Opacity and Insight of Science in Support of Decision Making

Decision making under uncertainty is hampered both by different varieties of uncertainty and by the wide variety of situations in which decisions are made. This presentation will focus on the role of uncertainty due to opacity; imprecision, indeterminacy, ambiguity and intractability will also come into play. Opacity captures uncertainty due to a lack of clarity on assumptions made within or to a failure in understanding the strength of scientific evidence. Provision of quantitative details from multiple simulation models or many forecasters can either increase of decrease opacity.

Opacity is increased when statistical manipulations are hidden; this is the case regardless of their rigour. It decreases when assumptions are made clear, again regardless of their rigour. There are, of course, Machiavellian attempts to increase opacity; a past lack of transparency can prove costly here. That said, there are also significant opportunities to advance the understanding of science by clarifying obfuscation, whether intentional or due to ignorance. Opacity is decreased when the limitations of scientific insight are made clear at the outset, when the source and potential impacts of each challenge are conveyed, and a timetable for lifting each is given.

All science is uncertain. The personal risk and public commitment of a decision maker can be impacted significantly by their confidence in their own understanding of the strengths and the weaknesses of the scientific evidence. It is suggested that confidence within the current level of uncertainty(s) is more robust when those uncertainties are grasped, leading to better decision making, and to a clearer vision on the part of decision makers as to evidence will be most value to them on the timescales of interest to them.

Berger, J.O. and Smith, L.A. (2019) **'On the statistical formalism of uncertainty quantification**,' *Ann Rev of Statistics and its Application,* 6. 3.1.

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

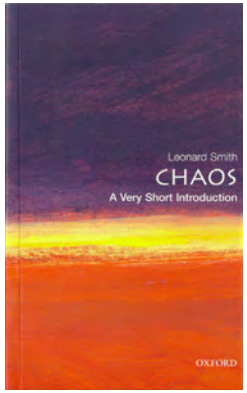
Smith, L.A. (2016) '**Integrating information, misinformation and desire: improved weather-risk management for the energy sector**', in Aston, P.J., Mulholland, A.J. and Tant, K.M.M. (ed.) *UK Success Stories in Industrial Mathematics*, 289-296. Springer.

Smith, L.A. (2002) '**What might we learn from climate forecasts?**', *Proc. National Acad. Sci.* USA, 4 (99): 2487-2492.

Space @ Virginia Tech
Center for Space Science and Engineering Research

COLLEGE OF ENGINEERING
BRADLEY DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
VIRGINIA TECH

LSE Data Science Institute



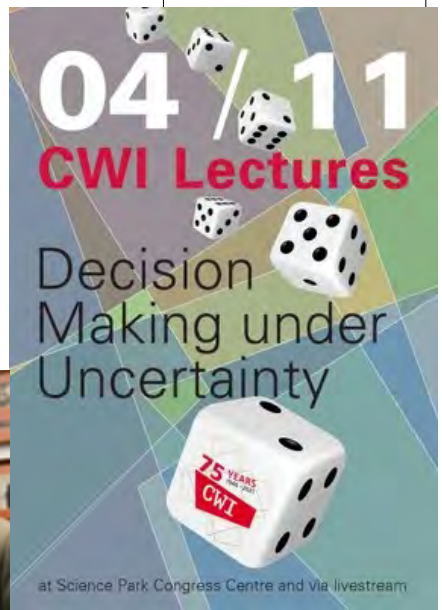
Opacity and Insight of Science in Support of Decision Making

Leonard Smith

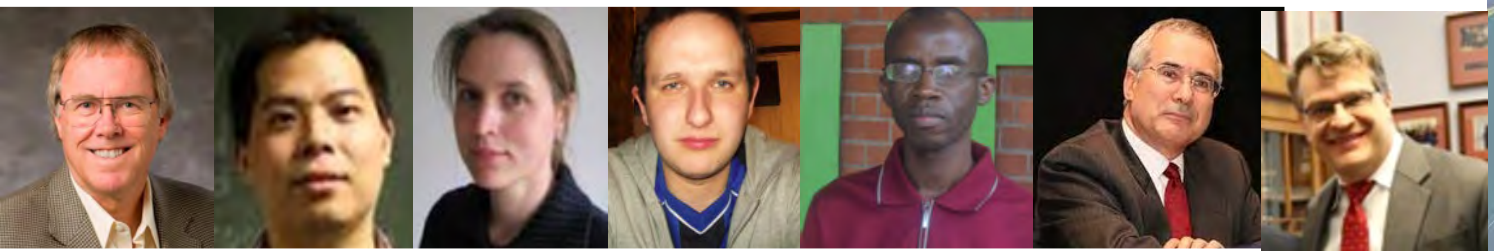
Space@VT in ECE, Virginia Tech

DSI London School of Economics

@lynyrdsmyth



This Talk Would Not Be *this* Talk without:



Uncertainty Regarding Uncertainty

Opacity is a type of uncertainty that often arises due to a failure to communicate the fidelity and strength of scientific evidence clearly, or the relevance of the products of simulation science to quantitative decision making.

Opacity can be increased by

- **mistaking one type of uncertainty for another.**
- **hidden statistical manipulation (whether justified or not)**
- **assuming the "best available" model is "adequate for purpose"**
- **a lack of clarity regarding Known Neglecteds.**

Opacity reduces the efficacy of multidisciplinary science, and the effectiveness of science in support of policy and decision making.

Opacity revealed can undermine confidence, leads leading to regret, a loss of trust in "as good as it gets" science, and retreat from quantitative evaluation. (Opacity maintained intentionally is, of course, much more damaging.)

Communication of Uncertainty for More Informed Decision Making

Clarity Consistency Confidence

Different Types of Uncertainty (Technical)

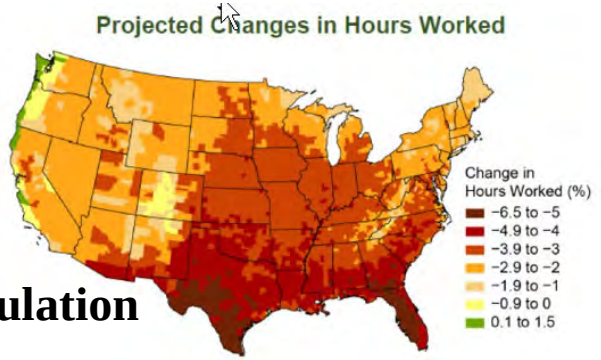
Origins of Scientific Uncertainty (in Practice)

Interpretation of Uncertainty from Model Land to Politics and other Sciences

Impacts of Opacity:

- **Hesitancy due to the failure to communicate the context of scientific insights**
- **Confusion of "As good as it Gets Science" with "The Best Available Simulation"**

"The cost of solving the Comet mystery must be reckoned neither in money nor in manpower."
Winston Churchill, 1954

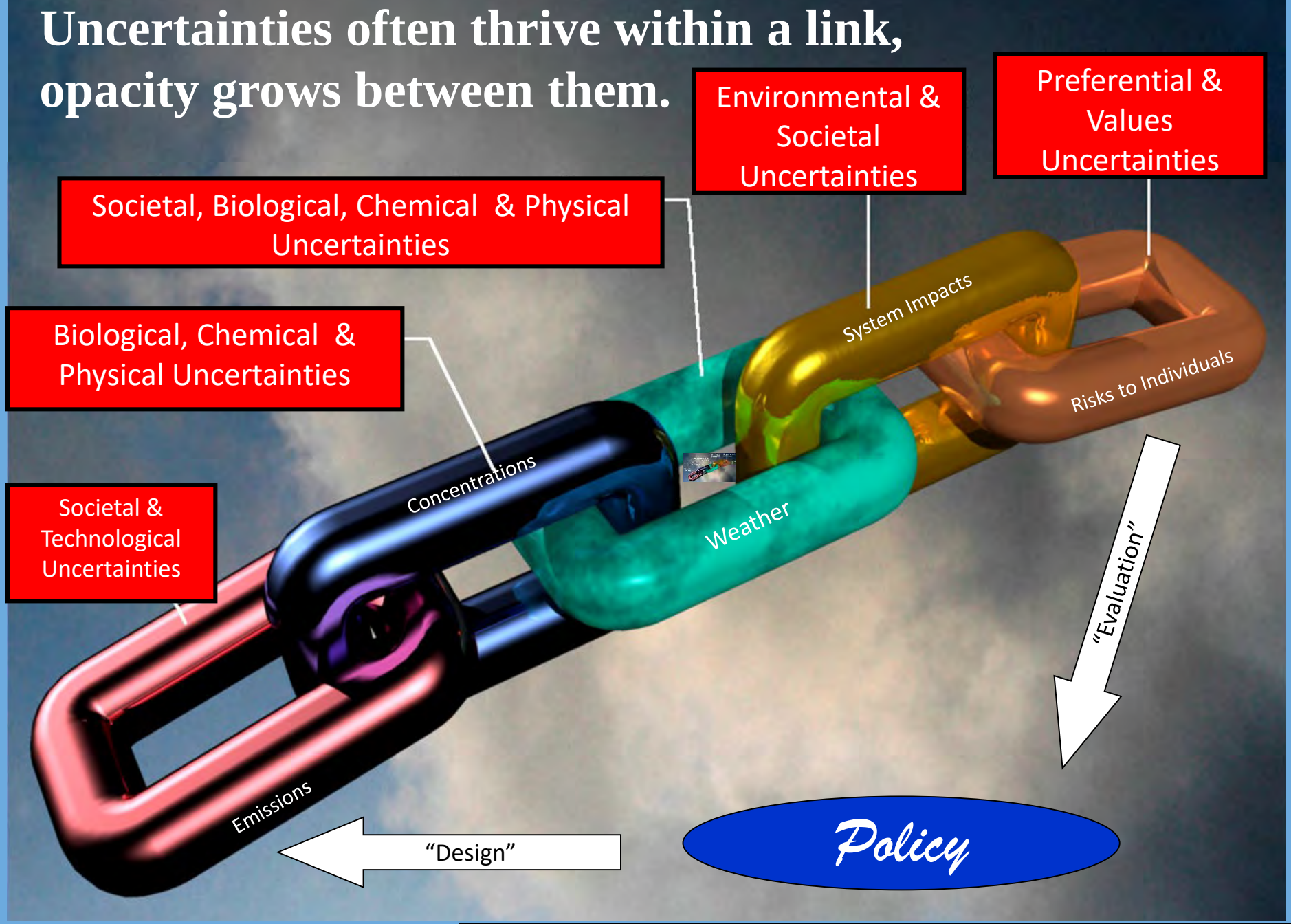


- **Misrepresenting scientists who quantify the fidelity of a simulation model as scientists who "do not believe in climate change."**

Decreasing Opacity can contribute to:

- **More effective science discussions on Capitol Hill**
- **Clearer (achievable) targets within science (improved resource allocation)**
- **More relevant modelling across disciplines**
- **Deeper public understanding of science**
- **Kinder, gentler discussion within policy-relevant sciences**

Uncertainties often thrive within a link, opacity grows between them.



From: Smith, L.A. and Stern, N. (2011) '[Uncertainty in science and its role in climate policy](#)', *Phil. Trans. R. Soc. A*, 369, 1-24.

After Palmer BAMS April 2008

Opacity is One of Several Types of Uncertainty

Imprecision

A well defined value that is considered imprecisely known
(acceleration of gravity at Den Haag, mass of the French kilogram,...)
on which we put a probability distribution given information I

Ambiguity

Probabilistic weather forecasts of a future temperature often aim to quantify the impact of imprecision in the initial condition.

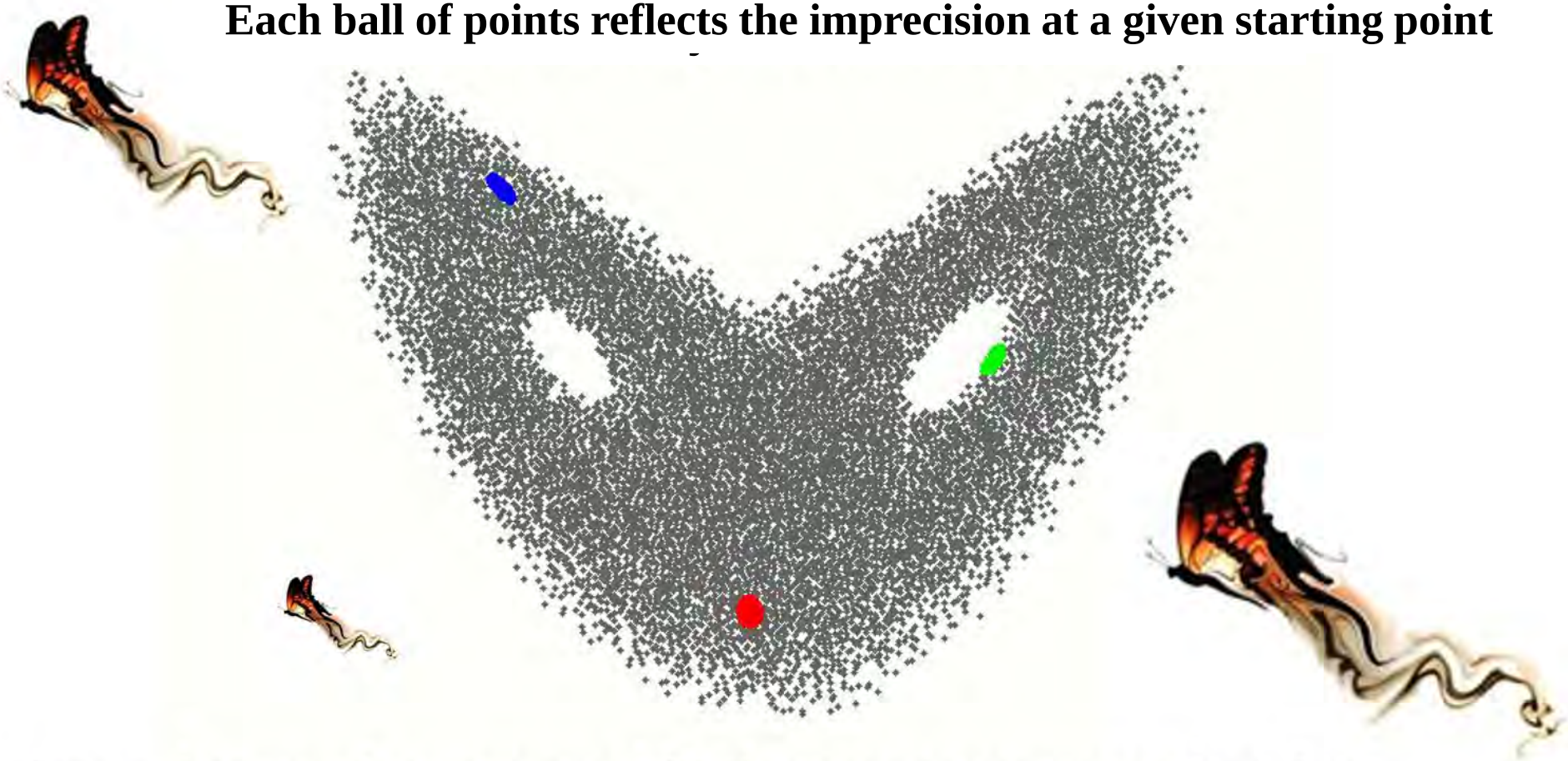
Intractability

Indeterminacy

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

Probability forecasts due to Imprecise Initial Conditions

Each ball of points reflects the imprecision at a given starting point

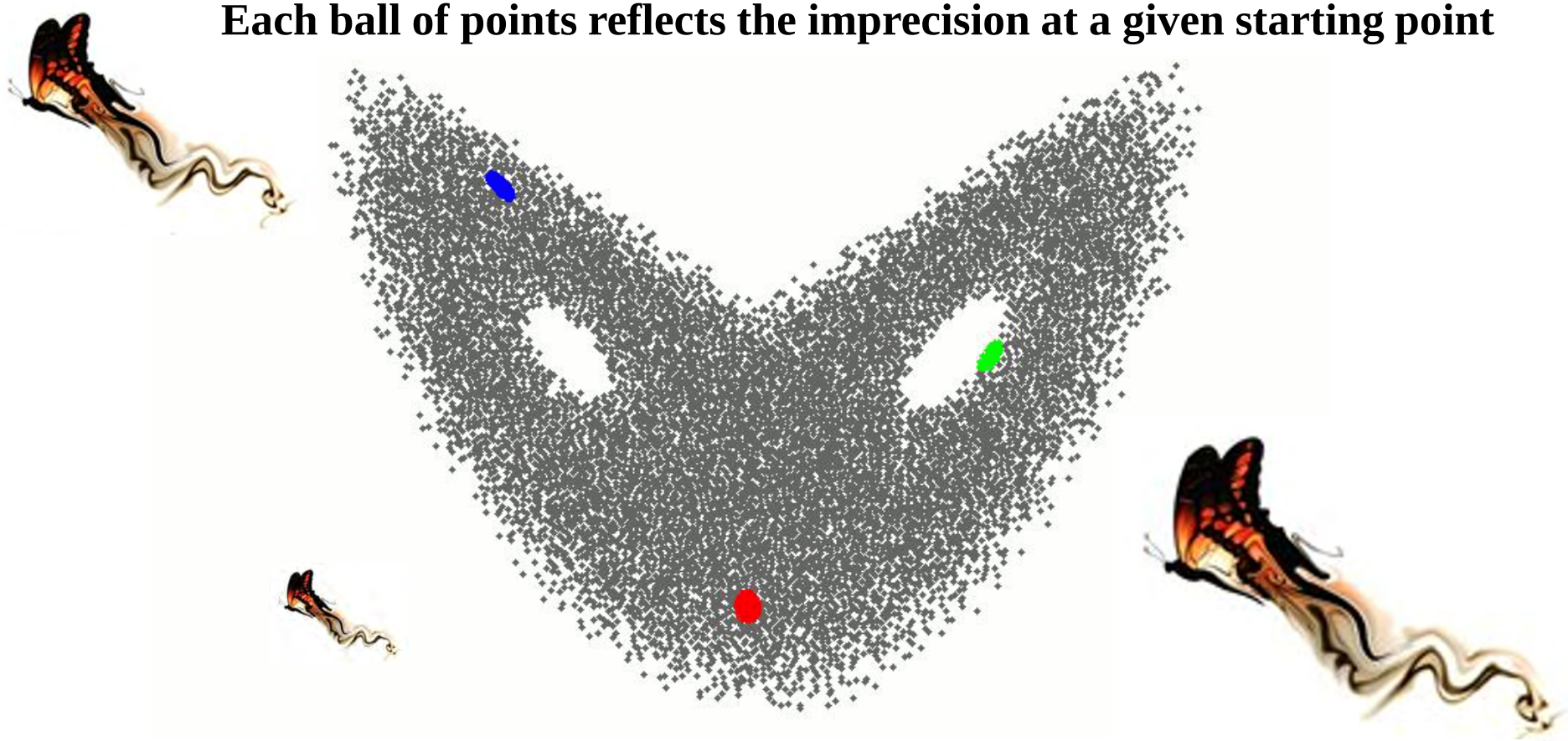


Some days we have more skill than average, some days less.

The hope is for ensembles to inform us which is which, in advance!

Probability forecasts due to Imprecise Initial Conditions

Each ball of points reflects the imprecision at a given starting point



Weather forecasts *aim* to propagate imprecision in the present forward in time and reflect the imprecision in our future as a probability distribution based on an ensemble of simulations.

Space @ Virginia Tech
Center for Space Science and Engineering Research

Thanks to Du

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Ambiguity

A well defined value for which we lack sufficient information to pose a quantitative probability distribution.

Intractability

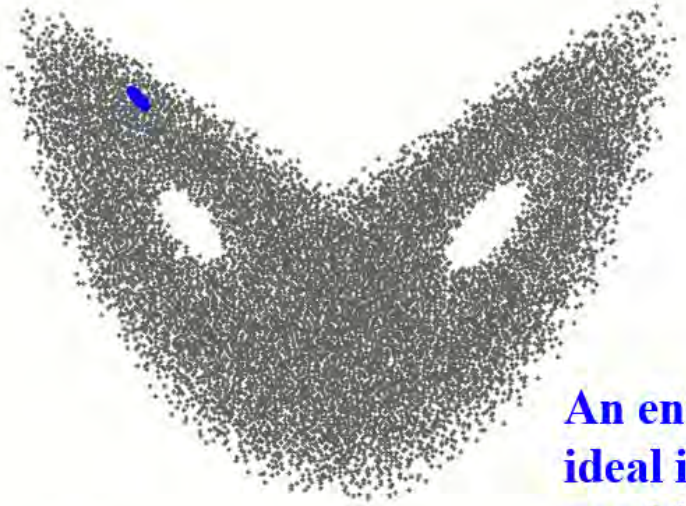
If the best available models have serious flaws in their mathematical structure, model-based probability distributions will not capture the fidelity of our forecast.

Indeterminacy

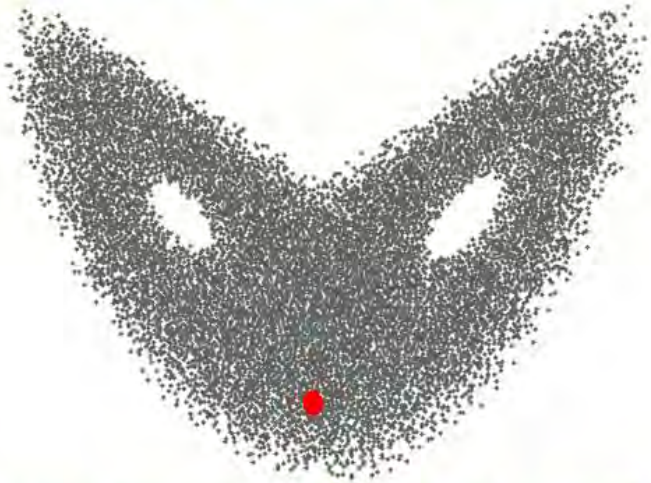
Smith, L.A. and Stern, N. (2011) 'Uncertainty in science and its role in climate policy', *Phil. Trans. R. Soc. A*, 369, 1-24.

Ambiguity reflects the limits of Probability Forecasting

Evolution of Sets of Identical States Differ between the Model and Reality



An ensemble of dynamically ideal initial conditions with good but imperfect model



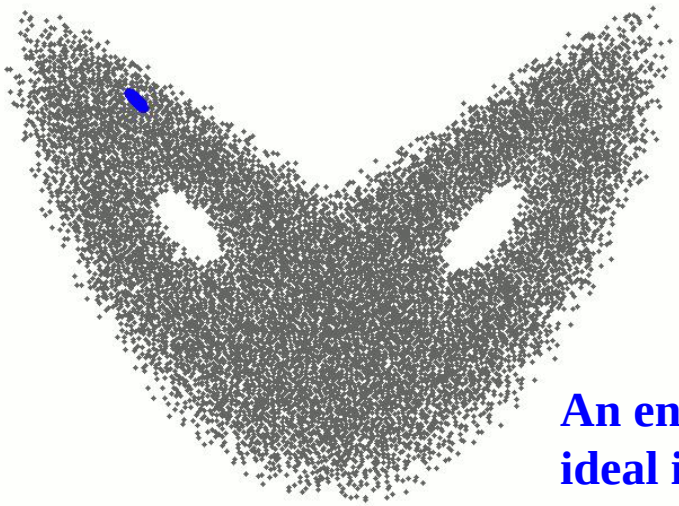
Here the best available model cannot produce decision-relevant probabilities.

