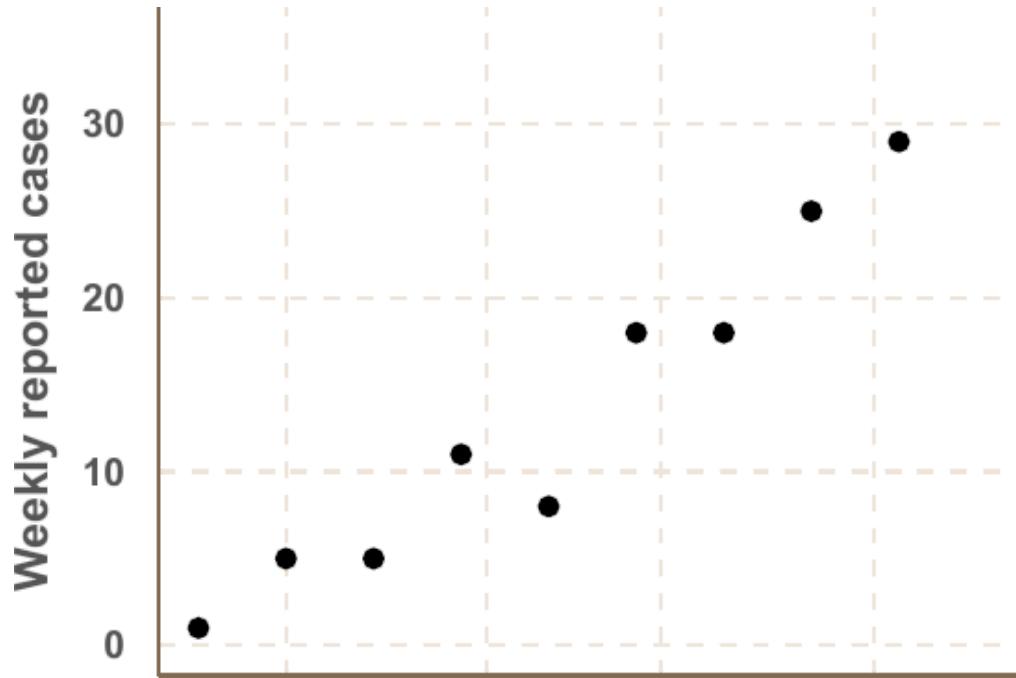
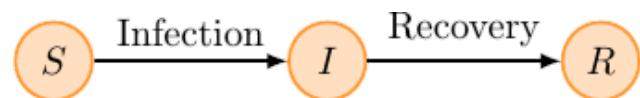


