Slightly Less Simple Mosquito Modeling

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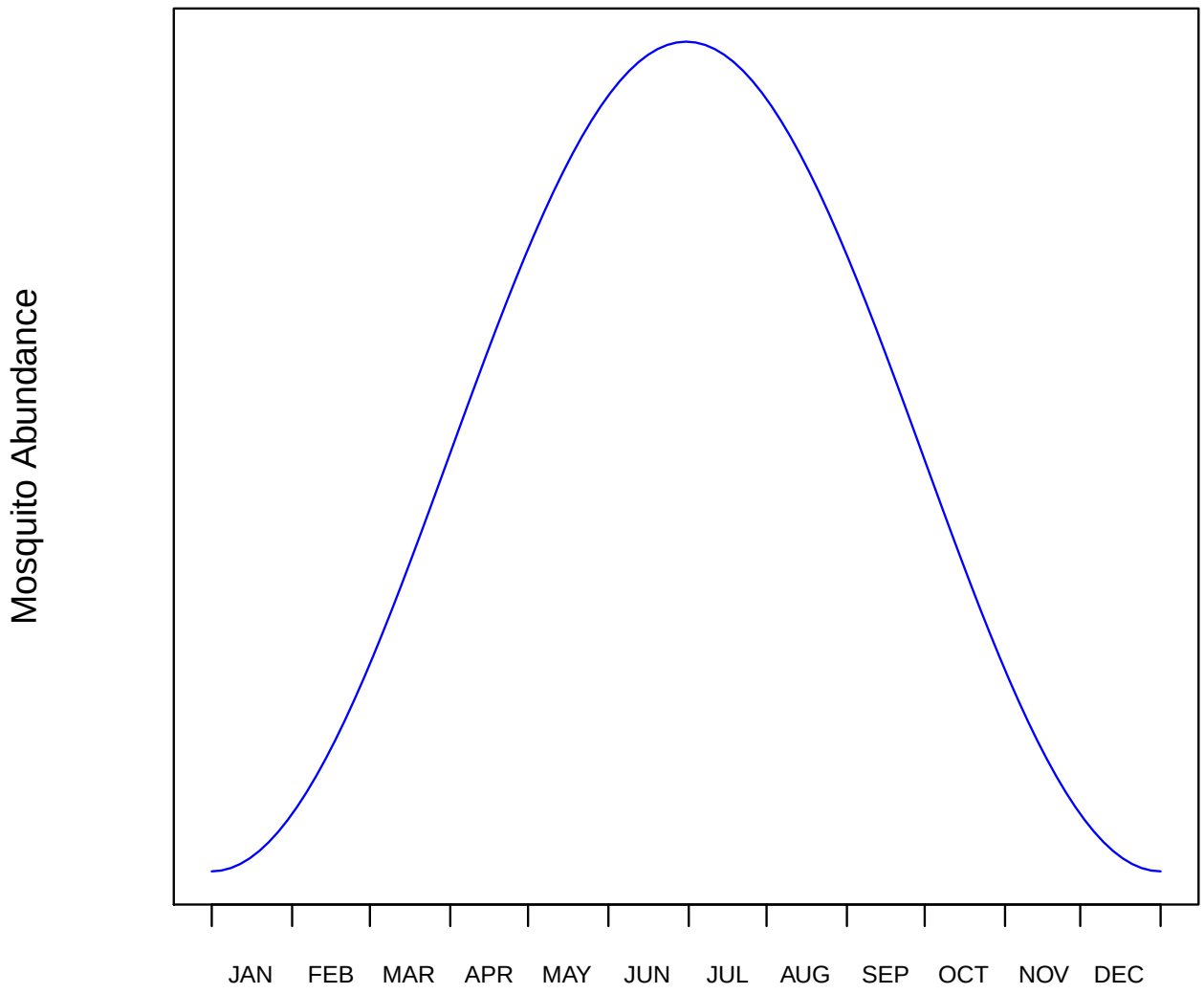
What's this talk really about?

- finding low-hanging fruit,
- expression with models,
- simple analytical approaches,
- a little dimensional analysis,
- how to connect those with experiments and get higher up the tree, and
- a little about work habits and tools

A Not Atypical Model of Vector Population



But...

