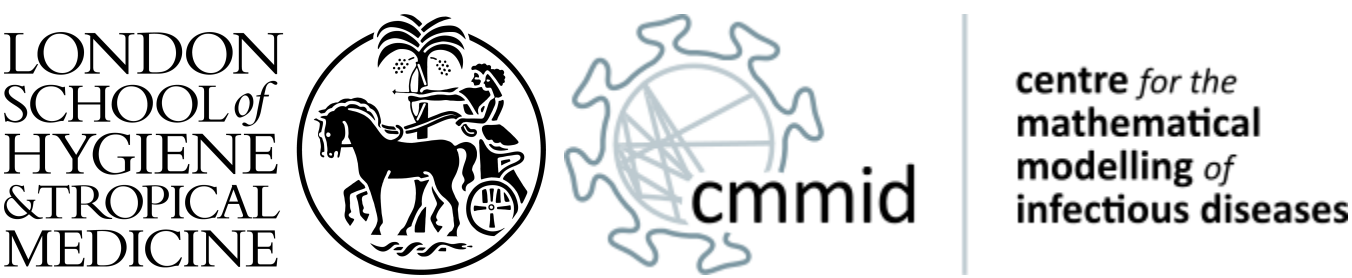
Real-time modelling and forecasting during infectious disease outbreaks