Real-time predictive modelling of epidemics

Sebastian Funk
15 March 2018
prowler.io, Cambridge

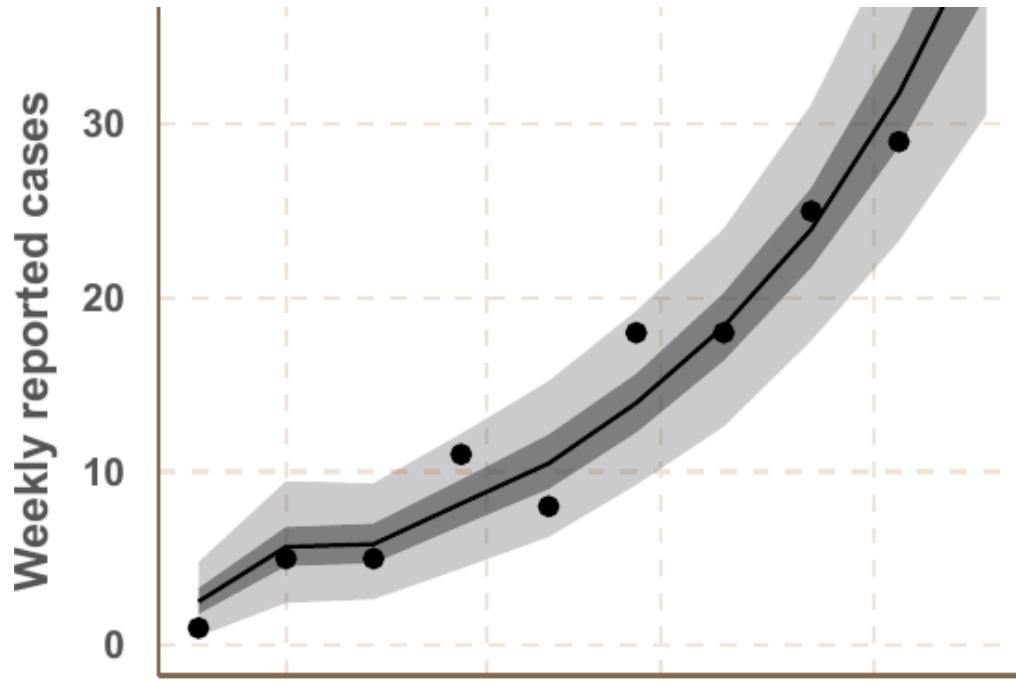


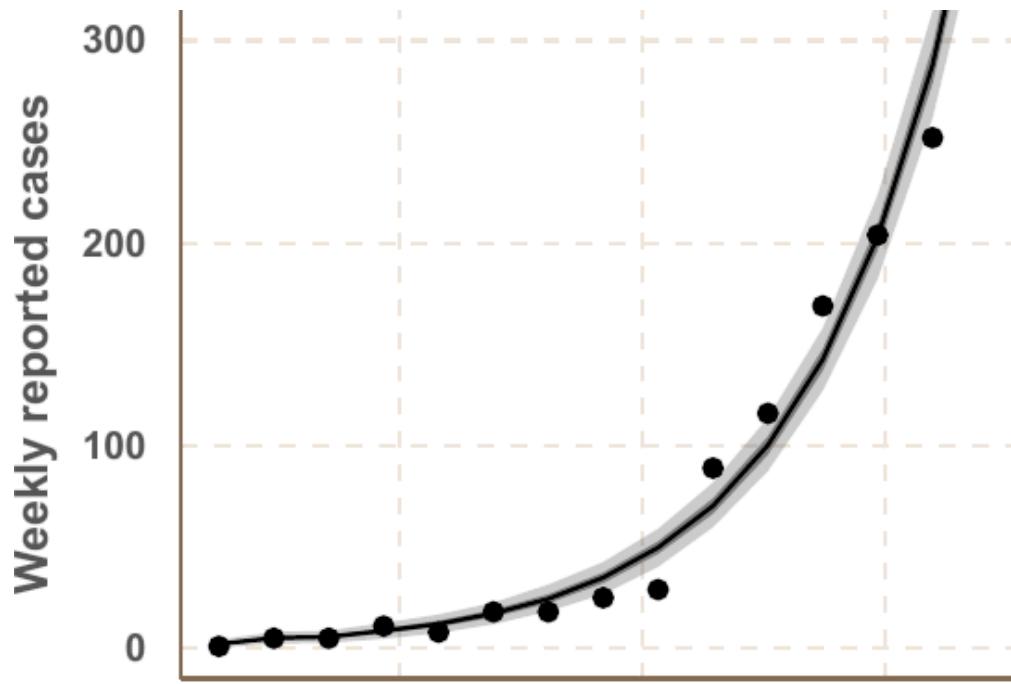


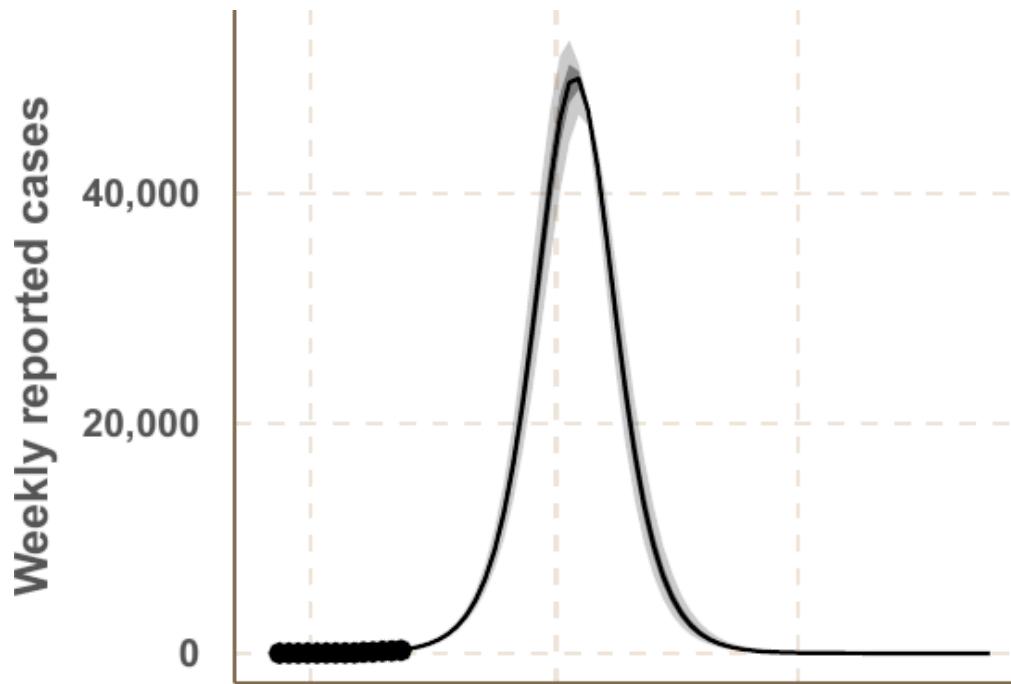
$$\dot{S} = -\beta \frac{S}{N} I$$

$$\dot{I} = +\beta \frac{S}{N} I - \gamma I$$

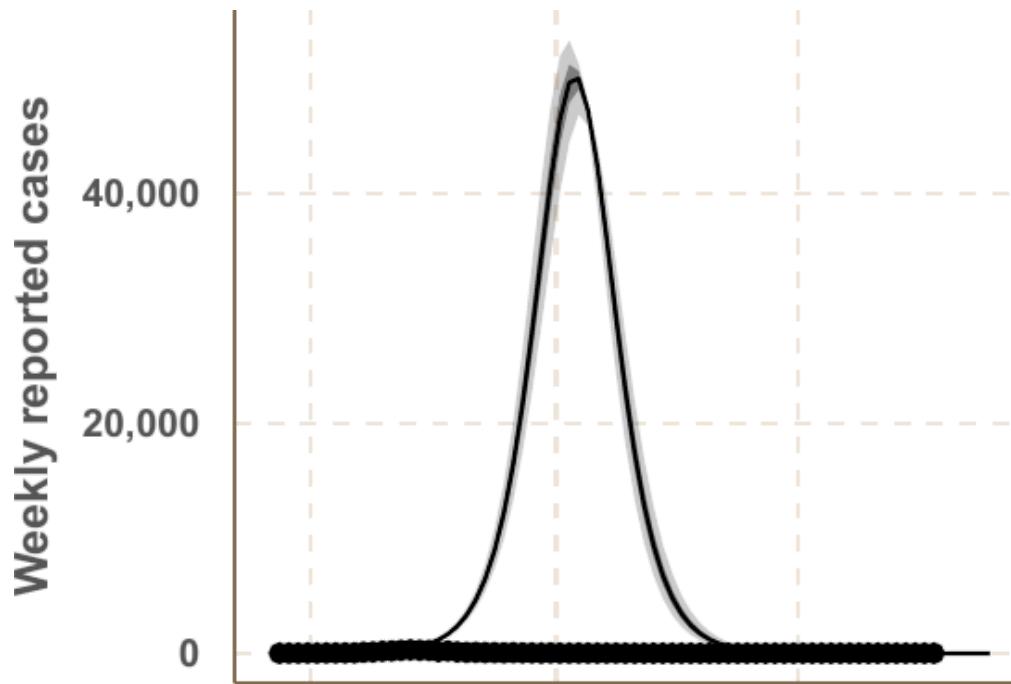
$$\dot{R} = +\gamma I$$

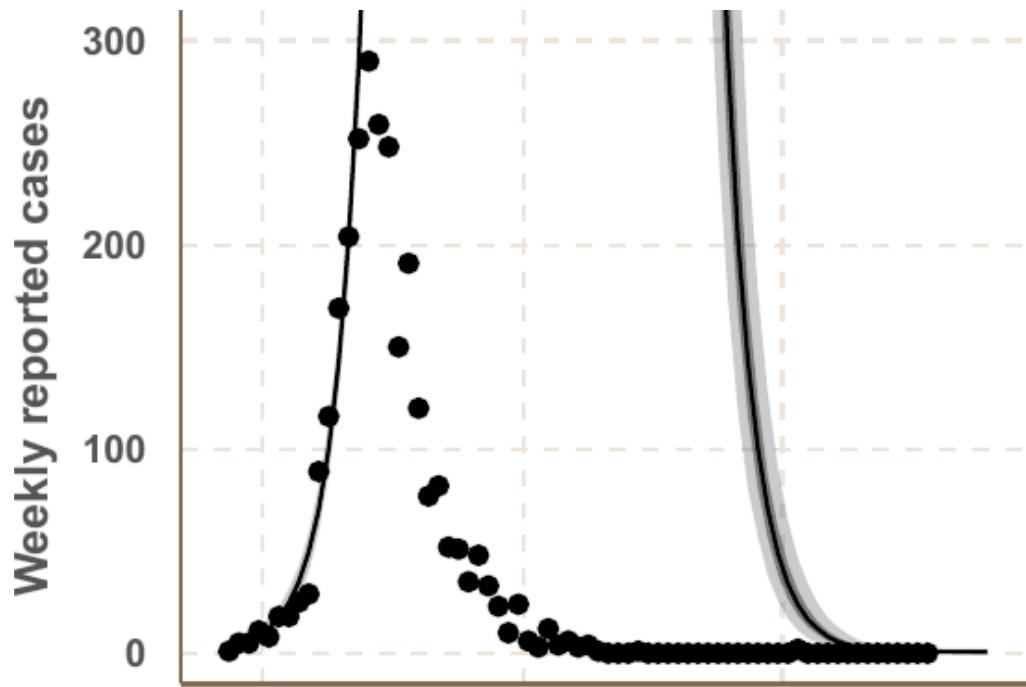






What really happened

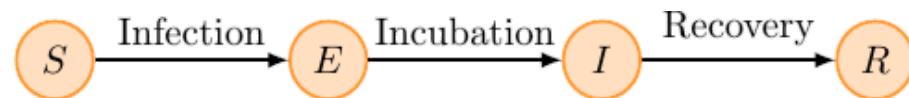




The unknown

- Community/hospital/funeral transmission
- Spatial dynamics
- Changes in behaviour
- Changes in reporting
- Interventions
- Seasonality
- etc

The known



- Average incubation period (~9 days)
- Average infectious period (~11 days)
- Case-fatality rate (~70%)

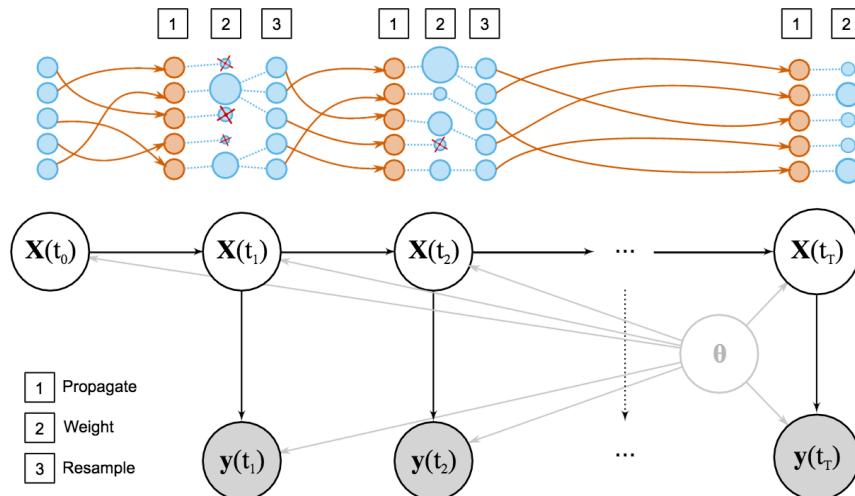
WHO Ebola response team (2014)

