

Uncertainty in climate change

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What are we uncertain about?

1. What events will happen? [*chance*]
2. How big are unknown quantities that we understand? [*parameter*]
3. How does the world work? [*model structure*]

Can we put probabilities on these, and also perhaps

1. What caused events in the past?
2. What could *possibly* happen?

Statistical approaches

1. Frequentist
2. Bayesian

But many subgroups, and uneasy compromises

Frequentist *procedures*

1. Justification comes from long-run properties on repeated use
2. May be 'model-free'
3. May be derived from a parametric model $p(X/\theta)$
4. For particular data x , *likelihood* shows relative support for parameters $l(\theta) \propto p(x/\theta)$
5. Will not put probabilities on parameters or models

Bayesian *analysis*

1. Justification comes from internal probabilistic coherence for assumed model $p(X/\theta)$
2. *Posterior* \propto *likelihood* \times *prior*
 $p(\theta/x) \propto p(x/\theta) p(\theta)$
3. Prior and posterior distributions express our knowledge/ignorance about unknown states of the world
4. May try to be '*objective*' (but well-known problems with uniform priors)
5. Happy to put probabilities on parameters, and (maybe) models

Generic statistical ideas

1. All models are wrong
2. Iterative cycle of model checking/refinement
3. Limit to how complicated it is worth making a model
4. Strong emphasis on decomposition into independent sources of variation/bias/error

Traditional lack of contact between 'realistic deterministic' and 'simplistic stochastic' models, but this is changing

Roger Street (UKCIP08)

A probabilistic climate projection:

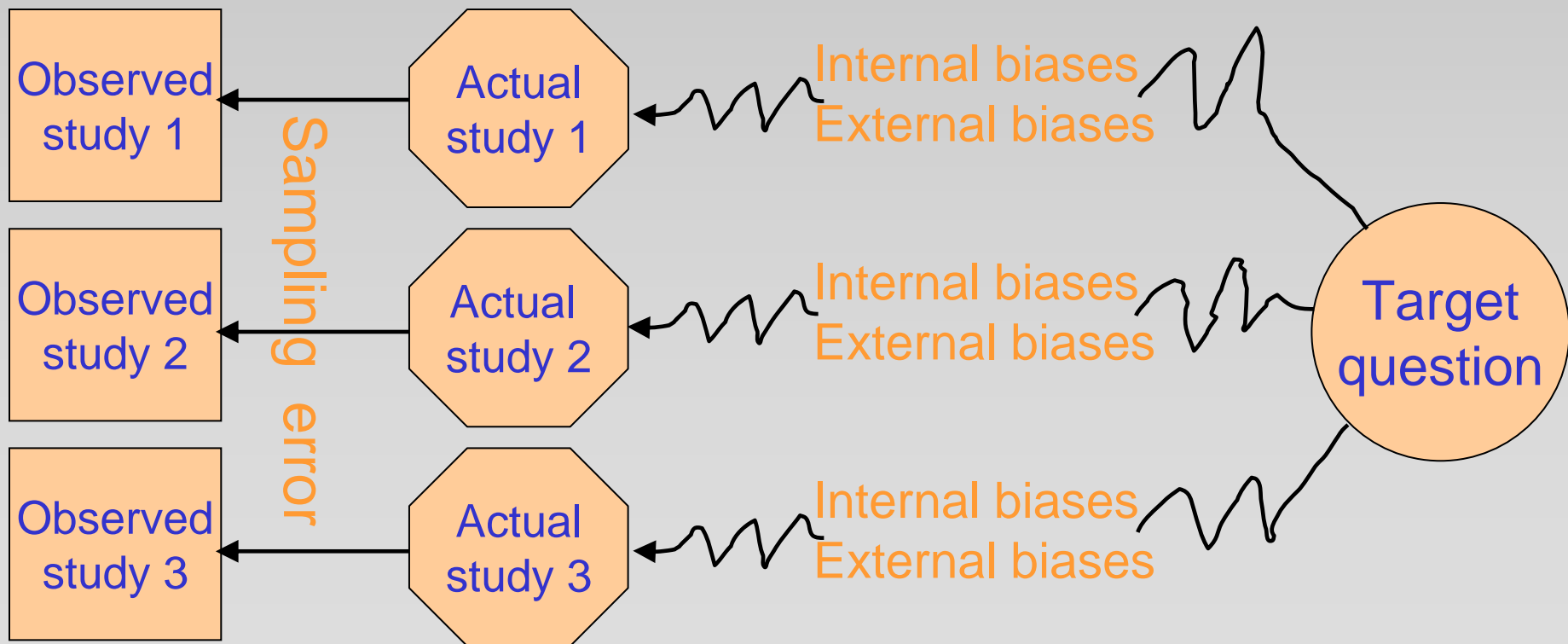
- *IS NOT an objective probability, where a situation is well understood, where all outcomes can be accounted for or where probabilities can be revised based on observed outcomes (such as tossing a coin or rolling a dice);*
- *IS rather a subjective probability, providing an estimate based on the available information and strength of evidence (similar to horse-racing odds);*