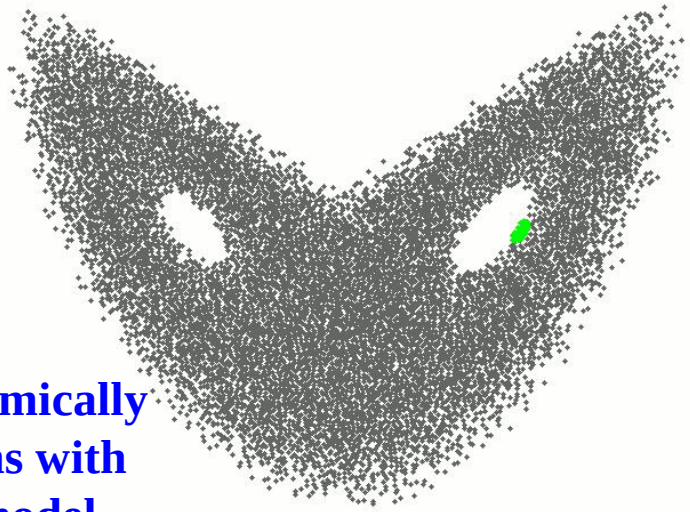
$x \rightarrow c \sin(x/c)$ on RHS with $c=128$

Thanks to Du

Ambiguity reflects the limits of Probability Forecasting

Evolution of Sets of Identical States Differ between the Model and Reality





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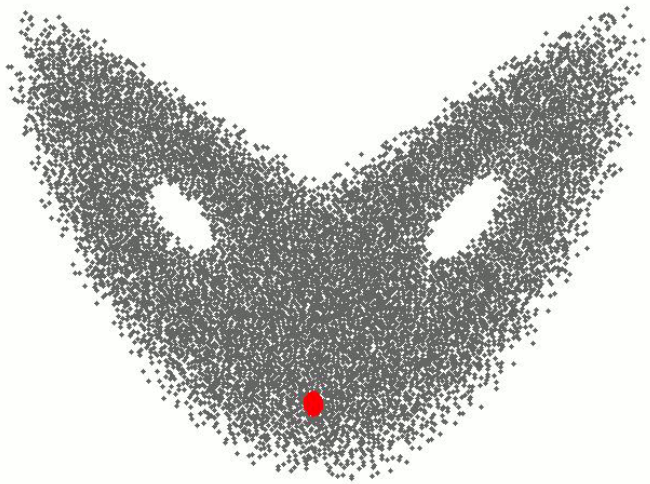

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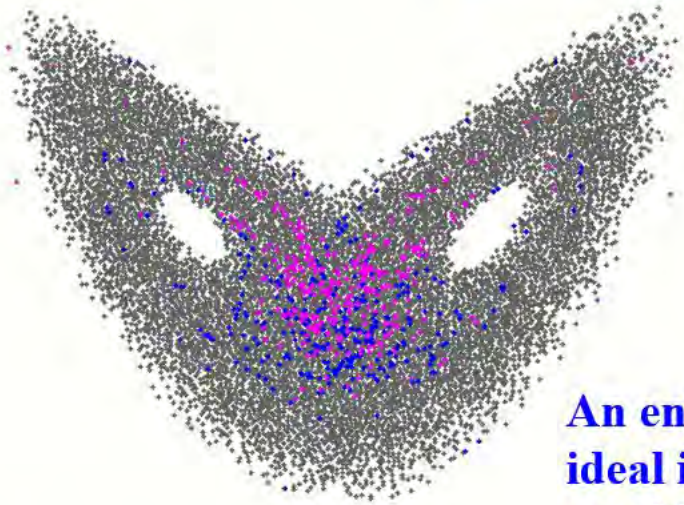
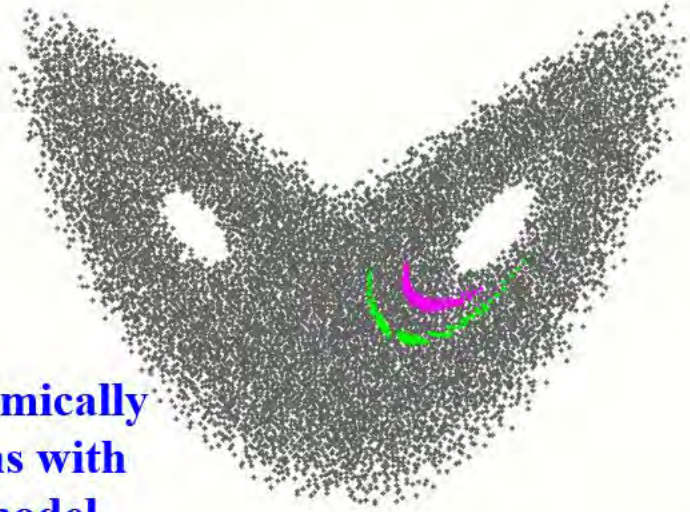
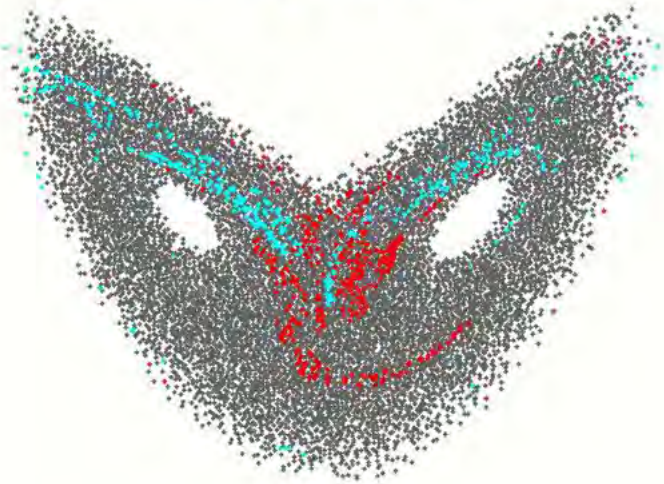




An ensemble of dynamically ideal initial conditions with good but imperfect model

Here our models might help us understand the dynamics of system, without being able to provide decision relevant probability forecasts.



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$x \rightarrow c \sin(x/c)$ on RHS with $c=128$

Thanks to Du

Opacity is One of Several Types of Uncertainty

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A well defined value that is considered imprecisely known
(acceleration of gravity at Den Haag, mass of the French kilogram,...)
on which we put a probability distribution given information I

Ambiguity

A well defined value for which we lack sufficient information to pose a quantitative probability distribution.

Intractability

If the best available models have serious flaws in their mathematical structure, model-based probability distributions will not capture the fidelity of our forecast.

Indeterminacy

Confusing imprecision and ambiguity is a common source of opacity.

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

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Intractability

A quantity that may be precisely defined, but which is beyond our (current) ability to estimate with quantified precision.
(billionth digit of π, smoothness of Navier-Stokes)

Indeterminacy

Some things we know we cannot compute. Today.

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

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(billionth digit of π, smoothness of Navier-Stokes)

Indeterminacy

A quantity which is in fact not uniquely (precisely) defined.
(the location of an electron, the drag of the aether, the worth of a forest ...)

Some things simply are not defined uniquely, if at all.

Smith, L.A. and Stern, N. (2011) '[Uncertainty in science and its role in climate policy](#)', *Phil. Trans. R. Soc. A*, 369, 1-24.

Consider an under-appreciated example of intractability due to technological constraints.

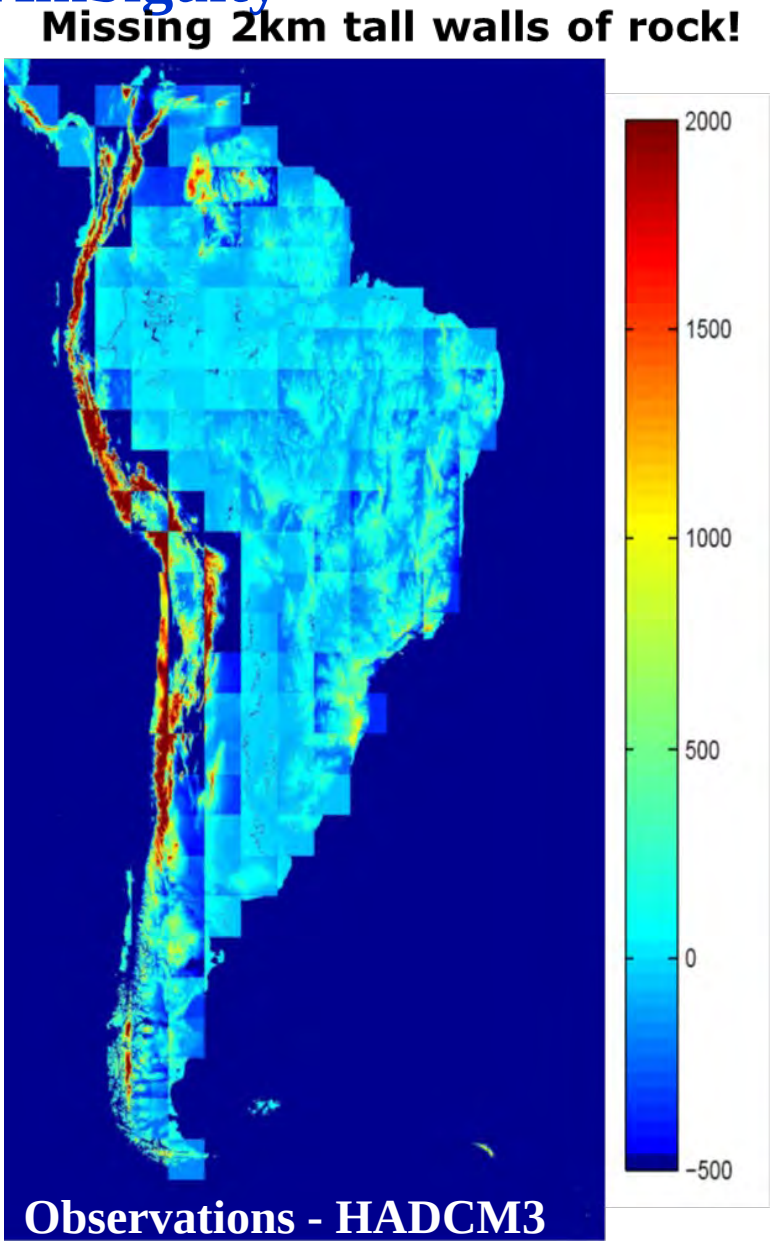
Technological Constraints:
Intractability leading to Ambiguity

HadCM3 is a workhorse climate model. The HadCM3 model-Andes are two kilometres too short.

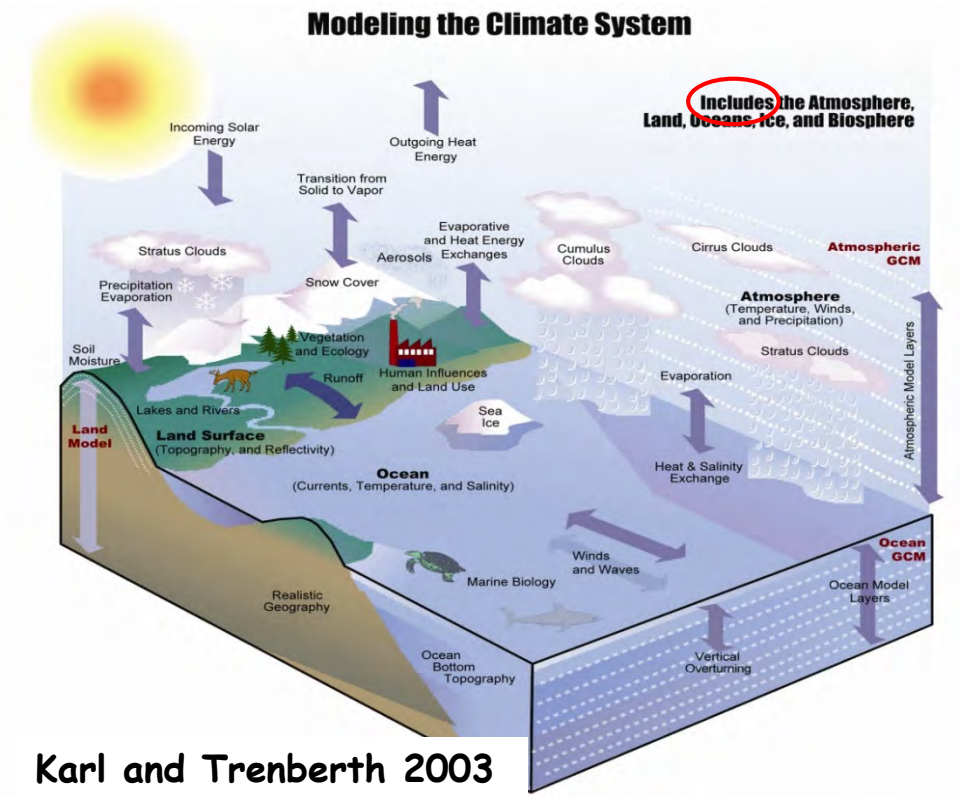
To be clear: it is not that we do not know how to simulate rock, rather that it was decided not too do so in order to achieve some other goal.

This "Known Neglected" limits the fidelity of our simulations on some space and time scales.

A more open discussion of these limits to model fidelity regarding various impacts as a function of lead time would be valued.



When opacity is revealed, decision makers may experience a loss of confidence, if not regret, independent of impact of the particular shortcoming of the model.

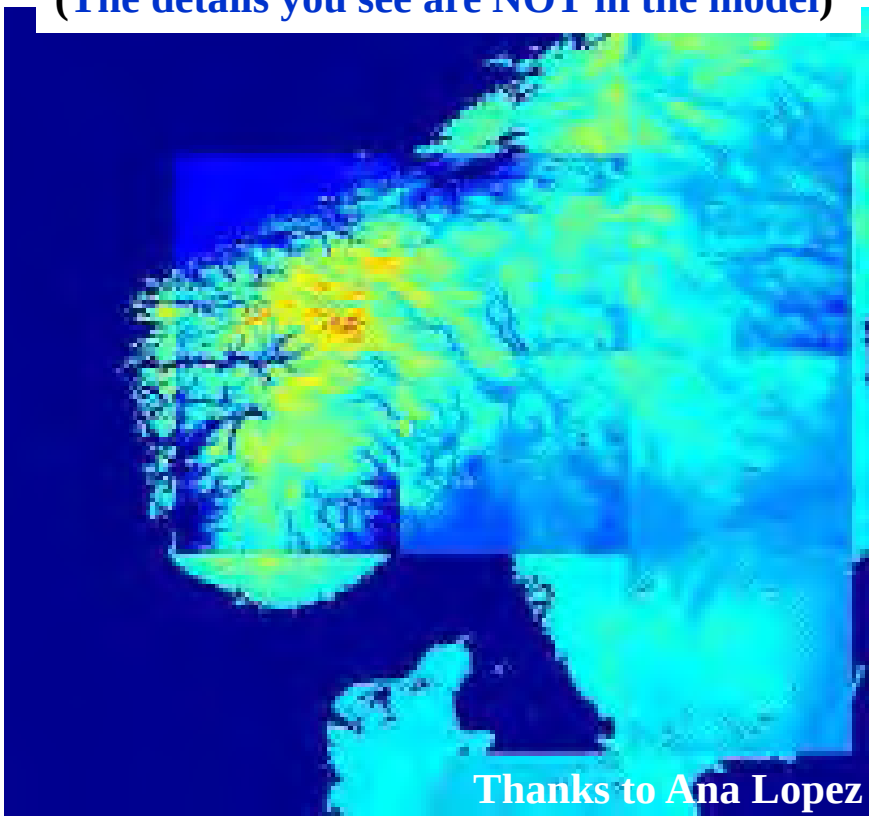


Karl and Trenberth 2003

A very schematic schematic reflecting phenomena the model "includes".

"included" vs "simulated realistically"

Climate Model Points(the squares)
(The details you see are NOT in the model)



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 which is said to be "constant" "within" a grid point.

Insurance Company with a snowfall question…

Achievable Goals in Reducing Opacity

Complete clarity is, of course, impossible; some Unknown Unknowns are inconceivable. Even "as good as it gets" science can prove incomplete.

Arguably, the Comet disasters resulted in the discovery of metal fatigue.

"The cost of solving the Comet mystery must be reckoned neither in money nor in manpower."
Winston Churchill, 1954

https://upload.wikimedia.org/wikipedia/commons/7/77/Comet_Prototype_at_Hatfield.jpg

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And the details of how models work and the strong science upon which they are based will never be communicated fully to decision makers who remain primarily decision makers.

That said, the failure to distinguish ambiguity from imprecision, or the promotion of a simulation as being from "the best available model" when that model is not thought to be adequate for purpose, undermines the application of science in support of decision making.

Maintaining the distinction between different types of probability also plays a role in reducing opacity.

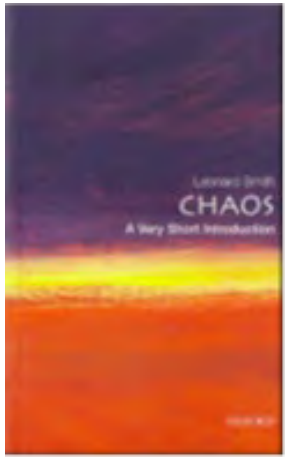
Laplacian Demons P(x | data, I)

Laplace's Demon (1814)

1) Perfect Equations of Motion (PMS)
2) Perfect noise-free observations
3) Unlimited computational power

P(x | Data,G) **G is complete True knowledge**

Demon's Apprentice (2007)



1) Perfect Equations of Motion (PMS)
2) Perfect ~~noise-free observations~~ (Noise Model)
3) Unlimited computational power

P(x | data, g_t) **g_t is incomplete but True**

Demon's Novice (2007)

1) ~~Perfect Equations of Motion (PMS)~~
2) ~~Perfect noise-free observations~~
3) Unlimited computational power

P(x | data, g) **g is useful approximations of g_t**

Still, g is known to be false!

Laplacian Demons

$P(x \mid data, I)$

Laplace's Demon (1814)

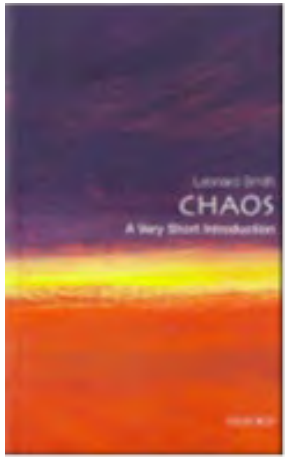
1) Perfect Equations of Motion (PMS)
2) Perfect noise-free observations
3) Unlimited computational power

46656 Varieties of Bayesians (#765)
By IJ Good (in Good Thinking)

Demon's Apprentice (2007)

$P(x \mid data, I_{Apprentice})$

As good as it gets science.
No Big Surprises: One in a million events happen once in a million times.



Demon's Novice (2007)

$P(x \mid data, I_{Novice})$

Big Surprises are expected.
While some we might see coming, how might I use P(X| FALSE) as a probability in decision making?

And what is a "Big Surprise"?

What is a "Big Surprise"?

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

In weather forecasting, we can see the lead times at which our models become silly, but in climate forecasting we are in the dark.
If our models agreed (in distribution) would we have more confidence in their simulations?

What if our models were developed independently, say, in separate space stations, do you feel you'd see their simulations converge in distribution?
For weather I expect so; for climate, I expect not.

A genuine expert can always foretell a thing that is 500 years away easier than he can a thing that's only 500 seconds off.
- *A Connecticut Yankee in King Arthur's Court*

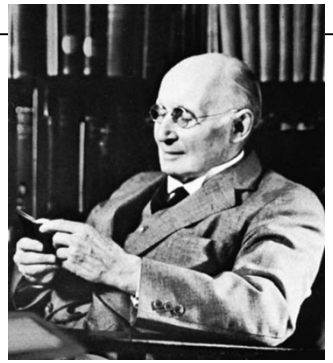
Fallacy of Misplaced Concreteness

"The advantage of confining attention to a definite group of abstractions, is that you confine your thoughts to clear-cut definite things, with clear-cut definite relations. … The disadvantage of exclusive attention to a group of abstractions, however well-founded, is that, by the nature of the case, you have abstracted from the remainder of things.

... it is of the utmost importance to be vigilant in critically revising your *modes* of abstraction.

Sometimes it happens that the service rendered by philosophy is entirely obscured by the astonishing success of a scheme of abstractions in expressing the dominant interests of an epoch."

A N Whitehead. Science and the Modern World. Pg 58/9



Whitehead was criticising the straightjacket of Newtonian science; today, perhaps, computer simulation may impede more than just the progress of science.

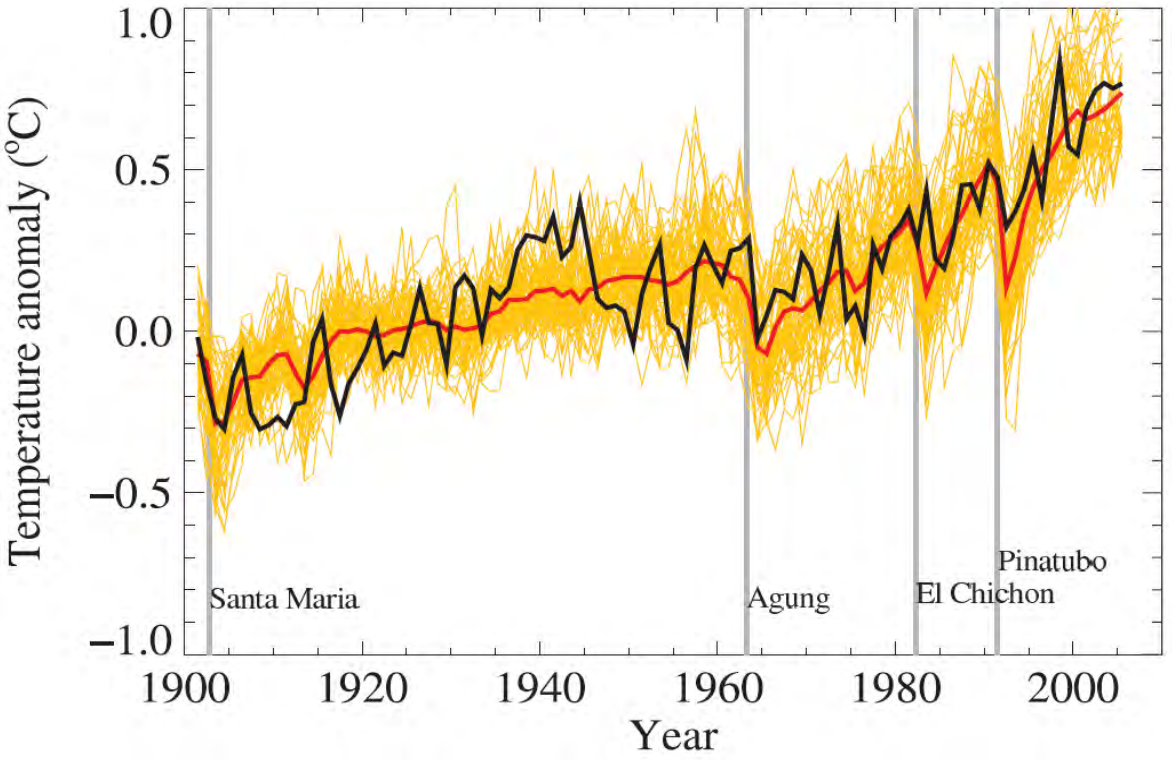
In the real world, mathematics is never rigorously relevant.