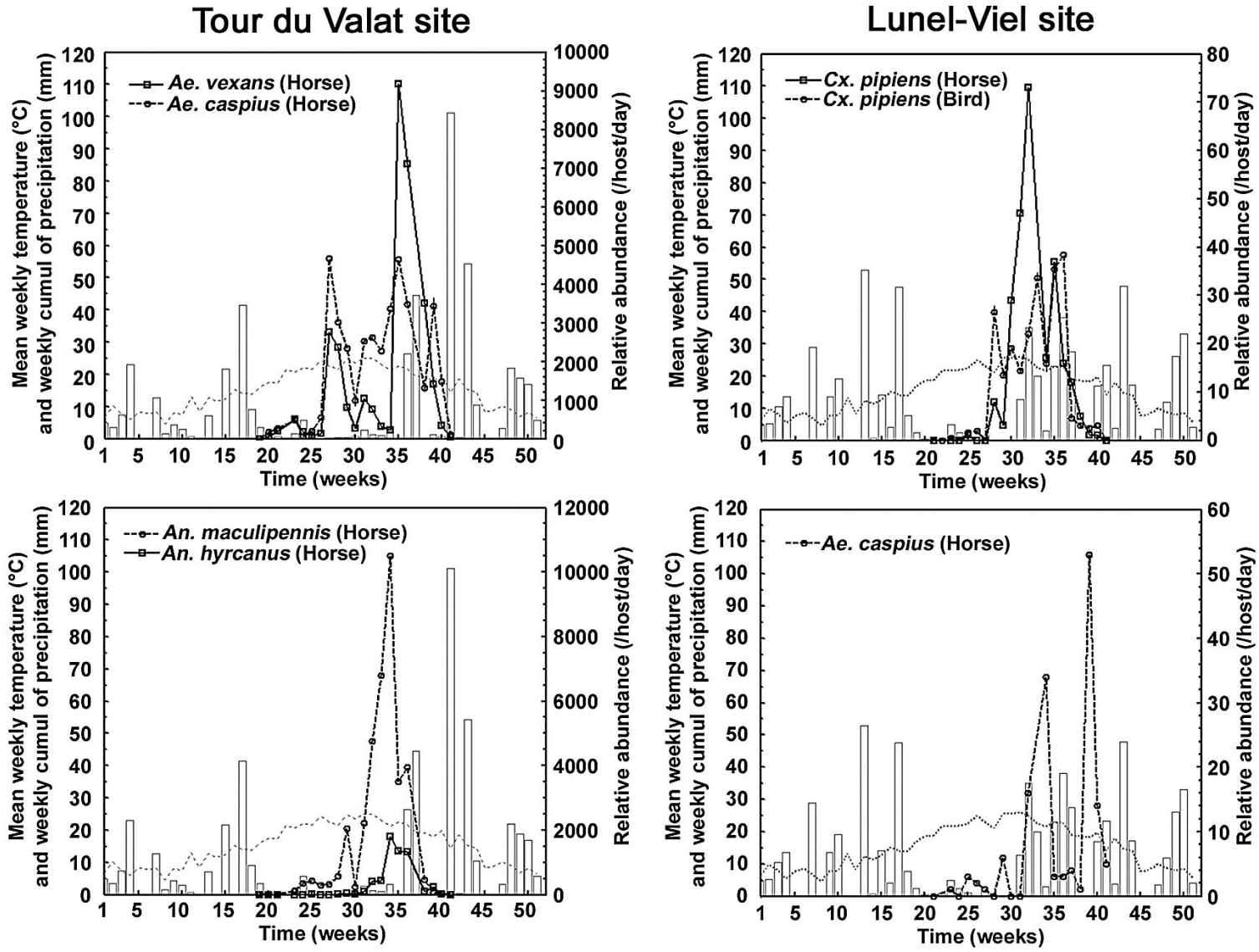


Figure: Bicout et al. J. Med. Entomol. 43(5): 936-946 (2006)

So, a Disconnect.

With

$$M(t) = C \sin(\omega t + \theta)$$

Impossible to match features like

- peak population,
- total population over a year, and
- turnover rate

These can be critical to predicting transmission dynamics.

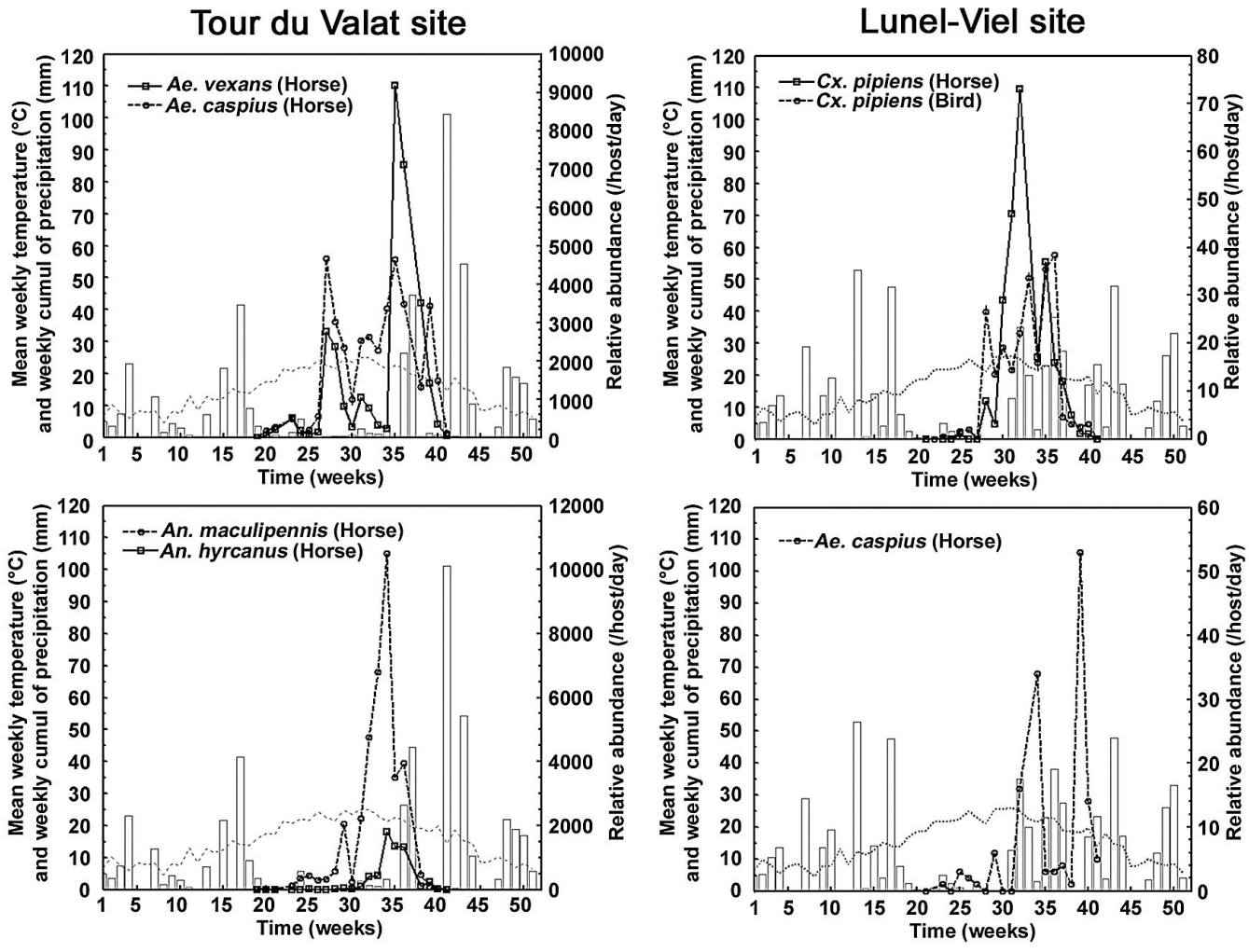
Do Better, But Keep It Simple

What's good about trigonometric representation? Simplicity:

- two parameters
- no spatial features
- "easy" analytical form

Possible to identify alternatives that *can* match salient features, but still retain these features?

What are those salient features? Let's look again.


Tour du Valat site
Ae. vexans (Horse)
Ae. caspius (Horse)
An. maculipennis (Horse)
An. hyrcanus (Horse)
Lunel-Viel site
Cx. pipiens (Horse)
Cx. pipiens (Bird)
Ae. caspius (Horse)
Mean weekly temperature (°C) and weekly cumul of precipitation (mm)
Relative abundance (/host/day)
Time (weeks)

Salient Features

- every year,
- over a relatively short duration,
- the mosquito population rapidly increases,
- sits at a high level of activity,
- then rapidly declines,
- apparently connected with resource availability & environmental suitability

Salient Features in Trig. Representation

- every year, **CHECK!** . . . *but not the rest of:*
- over a relatively short duration,
- the mosquito population rapidly increases,
- then rapidly declines,
- apparently connected with resource availability & environmental suitability

Getting at the Other Points

Need:

- worth connecting to external force
- "spikey"
- oscillatory

Can get that with repeating boundary conditions on

$$\dot{M}(t) = E(t) - \lambda M(t)$$

and appropriate $E(t)$.

