Hidden Markov Models in Marine Sciences

Tutorial Day 3: sharks, accelerometer data, depth data, hierarchical HMMs

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Sharks + Accelerometer Data

All shark data credit to Dr. Yannis Papastamatiou.

Acceleration Data

Static Acceleration + Dynamic Acceleration

Body position of shark

Movements of shark

ODBA = Σ Dynamic Acceleration

= Proxy for O_2 consumption and energy expenditure

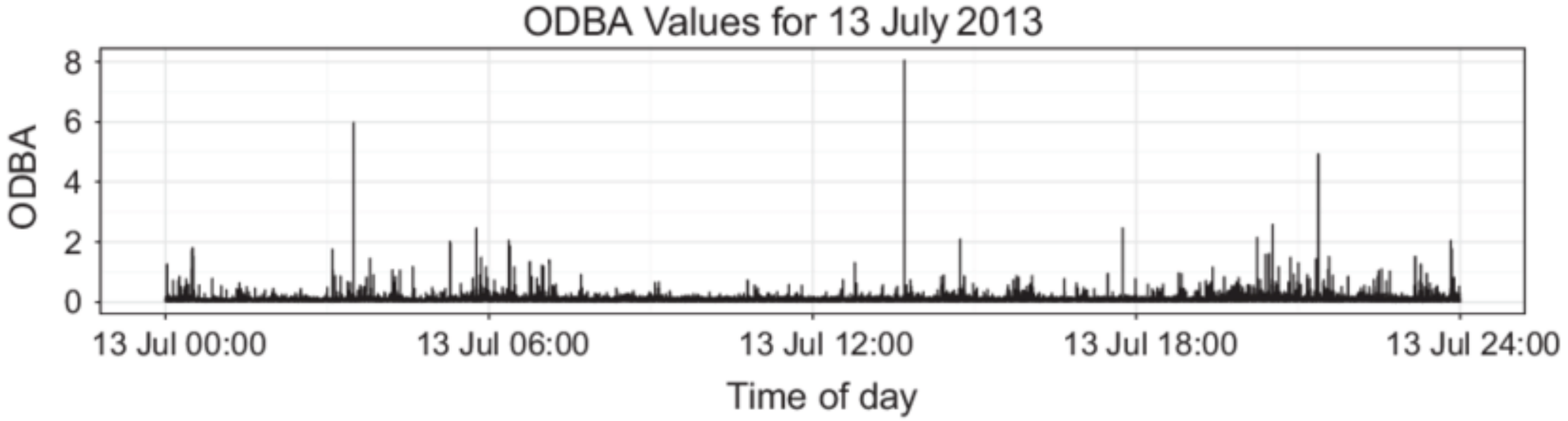
Wilson et al. 2006, Gleiss et al. 2011, Shepard et al. 2008

Horn Sharks

Overall Dynamic Body Acceleration (ODBA)

Blacktip Sharks

- First, we decompose the acceleration signal into ‘static’ + ‘dynamic’ components
- ODBA = $|x_{dynamic}| + |y_{dynamic}| + |z_{dynamic}|$