(beyond the integers!)

Anomalies, Systematic Errors, Laws of Physics

Models agree that a wide range of sorta-Earth-like planets warm about the same amount under the observed forcing.

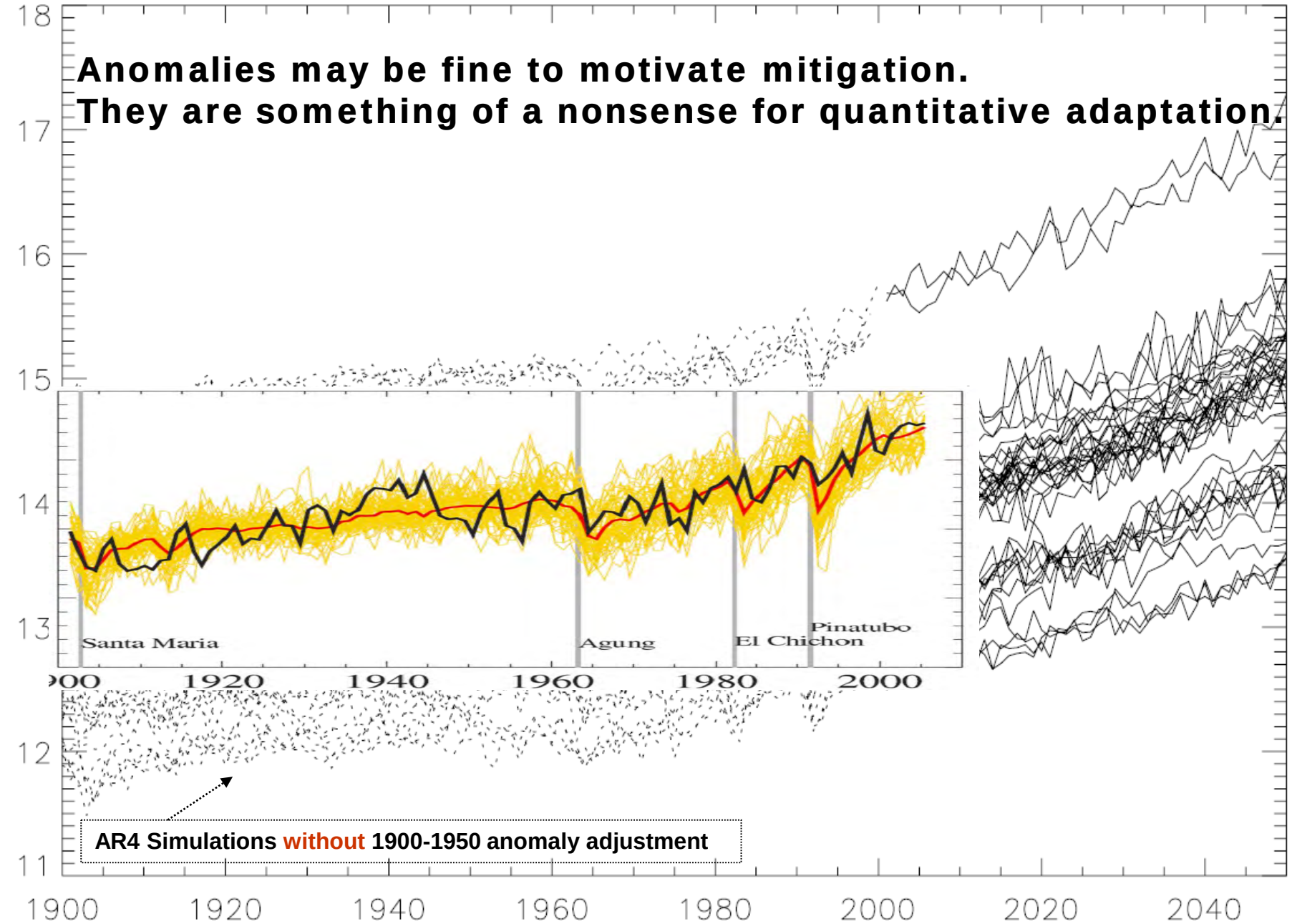
FAQ 8.1, Figure 1. *Global mean near-surface temperatures over the 20th century from observations (black) and as obtained from 58 simulations produced by 14 different climate models driven by both natural and human-caused factors that influence climate (yellow). The mean of all these runs is also shown (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.)*



IPCC AR4

Systematic errors are larger than the observed effect

Hindcasts and Forecasts of Global Mean Temperature



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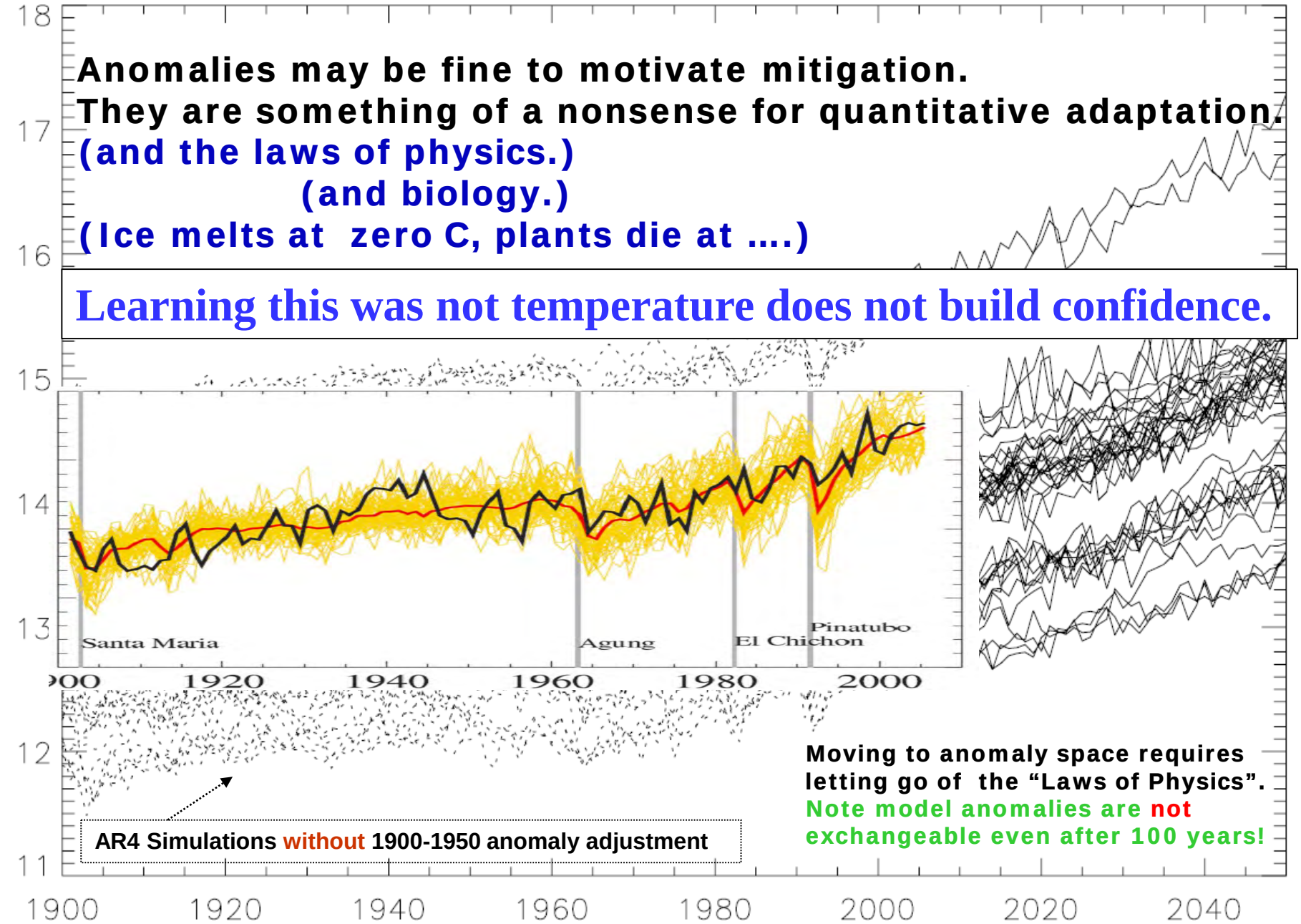
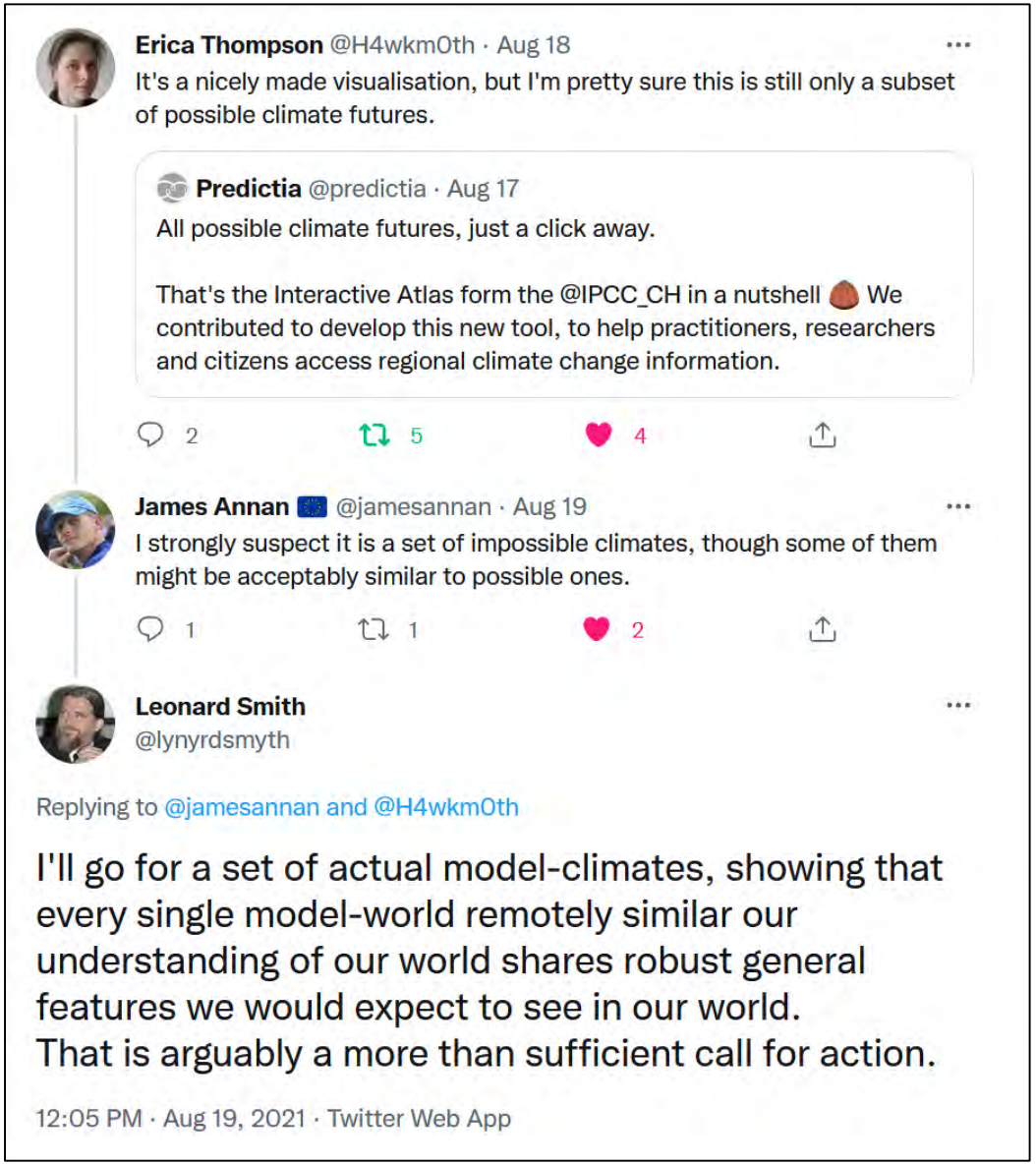


Anomalies Might be used to Reduce Opacity



Erica Thompson @H4wkm0th · Aug 18

It's a nicely made visualisation, but I'm pretty sure this is still only a subset of possible climate futures.

> **Predictia** @predictia · Aug 17
>
> All possible climate futures, just a click away.
>
> That's the Interactive Atlas form the @IPCC_CH in a nutshell We contributed to develop this new tool, to help practitioners, researchers and citizens access regional climate change information.

2 5 4

James Annan @jamesannan · Aug 19

I strongly suspect it is a set of impossible climates, though some of them might be acceptably similar to possible ones.

1 1 2

Leonard Smith
@lynyrdsmyth

Replying to @jamesannan and @H4wkm0th

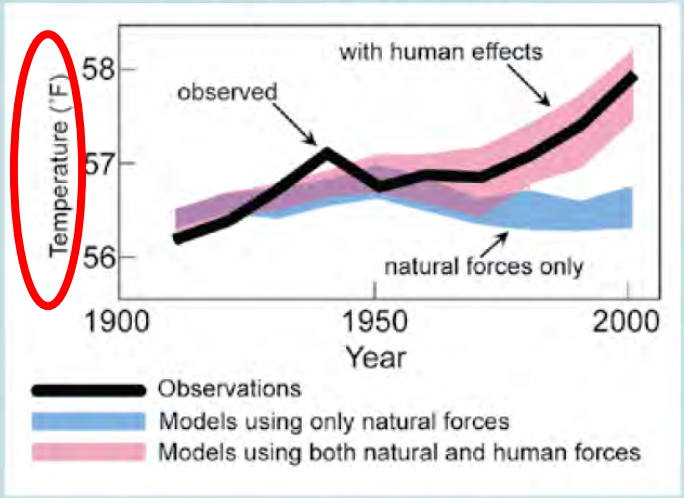
I'll go for a set of actual model-climates, showing that every single model-world remotely similar our understanding of our world shares robust general features we would expect to see in our world.
That is arguably a more than sufficient call for action.

12:05 PM · Aug 19, 2021 · Twitter Web App

"Hidden" statistical post-processing can increase opacity.

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).

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

ipcc INTERGOVERNMENTAL PANEL ON climate change WMO UNEP

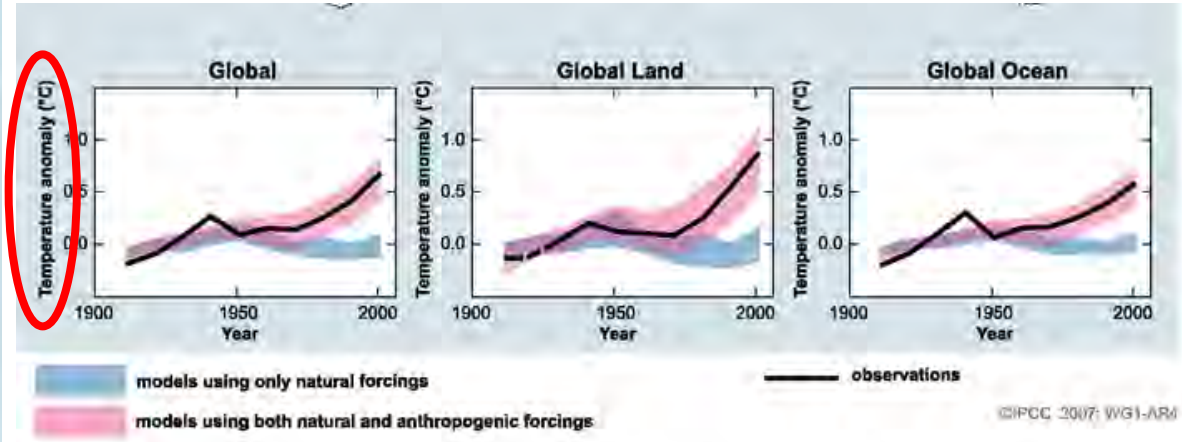
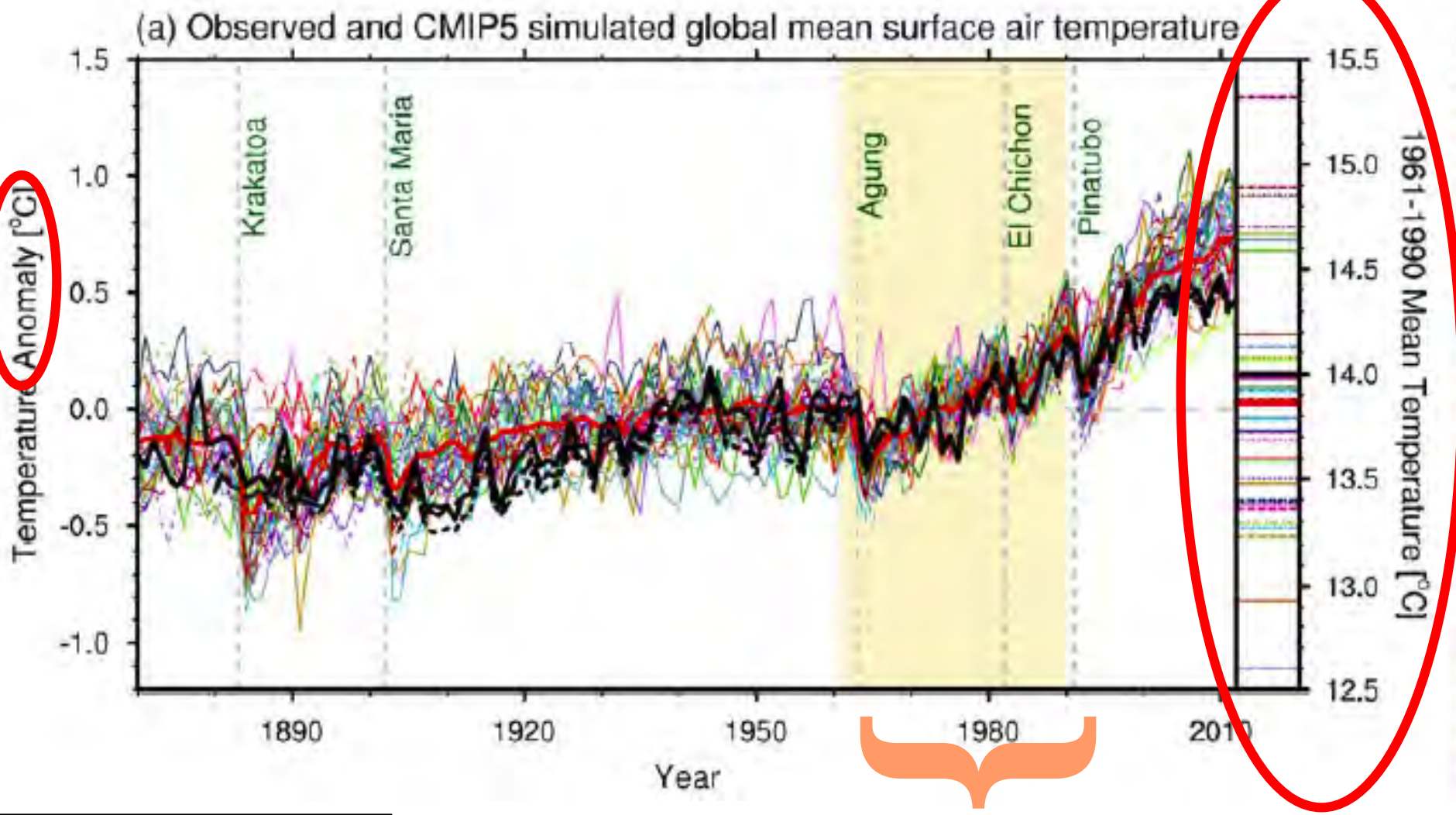


Figure SPM.4. Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906 to 2005 (black line) plotted against the centre of the decade 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}

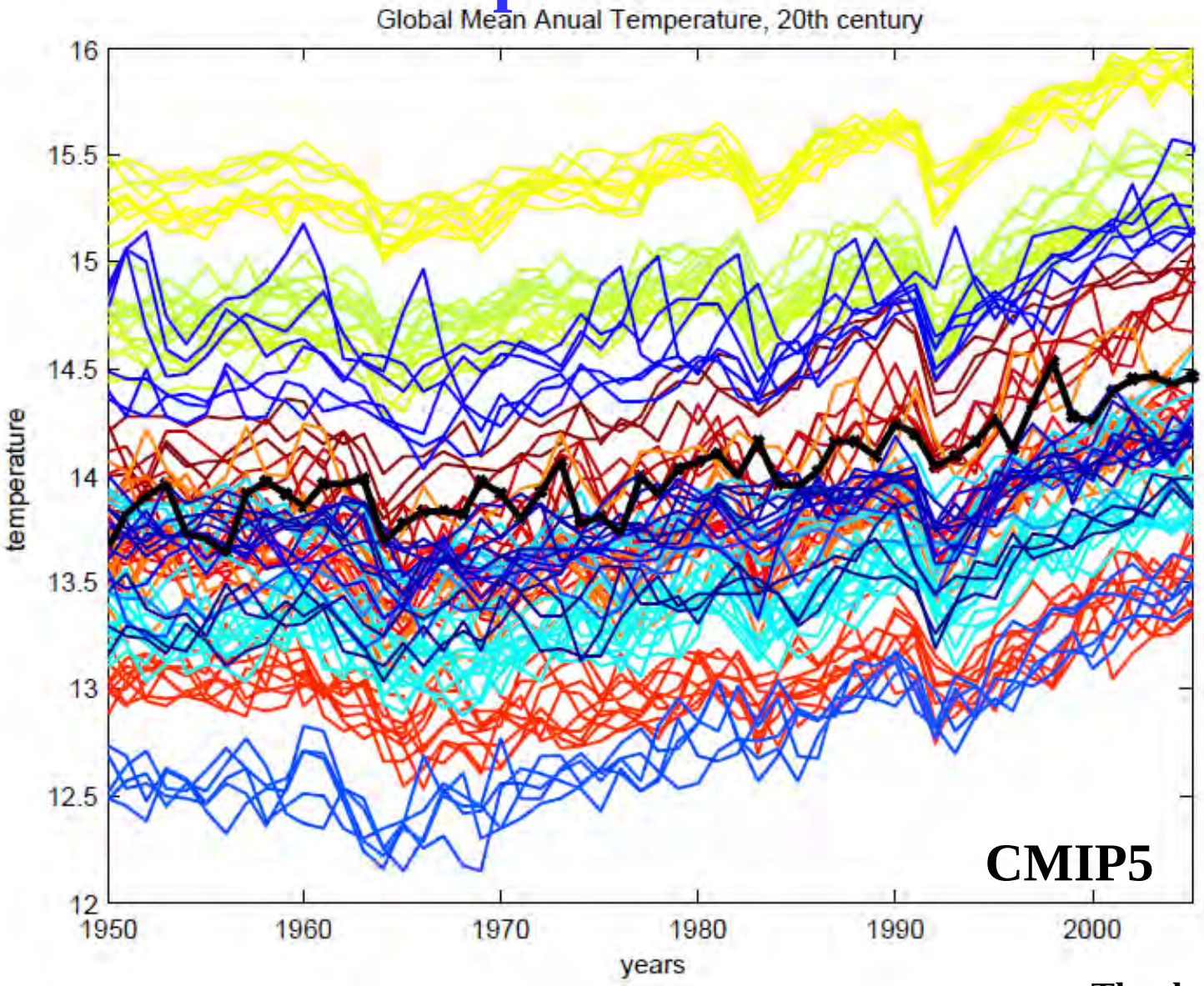
http://www.ipcc.ch/publications_and_data/ar4/wg1/en/figure-spm-4.html

The AR5 is a bit more forthcoming



Note that the anomaly period shifted. Why?

