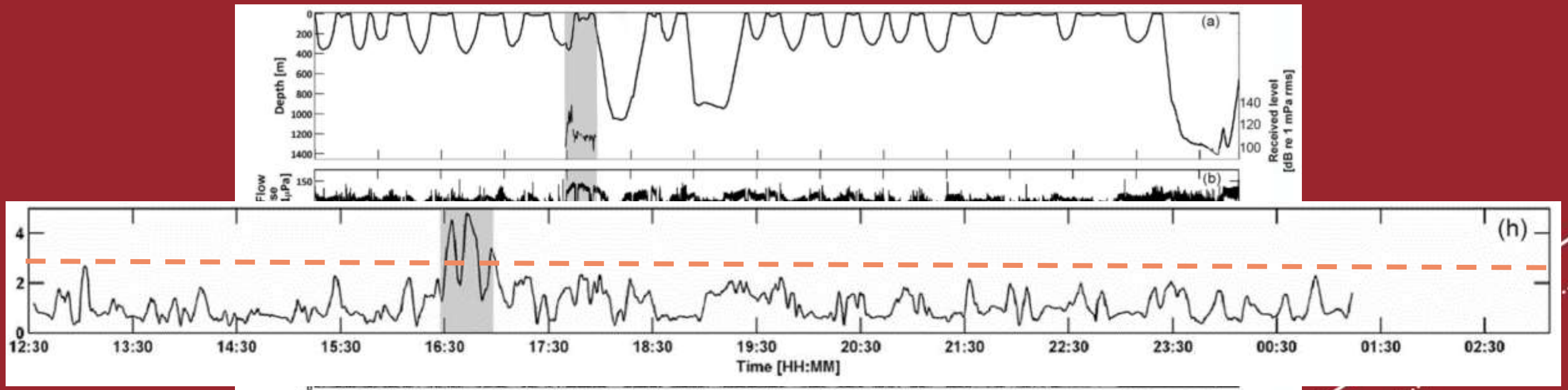
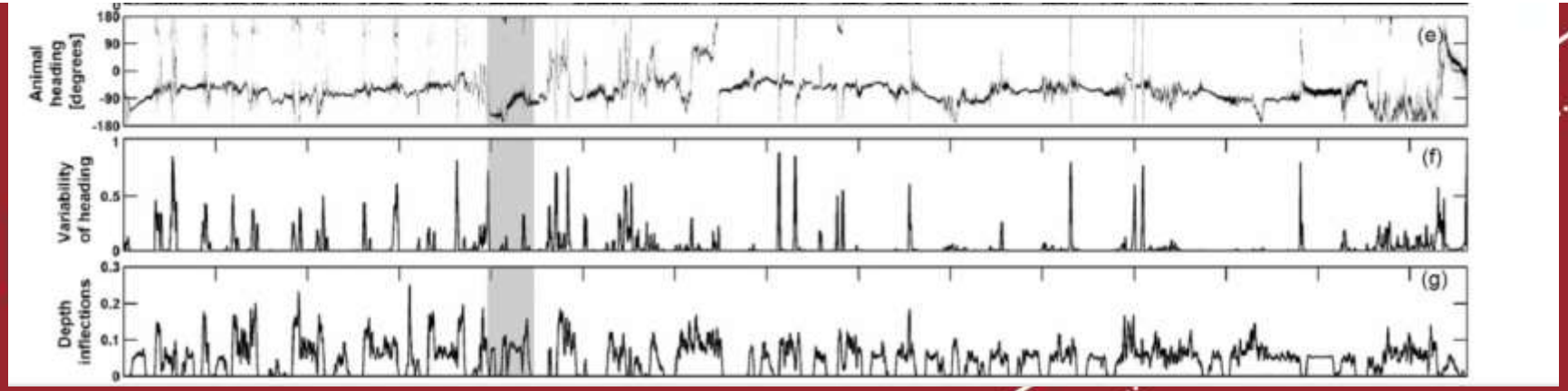


Figure: DeRuiter et al. 2013, http://dx.doi.org/10.1098/rsbl.2013.0223

Solution:
Dimension Reduction, Change-point





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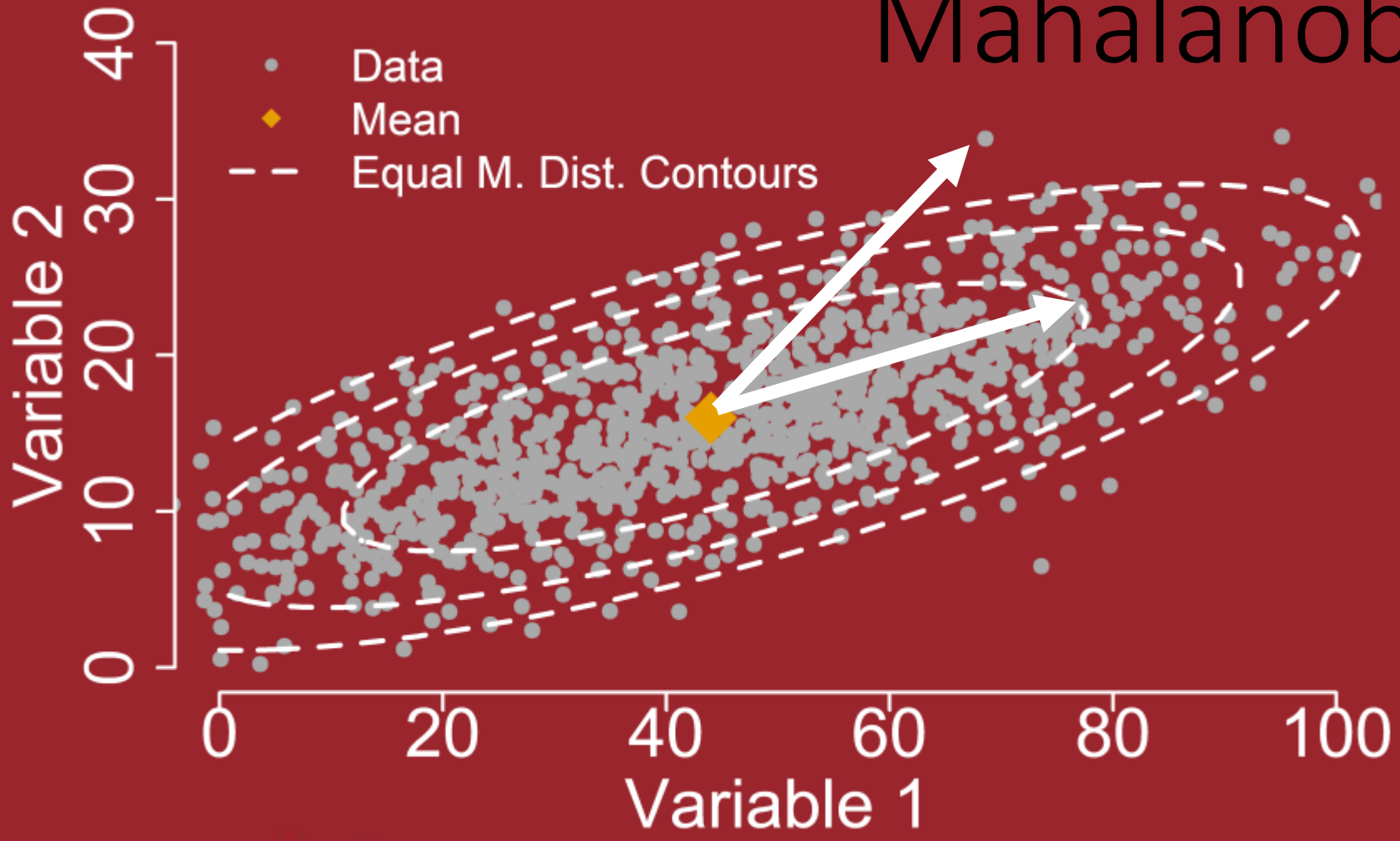
Mahalanobis Distance