So can we produce probabilities of future events when we are uncertain about the model structure and parameters?

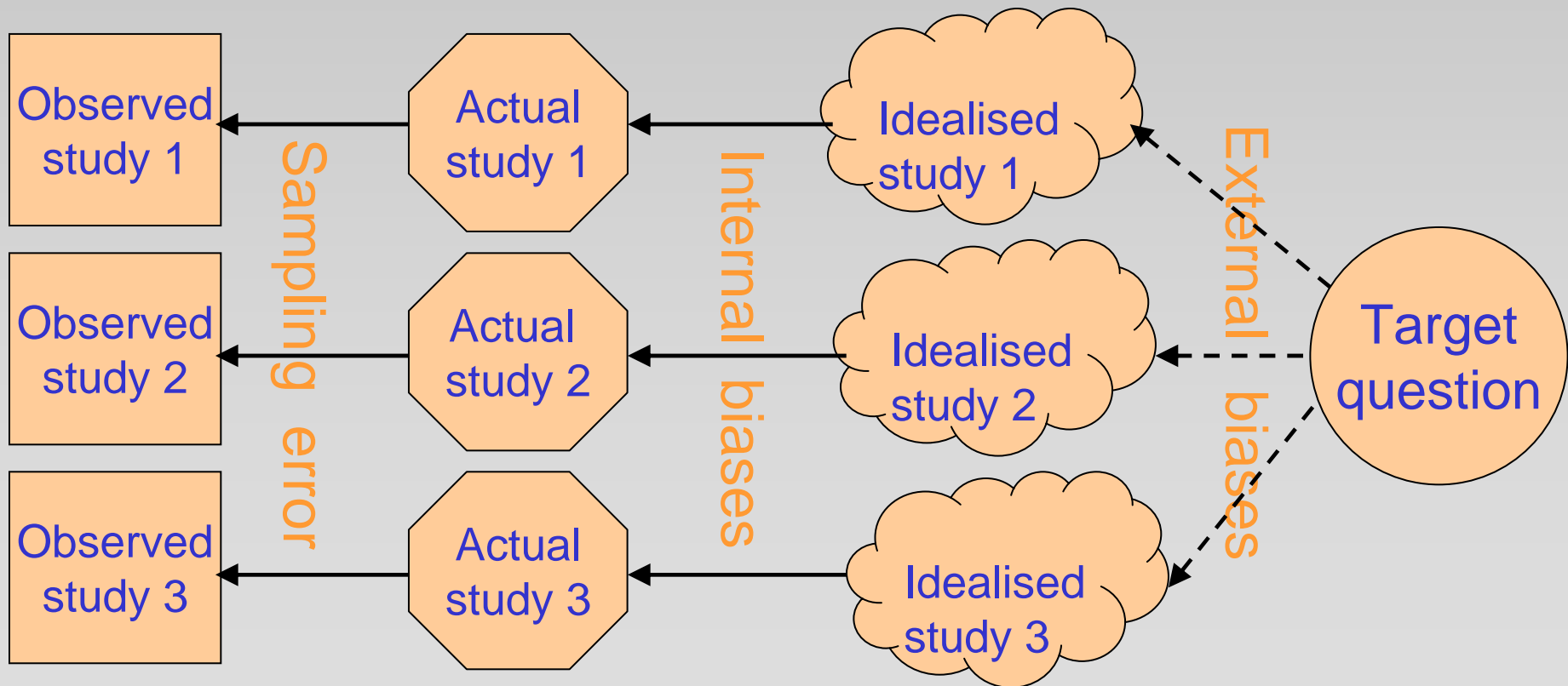
- Goldstein-Challenor:
 - Explicit consideration of sources of bias/error
 - ‘Reified model’ representing best conceivable
 - Decompose *model vs observation* into independent sources:
 - How close assumed model is to f^*
 - Inputs to f^*
 - How close f^* is to true climate
 - How close true climate is to observed climate