Actual Model Temperatures



Thanks to Ana Lopez

Frigg, R., Smith, L.A. and Stainforth, D.A. (2015) '[An assessment of the foundational assumptions in high-resolution climate projections: the case of UKCP09]', *Synthese.*

Kelvin's Gambit Can Reduce Opacity

Clarifying the assumptions made a priori while conveying confidence in the scientific conclusions obtained can aid decision makers.

Kelvin's Gambit: "As for the future, we may say, with equal certainty, that inhabitants of the earth can not continue to enjoy the light and heat essential to their life for many million years longer unless sources now unknown to us are prepared in the great storehouse of creation." William Thomson (1862) Macmillan's Magazine 5 388

This simple clarification of the assumptions made is a source of strength, not of weakness. It can decrease opacity significantly.

Learning that what one thought were model temperatures were model anomalies can lead to confusion, a loss of confidence and hesitancy to act.

Kelvin's Gambit Can Reduce Opacity

Heavily briefed researchers outside climate science have been impacted by opacity.

This includes senior academic statisticians

Jim Berger

and senior government (now academic) economists.

Nick Stern

Trever Maynard

Emerging risks managers in the insurance sector.

And lead scientists in industry including EDF, Eon and the UK National Grid.

It is challenging for a salesperson to lead with uncertainty.

The IPCC's WGI Has Long Acknowledged Structure Uncertainty Explicitly

10

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

IPCC AR4 2007

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

Smith, L.A. (2002) '[What might we learn from climate forecasts?](),' *Proc. National Acad. Sci.* USA, 4 (99): 2487-2492

The IPCC's WGI Has Long Acknowledged Structure Uncertainty Explicitly

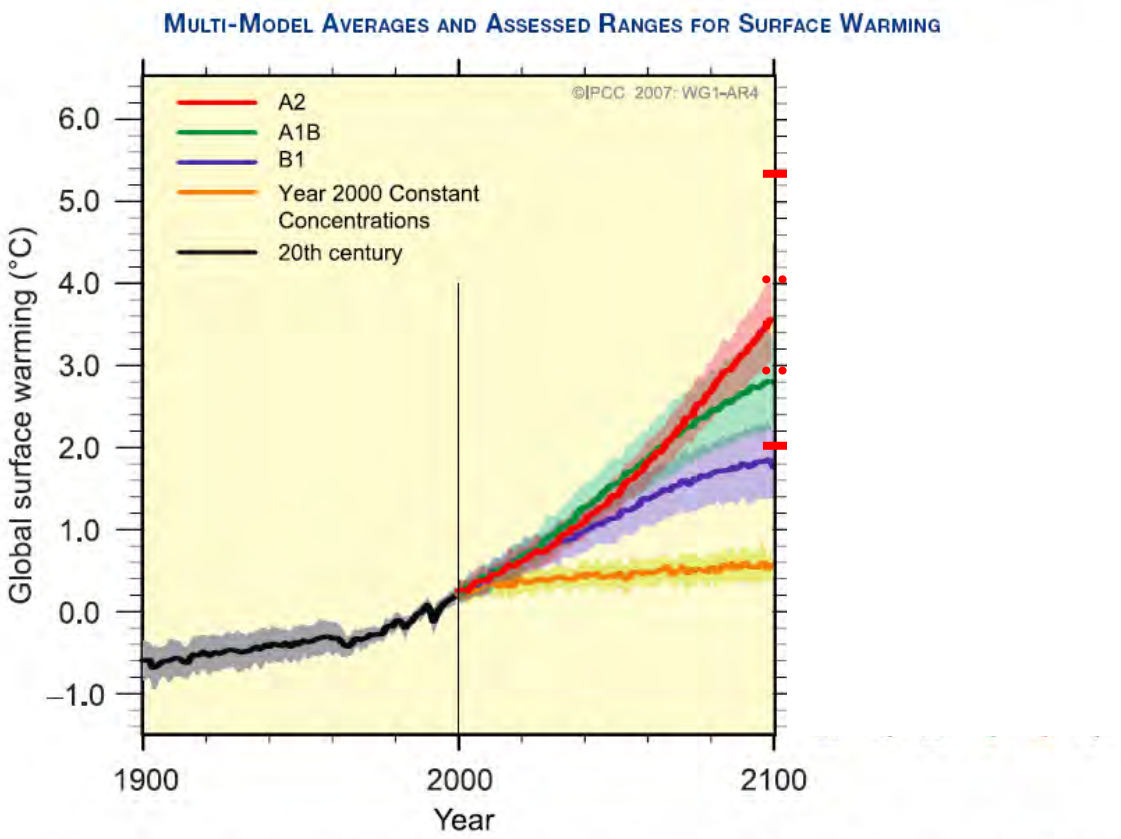


Figure SPM.5. *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the 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 IPCC has repeatedly rejected the notion that the diversity of ensembles reflects directly real world probability even for global mean temperature

The IPCC's WGI Has Long Acknowledged Structure Uncertainty Explicitly

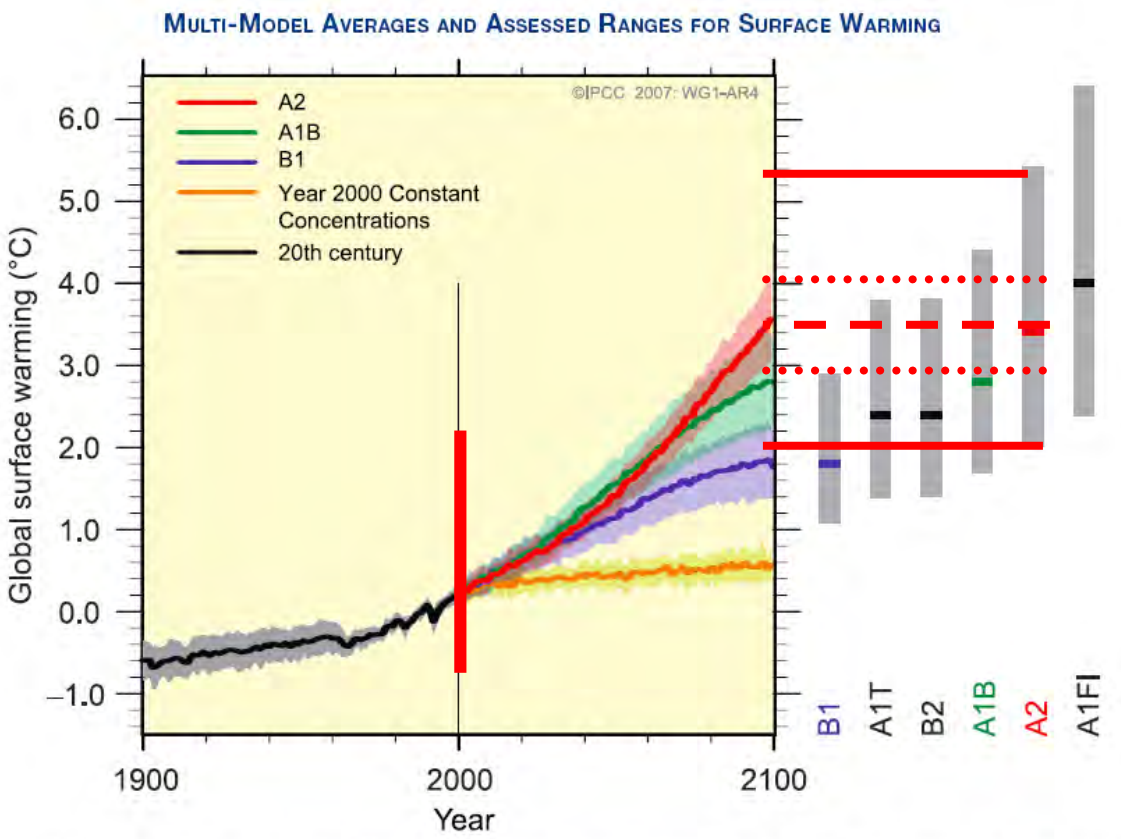
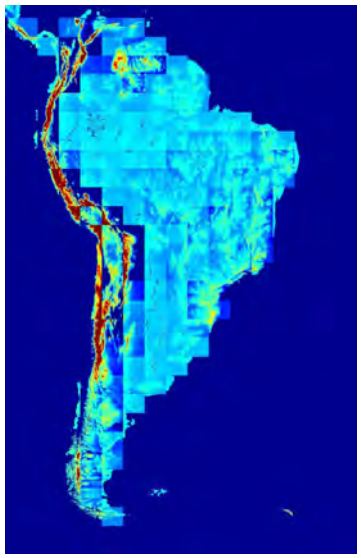


Figure SPM.5. *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the 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 IPCC has repeatedly rejected the notion that the diversity of ensembles reflects directly real world probability even for global mean temperature, yet this message is repeatedly lost in opacity.

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

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



"No presentation of model-based probabilities is complete without an expression of model irrelevance."

The potential of Known Unknowns, Known Neglecteds and Unknown Unknowns are each to be included.

https://www.ipcc.ch/report/ar5/wg1/docs/WGIAR5_SPM_brochure_en.pdf

AR5

- Increase of global mean surface temperatures for 2081–2100 relative to 1986–2005 is projected to *likely* be in the ranges derived from the concentration-driven CMIP5 model simulations, that is, 0.3°C to 1.7°C (RCP2.6), 1.1°C to 2.6°C (RCP4.5), 1.4°C to 3.1°C (RCP6.0), 2.6°C to 4.8°C (RCP8.5). The Arctic region will warm more rapidly than the global mean, and mean warming over land will be larger than over the ocean (*very high confidence*) (see Figures SPM.7 and SPM.8, and Table SPM.2). {12.4, 14.8}

Real-world GMT is "likely" (~66% chance) to be in "the range" of model-land GMT.

That suggests there is a significant chance the real-word will be outside the range of the models.

I think it is fair say the IPCC implies that the Probability of a Big Surprise (GMT in 2100) is about one in ~ four to ~ten.

Nevertheless we also find:

When might “Best Available” be “Adequate for Purpose”?

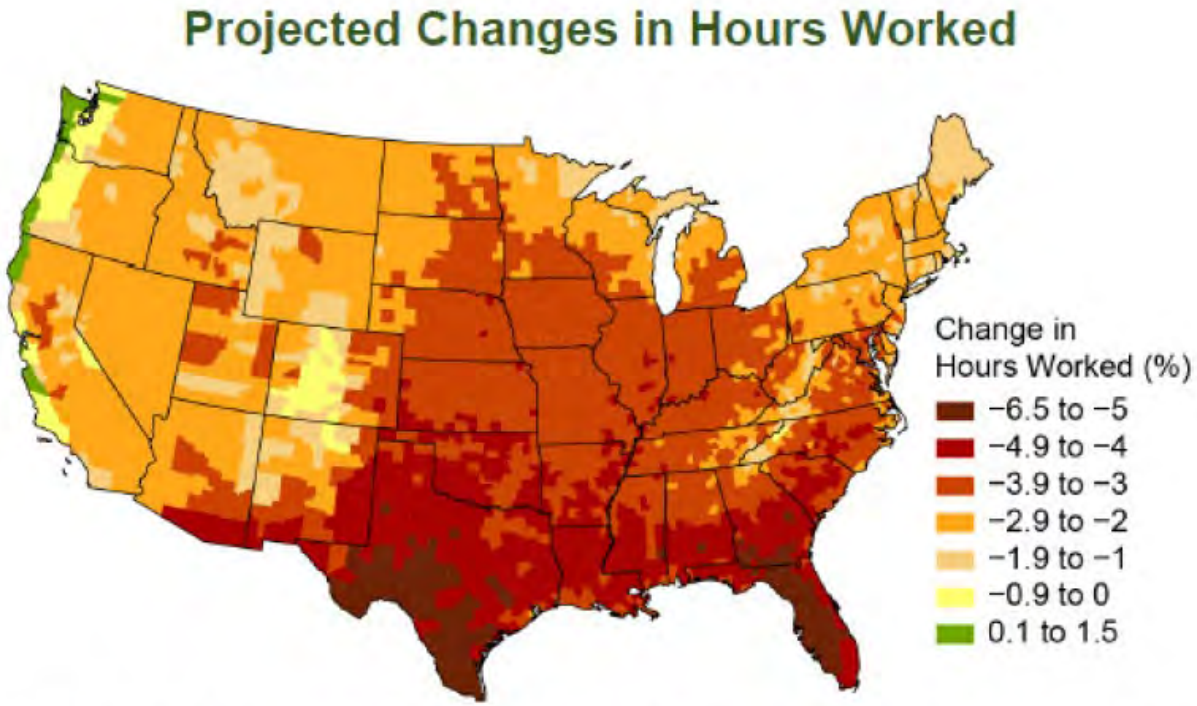


Figure 19.21: This map shows the estimated percent change in hours worked in 2090 under a higher scenario (RCP8.5). Projections indicate an annual average of 570 million labor hours lost per year in the Southeast by 2090 (with models ranging from 340 million to 820 million labor hours).[35] Estimates represent a change in hours worked as compared to a 2003–2007 average baseline for high-risk industries only. These industries are defined as agriculture, forestry, and fishing; hunting, mining, and construction; manufacturing, transportation, and utilities. Source: adapted from EPA 2017.[35]

The opacity in this graphic is nontrivial.

Policy Specialists Work to Reduce Opacity

Draft SPM

‘assessed likelihood of an outcome or a result’

Final SPM

‘assessed likelihood**, using expert judgement,** of an outcome or a result’

Example from the IPCC WG I 2013

Draft SPM

‘Probabilistic estimates of quantified measures of uncertainty in a finding are based on statistical analysis of observations or model results, or expert judgment.’

Final SPM

‘Probabilistic estimates of quantified measures of uncertainty in a finding are based on statistical analysis of observations or model results, or **both, and** expert judgment.’

Policy Specialists Work to Reduce Opacity

WORKING GROUP I CONTRIBUTION TO THE IPCC FIFTH ASSESSMENT REPORT (AR5), CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS

IPCC Working Group I Fifth Assessment Report — Comments from Governments on the Final Draft Summary for Policymakers

1dbc048d

Comment No	Chapter	From Page	From Line	To Page	To Line	Comment
SPM-31	SPM	0				Our Government fully accepts the anthropogenic origin of the ongoing climate change, but we consider to leave less points to attack at for the "climate sceptics". At some points, therefore, we recommend to avoid trials to cover or decrease the unestablished (unexplained) elements of uncertainty. [Government of Hungary]
SPM-32	SPM	0				Coverage of the extreme events is very poor and needs to be strengthened given the large implications for economies. [Government of India]
SPM-33	SPM	0				Policy makers have agreed under UNFCCC on the <2° C stabilization. Policy makers would like to know which RCP is close to 2 degree C warming, when 2 degree C threshold would be crossed under BAU. It is surprising that the whole of SPM does not address the most important policy relevant 2 degree threshold at all. This must be included under various sections of the SPM. [Government of India]
SPM-34	SPM	0				There is very little coverage of regional or continental level climate projections in the SPM. [Government of India]
SPM-35	SPM	0				The whole SPM does not discuss the warming under the BAU or reference emissions scenario and policy makers are very keen on this. [Government of India]
SPM-36	SPM	0				All the abbreviations used for the first time in the report need be introduced in their full words. For example, for RCP, CMIP5, SREX, ... [Government of Islamic Republic of Iran]

More transparent and consistent uncertainty formulation
The SPM should include a clear distinction between process-based and model-based uncertainty formulation. Model uncertainty is not transparent enough. A full acc… uired. W
furth… be
appl…
Spe…
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More transparent and consistent uncertainty formulation
The SPM should include a clear distinction between process-based and model-based uncertainty formulation. Model uncertainty is not transparent enough

(SPM-9, 27-29). These highlights should also emphasize very poor understanding if this is the case. Highlights subject to intense controversy may be part of a separate box. See next comment.

Separate major controversial highlights
For some highlights which are subject to intense controversy, such as the hiatus, sea level rise upper end projections… separate box with a concise explanation in simple language. Relevant conclusions in the SPM and FAQs can be copied, moved and rephrased if needed to improve readability.

More transparent and consistent uncertainty formulation
The SPM should include a clear distinction between process-based and model-based uncertainty formulation. Model uncertainty is not transparent enough. A full account of the uncertainty is often particularly difficult in paleo-climate studies because a model of the physical meaning of the observations is generally required. We further advice to check the SPM on inconsistencies in the use of likelihoods versus confidence. For example, it is not clear whether medium confidence may be applied with likelihoods. The uncertainty guidance leaves room for different interpretation.
Special attention must be devoted to the section 'Detection and Attribution of Climate Change'. Often 'very likely' is stated, implying 'high confidence' (so no confidence qualification) while in the 'Evaluation of Climate models' medium or low confidence is given to the model ability to simulate a certain variable. Also, confidence may be low in observable.

Use language suitable for the main target group
The scientific language of the SPM is unreadable for the main target group. Ideally, the SPM should be rewritten. Practically, it would already greatly help if the SPM

[Government of Netherlands]

Do not Cite, Quote or Distribute — Page 5 of 107

35

A Decade of Climate Science Days on Capitol Hill

Leonard Smith @lynyrdsmyth · Feb 11, 2015 ···

What can a scientist most usefully say when visiting their congresspersons in DC? Today is AAAS **Climate Science** on Capitol Hill **Day**

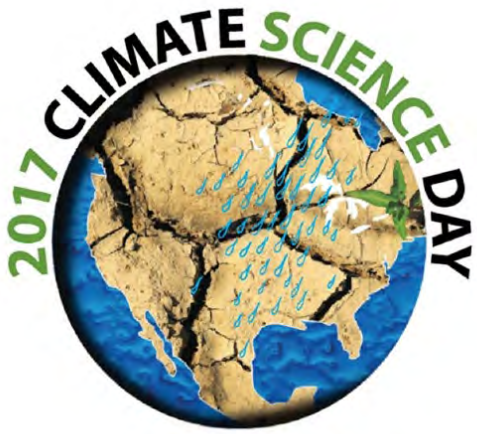
https://twitter.com/lynyrdsmyth/status/565499877065756672?s=20

Rep Ted Yoho, Fla 3rd Dist. (R)

Rep John Rutherford, Fla 4th D (R)

And listen to their concerns.

Find common interests.
Discuss impacts that matter to them (with no opacity).
Focus on vulnerabilities.
Discuss Known Neglecteds, and the time scales required for us to lift them.
Show them (observational) data.
Develop relationships with their staffers.



20-21 March 2017
2010-2019

If decision makers require anything it is only one thing:
A deadline.

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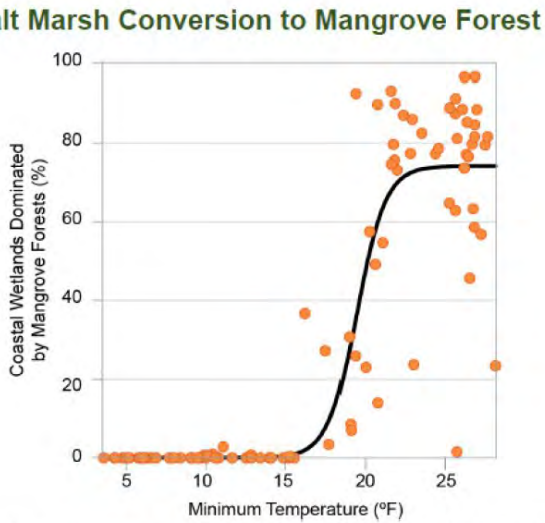

Figure 19.16: Where tropical and temperate ecosystems meet, warmer winter temperatures can lead to large ecological changes such as mangrove forest replacement of salt marshes along the Gulf and Atlantic Coasts. Mangrove forests are sensitive to freezing temperatures and are expected to expand northward at the expense of salt marshes. The figure shows the relationship between temperature and the percentage area dominated by mangrove forests. Mangrove expansion would entail a grassland-to-forest conversion, which would affect fish and wildlife habitat and many societal benefits. Source: adapted from Osland et al. 2013.[135] ©2012 Blackwell Publishing Ltd.

A Decade of Climate Science Days on Capitol Hill

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Rep Ted Yoho, Fla 3rd Dist. (R)

Rep John Rutherford, Fla 4th D (R)

SCIENTIFIC AMERICAN

Observations

Climate Change and the Political Landscape

How conservative lawmakers can start addressing the risks without losing their seats

By Steve Pierson, Leonard Smith on March 6, 2018

"You have your scientists and we have ours." That was the response from a Republican staffer when offered impartial information from our team of scientists at the first Climate Science Day (CSD) in 2011. An annual event

Nevertheless there remains a large disconnect between the scientific community's view of anthropogenic climate change and that publicly held

How can lawmakers serve the interests of their constituents on this immense challenge to America and the world without risking their seat at the table? There is a fine line to be walked here, yet there are many constructive steps they can take. Members could understand better the science of climate change and how their districts or states may be affected.

Answer their questions and listen to their (very real) concerns and constraints.

Avoid confusing a leader's public attitude toward uncertainty after a decision with their private attitude before the decision is made.

Space @ Virginia Tech
Center for Space Science and Engineering Research

What I wish I Understood in 2001

The role of opacity and how to reduce it.

Policy relevant simulation science is more effective when its limitations are made clear from the beginning.

Opacity is reduced when Known Neglecteds are given a higher profile.

To convey to decision makers our level of confidence, limits of insight and the vulnerability reduces opacity.

To be clear on what is meant by "probability".

Not only deploy all possible tests of internal consistency but also interpret the results in terms of the fidelity of decision relevant insights.

Avoid "best available" answers to questions when they are likely not to be adequate for that decision maker's purpose.

To better support our understanding of the thermodynamics of climate while more clearly questioning our understanding of circulation.

Learn to the concerns of and constraints on the person you seek to inform.

Thoughts?

"It is not their wrongness so much as their pretensions to rightness that have brought economic predictions and the theory that underlies them into well-deserved contempt." Peter Medawar 1981

Thompson, E.L. and Smith, L.A. (2019) Escape from model-land. Economics Discussion Papers, No 2019-23, Kiel Institute for the World Economy. http://www.economics-ejournal.org/economics/discussionpapers/2019-23.

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

Berger, J.O. and Smith, L.A. (2019) 'On the statistical formalism of uncertainty quantification,' *Annual Review of Statistics and its Application*, 6. 3.1-3.28

Parker, W.S. (2020) Model Evaluation: An Adequacy-for-Purpose View *Philosophy of Science* 87 (3):457

K Judd, CA Reynolds, LA Smith & TE Rosmond (2008) The Geometry of Model Error JAS 65(6) 1749

LA Smith, (2002) What Might We Learn from Climate Forecasts?
Proc. National Acad. Sci. USA 4(99): 2487 -2492.

Frigg, R., Smith, L.A. and Stainforth, D.A. (2015) 'An assessment of the foundational assumptions in high-resolution climate projections: the case of UKCP09', *Synthese.*

LA Smith (2006) Predictability past predictability present. Chapter 9 of Predictability of Weather and Climate (eds T. Palmer and R Hagedorn). Cambridge, UK. Cambridge University Press.

