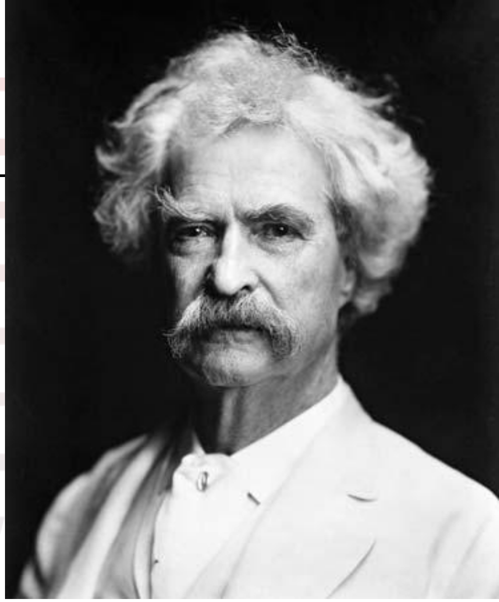
(with apologies to sam)

To the Physicist Sitting in Darkness



Probabilities are all well and good. And it is a fine thing to get in touch with your beliefs and feelings. Shall we bang ahead in our old-time, loud pious way, and commit new sciences to the game; or shall we sober up, sit down, and think it over first?

The Blessings-of-Subjective-Probability Trust, wisely and cautiously administered, is a Blue Chip. But Bayesians have been playing it badly of late, and must certainly suffer from it, in my opinion; they have been eager to solve every problem, especially the poorly posed ones, and the Physicists who sit in Darkness have begun to notice it – they have noticed it and have begun to show alarm. They have become suspicious of posteriors on empirically vacuous reals, not to mention function spaces; they have begun to resist the kindly extraction of priors. More – they have begun to examine them! This is not well. The Blessings of Bayesianism are all right, and a good RC commercial property; there could not be better, in a dim light. In the right kind of light, and at the proper distance, with the goods a little out of focus, they are a desirable enticement to the Physicists who sit in darkness.

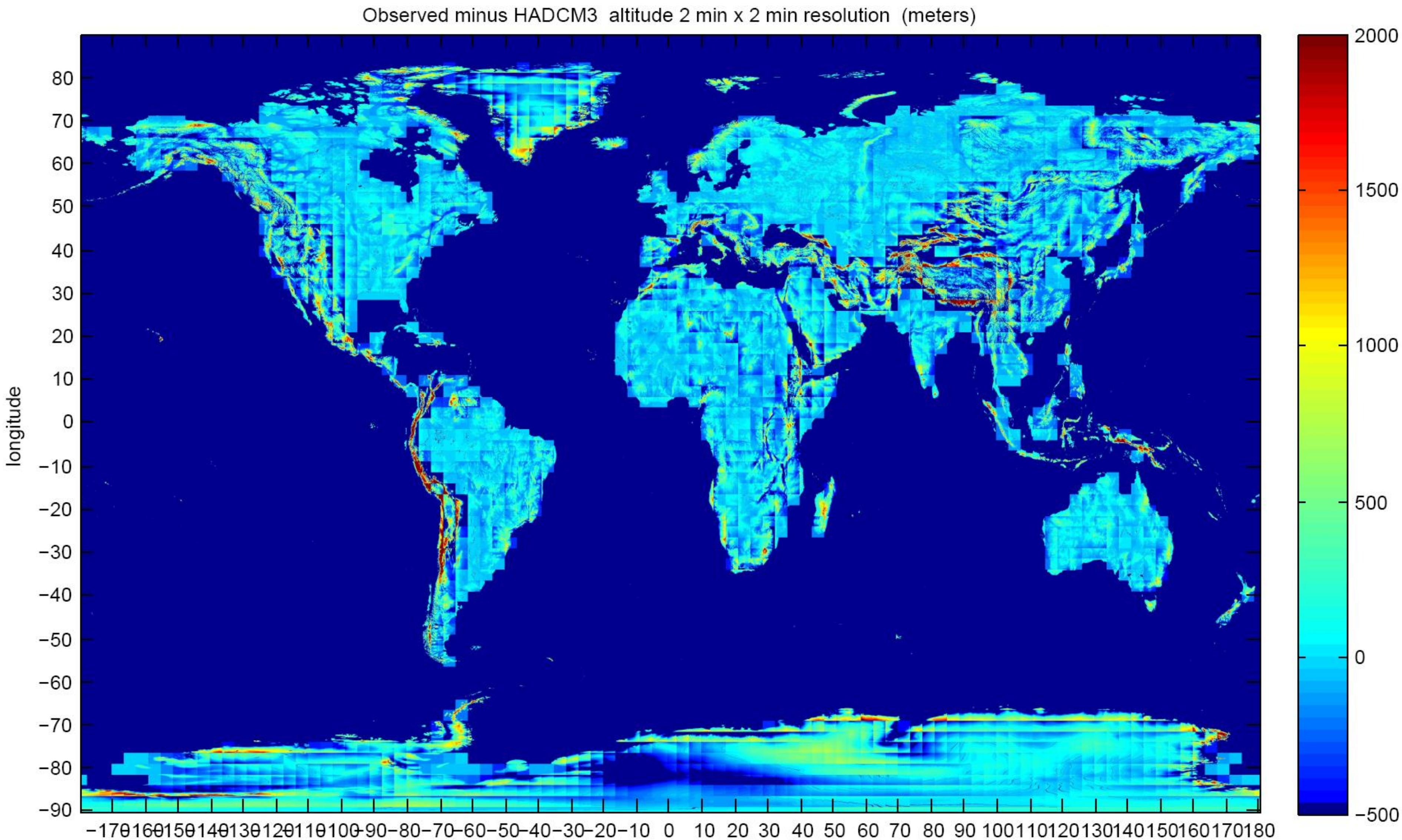
Probability theory eases the stress of decision making. And improves the outcome, but not if we adulterate it. For the Empirically Adequate and the Large Number Statistic, it is pie. But in cutting edge science, and in extrapolation, here the Physicist sitting in darkness is (almost) sure to say: “These is something curious about this – curious and unaccountable.” … There have been lies yes, but told in a good cause, it might have worked; yet we have passed on a Shadow from one who hadn’t it to sell, and long term infrastructure investments are being made.

Objection has been taken to such forecasts, because they cannot be always exactly correct,—for all places in one district. It is, however, considered by most persons that general, comprehensive expressions, in aid of local observers, who can form independent judgments from the tables and *their own instruments*, respecting their immediate vicinity, *though not so well for distant places*, may be very useful, as well as interesting: while to an unprovided or otherwise uninformed person, an idea of the kind of weather thought *probable* cannot be otherwise than acceptable, provided that he is in no way *bound* to act in accordance with any such views, against his own judgment.

Like the storm signals, such notices should be merely *cautionary*—to denote anticipated disturbance *somewhere* over these islands,—without being in the least degree compulsory, or interfering arbitrarily with the movements of vessels or individuals.

Certain it is, that although our conclusions may be incorrect—our judgment erroneous—the laws of nature, and the signs afforded to man, are invariably true. Accurate interpretation is the real deficiency.

Fitzroy, 1862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Abstract

The aims, means, and outputs of forecasts for decision support vary with the nature of the system, our level of understanding, and the nature of the decisions being made. Good practice in one case may be disadvantageous (indeed irrational, if not impossible) in another. In many cases one has an insightful prior probability distribution on the likely outcomes (the relevant climatology) and a large archive of forecast/outcome pairs. In this "weather-like" case the lifetime of a model is very long compared to the decision-relevant lead-time of a forecast. Contrast that case with a "climate-like" case in which the forecast/outcome archive is at best small, the lifetime of a model is much less than the lead-time of the forecast and it is questionable whether or not past observations provide a relevant prior. While probabilistic weather and climate forecasts will be used for concreteness, the weather-like/climate-like distinction is useful outside of the Earth sciences and arguably across the entire spectrum of forecast and modeling activities.

Clarifying this distinction throws some light on the friction commonly observed between proponents of "physical insight" and "statistical good practice" when forecasting the real world. The roles both of model inadequacy and of uncertainty in observations (and parameters) are shown to differ in the two cases; distinct challenges to the rationality of probability forecasts (used as such) for decision making raised in each case, and the possibility of replacing "fair odds" with "sustainable odds" is illustrated and argued for. The diversity of our models provides different information in weather prediction than in climate projection, but in neither case does it quantify the uncertainty in our future. How then are we to judge, constructively criticize, and improve operational forecasting and the models which underlie it?

Distinguishing Uncertainty, Diversity and Insight:

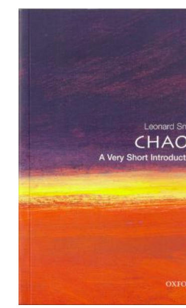
Contrasting the achievable aims of forecasting in weather-like cases and climate-like cases

Leonard A. Smith

London School of Economics

&

Pembroke College, Oxford



CATS CENTRE FOR THE ANALYSIS OF TIME SERIES

ENSEMBLES

EQUIP 2012

Grantham Research Institute on Climate Change and the Environment

My vocabulary and biases

I will focus only on probabilistic forecasts: never point forecasts.

I start fully nonlinear, but am happy to go linear whenever possible.

I will *attempt* to avoid the word "uncertainty" and distinguish:

"imprecision", "ambiguity" and "indeterminacy" and "intractability".

(Knightian risk) **(Knightian Uncertainty)**

I hold that to be decision-relevant, probabilities must be useful as such.

A few solid predictions/projections (as for decadal changes due to aerosol reduction) would go a long way.

An official minority opinion on every large project would be of great value (UKCP09, CCRA); at least publish the reviews!

Science to inform? **OR** Science to motivate?

Professional decision makers "*require*" only one thing:

a deadline

LA Smith & N Stern (2011) Uncertainty in science and its role in climate policy Phil. Trans. R. Soc. A (2011), 369, 1-24.

Distinguishing Weather-like and Climate-like tasks

Weather-like forecasting tasks:
  model lifetime is long in comparison to the typical forecast lead-time
  large archive of truly out-of-sample forecast-outcome pairs
  arguably extrapolation in time but interpolation in state space

Here the same model is deployed many times in similar circumstances and one can learn from past mistakes.

.

Climate-like forecasting tasks:
  lead-times of interest are far longer than the lifetime of model
  forecast-outcome archive is very small, arguably empty
  lead-times of interest are long compared to the career of a researcher.

By the nature of the problem there are no true out-of-sample observations.

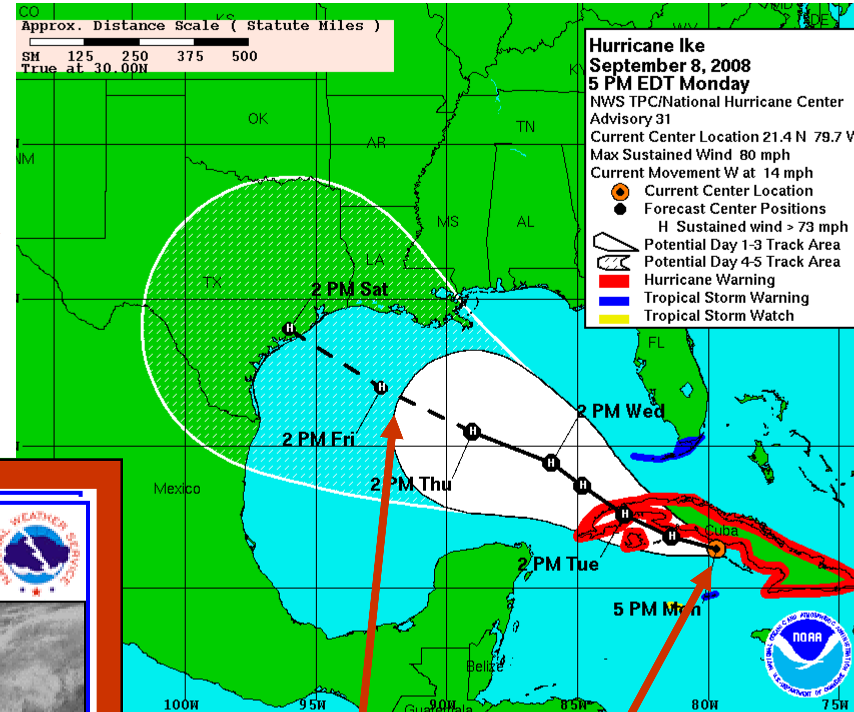
Best practice principles of forecasting differ in these two settings.

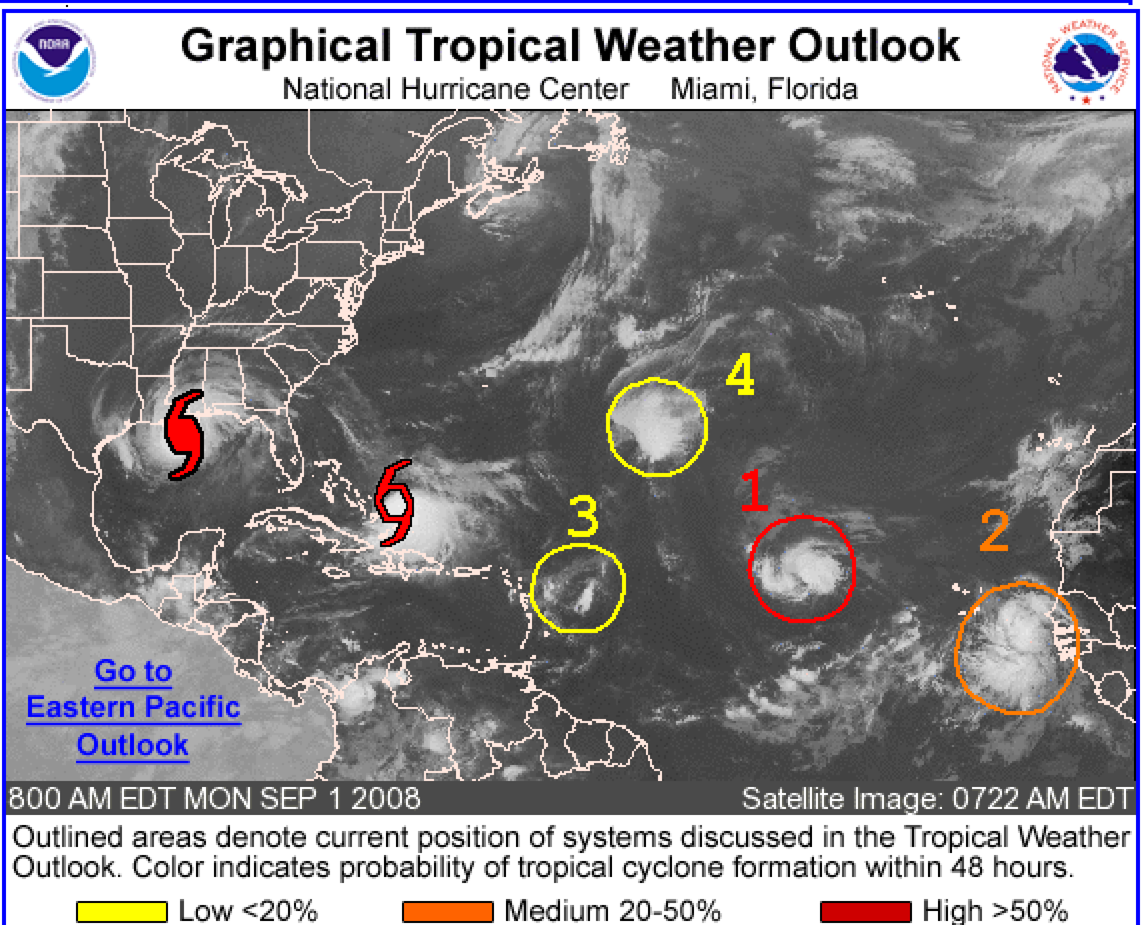
Distinguishing Weather & Climate

Weather-like Predictions

and

Climate-like Predictions?





Extreme weather.

Weather forecast.

Climate extreme.

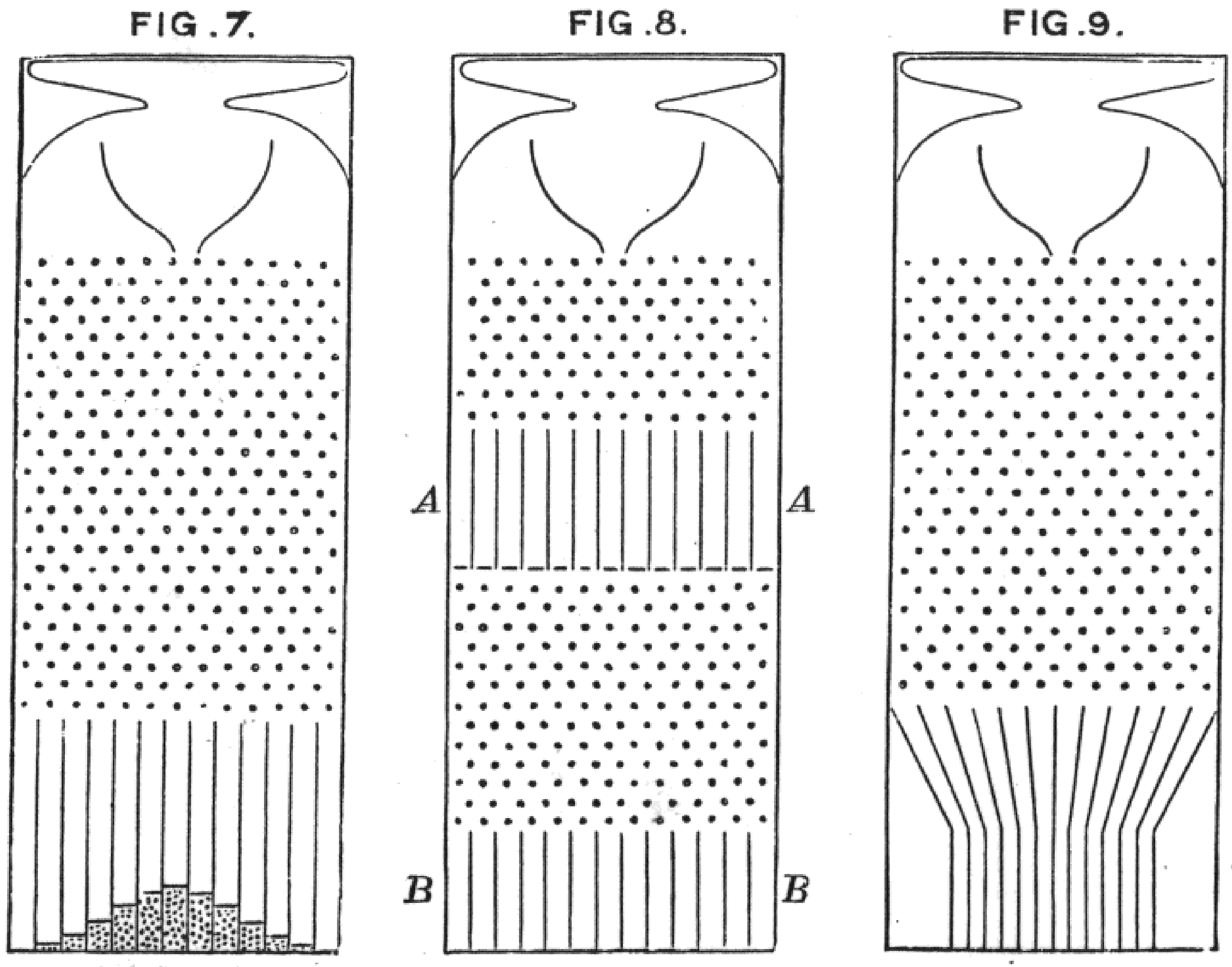
Climate forecast:

"We will see 6 active blobs more often in the 2030's."

http://www.nhc.noaa.gov/archive/2008/graphics/al09/loop_5W.shtml

The Galton Board (Galton 1889)

(quincunx)



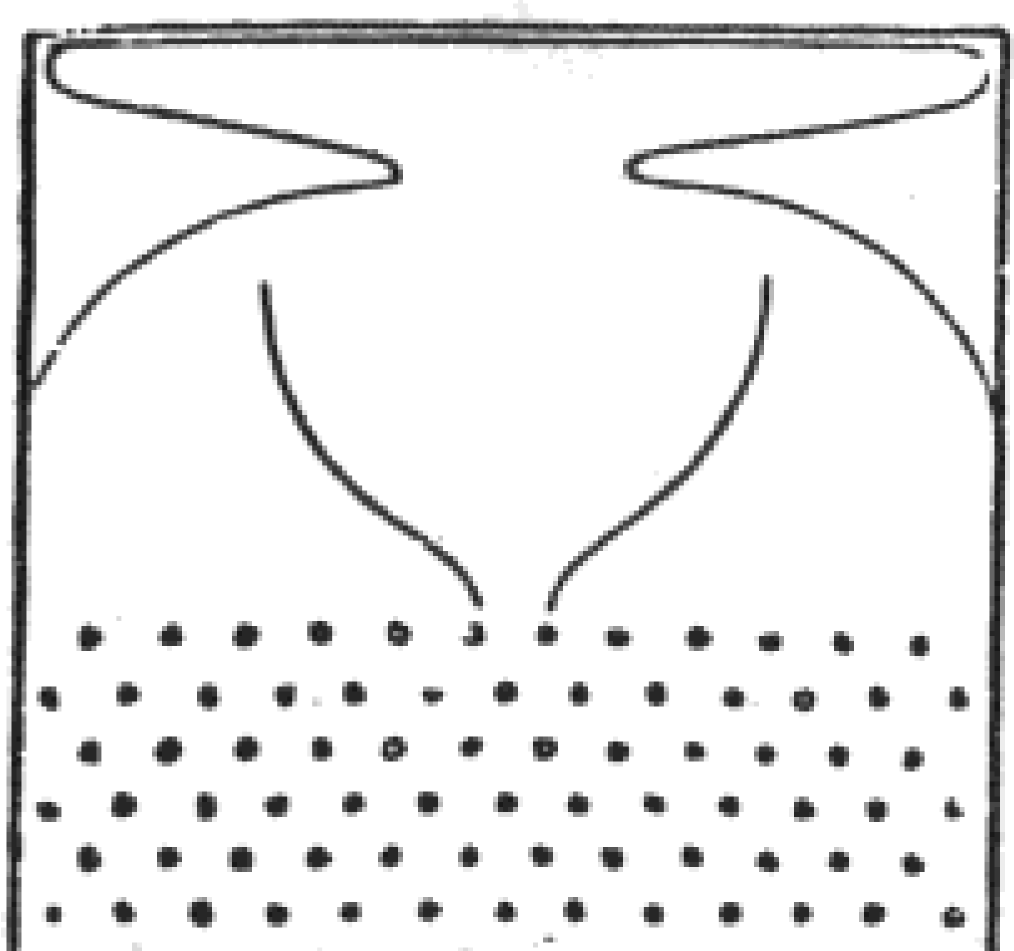
Each pellet has a 50/50 chance of going to the right (left) of each nail.

A mathematical result which is easier to match if you pour the shot in all at the same time…

The Galton Board (Galton 1889)

(quincunx)

FIG. 7.



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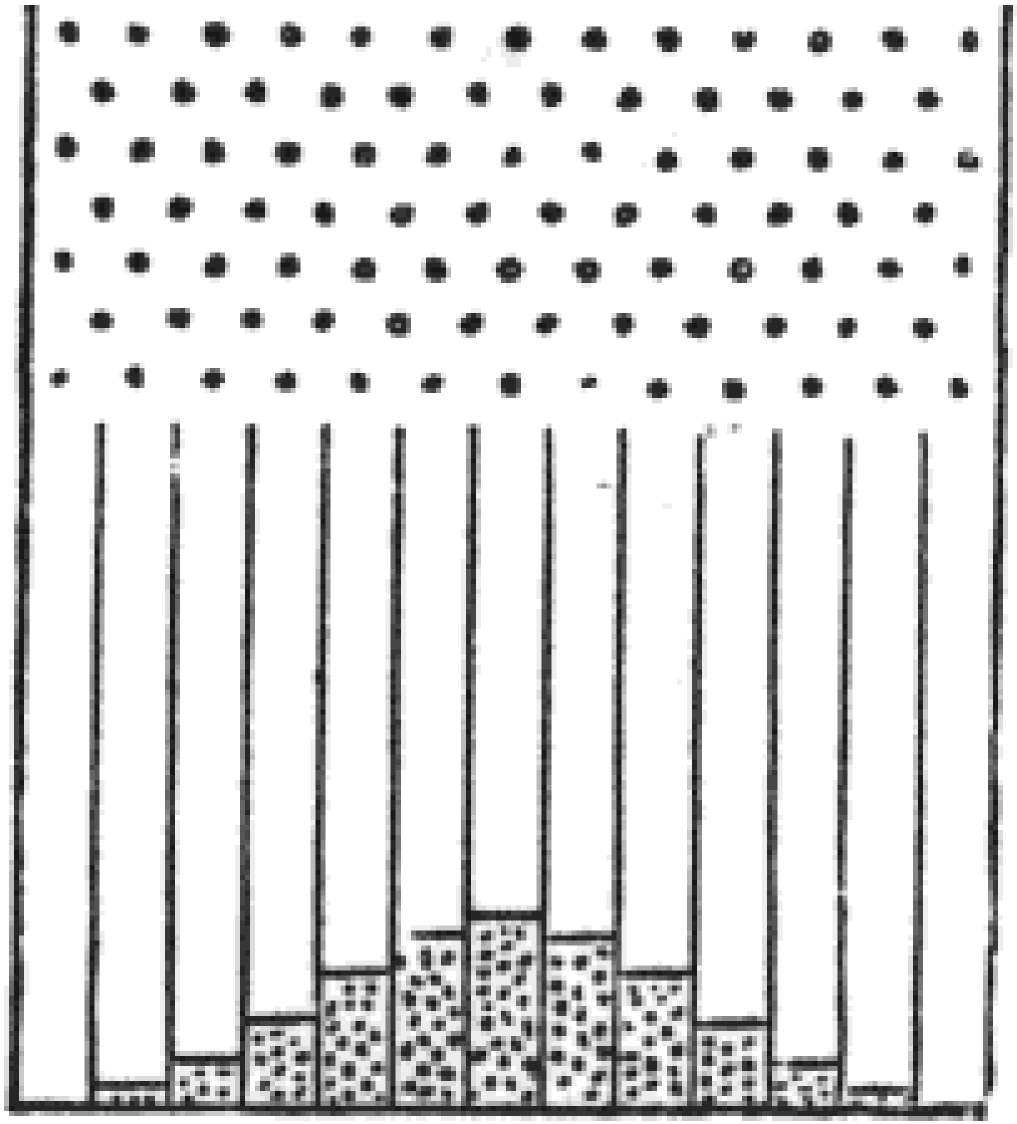

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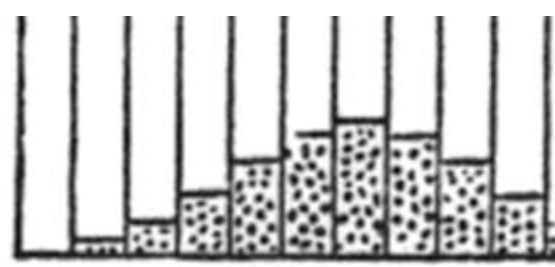


The NAG Board

(Not A Galton Board 2000)
150th Birthday of RMS

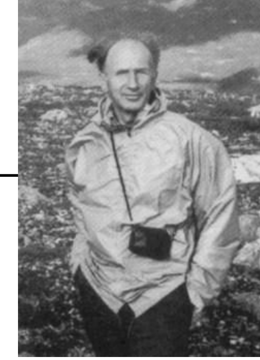
Enter Ensembles

How might ensembles help us understand uncertainty? Consider the Not A Galton (NAG) Board.

In the NAG board, probability forecasting corresponds to predicting with a collection (ensemble) of golf balls…

Ensembles inform us of uncertainty growth *within our model!*
(Telling us about the next golf ball.)