Transmission intensity as a stochastic process

$$d \log(\beta(t)) = \sigma dW_t$$

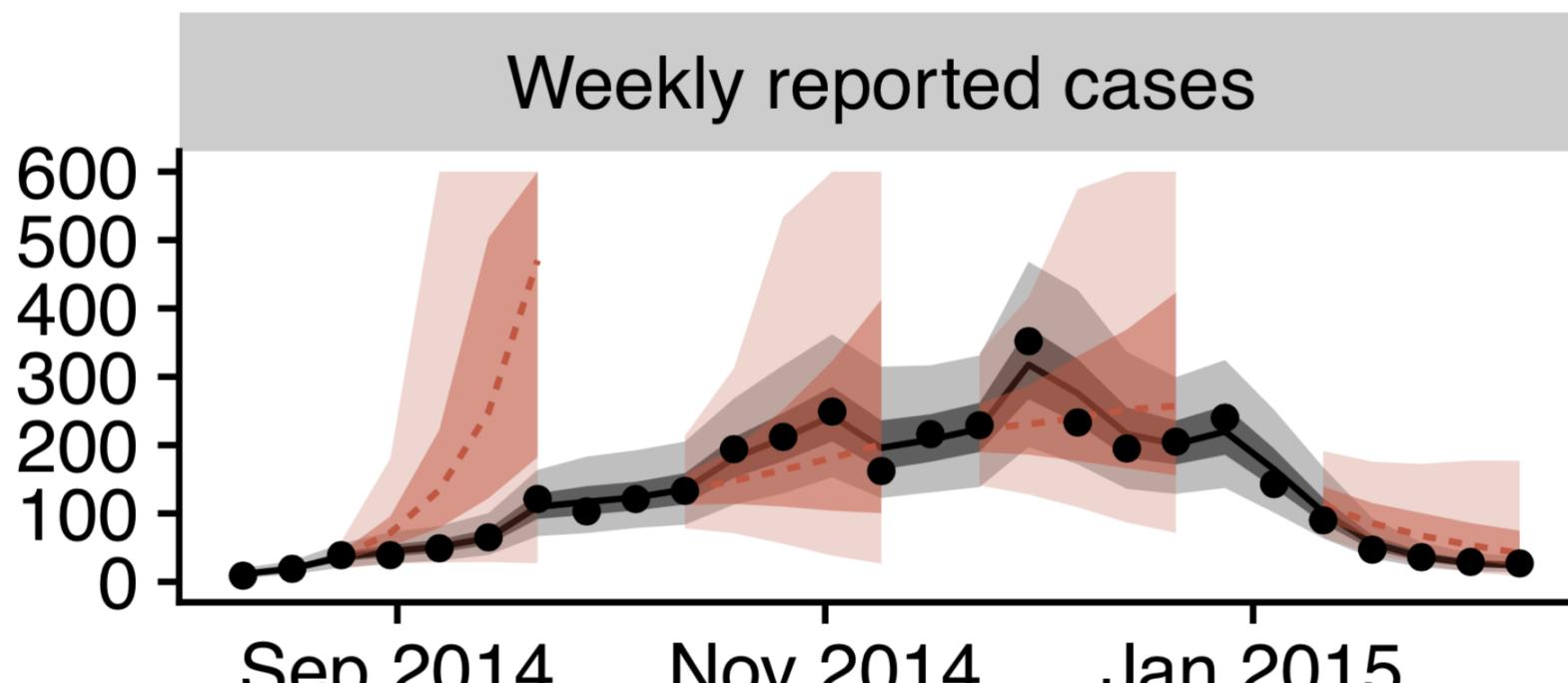
Dureau (2013)