LA Smith (2000) 'Disentangling Uncertainty and Error: On the Predictability of Nonlinear Systems' in Nonlinear Dynamics and Statistics, ed. Alistair I Mees, Boston: Birkhauser, 31-64.

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@lynyrdsmyth @H4wkm0th

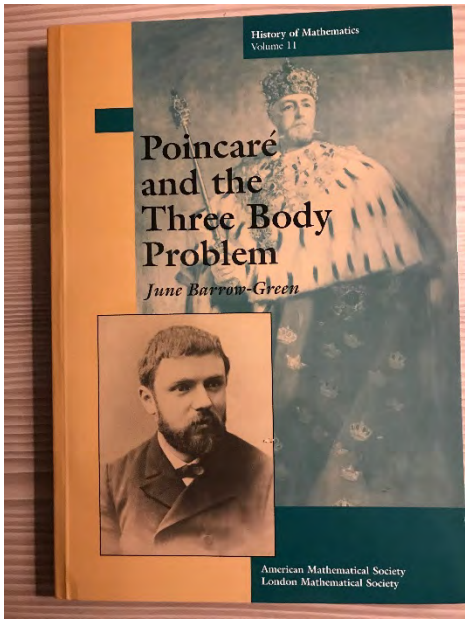
Space @ Virginia Tech
Center for Space Science and Engineering Research

END

Opacity limits the services science might render us

Some hypotheses are dangerous,— first and foremost those which are tacit and unconscious. And since we make them without knowing them, we cannot get rid of them. Here again, there is a service that mathematical physics may render us.

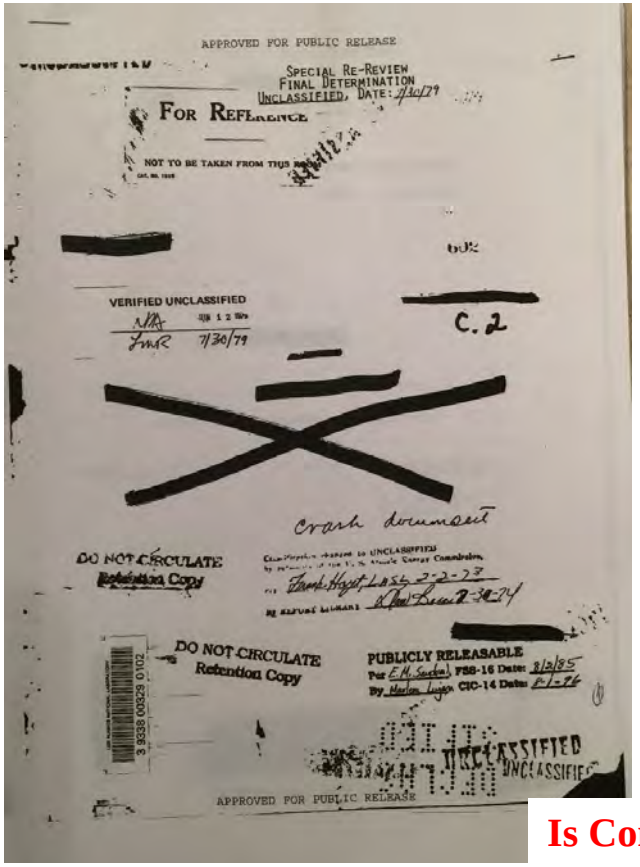
Poincare S&H 168

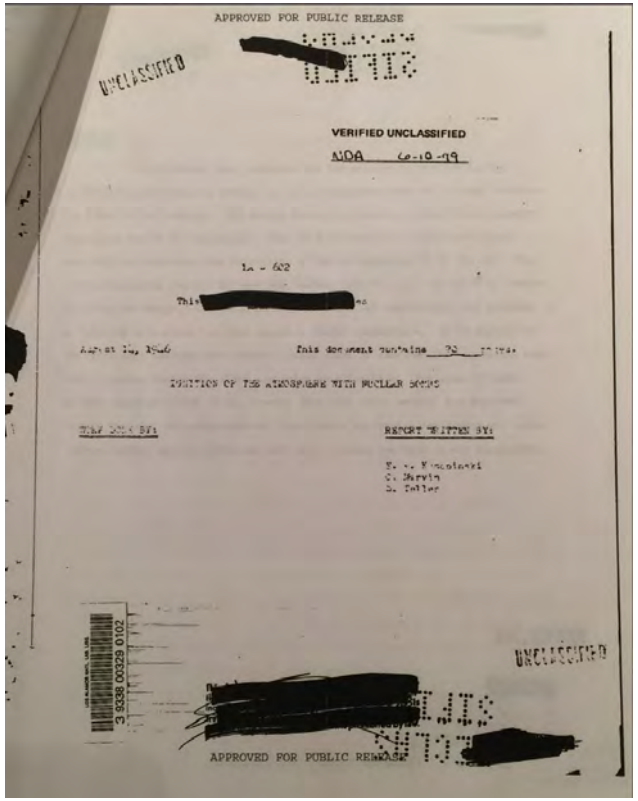


LeVerriers' Second Planet

A discovery due to misplaced concreteness.

Scientists, Decision Makers & the "Support" of Decision Making





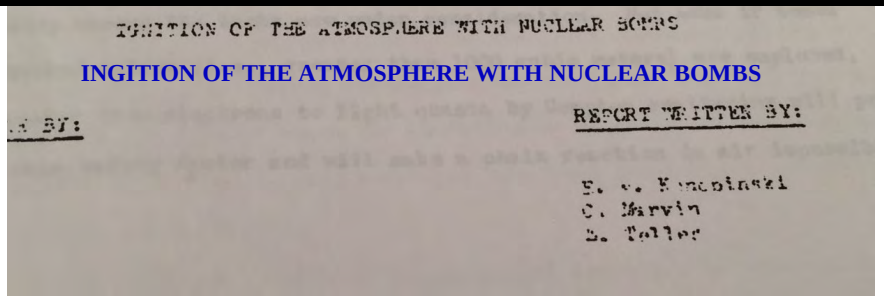
Is Computation Always the Best Way Forward?

Climate-like tasks are "one off."

Potentially rather high impact.

Best Available ? **Adequate for Purpose**

If this result was based on a new-fangled simulation, how would you develop enough confidence in the simulation to test the bomb?

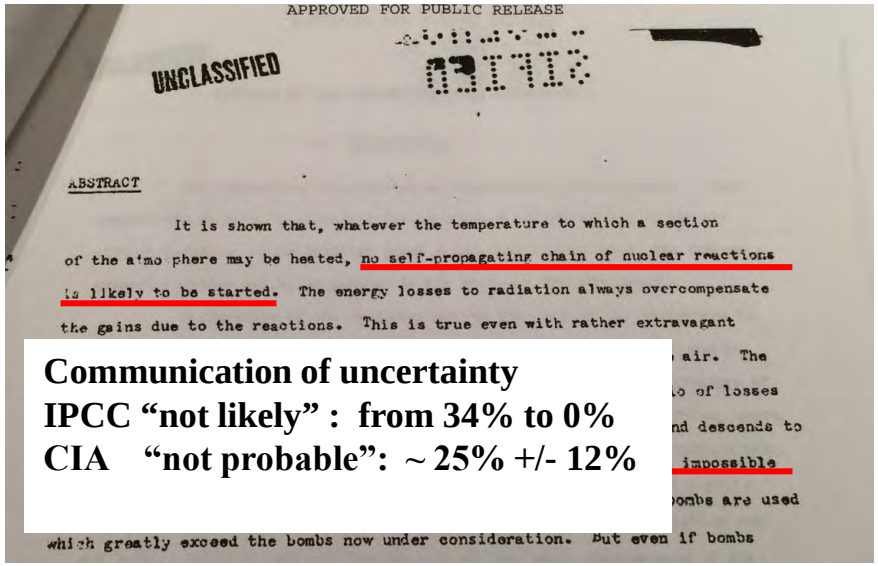


IGNITION OF THE ATMOSPHERE WITH NUCLEAR BOMBS

INGITION OF THE ATMOSPHERE WITH NUCLEAR BOMBS

REPORT WRITTEN BY:

E. J. Konopinski
C. Marvin
E. Teller



APPROVED FOR PUBLIC RELEASE

UNCLASSIFIED

ABSTRACT

It is shown that, whatever the temperature to which a section of the atmosphere may be heated, no self-propagating chain of nuclear reactions is likely to be started. The energy losses to radiation always overcompensate the gains due to the reactions. This is true even with rather extravagant

air. The

of losses

nd descends to

impossible

ombs are used

which greatly exceed the bombs now under consideration. But even if bombs

Communication of uncertainty
IPCC "not likely" : from 34% to 0%
CIA "not probable": ~ 25% +/- 12%

Uncertainty Guidance (without "UQ"?)

IPCC

Table 1. Likelihood Scale	
Term*	**Likelihood of the Outcome**
Virtually certain	99-100% probability
Very likely	90-100% probability
Likely	66-100% probability
About as likely as not	33 to 66% probability
Unlikely	0-33% probability
Very unlikely	0-10% probability
Exceptionally unlikely	0-1% probability

* Additional terms that were used in limited circumstances in the AR4 (*extremely likely* – 95-100% probability, *more likely than not* – >50-100% probability, and *extremely unlikely* – 0-5% probability) may also be used in the AR5 when appropriate.

CIA

100% Certainty		
The General Area of Possibility		
93%	give or take about 6%	Almost certain
75%	give or take about 12%	Probable
50%	give or take about 10%	Chances about even
30%	give or take about 10%	Probably not
7%	give or take about 5%	Almost certainly not
0% Impossibility		

Sherman Kent and the Profession of Intelligence Analysis

The Sherman Kent Center for Intelligence Analysis

Occasional Papers: Volume 1, Number 5, Nov. '02

Sherman Kent and the Profession of Intelligence Analysis
Jack Davis
Sherman Kent Center

Important note to consumers: You should be quite clear that when we say "such and such is unlikely" we mean that the chances of its NOT happening are in our judgment about three to one. Another, and to you critically important, way of saying the same thing is that the chances of its HAPPENING are about one in four. Thus if we were to write, "It is unlikely that Castro will attempt to shoot down a U-2 between now and November 1965," we mean there is in our view around a 25-percent chance that he will do just that. If the estimate were to read, "It is almost certain Castro will not . . . ," we would mean there was still an appreciable chance, say 5 percent or less, that he would attempt the shootdown.

Best Available ? Adequate for Purpose

The Dutch government officially requested greater clarity in "uncertainty" in the AR5 Summary for Policy Makers

Table 1. Likelihood Scale	
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Dutch Government Expert Panel on Uncertainty Communication in the IPCC AR5 WG I SPM

PBL Netherlands Environmental Assessment Agency
Bilthoven branch, room W 0.30-32
17 and 18 June 2013

SPM-39 More transparent and consistent uncertainty formulation
The SPM should include a clear distinction between process-based and model-based uncertainty formulation. Model uncertainty is not transparent enough.
[Government of Netherlands]

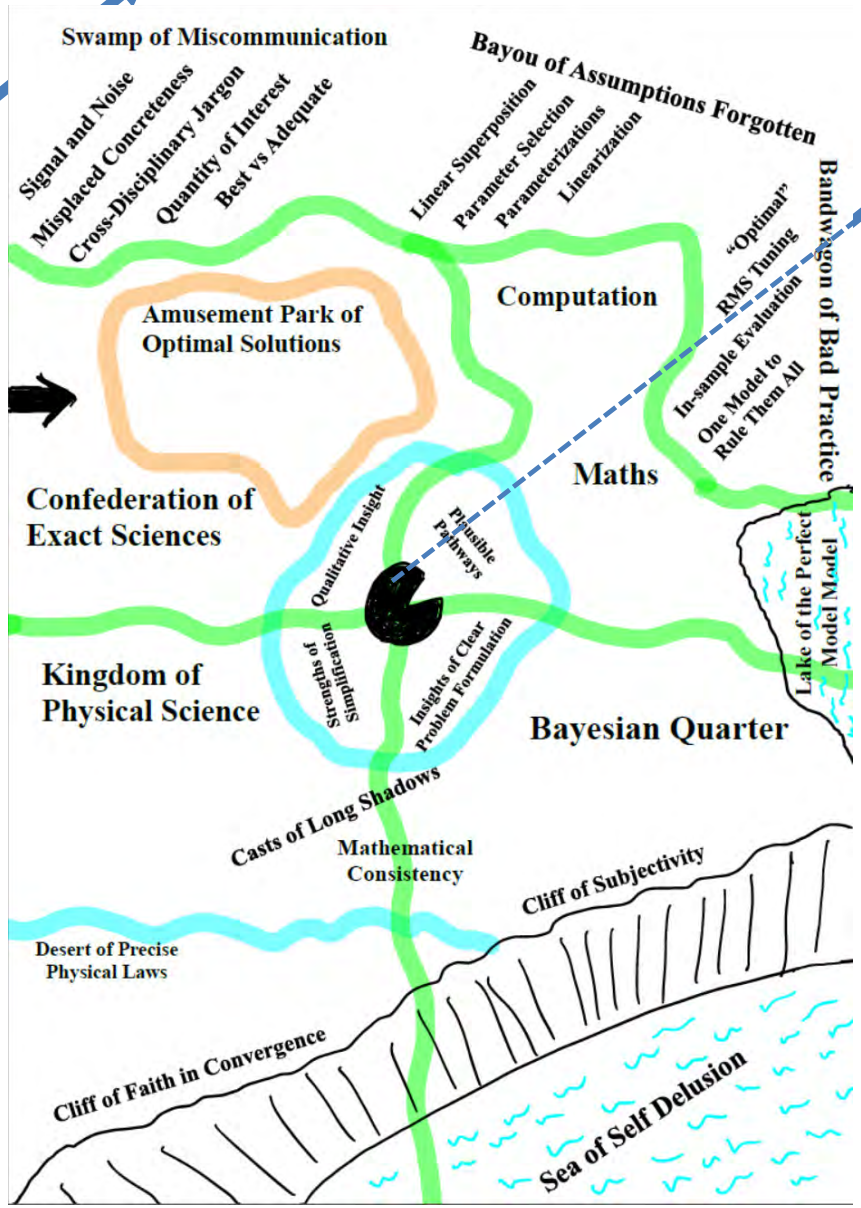
Clarify when one is in model-land and when in the real-world.

What is P(x | I)?

$P(x_m | I, m)$ → $P(x|I^*)$

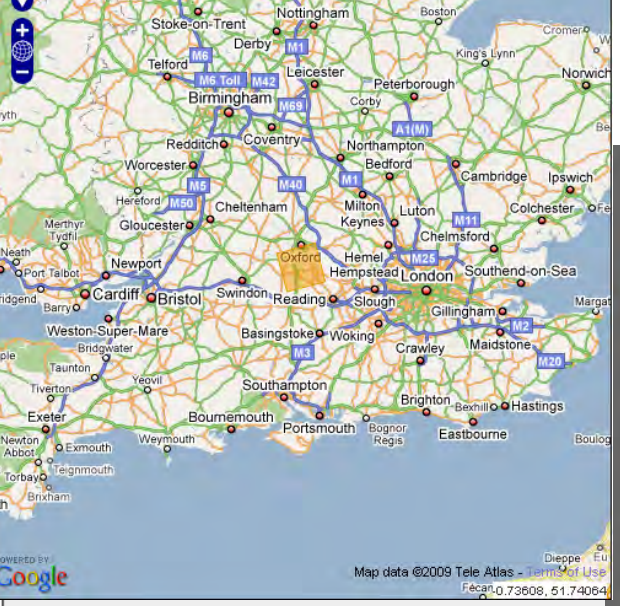
Insight

Observations & Understanding



Of course, this is only a model.

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)

UK CLIMATE PROJECTIONS USER INTERFACE http://www.ukcip.org.uk/

Start Page | My Jobs | My Details | Using UKCP09 | UI Manual | Need help?

Logged in as: lenny@maths.ox... Logout

Logged in users: 2

You have no pending jobs. See **My Jobs** for previously run jobs.

Request Status:

Request Summary:

Selecting your UK location first

This page is intended for novice users of the UI who know what location they are interested in. This page should be used as follows:

Step 1: Click on a point on the map (or type in the latitude/longitude coordinates and click "Select".
Step 2: Select a data source of interest from the list that appears on the right.
Step 3: Select the variable you are interested in and click the "Next" button.

You can search by place name or postcode using the box on the right-hand side. Note that clicking a result re-centres and zooms the map to the new location but does make a selection.

Selections on this page are restricted in that only a single location may be selected. Weather Generator simulations and Marine Model Simulations are not available from this start point.

Read about starting your request by making spatial selections in the UI Manual.

Next

Search place name or postcode to re-centre map:
ox1 1dw Search Clear
Postcode: OX1 1DW

Select by Latitude / Longitude by:
Latitude: 52.0018
Longitude: -0.1044
Select

Step 2: Select a data source
At your chosen location, there is data for following data sources (clicking an option will highlight the selected location on the map adjacent):

- UK Probabilistic Projections of Climate Change over Land for the 25km Grid Box with the ID: **1551**
- UK Probabilistic Projections of Climate Change over Land for the Administrative Region: **East of England**
- UK Probabilistic Projections of Climate Change over Land for the River Basin: **Anglian**

Step 3: Select a variable
Please choose one of the following variables:

Next

Funded by: defra, Department of Energy & Climate Change, Department of the Environment, The Scottish Government, Welsh Assembly Government

Provided by: Met Office

UK Climate Impacts Programme

Service hosted at: Science & Technology Facilities Council, Rutherford Appleton Laboratory.

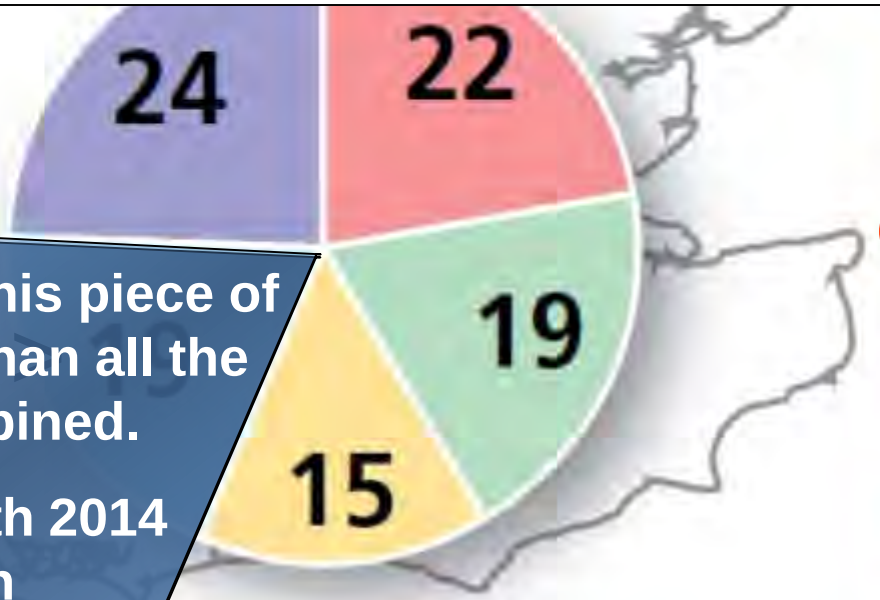
Smith

Reducing different sources of uncertainty?

Model diversity is only a lower bound on structural uncertainty, which may well be by far the biggest piece of the pie.

Uncertainties in winter precipitatic changes for the 2080s relative to 1961-90, at a

Learning this factoid does not build confidence.



Internal variability

Carbon cycle

Structural uncertainty

Parameter uncertainty

Downscaling

For all we know, this piece of the pie is bigger than all the other pieces combined.

A lower bound with 2014 hardware is not an estimated value.

What to do? Say?

New information, methods, experimental design can reduce uncertainty so ge in future and decision makers need to consider this

Sexton 2010 http://www.exeter.ac.uk/media/universityofexeter/research/inspiringresearch/sciencestrategy/ccsf/docs/Making_probabilistic_climate_projections_for_the_UK_presentation.pdf

Communication

Major uncertainties

There are limited studies documenting direct connections between climate changes and economic impacts. Models are limited in their ability to incorporate adaptation that may reduce losses. These factors restrict the potential to strongly associate declines in agricultural and forest productivity with the level of potential economic impact.

Projections of potential change in the frequency and extent of wildfires depend in part on models of future population growth and human behavior, which are limited, adding to the uncertainty associated with climate and forest modeling.

Many indicators of vulnerability are dynamic, so that adaptation and other changes can affect the patterns of vulnerability to heat and other climate stressors over time. Limited studies indicate concerns over the planning and preparedness of capacity at local levels; however, information is limited.

Projected labor hours lost vary by global climate model, time frame, and scenario, with a mean of 0.57 and a model range of 0.34–0.82 billion labor hours lost each year for RCP8.5 by 2090. The annual mean projected losses are roughly halved (0.28 billion labor hours) and with a model range from 0.19 to 0.43 billion labor hours lost under RCP4.5 by 2090.[35]

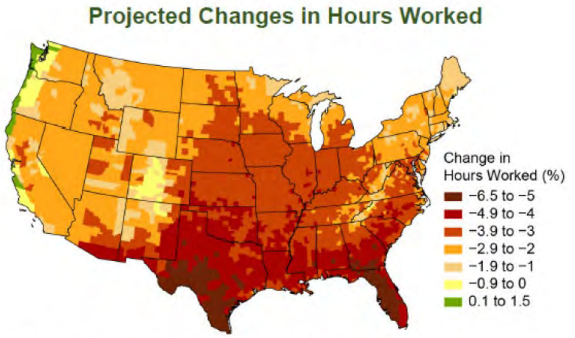


Figure 19.21: This map shows the estimated percent change in hours worked in 2090 under a higher scenario (RCP

Mature Probabilities P(x|I)

A mature probability is not expected to change without additional observation or new theoretical insight. (An nontrivial change in I)

If the fidelity of a simulation model is constrained by technology (as when you know exactly what you would do with more compute power, and it is NOT to run massive ensembles/emulators), then probability distributions based on simulations from that model (or family of similar models) are not expected to be mature.

Rational action is constrained only by mature probabilities.
Model-based Probability can be used in creative ways (as data).

Over confidence ("belief") leads to the mine shaft gap…

(?How might one use im-mature distributions in decision support?)

(Generalised from IJ Good's "Dynamic Probability", as when output from a chess program must be used before the algorithm completes.)

IJ Good (~1979) Science

Discuss Climate Change Wider Community?

Opacity leads to hostility in the community, even an appeal to Richard Feynman was met with contempt and insults.

The take home message here is not to give up, but rather to recognise as early as possible if the trail you are on does not lead to your goal, or that your goal might not exist!

"Physics only progresses by making mistakes, the key is to make them as fast as you can."

John Wheeler
Columbia University ~1987

What if
Can we make mistakes and move on faster?