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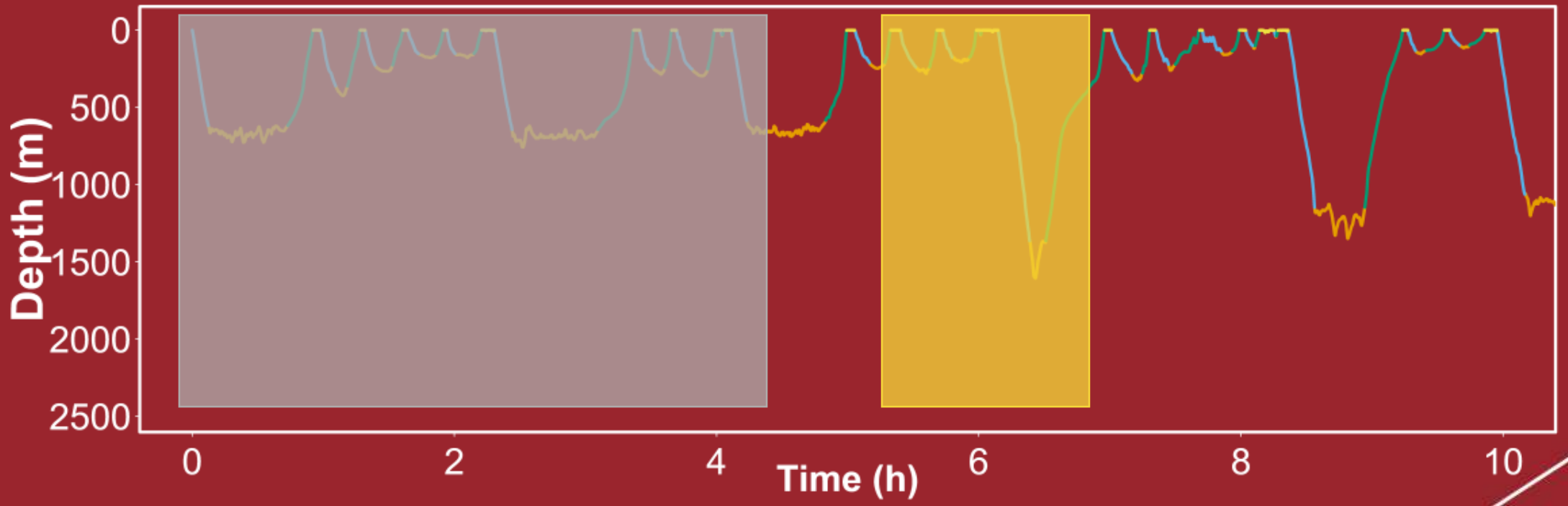
Distance between … *what* ?



Baseline and current period

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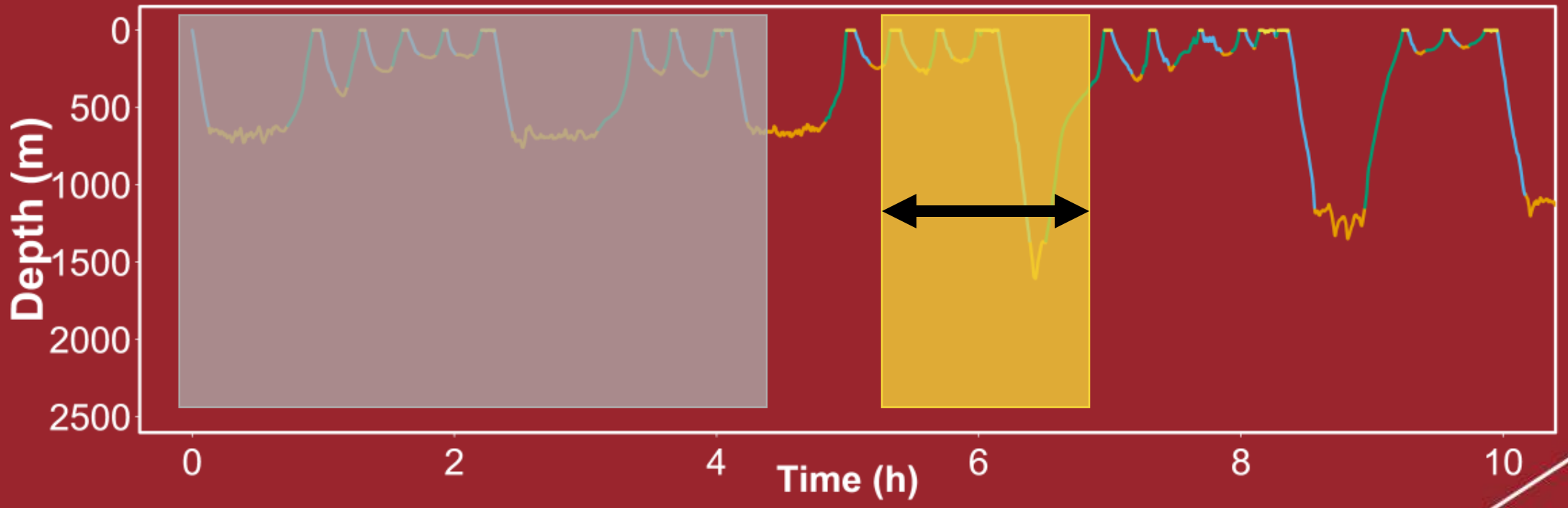
Window Size?



Baseline and current period

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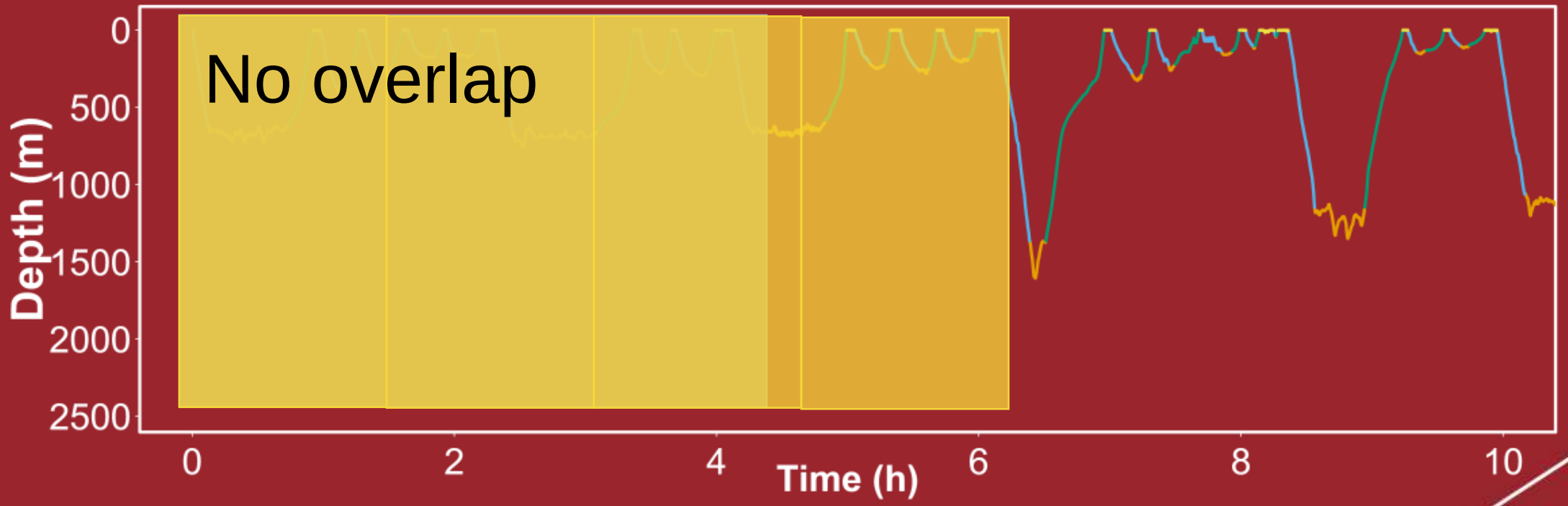
Overlap?