Diversity is not Uncertainty



Ensembles inform us of uncertainty growth *within our model!*

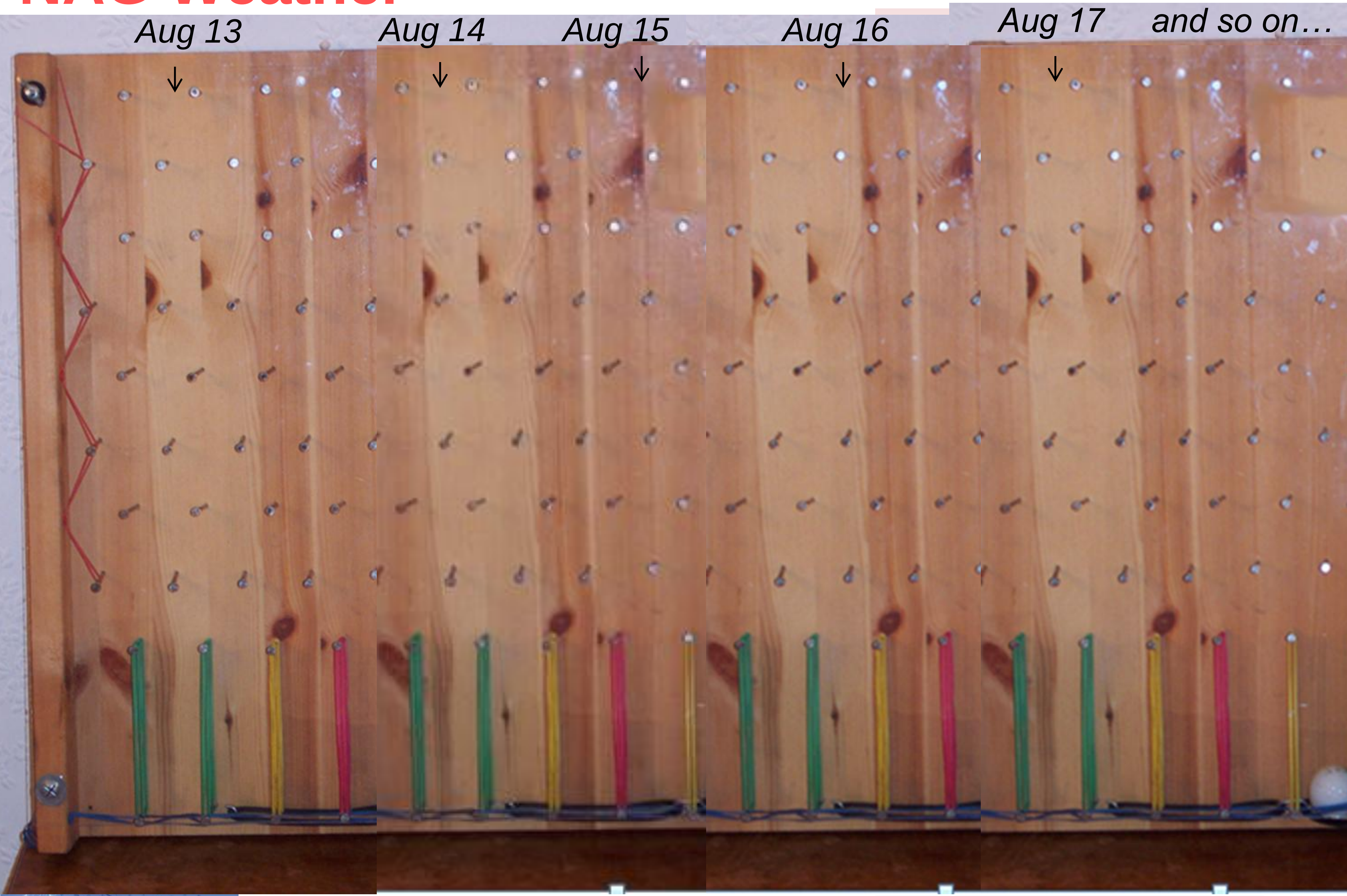
But reality is not a golf ball…

… reality is a red rubber ball.

What exactly does the distribution of 1024 golf balls tell us about the one (and only) red rubber ball?

While we never see similar initial states, we can still learn from our mistakes!(in this weather-like case)

NAG Weather



Science can anticipate surprises beyond of model-land

Interpreting even *weather-like* distributions is a challenge!

Climate predictions require extrapolating out of the observed archive: into the known-to-be-different (?fluid?) unknown.

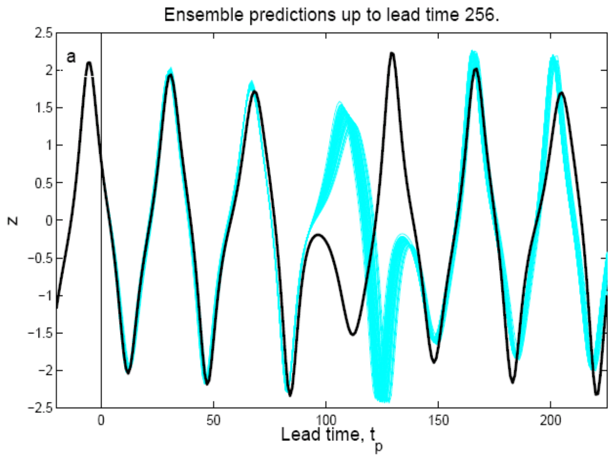
Scientific insight can help.

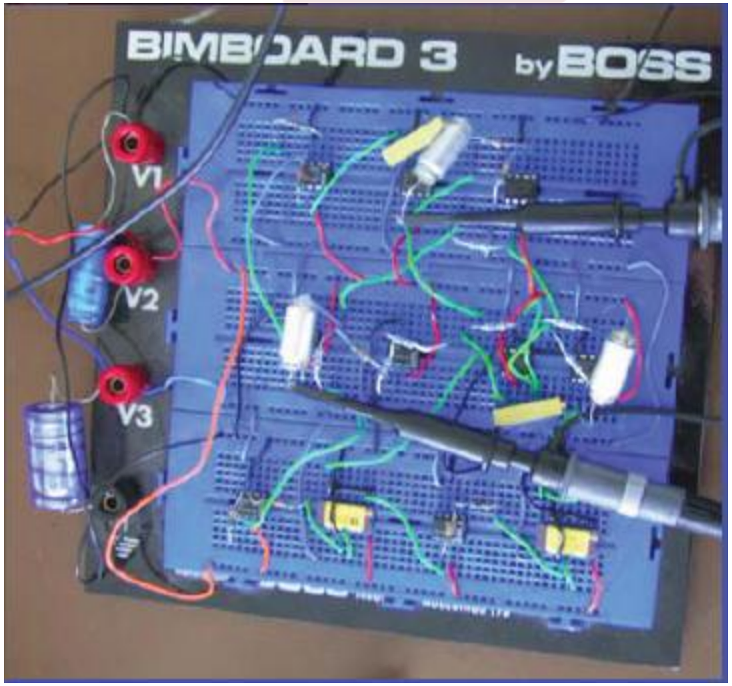
But the best we can hope for is sensible, consistency *in distribution* between our models (“the details do not matter”).

And to anticipate “**Big Surprises**”

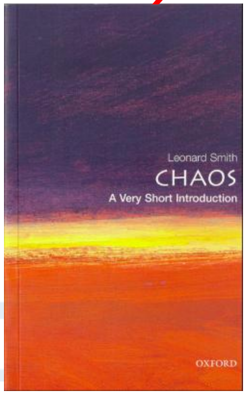
Probability Forecasts: “Simple” “chaotic” Physical System

Model 1





A Big Surprise in the Moore-Spiegel Circuit (by Reason Machette)



Probability Forecasts: "Simple" "chaotic" Physical System

Model 1

Model 2

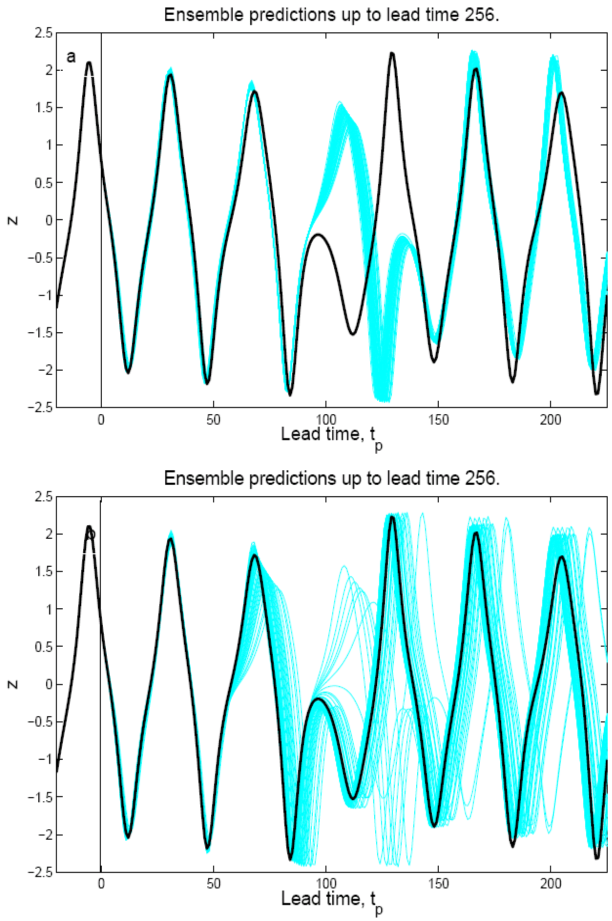
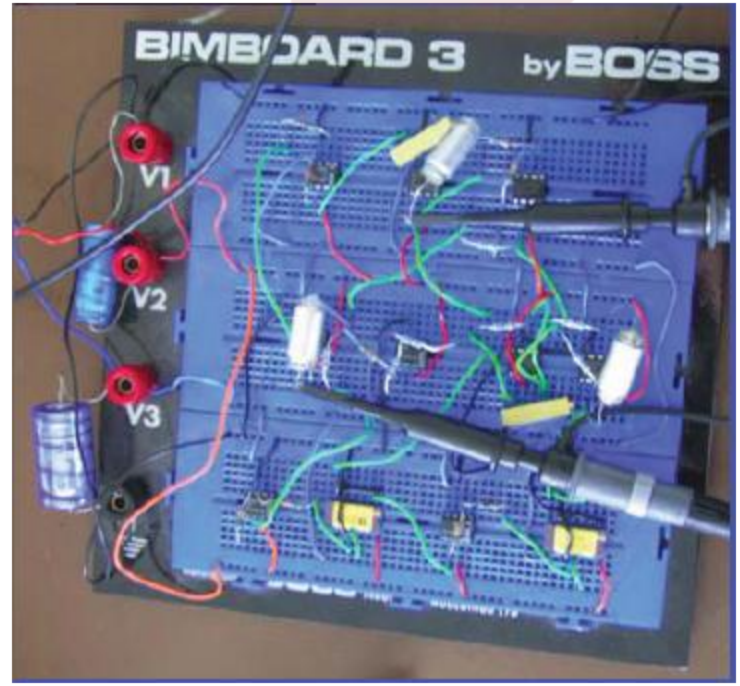
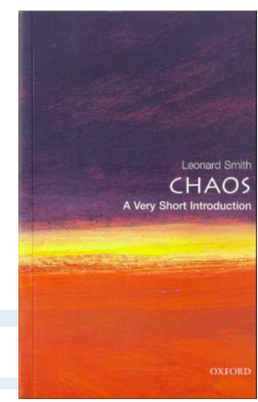


Figure 7: Ensemble predictions using (a) model 1 and (b) model 2. The



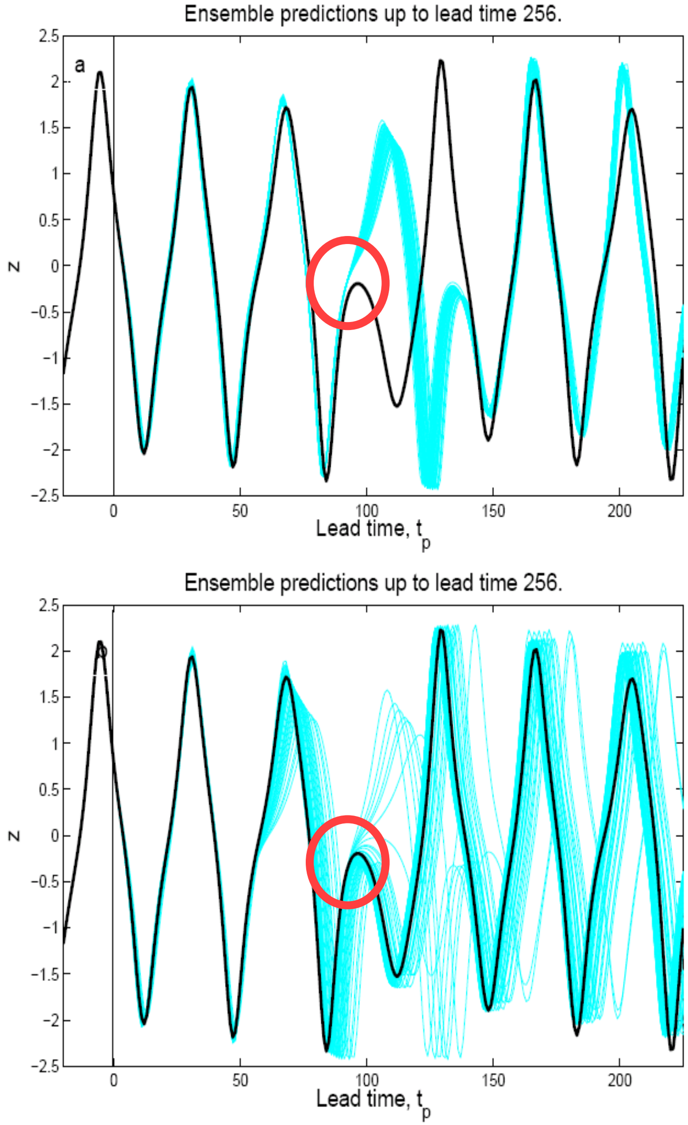


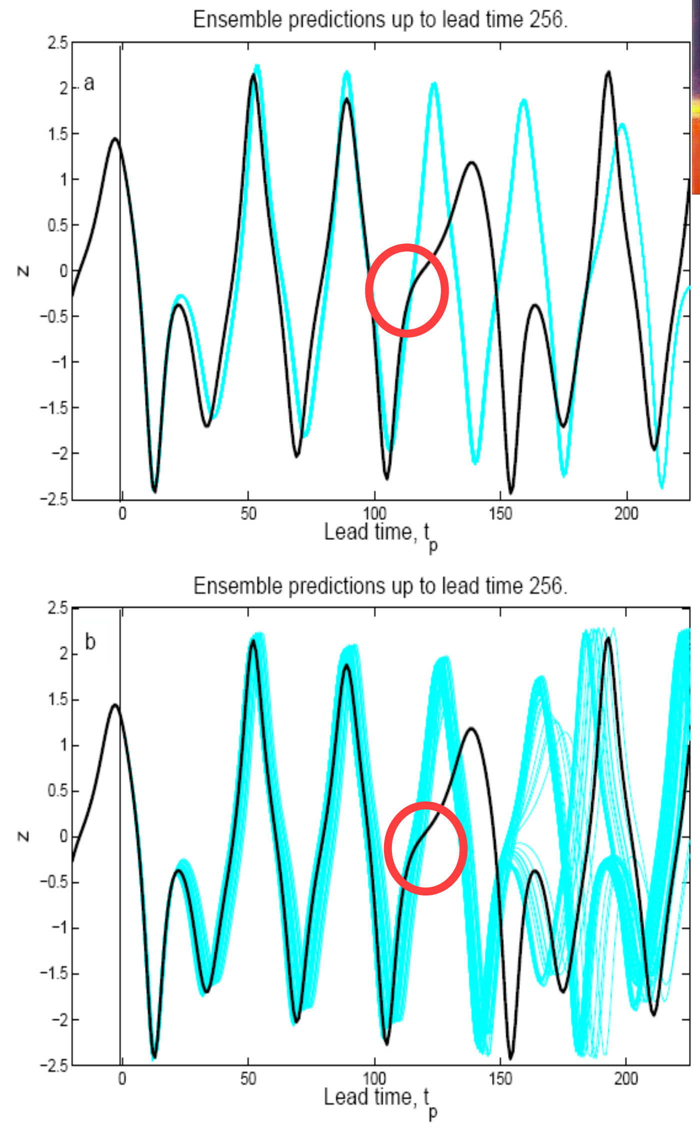
Big Surprise in the Moore-Spiegel Circuit (by Reason Machette)

One Initial State — Another Initial State

Model 1

Model 2





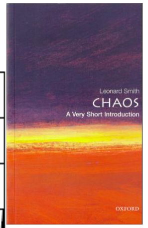


Figure 7: Ensemble predictions using (a) model 1 and (b) model 2. The 2: Ensemble predictions using (a) model 1 and (b) model 2.

“Accurate interpretation is the real deficiency” Fitzroy

Claim: **(implication)**

The difficulty is not initial conditions (no “chaos” fix)

The difficulty is not parameter values (no

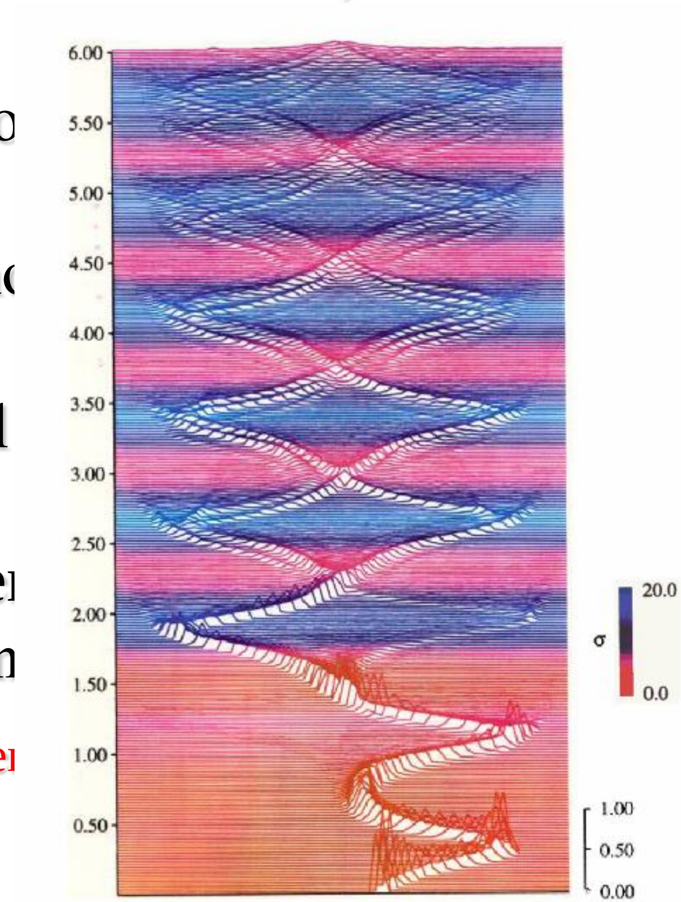
(empirically vacuous)

The difficulty is not determinism (n

The difficulty is not within today’s model

The difficulty is not with the policy make
probabiities when “we” tell them they can

In what year did climate prediction move beyond unde ?



Smith (2002) Chaos and Predictability in *Encyc Atmos Sci*

“Accurate interpretation is the real deficiency”

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VOLUME 83, NUMBER 21 PHYSICAL REV

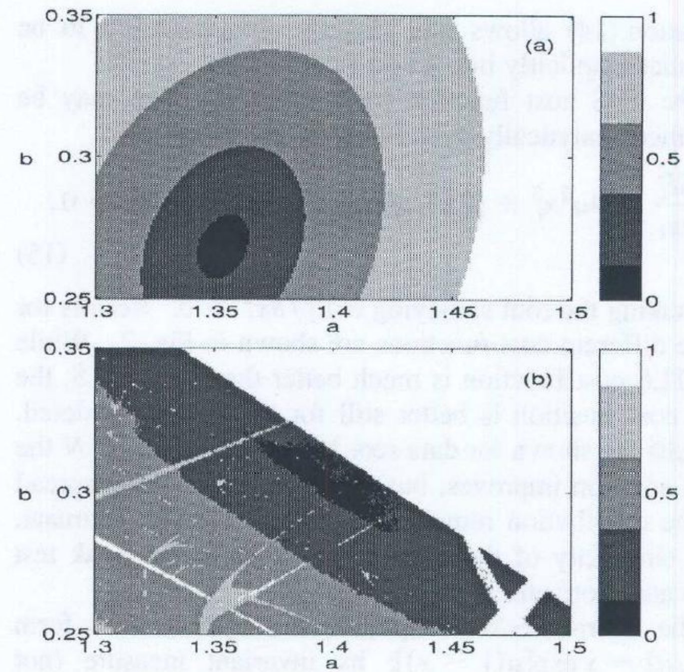


FIG. 4. Value of cost function in parameter space for a 2D delay reconstruction of the Hénon map for $a_0 = 1.4$, $b_0 = 0.3$, $N = 500$, and a noise level of 0.05: (a) C_{LS} and (b) C_{ML}.

“Accurate interpretation is the real deficiency”

Claim: **(implication)**

The difficulty is not initial conditions (no “chaos” fix)

The difficulty is not parameter values (no “stochastic physics” fix)

(empirically vacuous)

The difficulty is not determinism (no “stochastic” fix)

The difficulty is not within today’s model class (no Bayesian fix)

The difficulty is not with the policy makers (they only “need” probabilities when “we” tell them they can have probabilities.)

All uncertainties are scientifically interesting: but the Relevant Dominant Uncertainty (RDU) needs to be placed in the face of the decision maker.

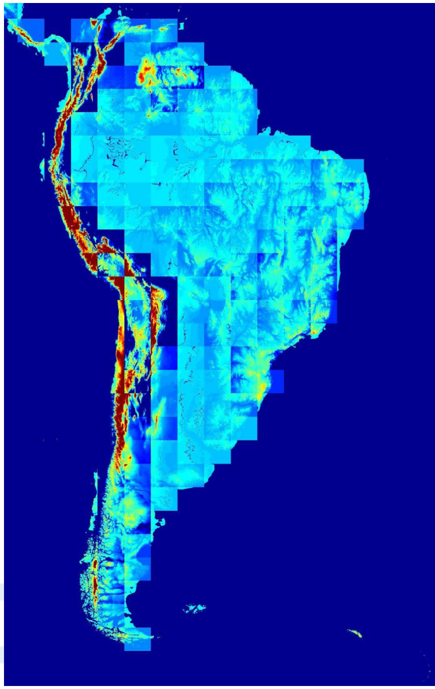
Communicating the Relevant Dominate Uncertainty

No scientist is admired for failing in the attempt to solve problems that lie beyond his competence."

P.D. Medawar

Good science can significantly improve the science in a model without decreasing Prob(BS)

Following Medawar's advice, scientists typically avoid the intractable parts of a problem, even when uncertainties there dominate the overall uncertainty of the simulation.



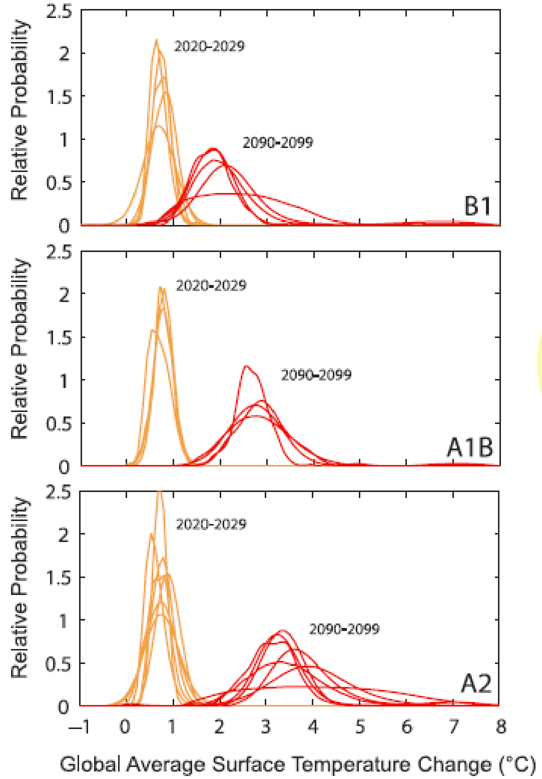
Clarifying the uncertainty most relevant to the decision maker, in terms of *dominating the uncertainty in the outcome whether well modelled or not*, would aid the use of projections in decision support.

Alternatives better than the probability of a big surprise would be welcome.

A report of Working Group I of the Intergovernmental Panel on Climate Change

Summary for Policymakers

PROJECTIONS OF SURFACE TEMPERATURES



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Global Climate Projections

The effects of uncertainty in the knowledge of Earth system processes can be partially quantified by constructing ensembles of models that sample different parametrizations of these processes. However, some processes may be missing from the set of available models, and alternative parametrizations of other processes may share common systematic biases. Such limitations imply that distributions of future climate responses from ensemble simulations are themselves subject to uncertainty (Smith, 2002), and would be wider were uncertainty due to structural model errors accounted for.

797

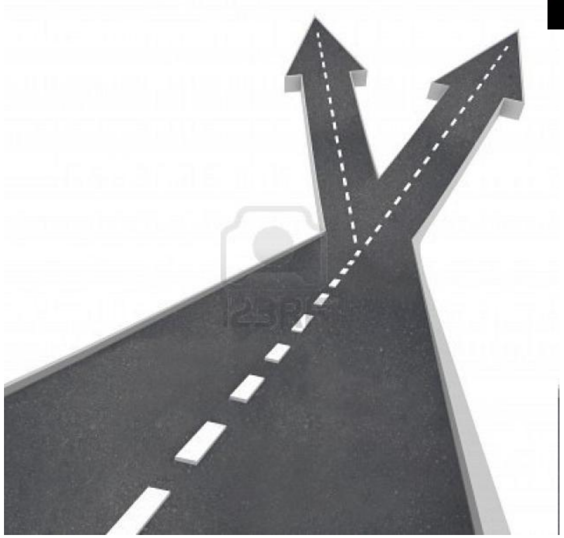
This risk of overconfidence is well known and well founded.

Not necessarily wider: they may narrow and shift under better models…

One would be exposed to significant losses/costs if distributions which are not decision-support relevant probabilities are interpreted as if they were.

The IPCC itself might say this a bit louder/earlier: What space-time scales are realistic as a function of leadtime? (Focus on robust, but discuss inappropriate use.)

Presentations of Uncertainty



Probability forecasts or something more complicated?

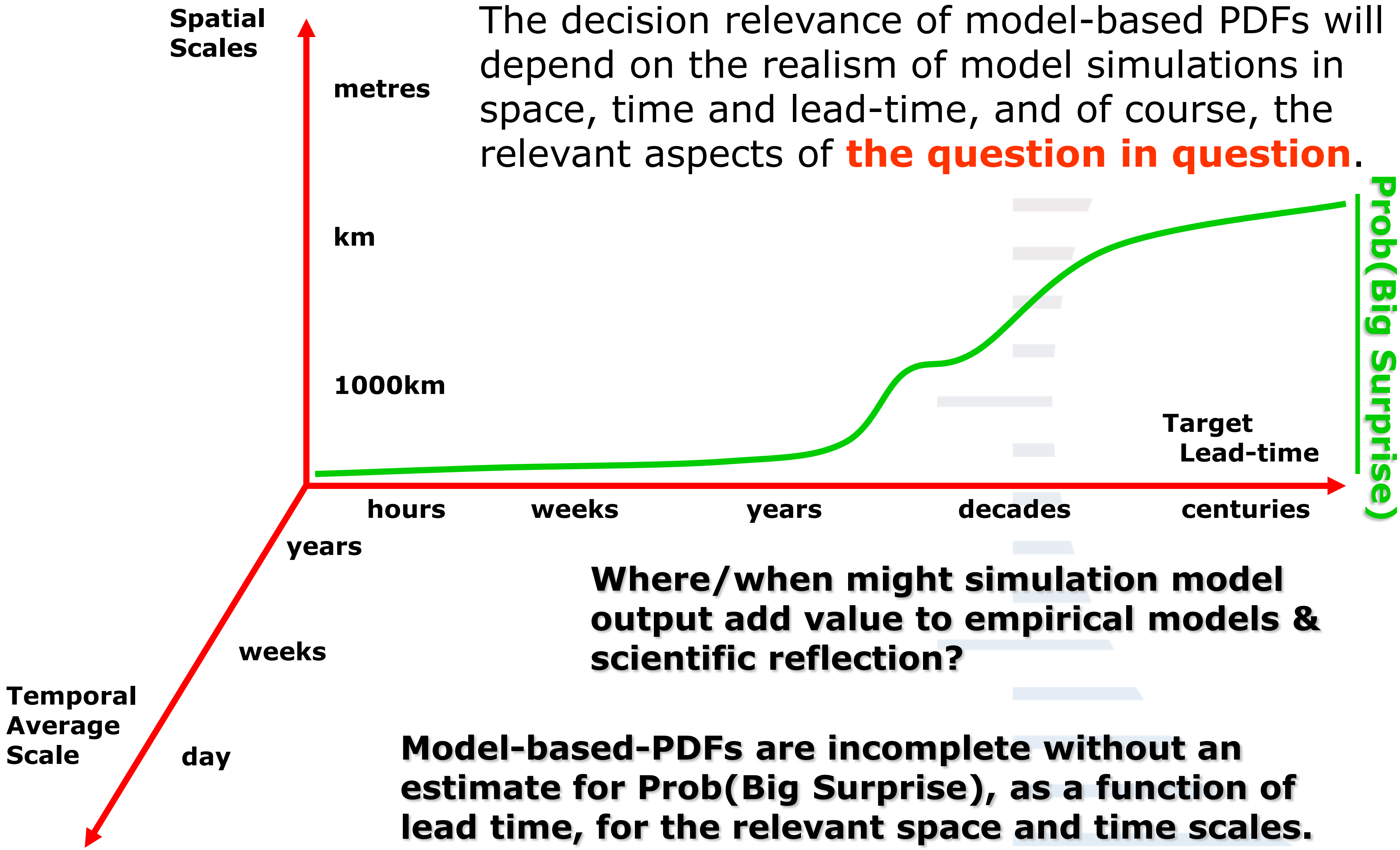
http://www.123rf.com/photo_12073667_the-road-ahead-of-you-splits-into-two-directions-with-arrows-pointing-left-and-right-so-you-must-mak.htm

http://www.mistymountaingraphics.com/gallery6.html

http://en.wikipedia.org/wiki/Thomas_Bayes

Very schematic schematic of Prob(Big Surprise) "surface".

