

# A simulation study

to assess performance

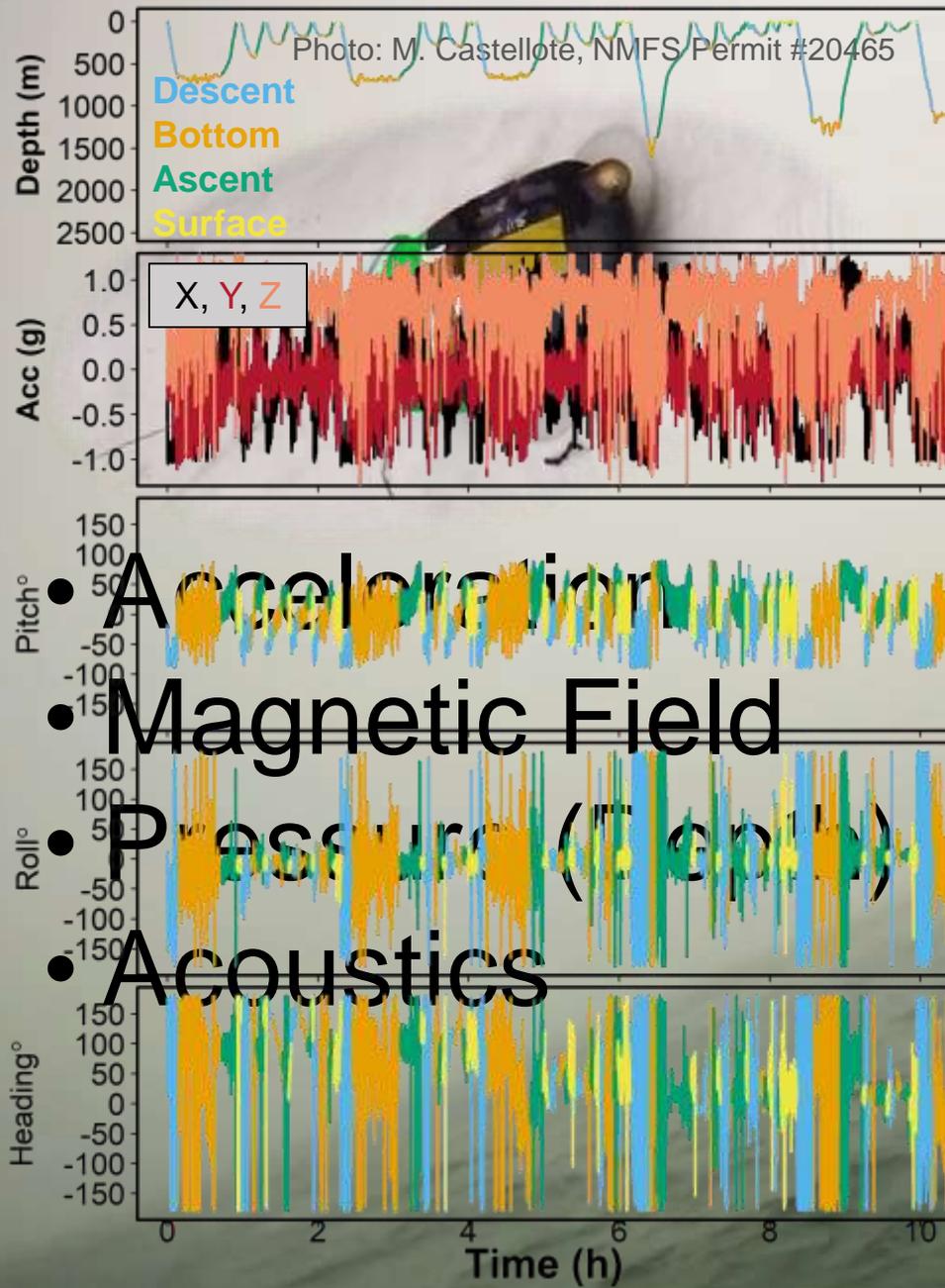
# of Mahalanobis distance

based metrics for dimension reduction and change-point detection

# in animal behavior time-series

Stacy DeRuiter<sup>1,2</sup>, Patrick Miller<sup>1</sup>, Len Thomas<sup>1</sup>, Catriona Harris<sup>1</sup>,  
and Dina Sadykova<sup>1,3</sup>