Particle MCMC

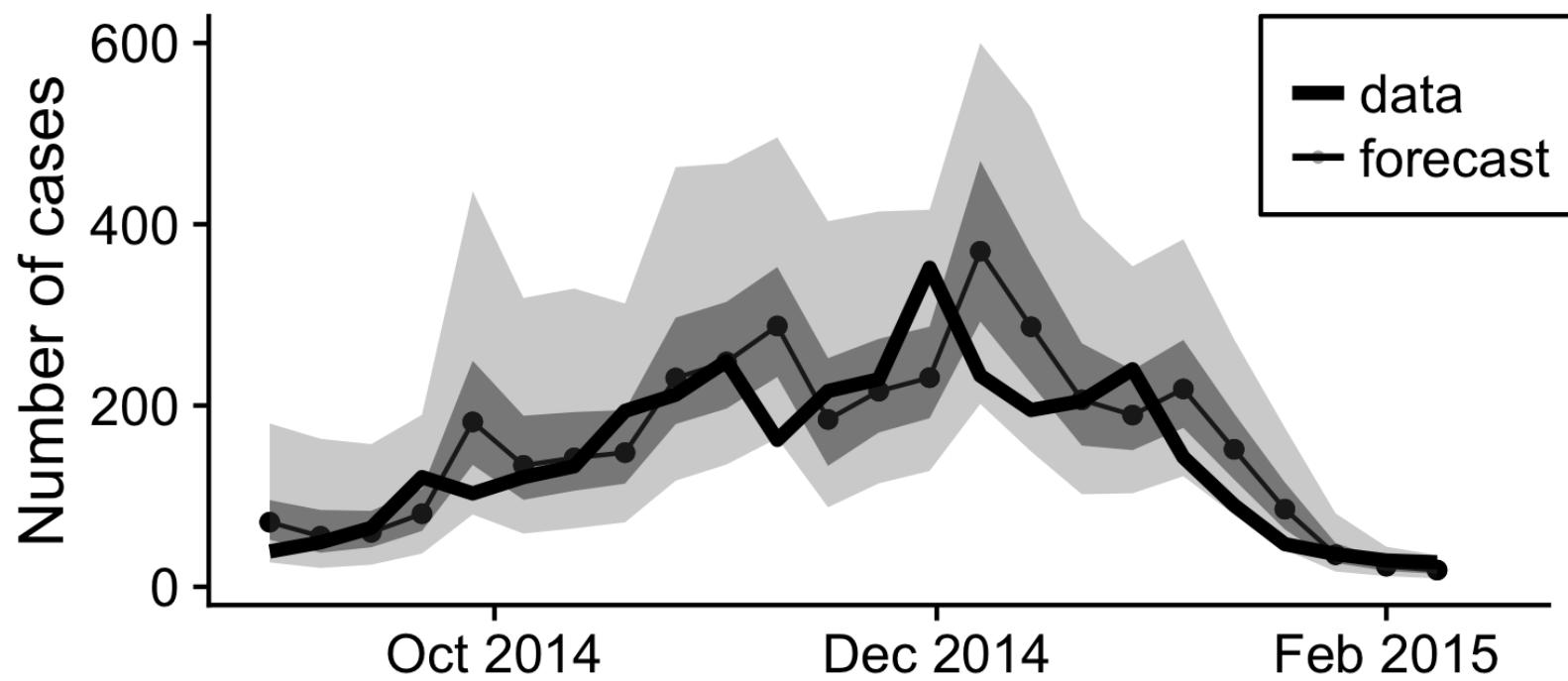


- Marginalise out stochastic process
- Highly parallelisable

Forecasting the Ebola epidemic in Western Area



Forecasting the Ebola epidemic in Western Area



ntncmch.github.io

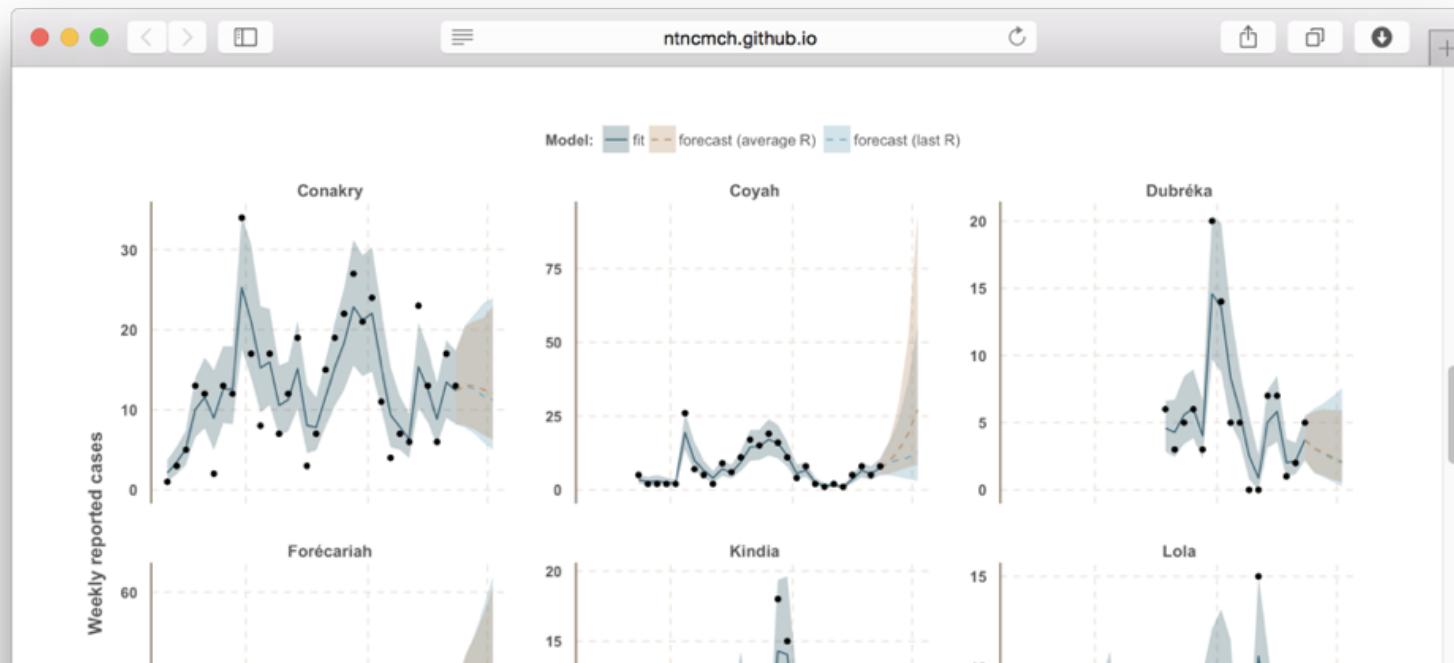
Visualisation and projections of the Ebola outbreak in West Africa

by the Centre for the Mathematical Modelling of Infectious Diseases
London School of Hygiene & Tropical Medicine

- [Latest weekly reports](#)
- [Modelling and projections](#)
- [Interactive maps](#)
- [Motivation](#)
- [Funding](#)

Latest weekly reports

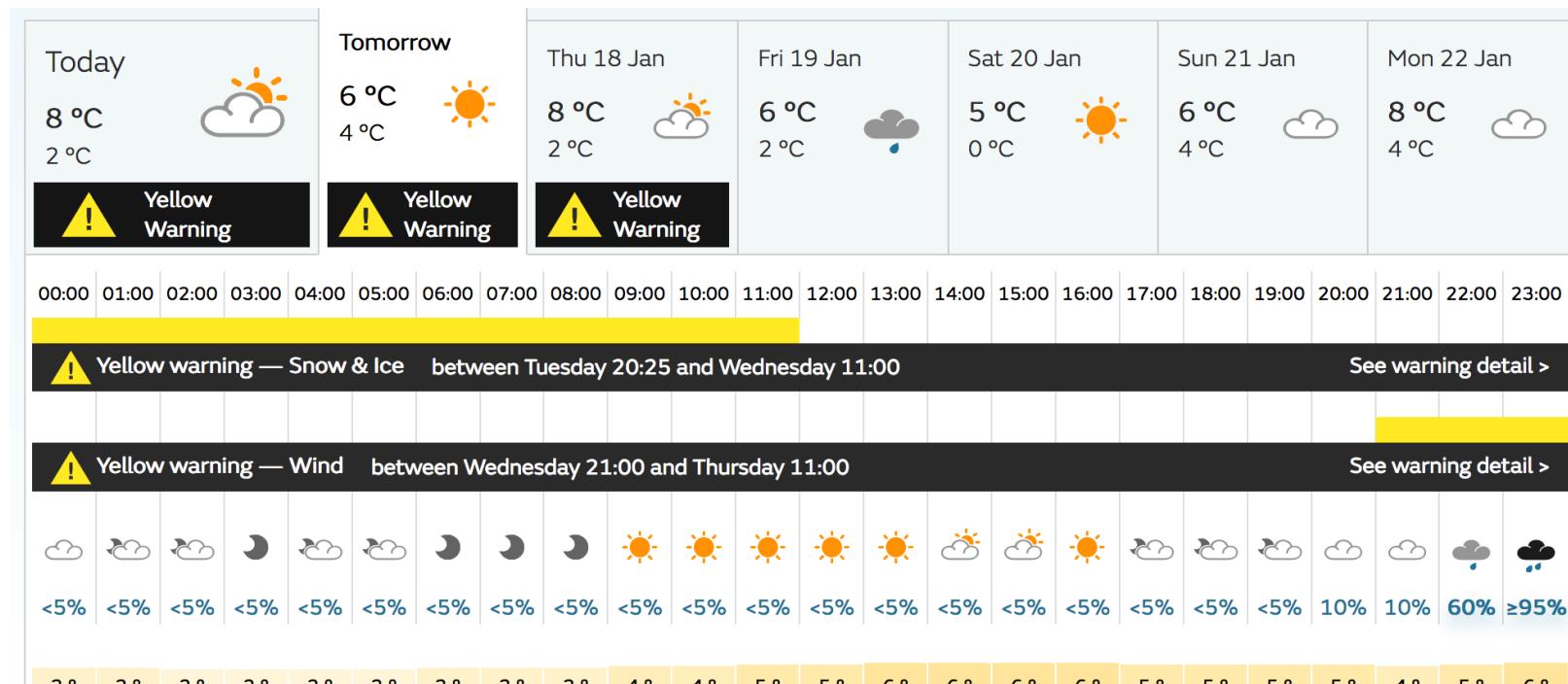
- Liberia (up to 15 March 2015): view [online version](#) or download [pdf slides](#)
- Sierra Leone (up to 15 March 2015): view [online version](#) or download [pdf slides](#)
- Guinea (up to 15 March 2015): view [online version \(French version\)](#) or download [pdf slides \(French version\)](#)