The decision relevance of model-based PDFs will depend on the realism of model simulations in space, time and lead-time, and of course, the relevant aspects of **the question in question**.



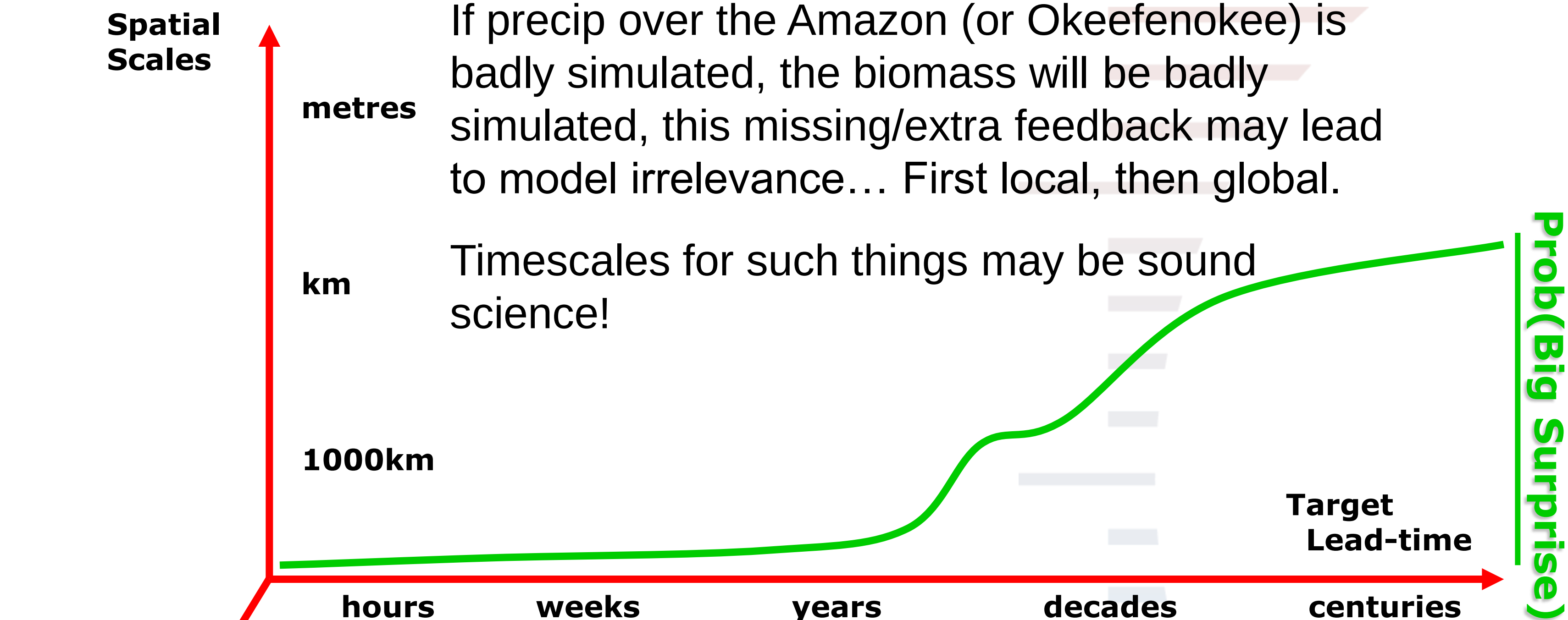
Where/when might simulation model output add value to empirical models & scientific reflection?

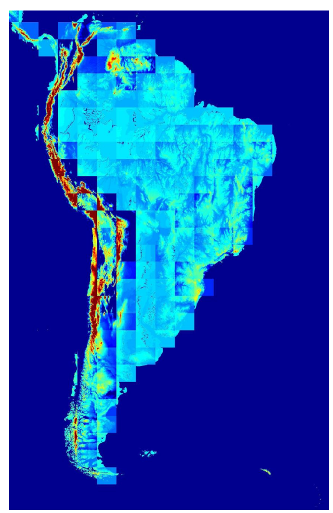
Model-based-PDFs are incomplete without an estimate for Prob(Big Surprise), as a function of lead time, for the relevant space and time scales.

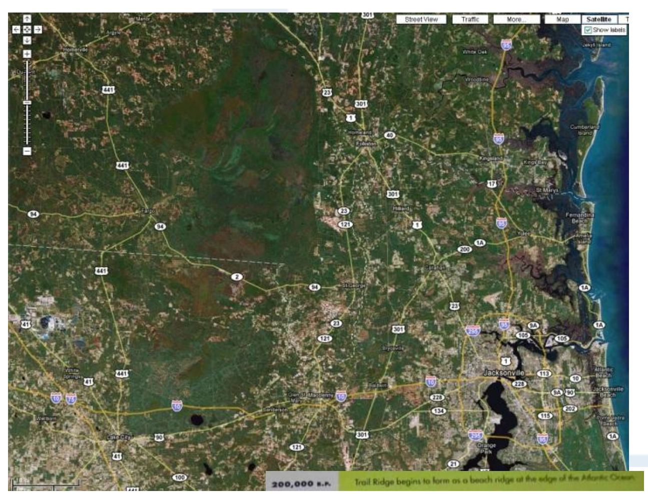
Model-based probability forecasts are incomplete without a quantitative measure of the likelihood of model irrelevance.

If precip over the Amazon (or Okeefenokee) is badly simulated, the biomass will be badly simulated, this missing/extra feedback may lead to model irrelevance… First local, then global.

Timescales for such things may be sound science!



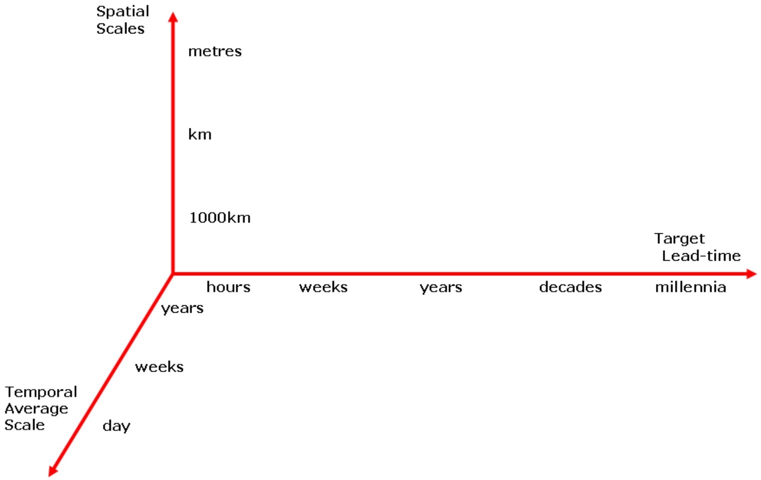


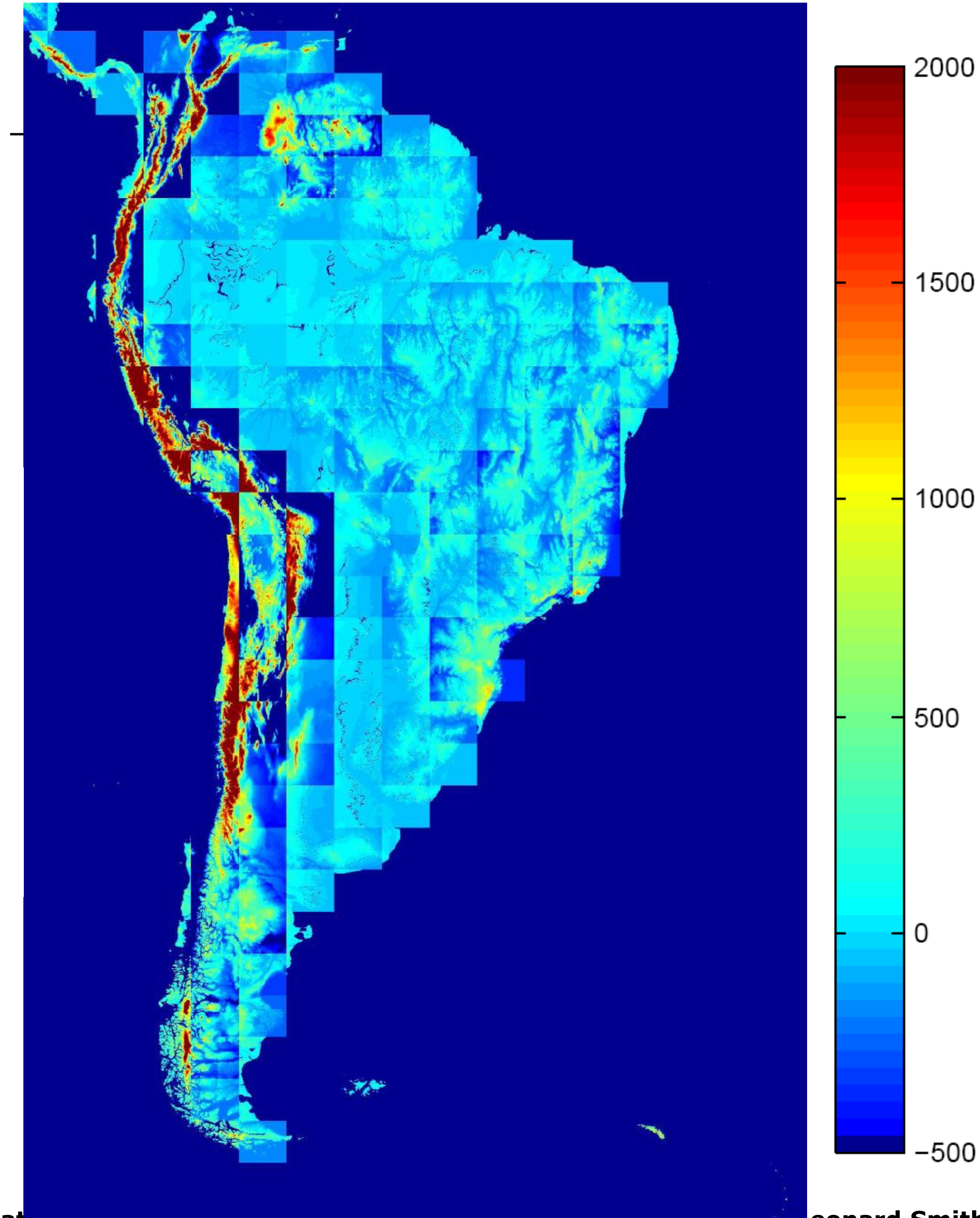


QUIZ: Missing mountains

And long term feedbacks (bio-feed backs, albedo, …)

At what lead times do inadequacies in downstream flow (or precipitation) result in feedbacks with beyond local impacts?





What is a “Big Surprise”?

Big Surprises arise when something our simulation models cannot mimic turns out to have important implications for us.

Often we can identify cases where we are “leaking probability” when a fraction of our model runs explore conditions which we know they cannot simulate realistically. (Science can warn of “known unknowns” even when the magnitude remains unknown)

Big Surprises invalidate (not update) model-based probability forecasts, the I in $P(x|I)$ (Arguably “Bayes” does not apply as this is not a question of probability theory.)

How might we better communicate the inadequacy as well as imprecision?

Financial and energy market assumptions

Condition explicitly on the euro not collapsing [Bank of England].

Provide subjective estimates of the probability that the model is misinformative in the future [P(BS)].

Refuse to issue a quantitative forecast, probability or otherwise [UK ML].

How did we get to zipcode PDFs from here?

(It would be interesting to trace how the idea that climate models could provided quantitative insight came about.)

Because of the various simplifications of the model described above, it is not advisable to take too seriously the quantitative aspect of the results obtained in this study. Nevertheless, it is hoped that this study not only emphasizes some of the important mechanisms which control the response of the climate to the change of carbon dioxide,

The Effects of Doubling the CO_2 Concentration on the Climate of a General Circulation Model[1]

Syukuro Manabe and Richard T. Wetherald

Geophysical Fluid Dynamics Laboratory/NOAA, Princeton University, Princeton, N.J. 08540

(Manuscript received 6 June 1974, in revised form 8 August 1974)

It is important to stress that our approach to the specification of discrepancy can only be expected to capture a subset of possible structural modelling errors and should be regarded as a lower bound. This is because models tend to share certain common systematic biases, which can be found in diverse elements of climate including multiannual means of basic quantities such as surface temperature,

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

A methodology for probabilistic predictions of regional climate change from perturbed physics ensembles

J.M Murphy, B.B.B Booth, M Collins, G.R Harris, D.M.H Sexton and M.J Webb

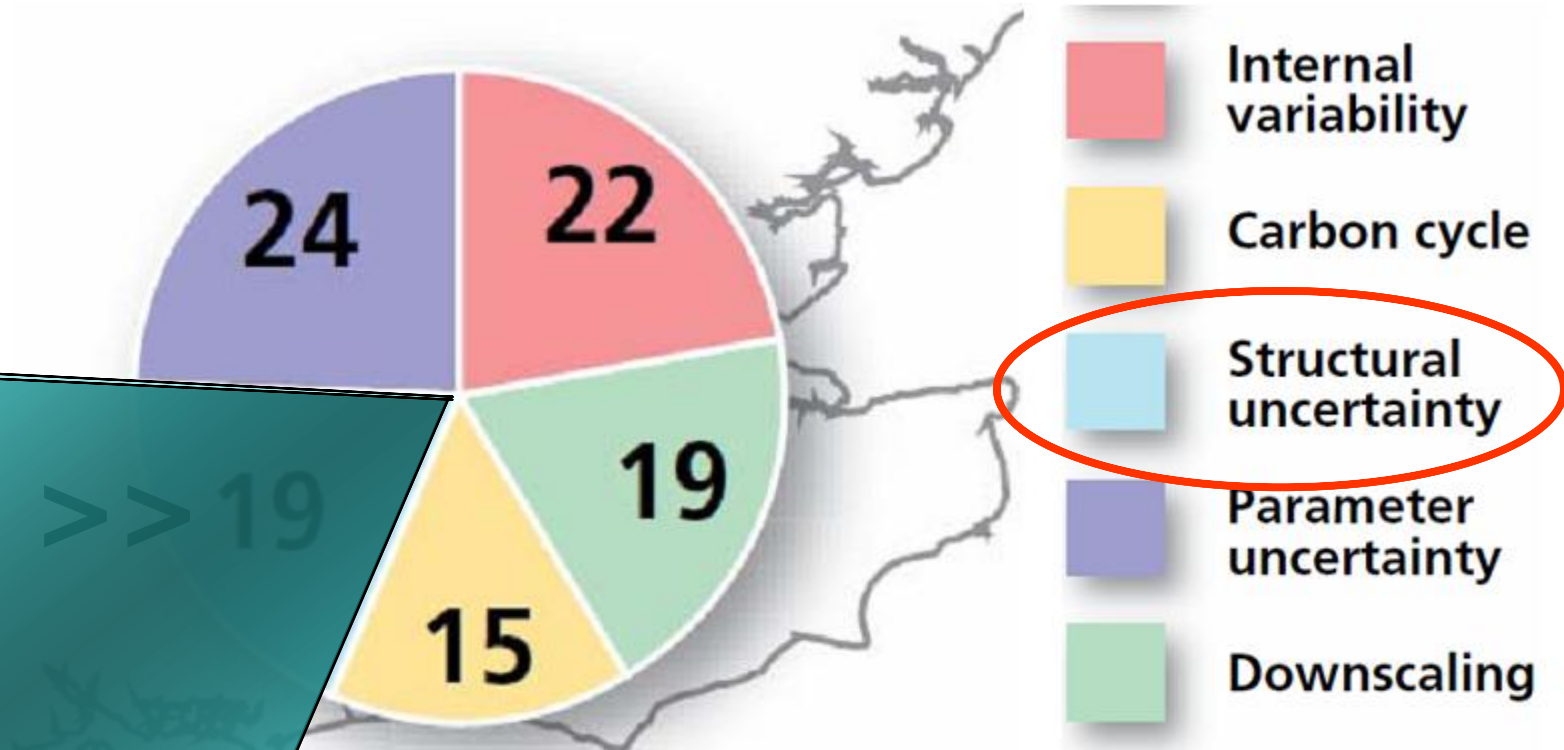
Phil. Trans. R. Soc. A 2007 **365**, 1993-2028
doi: 10.1098/rsta.2007.2077

Why do these words get lost in the graphics?
(?Was this stressed last week?)

How important are different sources of uncertainty?

Take Home Message: The value of qualitative insight is at risk of being discarded in favour of quantitative mis-information.

- Varies, but typically no single source dominates.



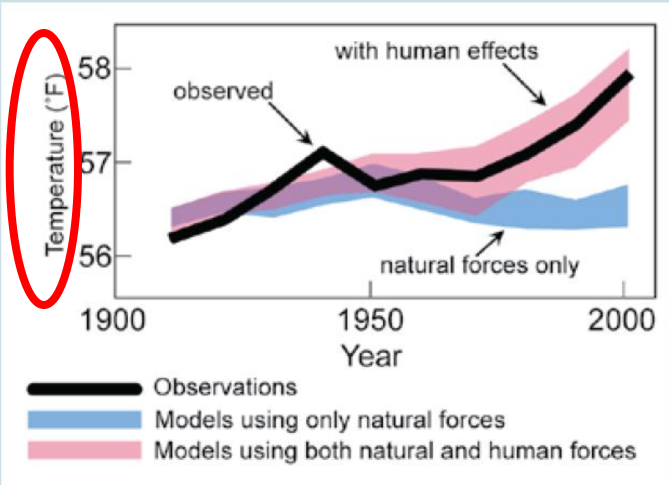
How might we avoid misuse in this case?

Uncertainties in winter precipitation changes for the 2080s relative to 1961-90, at a 25km box in SE England

Source: Met Office

United States Global Change Research Program

Separating Human and Natural Influences on Climate



As the blue band indicates, without human influences, global average temperature would actually have cooled slightly over recent decades. With human influences, it has risen strongly (black line), consistent with expectations from climate models (pink band).

ipcc INTERGOVERNMENTAL PANEL ON climate change WMO UNEP

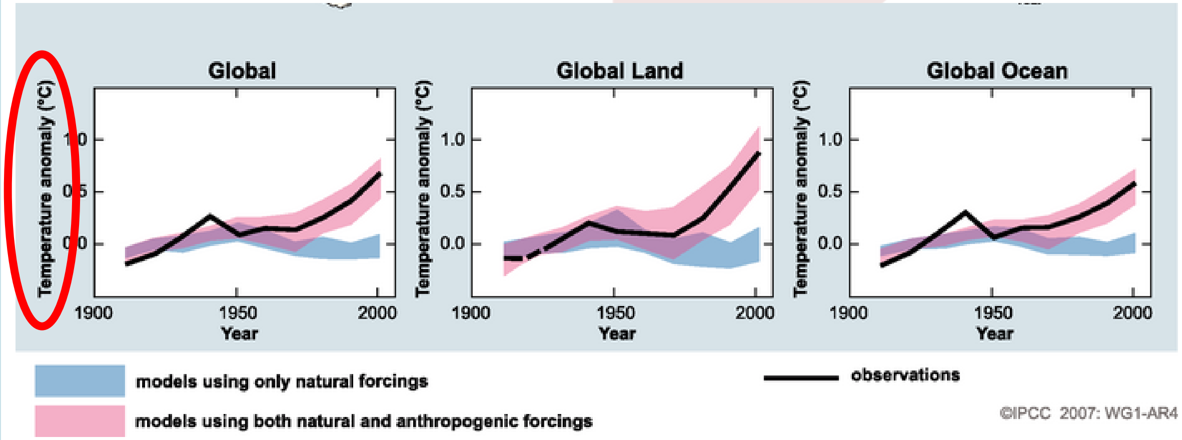


Figure SPM.4. Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906 to 2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901–1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5–95% range for 19 simulations from five climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5–95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings. {FAQ 9.2 Figure 1}

http://www.ipcc.ch/publications_and_data/ar4/wg1/en/figure-spm-4.html

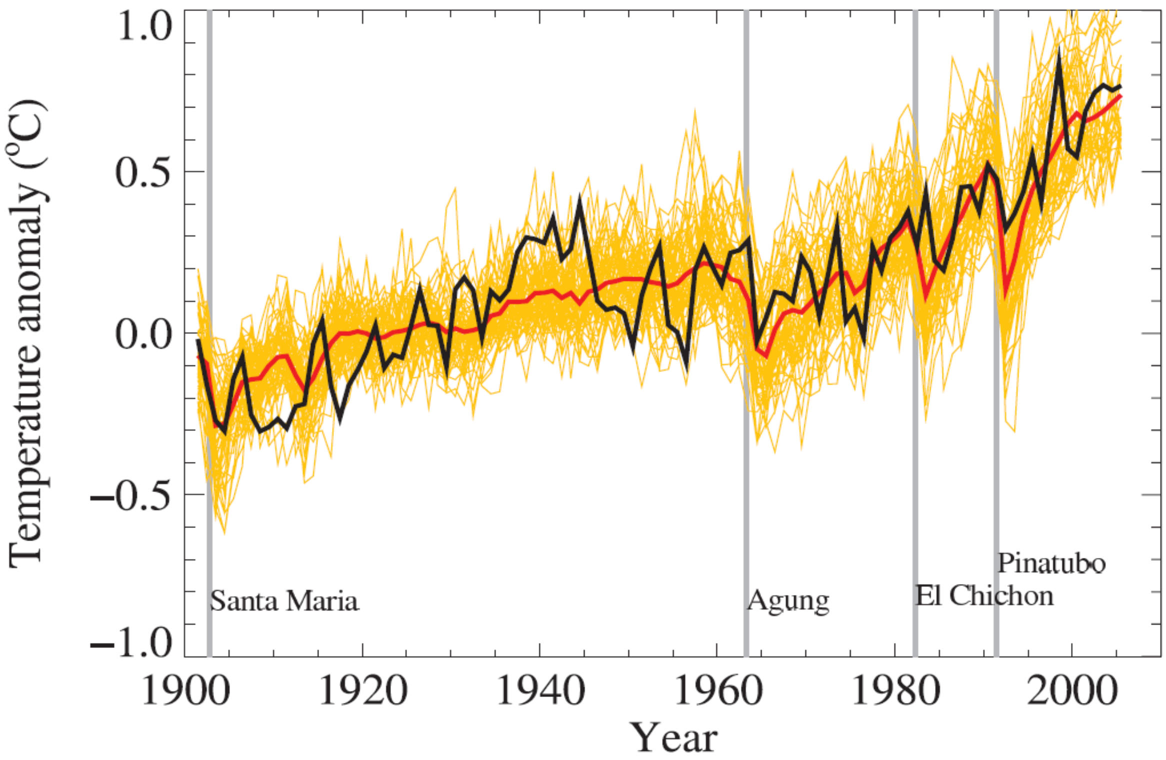
http://www.globalchange.gov/images/cir/pdf/20page-highlights-brochure.pdf

Statistical post-processing: These are anomalies, not temperatures. Parameterization of cloud formation is a bit of a distraction when we are missing two kilometre tall walls of rock…

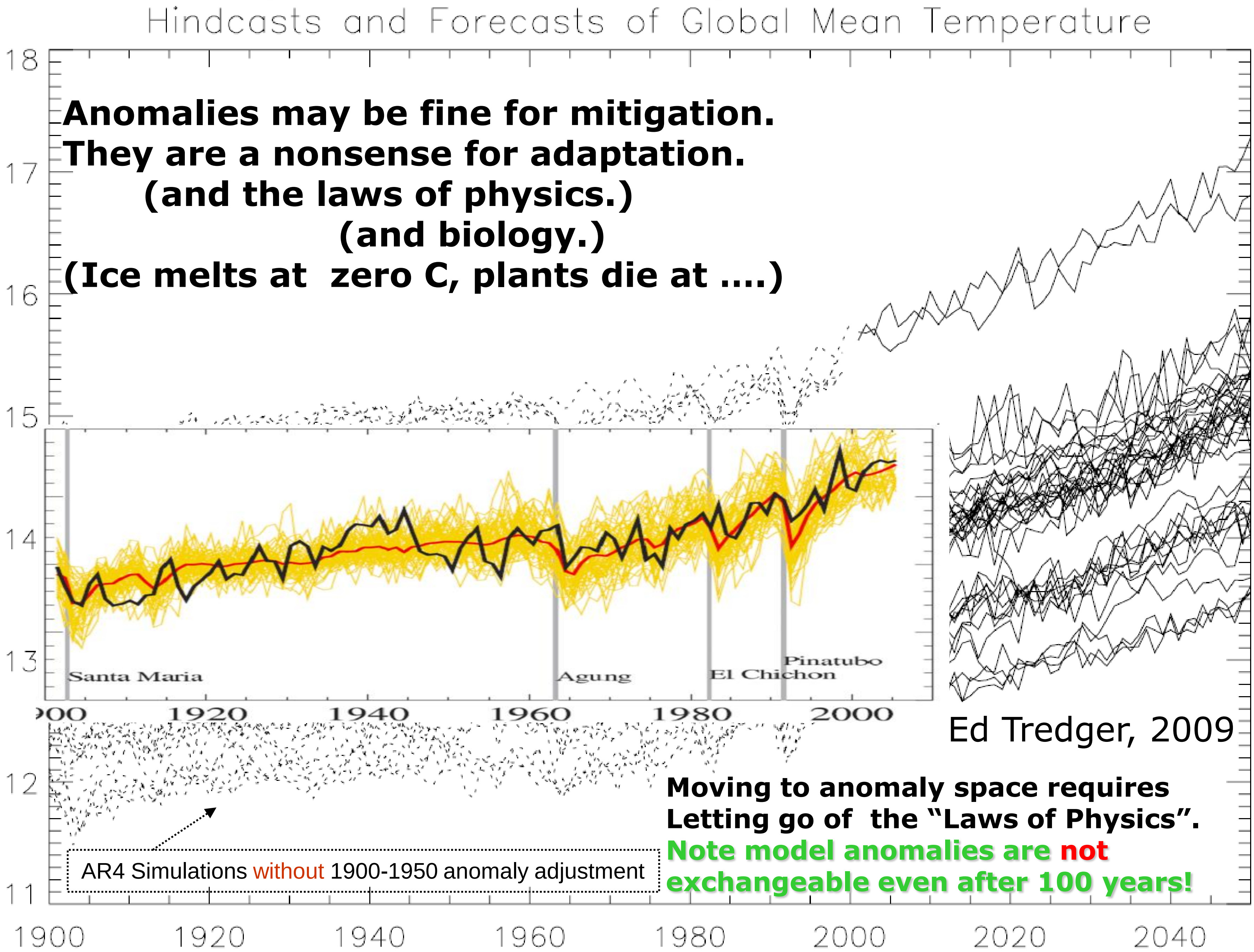
Climate in Practice: In-sample examples.

This graph tends to leave the impression they do rather well.

FAQ 8.1, Figure 1. *Global mean near-surface temperatures over the 20th century from observations (black) and as obtained from 58 simulations produced by 14 different climate models driven by both natural and human-caused factors that influence climate (yellow). The mean of all these runs is also shown (thick red line). Temperature anomalies are shown relative to the 1901 to 1950 mean. Vertical grey lines indicate the timing of major volcanic eruptions. (Figure adapted from Chapter 9, Figure 9.5. Refer to corresponding caption for further details.)*



While systematic errors are larger than the observed effect



Where should decision makers draw the line?

Climate models are based on well-established physical principles and have been demonstrated to reproduce observed features of recent climate (see Chapters 8 and 9) and past climate changes (see Chapter 6). There is considerable confidence that Atmosphere-Ocean General Circulation Models (AOGCMs) provide credible quantitative estimates of future climate change, particularly at continental and larger scales. Confidence in these estimates is higher for some climate variables (e.g., temperature) than for others (e.g., precipitation). This summary highlights areas of progress since the TAR:

Page 591

A report of Working Group I of the Intergovernmental Panel on Climate Change

Clear, plain spoken discussion of what today's models *cannot* capture quantitatively would be of great value.