(1) University of St Andrews; (2) Calvin College; (3) Queen's University Belfast



# 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

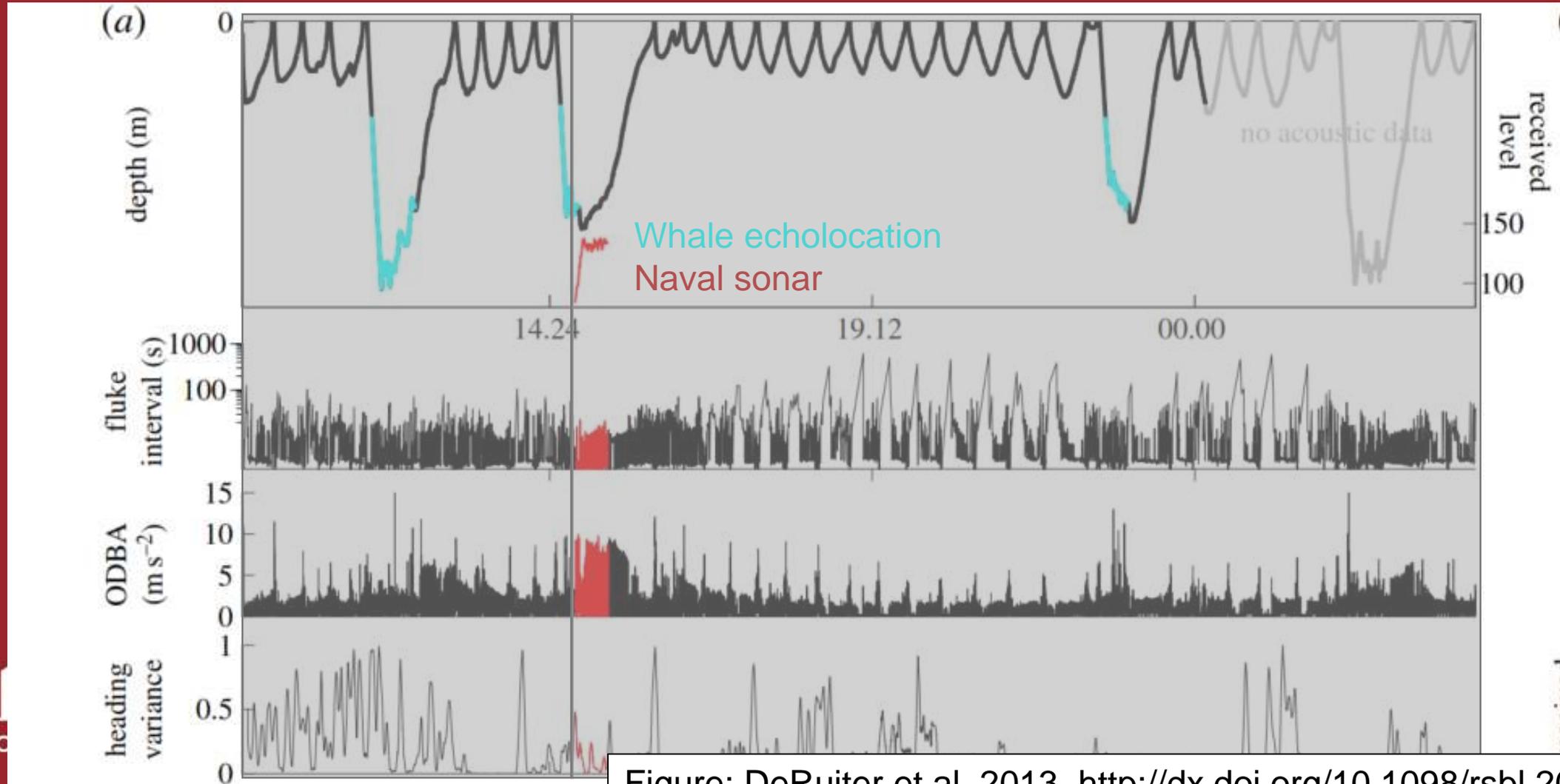
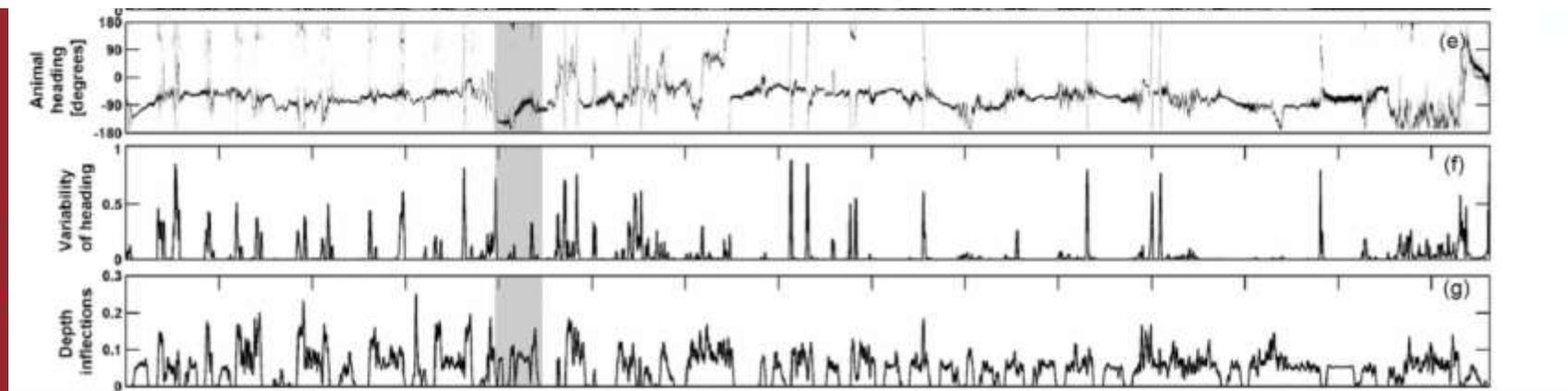
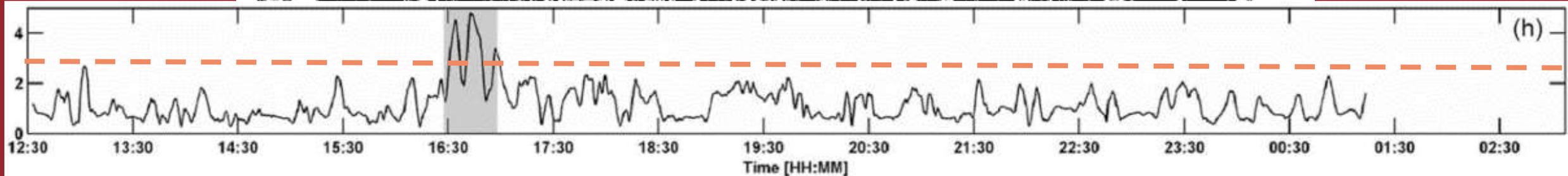
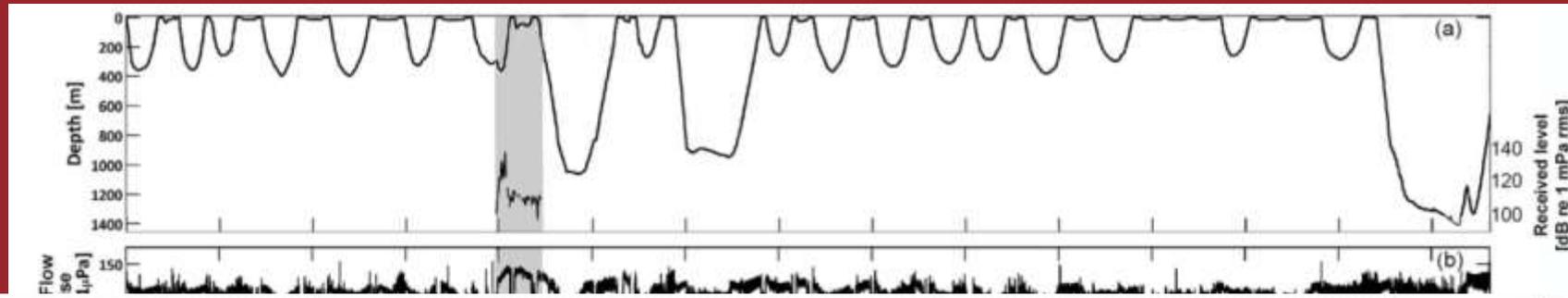
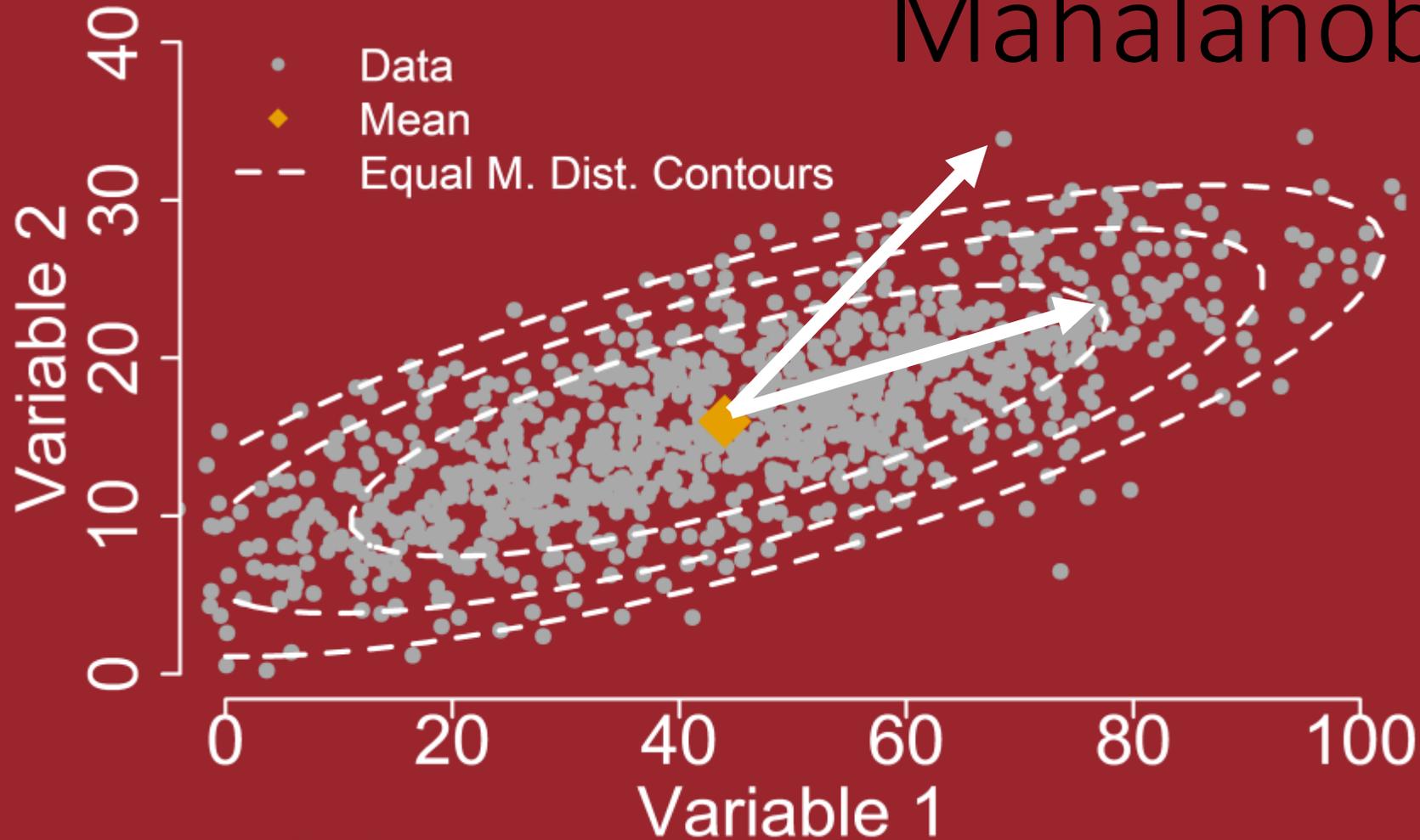


Figure: DeRuiter et al. 2013, <http://dx.doi.org/10.1098/rsbl.2013.0223>

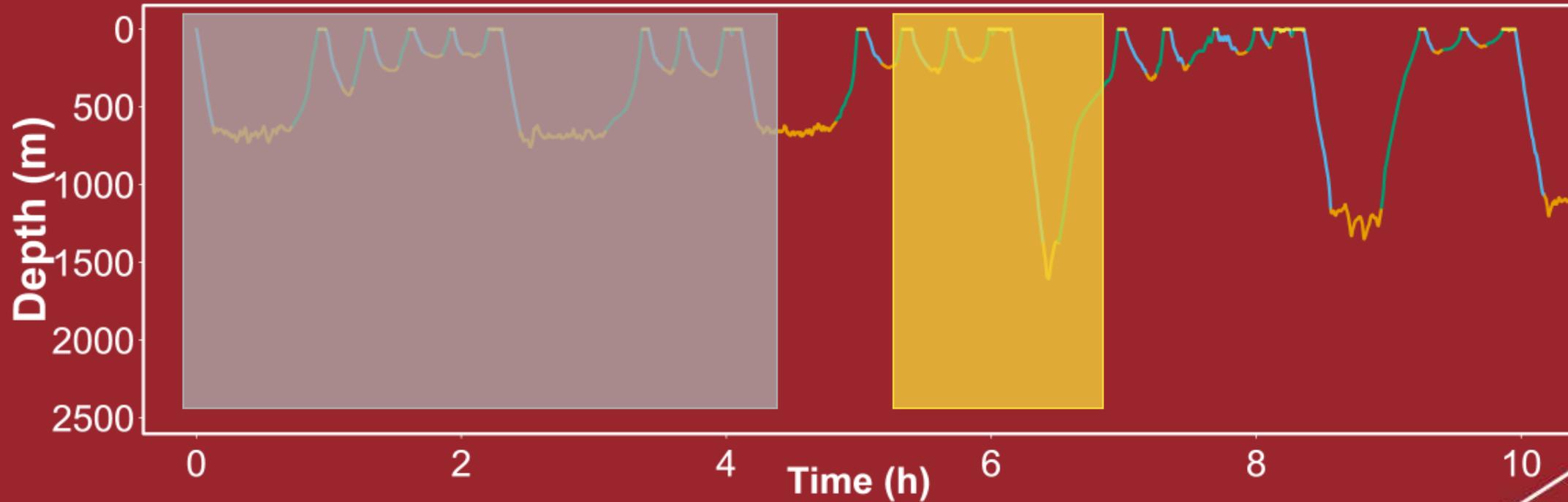
# Solution: Dimension Reduction, Change-point