Baseline and current period

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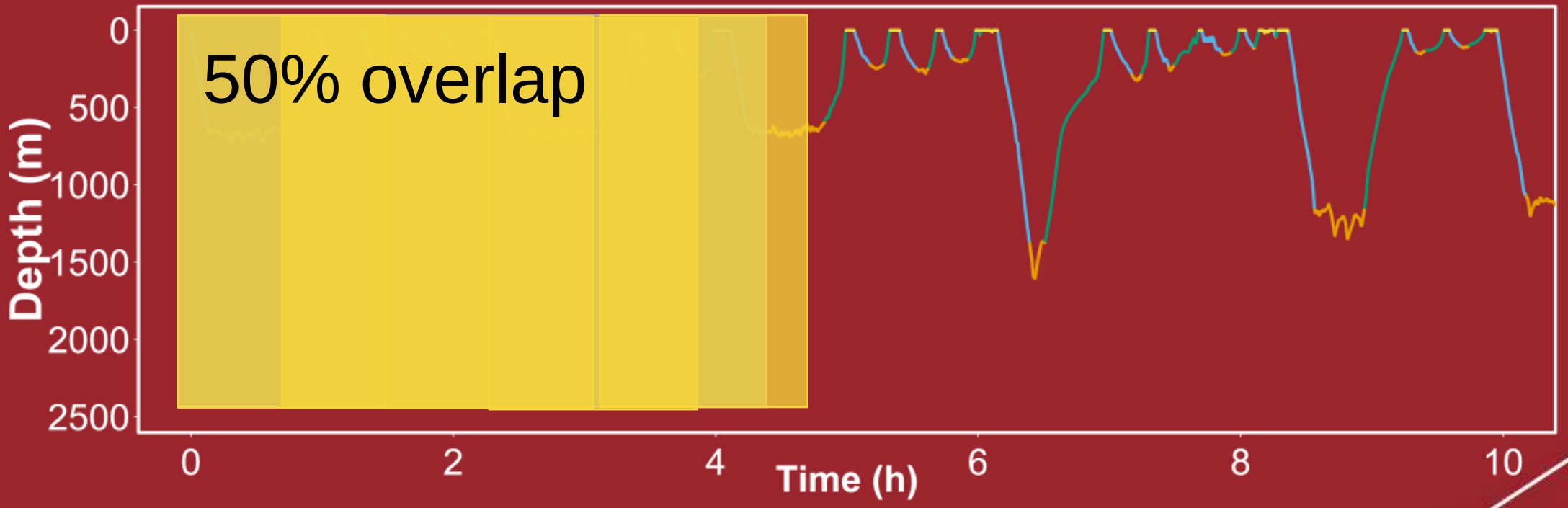
Overlap?



Baseline and current period

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Distance between … *what* ?

Consecutive periods

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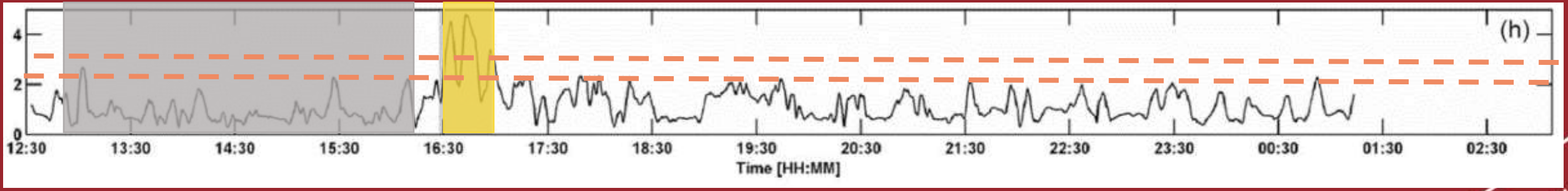
Change-point Threshold



Baseline

Experimental period

Threshold

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Previous Work

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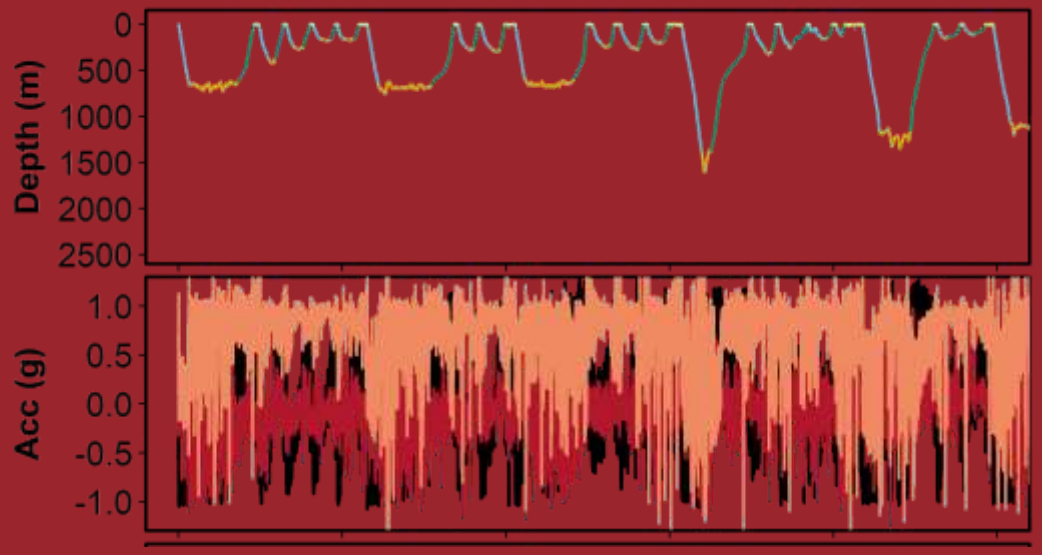
It’s hard to fake it