Appropriate $E(t)$

Most of the criteria boildown to a “spikey” function options. Suggestions?

What else would we need to ensure?

Alternatives I

$$E(t) = \begin{cases} \dfrac{M_+}{\Delta t} & t \in \Delta t \\ 0 & \text{otherwise} \end{cases} \qquad \text{(Step)}$$

$$E(\rho, t) = \begin{cases} \dfrac{2M_+}{\Delta t(2-\rho)} & t \in \Delta t(1-\rho) \\ \dfrac{2M_+}{\Delta t(2-\rho)\rho}\left(1 - \dfrac{2|t|}{\Delta t}\right) & t \in \rho\Delta t \\ 0 & \text{otherwise} \end{cases} \qquad \text{(Modified Step)}$$

$$E(t) = \frac{2M_+}{\Delta t}\sqrt{\frac{2}{\pi}}e^{-\frac{8t^2}{\Delta t^2}} \qquad \text{(Approximate } \delta\text{)}$$

Alternatives II

$$E(t) = \frac{M_+}{\Delta t}\sqrt{\frac{2}{\pi}}e^{-\frac{\sin^2 \omega t}{\omega^2 \Delta t^2}} \quad (\omega = \frac{\pi}{T}) \quad \text{(Trig. Approximate } \delta\text{)}$$

$$E(t) = \frac{M_+}{T}\left(1 + \cos\left(\frac{2\pi}{T}t\right)\right) \quad \text{(Trig.)}$$

$$E(t) = \frac{(2^n n!)^2}{(2n)!}\frac{M_+}{T}\cos^{2n}\left(\frac{4\pi}{T}t\right) \quad (n = \lfloor 2^{-1}\sin^{-2}\frac{\pi \Delta t}{2T}\rfloor)$$

(Proper Trig.)

$$E(c,t) = \frac{M_+}{\Delta t}\left[\frac{1}{1+e^{-c(t+\Delta t/2)}} - \frac{1}{1+e^{-c(t-\Delta t/2)}}\right]$$

(Double Logistic)

Aside: Dimensional Analysis

Those equations have a lot of parameters, as do the resulting integral solutions.

Fortunately, everything you learned in engineering coursework can apply here as well.

So, how can remove the scales?

Scale-free Alternatives I

$$\tilde{E}(\rho,\tau) = \begin{cases} \dfrac{1}{\rho} & |\tau| \le \rho/2 \\ 0 & \text{otherwise} \end{cases} \qquad \text{(Step)}$$

$$\tilde{E}(\rho,\rho_\Delta,\tau) = \begin{cases} \dfrac{2}{\rho(2-\rho_\Delta)} & \tau \in \rho(1-\rho_\Delta) \\ \dfrac{2}{\rho(2-\rho_\Delta)\rho_\Delta}\left(1-\dfrac{2|\tau|}{\rho}\right) & \tau \in \rho\rho_\Delta \\ 0 & \text{otherwise} \end{cases} \qquad \text{(Modified Step)}$$

$$\tilde{E}(\rho,\tau) = \frac{2}{\rho}\sqrt{\frac{2}{\pi}}e^{-\frac{8}{\rho^2}\tau^2} \qquad \text{(Approximate } \delta\text{)}$$

Scale-free Alternatives II

$$\tilde{E}(\rho,\tau) = \frac{1}{\rho}\sqrt{\frac{2}{\pi}}e^{-\frac{\sin^2 \pi\tau}{\pi^2\rho^2}} \qquad \text{(Trig. Approximate } \delta\text{)}$$

$$\tilde{E}(\tau) = (1+\cos 2\pi\tau) \qquad \text{(Trig.)}$$

$$\tilde{E}(\rho,\tau) = \frac{(2^n n!)^2}{(2n)!}\cos^{2n} 4\pi\tau \quad (n = \lfloor 2^{-1}\sin^{-2}\frac{\pi\rho}{2}\rfloor)$$

(Proper Trig.)

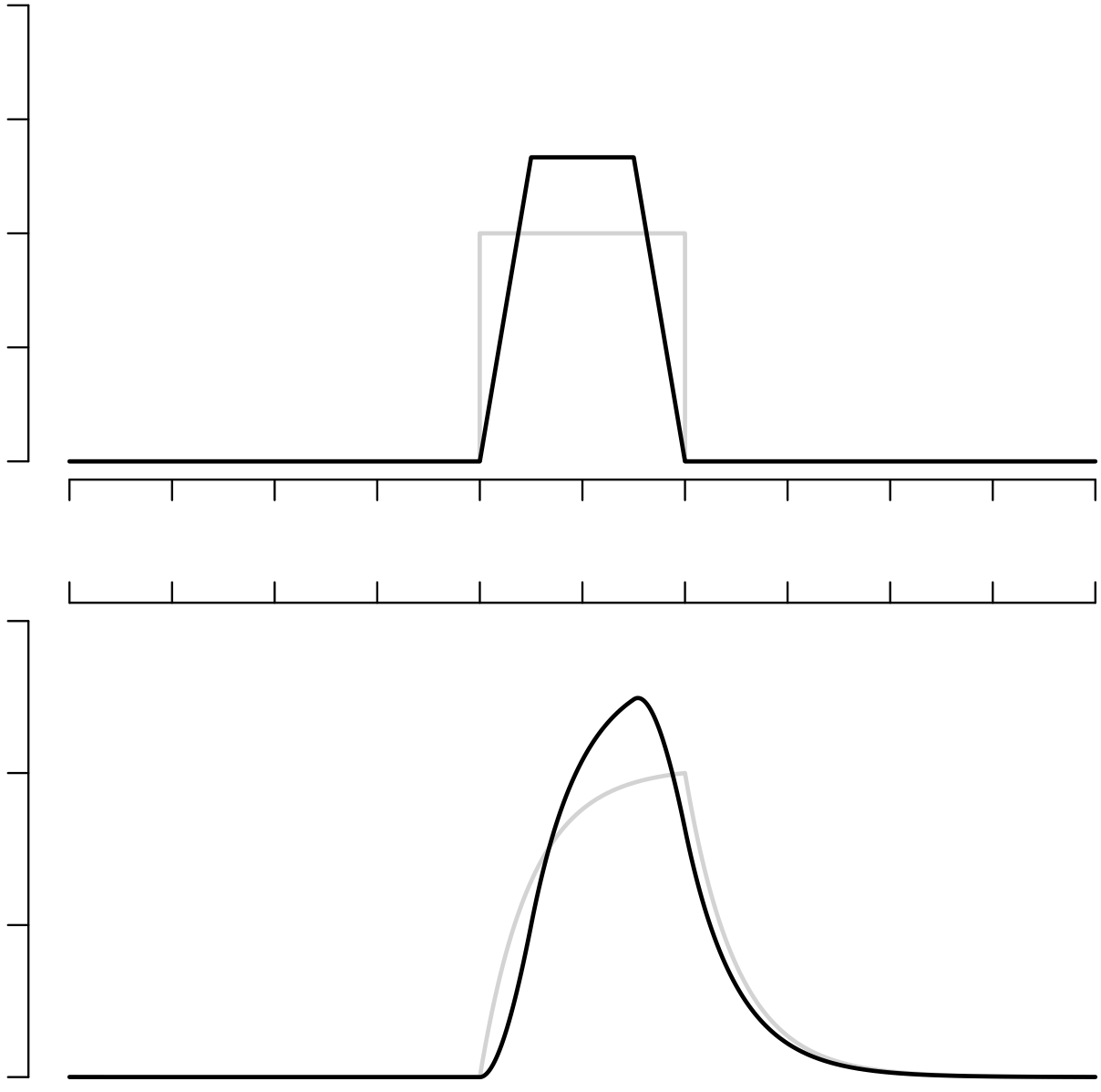
$$\tilde{E}(\tilde{c}=cT,\rho,\tau) = \frac{1}{\rho}\left[\frac{1}{1+e^{-\tilde{c}(\tau+\rho/2)}} - \frac{1}{1+e^{-\tilde{c}(\tau-\rho/2)}}\right]$$