# Mahalanobis Distance

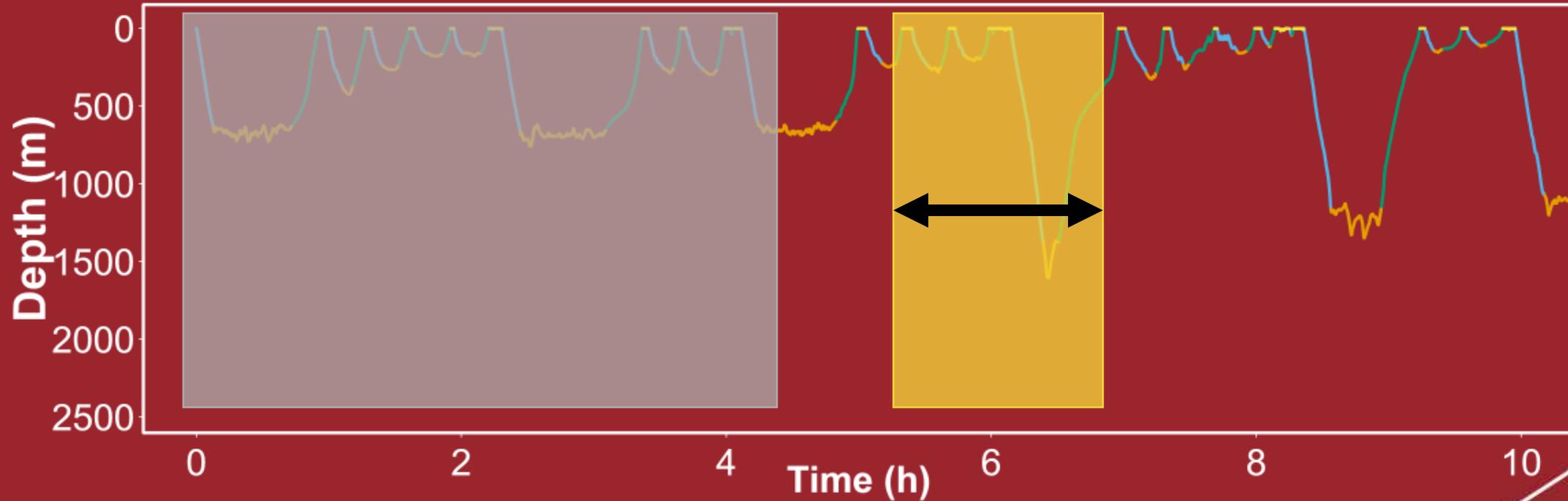


Distance between ... *what* ?



