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?

I have taught mathematical modelling courses for over a decade: all my students are now urged to pause if they ever hear themselves utter one of these phrases…

What should a national academy do if some government body is issuing environmental forecasts which are thought to be misleading, economically damaging, and without a scientific basis?

But, say some, and justly—are ships to remain waiting to avoid a gale that, after all, may not happen? Are fishermen and coasters to wait idle and miss their opportunities? By no means. All that the cautionary signals imply is—"Look out." "Be on your guard." "Notice your glasses and the signs of the weather." "The atmosphere is much disturbed."

This has happened in the UK.
About one hundred and fifty years ago,
with Admiral Robert Fitzroy's storm warnings, and the Royal Society (Galton)…

444 *Admiral Fitz-Roy* [March 28,

Is what follows just old unfair criticisms?

WEEKLY EVENING MEETING,

Friday, March 28, 1862.

JOHN PETER GASSIOT, Esq. F.R.S. Vice-President, in the Chair.

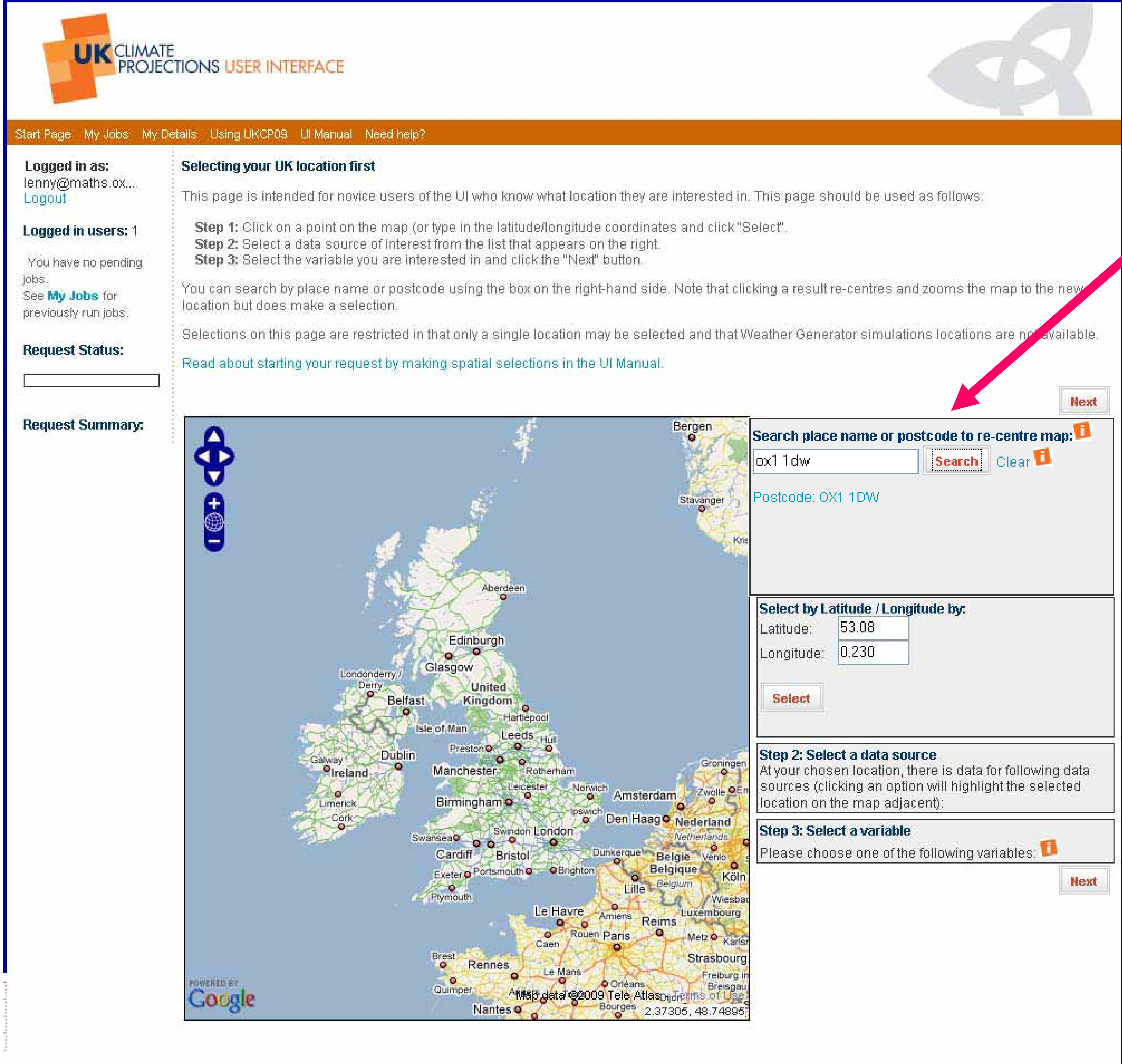
REAR-ADMIRAL FITZ-ROY, F.R.S.