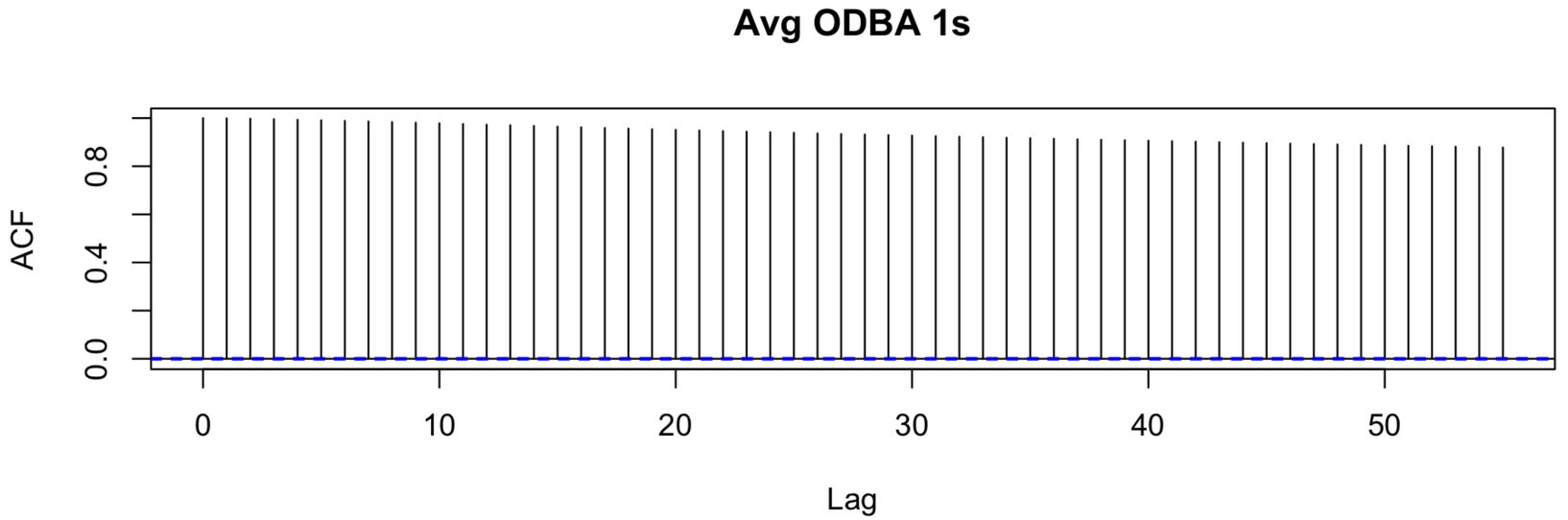
Building an HMM for accelerometer data

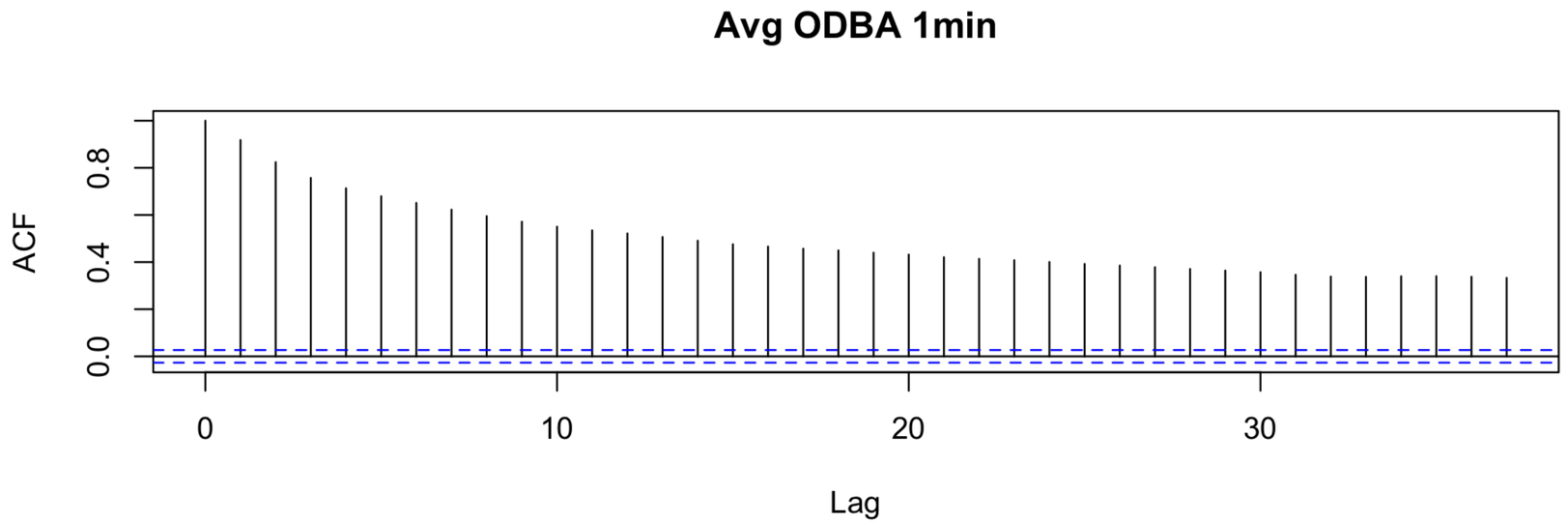
- Using ODBA as a proxy for…energy expenditure? Here, not quite. We'll use ODBA as a proxy for activity. If the sharks are exhibiting higher values of ODBA, we'll try to cluster those into a **'more active state'** and place the rest into a **'less active state'**, i.e. build a 2-state HMM.