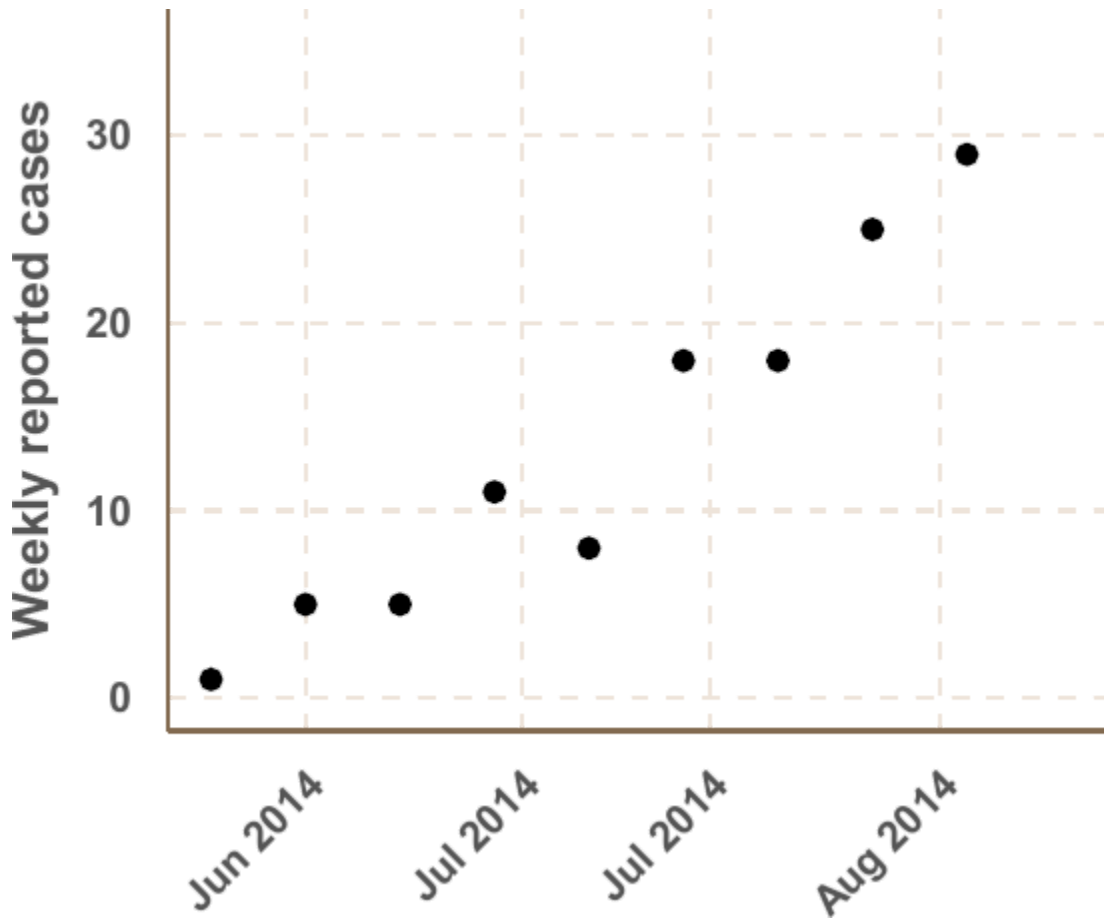
Sebastian Funk

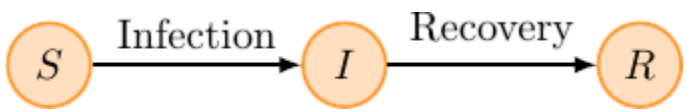
22 March, 2018

recon gathering, London



Summer 2014

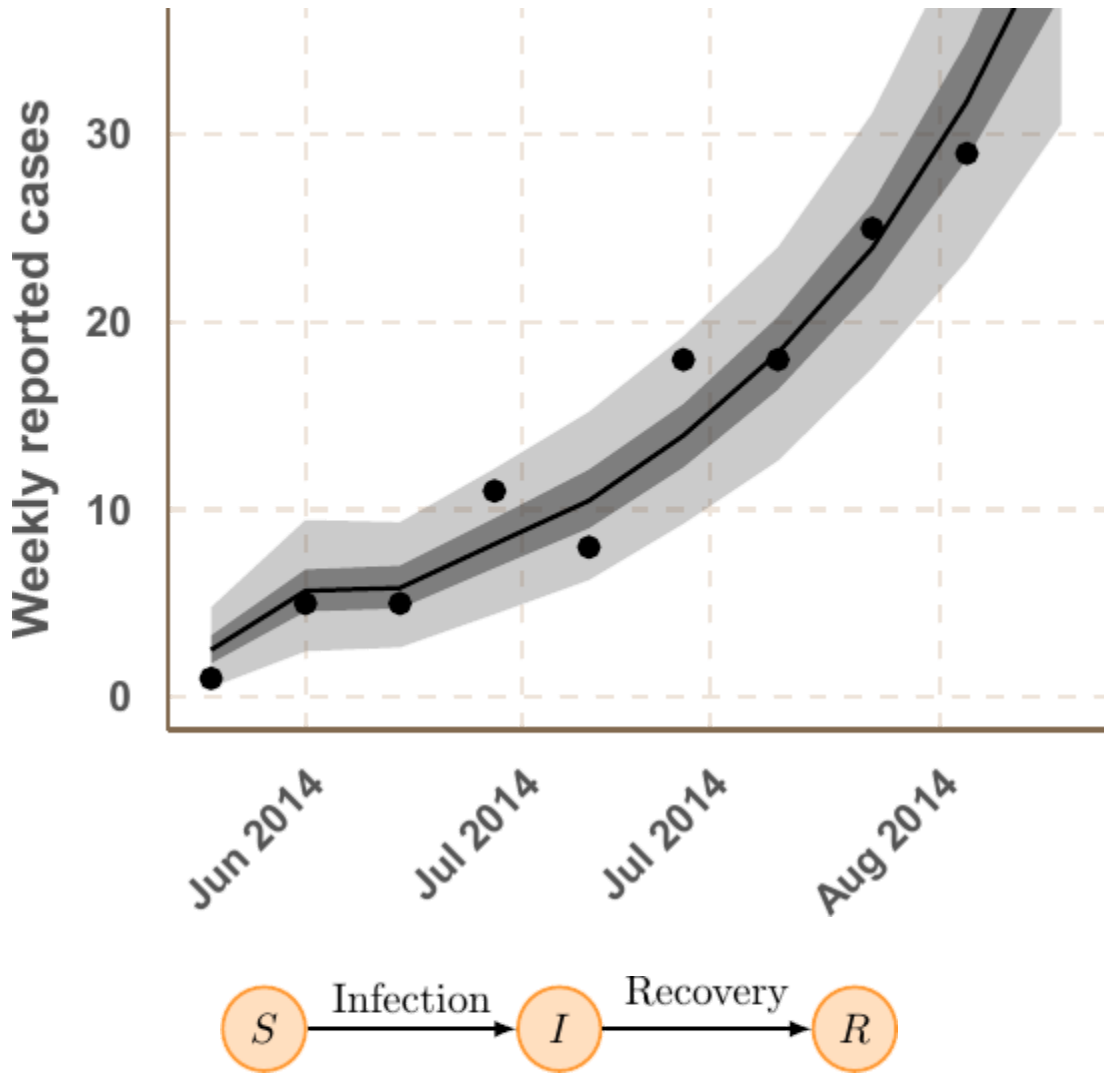

Weekly reported cases
30
20
10
0
Jun 2014
Jul 2014
Jul 2014
Aug 2014

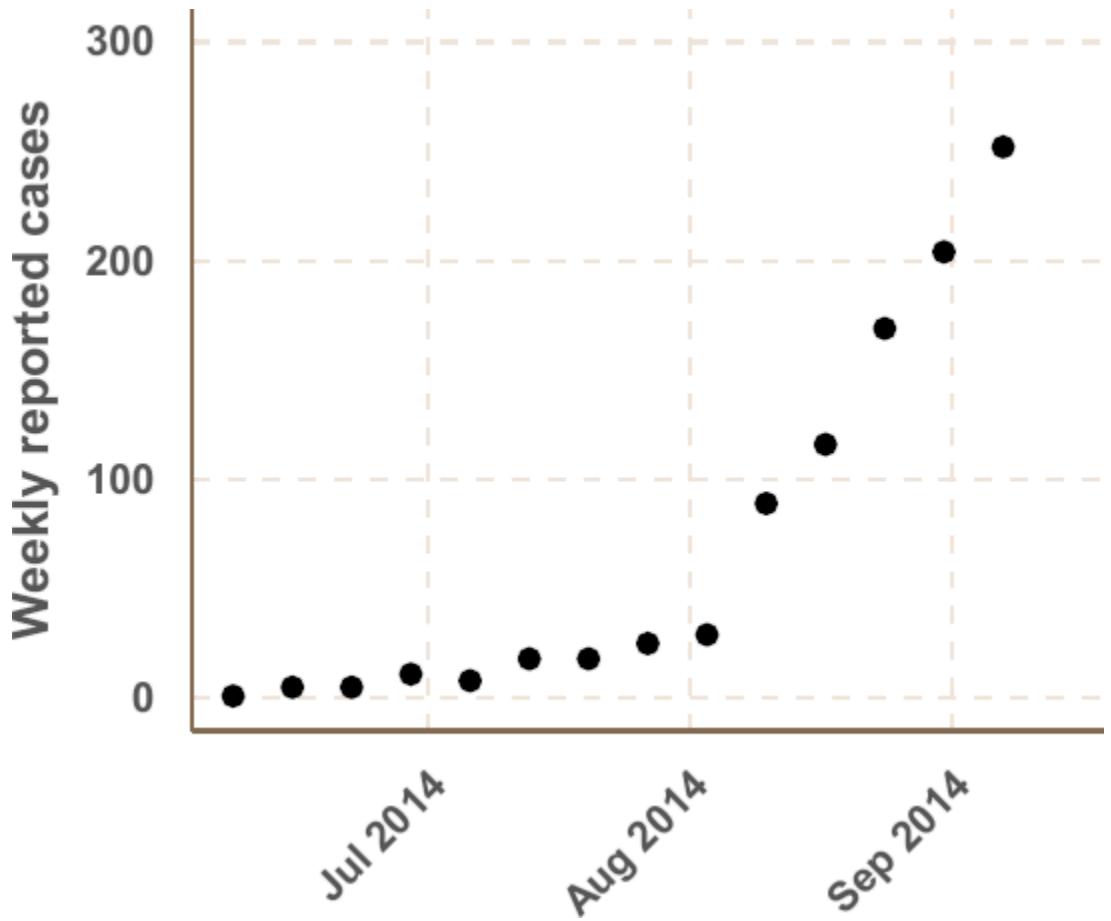


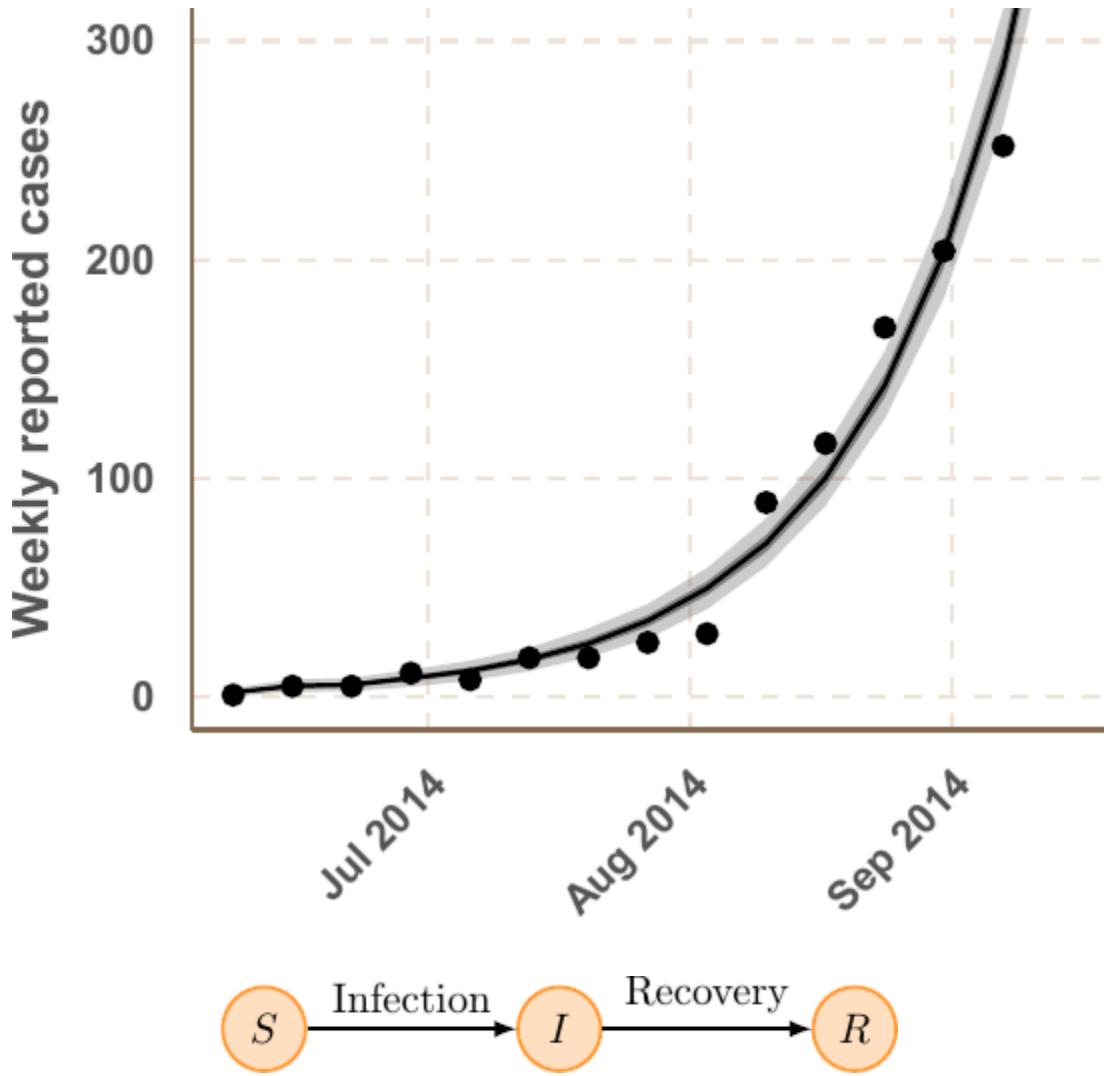
$$\dot{S} = -\beta \frac{S}{N} I$$

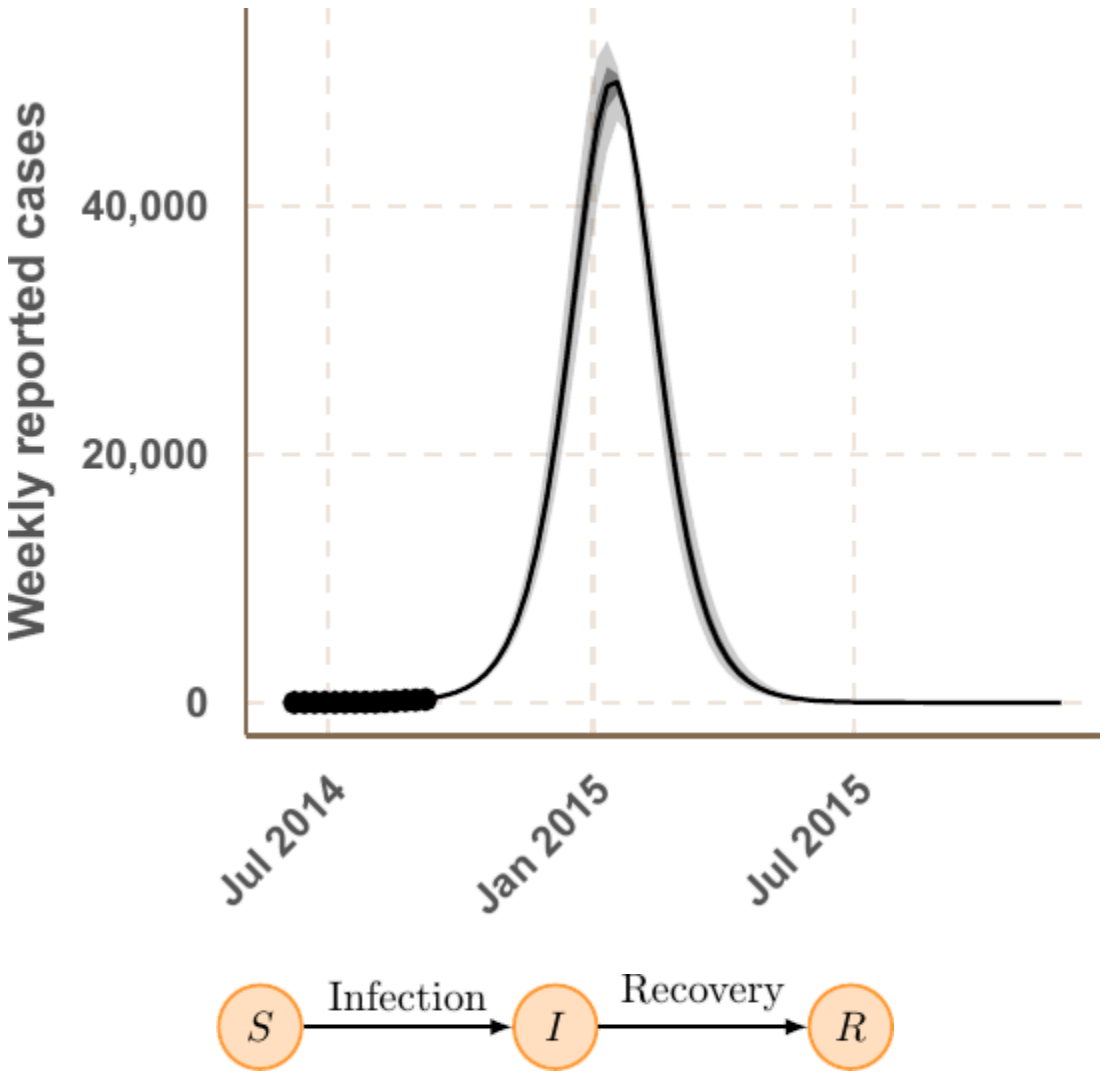
$$\dot{I} = +\beta \frac{S}{N} I - \gamma I$$

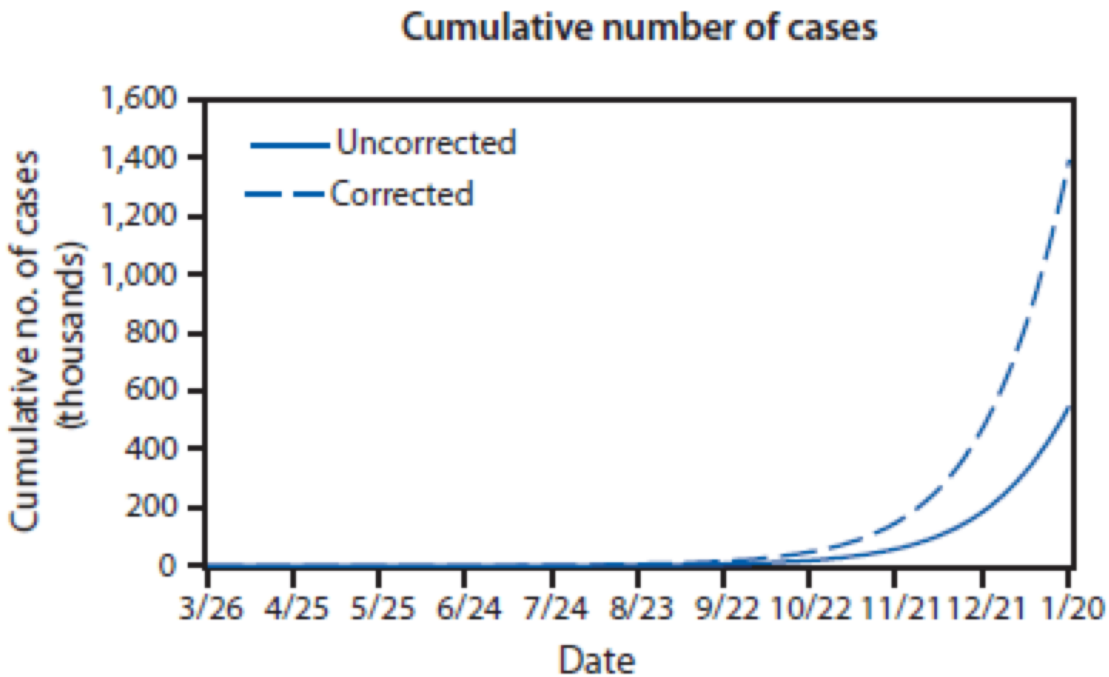
$$\dot{R} = +\gamma I$$


Weekly reported cases
30
20
10
0
Jun 2014
Jul 2014
Jul 2014
Aug 2014
S
Infection
I
Recovery
R