Chasing Model Inadequacy

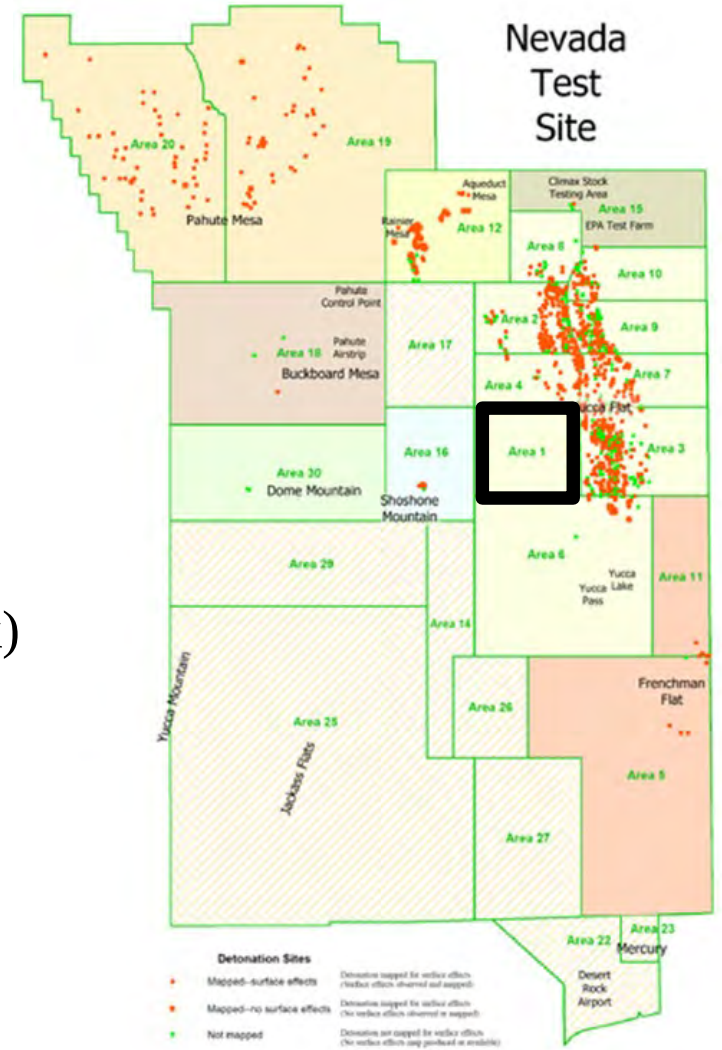
(by dropping balls off towers)

1000 ft Ua1 shaft

Ball(s)

2 bowling balls
3 Basketballs
2 golf balls
3 Wiffle balls
… (no rubber duck)

…ors



http://www2.nstec.com/Documents/Fact%20Sheets/U1a%20Facility.pdf

Clarity of Presentation Reduces Opacity

In simulation science, tests of internal consistency can limit the concreteness we assign to our model simulations. These are of particular value with "one-way coupled" models, and also model intercomparison.

The use of anomalies can lead to opacity even in statistically justifiable situations.

Anomalies remove the systematic errors in each model, forcing the appearance of agreement between models (and with anomalies of the observations) while obscuring the value of internal consistency.

A Randomly Chosen Example

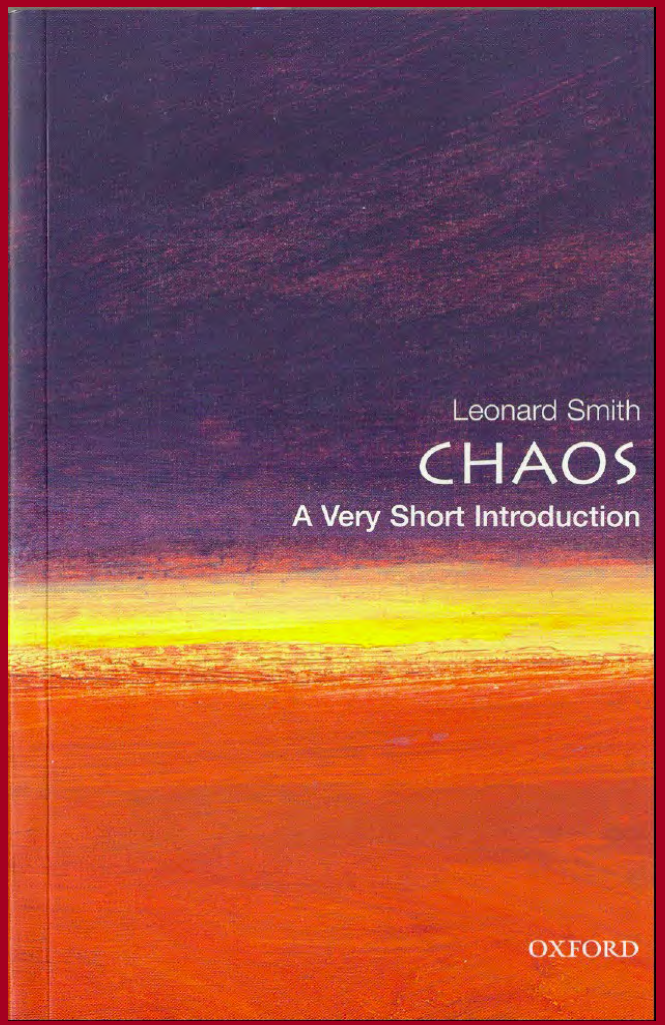
A scoping study on
the impacts of climate change
on the UK energy industry

Met Office

Final report

Prepared for: National Grid, EDF Energy and E.ON UK

Date: 26 May 2006



Commercial (non-neutral) dissemination complicates things.
It is hard for salespeople to lead with their uncertainty.

EDITION
US

THE HUFFINGTON POST

GREEN 03/09/2017 10:36 am ET | Updated 2 days ago

EPA Chief Scott Pruitt Disagrees With Science On Another Major Climate Change Is

He said he doesn't believe carbon dioxide emi

By Alana Horowitz Satl

POLITICS 03/10/2017 04:42 pm ET | Updated 1 day ago

Florida Republicans Challenge Climate-Denying EPA Chief

People in Florida know better than most that Americans can't afford to ignore global warming.

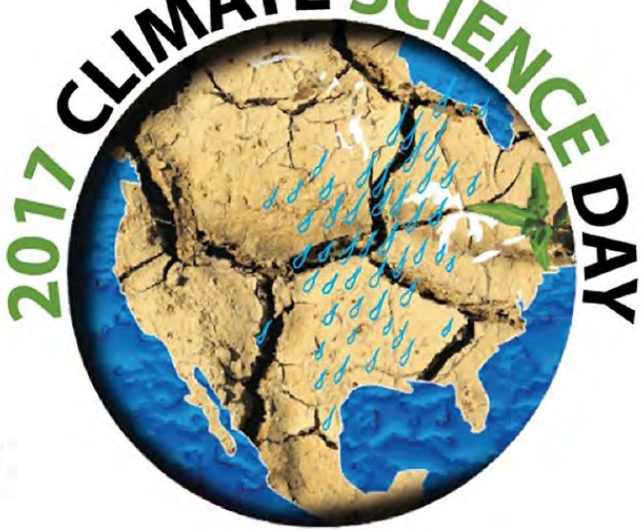
By Alexander C. Kaufman

Curbelo, Carlos

Representative for Florida's 26th congressional district, 2015-2018

Ros-Lehtinen, Ileana

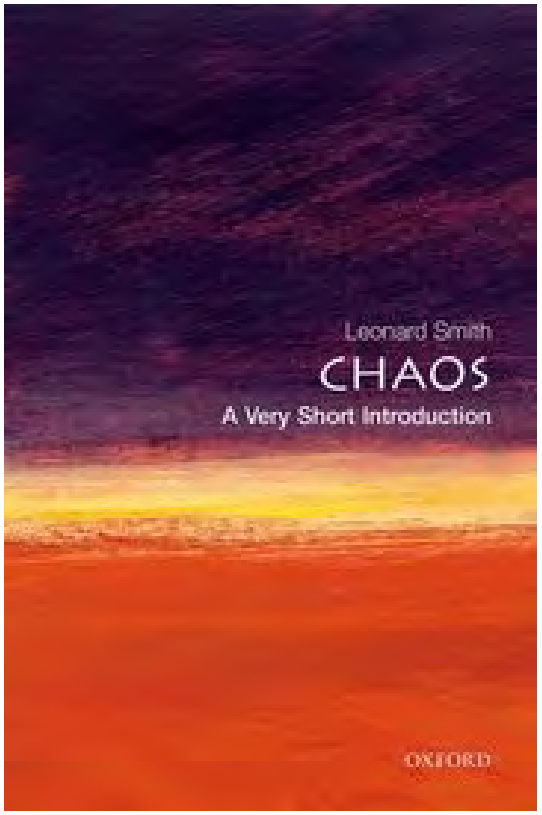
Representative for Florida's 27th congressional district, 2013-2018



20-21 March 2017

Space @ Virginia Tech
Center for Space Science and Engineering Research

What limits information from Ensembles?



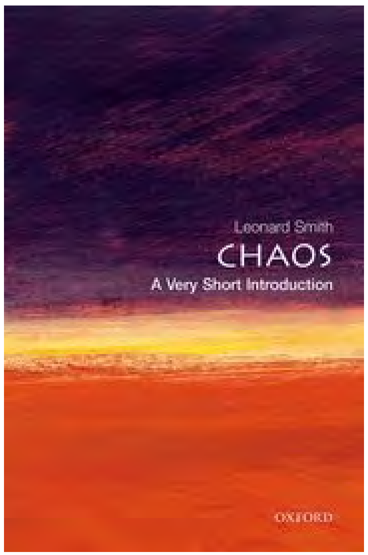
Suppose you wanted to better understand chaos…

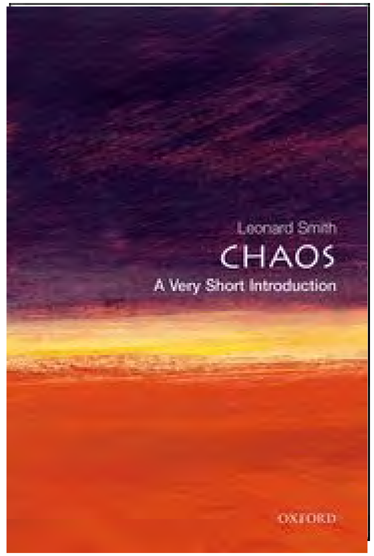
Obviously you could read my book!

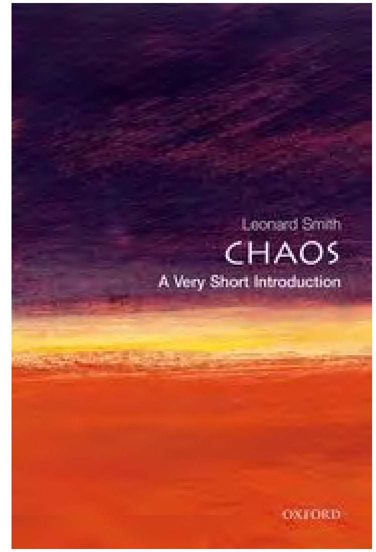
And then?

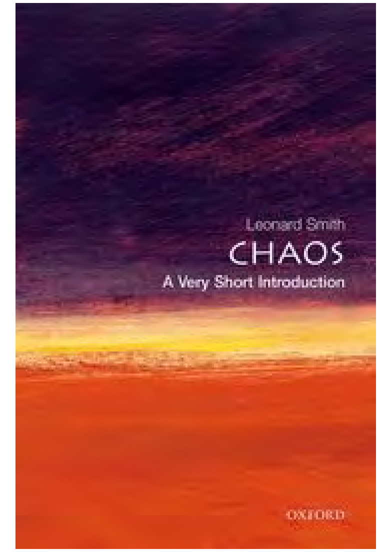
Well you could read an ensemble of books on chaos…

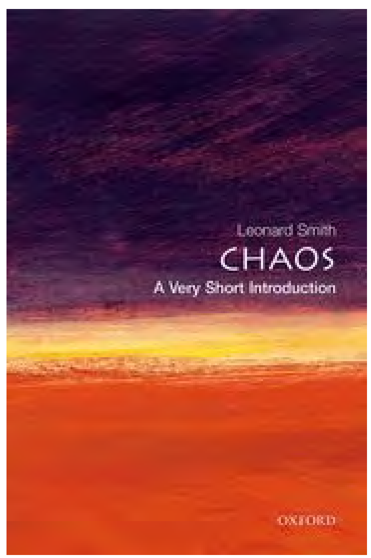
Some Ensembles Are More Informative Than Others

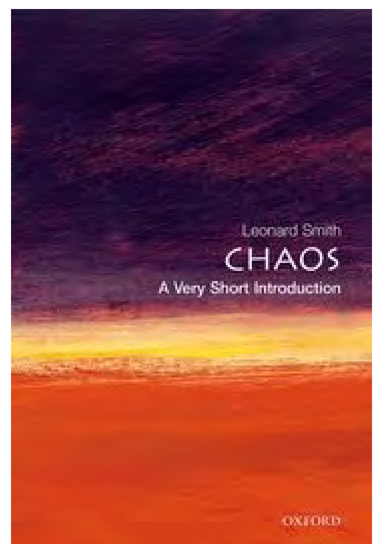


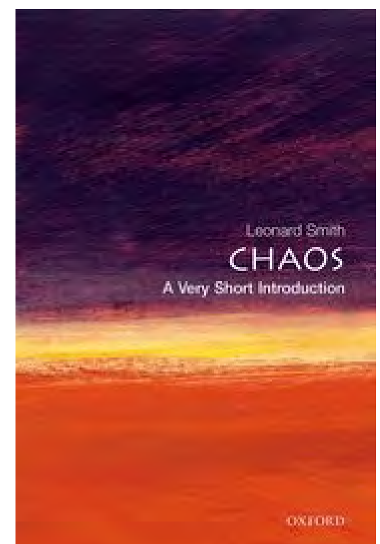






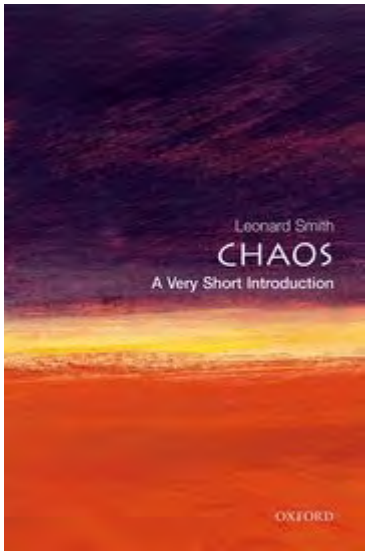


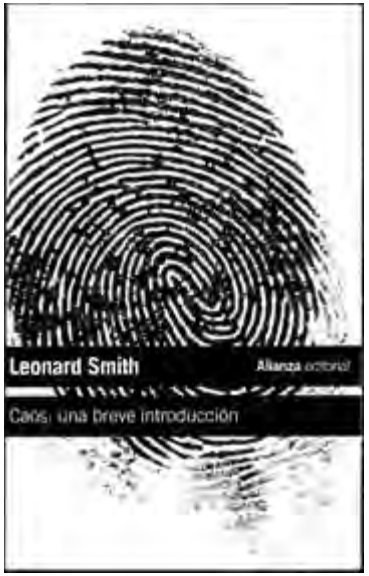


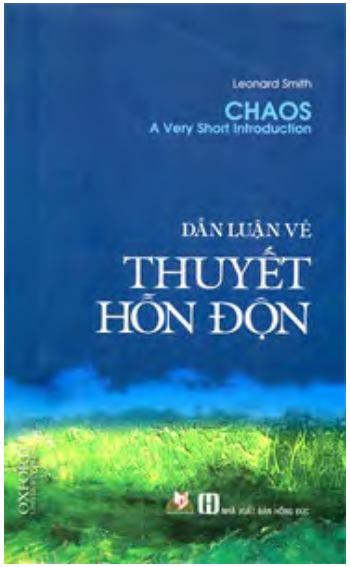


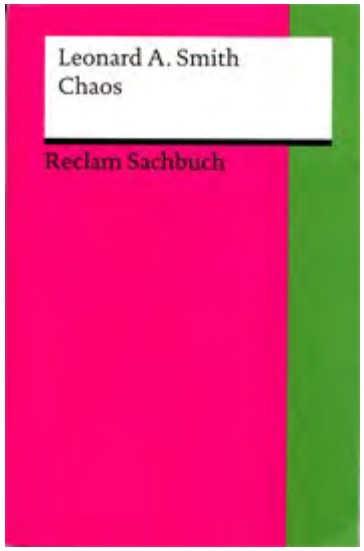
Apologies to Wittgenstein

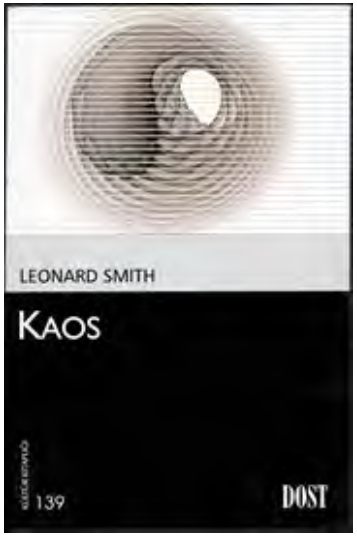
Some Ensembles Are More Informative Than Others



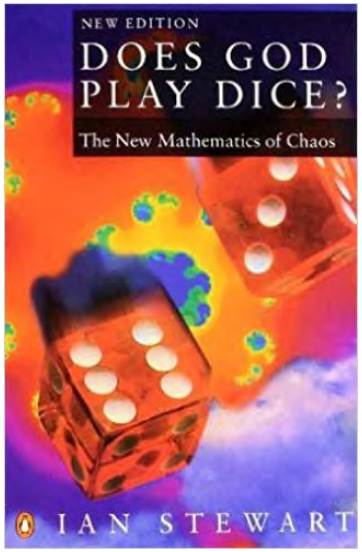


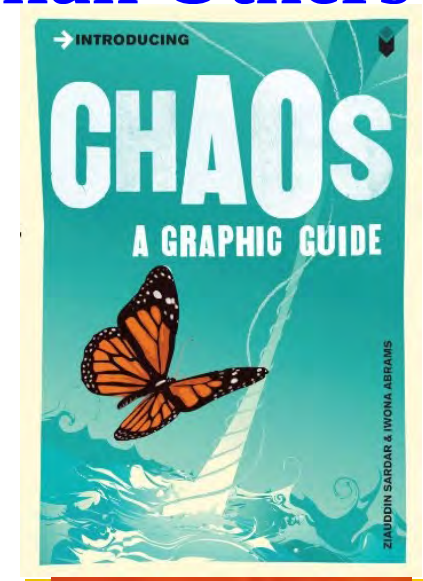


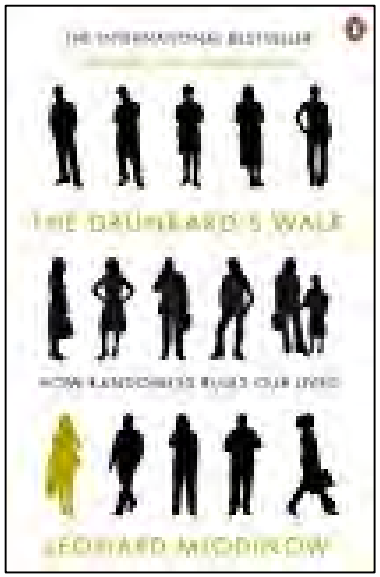


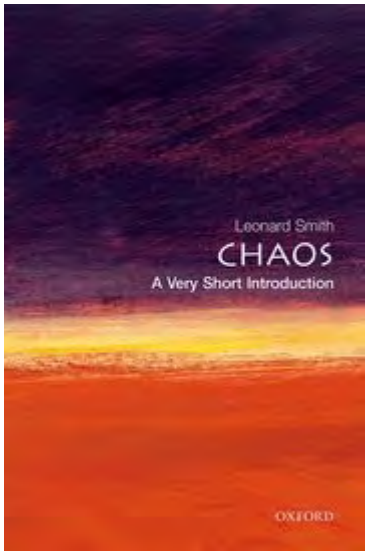


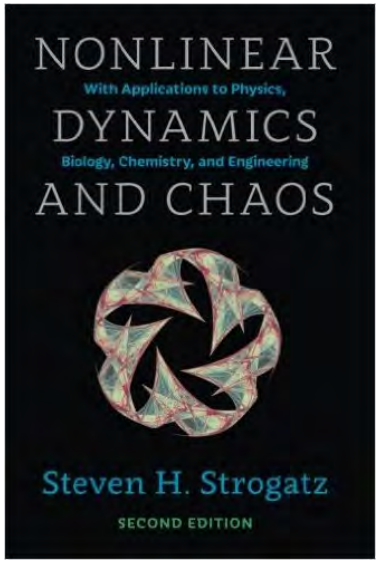
Some Ensembles Are More Informative Than Others

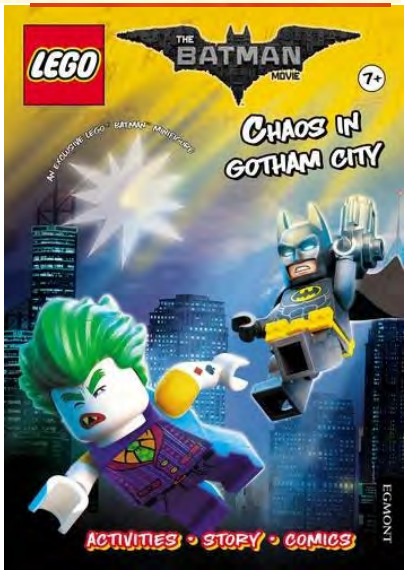


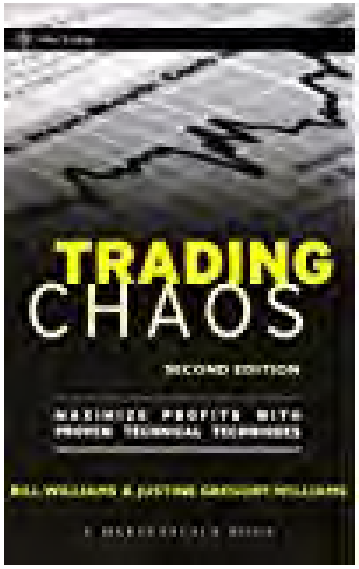




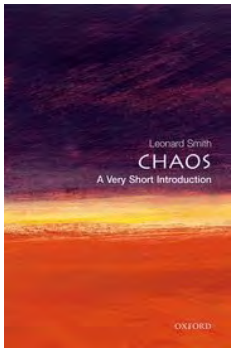




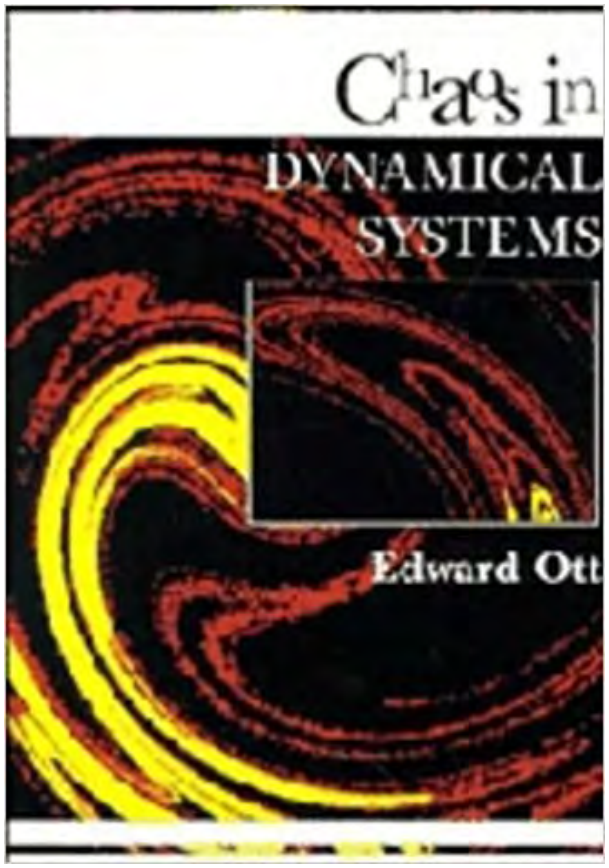




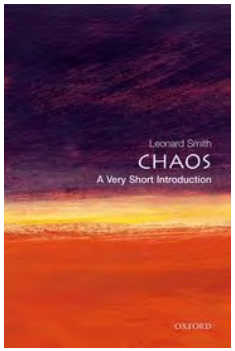
Even here, nothing unknown in 2015 can be learned!