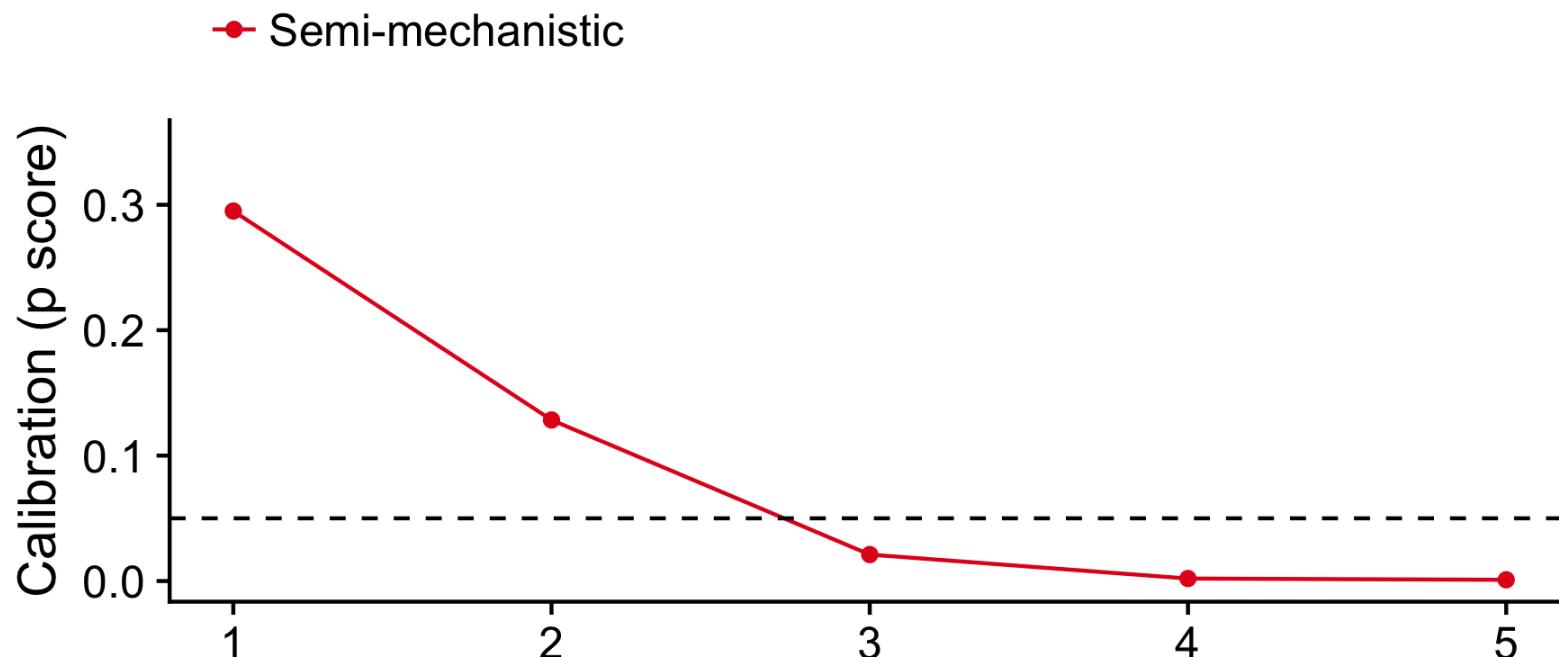
Uses of real-time forecasts in outbreaks

- Plan the scale of a response or intervention
- Allocate resources (e.g., geographically)
- Plan clinical trials

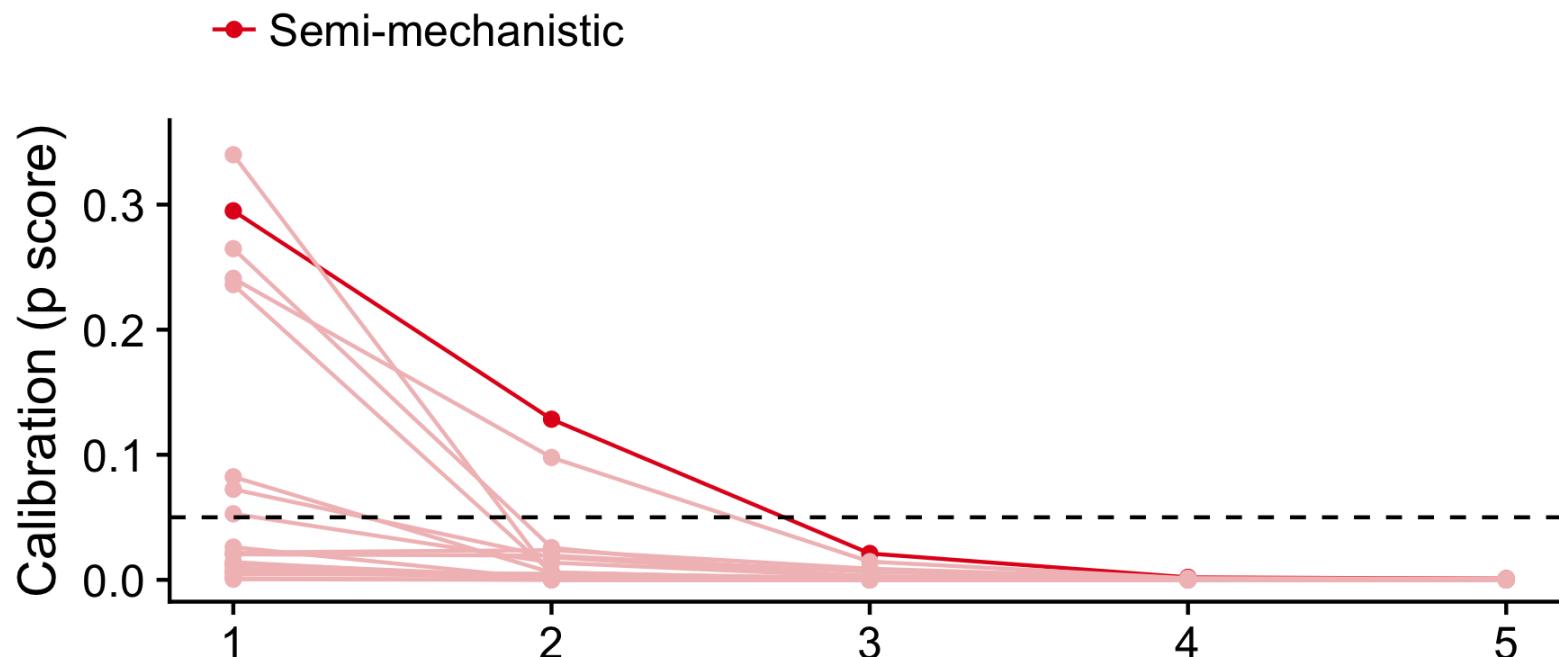
Assessing forecasts



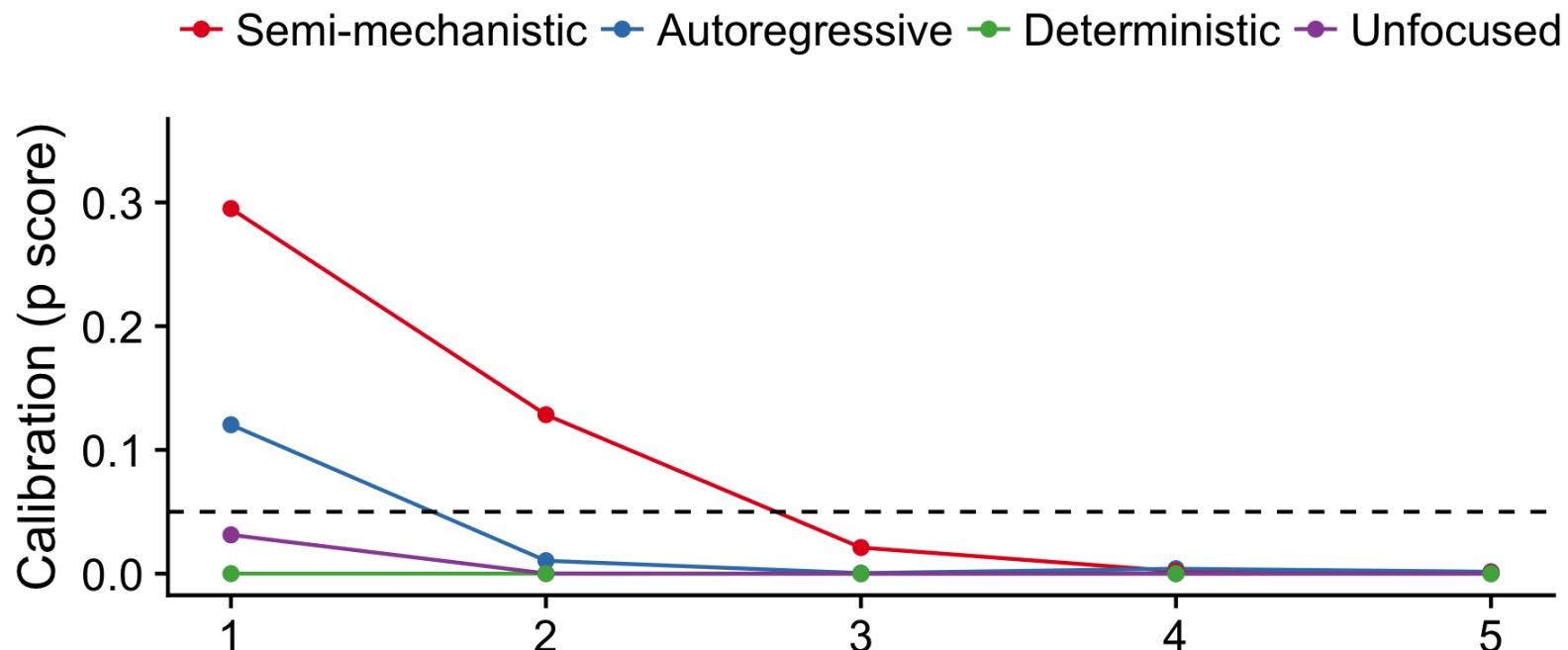
Calibration: Compatibility of forecasts and observations.