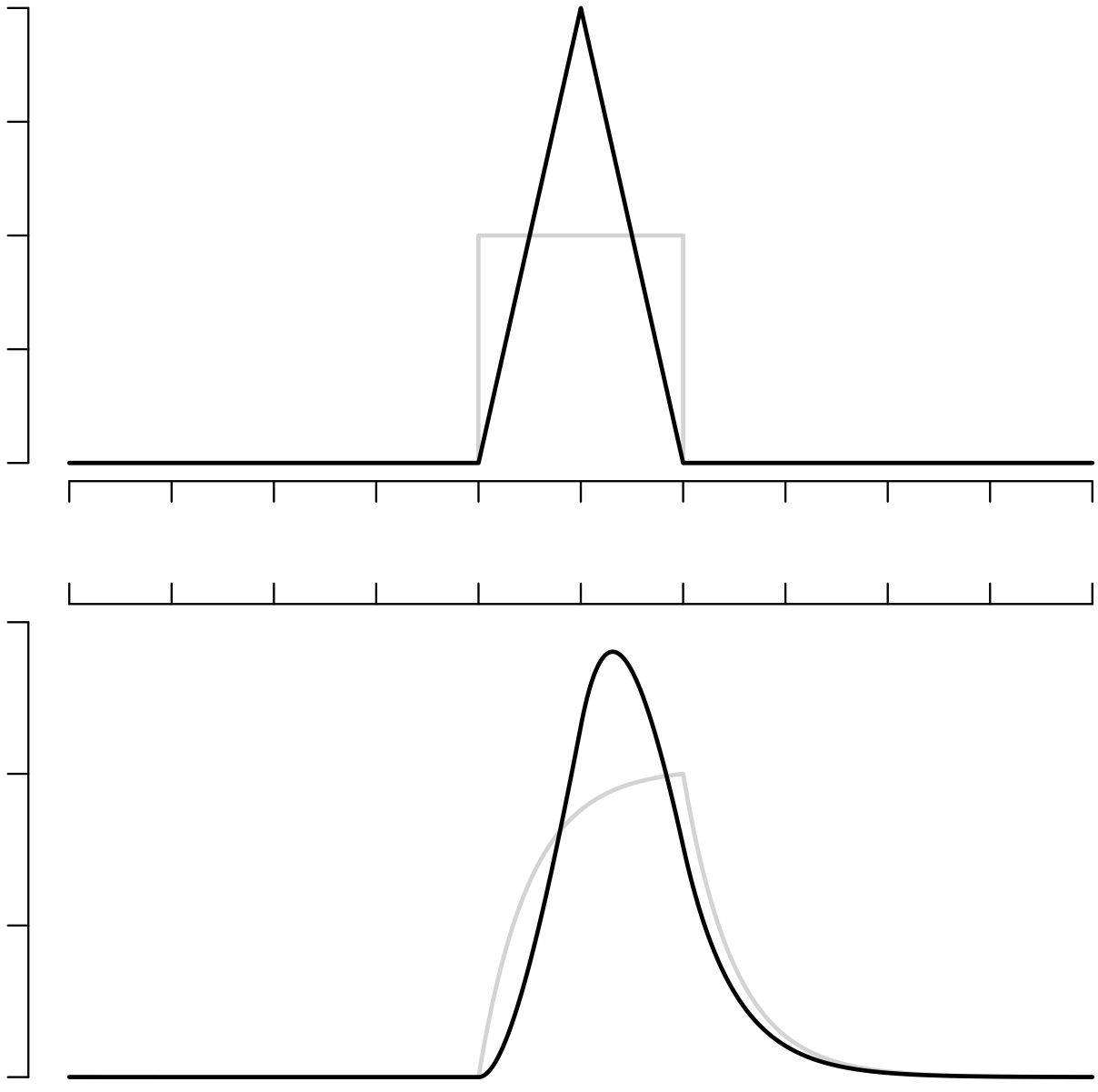
(Double Logistic)