Weekly reported cases
300
200
100
0
Jul 2014
Aug 2014
Sep 2014


Weekly reported cases
300
200
100
0
Jul 2014
Aug 2014
Sep 2014
S
Infection
I
Recovery
R


Weekly reported cases
40,000
20,000
0
Jul 2014
Jan 2015
Jul 2015
S
Infection
I
Recovery
R



"[...], Liberia and Sierra Leone will have approximately 550,000 Ebola cases (1.4 million when corrected for underreporting)"

Meltzer, 2014

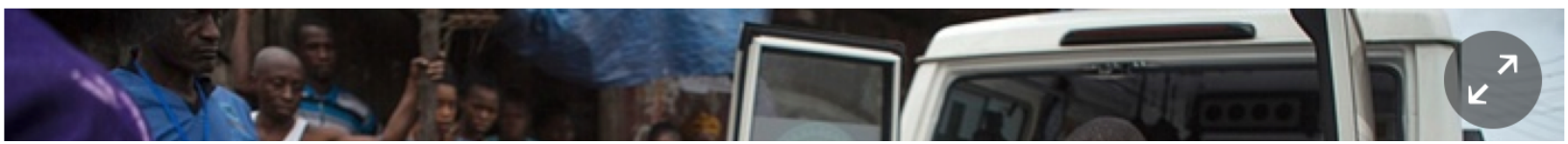
theguardian

Ebola

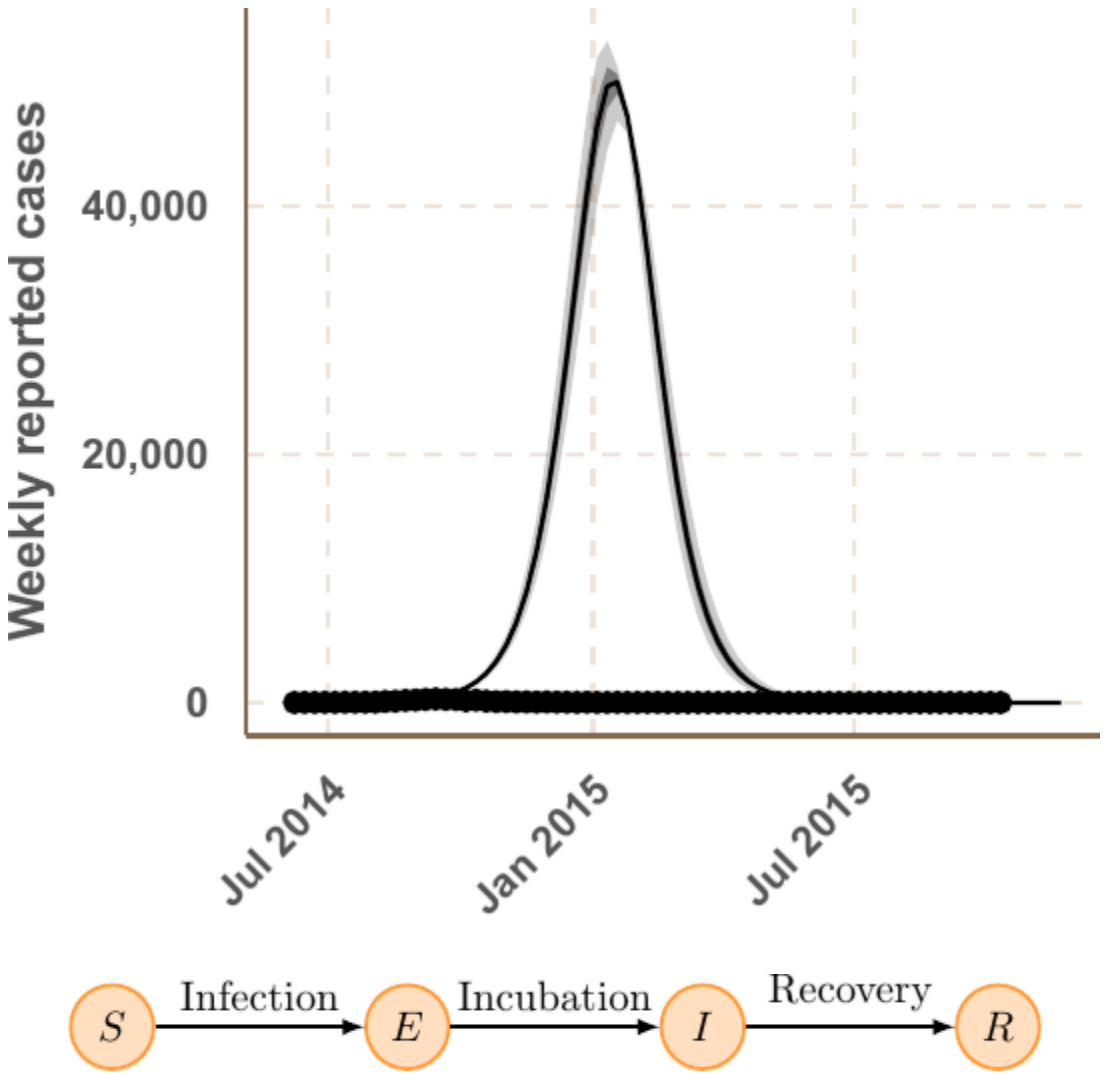
Up to 1.4m people could be infected with Ebola by January, CDC warns

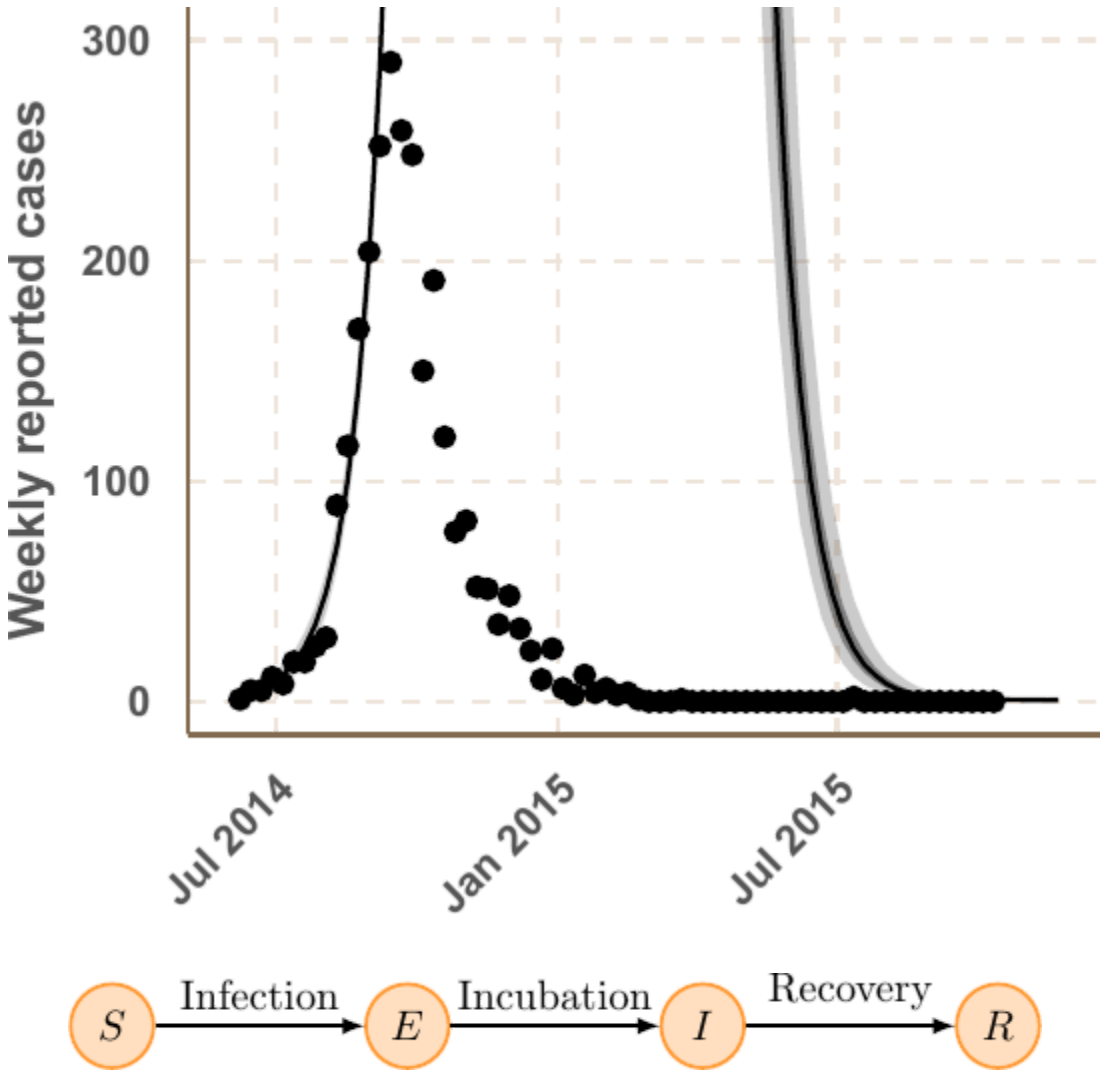
US doctors warn that without immediate action to quarantine and change burial practices, epidemic will spread

- Experimental drugs to be rushed to Africa
- Report from Freetown: 'Ebola makes you a risk to yourself'



What really happened


Weekly reported cases
40,000
20,000
0
Jul 2014
Jan 2015
Jul 2015
S
Infection
E
Incubation
I
Recovery
R