Probabilistic Forecasts: IPCC Sixty-Forty Rule

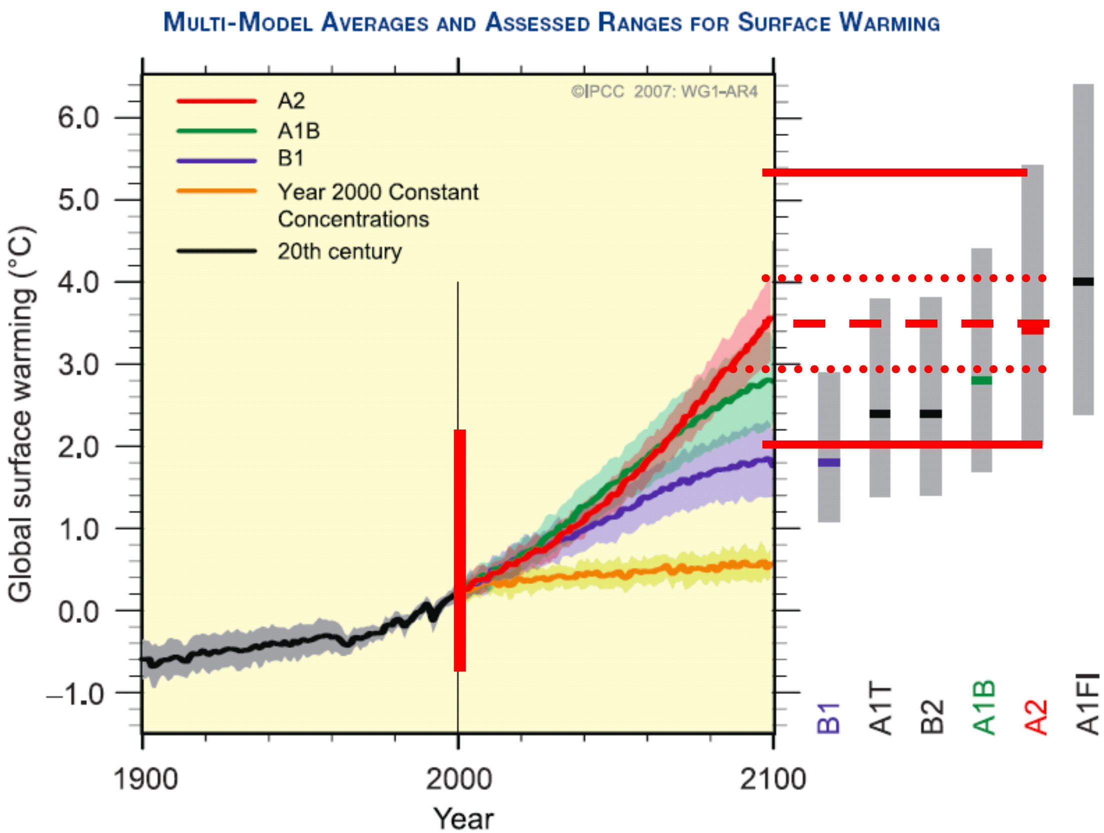


Figure SPM.5. *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the* **likely** *range assessed for the six SRES marker scenarios. The assessment of the best estimate and* **likely** *ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}*

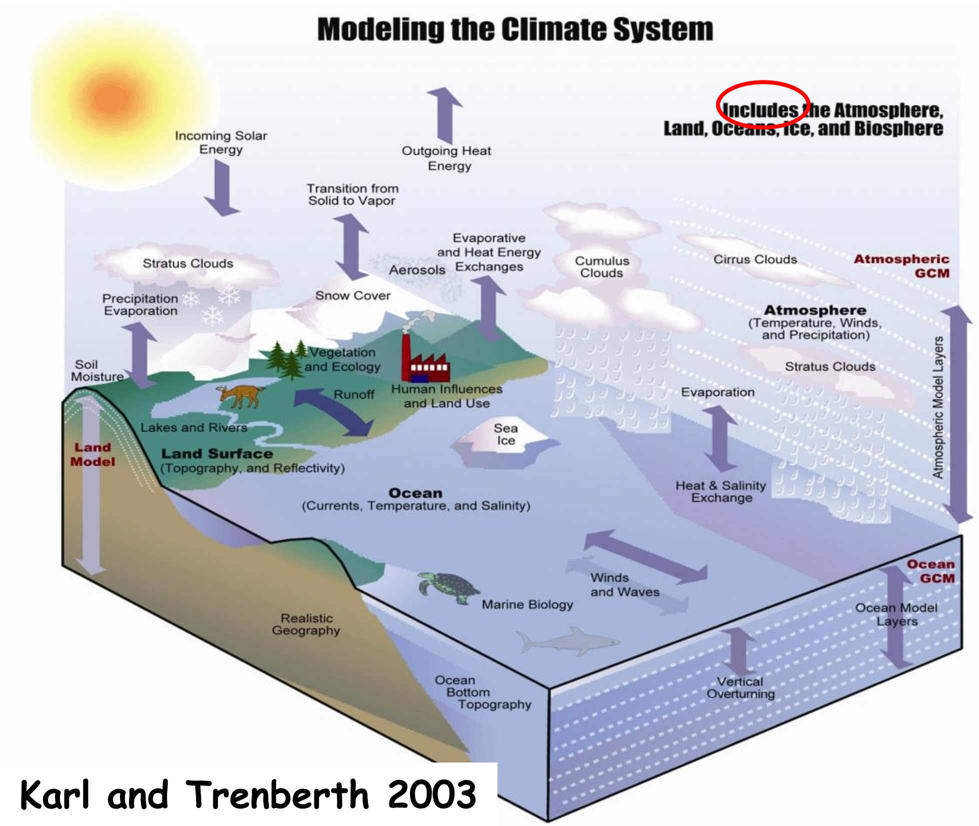
– The conditional forecasts (projections) are the grey bars (right); they differ from the ensemble distributions left and centre.

The real concern is that an adequately parameterised process might significantly shift the range.

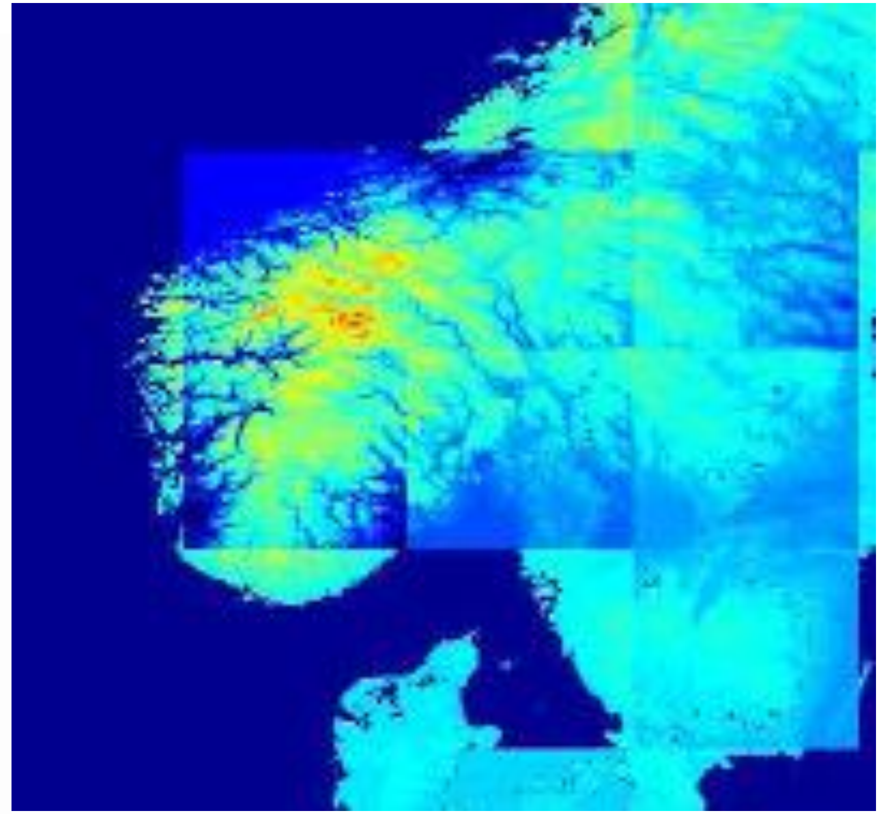
Discussions of broadening imply confidence in the location.

The IPCC rejects the diversity of ensembles directly reflecting the pdf of GMT, it follows that "downscaling" cannot provide local probabilities.

Climate Models: “Included” vs “realistically simulated”



Karl and Trenberth 2003



A very schematic schematic reflecting phenomena the model “includes”. (Note the turtle)

The detail you see above is what is *missing* in HadCM3: the large squares reflect model grid resolution, the detail reflects the difference between the observed surface height and the model surface height, “constant” within a grid point,

How can we know our simulation models are inadequate?

Science is more than simulations

When does
"Sit and Think" trump
"Simulate and Count"?

Example: When we know moist air must go over or around in (and only in) the real world!

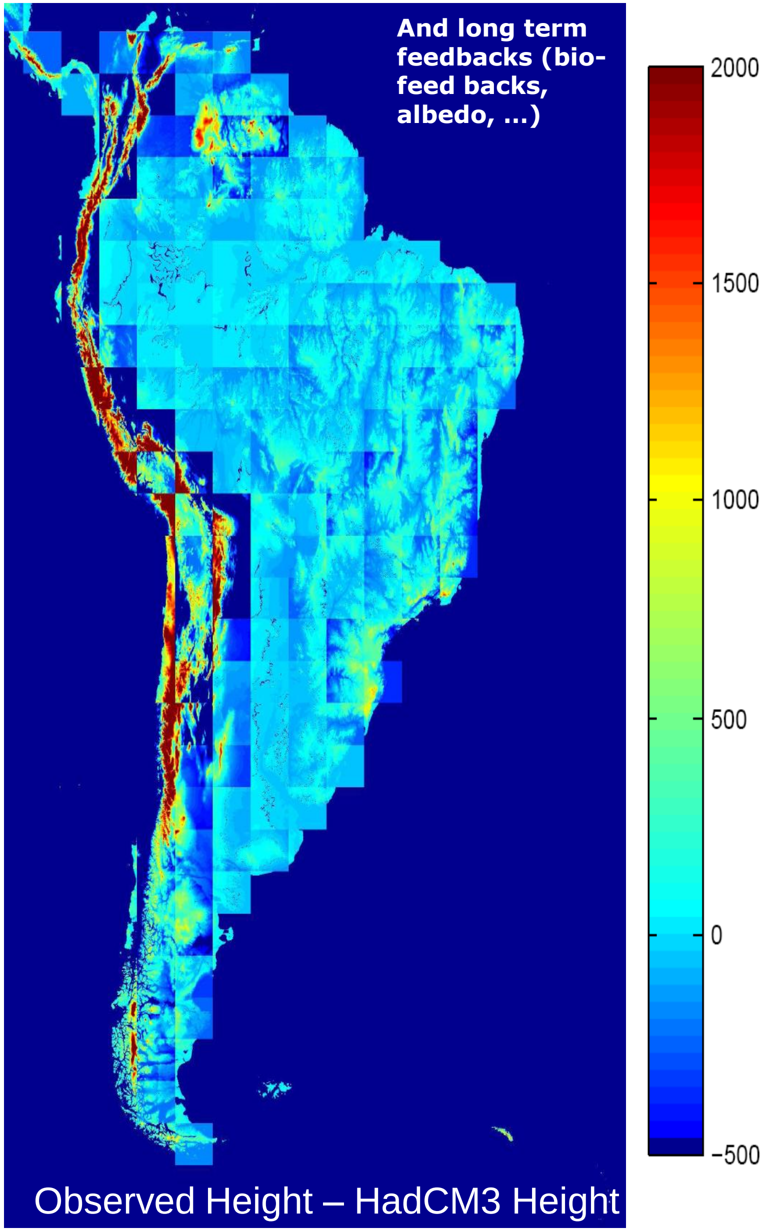
If our models cannot reproduce today's driving meteorological phenomena, can we expect them to get second order feedbacks "well enough"?

One-way coupled regional models *cannot* account for missing physics or inactive feedbacks.

At what lead times do inadequacies in downstream flow (or precipitation) result in feedbacks with beyond local impacts? alter extremes? &c?

Why not provide Prob(Big Surprise) with lead time?

Missing 2km tall walls of rock!

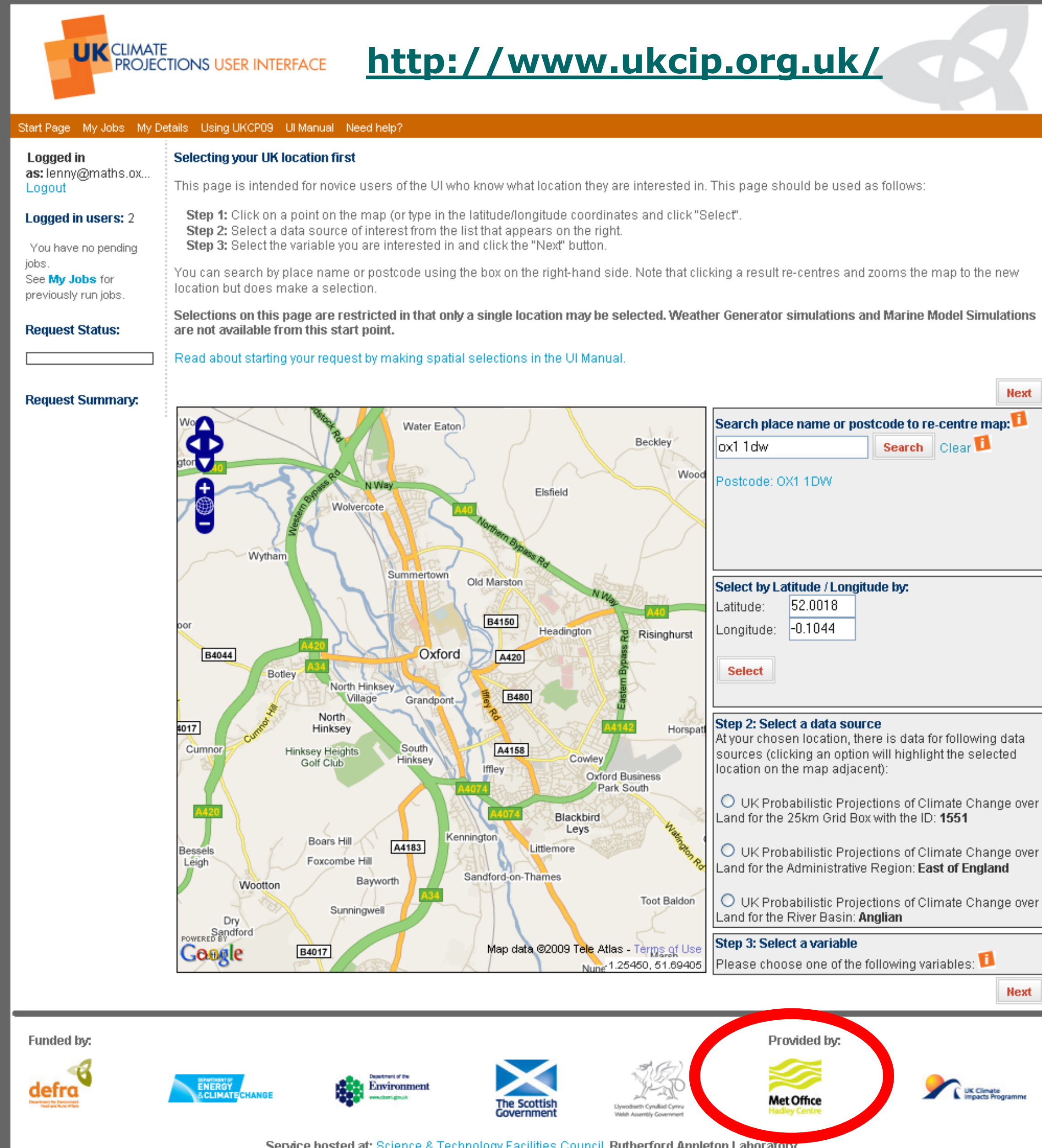


Is it plausible to provide a PDF of hottest or stormiest summer day in 2080's Oxford???

- Future Climate Change Only
- Future Absolute Climate Values

Variable

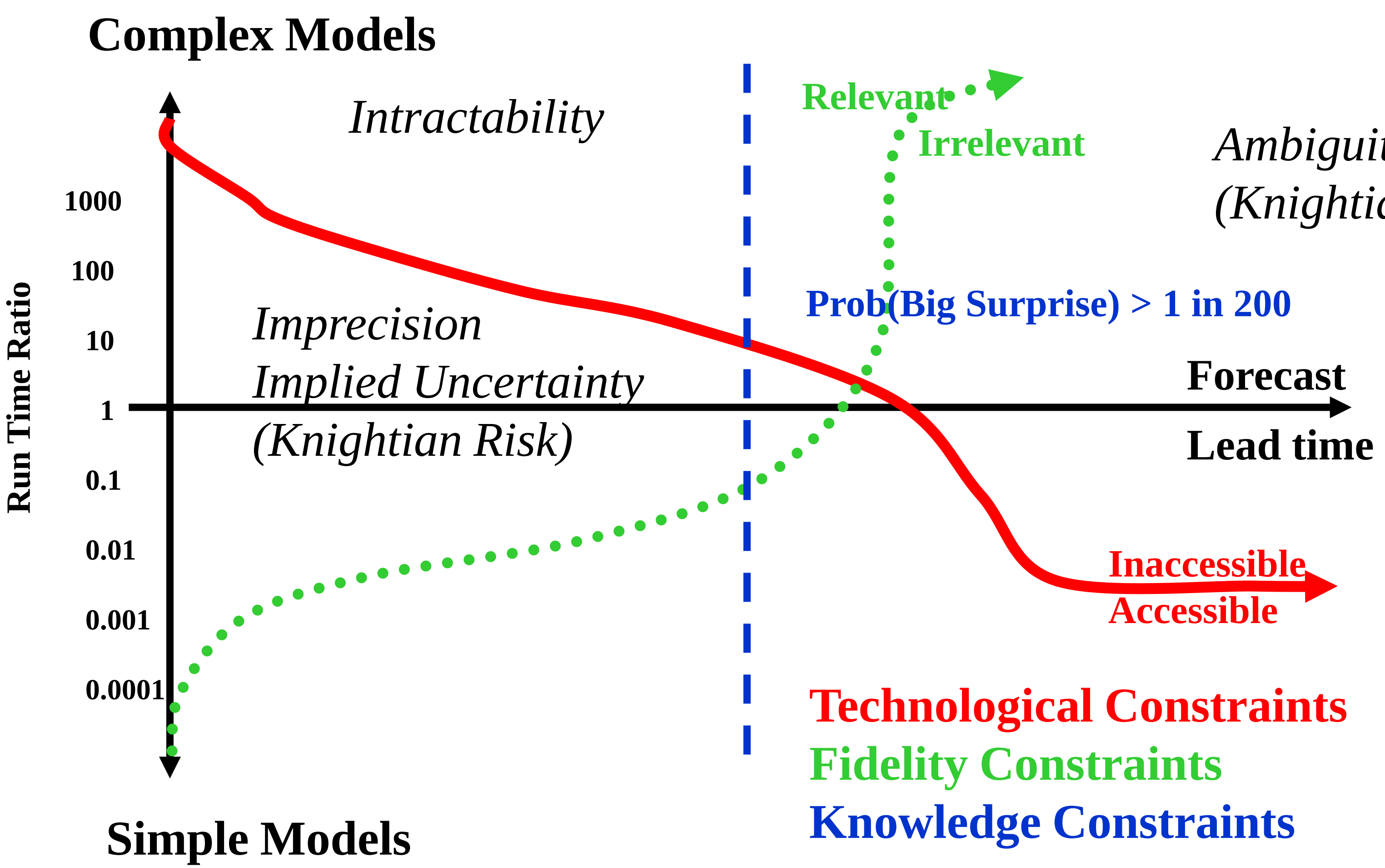
- Change in mean temperature (°C)
- Change in mean daily maximum temperature (°C)
- Change in mean daily minimum temperature (°C)
- Change in temperature of the coolest day (°C)
- Change in temperature of the warmest day (°C)
- Change in temperature of the coldest night (°C)
- Change in temperature of the warmest night (°C)
- Change in precipitation (%)
- Change in precipitation on the wettest day (%)
- Change in mean sea level pressure (hPa)
- Change in total cloud (%)
- Change in relative humidity (%)
- Change in specific humidity (%)
- Change in net surface longwave flux (W m-2)
- Change in net surface shortwave flux (W m-2)
- Change in total downward surface shortwave flux (W m-2)



Smith

The Constraints on Simulation Modelling for Prediction

What are the challenges we face with interpreting model simulations in different regions of this schematic?



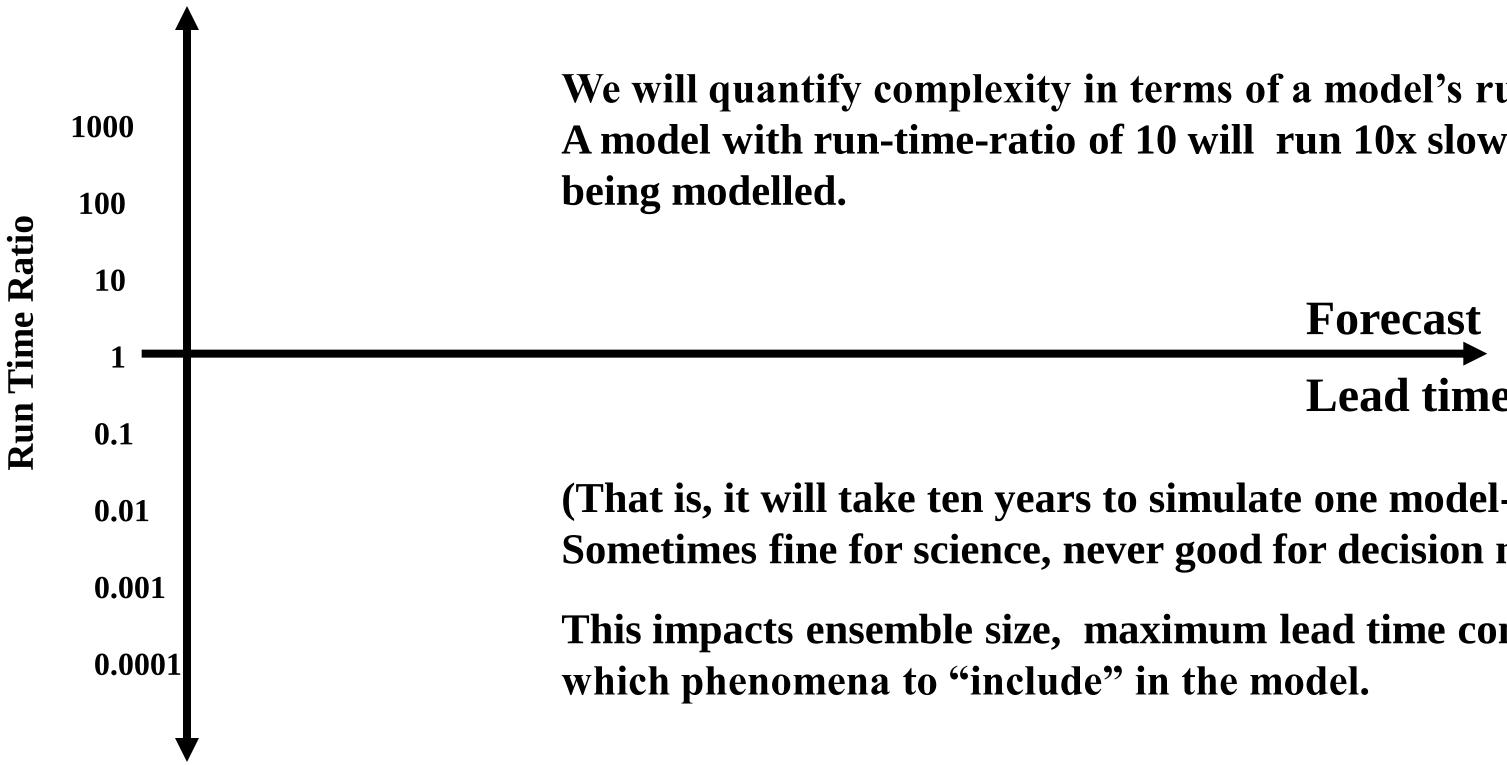
LA Smith & N Stern (2011) Uncertainty in science and its role in climate policy Phil. Trans. R. Soc. A (2011), 369, 1-24.

Leonard Smith

What are you constrained by?

For decision support, the model has to run faster than real time.
The larger the lead time, the fewer ensemble members you can run to examine sensitivity.

Complex Models



We will quantify complexity in terms of a model's run-time-ratio. A model with run-time-ratio of 10 will run 10x slower than the system being modelled.

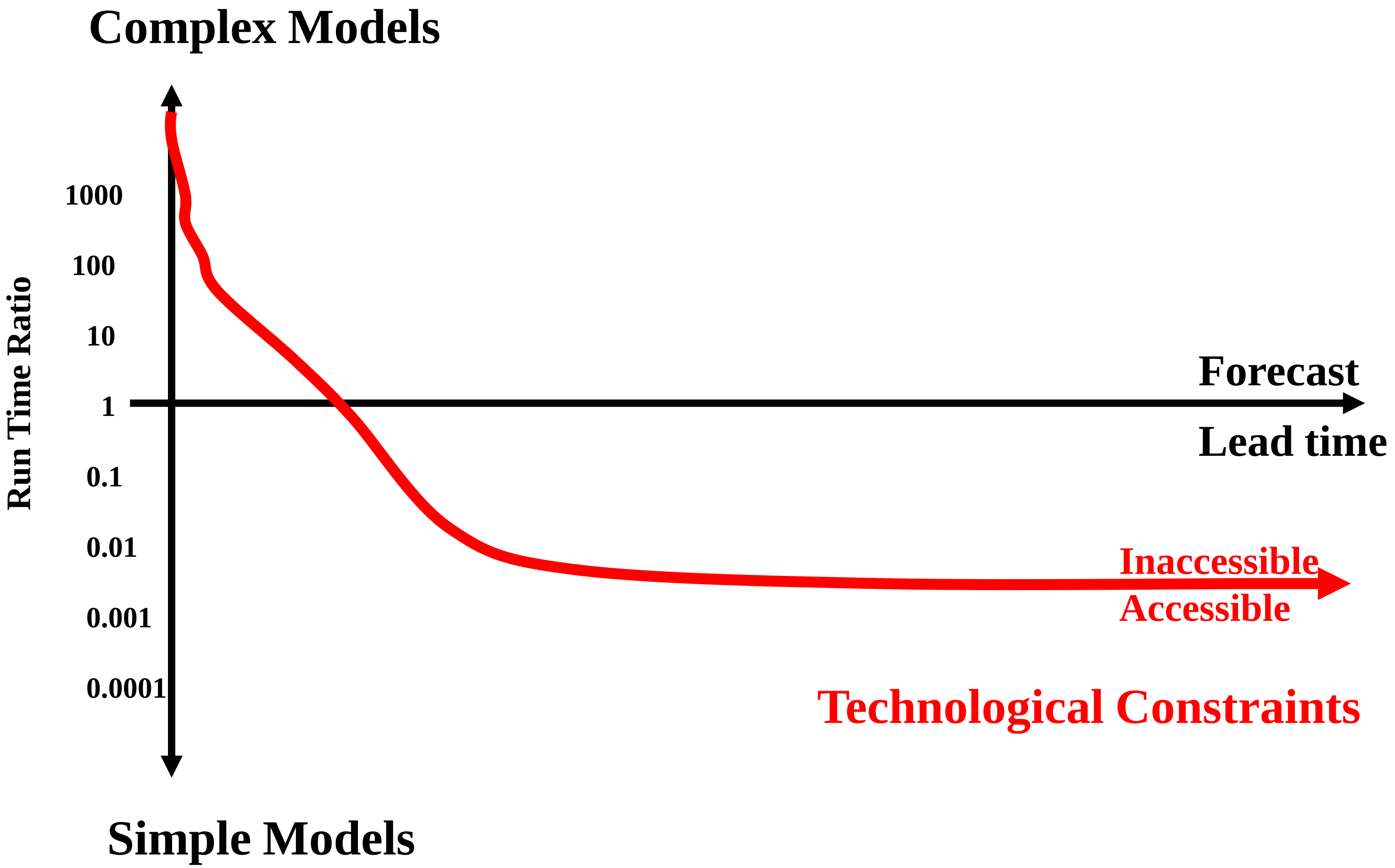
(That is, it will take ten years to simulate one model-year. Sometimes fine for science, never good for decision makers.)