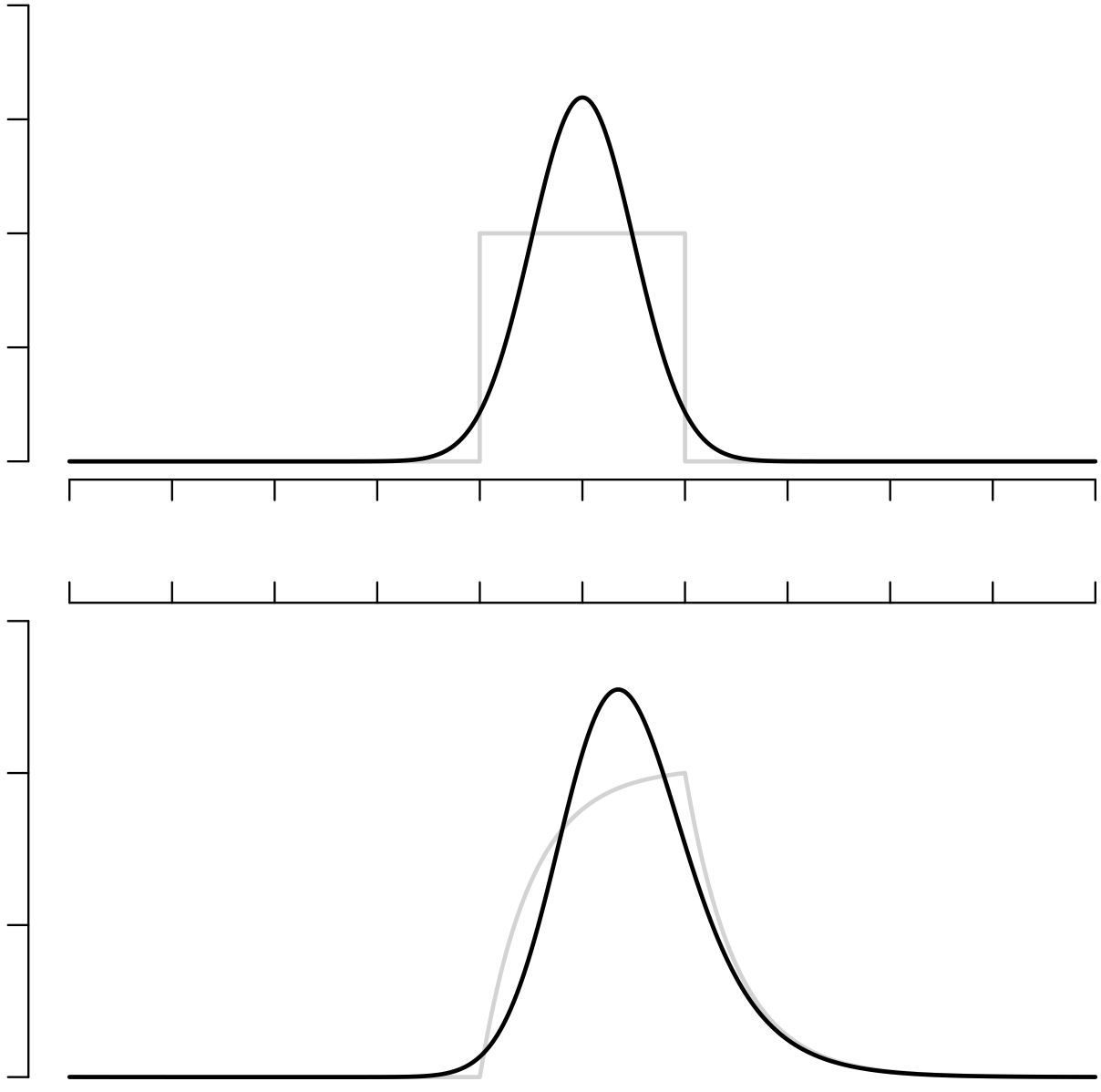
The Resulting Mosquito Populations

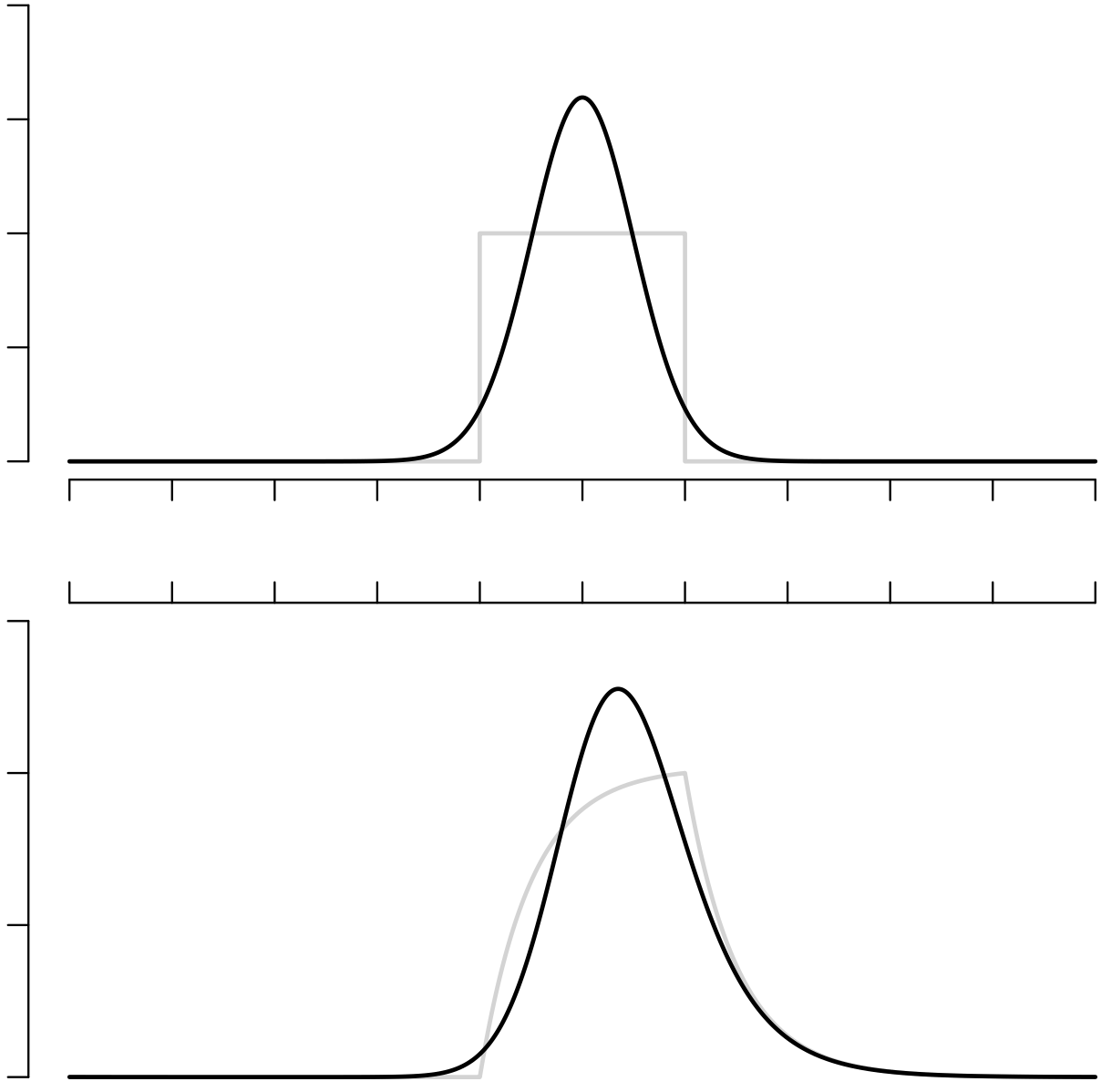
The analytical work to get exact $M(t)$ is. . . tedious. Thankfully, there are numerical integrators!