Weekly reported cases
300
200
100
0
Jul 2014
Jan 2015
Jul 2015
S
Infection
E
Incubation
I
Recovery
R

nature International weekly journal of science

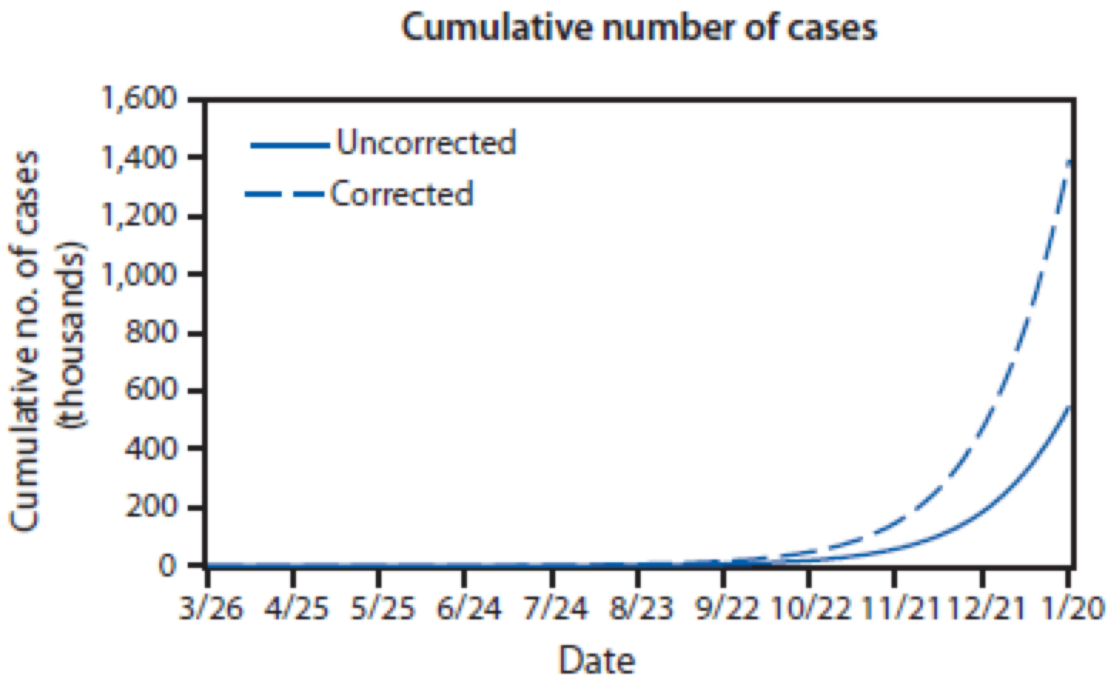
NATURE | NEWS

Models overestimate Ebola cases

Rate of infection in Liberia seems to plateau, raising questions over the usefulness of models in an outbreak.

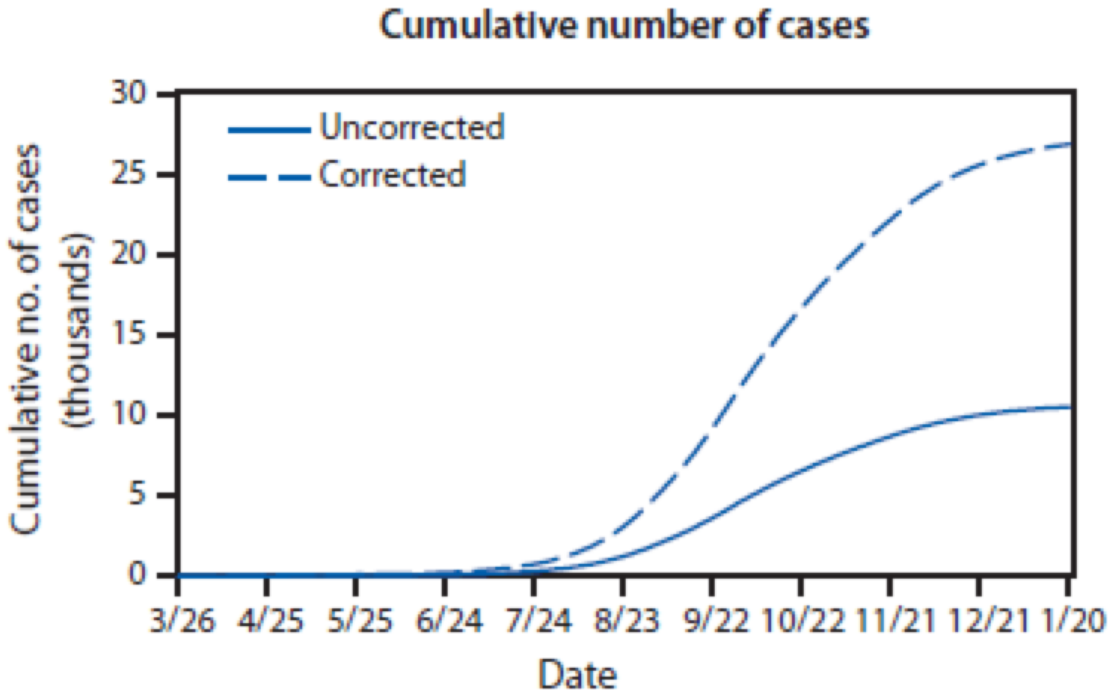
Declan Butler

04 November 2014



"[...], Liberia and Sierra Leone will have approximately 550,000 Ebola cases (1.4 million when corrected for underreporting)"

Meltzer, 2014



"**without additional interventions or changes in community behavior (e.g., notable reductions in unsafe burial practices)**, the model also estimates that Liberia and Sierra Leone will have approximately 550,000 Ebola cases (1.4 million...)"

Meltzer, 2014

TOWARDS EPIDEMIC PREDICTION: FEDERAL EFFORTS AND OPPORTUNITIES IN OUTBREAK MODELING

PRODUCT OF THE
Pandemic Prediction and Forecasting
Science and Technology Working Group
OF THE NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

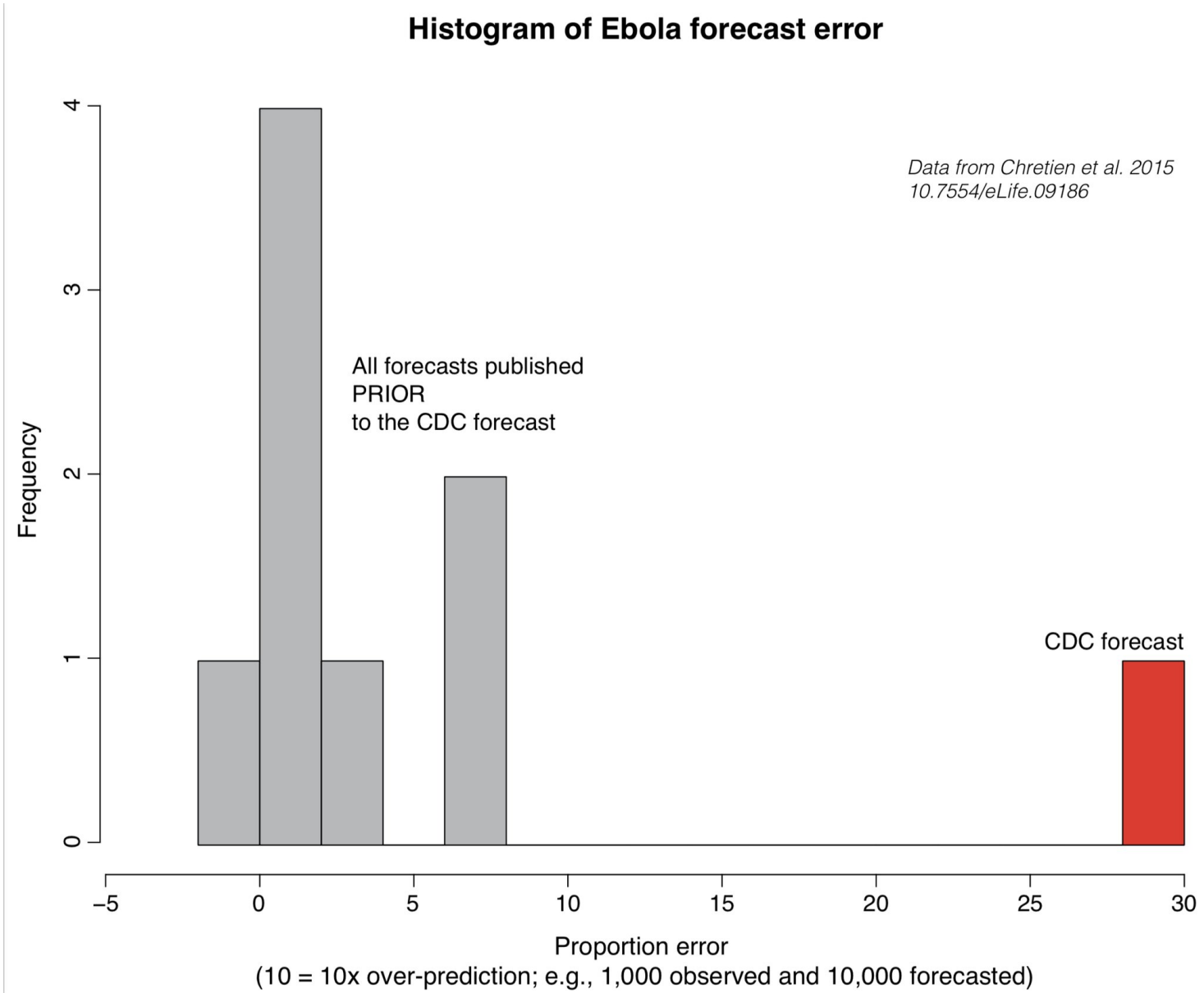
December 2016

"A CDC model [...] was key to increasing the speed and scale of the US and global response.