This impacts ensemble size, maximum lead time considered, and which phenomena to "include" in the model.

Simple Models

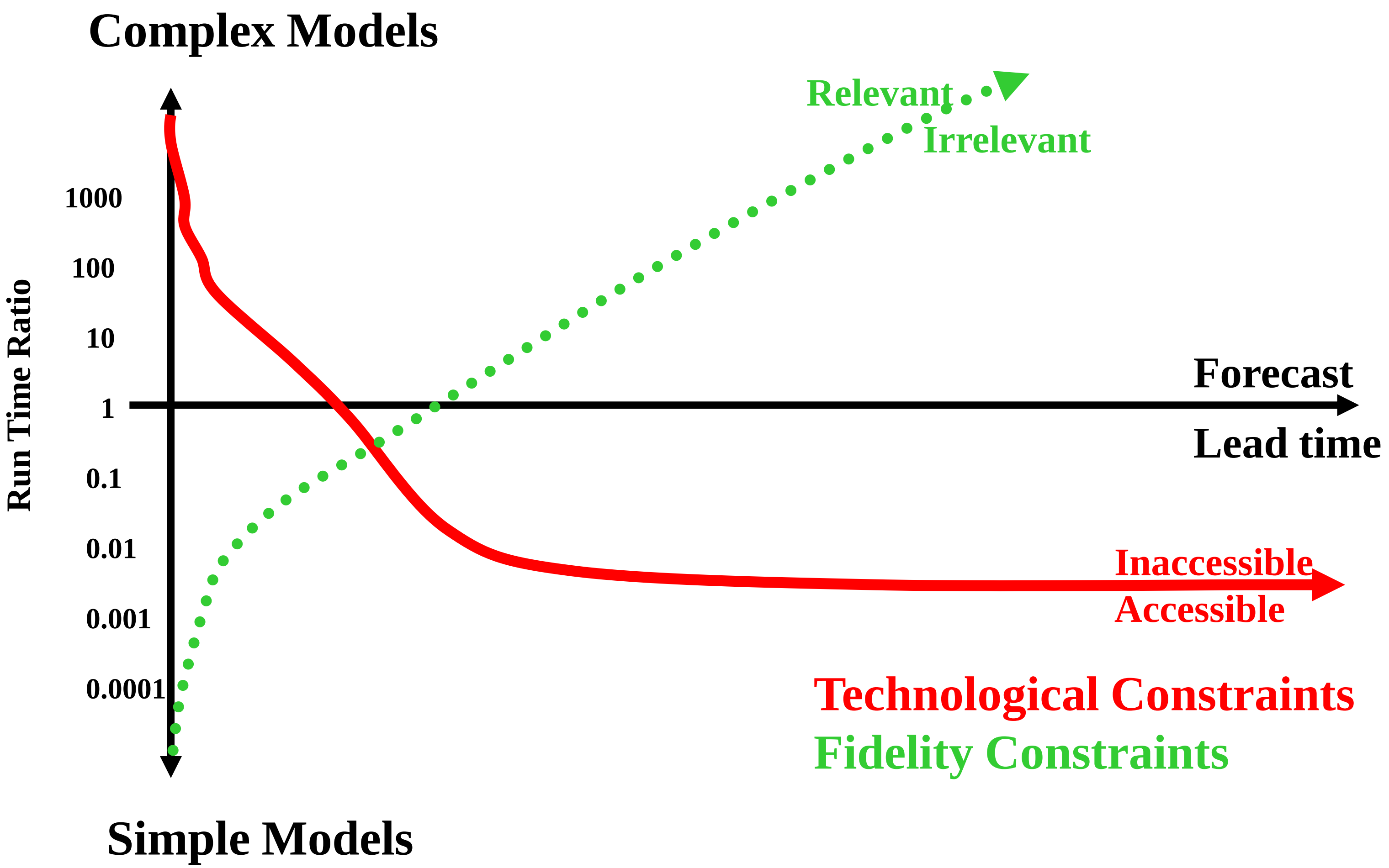
What are you constrained by?

Complex models may not fit in current hardware, even if you know what you would build. And the more complex your model, the fewer "simulation hours" you will have.



What are you constrained by?

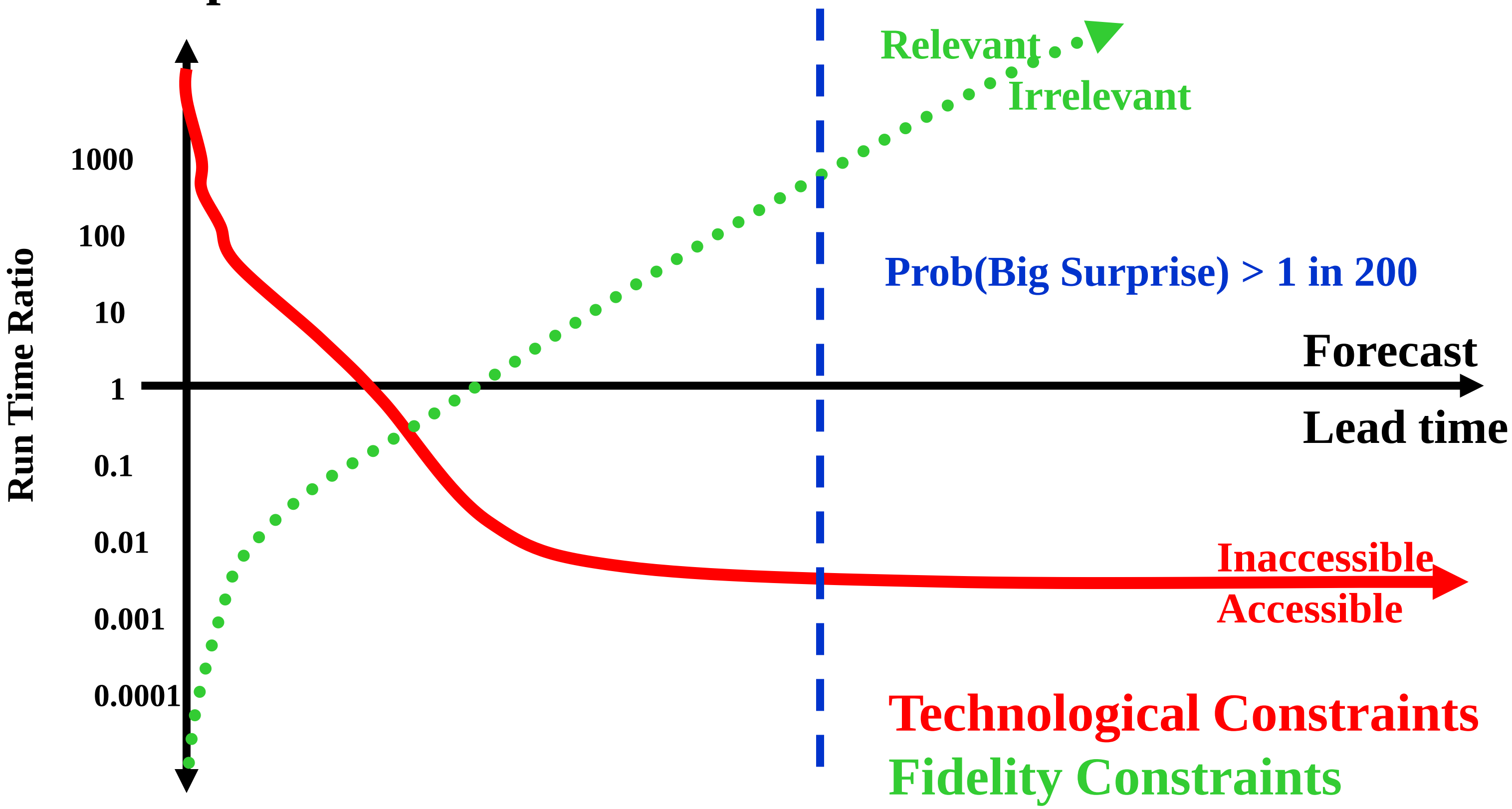
Requirements for model fidelity sets a lower bound on the complexity with lead time. Almost always, the model is required to grow more complex at larger lead times.



What are you constrained by?

Limits of current scientific/economic/mathematical knowledge mean the model may *be expected to* prove inadequate. We will tolerate this as long as the Prob(Big Surprise) < 0.05 (Basel III/Solvency II)

Complex Models

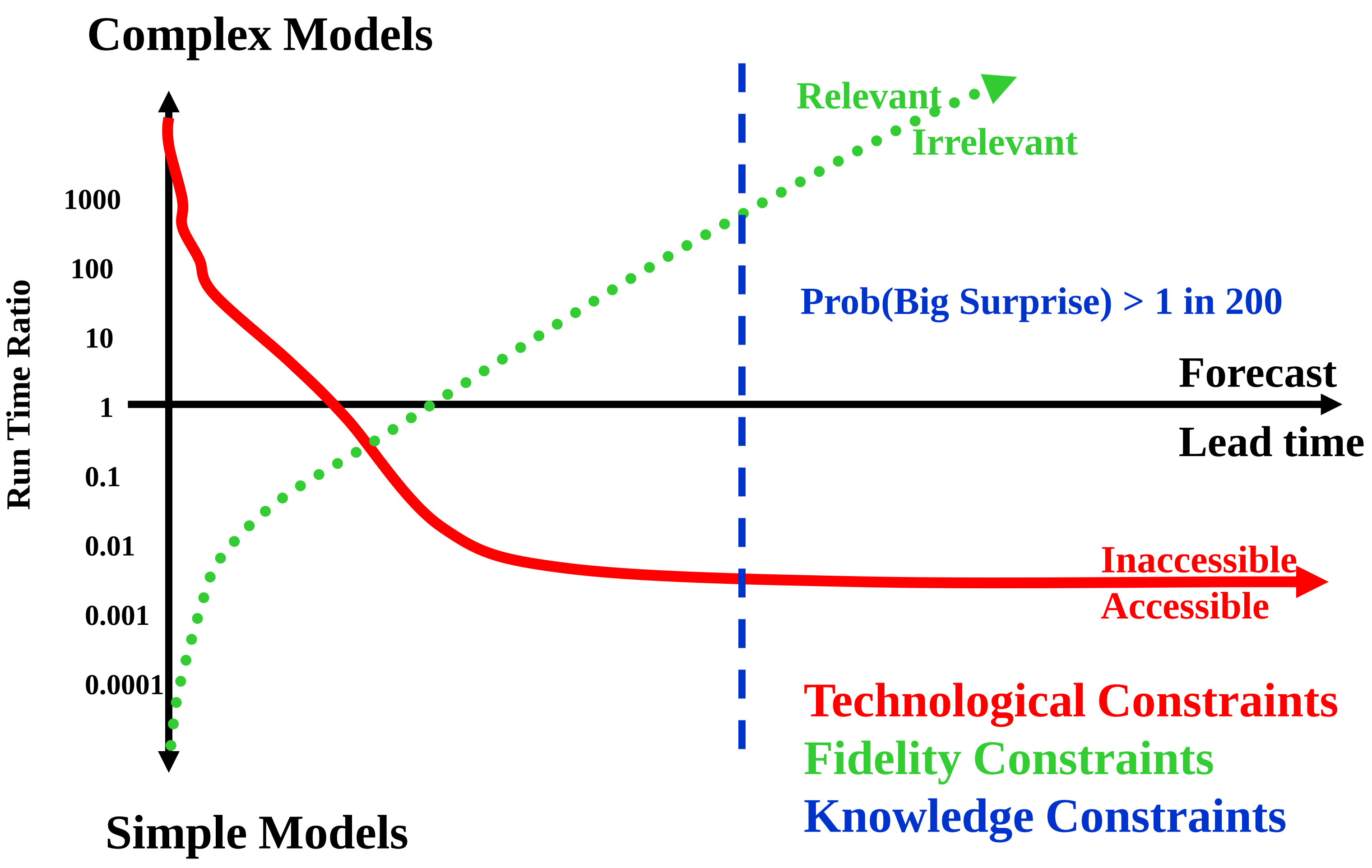


Simple Models

Technological Constraints
Fidelity Constraints
Knowledge Constraints

What are you constrained by?

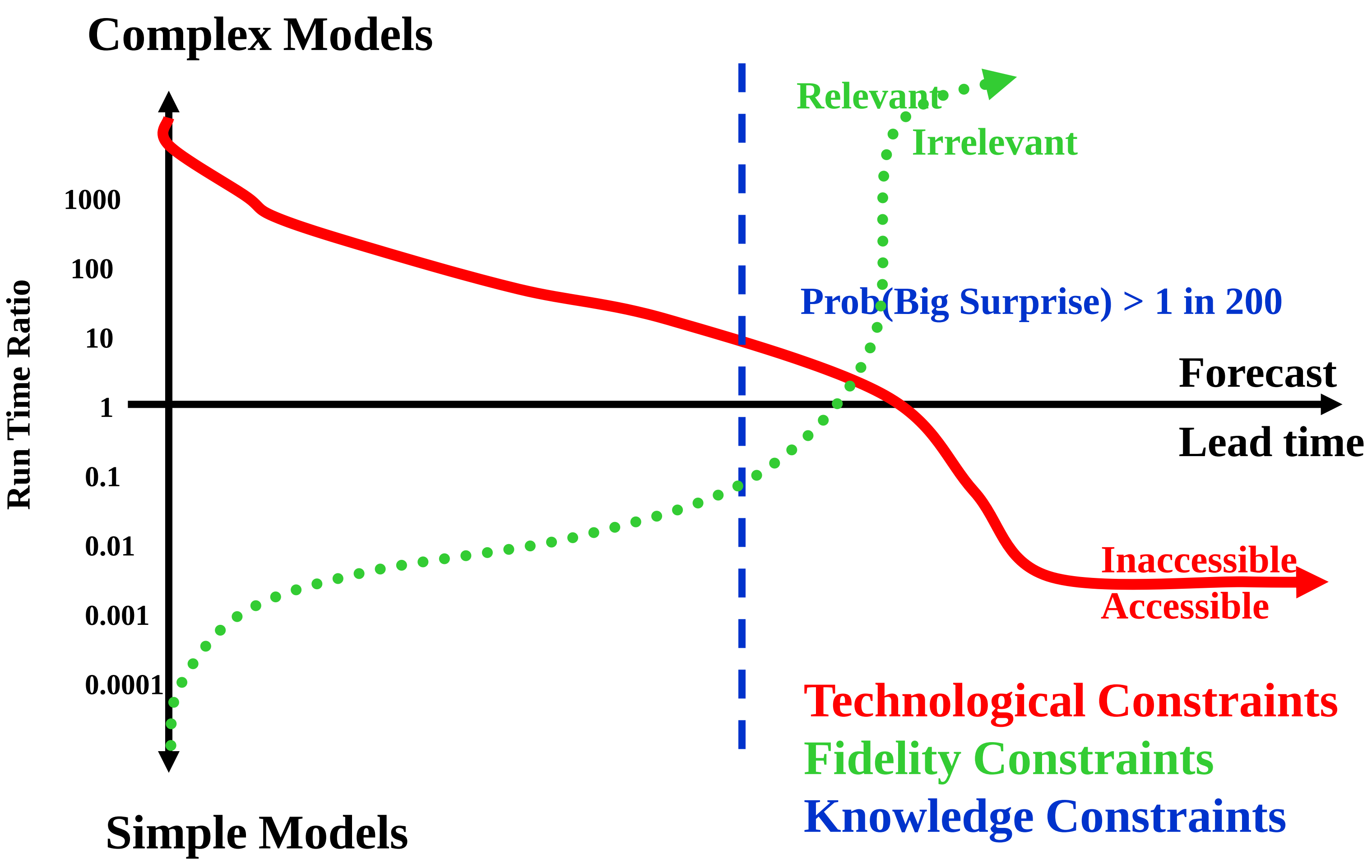
The decision you take will depend on how these three curves lie.



Leonard Smith

What are you constrained by?

The decision you take will depend on how these three curves lie.



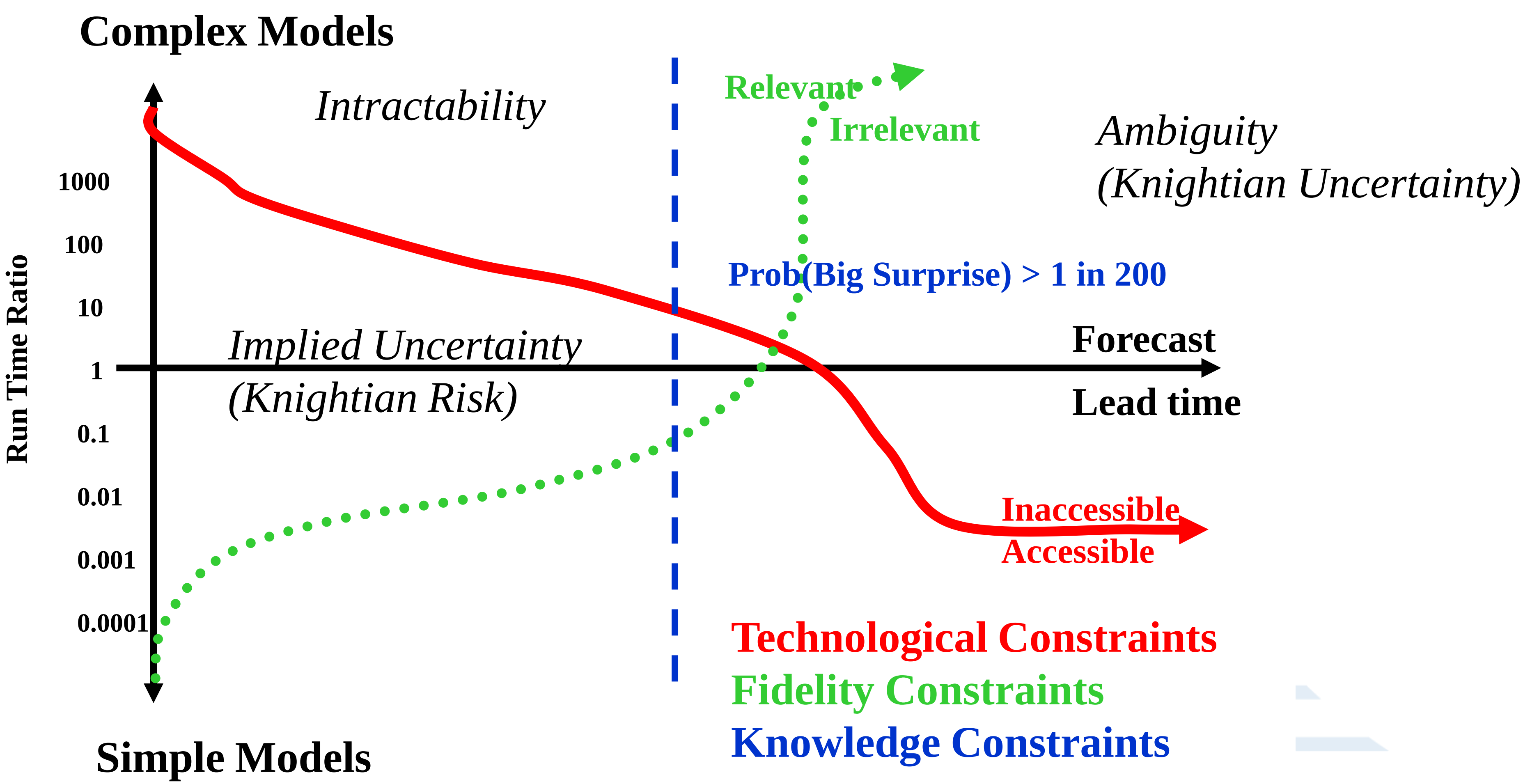
Technological Constraints

Fidelity Constraints

Knowledge Constraints

What are you constrained by?

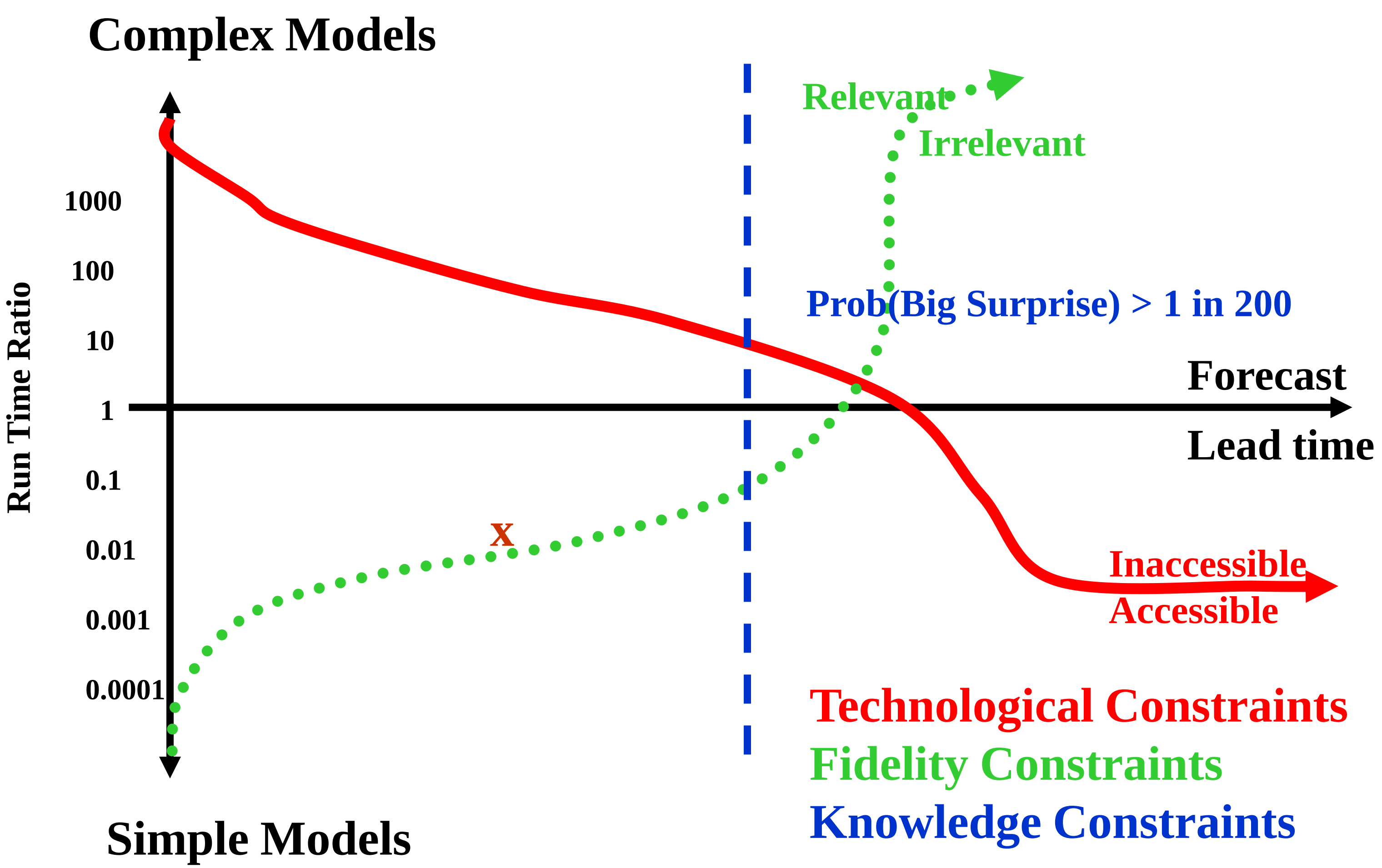
What are the challenges we face with interpreting model simulations in different regions of this schematic?



Leonard Smith

What are you constrained by?

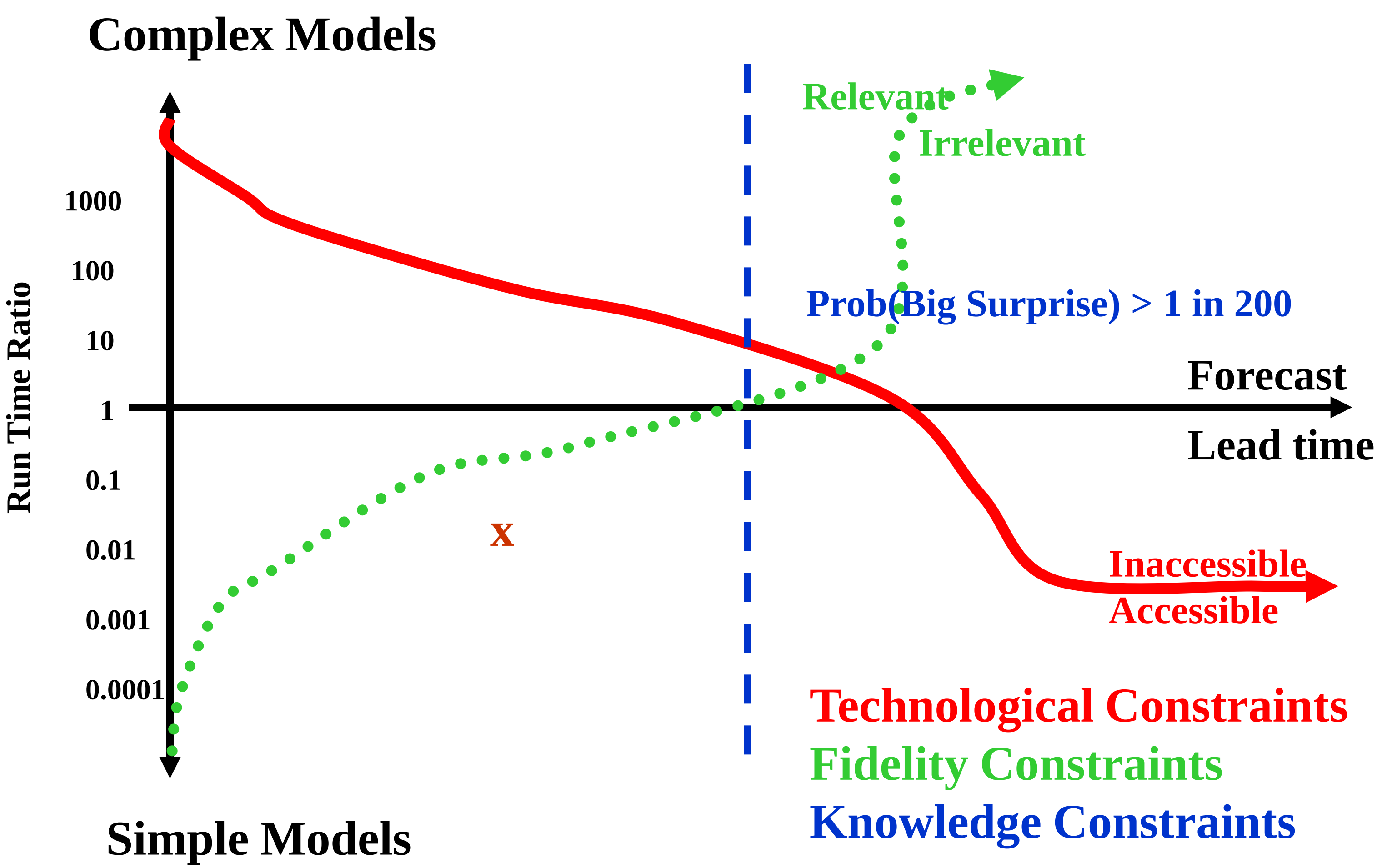
We need to be above the green line, below the red, and to the left of the blue.
So we could make a relevant 100 day simulation and have it a tomorrow.