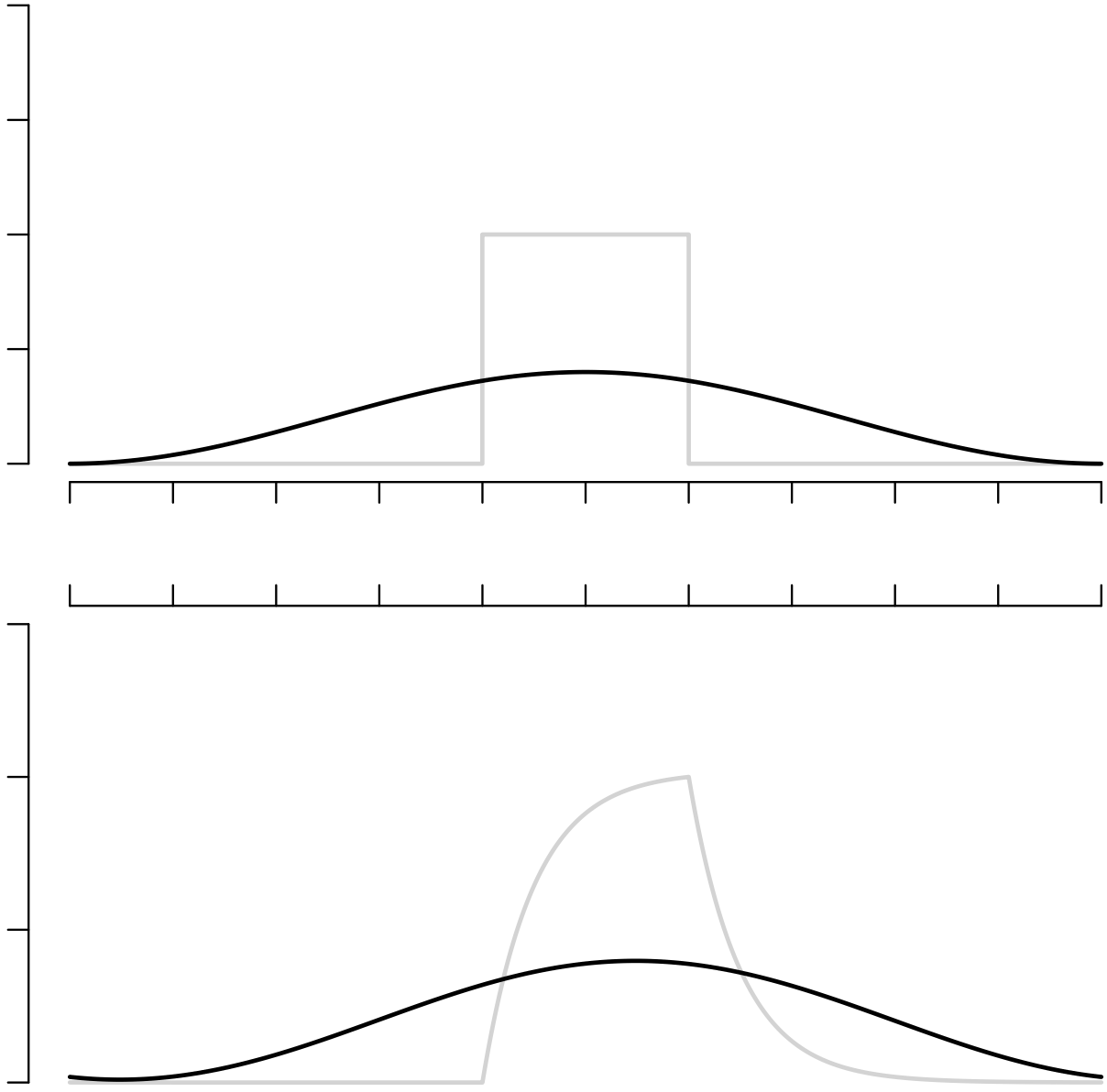
Which gives us a window to qualify these alternatives rapidly, and then decide which to thoroughly investigate.