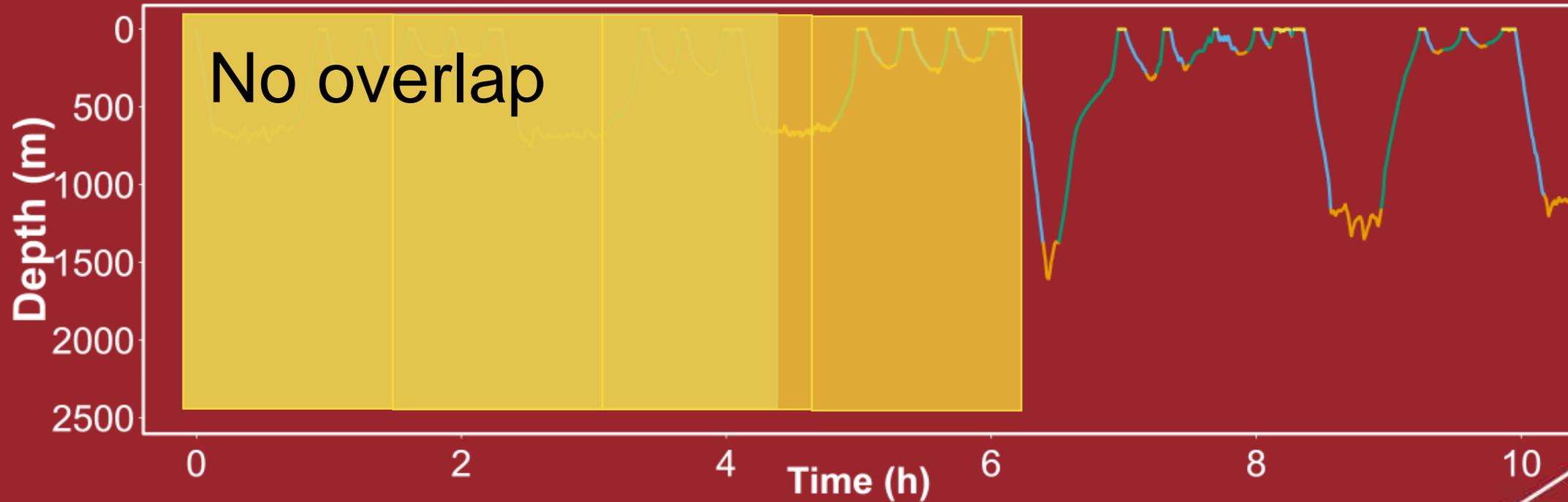
*Baseline and current period*

# Window Size?



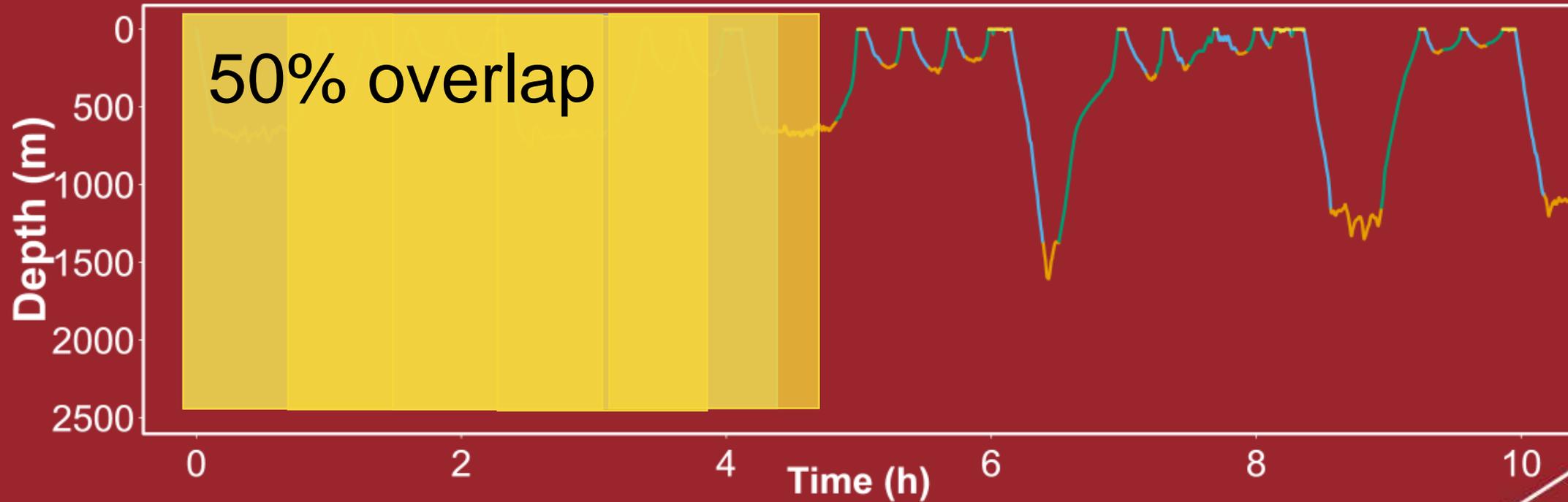
*Baseline and current period*

# Overlap?



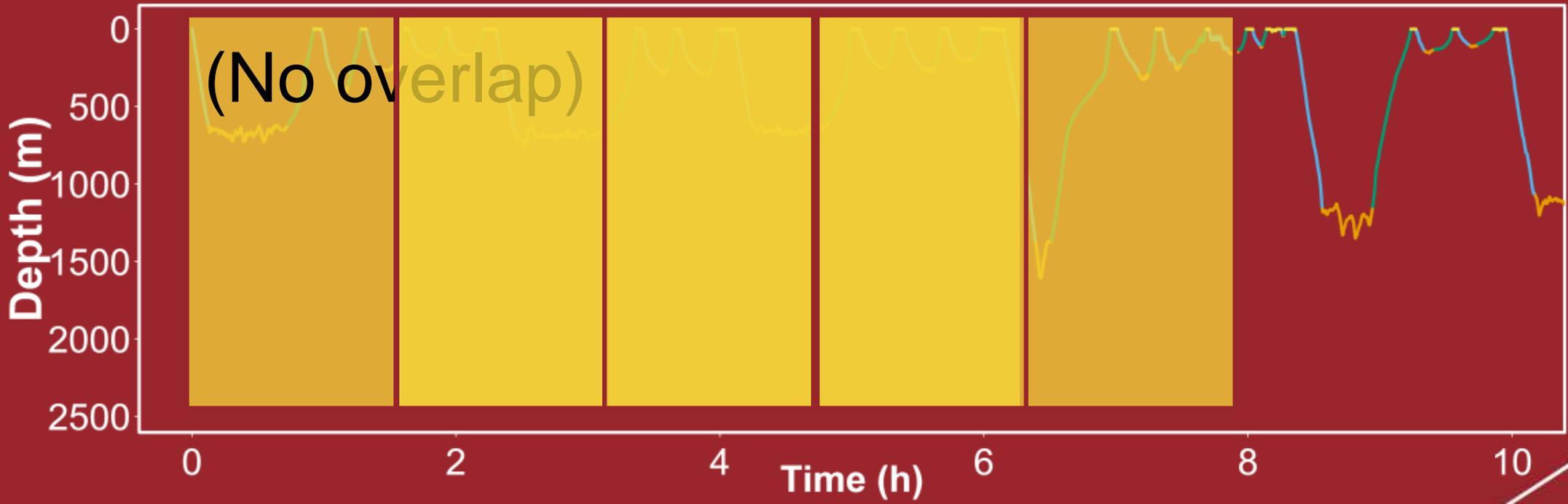
*Baseline and current period*

# Overlap?



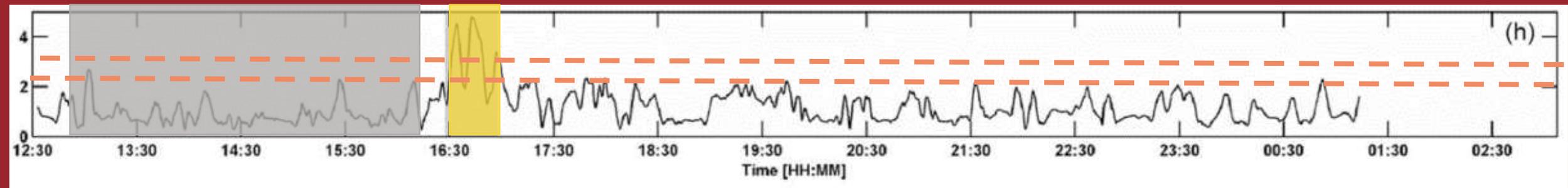
*Baseline and current period*

Distance between ... *what* ?



*Consecutive periods*

# Change-point Threshold



*Baseline*

*Experimental period*

*Threshold*

# Previous Work

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### First indications that northern bottlenose whales are sensitive to behavioural disturbance from anthropogenic noise

P. J. O. Miller, P. H. Kvadsheim, F. P. A. Lam, P. L. Tyack, C. Curé, S. L. DeRuiter, L. Kleivane, L. D. Sivle, S. P. van IJsselmuide, F. Visser, P. J. Wensveen, A. M. von Benda-Beckmann, L. M. Martín López, T. Narazaki, S. K. Hooker

Published 3 June 2015. DOI: 10.1098/rsos.140484

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#### Abstract

Although northern bottlenose whales were the most heavily hunted beaked whale, we have little information about this species in its remote habitat of the North Atlantic Ocean. Underwater anthropogenic noise and disruption of their natural habitat may be major threats, given the