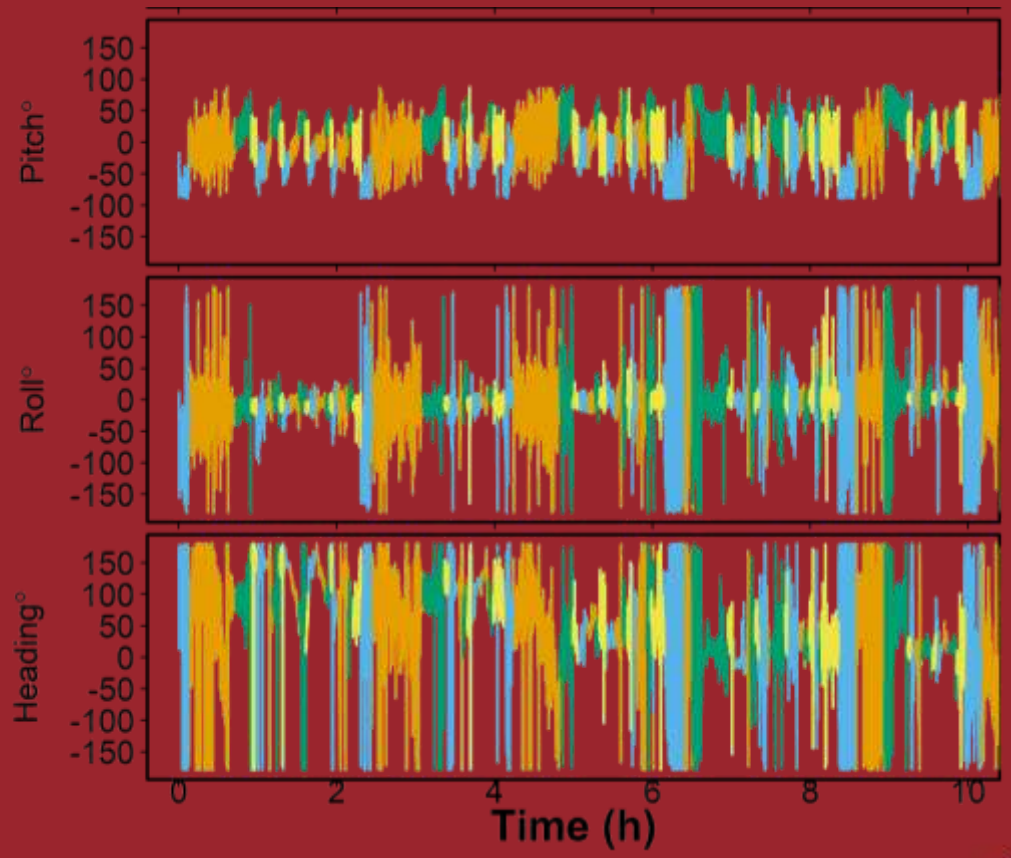
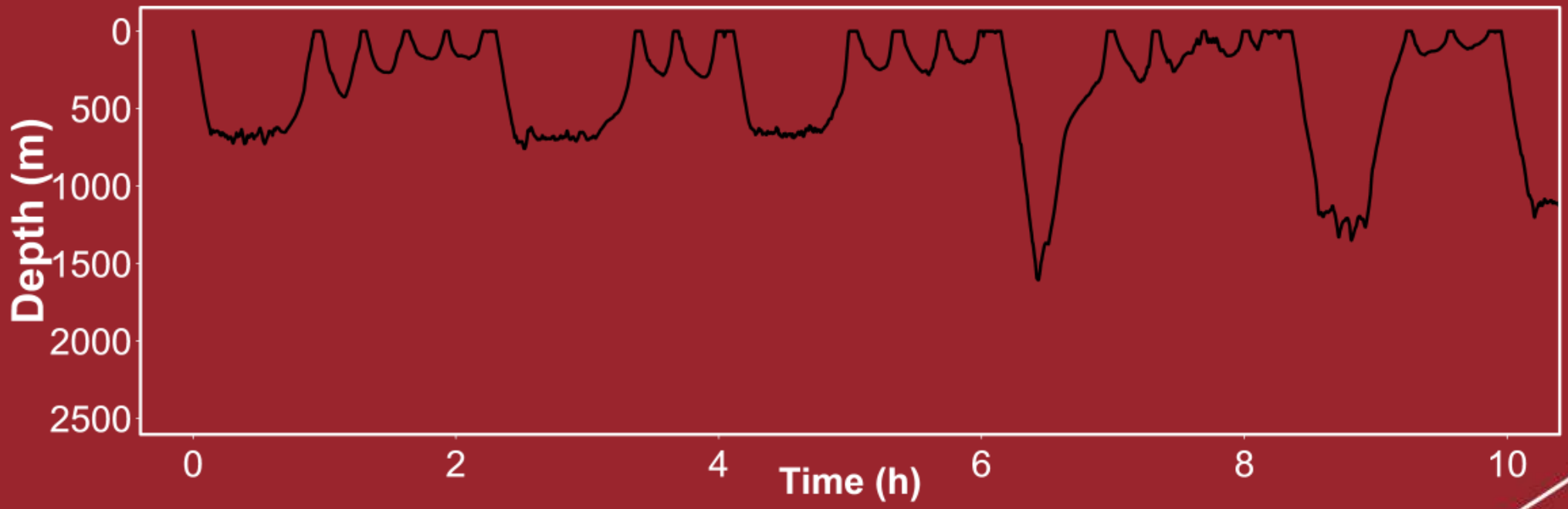


Photo: A Friedlaender, SOCAL BRS Project, NMFS permit #14534

Start with real tag data.
Example: Cuvier's beaked whale



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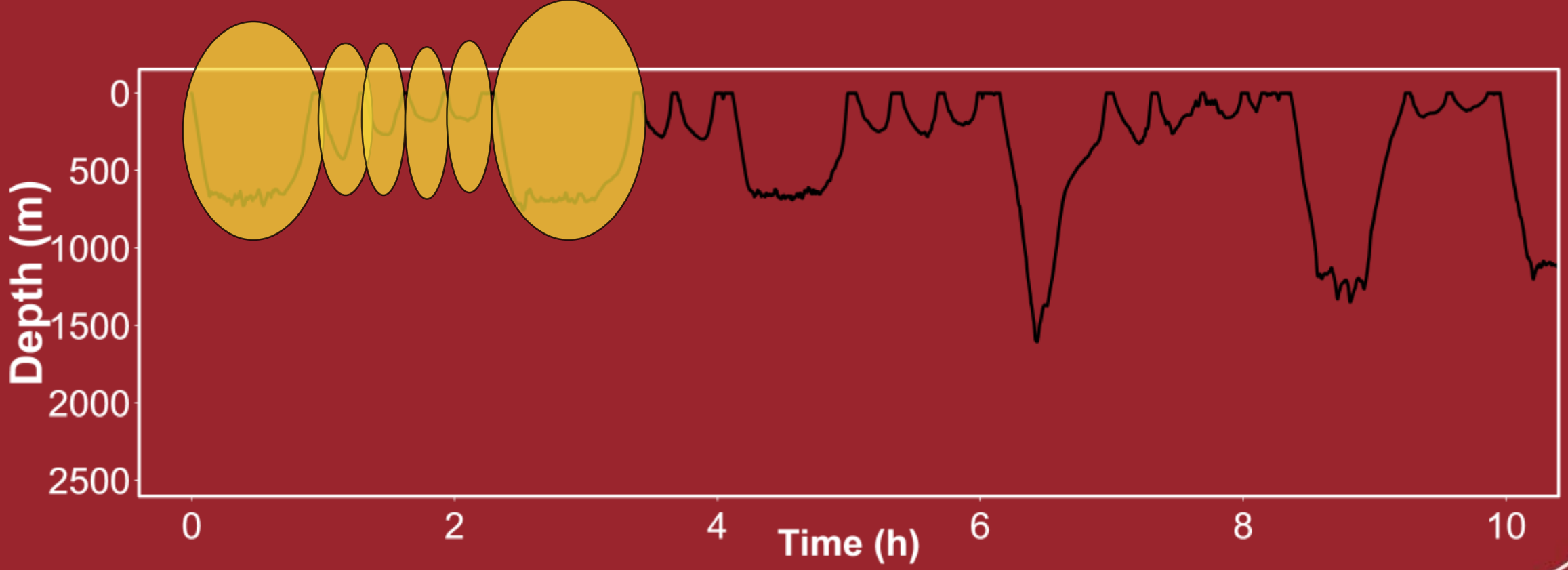

- Detect dives (depth threshold)

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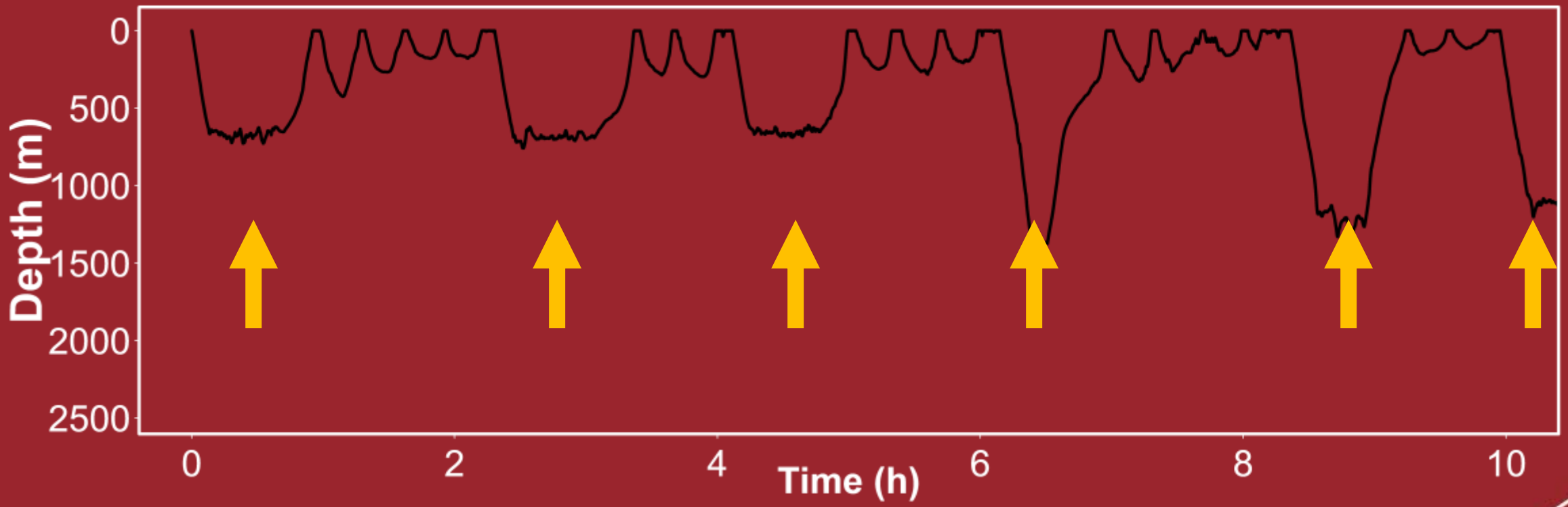