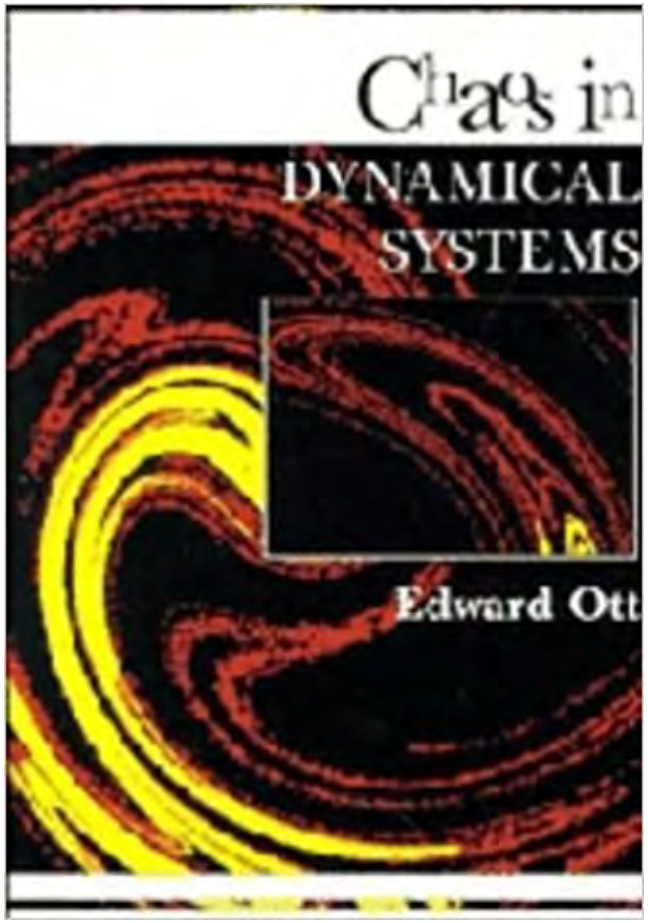
Alternatively, for the cost of an ensemble you could read a bigger book:

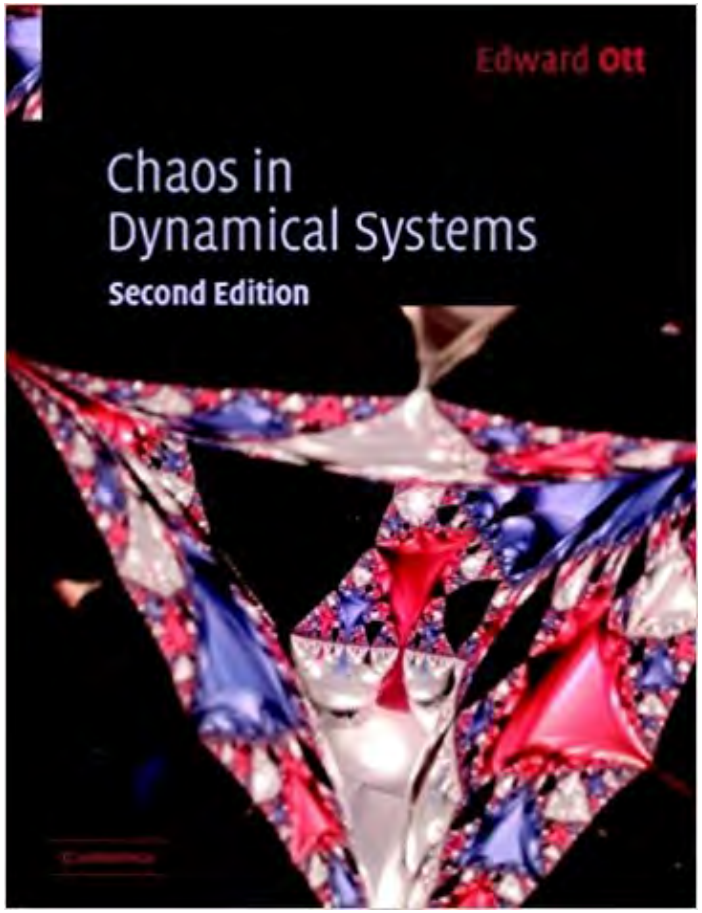


And then?



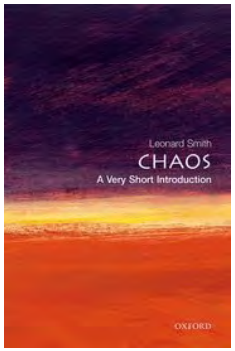
… perhaps make the bigger book even better:

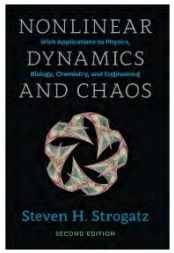


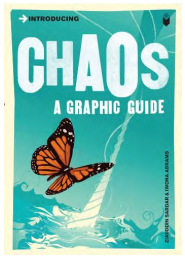


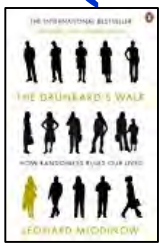
And then, give sufficient resources, you could

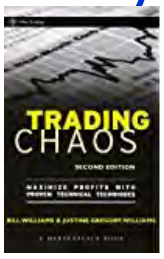
An ensemble of all (todays) books?

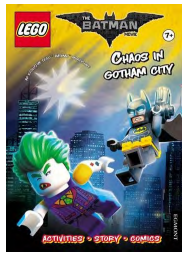




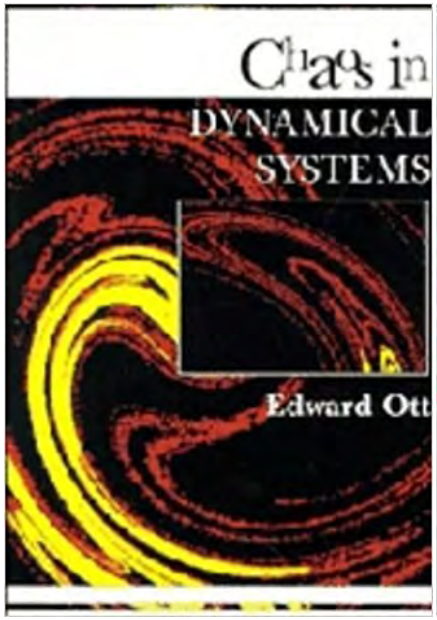


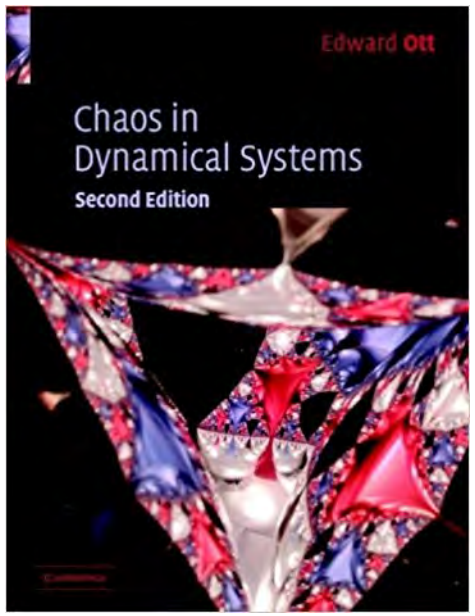






Even an ensemble of all books in print in 2021 is incomplete.





Better decision support come from aiming at achievable goals.
(An not incentivising unachievable goals.)

Should you fear Senator Inhofe's List?

U. S. Senate Report
Over 400 Prominent Scientists Disputed Man-Made Global Warming Claims in 2007
Scientists Debunk "Consensus"

U.S. Senate Environment and Public Works Committee
Minority Staff Report (Inhofe)
www.epw.senate.gov/minority

Released: December 20, 2007

cyclopedia

nhofe (/ˈɪnhɒf/; born
senior United States
nd a member of the
cted to the Senate in

n Environment
vities cause
ce, Chris
the science of

to

reviously served as
epresentative and

[hide]
business career

2.1 State legislature
2.2 1974 gubernatorial election

Jim Inhofe

United States Senator
from Oklahoma

Do you fear things like “Senator Inhofe’s List”?

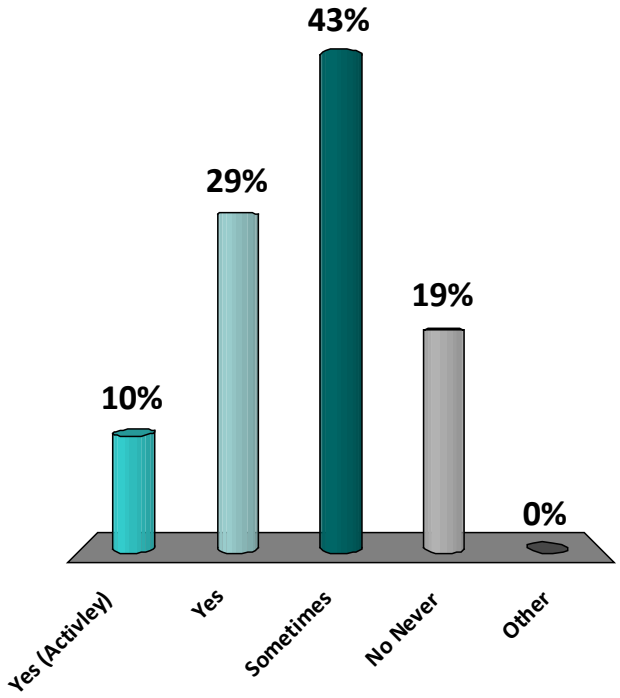
A. Yes (Actively)

B. Yes

C. Sometimes

D. No Never

E. Other



Q9.1

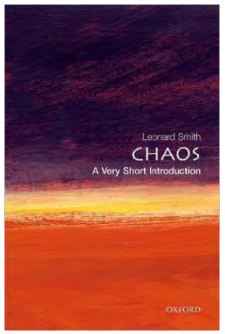
Five^{+1} Types of Probability

$P(x \mid \mathbf{I})$

Rational Decisions I. J. Good (1952) Journal of the Royal Stat Soc. Series B (Methodological) Vol. 14, No. 1 , pp. 107-114
Good Thinking I.J. Good (1983) Dover.

(o) Tautological Probability. A probability P(x|H) the value of which is specified in the definition of H. ("a fair coin", H is "a simple statistical hypothesis")
Arguably P(x) is conditioned on nothing beyond the problem statement.

(i) Physical Probability: $P(x \mid \mathbf{I}_{full})$ "True probability" of x.
(The probability held by Laplace's Demon/Infinite Rational Org)



(ii) Subjective$_{1952}$ Probability: $P(x \mid \mathcal{G} < \mathbf{I}_{full})$ probability of x given information $\mathcal{G}$ which is true but incomplete. $\mathcal{G}$ is a subset of $\mathbf{I}_{full}$
(The probability held by the Demon's Apprentice/?semi-finite Rational Org?)

(iii) Subjective$_{My}$ Probability: $P(x \mid \mathbf{I}_{my})$ my attempt to estimate the subjective$_{1952}$ probability, given imperfect models, inexact observations, finite computational power and tidbits.
Key point: I can know my $P(x \mid \mathbf{I}_{model})$ is not mature.
A *Mature probability* is not expected to change without some new insight or additional empirical observation (even given vast increases in computational power).

(iv) Dynamic Probability. The probability $P(x \mid \mathbf{I}_{time\text{-}up})$ "held" by an only partially completed algorithm.

Bayesians Bayarri and Berger

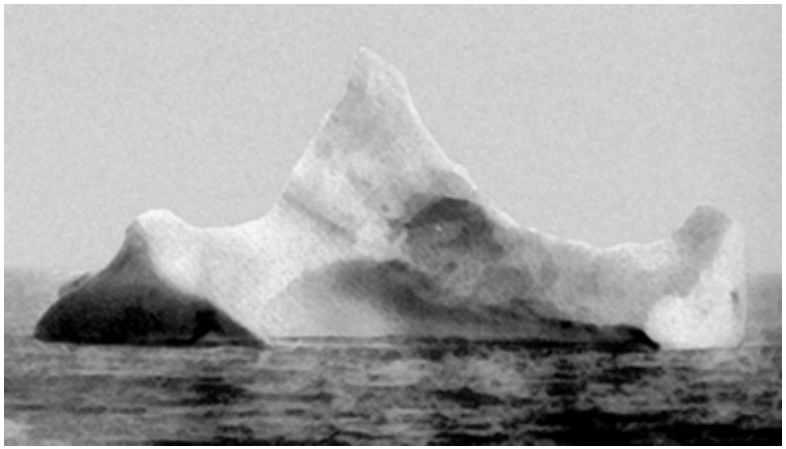
Bo

Just Enough Decisive Information (JEDI)

There are other ways to use our models.
There are other goals than probability forecasts that can be used as such.

One approach is to use our forecast models to look for things we are vulnerable too;
too look in the medium range;
to regulate industries so they can avoid dangerous situations.

Lets not shoot for probability forecasts,
but rather aim to extract Just Enough Decisive Information from our models.



Critical Distinctions

Is the best available model adequate for (your) purpose?

Large Forecast-Outcome Archive (or not): Can the model be evaluated?

Weather-like task or Climate-like task

System Responds to Forecast (or not)

Evaluation of the model is against observables?

A contrived index? Or Itself?

Is the sun-set lead time respected? Acknowledged?

How long can the model shadow the (empirical) Quantity of Interest?

Is a model evaluated on it foundation or on its performance?

Are there observed fast processes (with feedbacks) absent in Global Models (But perhaps simulated in "local" models)

Are explanatory models mistaken for forecast models?

Is the model modular (can the impact of turning bits "off" be investigated)?

Are linear approximations used beyond they range of rough validity?

Is the target system just to rich to simulate today?

Does your model help you to understand (interacting components of) the system?

Questions on the Table

Actually supporting real world decisions suggests a rather different approach to modelling and the presentation of forecast systems than the more straightforward scientific goal of learning something interesting about the physical system, or even just learning about the model. When there is little resemblance between forecast and outcome, making the model better (for everyone) may not need to consider specific detailed aspects of model performance. Expert opinion will play a very significant role in interpreting model output for decision making. As models and forecast systems improve, however, the role of the model-based forecast system in quantitative support for policy and decision making increases tremendously. Certainly in weather forecasting, and internal operational forecasting in other sectors, probabilistic forecasts provide useful, decision-relevant information. "The Question" then becomes critical. What question is being asked? What decision is being supported? What aspect of the world is being forecast? Answering "what question(s) will best inform that decision maker?" is a critical part of the design process. The "best available" model is irrelevant if it is not adequate for this purpose, answering with sufficient precision the particular question on the table.

These issues are discussed in the context of a particular application of weather forecasts by Électricité de France and anticipative disaster risk reduction (DRR) in Pakistan. The limits of traditional UQ, in particular the limited relevance of common approaches to UQ in model-land, are discussed. Other Buzz words in the meeting's description are touched upon, in terms of altering the experimental design to yield decision relevant results. Results from Model Intercomparison Projects (MIPs) are significantly less relevant than those of Reality Intercomparison Projects (RIPs). The very aim of Data Assimilation (DA) is unclear outside model land. Similarly, studies expected to improve forecast skill in the perfect model scenario may simply make things worse in actual application; evaluating pre-forecast sub-systems of the model-based forecast systems cannot be sure to improve the real-world forecast.

In short, the importance of experimental design for decision making is stressed along with the relevance of the forecast target. The critical aspects of "adequate for purpose" are contrasted with the potentially irrelevant "best available." And the importance of expert judgement in quantifying the probability of a big surprise and other critical statistics is noted.

The role of "The Question" in quantitative decision and policy support ties these components of model-based forecasting together. Without understanding of the question on the table, scientists and decision makers are unlikely to improve decision making, and can make it much worse. (Apologies to Karl Pearson.)

Berger, J.O. and Smith, L.A. (2019) 'On the statistical formalism of uncertainty quantification,' *Annual Review of Statistics and its Application*, 6. 3.1-3.28.

Smith, L.A. (2016) 'Integrating information, misinformation and desire: improved weather-risk management for the energy sector', in Aston, P.J., Mulholland, A.J. and Tant, K.M.M. (ed.) *UK Success Stories in Industrial Mathematics*, 289-296. Springer

Roulston, M.S. and Smith, L.A. (2004) 'The boy who cried wolf revisited: the impact of false alarm intolerance on cost-loss scenarios', *Weather and Forecasting*, 19 (2): 391-397.

With apologies to K Pearson

Just Enough Decisive Information (JEDI)

The original aim of "weather forecasting" was to warn of the weather thought probable.

Then the aim was to say what the weather would be.

When this was deemed impossible in principle, the aim shifted to early warning, then accountable probability forecasts of the weather. (Back to Galton vs. Fitzroy.)

I believe that we are now at another such junction, but we do not have a well defined mathematical target.
For *users* of forecasts, I suggest we call this aim "just enough decisive information."
Information which aides decision making, but does not make it w-trivial.

Slido.com
#D571

Things are NOT HOPELESS (Useless)!
A Weather-like task: Predicting Pirates

U.S. Naval Research Laboratory physical scientist Dr. James Hansen, of the Meteorological Applications Development Branch, Monterey, Calif., is the recipient of the Department of the Navy Meritorious Civilian Service Award for meritorious performance of service as research and development lead in the Piracy Attack Risk Surface (PARS) project.

PARS dynamically couples shipping, pirate behavior, and meteorology and oceanography (METOC) to identify areas that are subject to the greatest risk of pirate attack. This predictive product enables the Naval Forces Central Command (NAVCENT) and others policing piracy to maximize placement of limited assets for successful deterrence and interdiction operations.

"Dr. Hansen's high level of technical proficiency in probability, statistics, and ensemble modeling enabled him to develop methodologies to successfully model pirate behavior and quantify the uncertainties associated with these predictions," said Dr. Simon Chang, superintendent, Marine Meteorology Division. "His exceptional ability, superb leadership, professionalism and loyal dedication to duty reflect great credit upon himself and is in keeping with the highest traditions of the United States Naval Service."

The sophisticated PARS model simulates piracy behavior ranging from a single small skiff operating near the coast using ocean currents to extend their range, to the use of multiple mother ships supporting numerous independent and coordinated piracy attack groups thousands of miles

CAPT Anthony J. Ferrari, NRL Commanding Officer, presents Dr. James Hansen, physical scientist at the U.S. Naval Research Laboratory Meteorological Applications Development Branch, the Department of the Navy Meritorious Civilian Service Award. Dr. Hansen receives the award for meritorious performance of service as research and development lead in the Piracy Attack Risk Surface (PARS) project. *(Photo: U.S. Naval Research*

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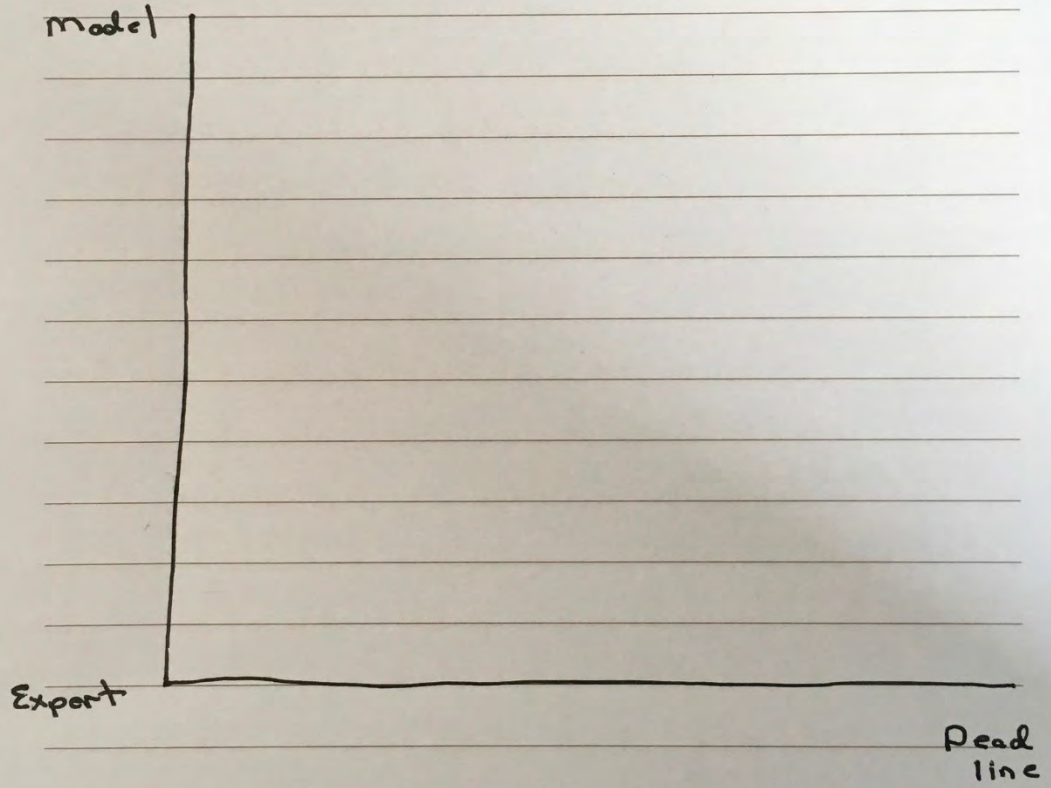
KONTAKT DER KONTINENTEN

Climate modellers balance expert judgement and simulation in a different manor than economists.



Optimal = The valve we had **when** time ran out.

Not even a cartoon.