June 2015

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# It's hard to fake it

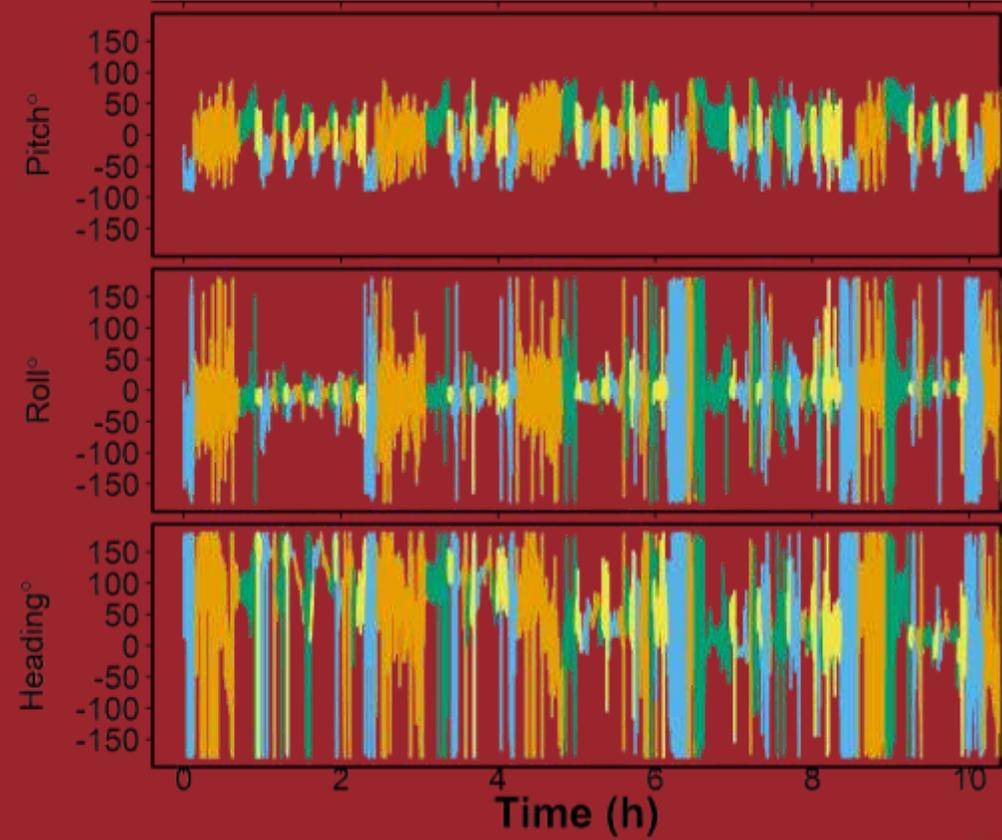
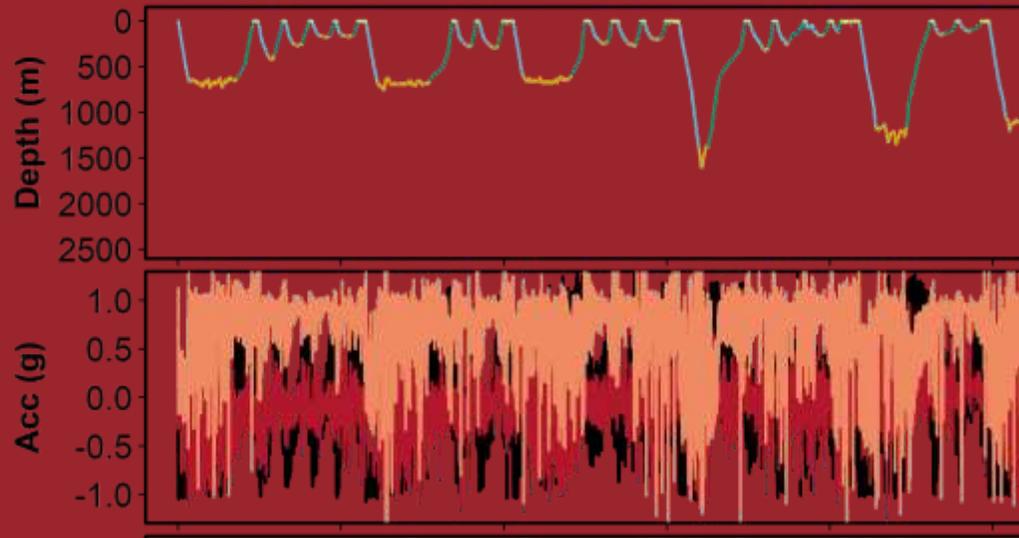
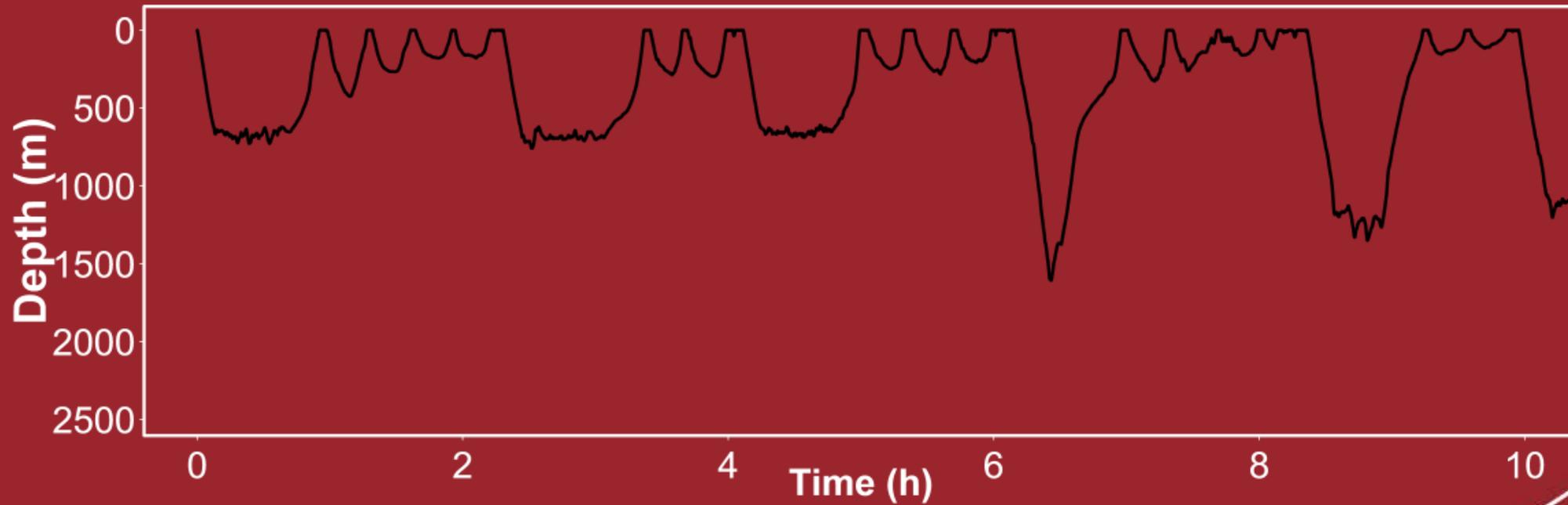
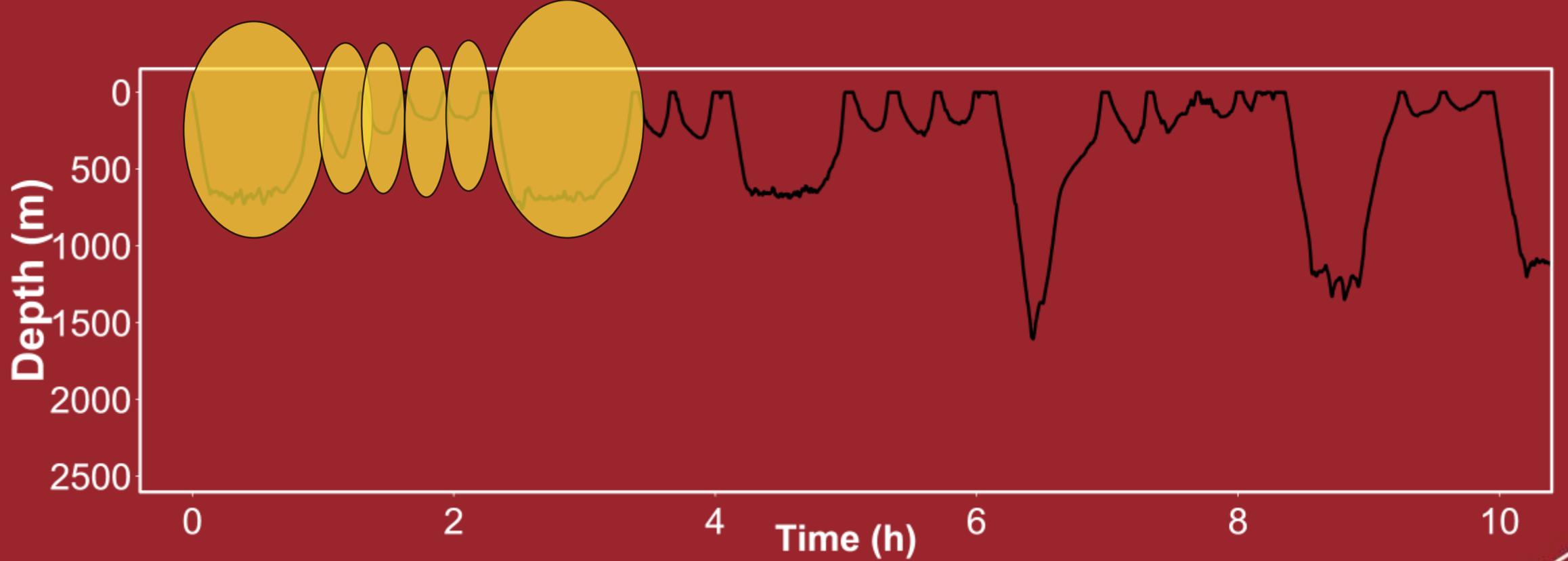


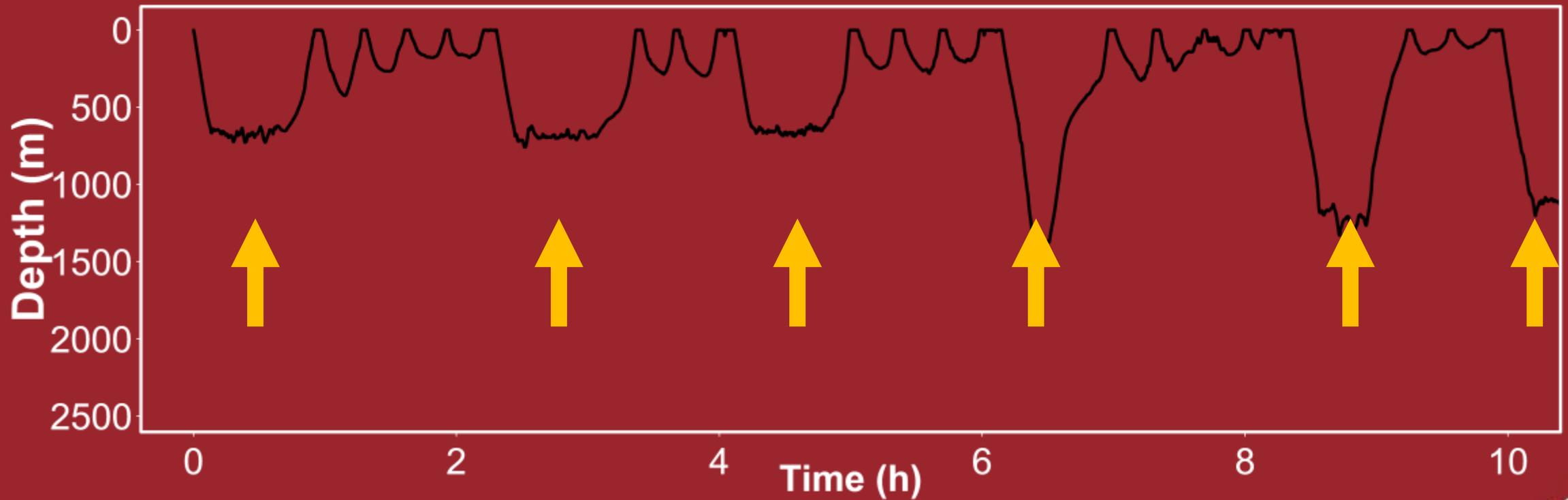
Photo: A Friedlaender, SOCAL BRS Project, NMFS permit #14534