An Explanation of the Meteorological Telegraphy, and its Basis, now under trial at the Board of Trade.

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.

No! (In fact I fall on Fitzroy’s side of the “Storm warning” debate, as did Lloyd’s).
The case against detailed 2007 “climate-proofing” differs in that:

(a) one can learn how to use storm warning, day after day.
(b) storm warning did in fact reflect the weather “thought probable.”
(c) Fitzroy argued captains to be left entirely to their own judgement.



The claim/ aim is to provide postcode (5km) resolution multivariate subdaily time series for the 2030's, 2050's, 2080's …

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What damage will it do?

Those in yellow I have heard uttered with respect to UKCIP08, et al.

Centre for Climate Change Economics and Policy

The Munich Re Programme: *Evaluating the Economics of Climate Risks and Opportunities in the Insurance Sector*

The Science of Impacts and the Impacts of Science:

Bayesian Climate Forecasts and Adaptation in the United Kingdom

Leonard A Smith

London School of Economics

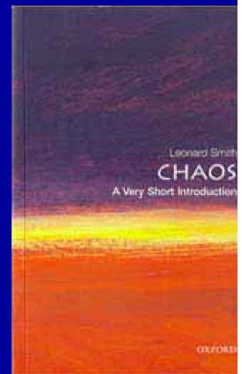
& Pembroke College, Oxford

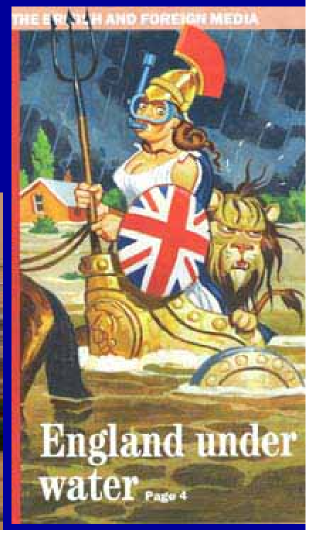
Dave Stainforth, Nicola Ranger,

Falk Niehörster, Ana Lopez

&Ed Tredger

www.lsecats.org





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Living With Environmental Change LWEC

Münchener Rück Munich Re Group

THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE

UNIVERSITY OF LEEDS

I would like to consider evidence for and against this proposition:

To apply Bayesian Analysis
to today's ensemble(s) of climate-model output,
with the aim of deriving probability density functions
for decision support
is to commit a fundamental category error.
(Perhaps 3)

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Basic point: The diversity among physical models of a phenomena is not intended to be indicative of the uncertainty in an actual outcome.

The Diversity of our models does not reflect the uncertainty in our future.

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to today's ensemble(s) of climate-model output,
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(Perhaps 3)

Critical post-Copenhagen question(s):

How do we proceed rationally?
How do we limit the damage already in the pipeline?

The Diversity of our models does not reflect the uncertainty in our future.

This does not imply climate change is not happening.
(It may well be worse than today's models suggest!)

This is not an attack on Bayesian methodology.
Prob(Moon made of Swiss Cheese | Moon is made of cheese)
[NOT a question of probability calculus –or- a frequentist bias]
more a question of interpreting model noise as if it were signal.

This does not imply ensembles are uninteresting!
I am in part responsible for the largest ensemble of climate models ever run (and I just launched 512 more last week!)

This has nothing to do with a need/desire for "perfect models"!

This does not imply that there is nothing for the SAMSI climate working group to do!
(But it does suggests care in designing the questions.)

Prob(Moon made of Swiss Cheese | Moon is made of cheese)

?

"Evidence"
"Available Evidence"
"Evidence Considered"
" X>2 & Y>3 & X+Y < 1"

After this slide, whenever I say "Probability" or "Probability Distribution" I mean to say "decision relevant probability distribution" (where by decision I mean an event of more than academic interest!)

It is of course possible, and potentially interesting, to develop a PDF related to the properties of next run of climateprediction.net to return home….

The decisions I wish to inform regard adaptation or mitigation.