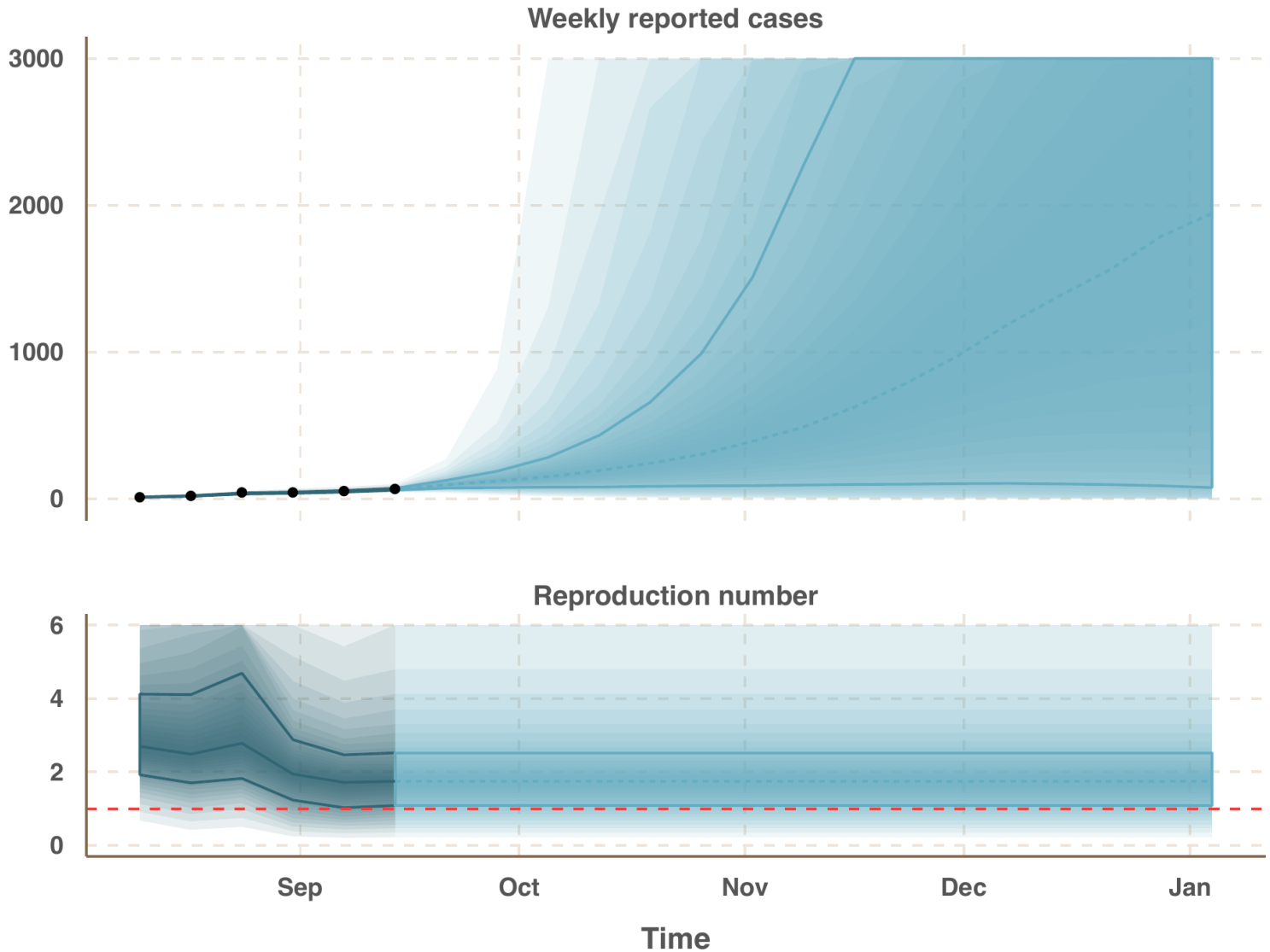
Frieden, 2015

Key findings:

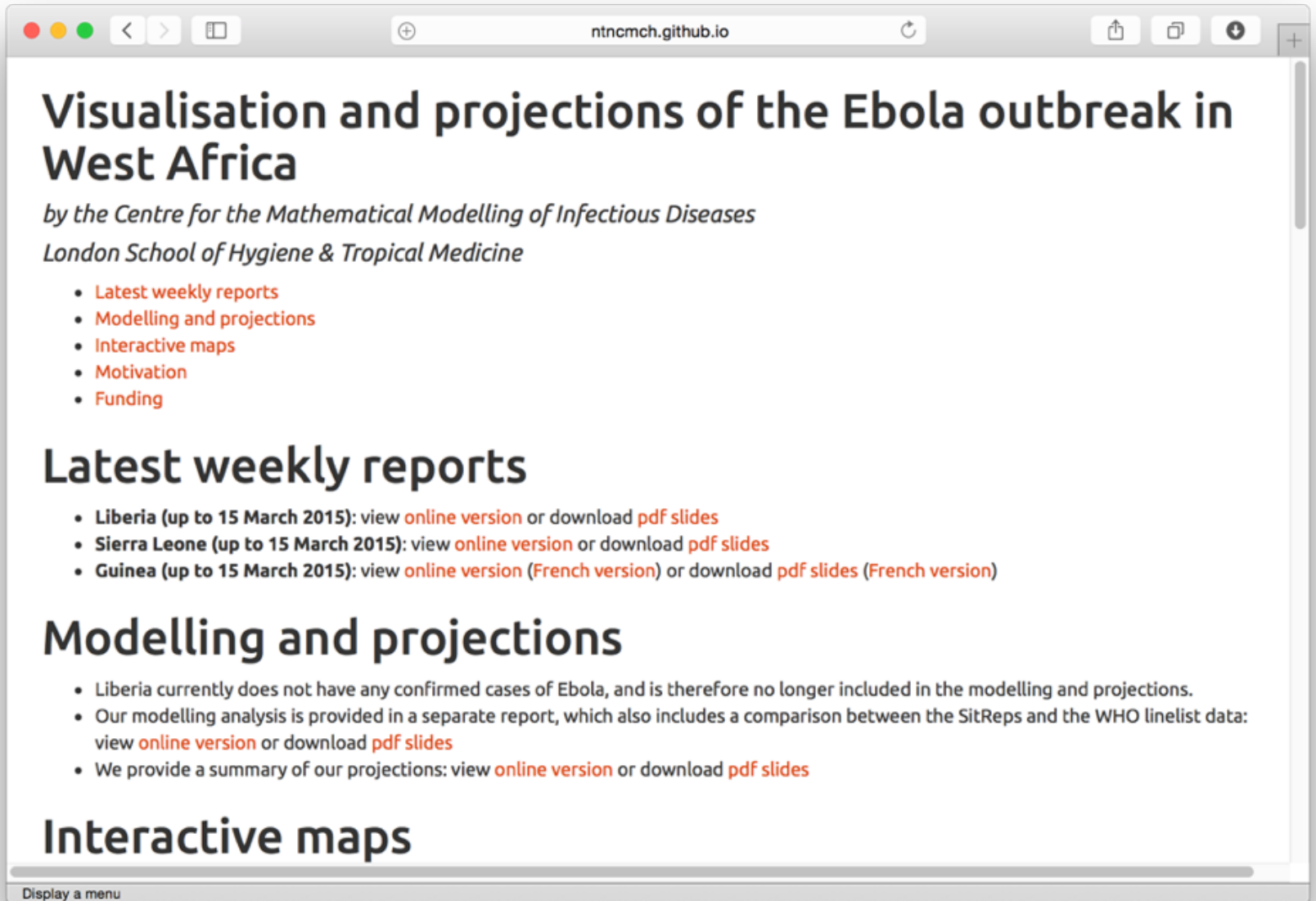
1. "cases were increasing exponentially, and the response needed was massive and urgent"
2. "the model predicted a severe penalty for delay"
3. "the model identified a tipping point at which the epidemic would [..] decline if enough Ebola patients were isolated effectively and decedents buried safely"
4. "the model predicted that when the tipping point was reached, transmission would decline rapidly"

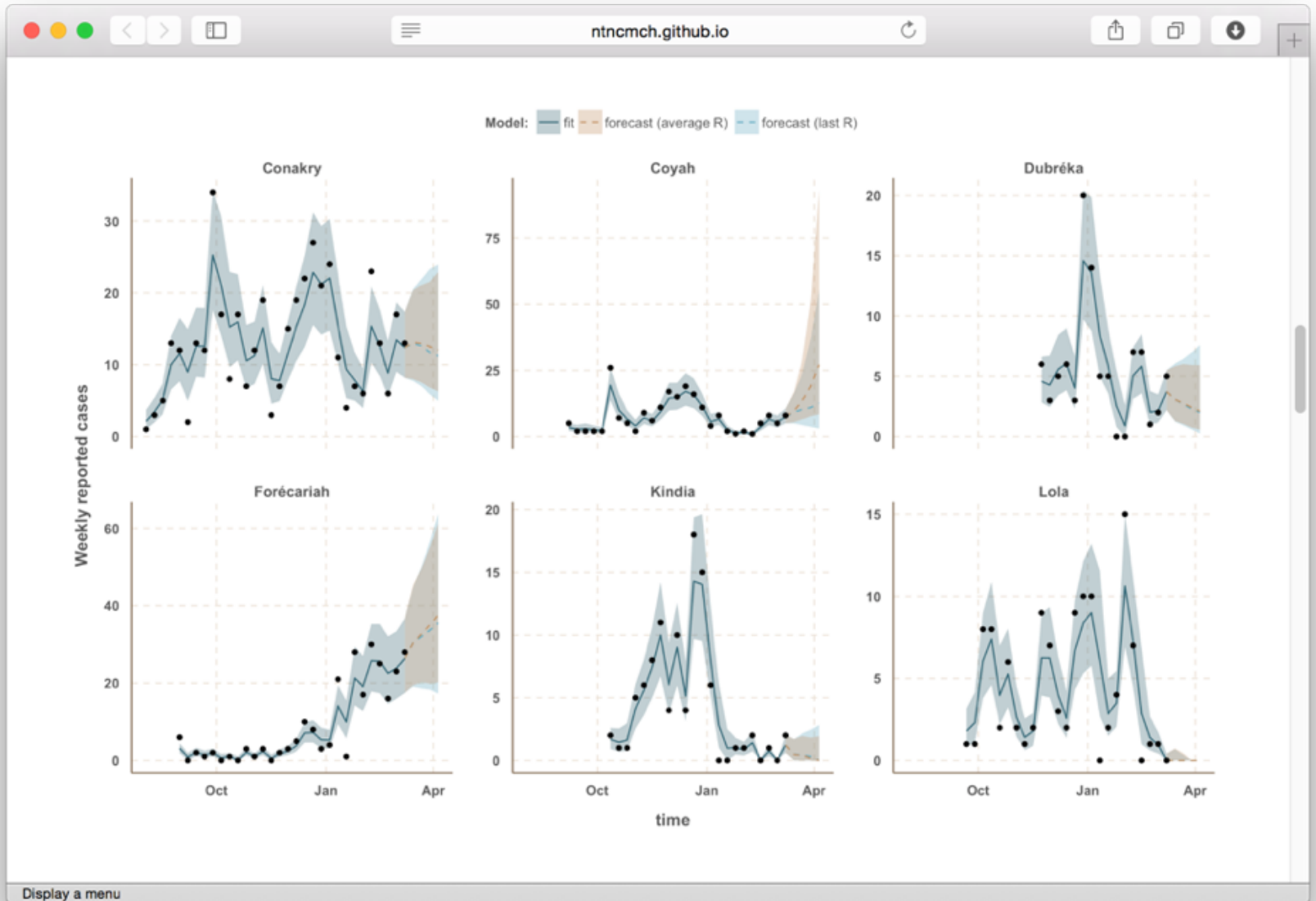


Samuel V. Scarpino @svscarpino



Meaningful forecasts are **probabilistic**.