NICE appraisals for reimbursement of medical interventions: Using multiple imperfect studies to inform a policy question

- ◆ Write down precise definition of target question
- ◆ Identify internal and external biases by comparing target question vs. completed studies



- ◆ Write down mini-protocol for idealised study
- ◆ To identify internal biases, compare actual vs. idealised study
- ◆ To identify external biases, compare idealised study vs. target question



- Knutti:
 - Meta-analysis of independent biased studies is not an appropriate analogy
 - Better to think of each model providing an idea of what a 'super-model' (reified) might report
 - Strong analogies with issues of pooling opinions/forecasters – the *opinion* is the data point, it does not 'represent data'

Allen:

- Can have unintended sensitivity to ‘uninformative’ priors
- Contrive nuisance sampling distributions to create uniform predictive distributions on quantities of interest (long tradition)
- Profile likelihoods are attractive: ‘letting the data speak for itself’

But

- Decision-making does need pdfs
- Ideally need to present likelihood and priors (if only to spot conflict)
- Difficult in high-dimensional problems

'Objective' Bayesian methods

- Attempt to use Bayesian probabilistic reasoning without introducing quantitative subjective judgement
- Vast effort expended, but no generally accepted methods

****** *Personal opinion* ******

- It is a public-relations exercise
- Judgement enters at all levels of the process and it is a pretence to suddenly become sanctimonious about 'the data'.
- Better to acknowledge judgement and claim robustness to a range of opinion

Bayesian methods in health policy models

- 'Bayesian melding' in international AIDS projections
- NICE appraisals for reimbursement of new treatments in NHS
- HIV projections in UK
- Bayesian methods encouraged by FDA for regulation of medical devices