Reference: Probability

Probability (objective and subjective)

Probability is a concept most of us deal with in everyday life. There are, however, two types of probability. That which most people are familiar with is objective probabilities (frequency of occurrence of an outcome based on observations). UKCP09 probabilities are not this type, but are subjective/Bayesian probability (strength of considered evidence).

In detail

Objective probability:
The expected frequency of occurrence of some outcome based on observations of a large number of independent trials carried out under the same conditions for which all outcomes are accounted for (e.g. rolling a pair of dice).

Subjective/Bayesian probability:
A measure of the degree to which a particular outcome is consistent with the information considered in the analysis (i.e. strength of the evidence).

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 historical climate observations, expert judgement and results of considering the outputs from a number of climate models, all with their associated uncertainties.

The methodology that generates the probabilities is based on large numbers (ensembles) of climate model simulations, but adjusted according to how well different simulations fit historical climate observations. As such, the probabilities provide information on the consistency of future climate outcomes with the evidence considered which can be used to support decisions related to impacts and adaptation options.

One important consequence of the definition of probability used in UKCP09 is that the probabilistic projections are themselves

Decision Support

- Decision Support requires specific questions
  - Typical questions: pub kitchens, Atlantic storms, UK floods, Diameter of high capacity cables under the streets of London, Norwegian snow fall, castle location, subsidence coverage …
- When might quantitative model output add value to decision making?
  - Value beyond the use of today's climate science?
- Why "Better" and even "Best" does not imply model output is relevant to policy or decision makers!
  - a schematic picture on finding necessary conditions (re: fit for purpose)
  - estimating the probability of a big surprise
  - cost of obscuring what we know with what is also true (the credibility of science)
- How do we make progress in applying climate science +models
  - Expectation management and the impact of model noise.
  - How to communicate insight when the probability of a big surprise is high.
  - Openness to communicate (today's) limitations. (and estimate next years).

When can we use models to inform decisions?

Given a decision relevant Probability Distribution we can apply the tools of Decision Theory 101

Can Today's science provide a decision-relevant PDF for the for the question of interest to you?

Is this an obvious "yes"?

If not, (a) what would you look for? and (b) how would you proceed?

(a) Information which is believed: Robust. Relevant. Informative.

(b) When all the models are run and all the approximation are made:

?What is the probability of a "Big Surprise"?

(is this a standard Bayesian procedure?)


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Last Updated: Friday, 1 December 2006, 05:51 GMT

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England smoke ban to start 1 July

Smoking in enclosed public places will be banned in England from 1 July next year, the government has announced.

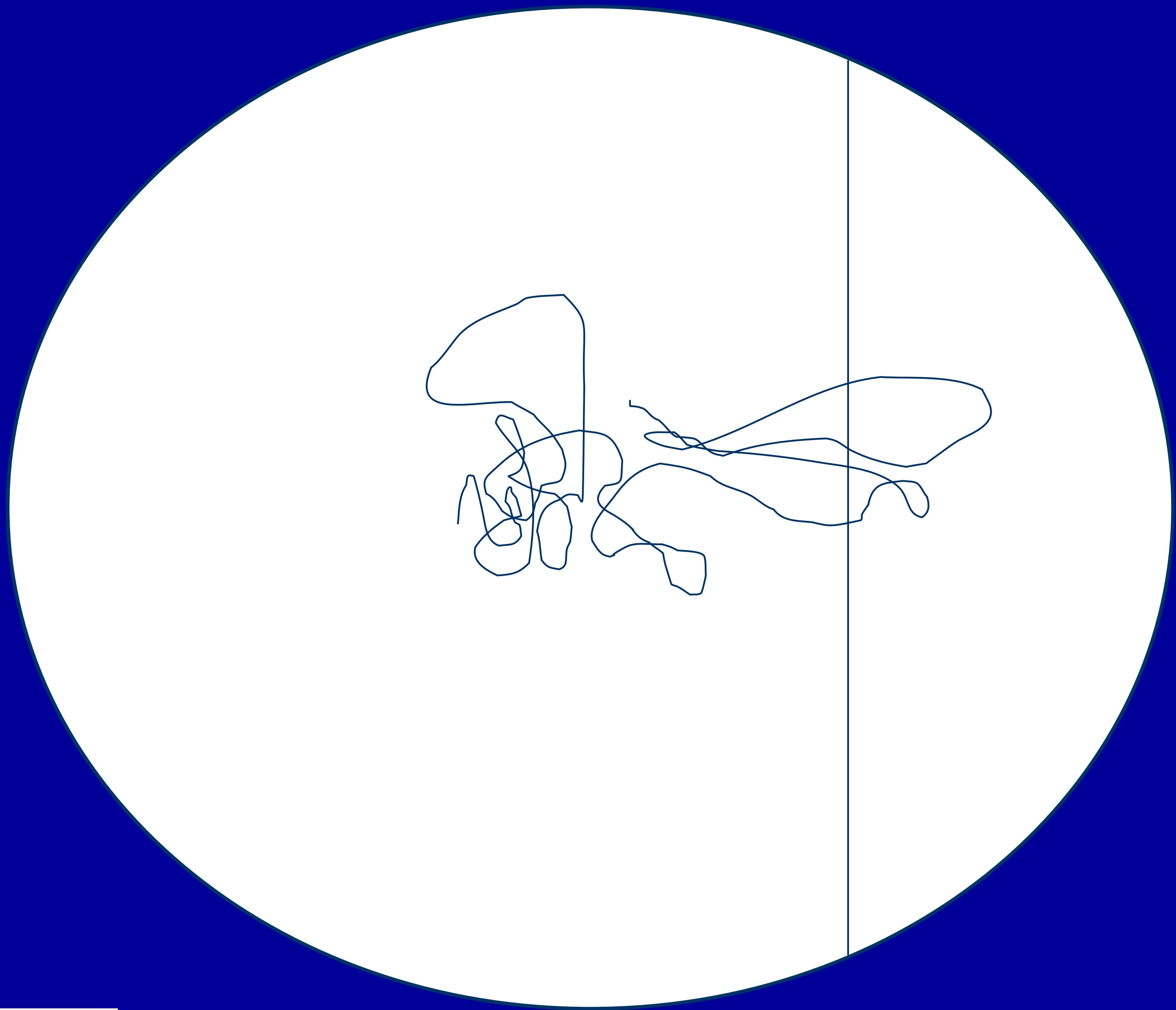
The ban covers virtually all enclosed public places including offices, factories, pubs and bars, but not outdoors or in private homes.