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)
Modelling and projections
Liberia currently does not have any confirmed cases of Ebola, and is therefore no longer included in the modelling and projections.
Our modelling analysis is provided in a separate report, which also includes a comparison between the SitReps and the WHO linelist data: view online version or download pdf slides
We provide a summary of our projections: view online version or download pdf slides
Interactive maps
Display a menu

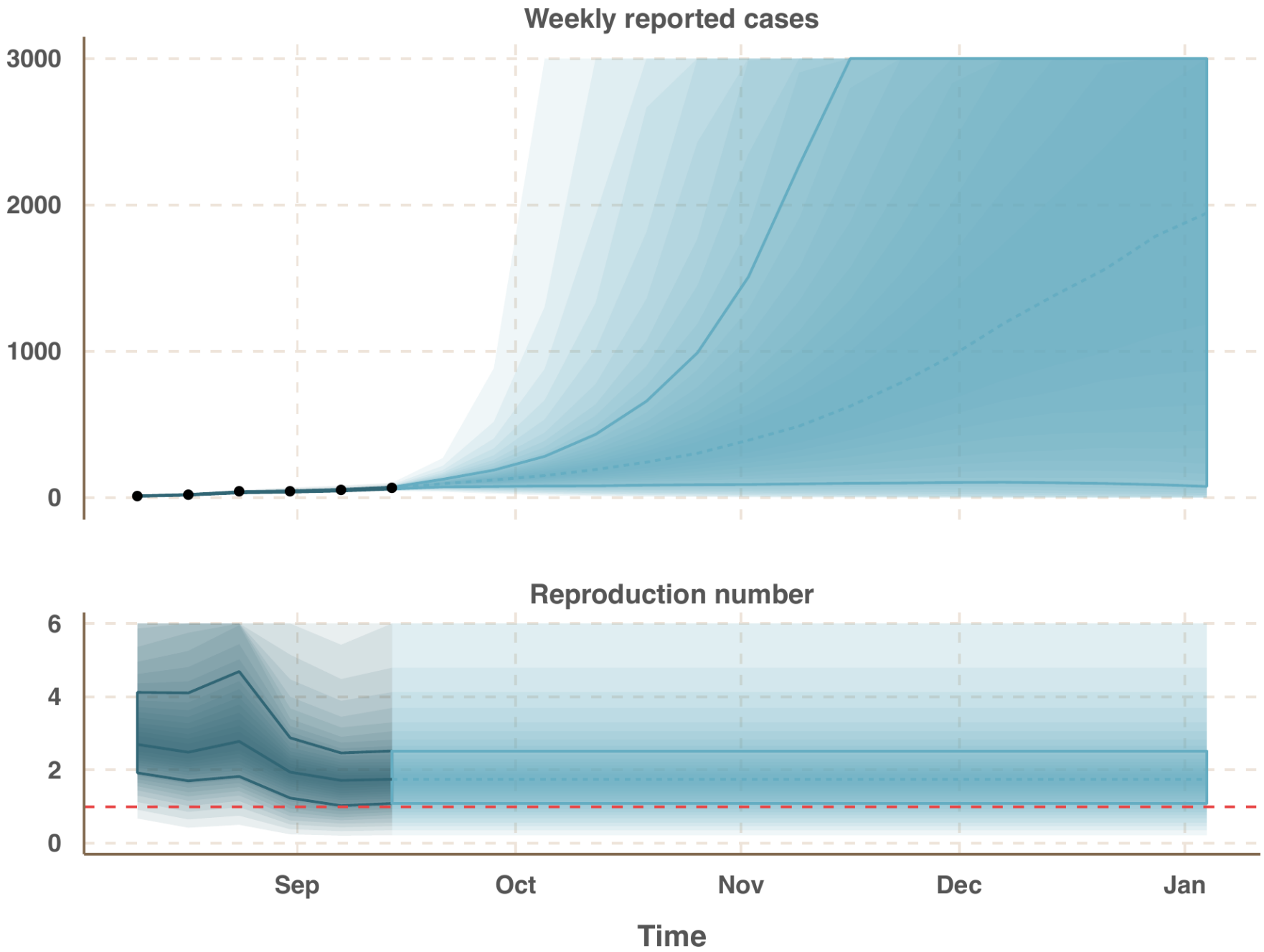

ntncmch.github.io
Model: fit forecast (average R) forecast (last R)
Conakry
Coyah
Dubréka
Forécariah
Kindia
Lola
Weekly reported cases
time
Oct
Jan
Apr
Display a menu

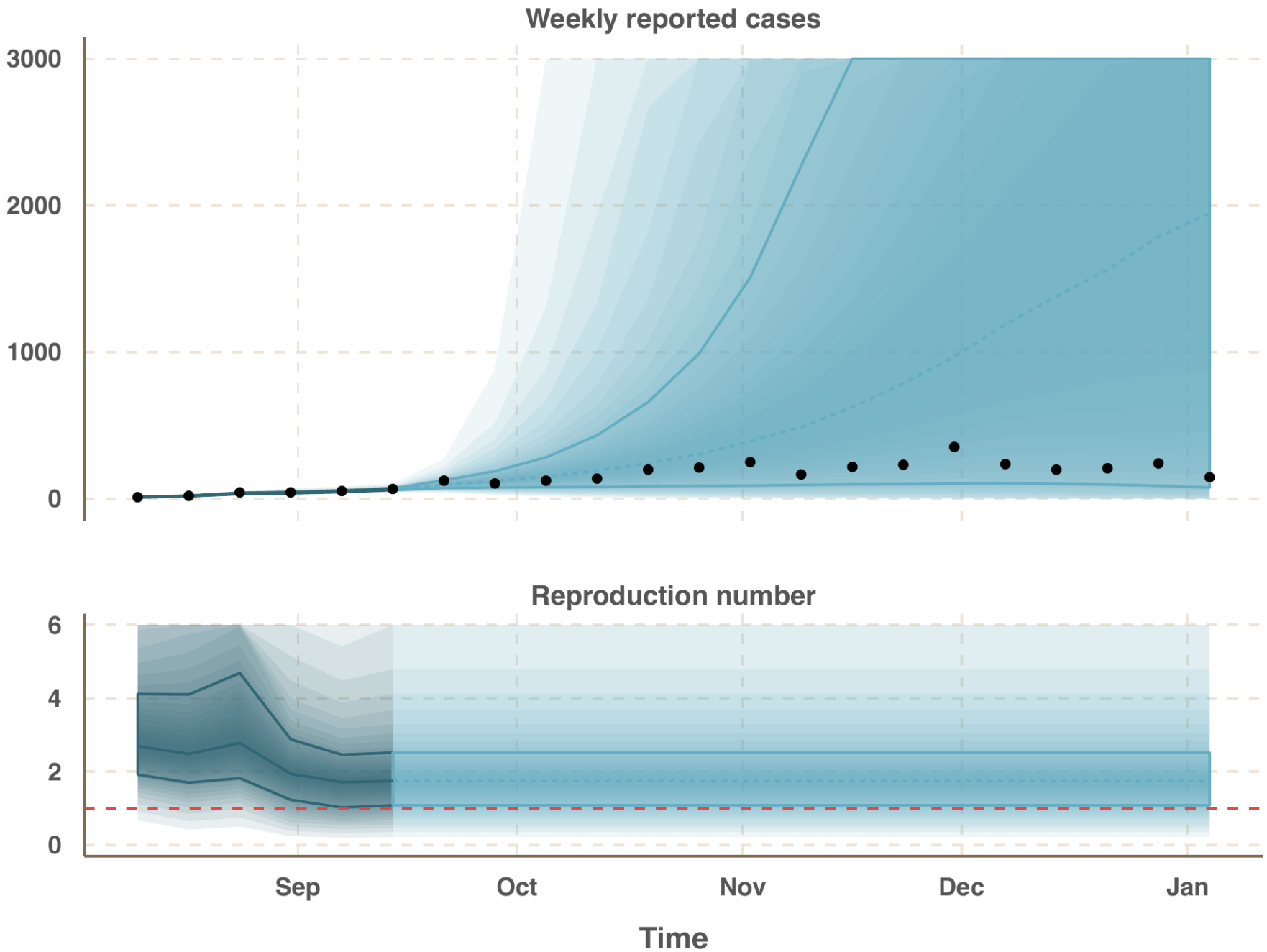
Uses of real-time forecasts in outbreaks

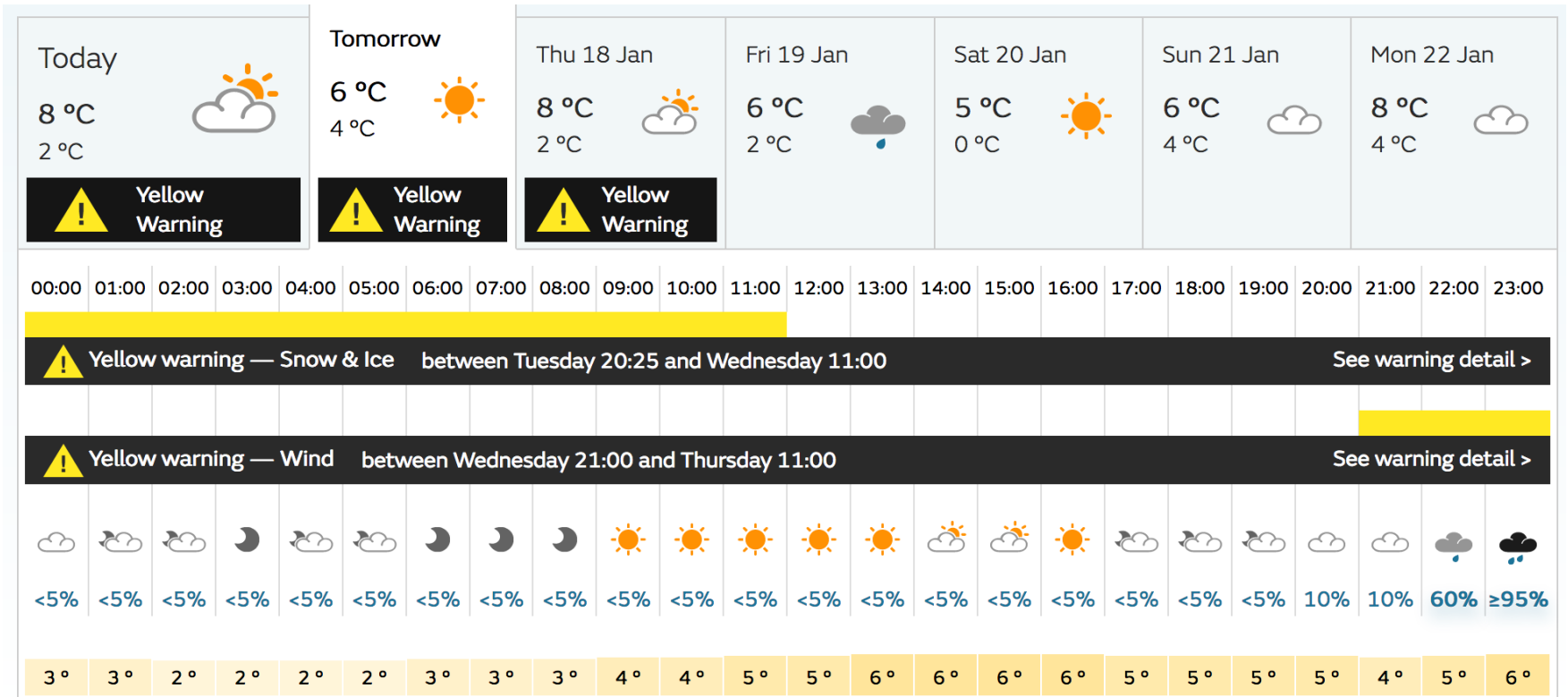
- Plan the scale of a response or intervention
- Allocate resources (e.g., geographically)
- Plan clinical trials