PROBABILISTIC PROJECTIONS OF HIV PREVALENCE USING BAYESIAN MELDING¹

BY LEONTINE ALKEMA, ADRIAN E. RAFTERY AND SAMUEL J. CLARK

PROBABILISTIC PROJECTIONS OF HIV PREVALENCE

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Combination of

(i) deterministic model

(ii) historical data

(iii) expert prior distributions on both inputs and outputs

In use by
UNAIDS

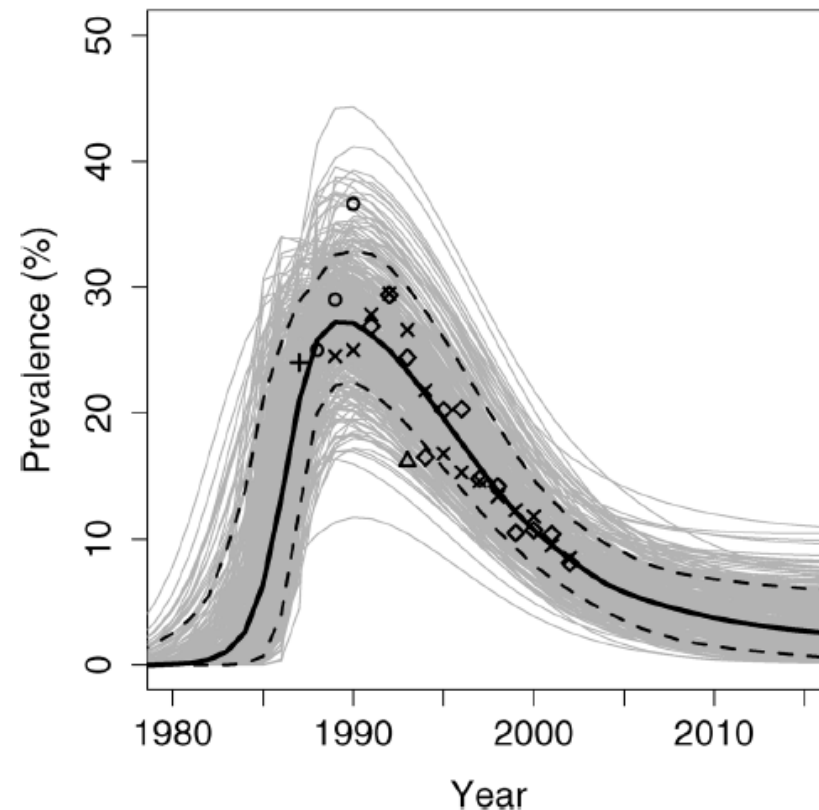


FIG. 2. Posterior distribution of urban HIV prevalence in Uganda over time. Each dot is an observation, and dots with the same symbol correspond to repeated observations at the same clinic. Each grey line is a unique trajectory in the posterior sample of epidemic curves. The dashed lines are the 2.5% and 97.5% quantiles, and the solid black line is the median of the posterior sample.

Communication of uncertainty to public and policy-makers

- Risk communication is difficult, even with 'known risks'
- Will admitting uncertainty encourage denial?
- Some evidence that acknowledging uncertainty can *increase* trust

It is important to be aware that predictions from climate models are always subject to uncertainty because of limitations on our knowledge of how the climate system works and on the computing resources available. Different climate models can give different predictions (Hadley centre)



The Treatment of Uncertainties in the Fourth IPCC Assessment Report

Clearly a long and arduous struggle for consistency

Likelihood, as defined in the workshop, expresses the chance of a defined outcome in the physical world and is estimated using expert judgment.

Confidence, as defined in the workshop, expresses the degree of understanding and / or consensus among experts and is a statement about expert judgment.

'Likelihood'

Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations.¹² This is an

Table 4 Likelihood Scale

Terminology	Degree of confidence in being correct
Virtually certain	> 99% probability of occurrence
Very likely	> 90% probability
Likely	> 66% probability
About as likely as not	33% to 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Exceptionally unlikely	< 1% probability

Probabilities applied to retrospective hypotheses ('*A caused B*') is unusual

Use of 'likelihood' for clearly Bayesian subjectivist probabilities is perhaps unfortunate

'Confidence'

*Example in
WG2*

Cities that currently experience heatwaves are expected to be further challenged by an increased number, intensity and duration of heatwaves during the course of the century, with potential for adverse health impacts. Elderly populations are most at risk. ***
D [14.4].

Level of confidence in the whole statement:

*** Very high confidence
** High confidence
* Medium confidence

Table 3 Quantitatively calibrated levels of confidence

Terminology	Degree of confidence in being correct
Very High confidence	At least 9 out of 10 chance of being correct
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

Numerical 'chance' also used for confidence in science – what do these numbers mean?

WG3

Table SPM.E.1: *Qualitative definition of uncertainty*

↑
Level of agreement
(on a particular finding)

High agreement, limited evidence	High agreement, medium evidence	High agreement, much evidence
Medium agreement, limited evidence	Medium agreement, medium evidence	Medium agreement, much evidence
Low agreement, limited evidence	Low agreement, medium evidence	Low agreement, much evidence

Amount of evidence³³ (number and quality of independent sources)