- Detect dives (depth threshold)
- Cluster dives (k-means on depth, duration; silhouette)

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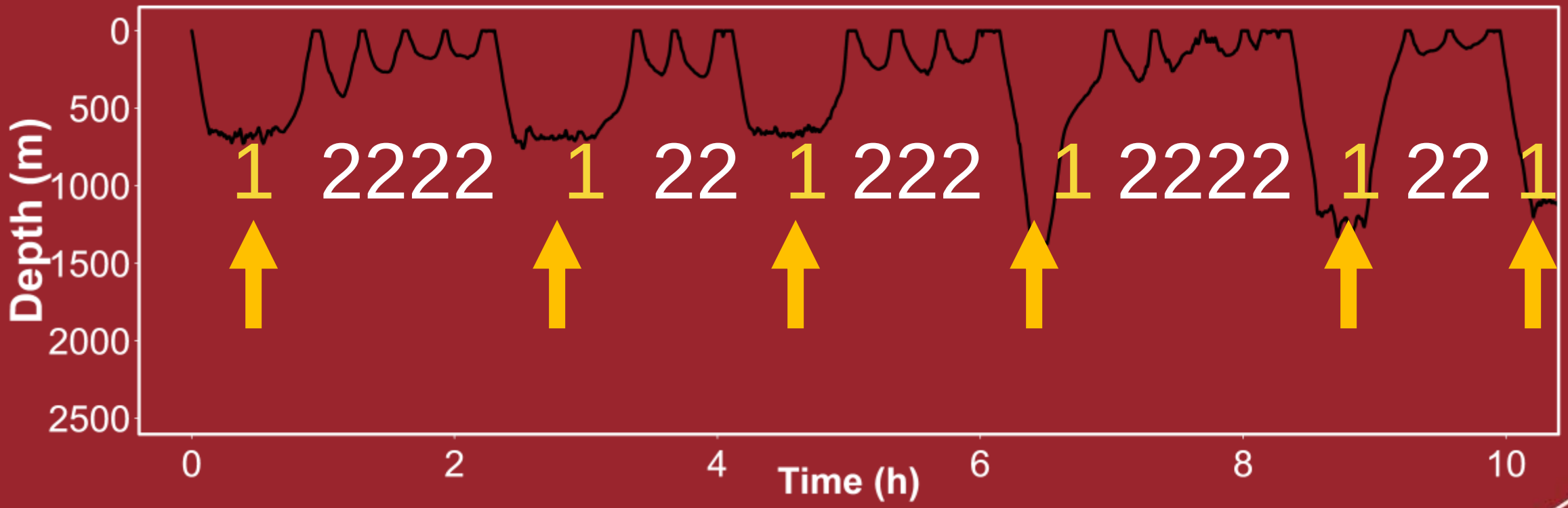

- Detect dives
- Cluster dives

- Dive sequence (MC)

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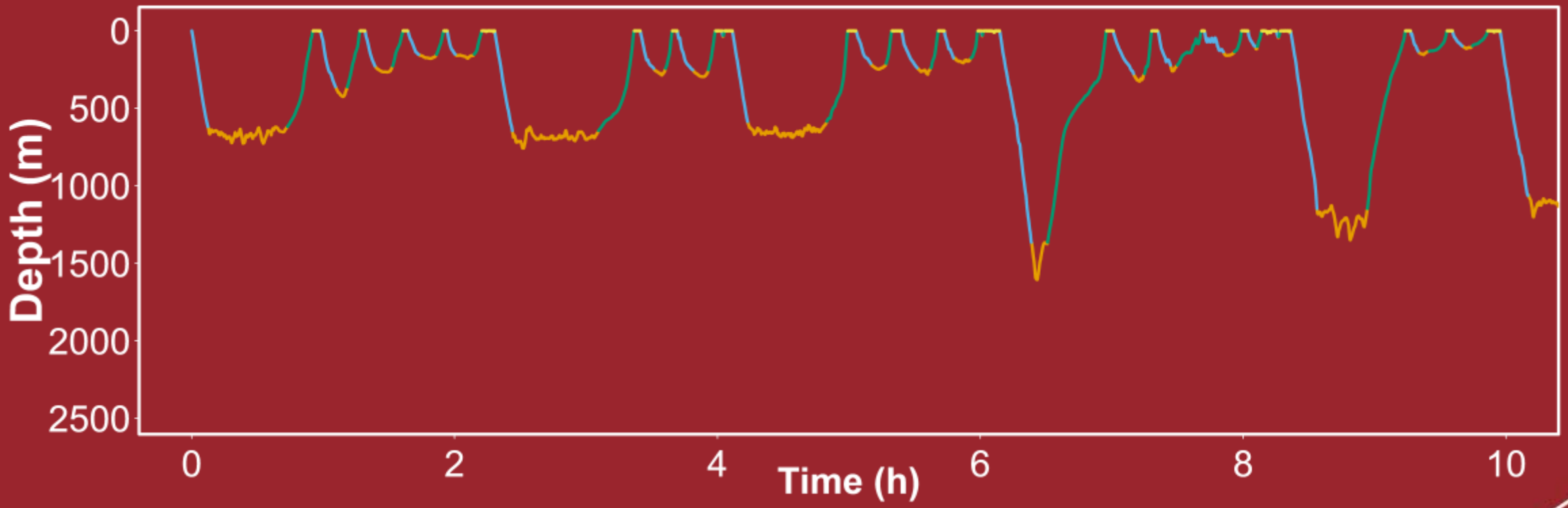

- Detect dives
- Cluster dives
- Dive sequence (MC)

- Phase durations by type (Box-Cox; MVN)