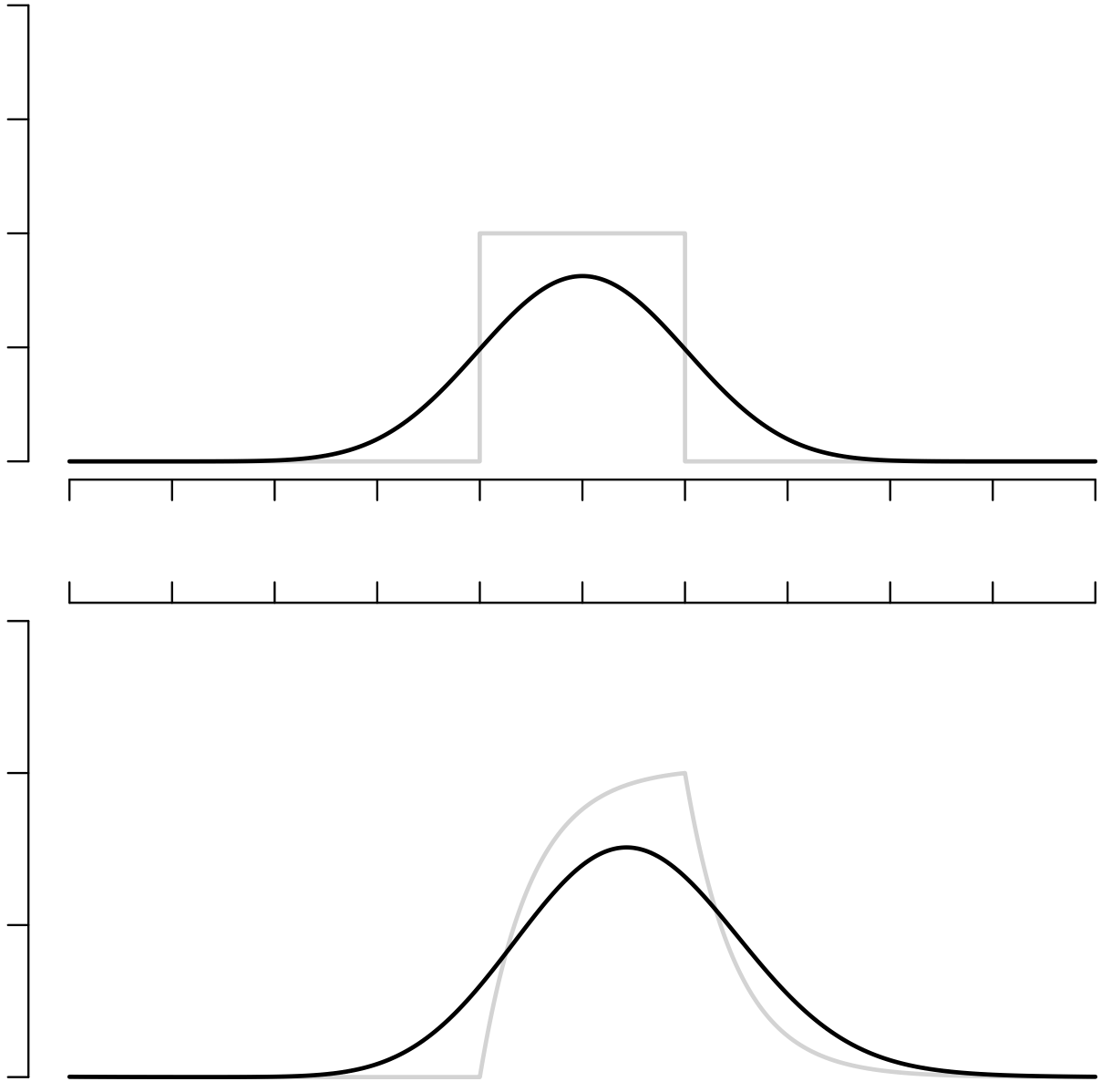


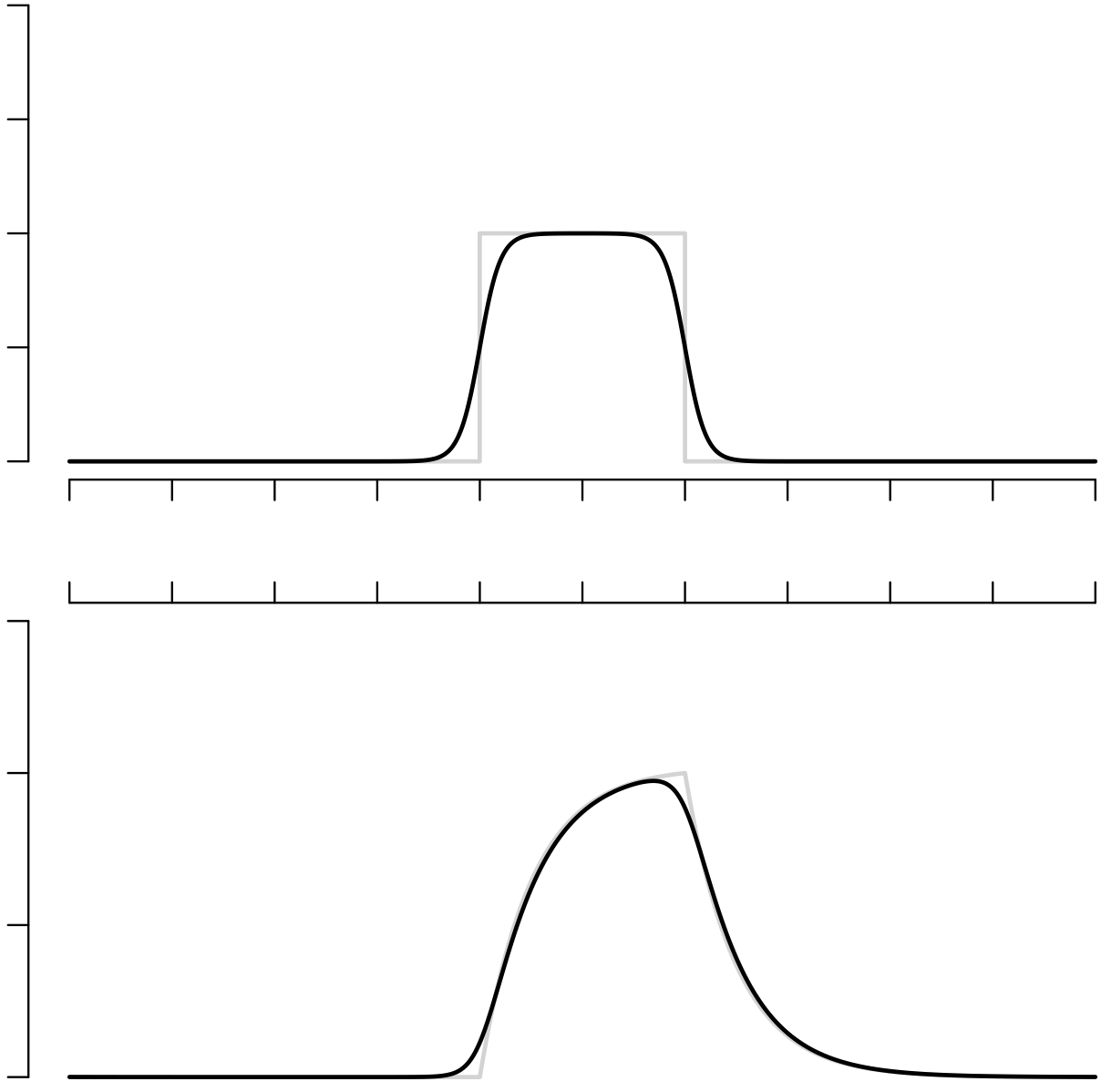






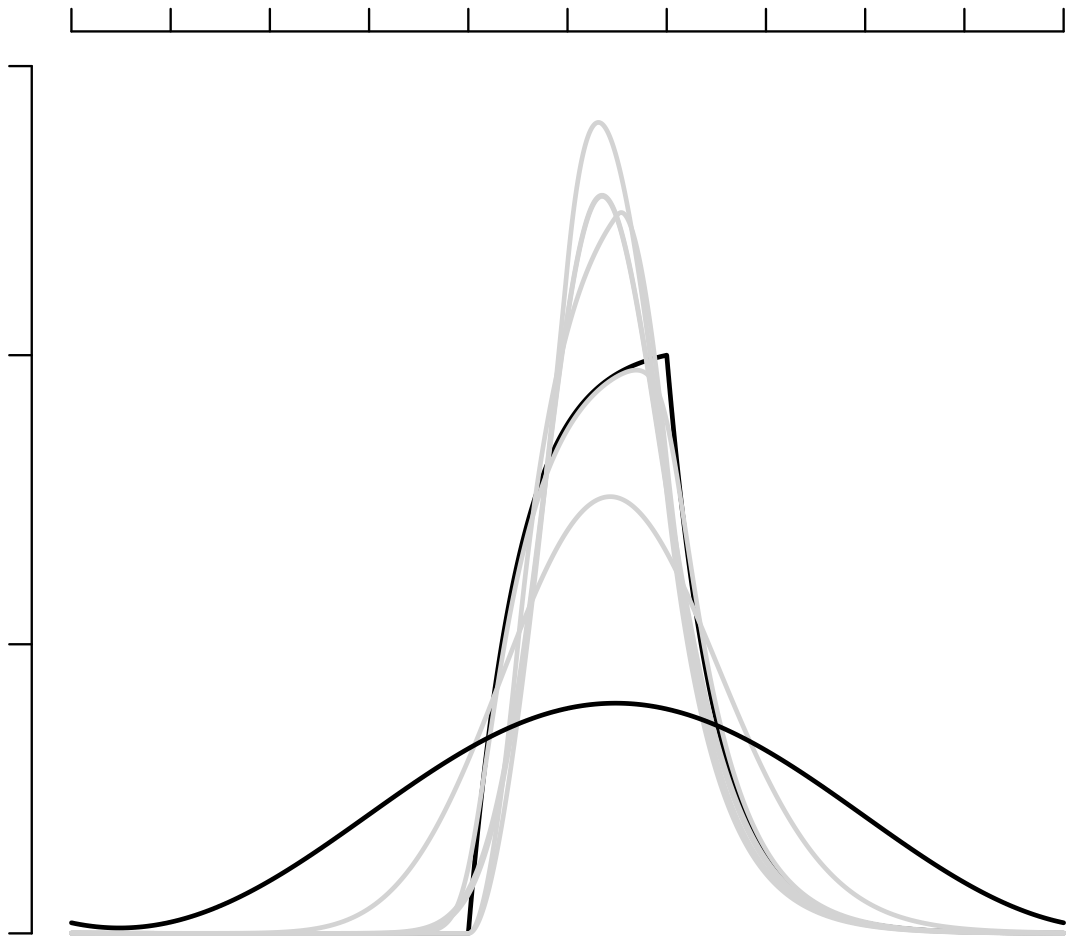






Thoughts?

What do *you* think about the options?



Back To Oversimplification Question

Are these alternatives still too simple?

They are all built assuming a stable driver, which is inaccurate.

But: this framework presents an easy way to consider $E(t)$ changes as perturbations.

So What?

What does this basic analysis give us?

- rough boundaries as input to other models,
- where more complex approaches are needed (agent-based, spatially explicity, *etc.*)
- a component connectable to other models

Seque: Need "New" Habits and Tools

New challenges to getting science done:

- lashing together methods from different fields,
- getting genuine peer-review, and
- the purely mechanical handling of different people simultaneously working on the same "thing"

How can we address these issues?

Solutions from Software Industry?