The government says 600,000 people will quit as a result

Can current climate science communicate relevant, timely, robust information for John?

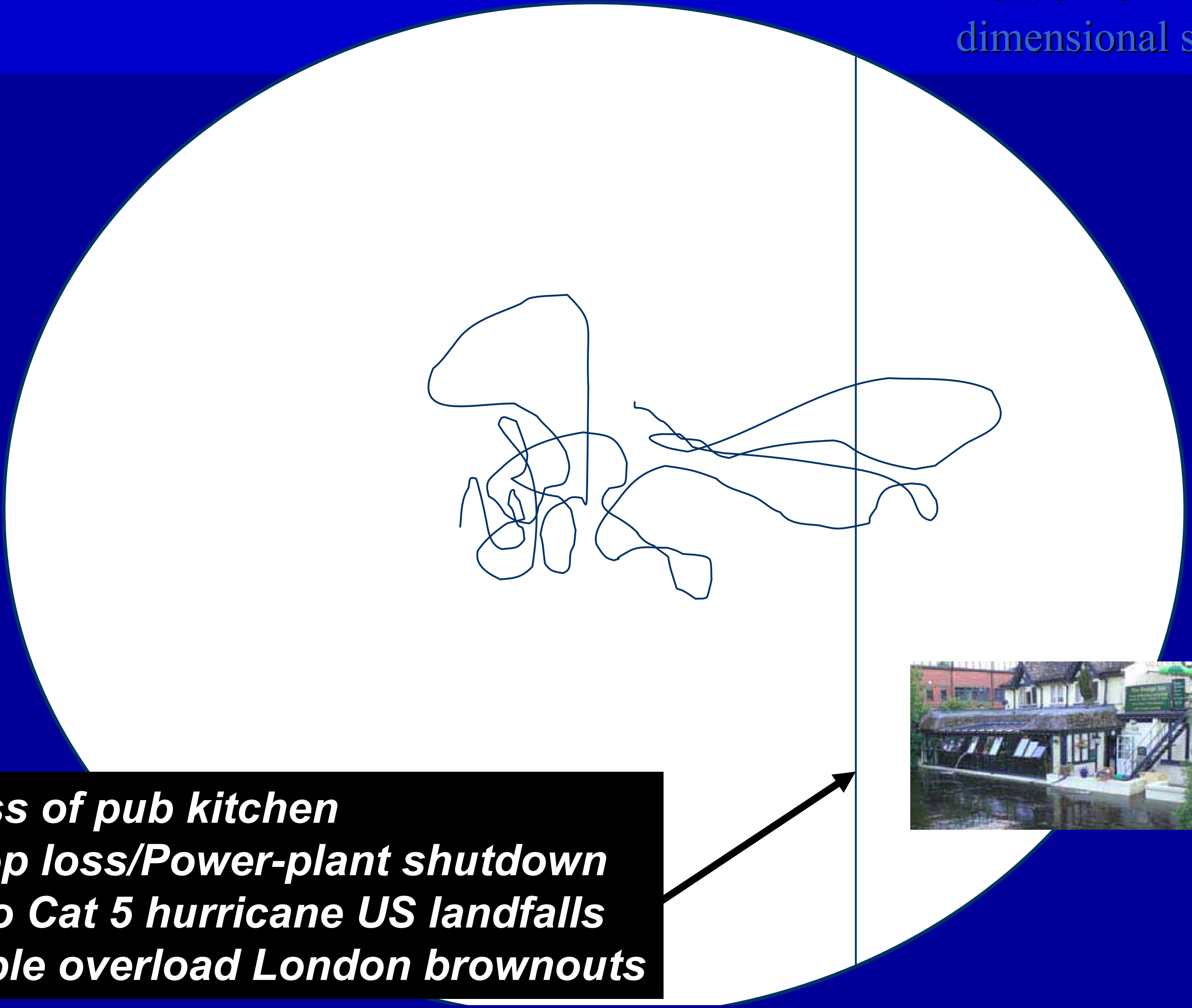
Can today's science "climate-proof" this pub? Or it's insurer?
(or their reinsurer?)
Is it a question of mere probabilities? Or might we have a "Big Surprise"?
How to best manage Expectations (Theirs) and Credibility (Ours) ?
Why is this so hard?