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

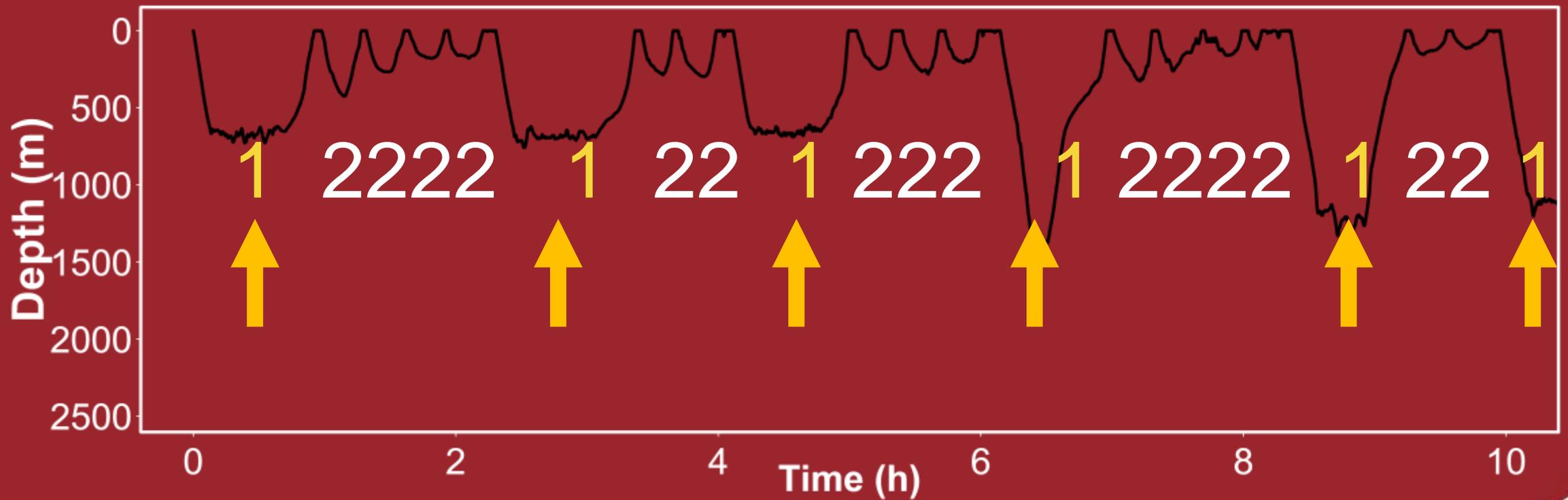




- Detect dives (depth threshold)

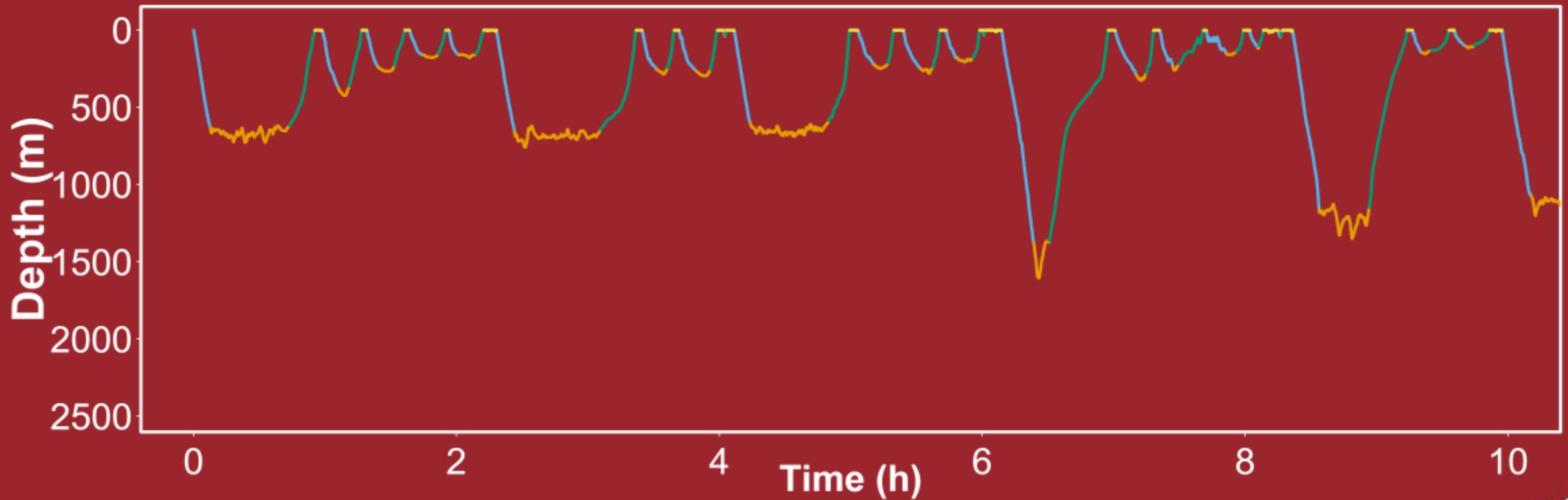


- Detect dives (depth threshold)
- Cluster dives (k-means on depth, duration; silhouette)



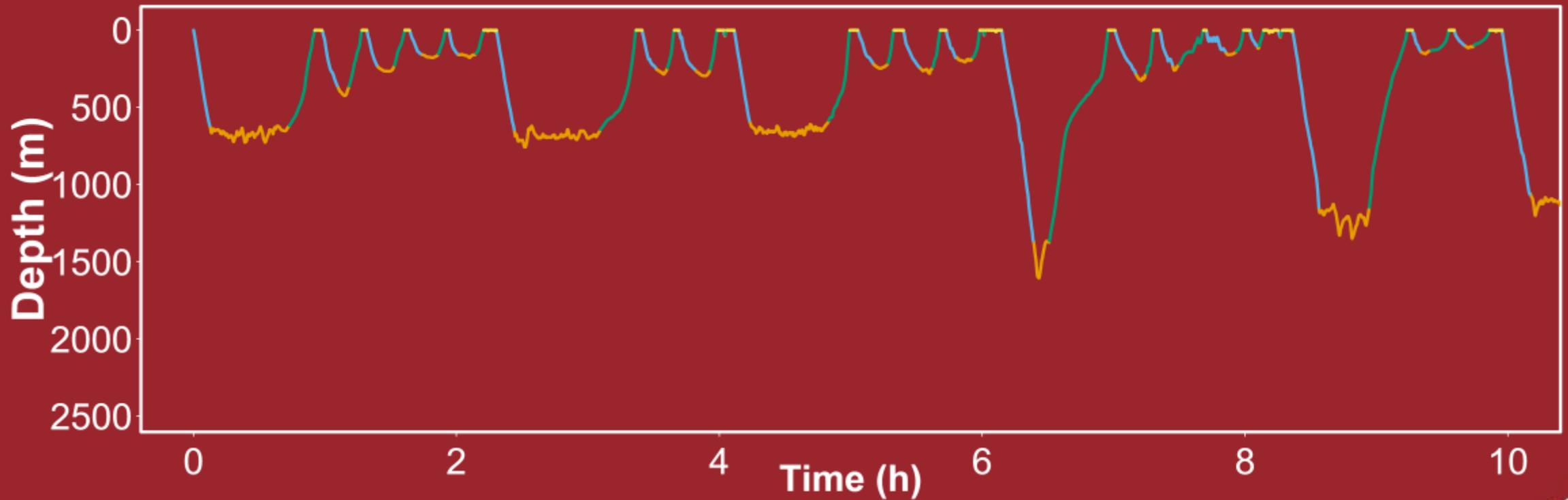
- Detect dives
- Cluster dives

- Dive sequence (MC)



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

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



- Detect dives
- Cluster dives
- Dive sequence

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

# Tag Data Model/Simulation Summary

- K-means clustering to identify dive types
- 1<sup>st</sup>-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

# animaltags.org & github.com/stacyderuiter/TagTools

← → ↻ ⓘ animaltags.org/doku.php ☆ 🔍 🌐 📄 📄 📄 📄

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## Animal Tag Tools

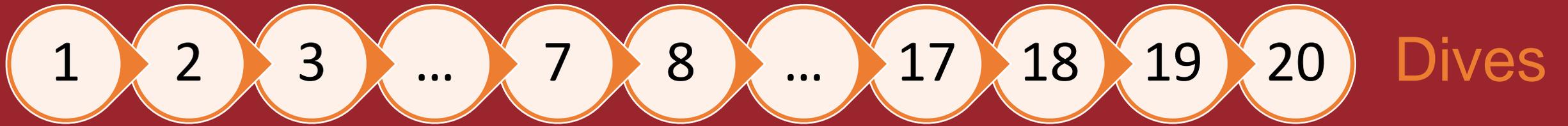
Welcome to the Animal Tags Tools Wiki.

Here you can find information, help & support for the Animal Tags Toolbox. The Animal Tags Toolbox is a set of functions created for Tag Users by Tag Developers & Users and designed to run in Matlab, Octave & R. To navigate the Wiki follow the links in the menubar or visit our [Navigation Page](#).