- Covariates — time of day (as a function of cosine and sines)

- We can of course build more complex HMMs, with more states, or also include the multivariate data itself!

Temporal Resolution





Breaking HMM Assumptions

- The finer the temporal resolution, especially with accelerometer data, we'll likely break the "conditional independence assumption".

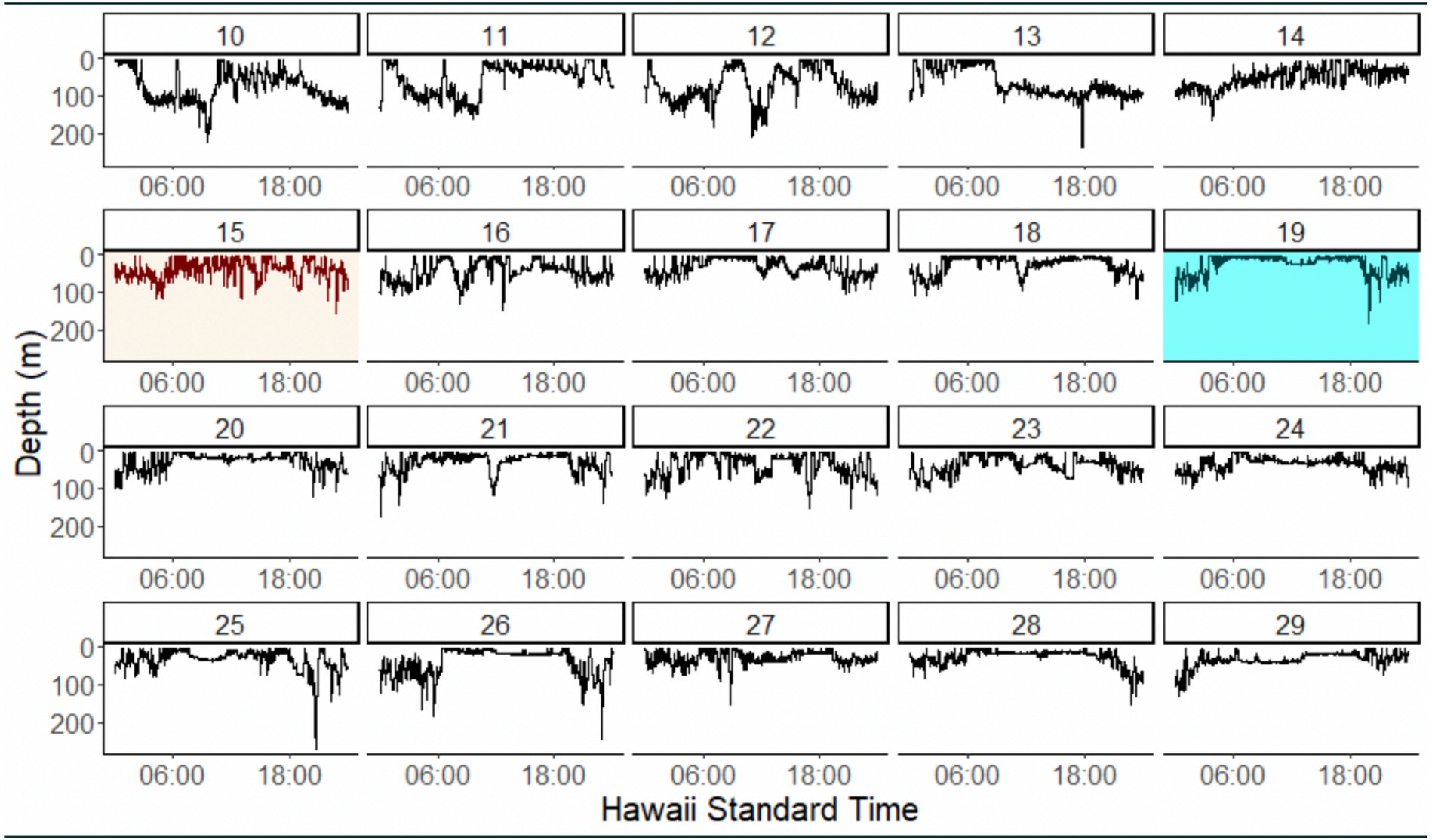
- Our pseudo-residuals are likely to show high autocorrelation.