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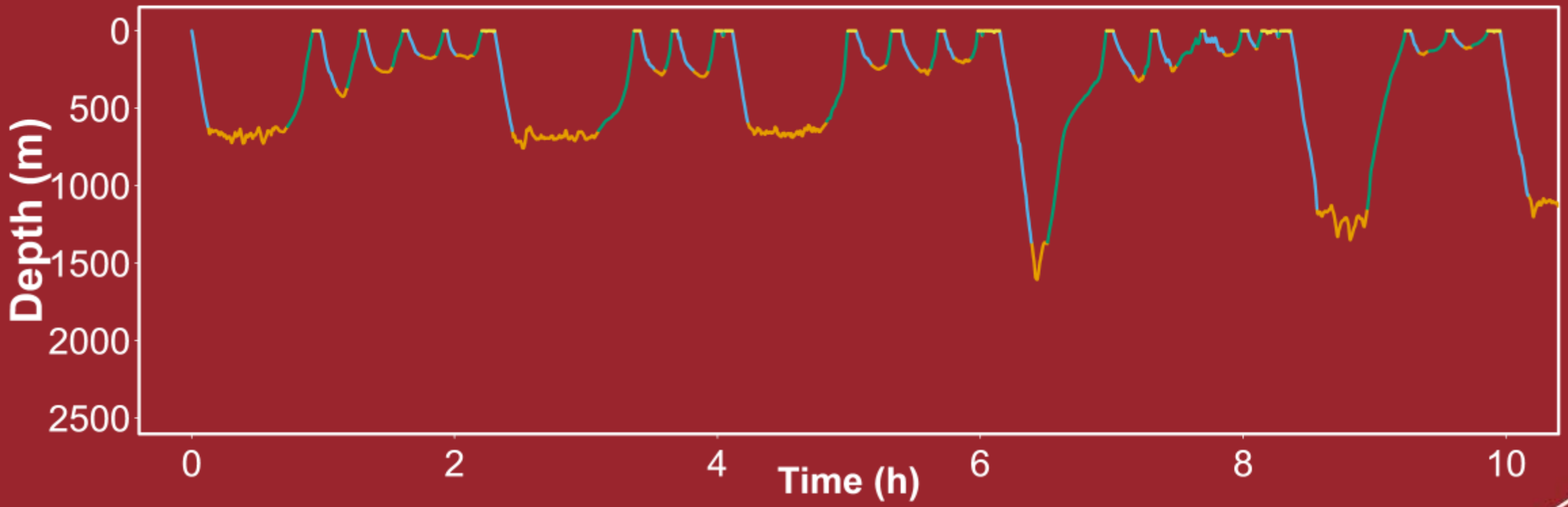

- Detect dives
- Cluster dives
- Dive sequence

- Phase durations by type
- Data in phase (mAR1)

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Tag Data Model/Simulation Summary

- K-means clustering to identify dive types
- 1st-order Markov chain to model dive type time-series
- MVN distribution to model (Box-Cox) dive phase durations
- mAR(1) process to model tag data time series within phase
  - Acceleration (x, y, z)
  - Pitch and roll (sine and cosine)
  - First difference of depth and heading
  - Normalized MSA and ODBA

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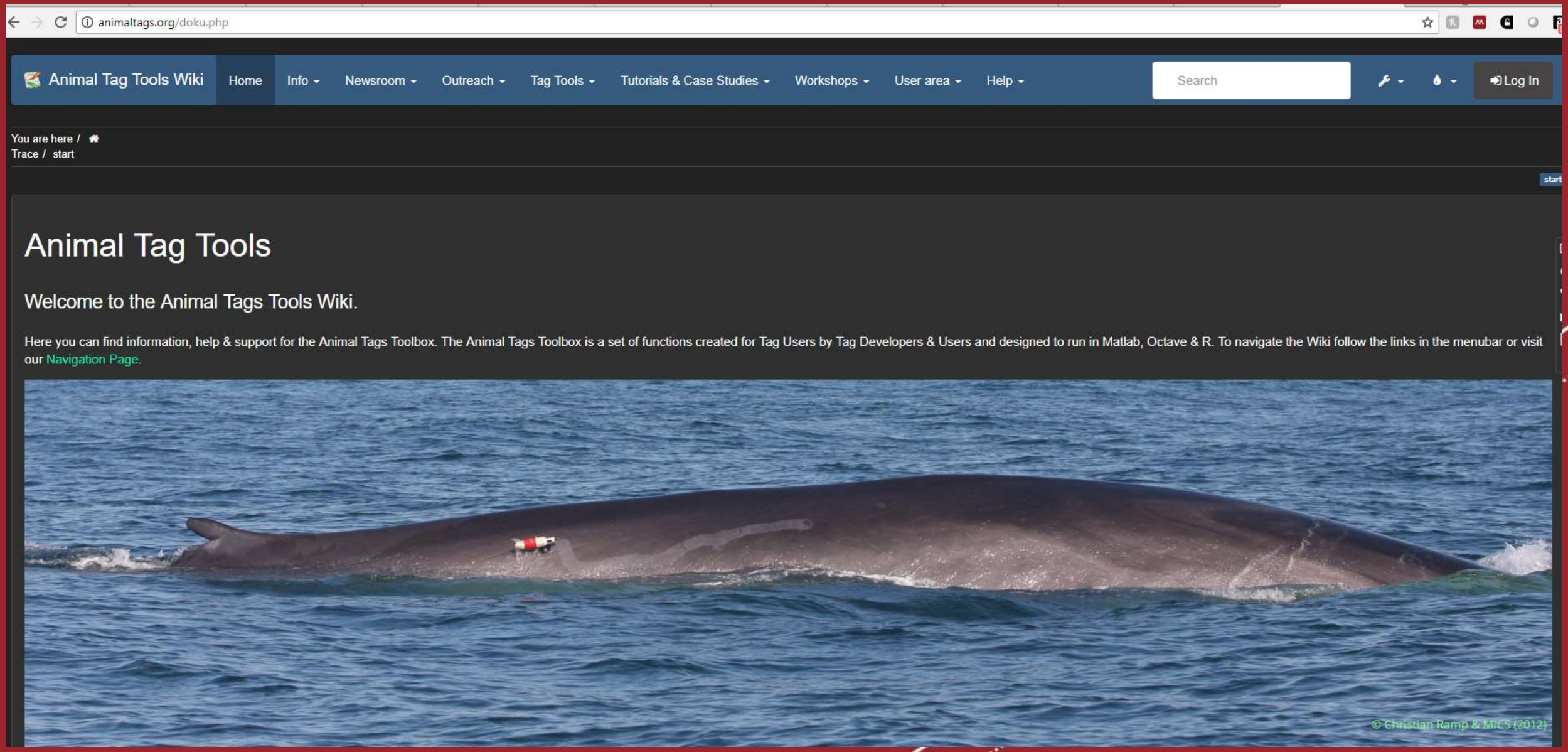
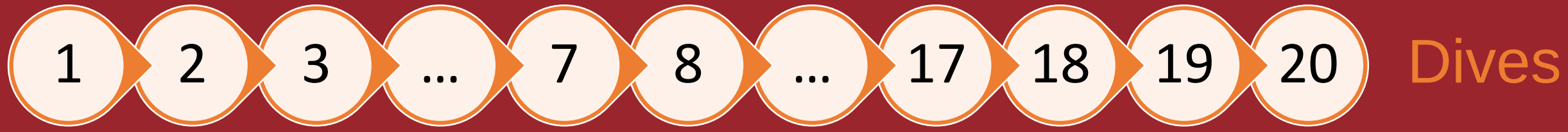
animaltags.org & github.com/stacyderuiter/TagTools



Simulations



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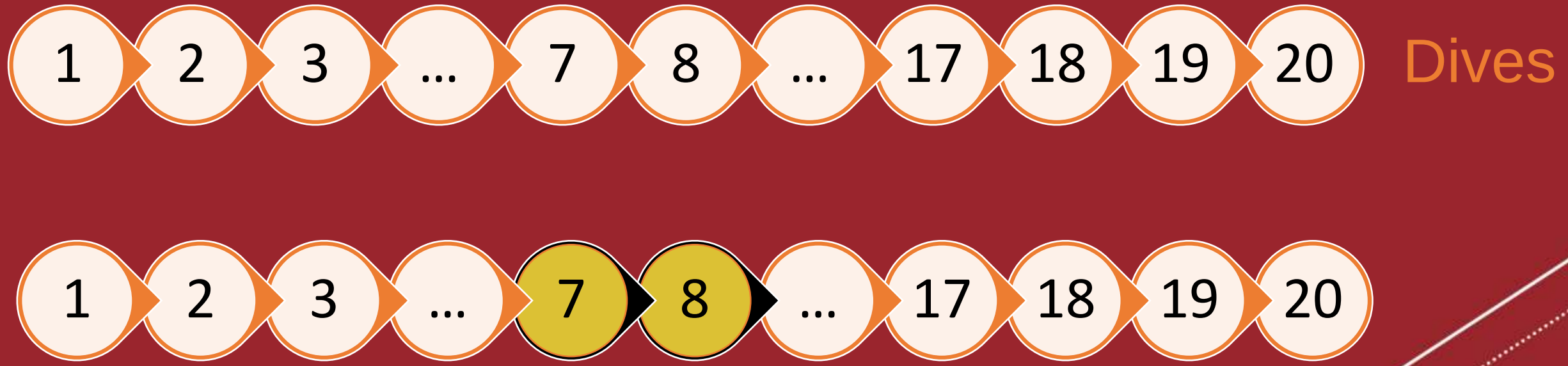
Simulations