Calibration: Compatibility of forecasts and observations.



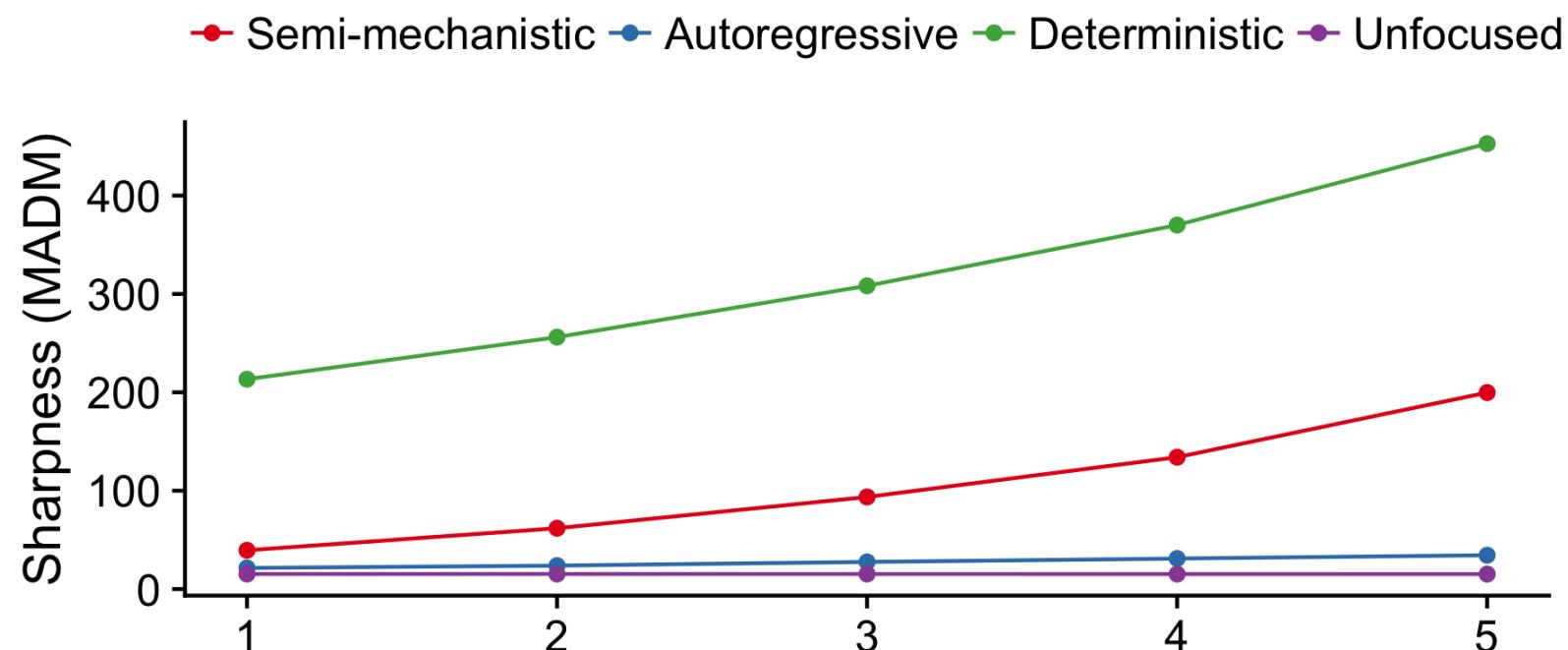
Calibration: Compatibility of forecasts and observations.



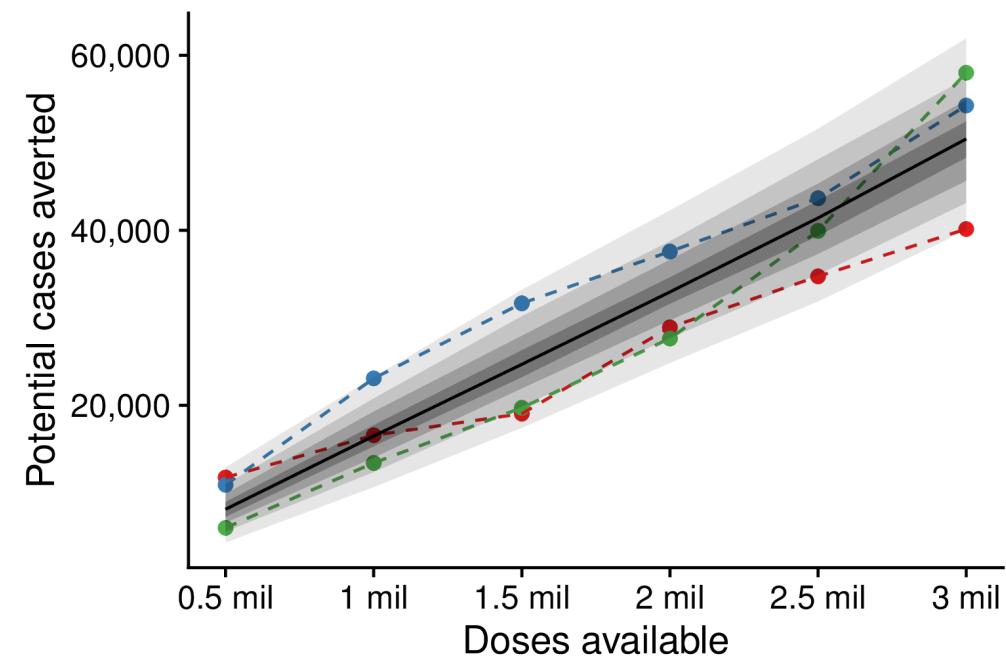
"Evaluate predictive performance on the basis of
maximising the sharpness of the predictive distribution
subject to calibration"

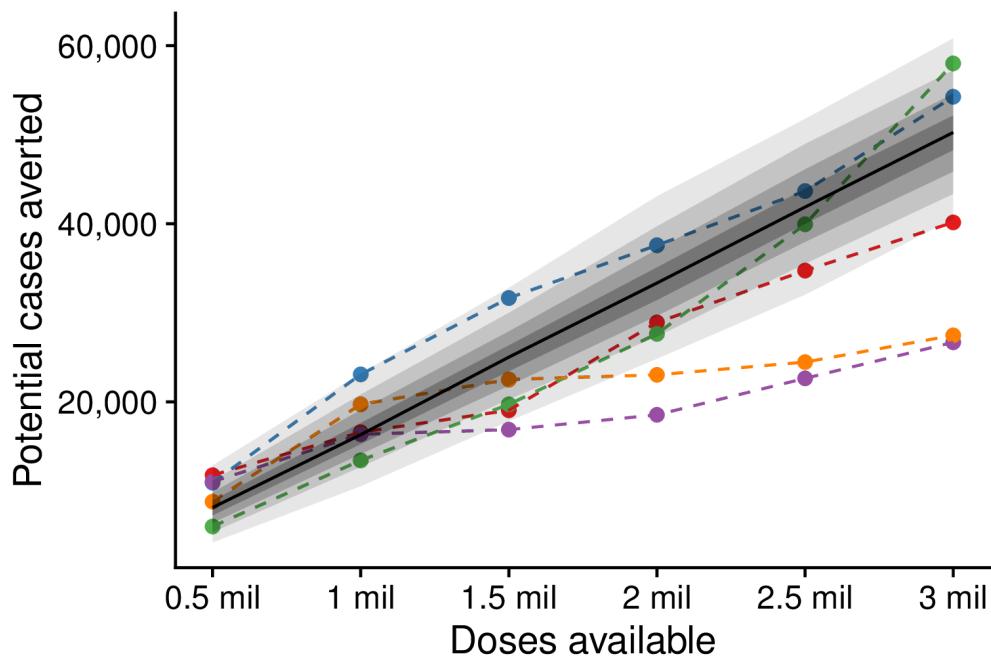
Gneiting et al., *J R Stat Soc B* (2007)