- What can we do in practice:

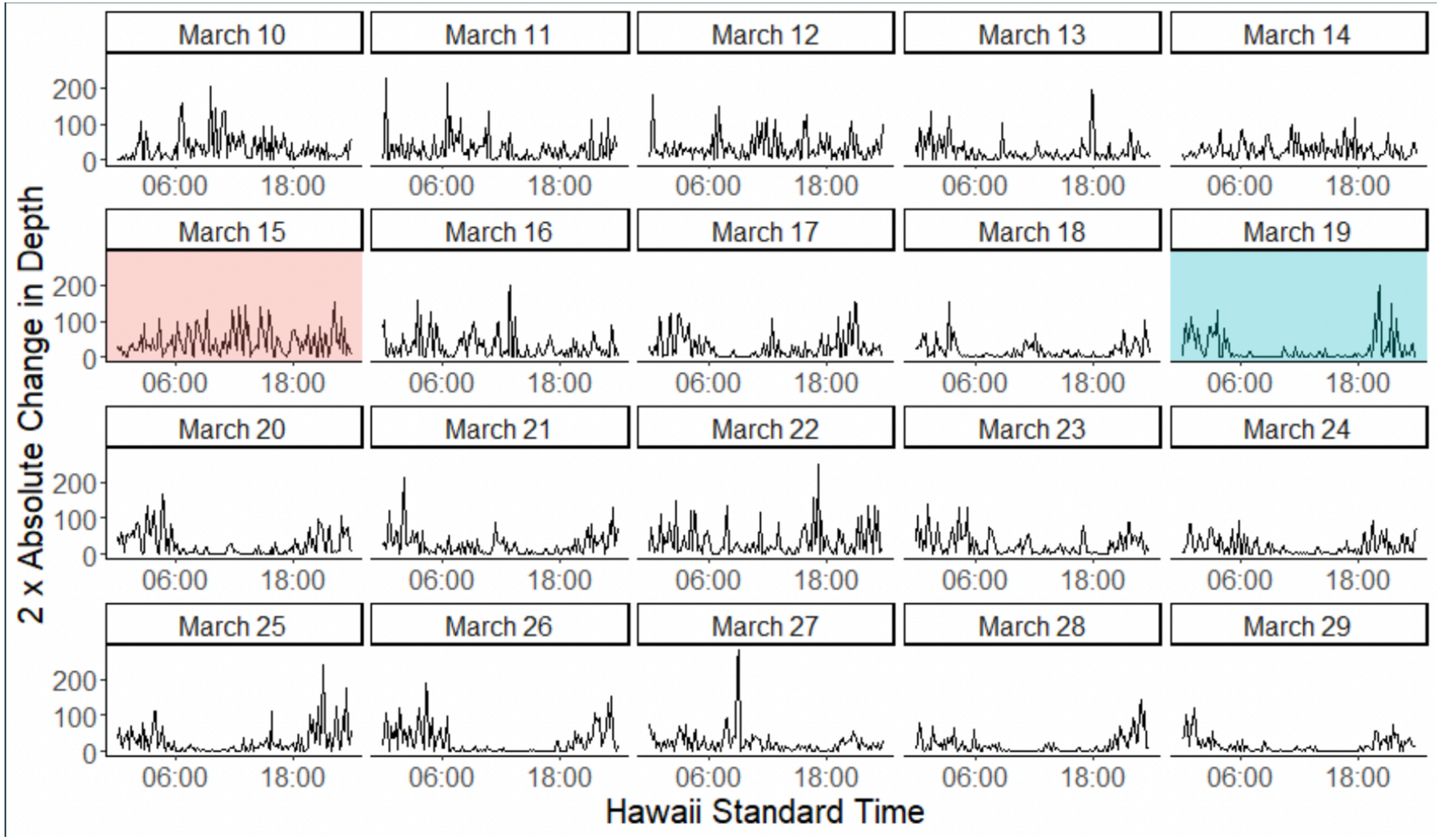
  - move to a coarser temporal scale to fit a basic HMM that fits the data well
  - include more structure in our HMM
  - accept a certain degree of lack of fit if our model is interpretable