Challenges/opportunities

1. Evaluation of probabilistic forecasts

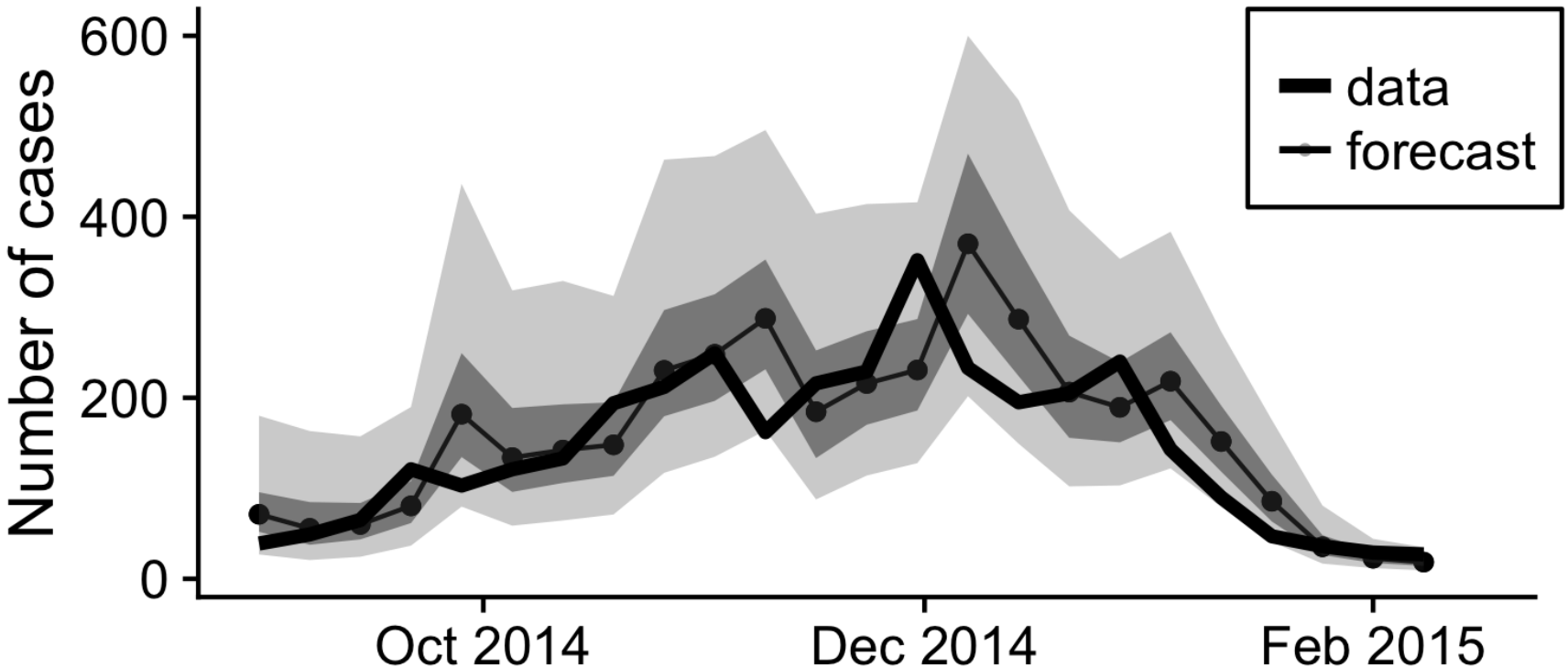

Weekly reported cases
3000
2000
1000
0
Reproduction number
6
4
2
0
Sep
Oct
Nov
Dec
Jan
Time


Weekly reported cases
3000
2000
1000
0
Reproduction number
6
4
2
0
Sep
Oct
Nov
Dec
Jan
Time

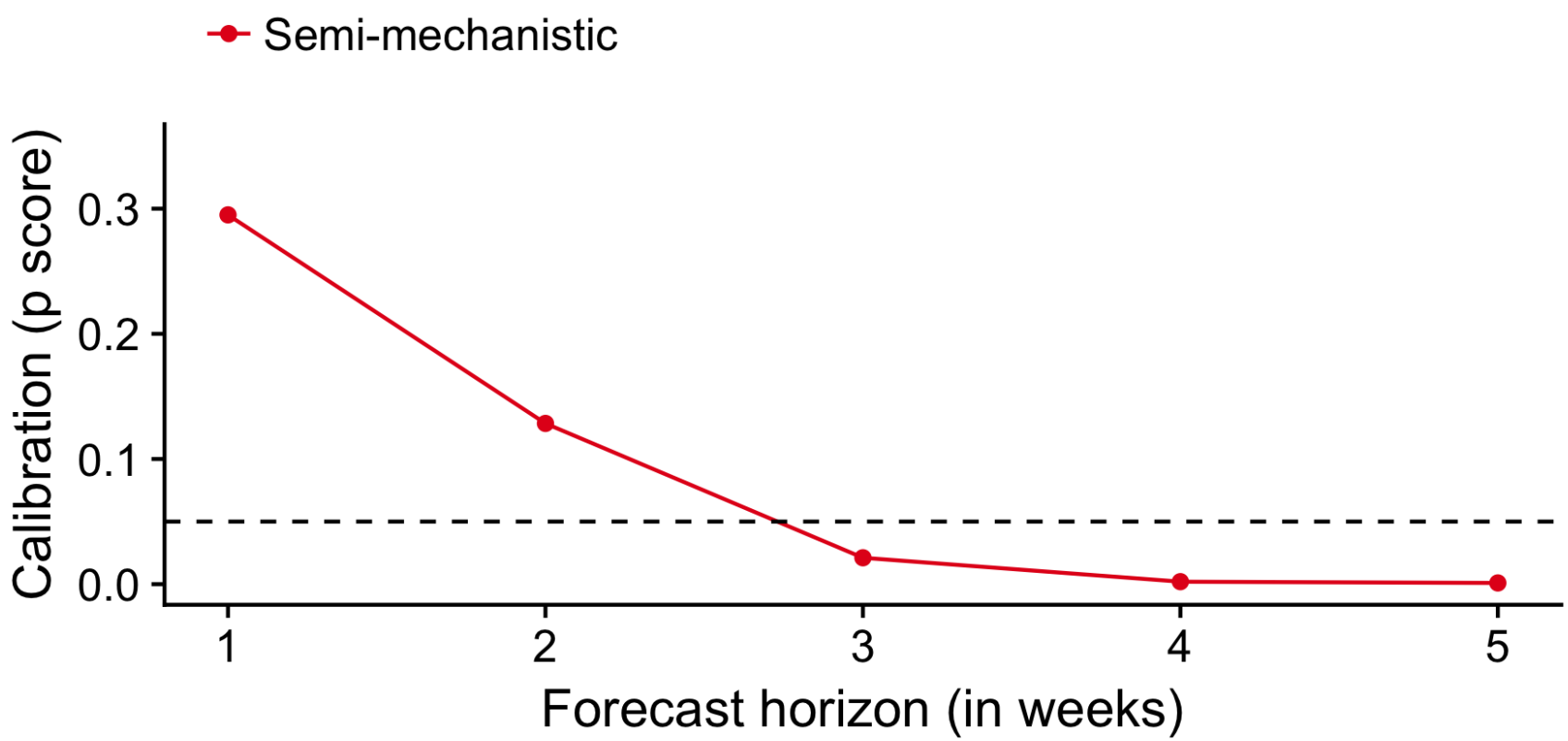


Evaluating probabilistic forecasts requires **multiple observations**.

1-week forecasts



Calibration: Compatibility of forecasts and observations.



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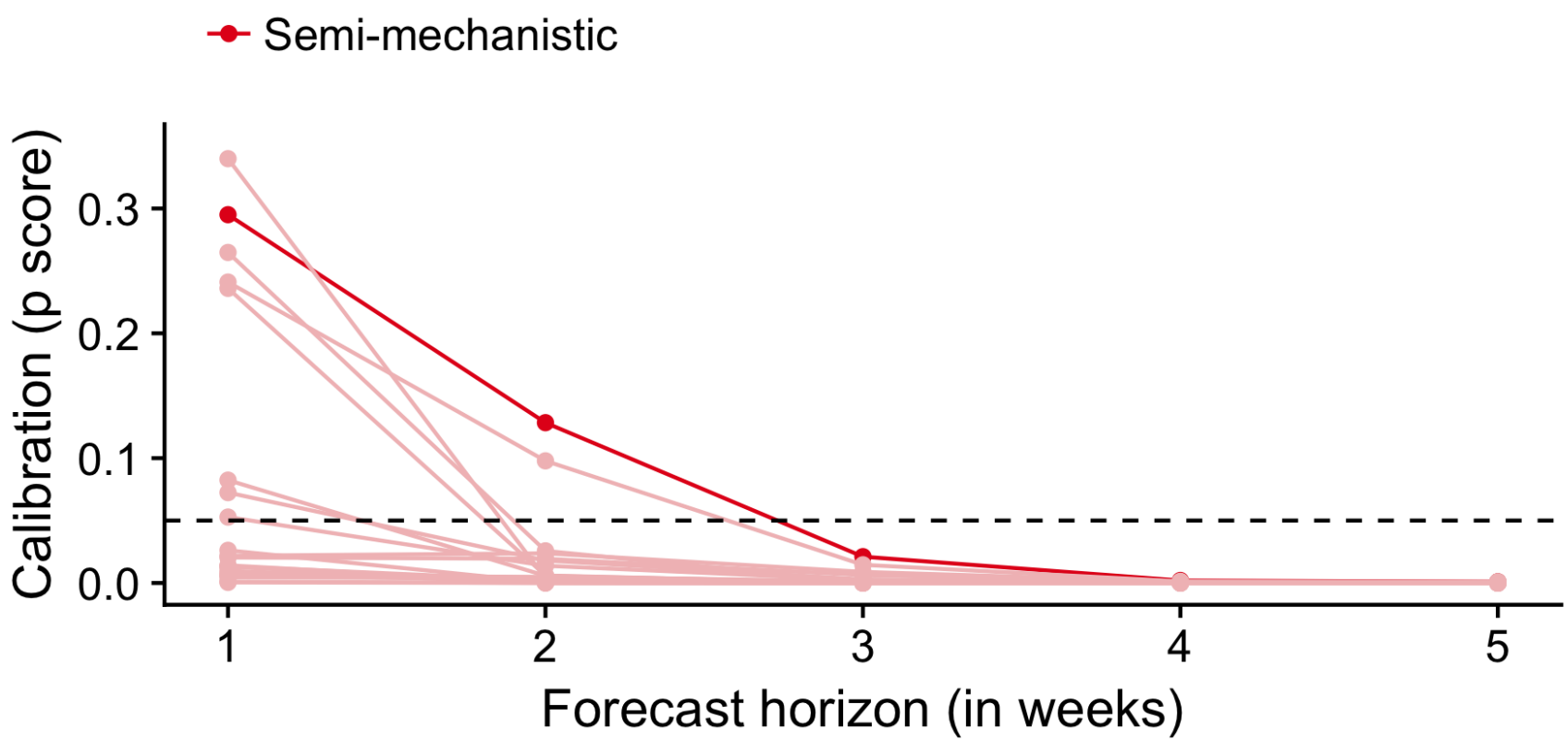