Short response

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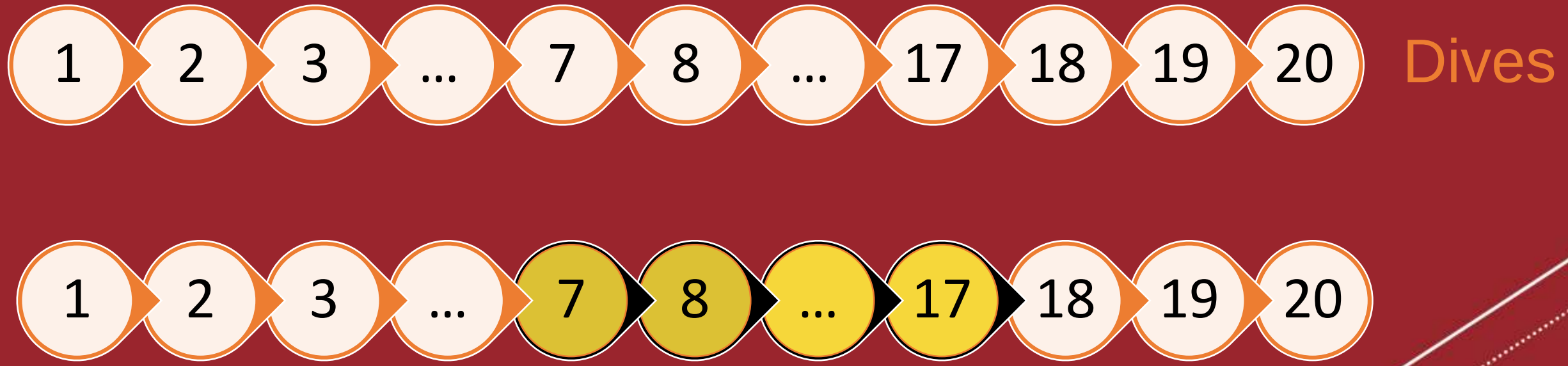
Simulations



Long response

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Simulated Data Streams

Direct Simulation

- Acceleration (X,Y,Z)
- Δdepth
- Δheading
- Pitch, roll (sine and cosine)
- ODBA and MSA (normalized)

Derived

- Heading
- Depth
- Var(heading)
- Var(pitch)
- Var(Δdepth)

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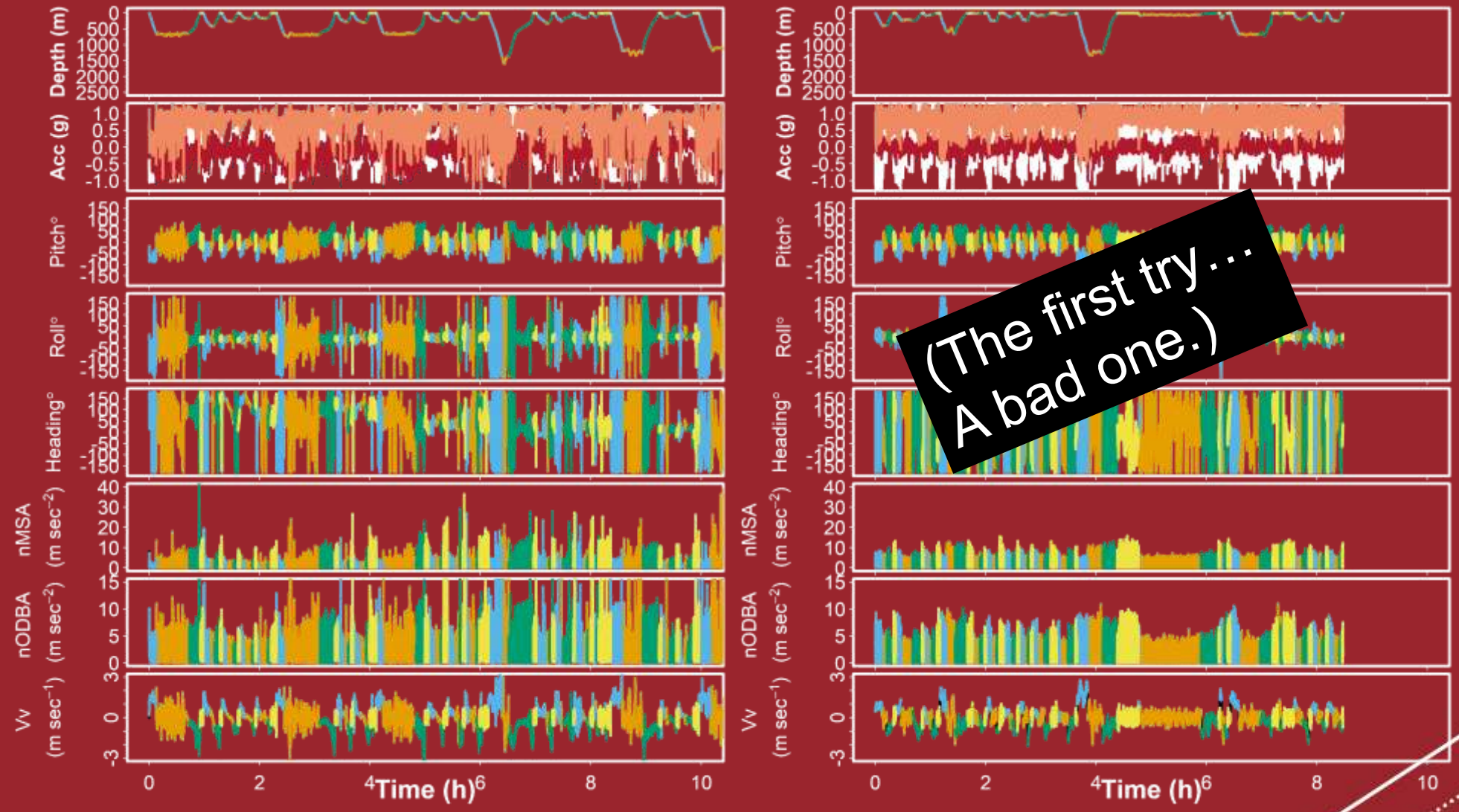

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Real and Simulated Data Examples

Response Types

Avoidance

- Decreased heading variability
- Decreased pitch variability
- Increased body movements (e.g., ODBA, MSA).

Cessation of Foraging

- Decreased variability of body movements (ODBA, MSA)
- Longer deep dives
- Longer inter-deep-dive intervals
- Longer bottom and ascent phases of deep dives
- Less variability in pitch & vertical velocity during deep-dive bottom phase.