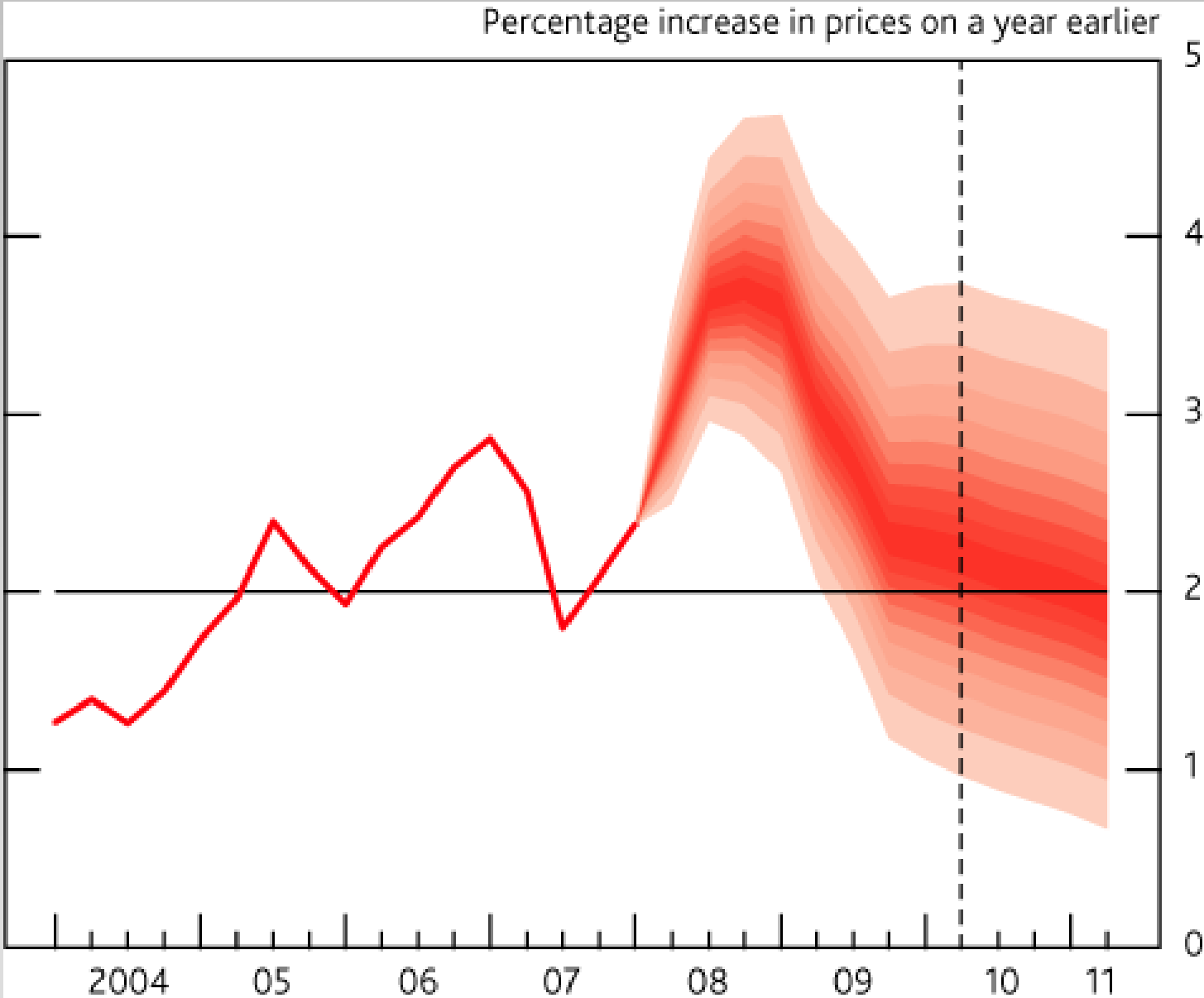
Probabilistic projections – how to present?

Well-known possible biases from,
e.g.