Most decisions depend neither on ***"average meteorological variables"*** nor ***"standard deviation of the average weather"*** they depend on the trajectory.



As they are nonlinear we have to evaluate them along trajectories. Crops, cables, wind energy and system failures depend on what and even when weather events unfold.

Hence the $\sim 10^6 \times 10^{21}$ dimensional space



Loss of pub kitchen
Crop loss/Power-plant shutdown
Two Cat 5 hurricane US landfalls
Cable overload London brownouts

This kind of information is not available from today's models, nor will it ever be visible in model mean values!

Uncertainty vs Inadequacy: Newton's Laws

$$F = \frac{G\, m_1\, m_2}{r^2}$$

If we believe G is a universal constant, a real number which is not known exactly, we can usefully describe our uncertainty via P(G).

A Bayesian approach to new evidence makes perfect sense:

P(G | available evidence)

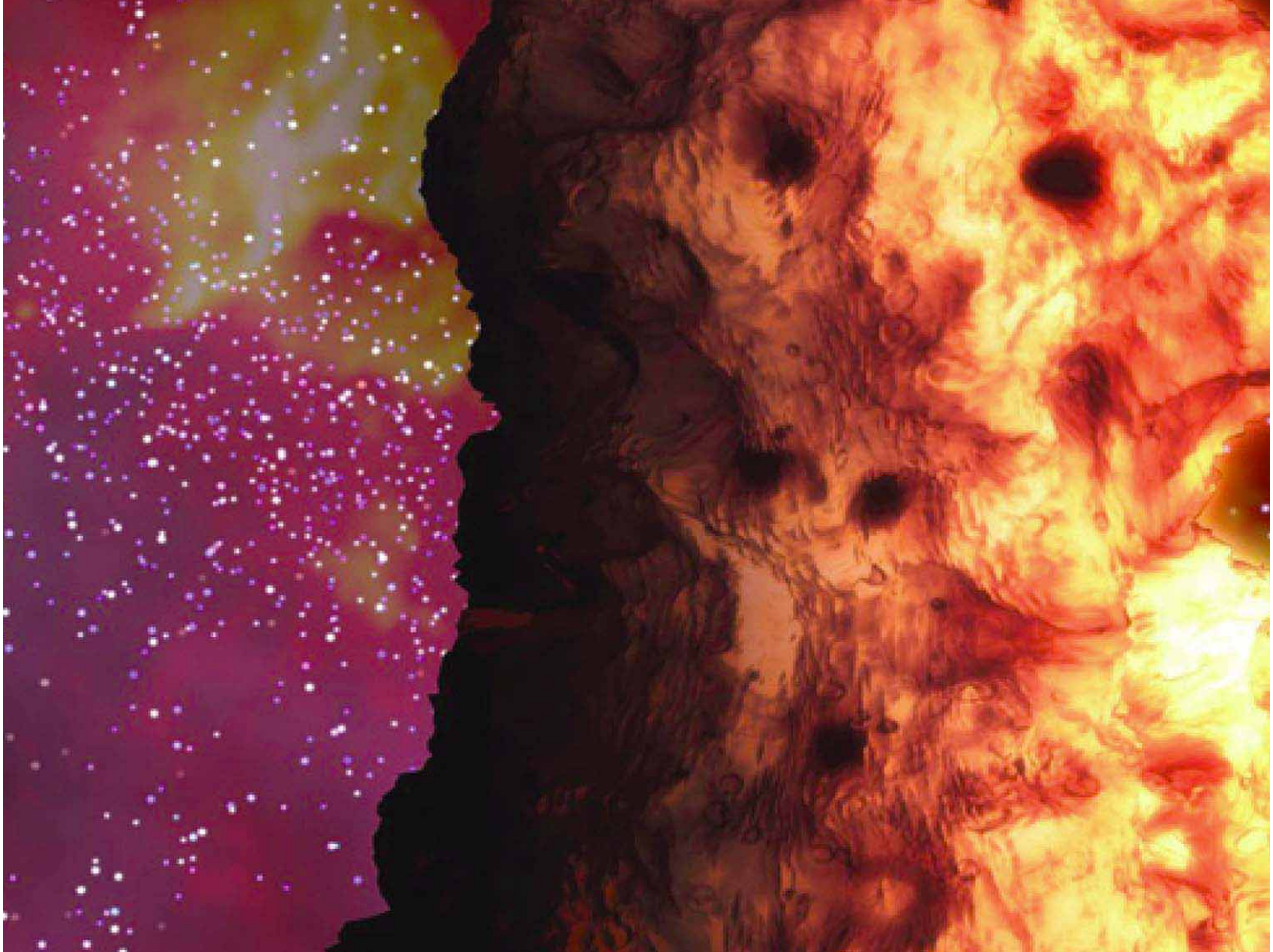
or better:

P(G | available evidence & Newton's Laws Universal)

But for almost 100 years we have known that Newton's Laws are not Universal; the point is that G is not a number the value of which is uncertain but that arguably there is no such number to be uncertain of!

Nevertheless, it is good enough to get us to the moon, and back.
A model need not be perfect to be useful now and then. The question is:

Is it useful for the current purpose?



Decision support: potential collisions with near Earth asteroids over the next 10000 years.

We know the Newtonian model is structurally incorrect, its parameters have no precise empirical values to find, but it can shadow relevant observed trajectories on time scales much longer than 50 years. (well, some of them.)

Main points:

Utility (probabilistic similarity) does not require a perfect model, merely one fit for purpose.
(?or at least plausibly fit for purpose?)

Show that physics models can have trajectory dependent inadequacy.

Motivate the case for Prob(Big Surprise).

Red dots represent asteroids that cross the Earth's path, while those represented by green dots do not. Note that these dots are not to scale and the colors are intended only to give a visual cue to the pace of discovery.

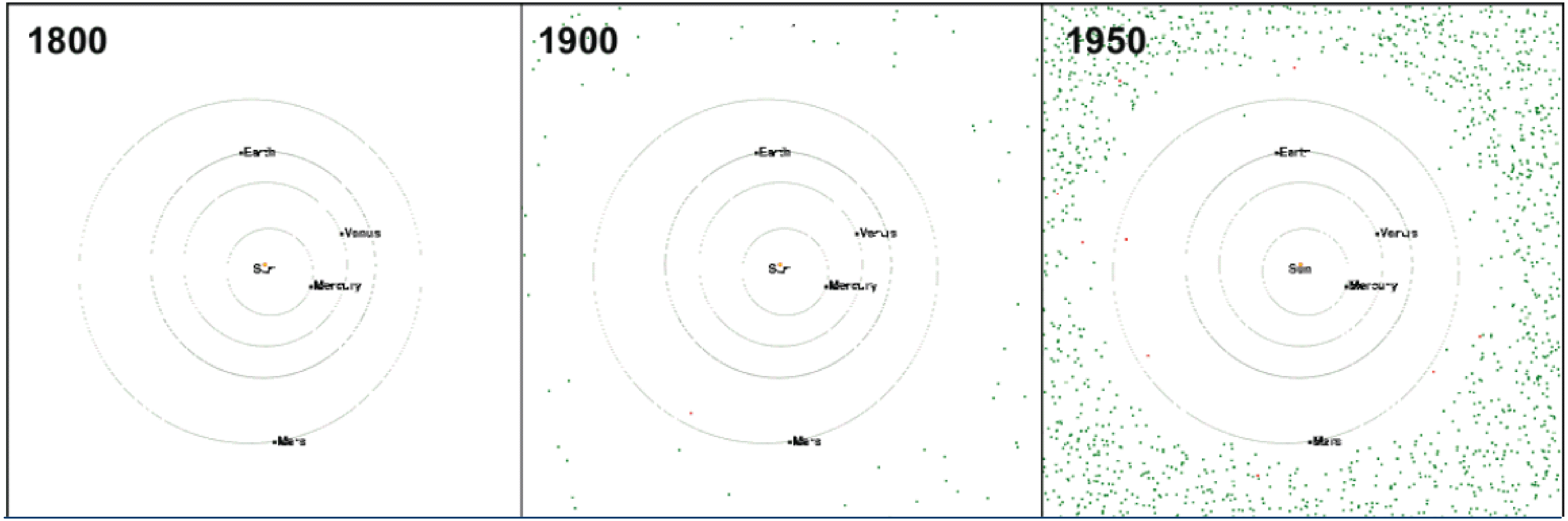


Figure 3. History of Asteroid Discoveries

Red dots represent asteroids that cross the Earth's path, while those represented by green dots do not. Note that these dots are not to scale and the colors are intended only to give a visual cue to the pace of discovery.