Sharks + Depth Data

Diving with a tiger shark



Diving with a tiger shark



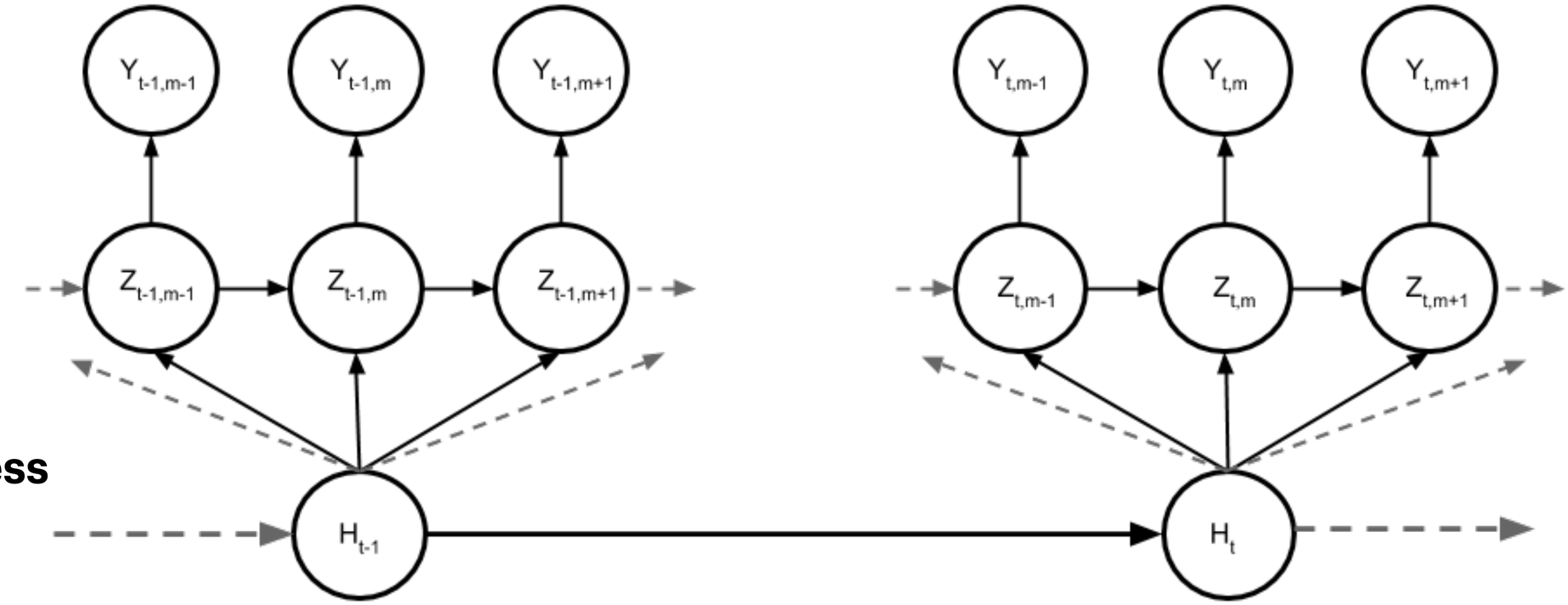
Multi-Scale HMMs (Hierarchical HMMs)

Observation process

Fine-scale state process
(production state)

Coarse-scale state process

(internal state)



Coarse- vs fine- scale processes

- Coarse-scale

- Fine-scale

What else?

- We can fit HMMs to all sorts of marine animal movement data:

  - GPS
  - accelerometer
  - dive data

- Toward the end of the tutorial, we'll open the floor to others who may want to work on their own data and get personalized advice.

- We've just gotten started with what HMMs can do. Feel free to ask us about further extensions!