Leonard Smith

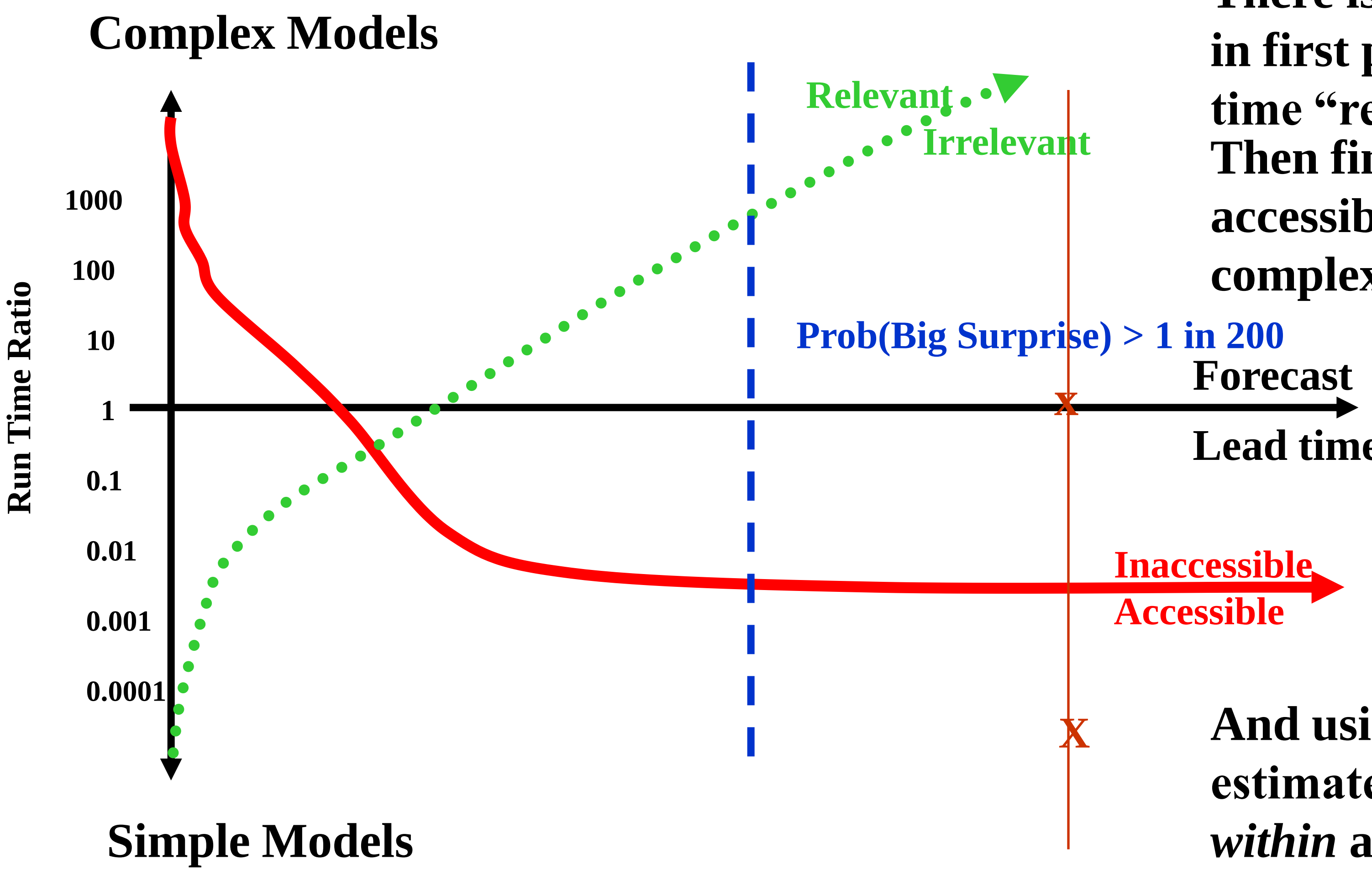
What are you constrained by?

But in this case, this "100 day" model is out of our reach.
Of course we can build it anyway, call it "best available" knowing it is both best and irrelevant; and pass it on (saying clearly that Prob(B.S.)~1)



Leonard Smith

Decision Support Model (Designed to deliver)



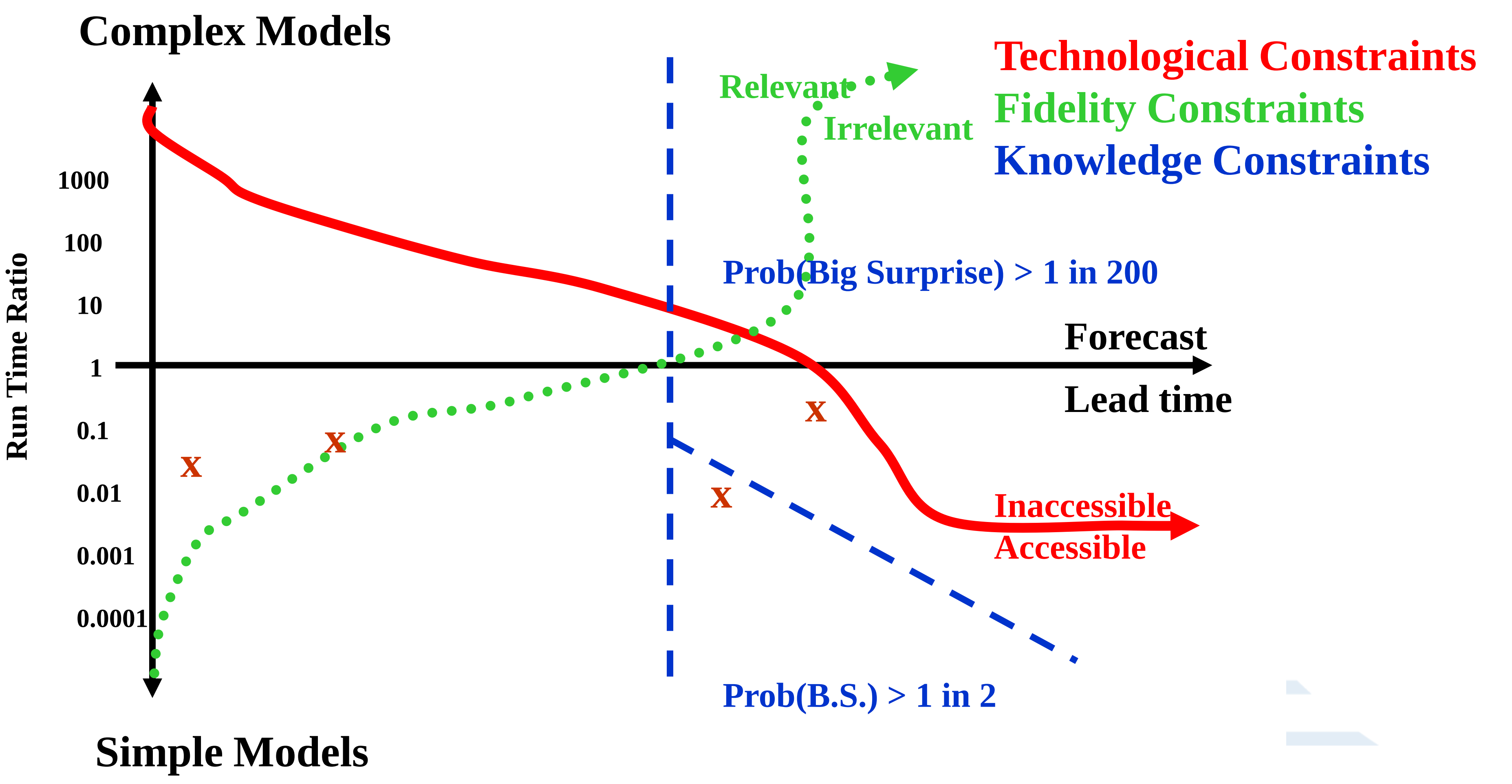
There is some danger in first picking the lead time "required."
Then finding an accessible level of complexity

And using ensembles to estimate "uncertainty" *within* an irrelevant model.

Technological Constraints
Fidelity Constraints
Knowledge Constraints

Where have we designed operational models?

My subjective view of operational weather (< 10 days), seasonal (< 18 months), and hires Climate (< 80 years) models each fall.



Leonard Smith

Solvency II and Risk Management

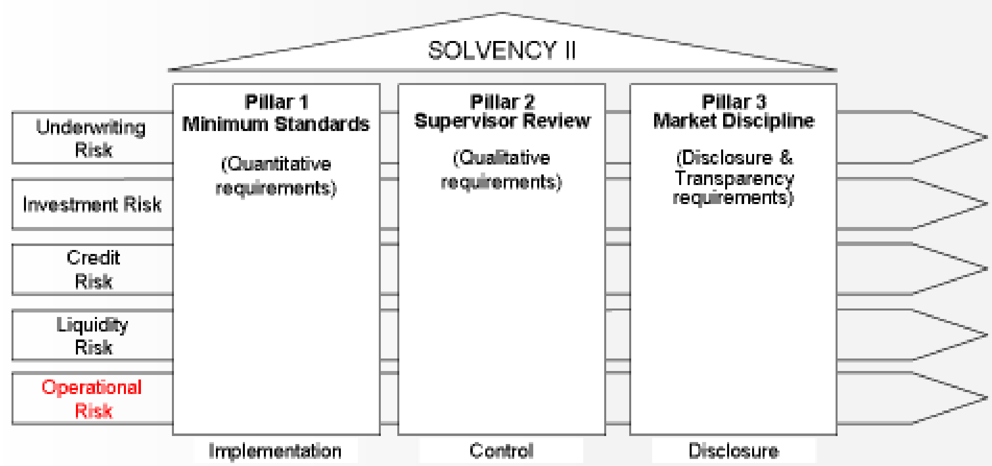
Solvency II is a set of regulatory requirements for insurance firms that operate in the EU designed to prevent insurance company failures by unbundling "operational risk".

The aim here is not to integrate over all risks and opportunities to estimate the PDF of expected annual income but simply to ensure that insurers have sufficient "regulatory capital" to survive any (every) adverse event which has more than a 1 in 200 chance of occurring.

Question: Can climate science ascertain whether the probability of an outcome is
a) >> 1 in 200
b) ~ 1 in 200
c) << 1 in 200

Clearly identify risks without the investigative distraction of the whole shebang PDF.

The Solvency II framework consists of three pillars, each covering a different aspect of the economic risks facing insurers, see figure 1. This three-pillar approach aims to align risk measurement and risk management. The first pillar relates to the quantitative requirement for insurers to understand the nature of their risk exposure. As such, insurers need to hold sufficient regulatory capital to ensure that (with a 99.5% probability over a one-year period) they are protected against adverse events. The second pillar deals with the qualitative aspects and sets out requirements for the governance and risk management of insurers. The third pillar focuses on disclosure and transparency requirements by seeking to harmonise reporting and provide insight into insurers' risk and return profiles.



Solvency II (SII) is the updated set of regulatory requirements for insurance companies operating in the European Union. It revises the existing capital adequacy regime and is expected to come into force in 2012. It has a number of expected benefits, both for insurers and consumers. Although the most obvious benefit seems to be preventing catastrophic losses, other less obvious benefits which are considered to be important are summarised in table 1.

Ambiguity should not be disguised as imprecision!

What is the precise question you are trying to answer? And which thresholds are likely to impact you (vulnerability)?

What are the relevant "meteorological" quantities? And how realistically are they simulated? How adequately are their drivers simulated?

The cost of waiting? The likelihood of significantly improved foresight?
How costly would it be to have to start over and rebuild?

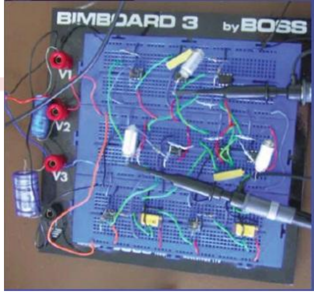
At what lead time are forecasts likely to be informative for those quantities?

Ask for the probability that model-based information relayed to you is mis-informative due to model inadequacy. Request an official minority report.

What is the RDU? And when is it likely to be addressed effectively?
?Ask for a "minority report"?

Talk through the phenomena that you are vulnerable too, and the options.
Do we want to go there at all?

Take home questions



How might we better communicate model diversity given the possibility that we cannot get probabilities useful as such!

Do we have a single example of a nontrivial system where anyone has succeeded (and willing to bet on their model-based probabilities?)

At what lead times do inadequacies drive (or fail to drive) feedbacks yielding local impacts? extremes? global impacts?
How far to one go with a simulation model (when to stop: in time? space?)

How can we best deal with models behaving badly?

What prevents the provision of Prob(Big Surprise) with lead time?

How can we improve the communication of insights from simulations without falling afoul of forecasting good practice?

How to distinguish the value of improvement from the utility of prediction?

Might the provision of probability be maladaptive?

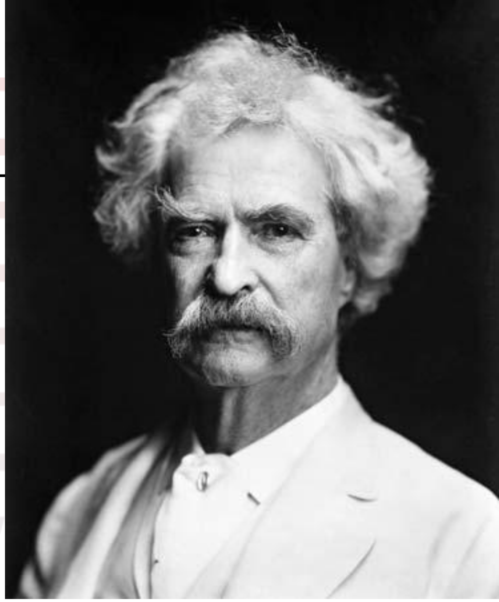
How might we better communicate the inadequacy as well as imprecision

Is the value of qualitative insight at risk of being discarded in favour of quantitative mis-information?

Thank you

(with apologies to sam)

To the Physicist Sitting in Darkness



Probabilities are all well and good. And it is a fine thing to get in touch with your beliefs and feelings. Shall we bang ahead in our old-time, loud pious way, and commit new sciences to the game; or shall we sober up, sit down, and think it over first?

The Blessings-of-Subjective-Probability Trust, wisely and cautiously administered, is a Blue Chip. But Bayesians have been playing it badly of late, and must certainly suffer from it, in my opinion; they have been eager to solve every problem, especially the poorly posed ones, and the Physicists who sit in Darkness have begun to notice it – they have noticed it and have begun to show alarm. They have become suspicious of posteriors on empirically vacuous reals, not to mention function spaces; they have begun to resist the kindly extraction of priors. More – they have begun to examine them! This is not well. The Blessings of Bayesianism are all right, and a good NSF commercial property; there could not be better, in a dim light. In the right kind of light, and at the proper distance, with the goods a little out of focus, they are a desirable enticement to the Physicists who sit in darkness.

Probability theory eases the stress of decision making. And improves the outcome, but not if we adulterate it. For the Empirically Adequate and the Large Number Statistic, it is pie. But in cutting edge science, and in extrapolation, here the Physicist sitting in darkness is (almost) sure to say: “These is something curious about this – curious and unaccountable.” … There have been lies yes, but told in a good cause, it might have worked; yet we have passed on a Shadow from one who hadn’t it to sell, and long term infrastructure investments are being made.

Bayesian's Burden

Take up the Bayesian's burden,
Your best students send out,
To give each and every science,
It's PDF of quantified doubt.

Sacrifice theoretical advances
In maths, your career may cease,
To help doubters in the darkness
Find their distributions and peace.

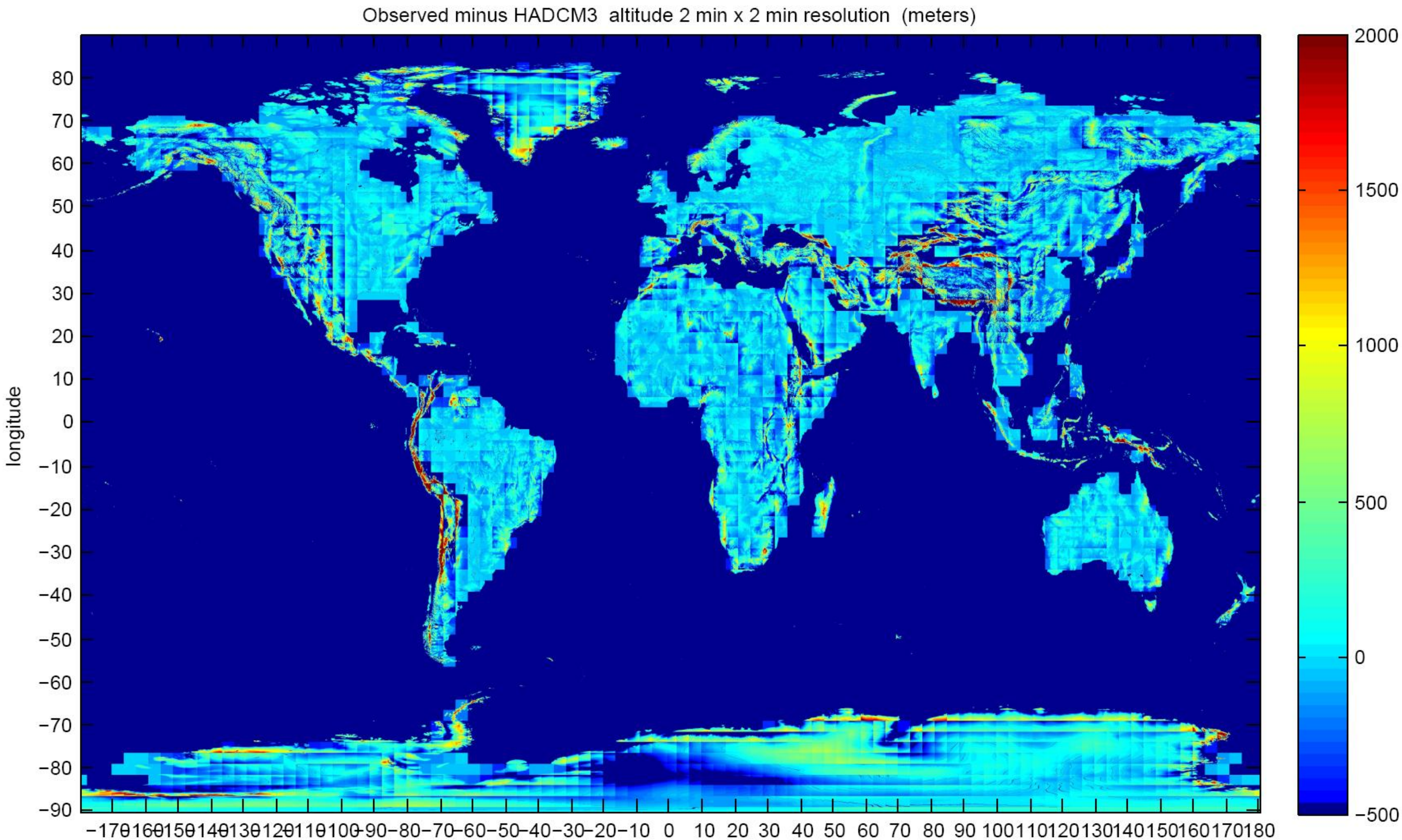
In the dreary halls of physics,
Encapsulate their beliefs,
Their model's empirically inadequate,
Still only B's way gives coherent release.

Extract priors without mercy,
It is the only way,
The numbers must mean something,
Whatever the captives say!

Allow him his posterior only
Not his heart, certainly not his head;
Constrain the result with priors,
Before the data's been read.

Then free him to act blindly,
As his posterior says he should,
Once he finds a utility function,
All will be well and good.

Rev. T. Bayes


Observed minus HADCM3 altitude 2 min x 2 min resolution (meters)
longitude
80
70
60
50
40
30
20
10
0
−10
−20
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−80
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2000
1500
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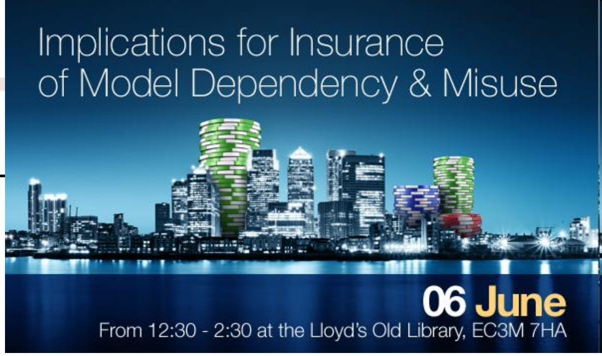
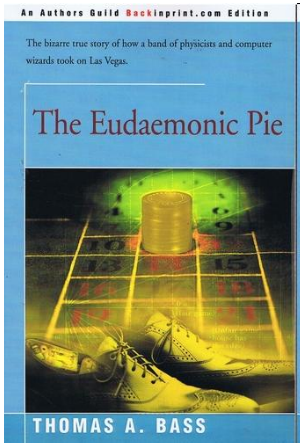
Are “Fair Odds” Sustainable?

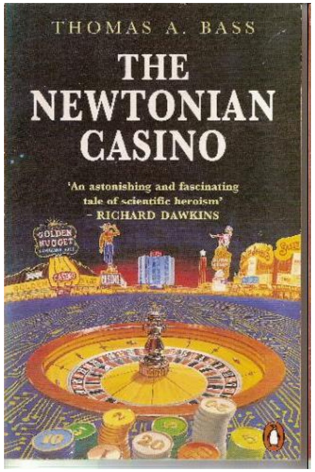


Suppose you are a mutual insurer or a cooperative Casino, aiming neither to make a profit nor a loss in the long run. Can you base the odds you offer on model-based probabilities and expect to survive?

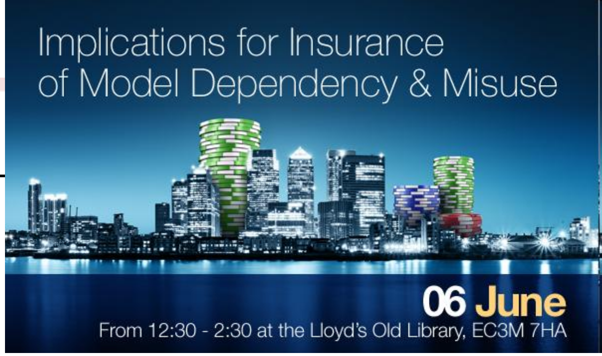


Case one: You are competing against a group that has more information (“a better model”) than you do.

*This case is **not** of interest to us today.*



Are "Fair Odds" Sustainable?



Suppose you are a mutual insurer or a cooperative Casino, aiming neither to make a profit nor a loss in the long run. Can you base the odds you offer on model-based probabilities and expect to survive?

Case Two: You are competing against a group that knows nothing more than you, but knows that your model is imperfect.

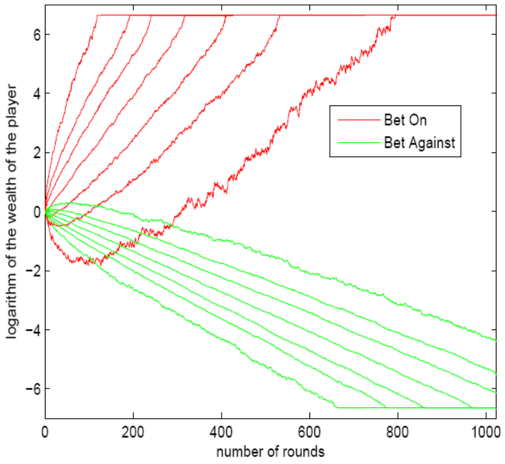


Figure 1: Player's wealth as a function of number of rounds, 1024 players are used to calculate the percentiles(1th, 10th, 25th, 50th, 75th, 90th, 99th) of the wealth changes, $g = 1.1, g_{play} = 1.05$.

If in this case one can expect to be driven into bankruptcy "quickly", then should we not rethink the use of model-based probabilities as such in decision support!

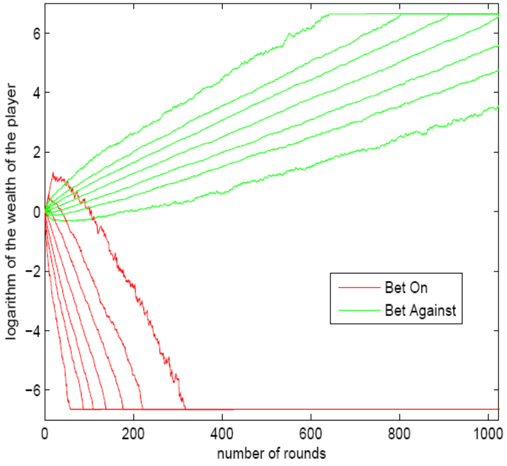
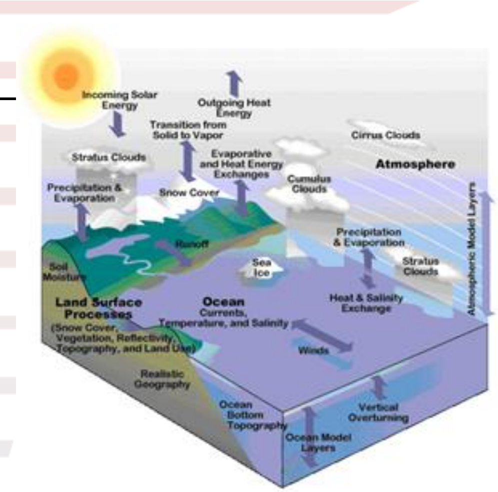


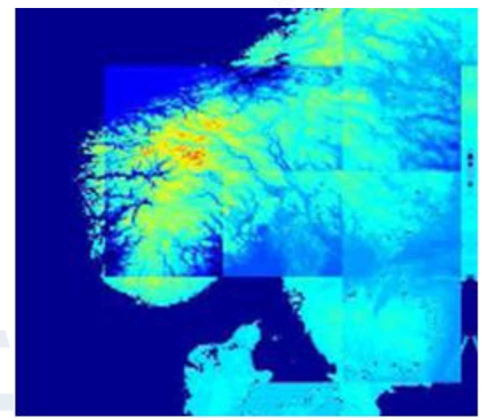
Figure 2: Player's wealth as a function of number of rounds, 1024 players are used to calculate the percentiles(1th, 10th, 25th, 50th, 75th, 90th, 99th) of the wealth changes, $g = 1.1, g_{play} = 0.95$.

The Portfolio bets when a certain probability is forecast, not on a particular kind of event.

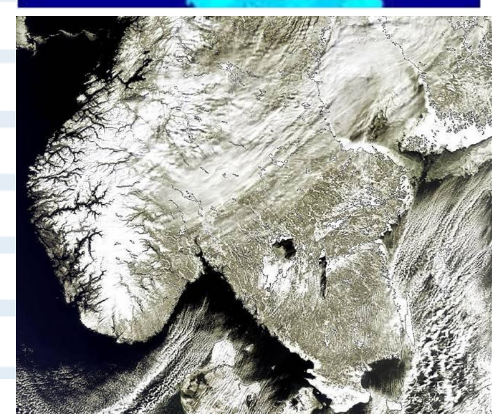
Plausible Planets or Implausible Earths?



The kitchen sink approach "includes" everything we can think of that might be important.
At best, this yields an implausible Earth, and parameter variation samples an empirically vacuous space of unphysical, unbiological, uninteresting & irrelevant model diversity. (**Unless the model is empirically adequate!**)



One alternative is to build plausible planets, while omitting any Earth-relevant process for which the model cannot provide coherent physical drivers on Earth-like scales. (no suggestion of linear superposition intended!)



Does water vapour come after mountains?
Does vegetation come after water vapour?
Do we avoid the penguin effect?
(until it is simulated realistically)

Challenges to the sustainability of "Fair" Odds

"Fair Odds" on are commonly defined as those at which one would accept either side of a bet. They correspond to probabilities (on and against) which sum to one.

"Sustainable Odds" are odds that can be offered (on and against) repeatedly, with an acceptable, small (a priori known) chance of ruin. The implied probabilities need not sum to one, but can not sum to less than one (Dutch Book).

If model-based probabilities are used to determine "Fair Odds", are those Odds sustainable?

Obviously not, if a player has access to a better predictions system than the house, if for example they use the same model but the player uses a better data assimilation scheme (GD/ISIS) than the house (EnKF).

But can a player knowing nothing more than that the model is imperfect systematically beat a house which attempts to set fair odds?

END

How do scientists best support quantitative risk management and policy making when:

For Extremes: Today's "Best Available" simulations are not "Fit for Purpose"?

"Model Diversity" is mis-interpreted as reflecting "Decision Relevant Probability"

Systematic Errors (due to shared model deficiencies) are:
(a) larger than the impacts of interest
(b) prevent realistic feedbacks (land, biology) even with perfect "forest models"

Oversell under the "best available" fig-leaf threatens the credibility of science.

Given that:

Physical Arguments for warming are strong
and the obs show significant warming:
What is the max lead time do we believe CMIP3 models might be informative
(as a function of space and time scales).
At which lead time should we refuse to downscale CMIP3 model output?
or consider global statistics "likely" to be mis-informative?

How do we stress scientific understanding over model over-interpretation?

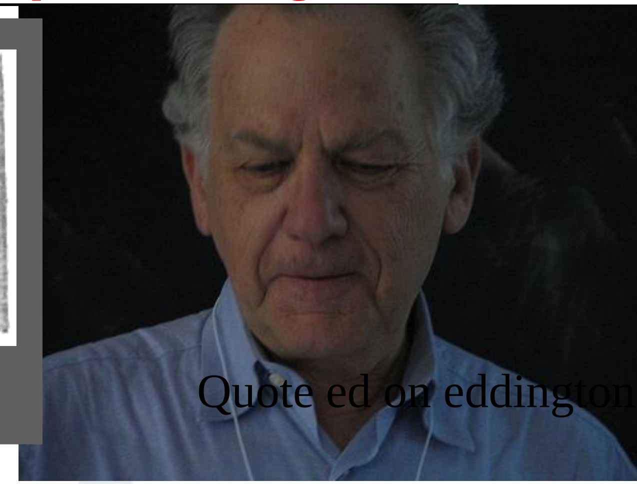
Can we provide a Prob(Big Surprise) with lead time?