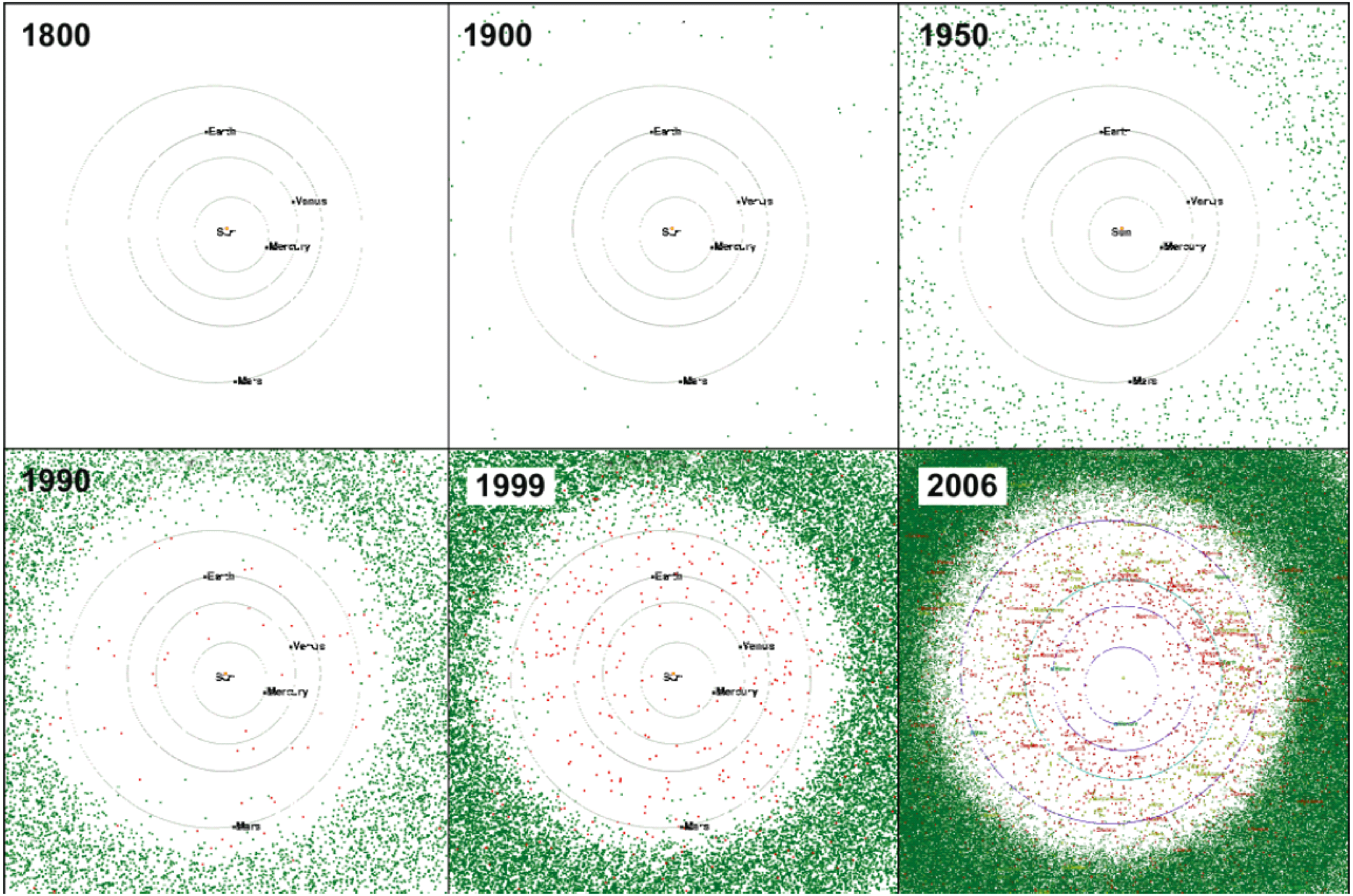