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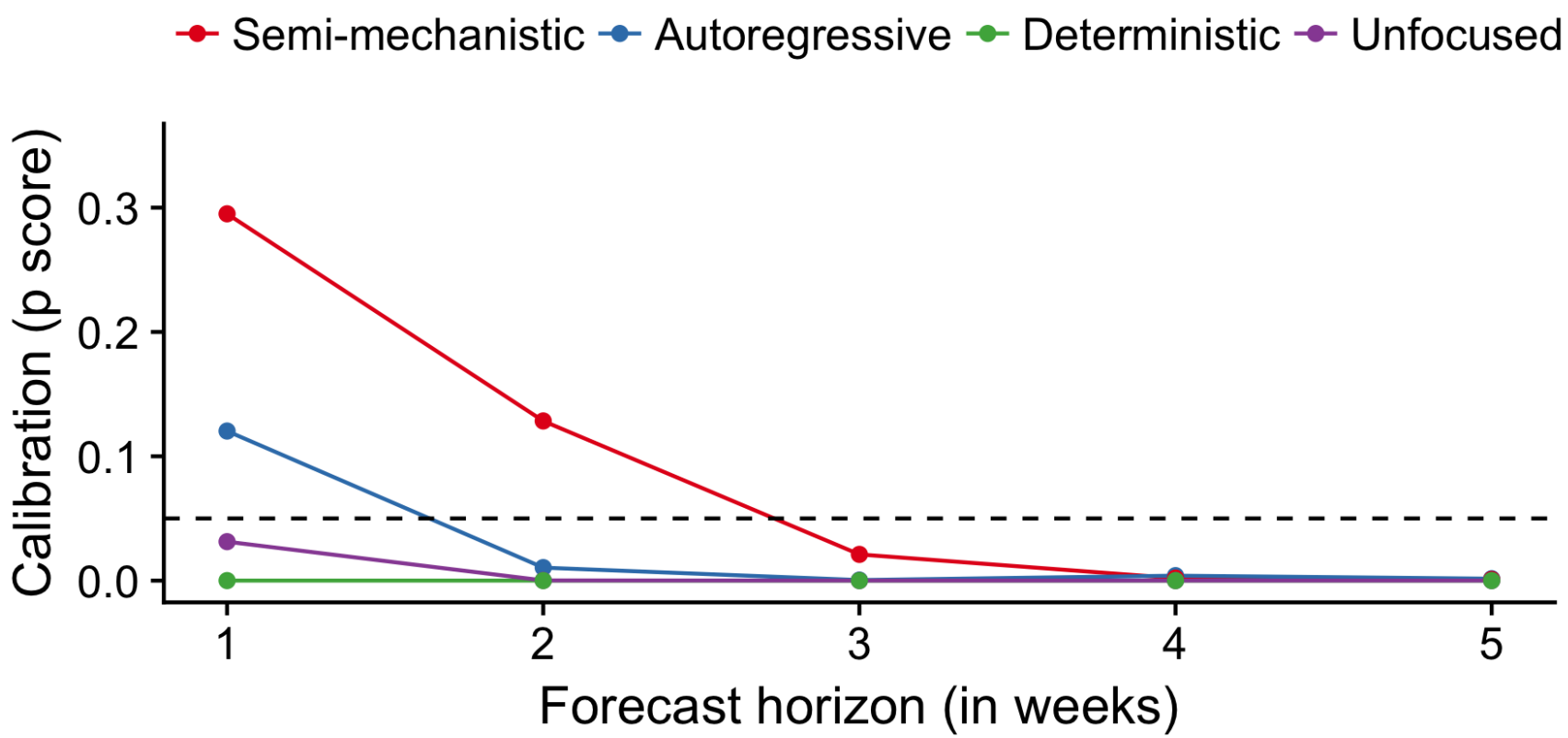
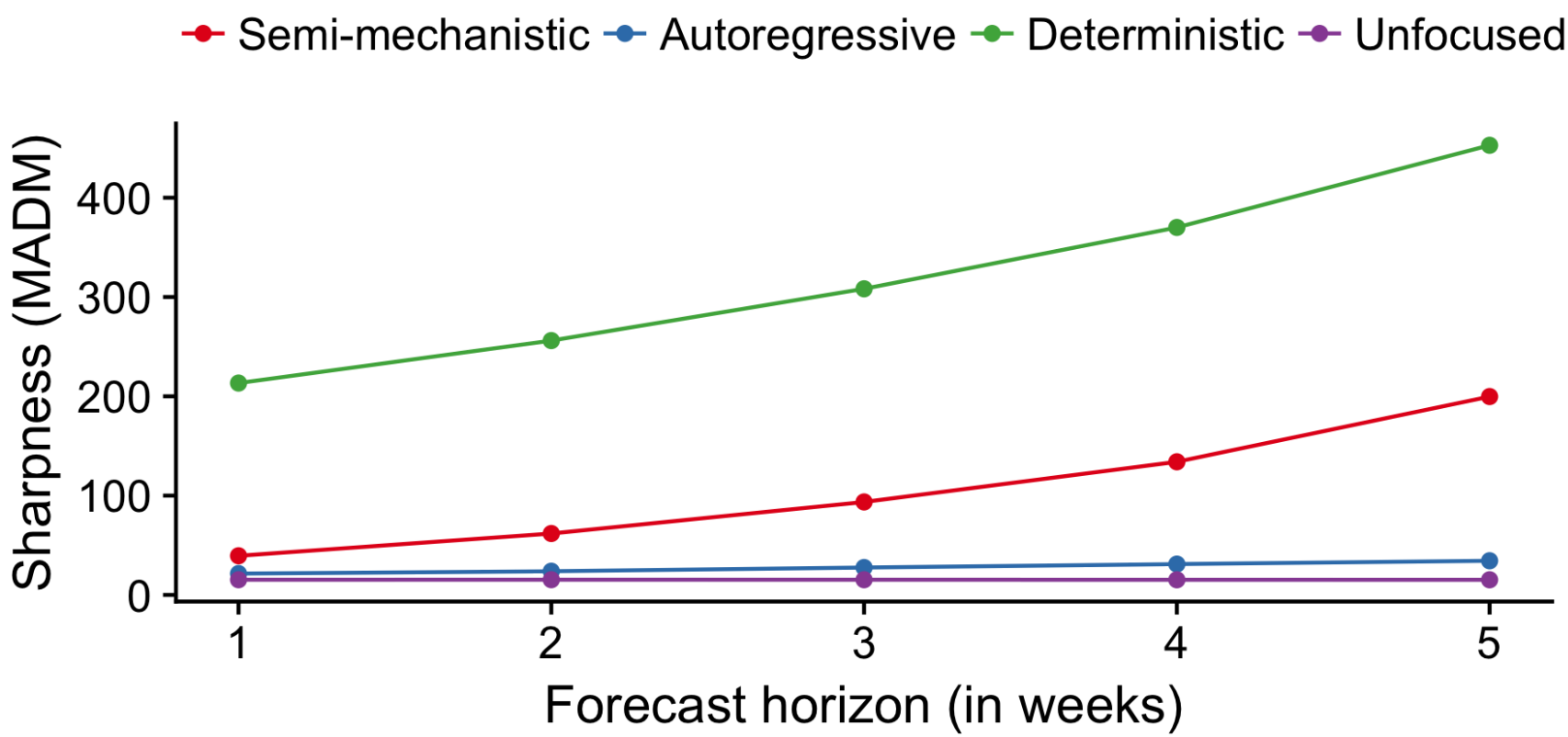
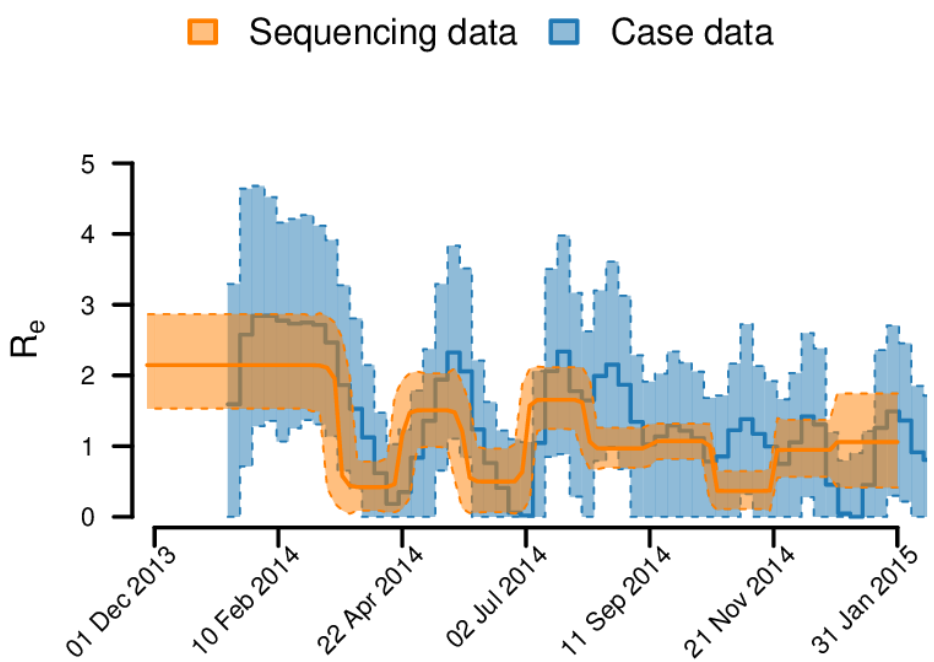


Sharpness


Semi-mechanistic
Autoregressive
Deterministic
Unfocused
Sharpness (MADM)
0
100
200
300
400
1
2
3
4
5
Forecast horizon (in weeks)

2. Integration of different data sources

Improve forecasts by
all available **data streams**
(individual/behavioural/spatial/genetic)?



Louis du Plessis, University of Oxford (unpublished)

New tools

libbi.org

LibBi

Download Stable | **View** Dev

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Papers
Mailing list
FAQ

LibBi has been developed under a CSIRO project that forms part of the Computational and Simulation Sciences platform.

Website theme adapted from work by orderedlist.

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 SMC^2. 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
  14 Dec 2016
- Easily install LibBi from Homebrew
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- RBi package: Use LibBi within R
  19 Oct 2016

New tools

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3. Forecasting for decision making

Acknowledgements

Anton Camacho, Adam Kucharski, John Edmunds, Rachel Lowe,
Roz Eggo (LSHTM), Louis du Plessis (Oxford),
Tilmann Gneiting (Heidelberg), James Hensman (prowler.io),
Lawrence Murray (Uppsala)

MRC Medical Research Council

elrha enhancing learning & research for humanitarian assistance

wellcome trust

r2hc research for health in humanitarian crises

Summary

- Real-time forecasts can aid decision making
- Meaningful forecasts are probabilistic
- Forecasts must be evaluated to establish reliability and limitations
- Some big challenges remain

Assessing the performance of real-time epidemic forecasts
S.F., A. Camacho, A. J. Kucharski, R. Lowe, R. M. Eggo, W. J. Edmunds
bioRxiv 177451; doi: https://doi.org/10.1101/177451