How precautionary should we be, when we know we cannot appeal to expected utility/impact computations?

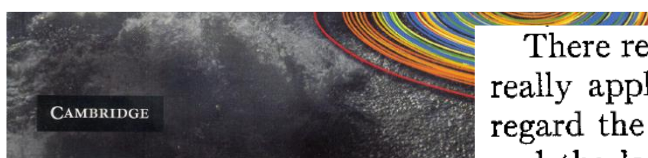
Models can aid insight, without providing numbers!

> The events are connected with one another. Remember the charming, if somewhat irrelevant, analogy used by explicators of chaos theory: A butterfly flutters its wings in Beijing and next month there is an earthquake in Chile.

The Western Australian (1994)



We are therefore led to conclude that a great number of phenomena observed in variable stars can be explained by the instability mechanism discussed by Eddington, once non-linear, non-adiabatic solutions can be found. We feel, however, that progress in this direction can be made through the study of elementary prototype equations perhaps more closely related to the stellar model than ours, but hopefully not more complicated.



There remains the question as to whether our results really apply to the atmosphere. One does not usually regard the atmosphere as either deterministic or finite, and the lack of periodicity is not a mathematical certainty, since the atmosphere has not been observed forever.

Take home points

Robust uncertainty management must take into account the realities of the market, in addition to imprecision (uncertainty assuming the model is informative) and ambiguity (the chance that the model is inadequate).

Even when money is not object, technological constraints limit model adequacy.

Even when technological constrains are no object, our understanding limits model adequacy.

Providing information on second order uncertainty can reduce over-dependence on models.

Using model-based probabilities (as probabilities) may prove a misuse of models that can still yield valuable insight and decision support.

The AOGCMs cannot sample the full range of possible warming, in particular because they do not include uncertainties in the carbon cycle. In addition to the range derived directly from the AR4 multi-model ensemble, Figure 10.29 depicts

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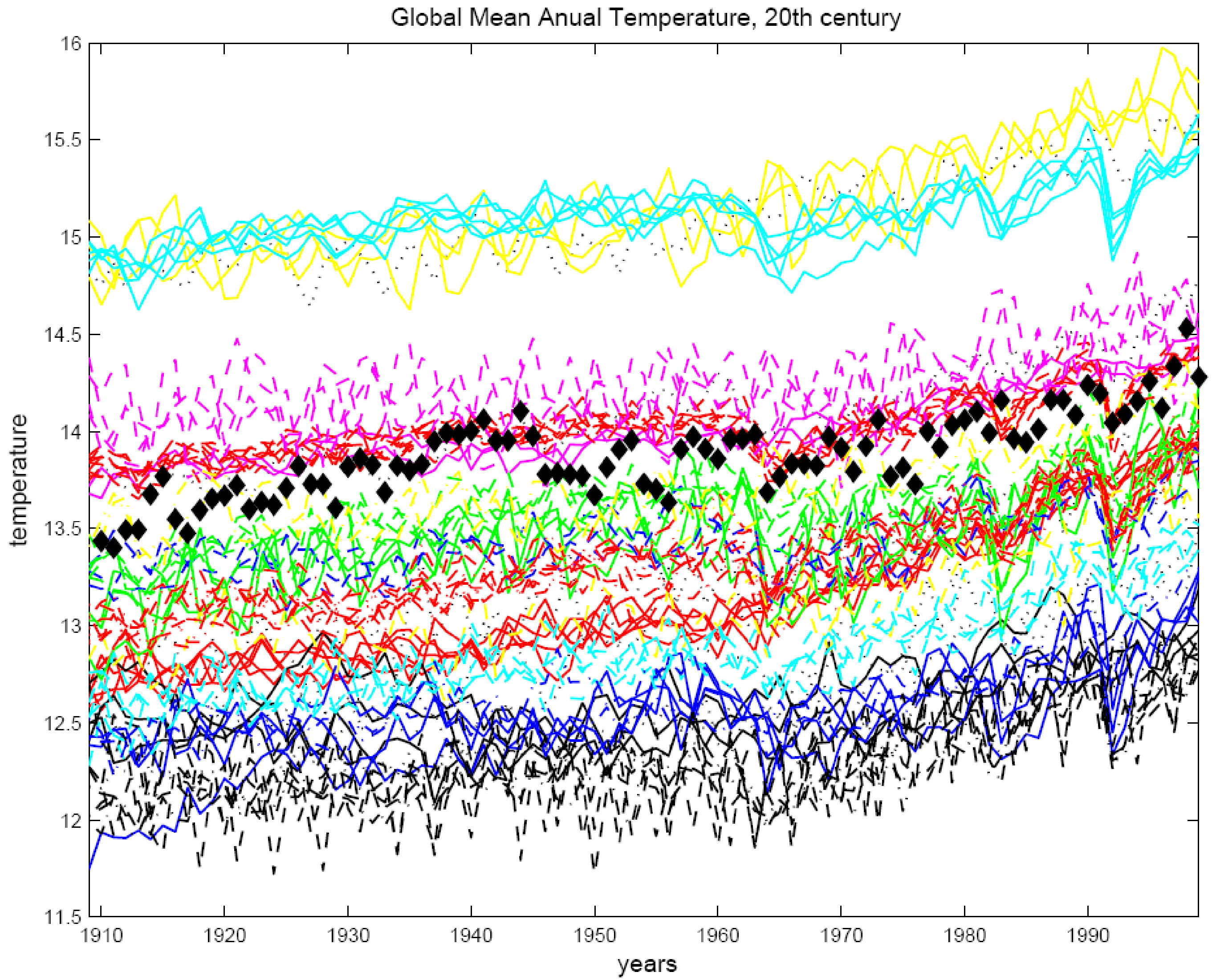
C^4MIP coupled climate-carbon cycle models. Based on these results, the future increase in global mean temperature is likely to fall within –40 to +60% of the multi-model AOGCM mean warming simulated for each scenario. This range results from an expert judgement of the multiple lines of evidence presented in Figure 10.29, and assumes that the models approximately capture the range of uncertainties in the carbon cycle. The range is well constrained at the lower bound since climate sensitivity is better constrained at the low end (see Box 10.2), and carbon cycle uncertainty only weakly affects the lower bound. The upper bound is less certain as there is more variation across the different models and methods, partly because carbon cycle feedback uncertainties are greater with larger warming. The uncertainty ranges derived from the above percentages for the warming by 2090 to 2099 relative to 1980 to 1999 are 1.1°C to 2.9°C, 1.4°C to 3.8°C, 1.7°C to 4.4°C, 1.4°C to 3.8°C, 2.0°C to 5.4°C and 2.4°C to 6.4°C for the scenarios B1, B2, A1B, A1T, A2 and A1FI, respectively. It is not appropriate to compare the lowest and highest values across these ranges against the single range given in the TAR, because the TAR range resulted only from projections using an SCM and covered all SRES scenarios, whereas here a number of different and independent

Page 810

WCRP CMIP3 Multi-Model Data

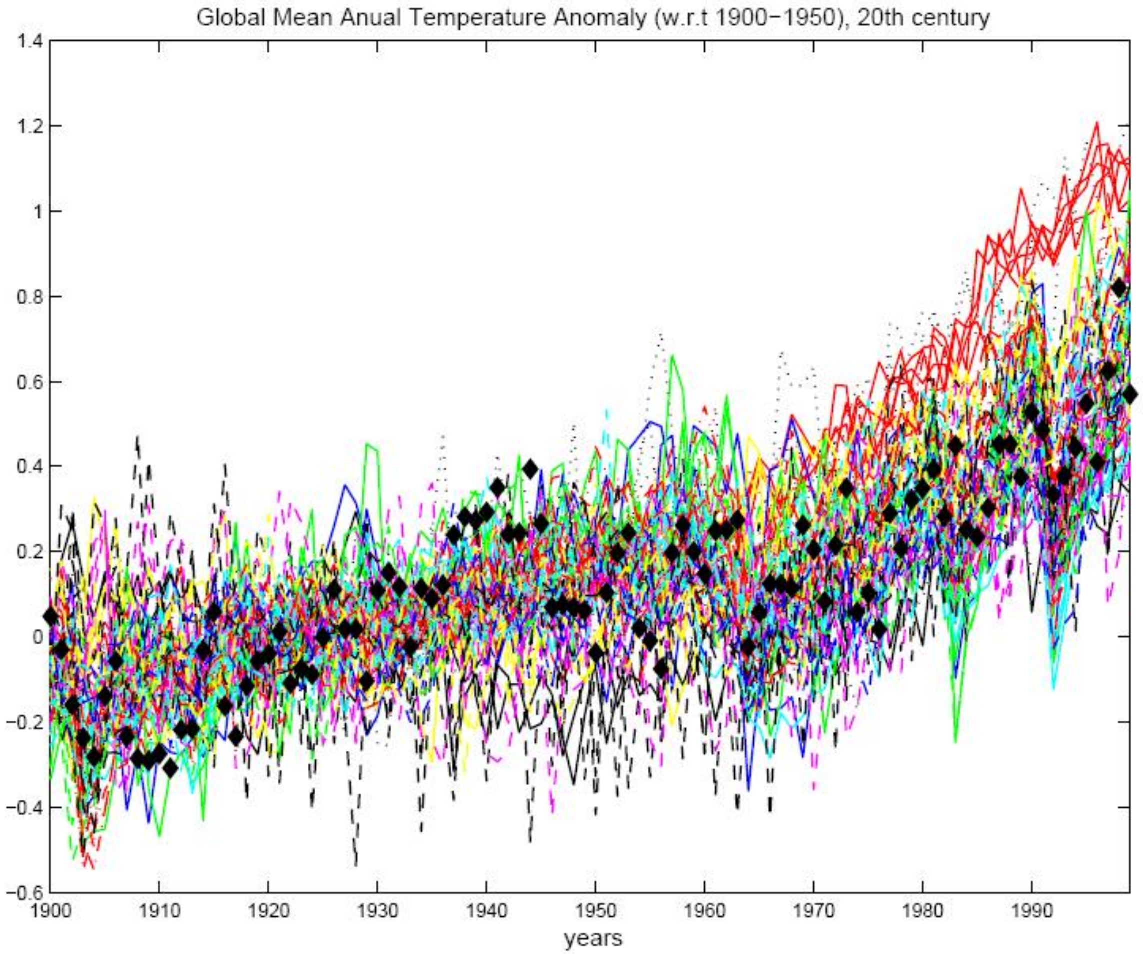
Home Data About ESG Login

What do we do given such systematic errors?



CATS CENTRE FOR THE ANALYSIS OF TIME SERIES

Even after a 100 year run, anomolies are not exchangeable



Questions (mine)

Does model inadequacy do in probability just as nonlinearity did in least squares?

(if so, what then is UQ?)

What are “good” initial conditions/parameters in simulation-based forecasting?

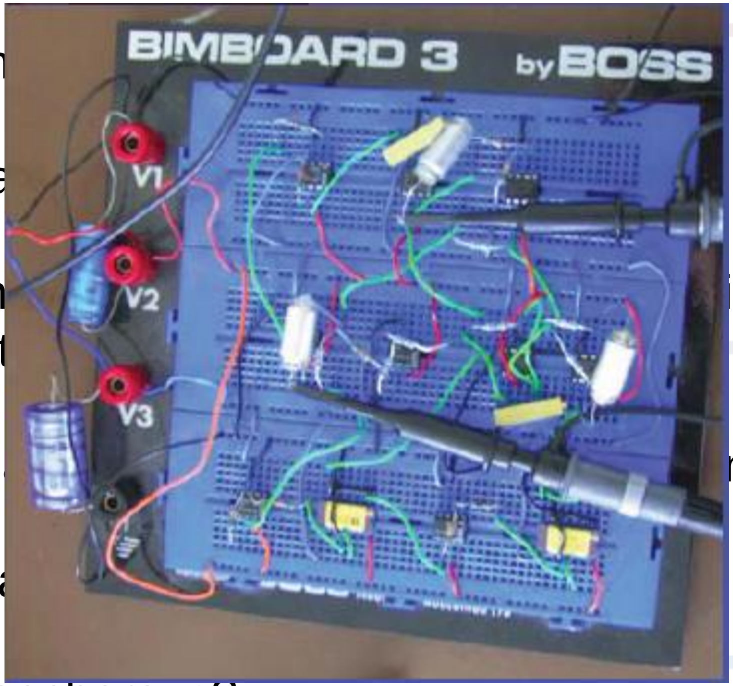
Is weighting models a n

Is a prior on a model pa

In weather-like problem istributions as probability density funct

When might the Bayesi n *ad hoc* sorta way).

Can model-based proba

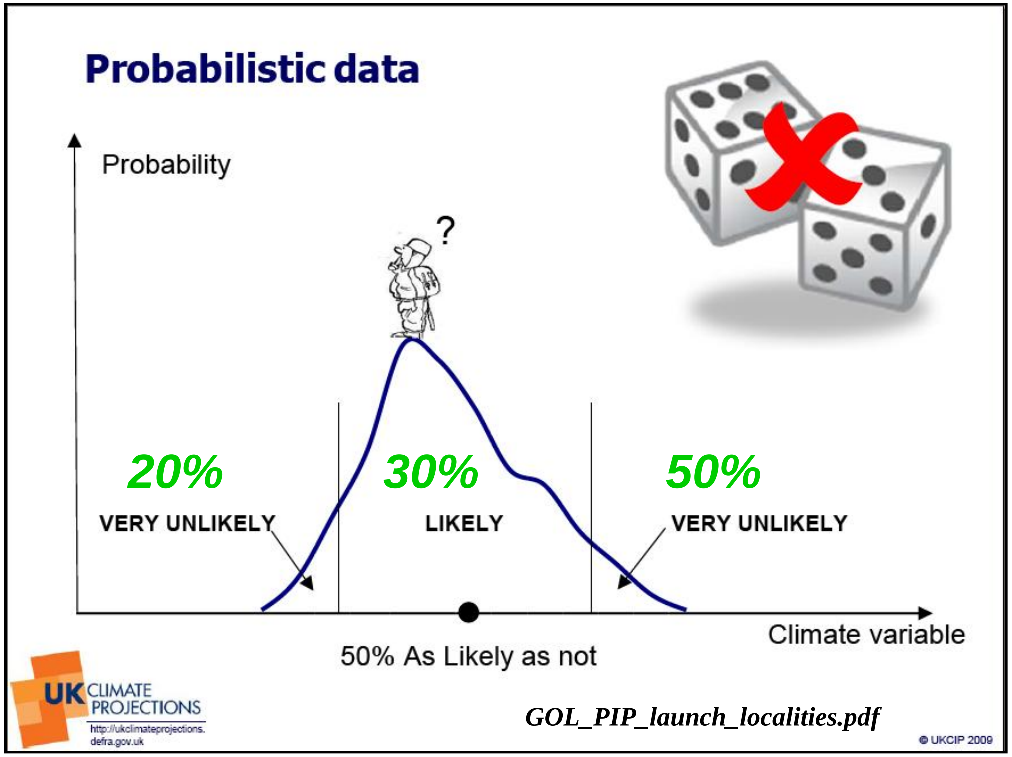


Is the Bayesian Way treacherous?

Is there a viable in-principle approach for handling model class inadequacy?

So what about UKCP probabilities?

What is the chance of falling above the 90% line of UKCP PDFs?



The probability of the real world falling above the 90% line of the UKCP PDF can be much ***much*** *greater than 10%.*

The shortcoming of climate models are more clearly acknowledged in the peer reviewed literature than in the UKCP user guidance.

It is important to stress that our approach to the specification of discrepancy can only be expected to capture a subset of possible structural modelling errors and should be regarded as a lower bound. This is because models tend to share certain common systematic biases, which can be found in diverse elements of climate including multiannual means of basic quantities such as surface temperature,

But is this something to worry about? Really?

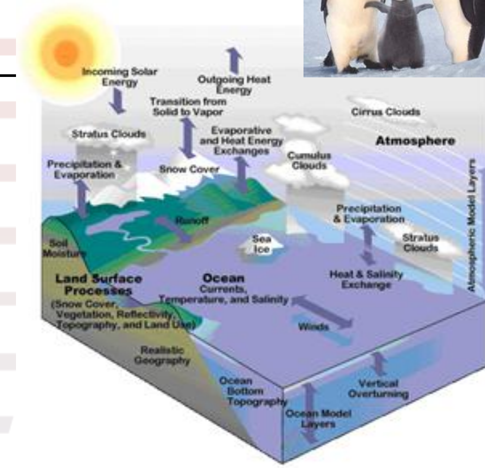
PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

A methodology for probabilistic predictions of regional climate change from perturbed physics ensembles

J.M Murphy, B.B.B Booth, M Collins, G.R Harris, D.M.H Sexton and M.J Webb

Phil. Trans. R. Soc. A 2007 **365**, 1993-2028
doi: 10.1098/rsta.2007.2077

Moving Forward:
Plausible Planets or Implausible Earths?



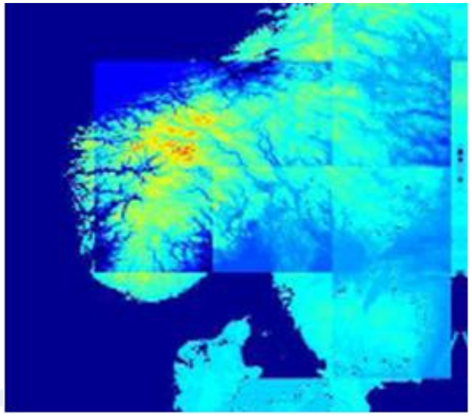
How can we best develop our models as the available computational power increases?

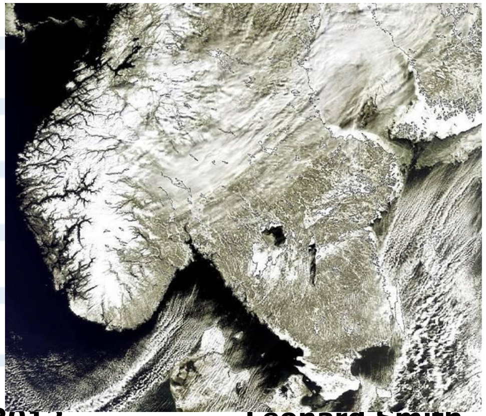
A) Simulate potentially real planets that get more and more Earth-like while omitting any Earth-relevant process for which the model cannot provide coherent physical drivers on Earth-like scales. (no suggestion of linear superposition intended!)

Does water vapour come after mountains?
Does vegetation come after water vapour?
Do we avoid the penguin effect? (until it is simulated realistically)

B) Via an hodgepodge of unphysical/unbiological simulations resembling no planet that could possibly exist, but "including" every phenomena we can think of that might be important (including penguins), and hoping the simulated planets will suddenly become Earth-like at some resolution in an ill-defined higgledy-piggledy way.

One might argue physical intuition is more effective in evaluating plausible planets, as there is physics to intuit in that case. (and at least a few examples.)





Watch out for the Penguin Effect

The challenge of climate change will be with us for some time.

Can we maintain parallel streams: pure research to apply in 2050, and applied research to improve the modelling position we are in when we get there?

When selecting a thesis problem: do you suggest something important, like understanding cloud dynamics (better)?

Or to be the first person in the world to include the penguin effect in a global model? (and thereby all but assured a job at a rival modelling centre?)

(Similar effects plague economics and statistics)

THERE IS NO PENGUIN EFFECT

(My prior on this effect is zero)

It is a joke regarding climate,

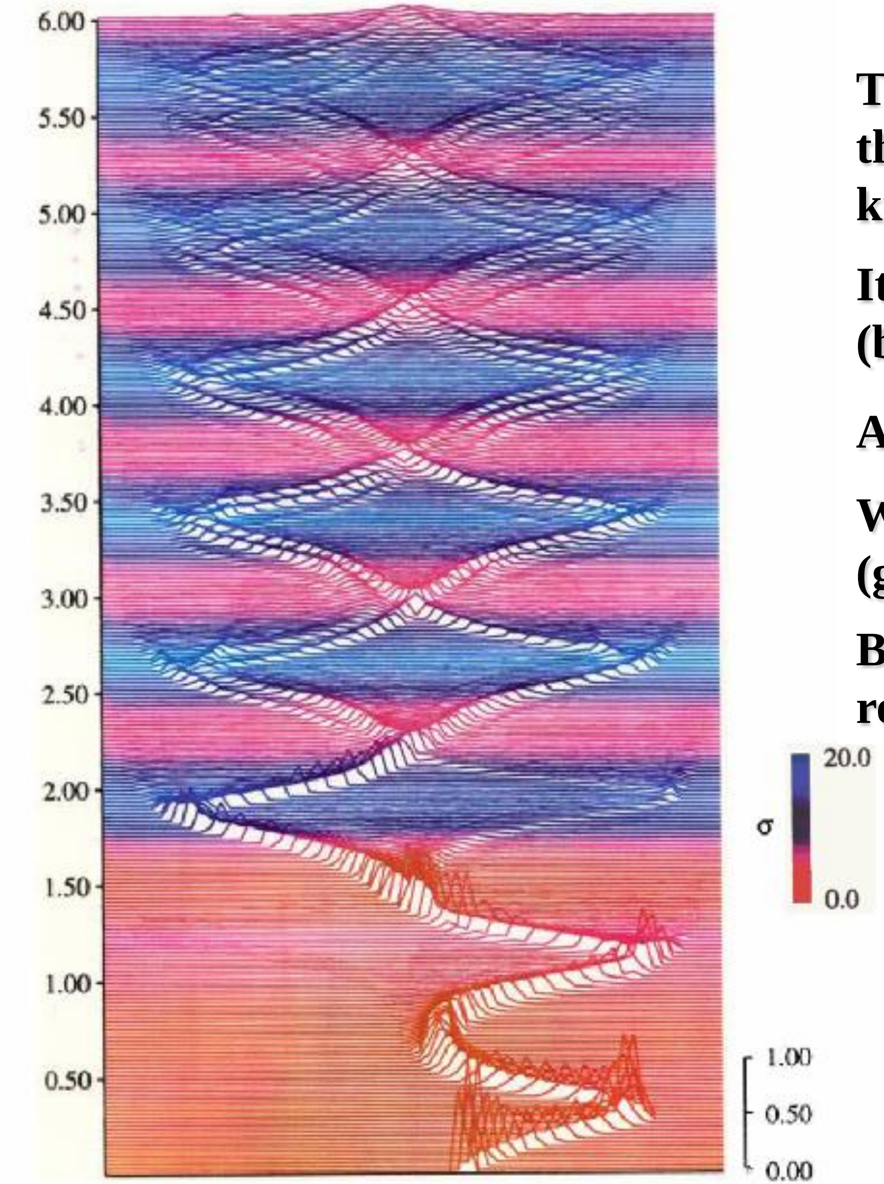
but sadly not career paths!

We are walking in Florida.
You find you have just been bitten on the hand by a snake.
We did not see the snake.
If it was the deadly carbonblack snake, the bite will kill you in a painful way, unless you cut off your hand within 15 secs.
I have a hatchet.
You have 5 seconds left.
Did you cut off your hand?

How would a society learn to make such decisions?

Luckily with climate change we have more than 15 seconds.
What research question do you hope advance in the next 5 years?

Probability Forecasts: Chaos



Smith (2002) Chaos and Predictability in *Encyc Atmos Sci*

The evolution of this probability distribution for the chaotic Lorenz 1963 system, tells us all we can know of the future, given what we know now.

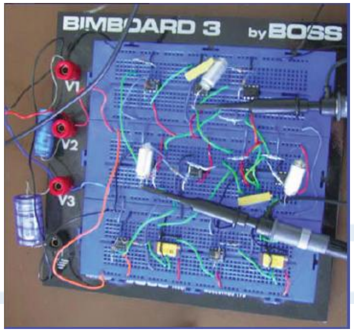
It allows prudent quantitative risk management (by brain-dead risk managers)

And sensible resource allocation.

We can manage uncertainty for chaotic systems (given a perfect model).

But how well do we manage uncertianty in the real world? For GDP? Weather? Climate?

Do we have a single example of a nontrivial system where anyone has succeeded (and willing to bet on their model-based PDFs?)



Stapled Presentation of Projections

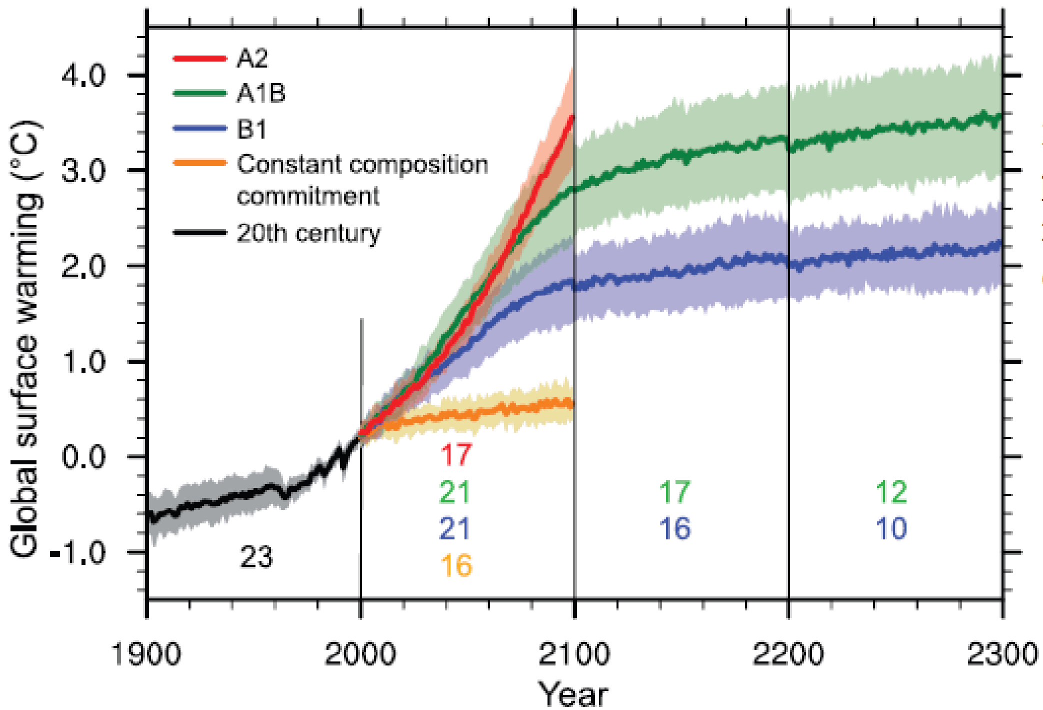


Figure 10.4. *Multi-model means of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th-century simulation. Values beyond 2100 are for the stabilisation scenarios (see Section 10.7). Linear trends from the corresponding control runs have been removed from these time series. Lines show the multi-model means, shading denotes the ±1 standard deviation range of individual model annual means. Discontinuities between different periods have no physical meaning and are caused by the fact that the number of models that have run a given scenario is different for each period and scenario, as indicated by the coloured numbers given for each period and scenario at the bottom of the panel. For the same reason, uncertainty across scenarios should not be interpreted from this figure (see Section 10.5.4.6 for uncertainty estimates).*

2001). The potential for missing or inadequately parametrized processes to broaden the simulated range of future changes is not clear, however, this is an important caveat for the results discussed below.