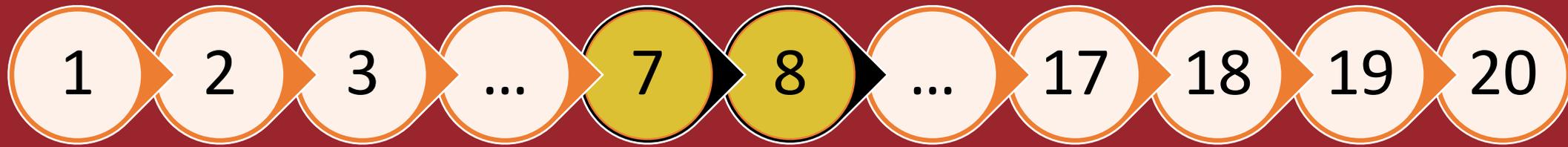
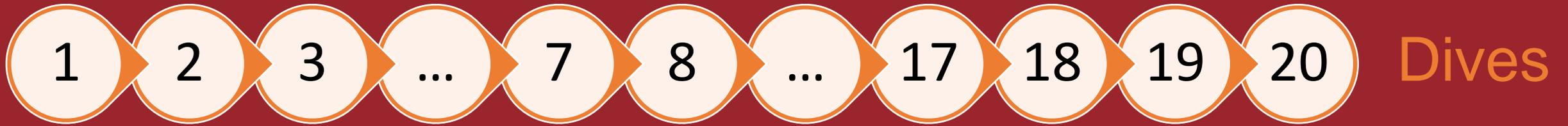


© Christian Ramp & MICS (2012)

# Simulations

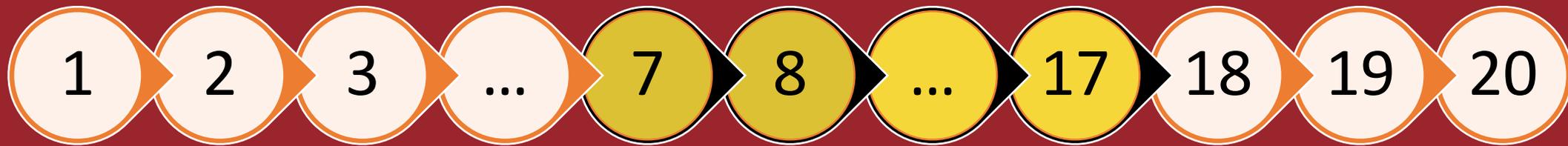
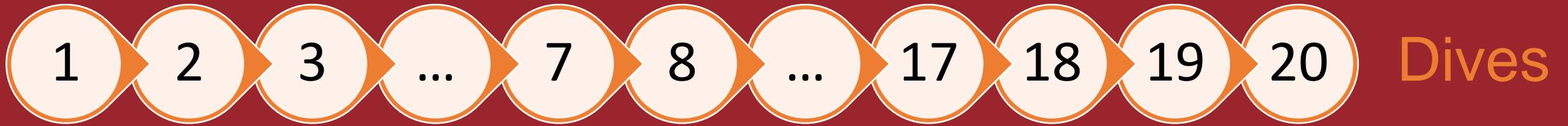


# Simulations



# Short response

# Simulations



Long response

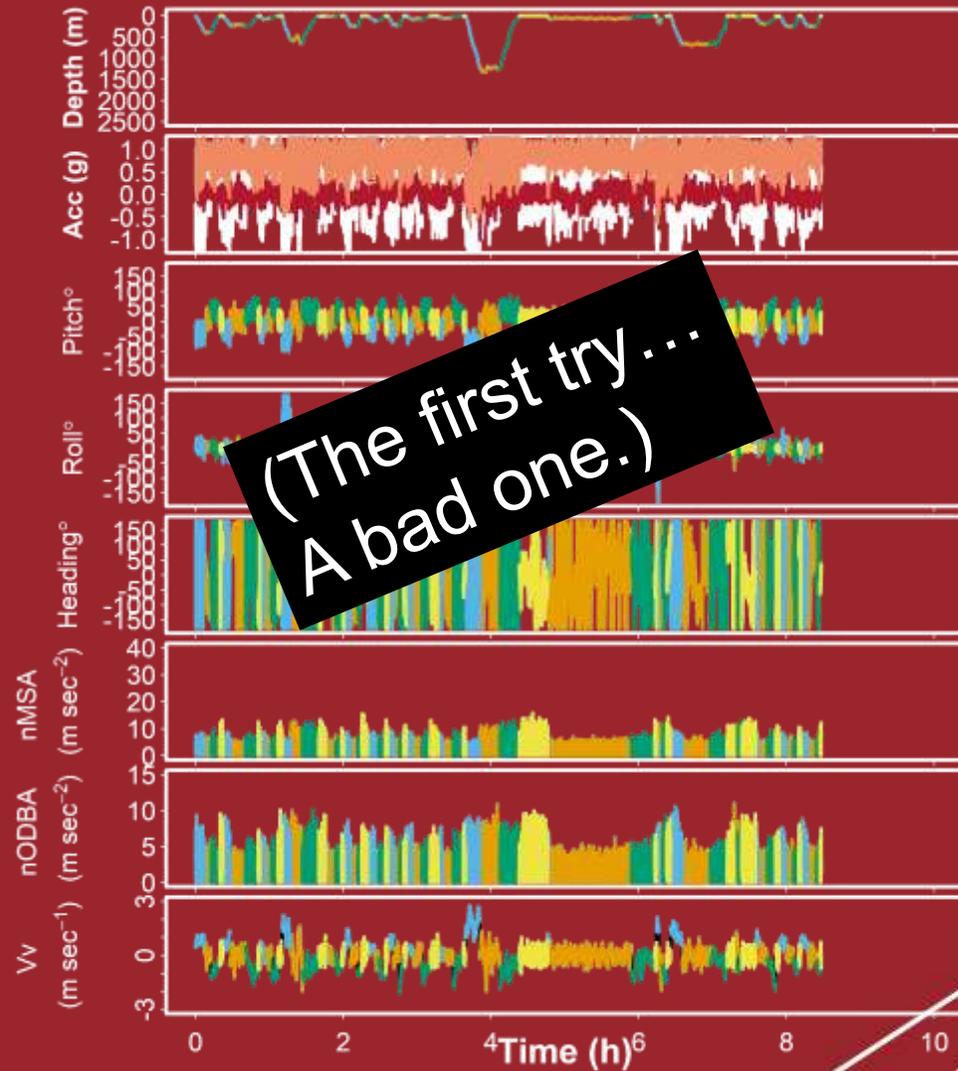
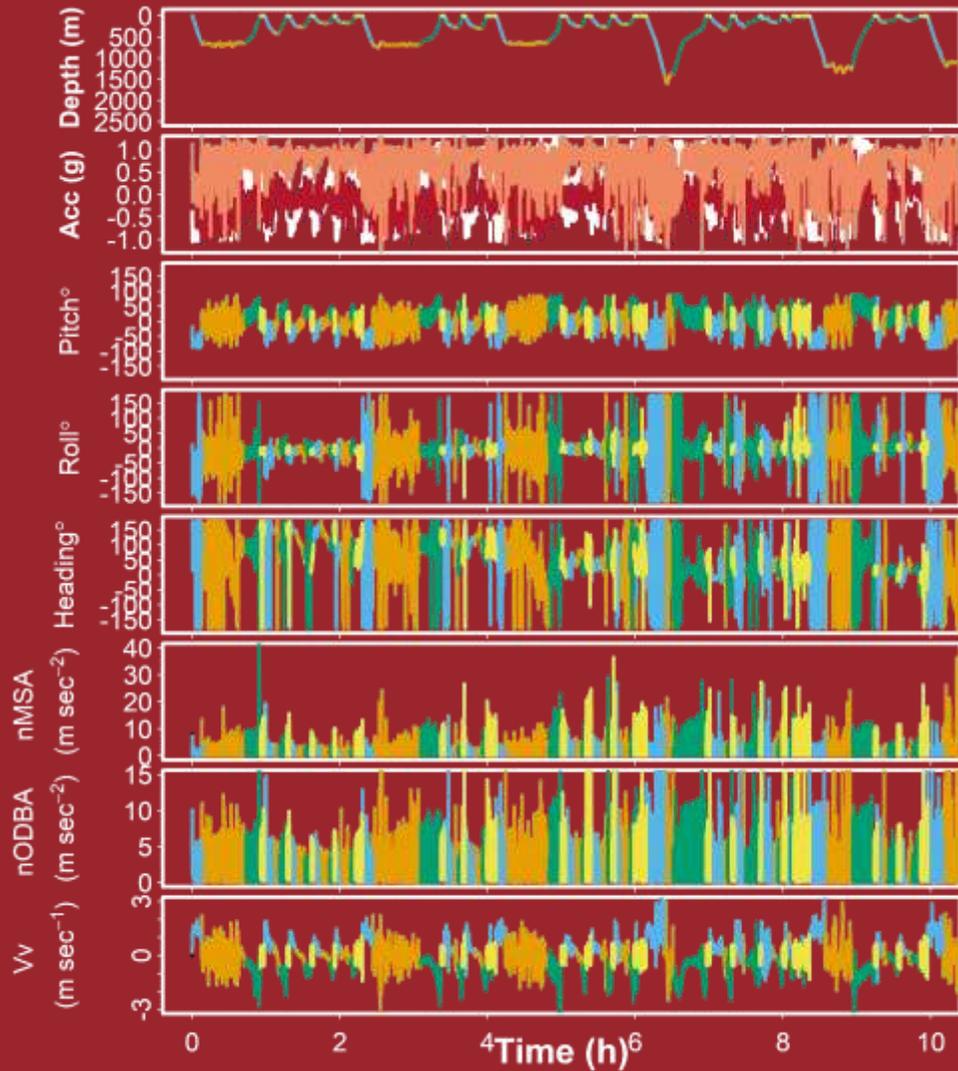
# Simulated Data Streams