- Framing in words
- Framing in graphics

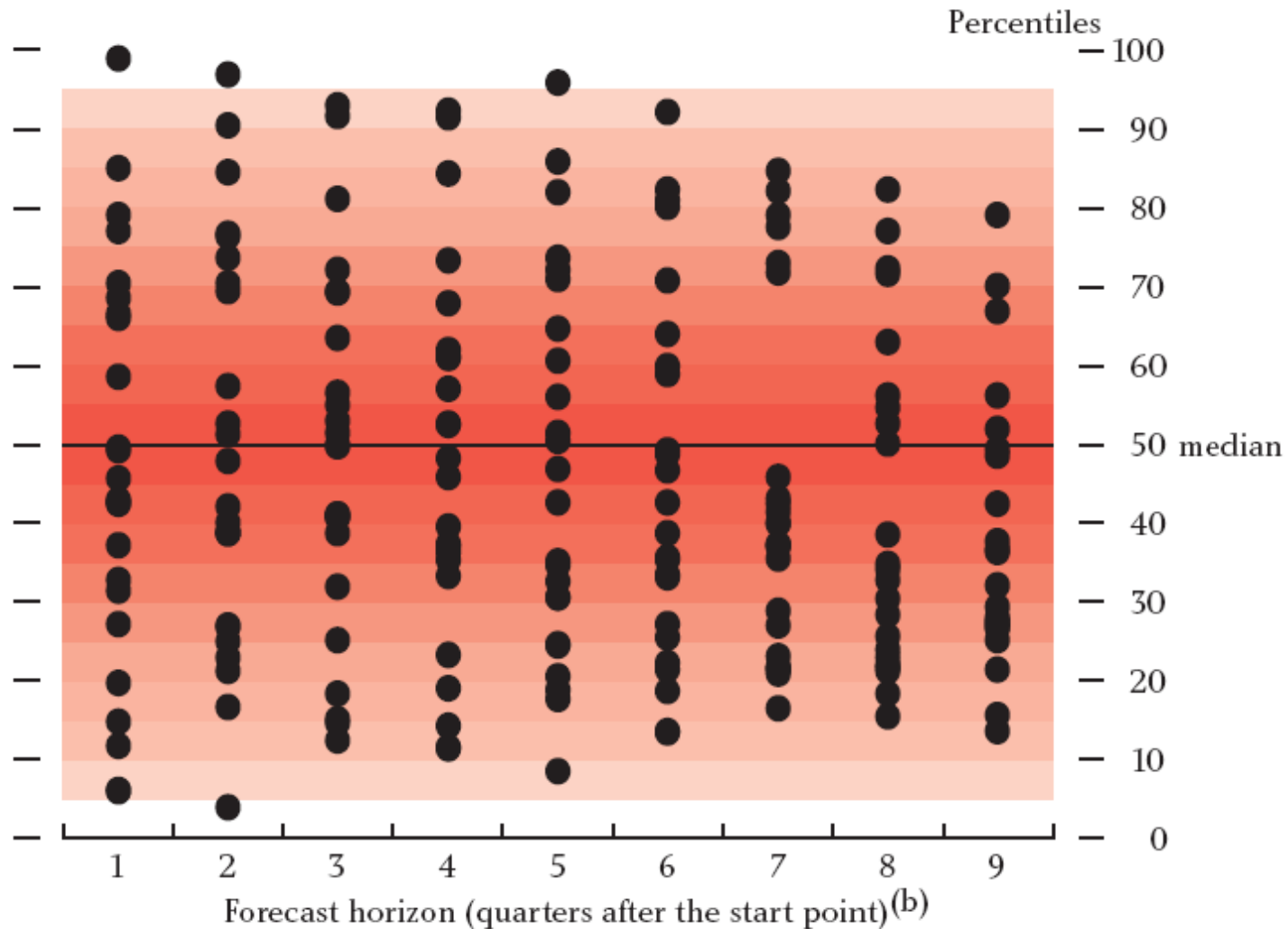


Bank of England 'fan charts' – May 08

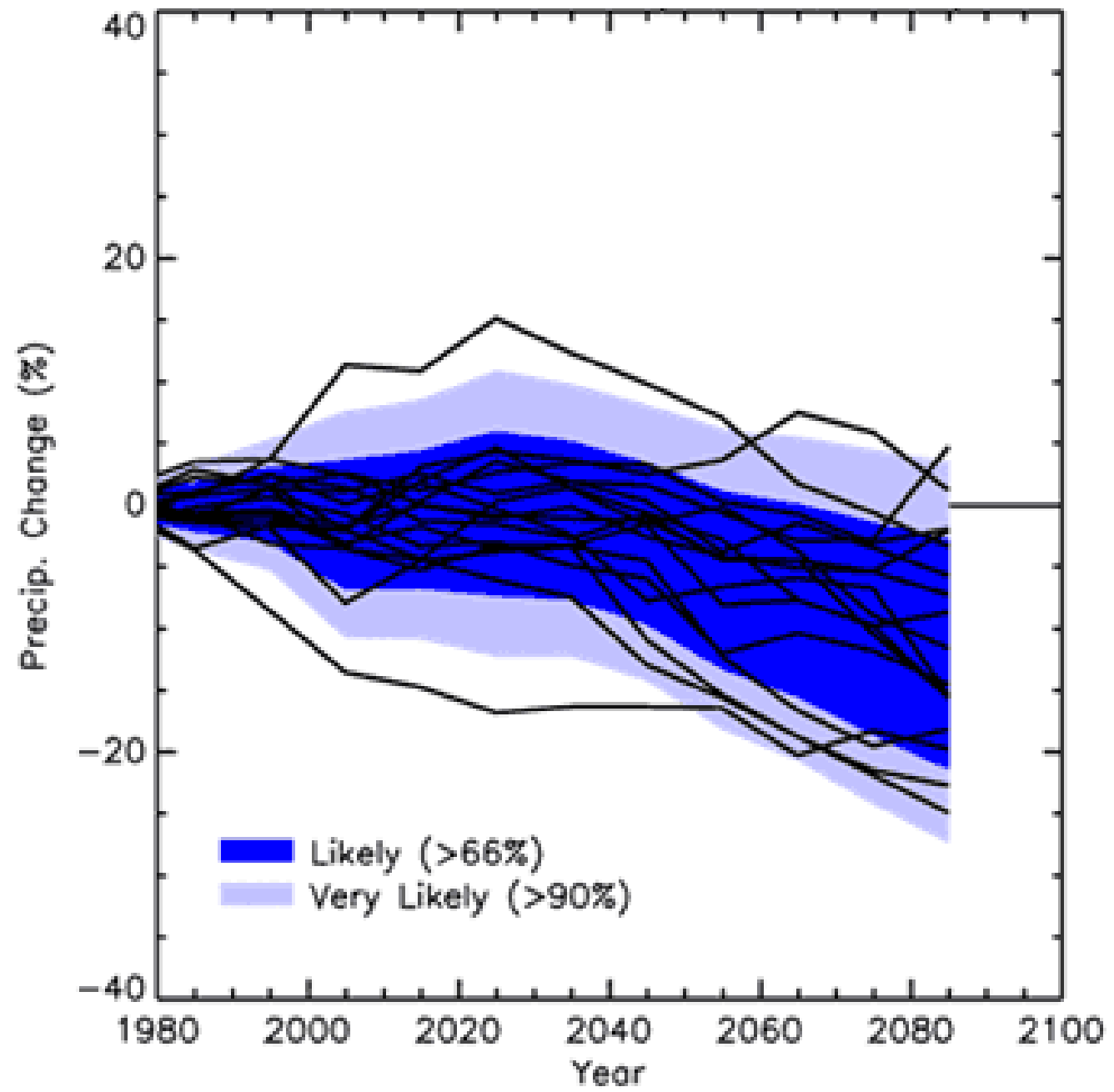


Calibration of fan charts

RPIX inflation outturns relative to fan chart probability distributions^(a)



Difficult to calibrate, and anyway things will have changed





“But there are also unknown unknowns. There are things we do not know we don’t know”

"Cromwell's Law"

OLIVER CROMWELL'S

LETTERS AND SPEECHES:

WITH ELUCIDATIONS.

BY

THOMAS CARLYLE.

To the General Assembly of the Kirk of Scotland; or, in case of their not sitting, To the Commissioners of the Kirk of Scotland: These.

SIRS,

Musselburgh, 3d August 1650.

Is it therefore infallibly agreeable to the Word of God, all that *you* say? I beseech you, in the bowels of Christ, think it possible you may be mistaken. Precept may be upon

picking our horses' beans, eating our soldiers' leavings: 'they are much enslaved to their Lords,' poor creatures; almost destitute of private capital,—and ignorant of soap to a terrible extent!²⁵ Cromwell distributes among them 'pease and wheat

Conclusions (very personal)

- Probabilistic projections seem appropriate
- Full distribution needed as input to decisions (not just interval)
- Judgement is unavoidable – it is a pretence that projections can be objective (but they may be robust to range of opinion)
- Could separate likelihood from prior, and present separately as meta-analysis
- Does not seem reasonable to place probabilities on alternative models structures, when *none* are correct
- Beware of Cromwell's Law