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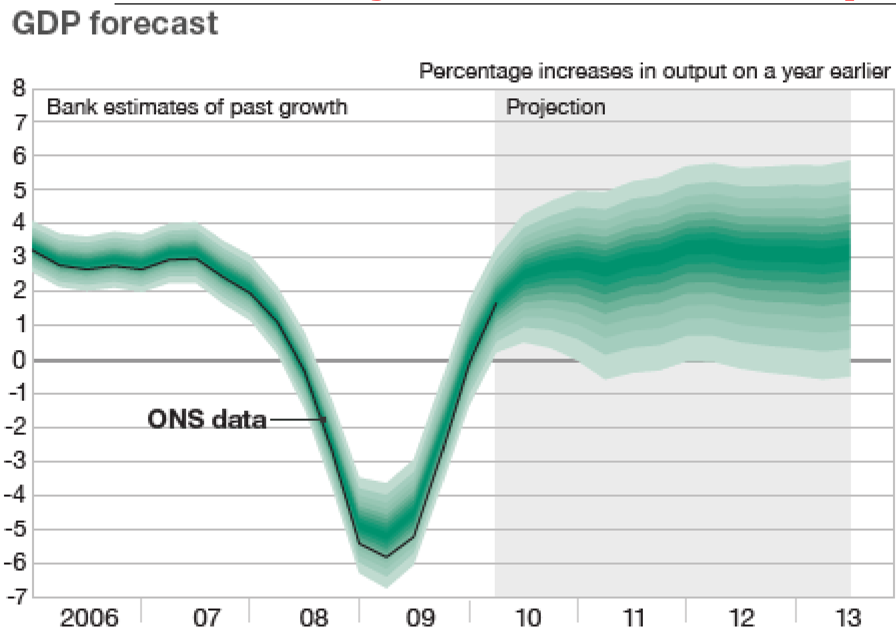
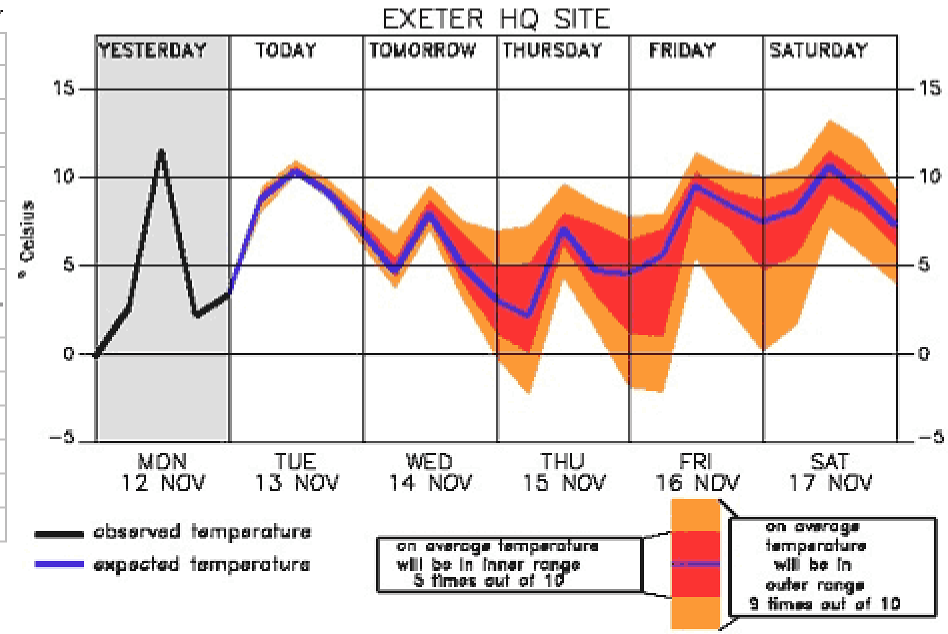
The real concern is that an adequately parameterised process might significantly shift the range.

Discussions of broadening imply confidence in the location.

Probability Forecasts: Expert Based Bank of England





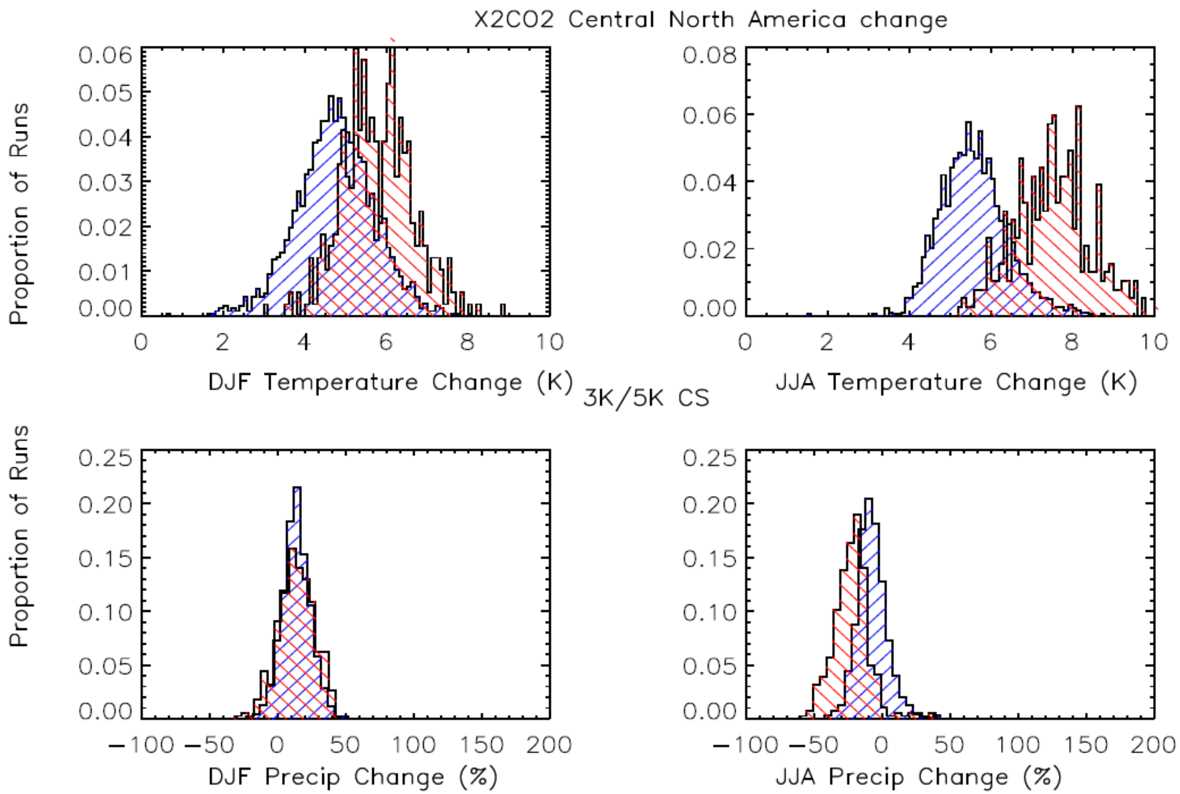
Source: Bank of England http://www.bbc.co.uk/news/business-10934302

At least the forecast on the right is not expected to alter the target predicted!

Nor does is the Bank of England so confident in the present (or past).

For Policy and Decision Support: All climate change in local!

What's the chance a 3 degree globally is "worse" than 5 degrees?



For Central North America, for instance, there is about a one in five chance that a random draw from CS=3 is hotter than one from CS=5

Assuming the model is perfect!

Distributions for Giorgi regions
CS = 3 +/- 0.1 runs (1835) in blue
CS = 5 +/- 0.1 runs (385) in red
Final 8 year means (years 8-15), Phase 3 – Phase 2.

Towards Comprehensive Earth System Models
Past present and future

1975	1985	1992	1997	Present	
Atmosphere	Atmosphere	Atmosphere	Atmosphere	Atmosphere	Atmosphere
	Land surface	Land surface	Land surface	Land surface	Land surface
		Ocean & sea-ice	Ocean & sea-ice	Ocean & sea-ice	Ocean & sea-ice
			Sulphate aerosol	Sulphate aerosol	Sulphate aerosol
				Non-sulphate aerosol	Non-sulphate aerosol
				Carbon cycle	Carbon cycle
					Atmospheric chemistry

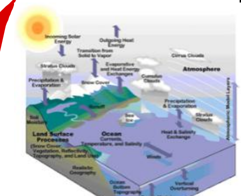
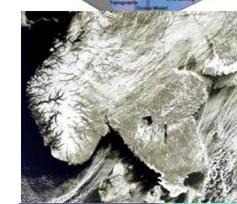
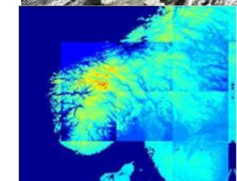
Stamp Collecting?
Must get one first…
then find a better one.

In 1975 each was known to be potentially important.

Off-line model development

- Ocean & sea-ice model
- Sulphur cycle model
- Non-sulphate aerosols
- Land carbon cycle model + Ocean carbon cycle model → Carbon cycle model
- Atmospheric chemistry
- Atmospheric chemistry

Strengthening colours denote improvements in models

NCAR

And which anomaly period matters.

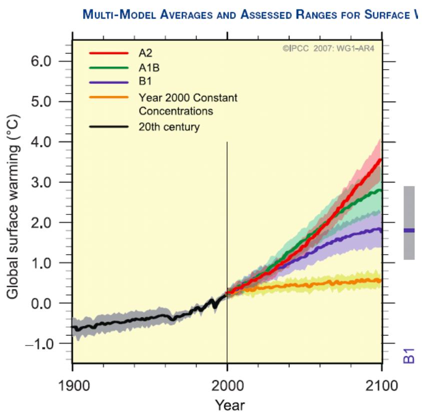
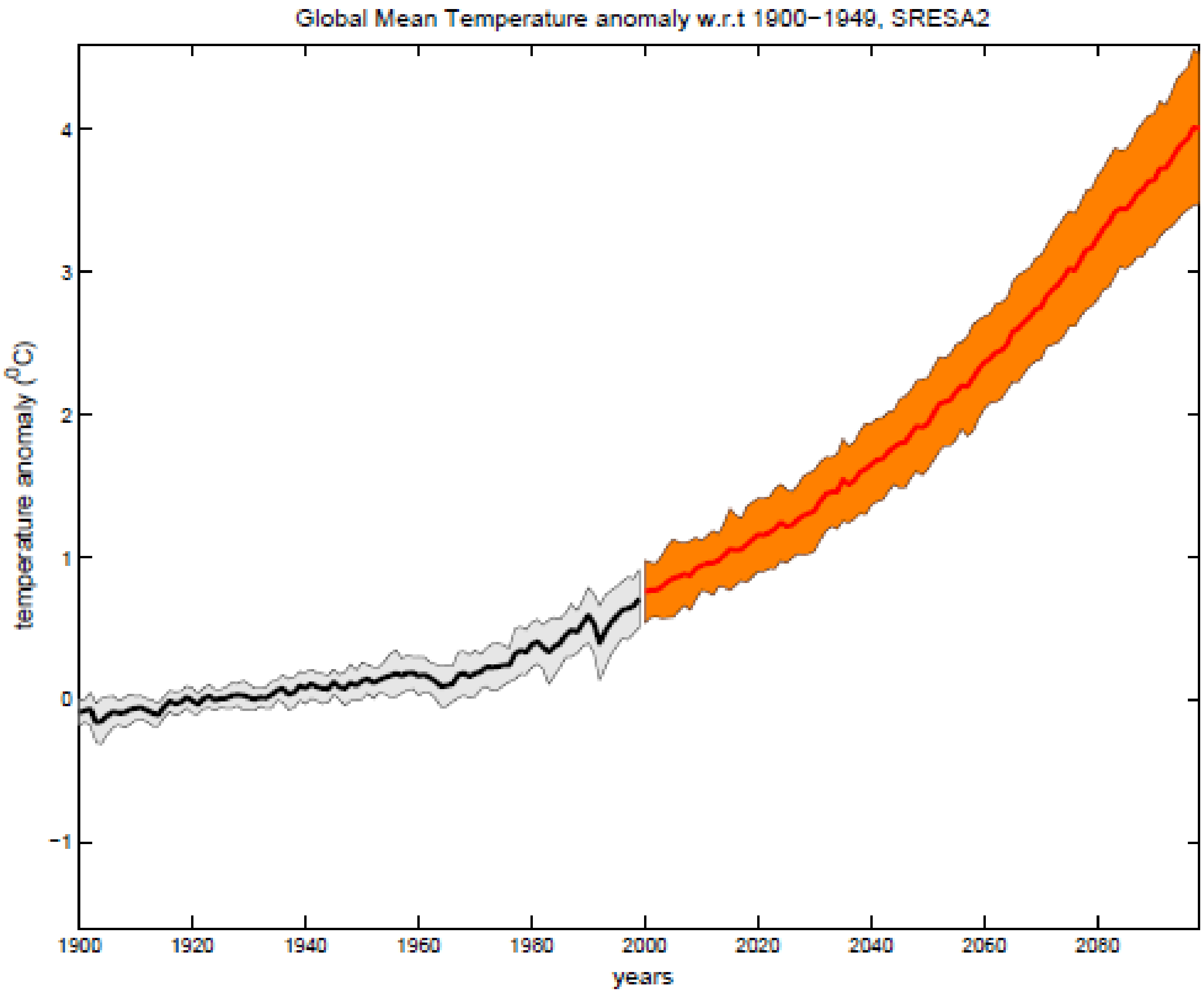
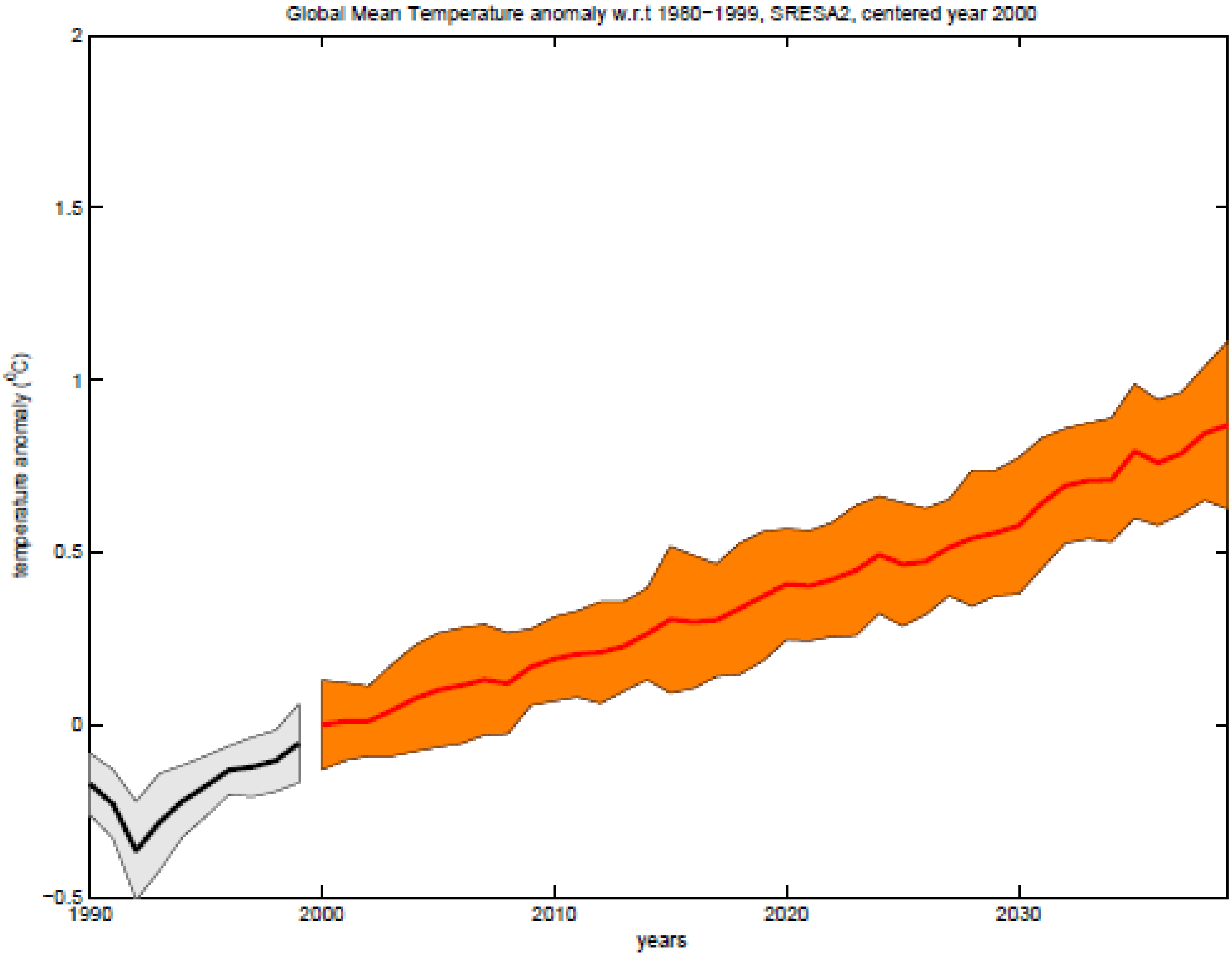


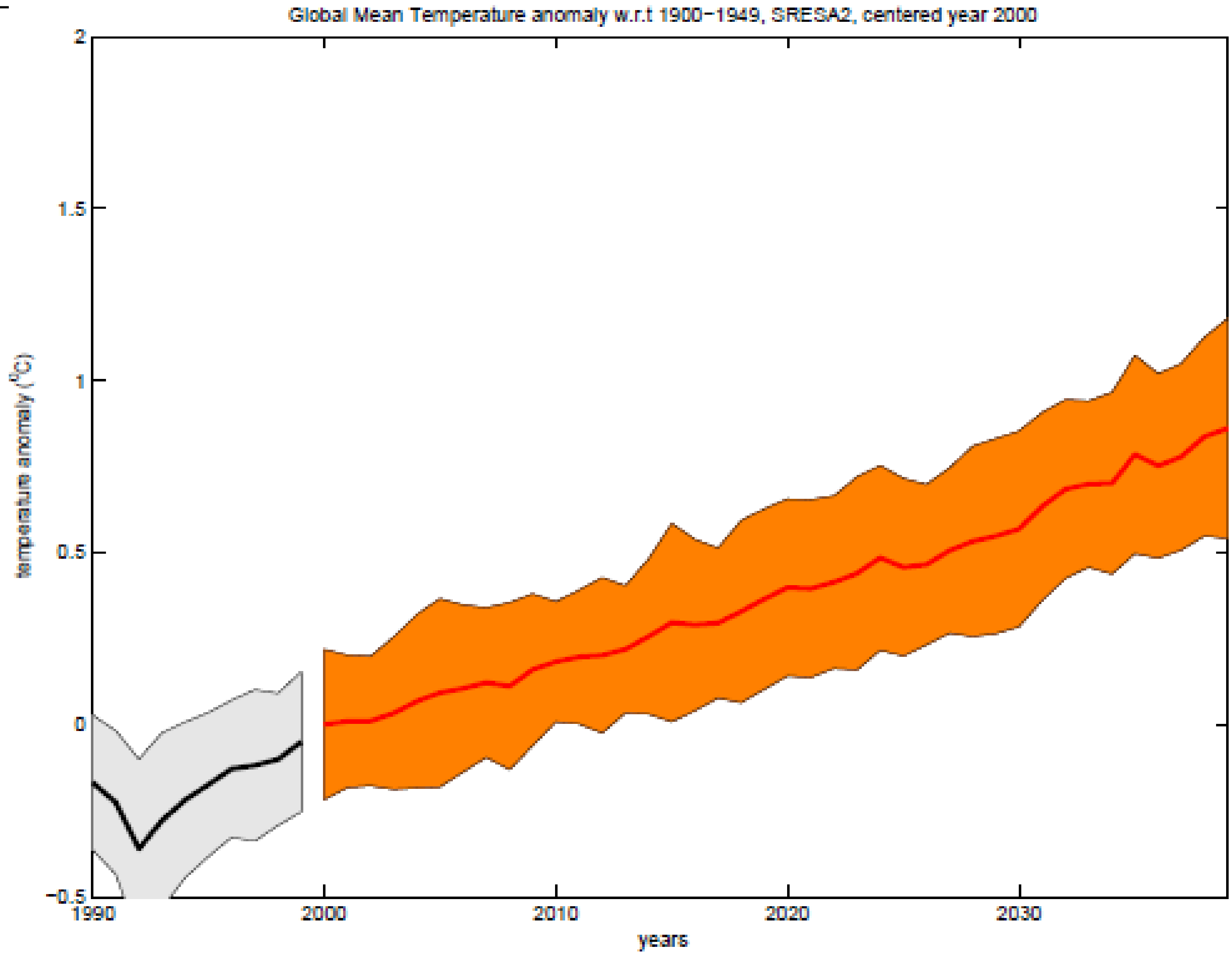
Figure SPM.5. *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) fo shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation ra averages. The orange line is for the experiment where concentrations were held constant at year 200 indicate the best estimate (solid line within each bar) and the* ***likely*** *range assessed for the six SRES mark the best estimate and* ***likely*** *ranges in the grey bars includes the AOGCMs in the left part of the figure, as of independent models and observational constraints. {Figures 10.4 and 10.29}*



Which anomaly matters? 1980-1999 ref



Which anomaly matters? 1900-1949 ref



Poor Communication does not reduce Real Risk

CLIMATIC LAWS

NINETY GENERALIZATIONS WITH NUMEROUS COROLLARIES AS TO THE GEOGRAPHIC DISTRIBUTION OF TEMPERATURE, WIND, MOISTURE, ETC.

A SUMMARY OF CLIMATE

BY

STEPHEN SARGENT VISHER, Ph.D.

Fel. Amer. Meterol. Soc., Royal Geog. Soc., Assoc. Amer. Geogrs. etc.
Associate Professor of Geography, Indiana University

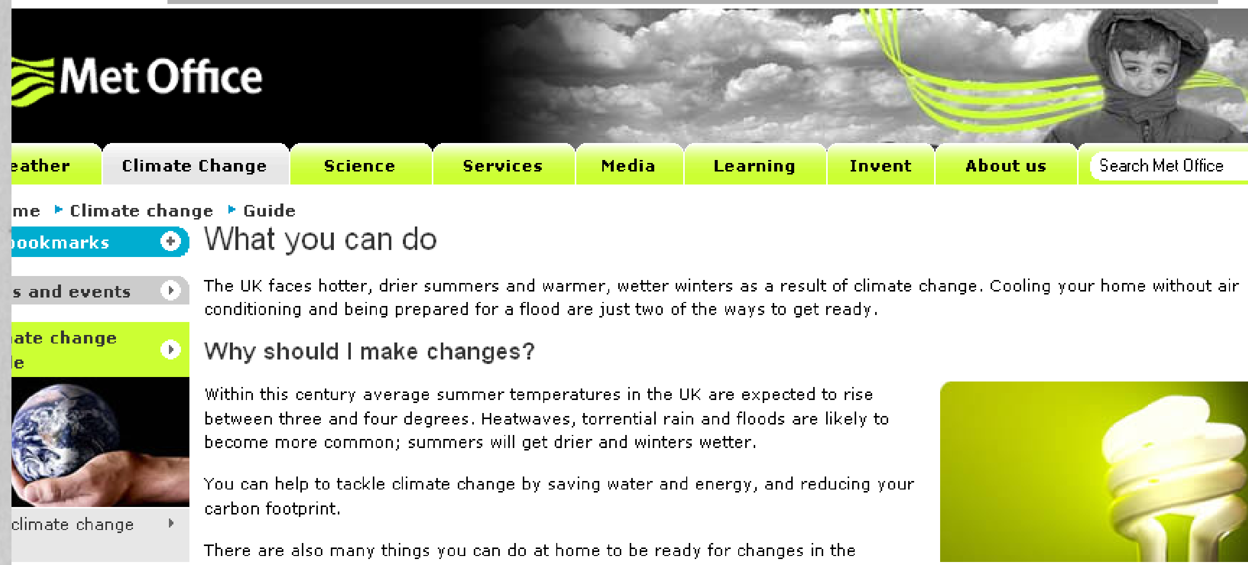
NEW YORK
JOHN WILEY & SONS, INC
LONDON CHAPMAN & HALL, LIMITED
1924

1924

More atmospheric CO_2 would mean a somewhat greater retention of heat and thus more water vapor accompanied by a further increase in heat retention. Huntington[43] reports evidence

26 CLIMATIC LAWS

of a change in storminess and in the location of storm tracks, and points out that heat retention would alter with storminess.



What exactly do today,s models add? ?Confidence? ?Insight? ?Numbers?

http://www.metoffice.gov.uk/climatechange/guide/what/

The Bayesian Way (UKCIP)

UK CLIMATE

More formally, Bayesian inference uses Bayes' formula for conditional probability:

$$P(H|D) = \frac{P(D|H)\,P(H)}{P(D)}$$

where

- H is a hypothesis, and D is the data.
- $P(H)$ is the *prior probability* of H: the probability that H is correct before the data D was seen.
- $P(D \mid H)$ is the conditional probability of seeing the data D given that the hypothesis H is true. $P(D \mid H)$ is called the *likelihood*.
- $P(D)$ is the marginal probability of D.
- $P(H \mid D)$ is the *posterior probability*: the probability that the hypothesis is true, given the data and the previous state of belief about the hypothesis.

$P(D)$ is the prior probability of witnessing the data D under all possible hypotheses. Given any exhaustive set of mutually exclusive hypotheses H_i, we have:

$$P(D) = \sum_i P(D, H_i) = \sum_i P(D|H_i)P(H_i).$$

All these P(•|•,Γ) are implicitly conditioned on the model class Γ (being adequate), in practice P(D| Γ) →0 ! (often very quickly)

In UKCP09 the probabilistic climate pr

~~Bayes' Therоem in a Bayesian statistical framework.~~ The starting point in production of UKCP09 Probabilistic Projections is to use a statistical emulator (trained on simulations from HadSM3) to estimate climate, and these emulated values form the prior distribution. This prior is then updated using weightings which are obtained from how closely each of the emulated climates compares to historical observations of climate and four indices of global temperature. These historical observations and global temperature indices constitute the observational evidence. In addition, the emulated weighted prior is updated through incorporation of a discrepancy term, which is obtained from the multi-model ensemble. This then results in the production of the final (posterior) probabilistic distribution.

Perfect Model Class by the back door.
(or P(H) is zero)

http://ukclimateprojections.defra.gov.uk/content/view/542/507/

The Bayesian Way (UKCIP)

UK CLIMATE PROJECTIONS

Reference: Probability level

Probability level

Describes the strength of evidence associated with a given value within a probabilistic climate projection. Probabilistic climate projections fall under subjective probability as the probabilities are a measure of the degree to which a particular level of future climate change is consistent with the evidence considered. In the case of UKCP09, the evidence comes from observations and outputs from a number of climate models, all with their associated uncertainties.

In detail

One of the main advances associated with UKCP09 is that it provides probabilistic climate projections. This means that different future climate outcomes described by a probabilistic projection have different strengths of evidence associated with them. As such, probability levels associated with a given change should be interpreted as indicating the relative likelihood of the projected change being at or less than the given change.

For example, if a projected temperature change of +4.5°C is associated with the 90% at a particular location in the 2080s for the UKCP09 medium emission scenario, this should be interpreted as it is projected that there is a 90% likelihood that temperatures at that location will be up to and including 4.5°C warmer than temperatures in the 1961–90 baseline period. Conversely, there is a 10% likelihood that those temperatures will be at or greater than 4.5°C warmer than the baseline period.

See also Radio 4's GQT!

What is climate?

Climate is what you expect, Weather is what you get.

Robert Heinlein (1973)

The climate system is a complex, interactive system consisting of the atmosphere, land surface, snow and ice, oceans and other bodies of water, and living things. The atmospheric component of the climate system most obviously characterises climate; climate is often defined as 'average weather'. Climate is usually described in terms of the mean and variability of temperature, precipitation and wind over a period of time, ranging from months to millions of years (the classical period is 30 years).

A report of Working Group I of the Intergovernmental Panel on Climate Change

Summary for Policymakers

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GLOSSARY OF METEOROLOGY

Edited by RALPH E. HUSCHKE

Sponsored by
U. S. Department of Commerce Weather Bureau
U. S. Air Force Air Weather Service, MATS and Geophysics Research Directorate AFCRC, ARDC
U. S. Army Signal Corps
U. S. Navy Office of Naval Research

AMERICAN METEOROLOGICAL SOCIETY
Boston, Massachusetts
1959

climate—"The synthesis of the weather" (C. S. Durst); the long-term manifestations of weather, however they may be expressed. More rigorously, the climate of a specified area is represented by the statistical collective of its weather conditions during a specified interval of time (usually several decades).

Climate is a distribution of multivariate time series!
(It's not just a number or two)
And for policy and (most) decision support:
"All Climate is Local"

The Modeler's Mantra

This is the best available information, so it must be of value.
Everyone knows the limitations. Everyone understands the implications of these assumptions.
This is better than nothing.
No one has proven this is wrong.
There is no systematic error, on average. The systematic errors don't matter.
The systematic errors are accounted for in the post processing.
Normality is always a good first approximation. In the limit, it has to be normally distributed, at least approximately.
Everyone assumes it is normally distributed to start with.
Everyone makes approximations like that.
Everyone makes this approximation.
We have more advanced techniques to account for that.
The users demand this. The users will not listen to us unless we give them the level of detail they ask for.
We must keep the users on-board.
If we do not do this, the user will try and do it themselves.
There is a commercial need for this information, and it is better supplied by us than some cowboy.
Refusing to answer a question is answering the question.
Refusing to use a model is still using a model.
Even if you deny you have a subjective probability, you still have one. All probabilities are subjective.
The model just translates your uncertainty in the inputs to your rational uncertainty in the future.
Sure this model is not perfect, but it is not useless.
No model is perfect.
No model is useless if interpreted correctly. It is easy to criticise.
This model is based on fundamental physics.
The probabilities follow from the latest developments in Bayesian statistics.
Think of the damage a decision maker might do without these numbers.
Any rational user will agree.
Things will get better with time, we are making real progress.
You have to start somewhere. What else can we do? It might work, can you deny that?
What damage will it do?