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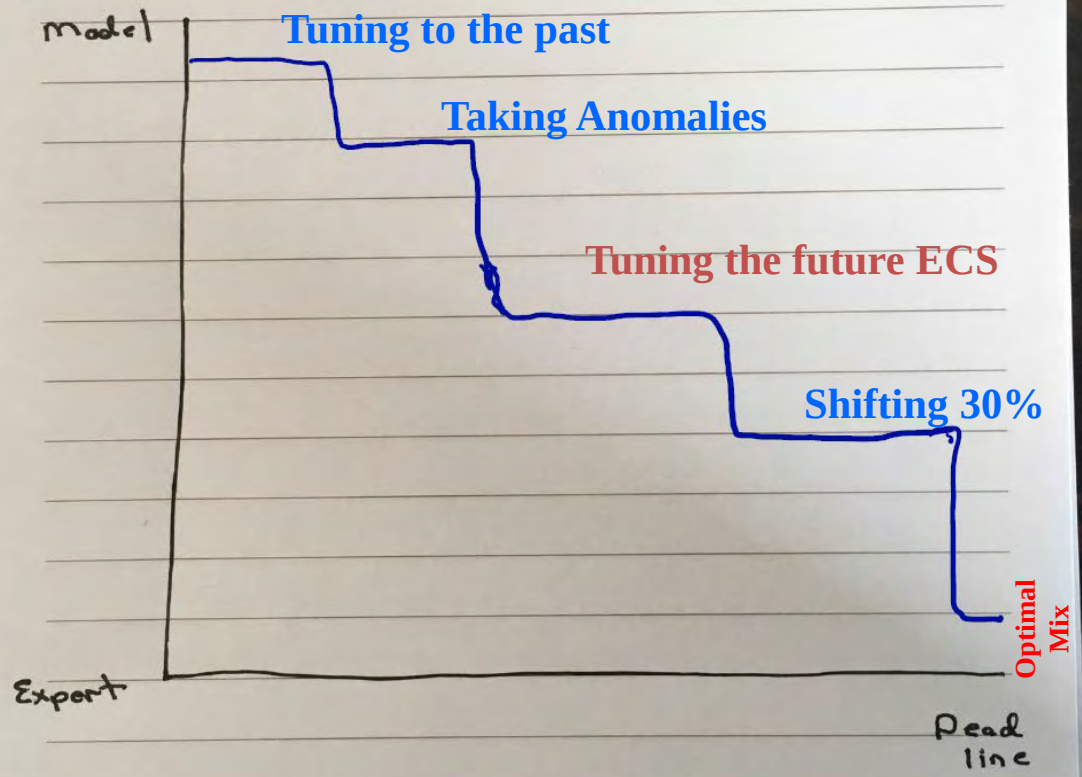

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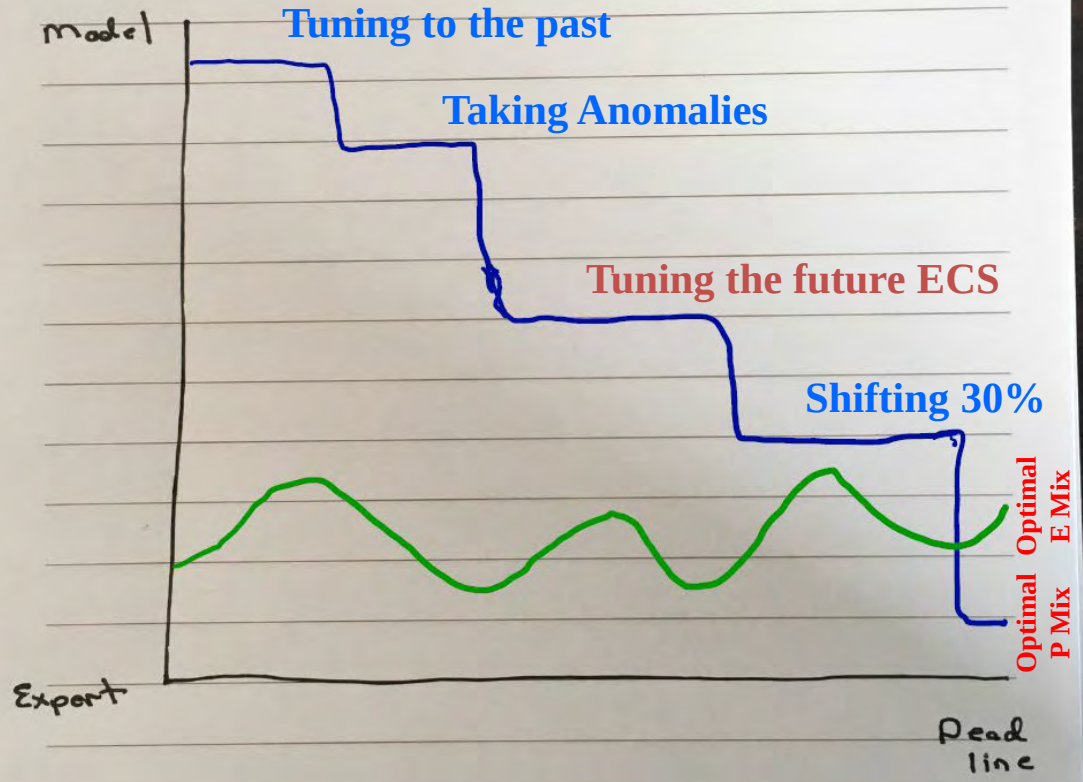

Optimal = The value we had when time ran out.

What is my next experimental design?

Mervyn King: How to include reactions to the forecast in the forecast?

Not even a cartoon.

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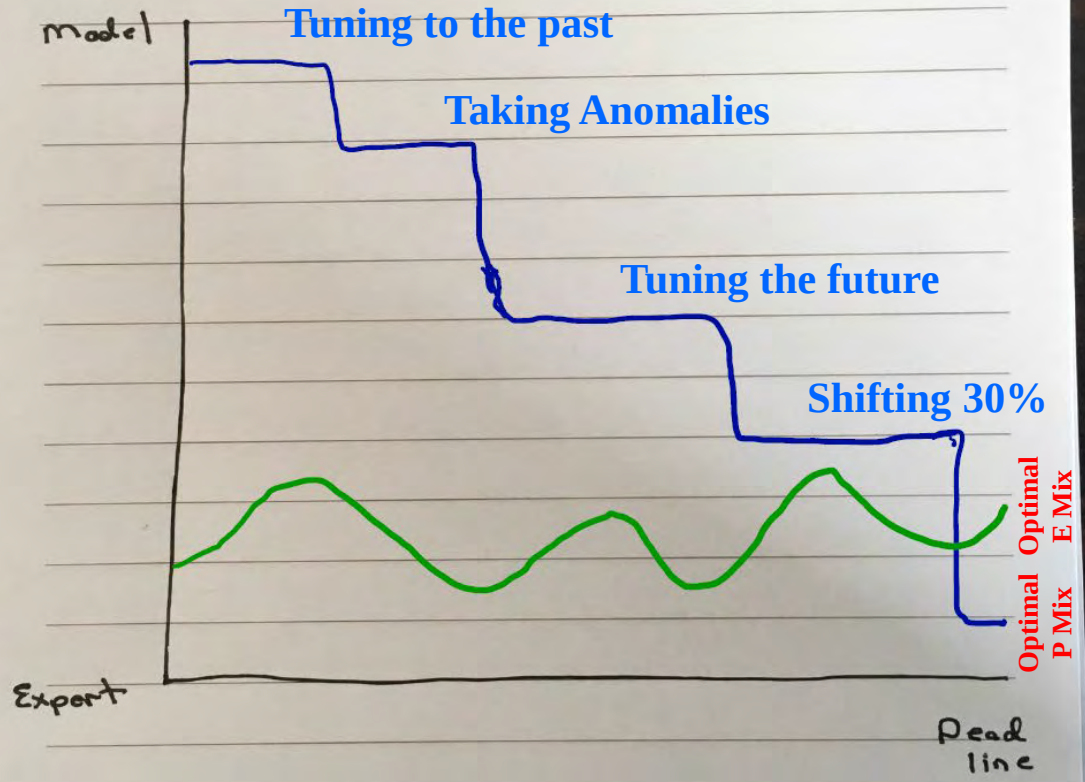


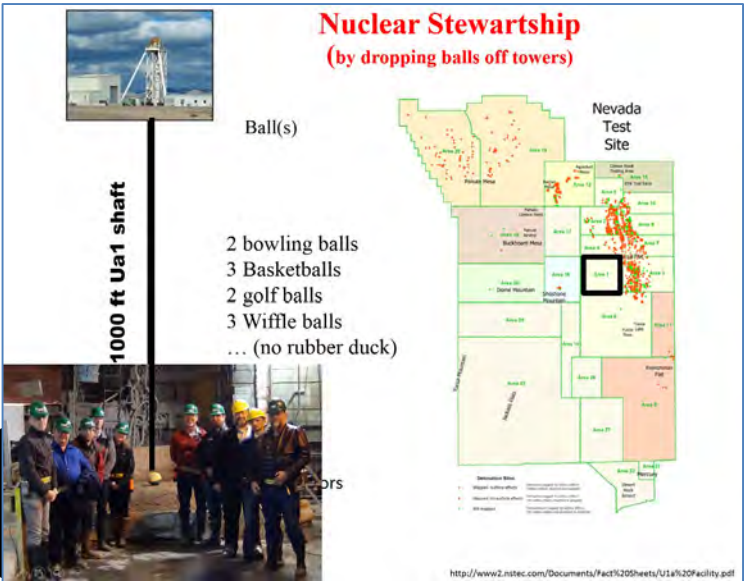
Optimal = The valve we had when time ran out.

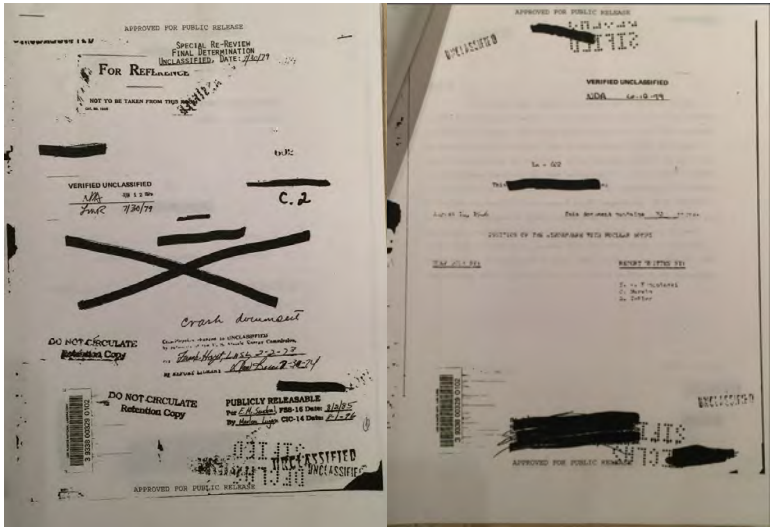
Might jellyfish shut down my nuclear power plant this week?

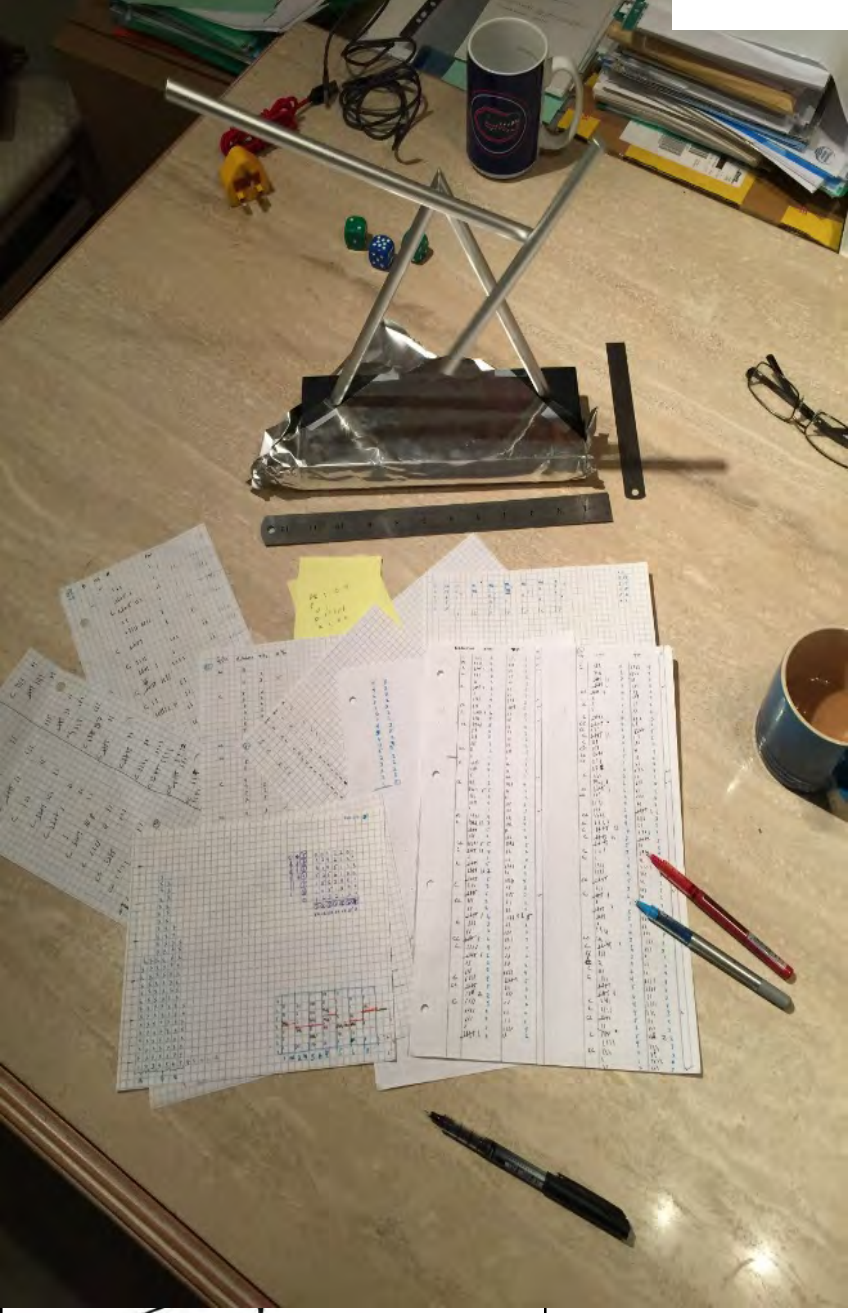
How often should we train in really dangerous weather conditions?

Can Structural Model Error be illustrated in a simple ball drop experiment?

How likely is it that testing this bomb will accidentally ignite the earth's atmosphere







Given this system and detailed time series observations, the first thing a statistician does is the compute (say) the autocorrelation function.

Given this system and detailed time series observations, the first thing a physicist does is to take out the batteries.

Sometimes each are too excited to think about the target question.

As always, given Laplace Conditions (a perfect model, exact obs, and unlimited computational power) the physicist's simulations will always yield the best (and most adequate) answers.

Yet in reality we never have the Laplace Conditions!

$$\mathbf{P(x|I)}$$

Questions:
Probability of duration before next "over the top"?
The probability this swing will go "over the top".
The number of swings before the next OTT?
The number of OTT in the next 5 min?

The model class you draw from, the pdf's you form, will vary with the questions you ask.

And the impacts: Tony Stark panicked here, would Bruce Banner have panicked?

Taking Forecasts off the Table (Sometimes)

Erica Thompson

START NETWORK

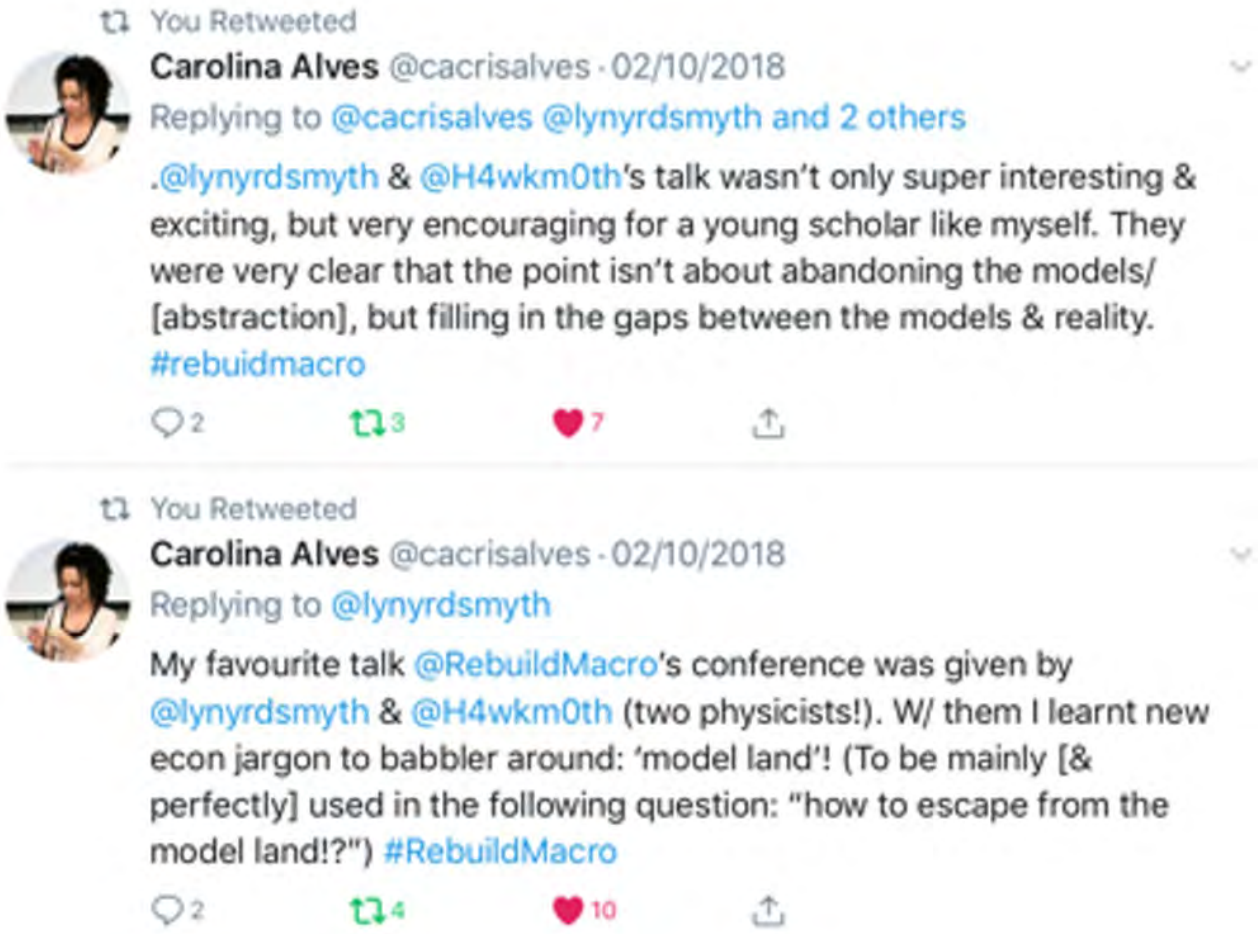
GETTING AHEAD OF DEADLY HEAT

The Start Network partners with the London School of Economics to forecast and mitigate a heatwave in Pakistan

In May this year, members in Pakistan raised a Start Fund alert for a heatwave, the alert was activated. Members had collectively analysed weather forecasts and had raised the alert before temperatures reached deadly levels. Start Network's Sarah Klassen discusses the challenges of forecasting heatwaves, and why a similar alert in 2017 was not activated.

https://startnetwork.org/news-and-blogs/getting-ahead-deadly-heat

This is NOT a depressing talk!



You Retweeted

Carolina Alves @cacrisalves · 02/10/2018

Replying to @cacrisalves @lynyrdsmyth and 2 others

.@lynyrdsmyth & @H4wkm0th's talk wasn't only super interesting & exciting, but very encouraging for a young scholar like myself. They were very clear that the point isn't about abandoning the models/ [abstraction], but filling in the gaps between the models & reality. #rebuidmacro

2 3 7

You Retweeted

Carolina Alves @cacrisalves · 02/10/2018

Replying to @lynyrdsmyth

My favourite talk @RebuildMacro's conference was given by @lynyrdsmyth & @H4wkm0th (two physicists!). W/ them I learnt new econ jargon to babbler around: 'model land'! (To be mainly [& perfectly] used in the following question: "how to escape from the model land!?") #RebuildMacro

2 4 10

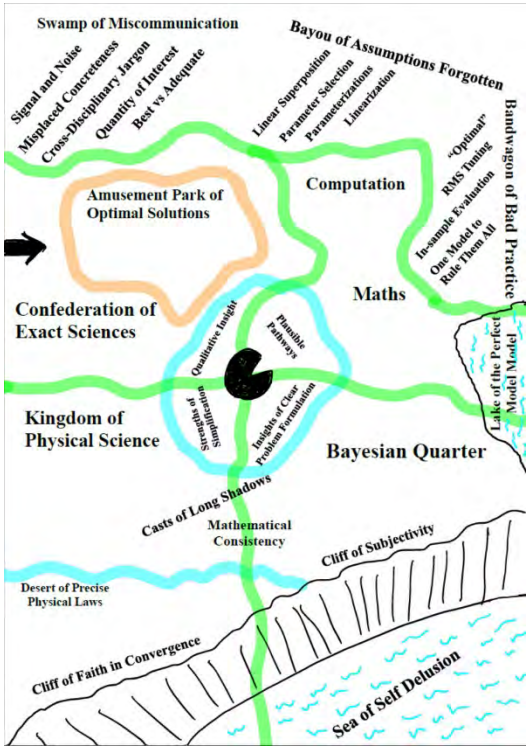
Purple Lights and Probabilities

What "probability" should you offer given a purple light?

What probability should you offer if your predicted probabilities are inconsistent with the observed relative frequencies?

What probability should you offer when something (previously) unimaginable happens?

What will you tell an autonomous vehicle to do?



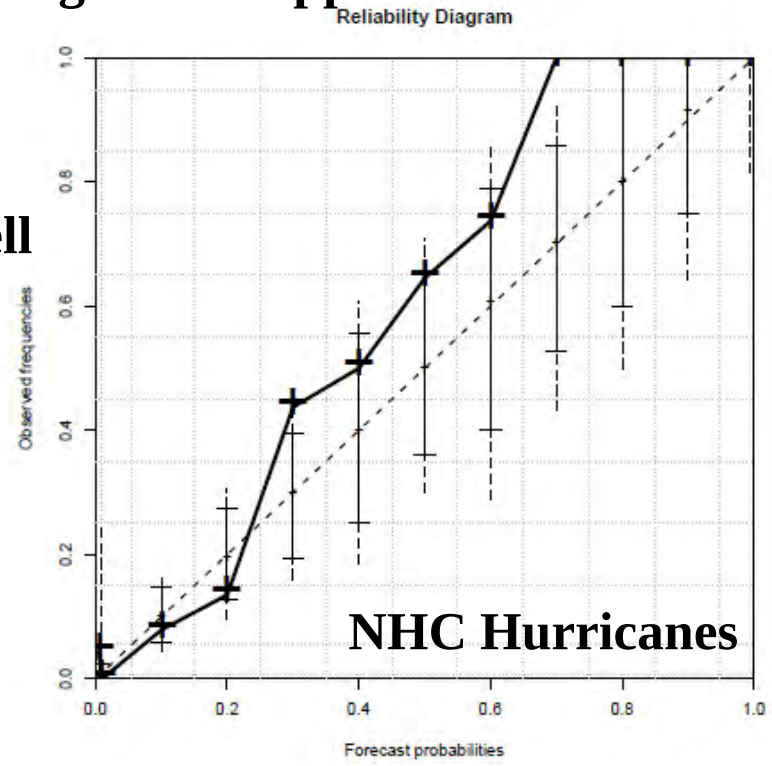


Figure 6.2: NHC 2012 TC forecast reliability: reliability diagram for the NHC's 2012 48-hr TC forecasts* with 5% - 95% (1% - 99% vertical dashed line) consistency bars. All but

Blue Dice

Jarman, Alex S. (2014) *On the provision, reliability, and use of hurricane forecasts on various timescales.* PhD thesis, LSE.

Bröcker, J. and Smith, L.A. (2007) 'Increasing the reliability of reliability diagrams', *Weather and Forecasting*, 22(3): 651-661.