What tools and habits can we adopt from this field?

What risks are associated with that?

What's still missing?

The Good

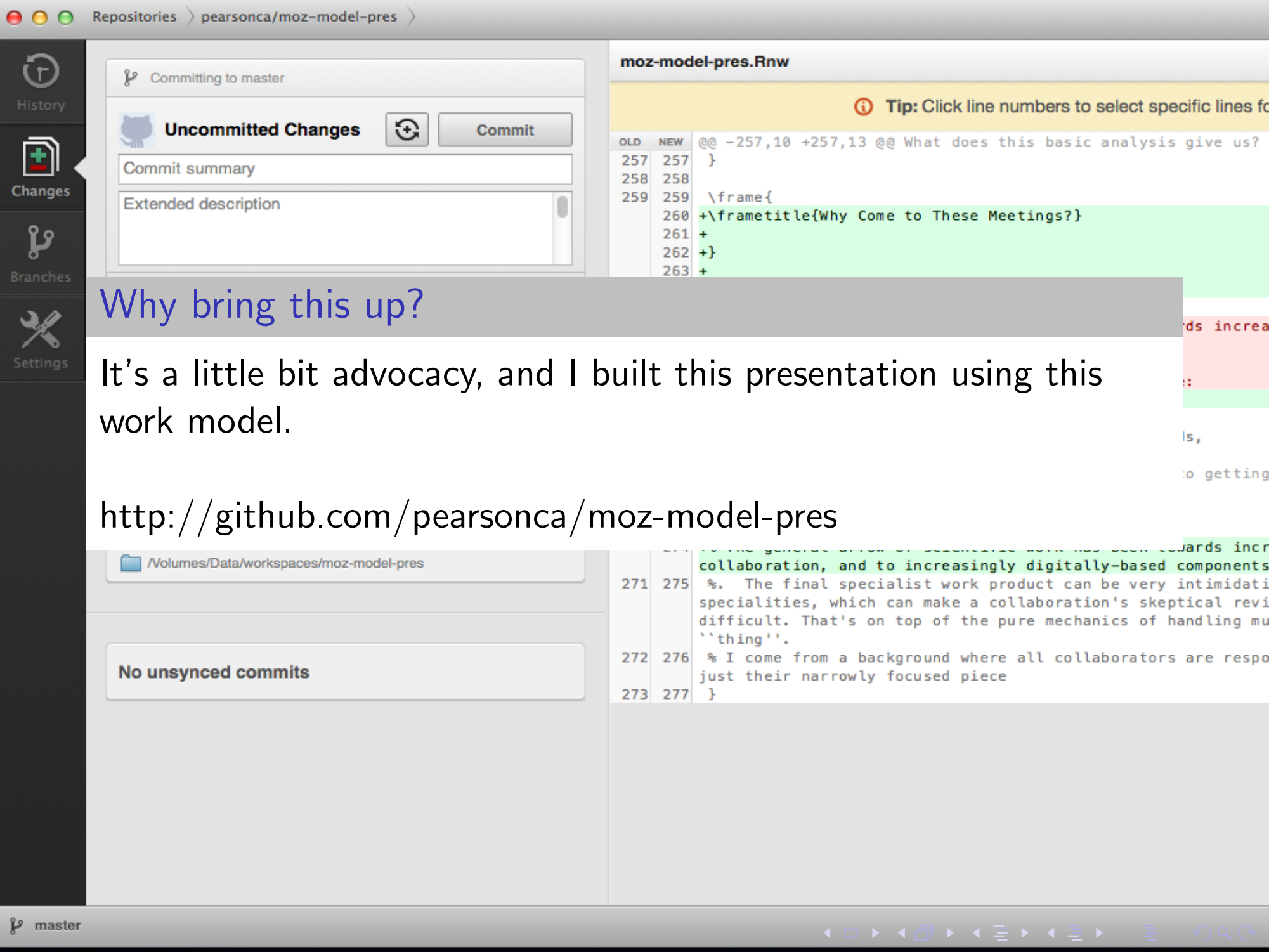
- version control systems,
- collaborative tools on top of those,
- preference for code documentation leading to
  - bite-sized parts,
  - modularity,
  - re-usability, and
  - verifiability (a/k/a unit testing)
- open availability of all source,
- combines with version control to provide complete history of work product

The Bad

- openness can make for opportunity to be “scooped”,
- can focus more on process than product,
- learning curve for most scientists

The Ugly

- university contracts' intellectual property clauses,
- academic institutions don't "get" these tools,
- community adoption?



Why bring this up?

It's a little bit advocacy, and I built this presentation using this work model.

http://github.com/pearsonca/moz-model-pres

Why Come to These Meetings?