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Input variables for distance calculations

- ***AVOIDANCE:***
  - heading variance,
  - pitch variance,
  - nODBA
- ***FEEDING:***
  - nODBA variance,
  - pitch variance,
  - Δdepth,
  - Δdepth variance
- ***LITERATURE:***
  - nODBA,
  - pitch variance,
  - heading variance,
  - sin(heading),
  - cos(heading)

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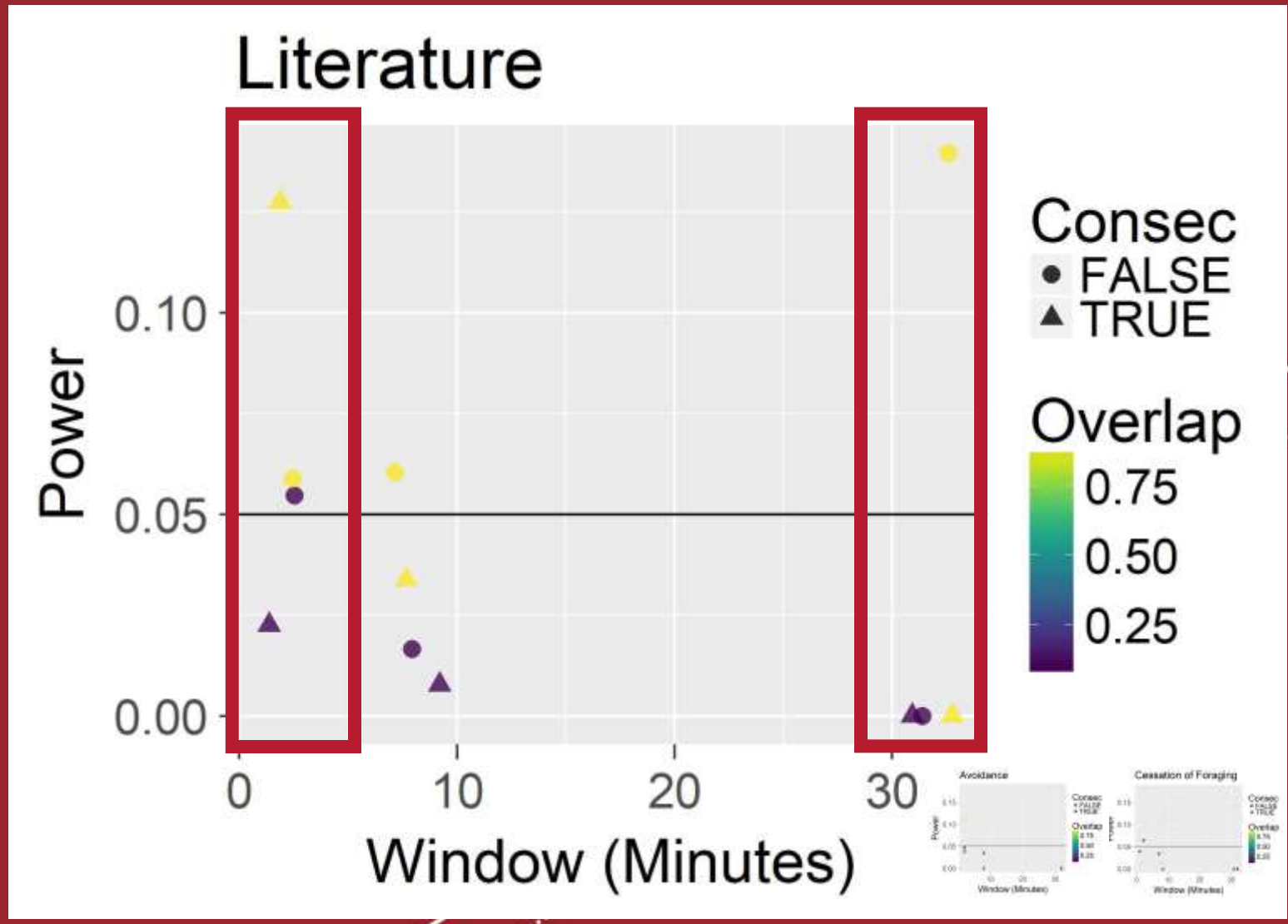
Results of simulations: Control (no response)

(500 whales per scenario)

- Window too short: ☹ (noise=false detections)
- Window too long: ☹ (oversmooth= no detections)



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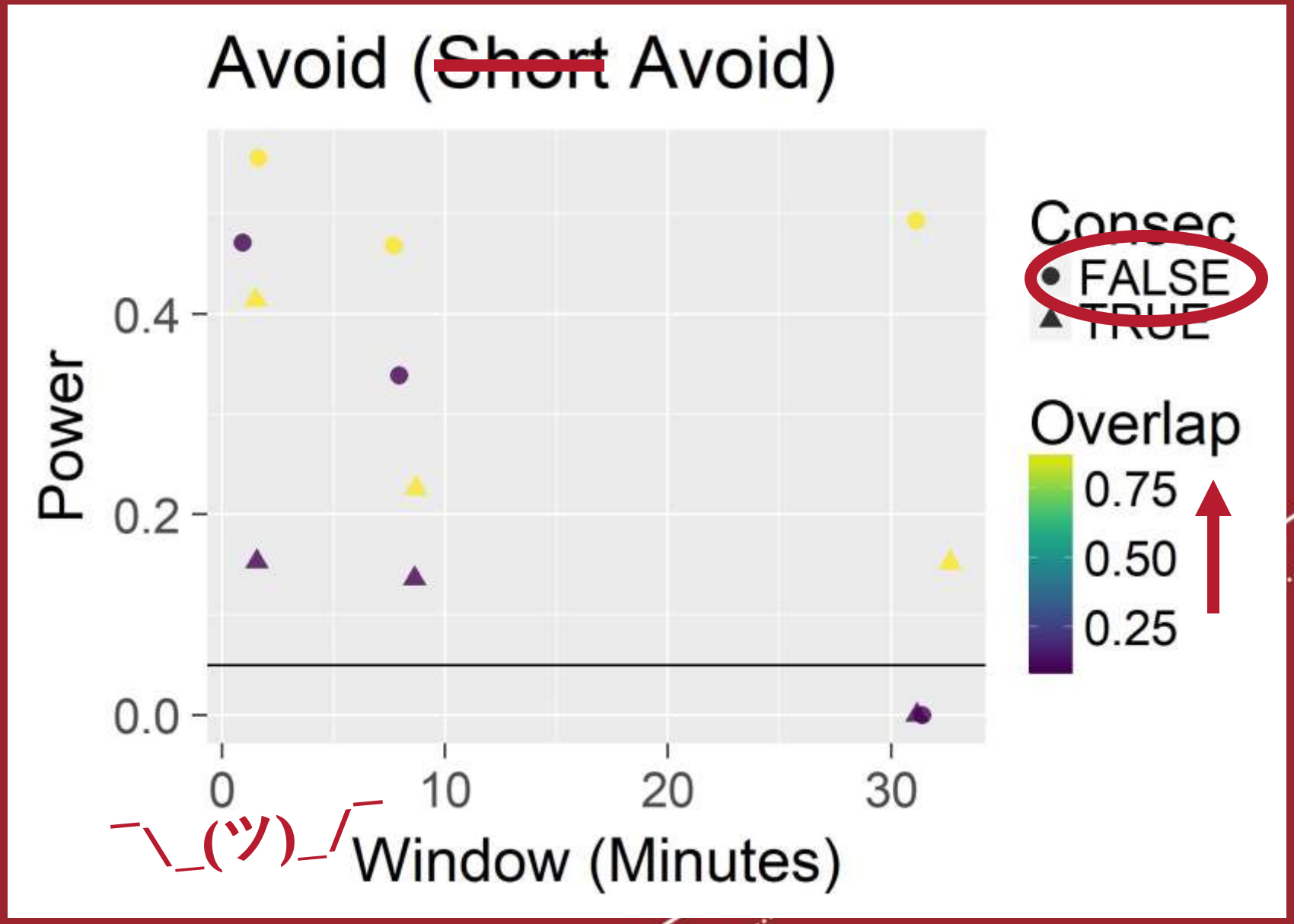
Results of Simulations: Representative Example



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Conclusions & Perspectives

- Mahalanobis distance analysis effectively (?) detects behavioral change-points in dependent multivariate time-series data
  - Caveat: Only “weak” responses simulated so far.

- Additional simulations with pilot whales, blue whales forthcoming
- Tagtools package to be submitted to CRAN ASAP

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Thank you: MOCHA, SOCAL, 3S, Sirena Projects; Doug Nowacek, Andy Read, Peter Tyack, Mark Johnson, Brandon Southall, Erin Falcone…

Photo: A Friedlaender, SOCAL BRS Project, NMFS permit #14534