Sharpness



Quality of forecasts vs quality of decisions





Outlook

Forecasts are becoming part of outbreak response

TOWARDS EPIDEMIC PREDICTION:
FEDERAL EFFORTS AND OPPORTUNITIES
IN OUTBREAK MODELING

Forecasting challenges

EBOLA CHALLENGE

Welcome to the RAPIDD Ebola challenge

Comparison of disease forecasting models



DARPA Forecasting Chikungunya Challenge

Epidemic Prediction Initiative **BETA**

LOGIN CREATE AN AC

FluSight 2016-17

Home

National Forecasts

FluSight: Seasonal Influenza Forecasting

Influenza (flu) is a respiratory virus that can result in illness ranging from mild to severe. Each year, millions of people get sick with influenza, thousands are hospitalized and thousands of people die from flu.



DENGUE FORECASTING

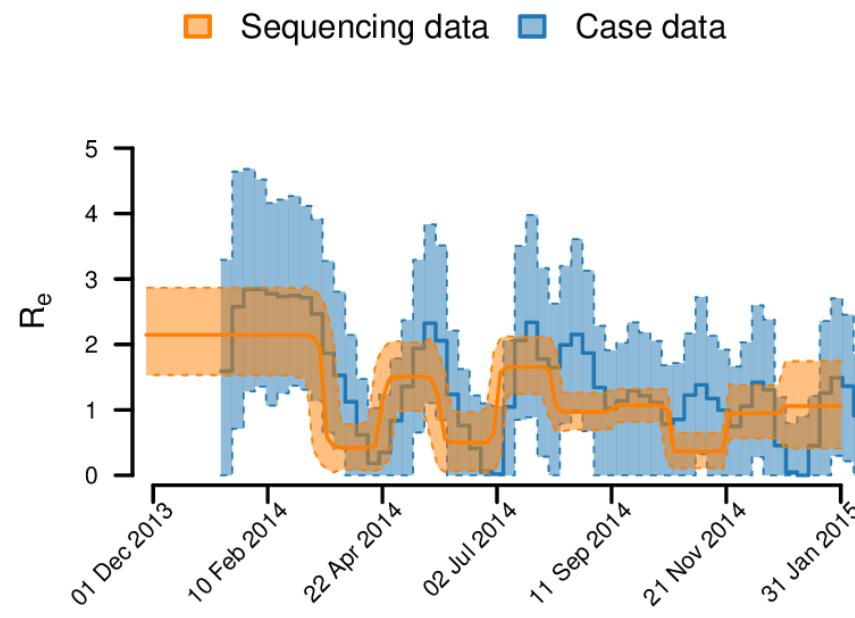
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

HOME NEWS ABOUT SEARCH

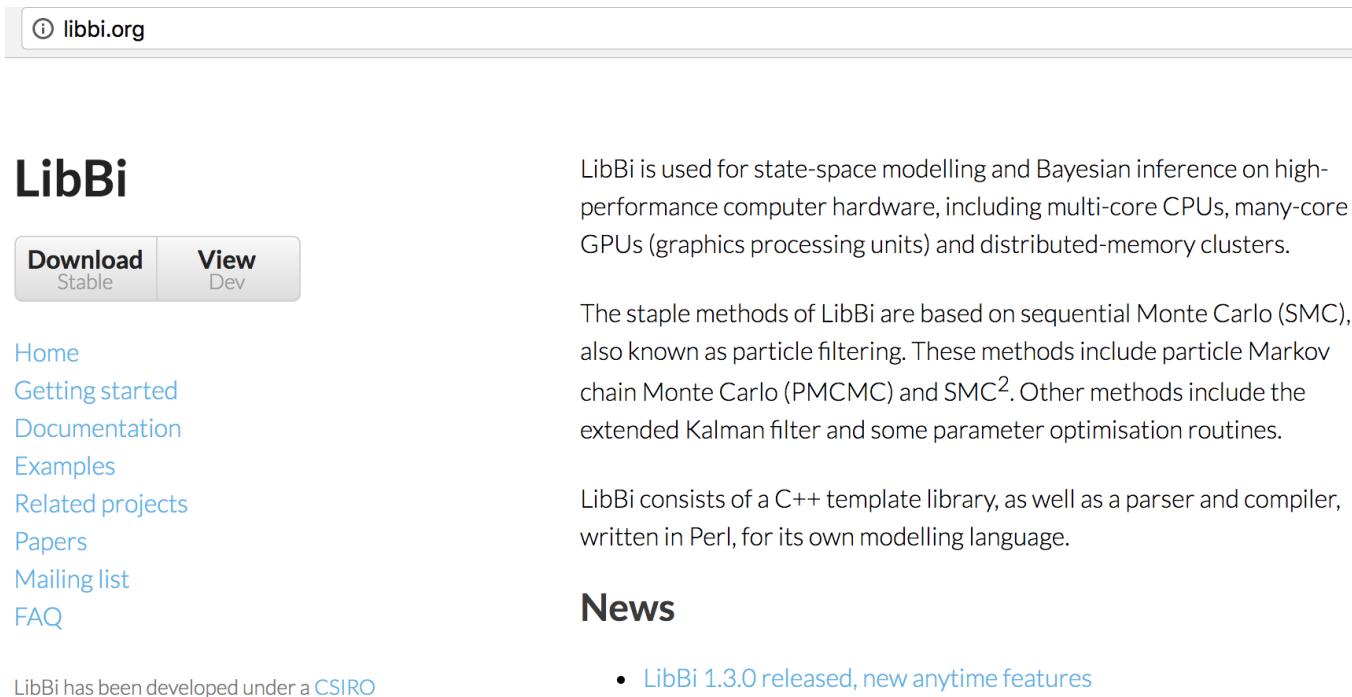
Welcome to the Dengue Forecasting project website. This site is designed specifically for the data, rules and background about the effort.

Forecasting methodology is underdeveloped

Need methods to **select the best model** and
combine all available **data streams**
(individual/spatial/genetic/social)



New tools



The screenshot shows the LibBi project page on libbi.org. At the top, there's a navigation bar with a logo and links for "Home", "Getting started", "Documentation", "Examples", "Related projects", "Papers", "Mailing list", and "FAQ". Below the navigation is a search bar with placeholder text "Search LibBi". The main content area features a large image of a computer monitor displaying a terminal window with the text "libbi>". To the left of the image is a sidebar with "LibBi" in large letters, two download buttons ("Download Stable" and "View Dev"), and a list of links: Home, Getting started, Documentation, Examples, Related projects, Papers, Mailing list, and FAQ. To the right of the image, there are two columns of text. The first column describes LibBi's use for state-space modelling and Bayesian inference on high-performance hardware. The second column details the staple methods (SMC, PMCMC, SMC²) and other features like the extended Kalman filter and parameter optimisation. At the bottom, there's a "News" section with a single bullet point about the release of version 1.3.0.

libbi.org

LibBi

[Download Stable](#) [View Dev](#)

[Home](#) [Getting started](#) [Documentation](#) [Examples](#) [Related projects](#) [Papers](#) [Mailing list](#) [FAQ](#)

LibBi is used for state-space modelling and Bayesian inference on high-performance computer hardware, including multi-core CPUs, many-core GPUs (graphics processing units) and distributed-memory clusters.