## Direct Simulation

- Acceleration (X,Y,Z)
- $\Delta$ depth
- $\Delta$ heading
- Pitch, roll (sine and cosine)
- ODBA and MSA (normalized)

## Derived

- Heading
- Depth
- Var(heading)
- Var(pitch)
- Var( $\Delta$ depth)



# 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.

# Input variables for distance calculations

- ***AVOIDANCE:***

- heading variance,
- pitch variance,
- nODBA

- ***FEEDING:***

- nODBA variance,
- pitch variance,
- $\Delta$ depth,
- $\Delta$ depth variance

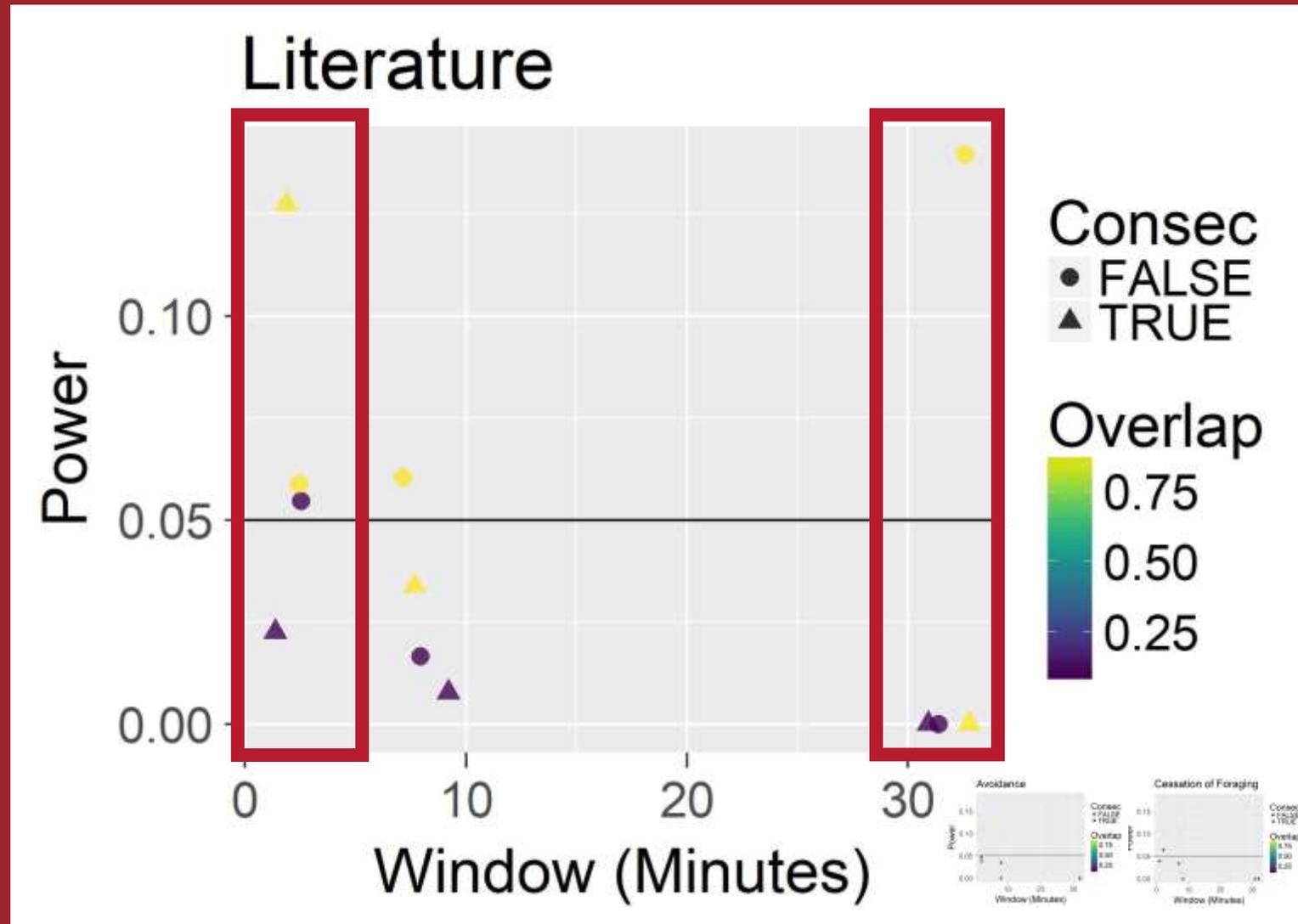
- ***LITERATURE:***

- nODBA,
- pitch variance,
- heading variance,
- $\sin(\text{heading})$ ,
- $\cos(\text{heading})$

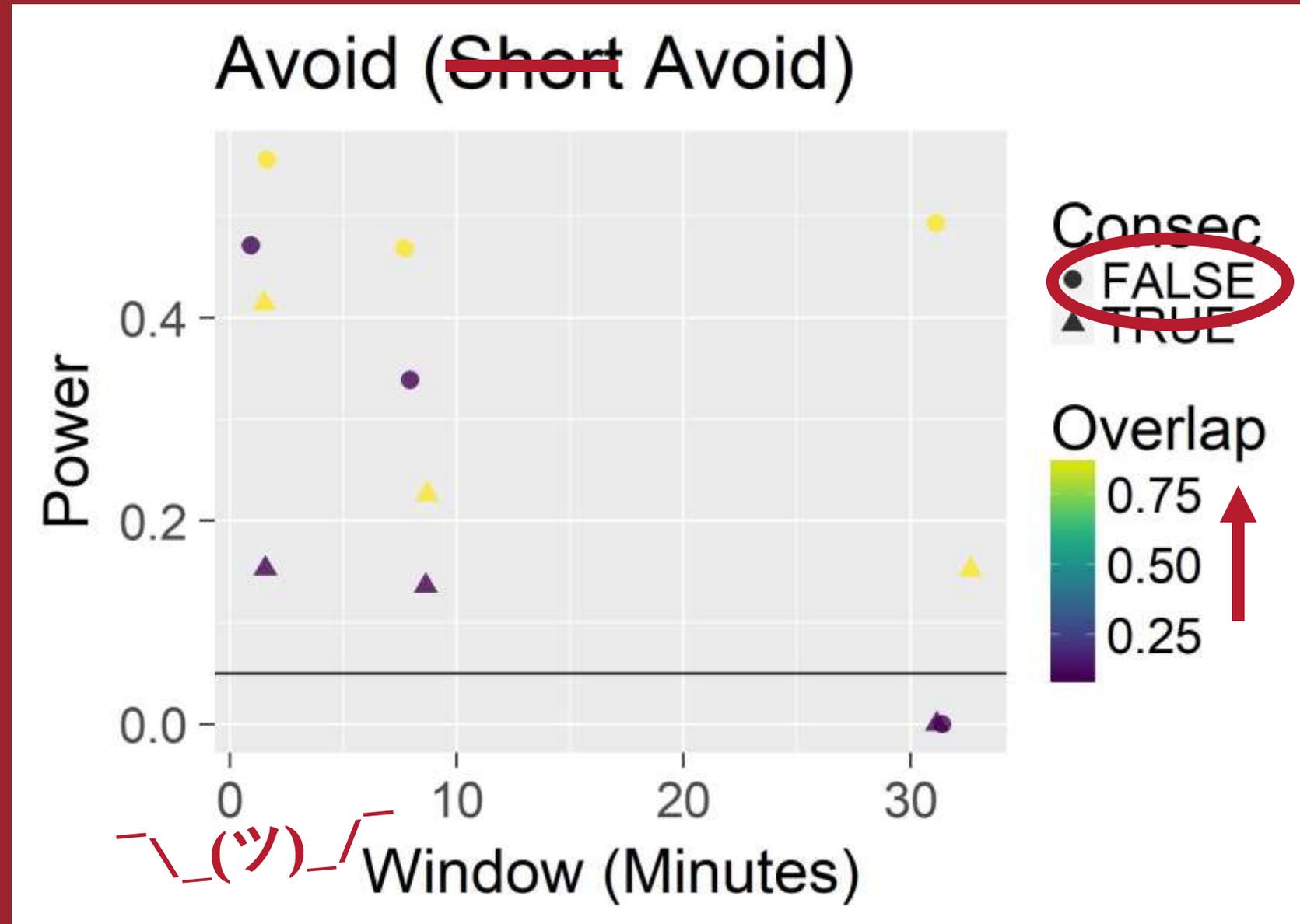
# Results of simulations: Control (no response)

(500 whales per scenario)

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



# Results of Simulations: Representative Example



# 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





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