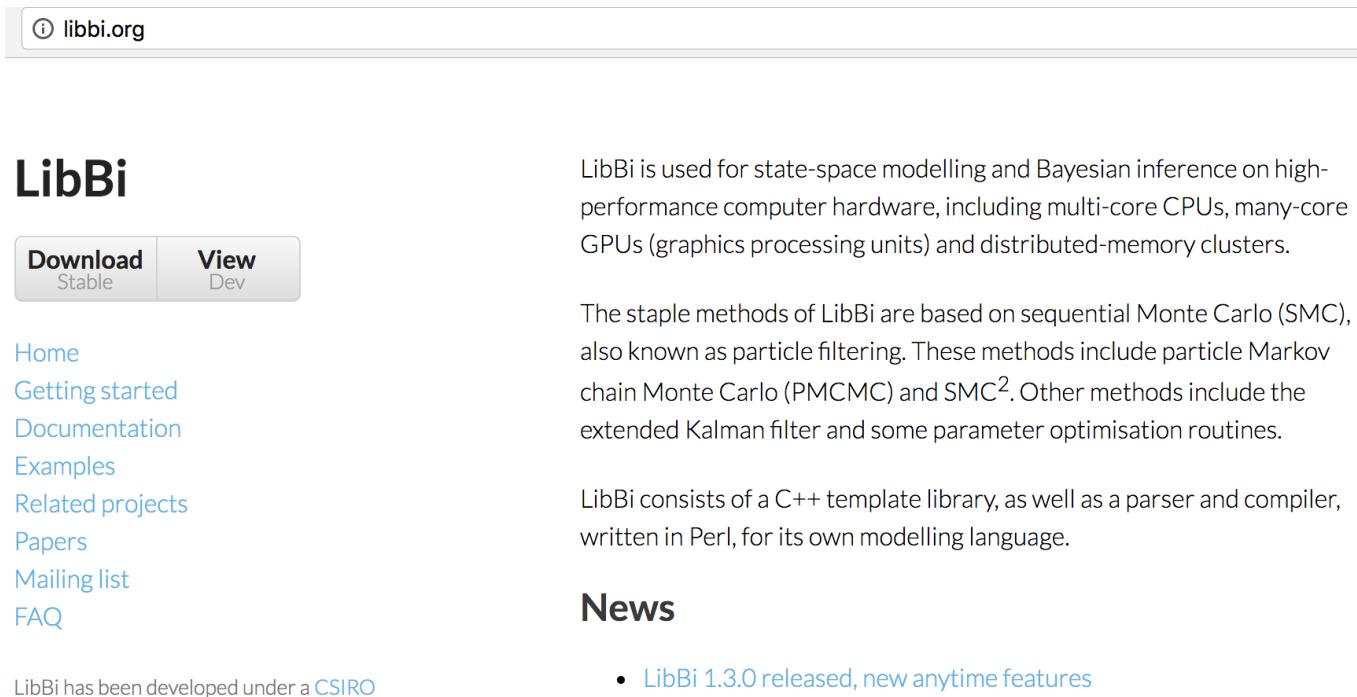
The staple methods of LibBi are based on sequential Monte Carlo (SMC), also known as particle filtering. These methods include particle Markov chain Monte Carlo (PMCMC) and SMC². Other methods include the extended Kalman filter and some parameter optimisation routines.

LibBi consists of a C++ template library, as well as a parser and compiler, written in Perl, for its own modelling language.

News

- LibBi 1.3.0 released, new anytime features

New tools



The screenshot shows the LibBi project page on libbi.org. At the top, there's a navigation bar with a logo and links for "Home", "Getting started", "Documentation", "Examples", "Related projects", "Papers", "Mailing list", and "FAQ". Below the navigation is a search bar. The main content area features a large image of a computer monitor displaying a terminal window with the text "libbi\$./libbi -h". To the right of the image, there's a section titled "What is LibBi?" with a brief description and a link to "Read more". Further down, there's a "Download" section with "Stable" and "Dev" options, and a "View" section with "Source code" and "Issues" links. A "News" section lists recent updates, and a "About" section provides credits and links to GitHub and Stack Overflow.

libbi.org

LibBi

[Download Stable](#) [View Dev](#)

[Home](#) [Getting started](#) [Documentation](#) [Examples](#) [Related projects](#) [Papers](#) [Mailing list](#) [FAQ](#)

What is LibBi?

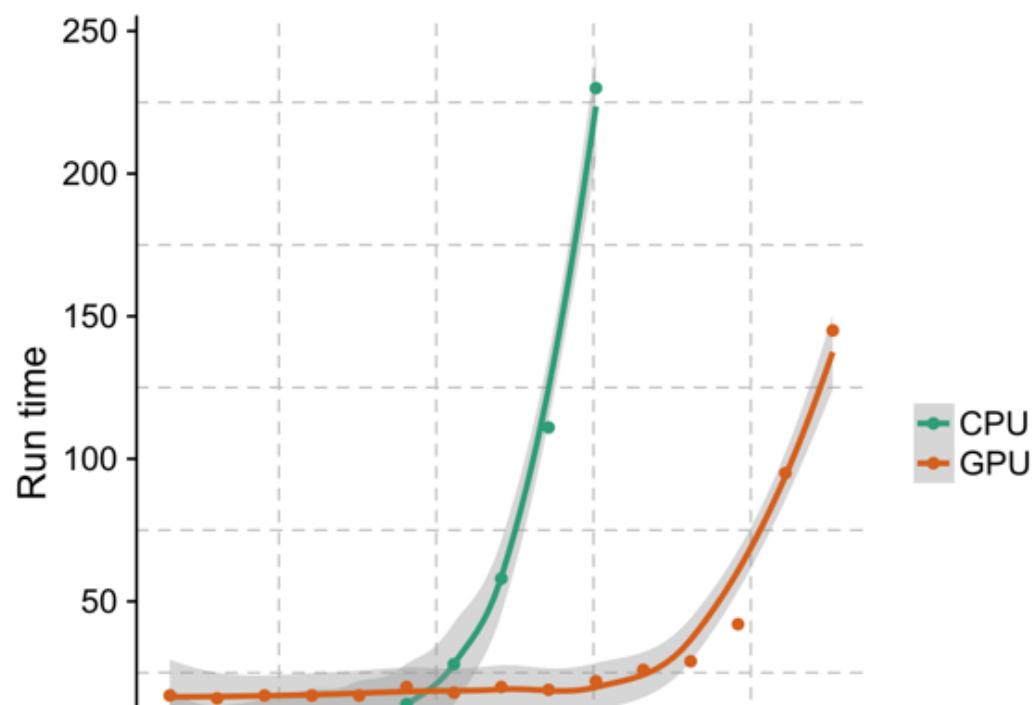
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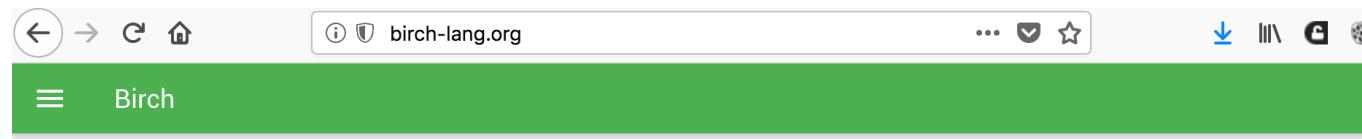
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News

- LibBi 1.3.0 released, new anytime features



Birch



Probabilistic Programming in Birch



Birch is an imperative, object-oriented, universal probabilistic programming language. It compiles to C++14 for Linux, macOS, and Windows 10, and is free and open source.

Acknowledgements

Anton Camacho, Adam Kucharski, Roz Eggo, John Edmunds (LSHTM)
Bruce Reeder, Etienne Gignoux, Iza Ciglenecki, Amanda Tiffany (MSF)
James Hensman (prowler.io), Lawrence Murray (Uppsala)



Thank you!

<http://sbfnk.github.io>
@sbfnk