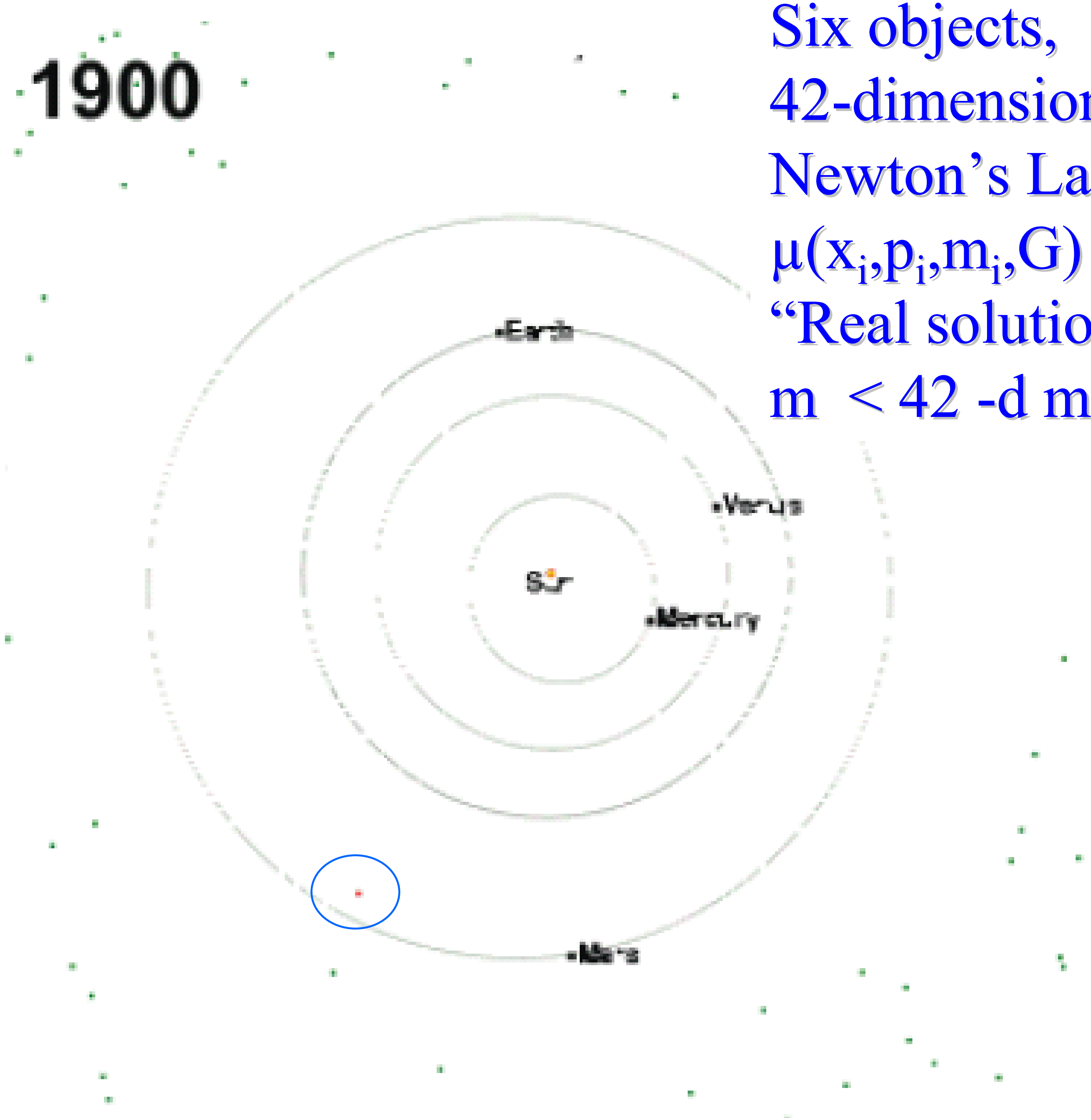
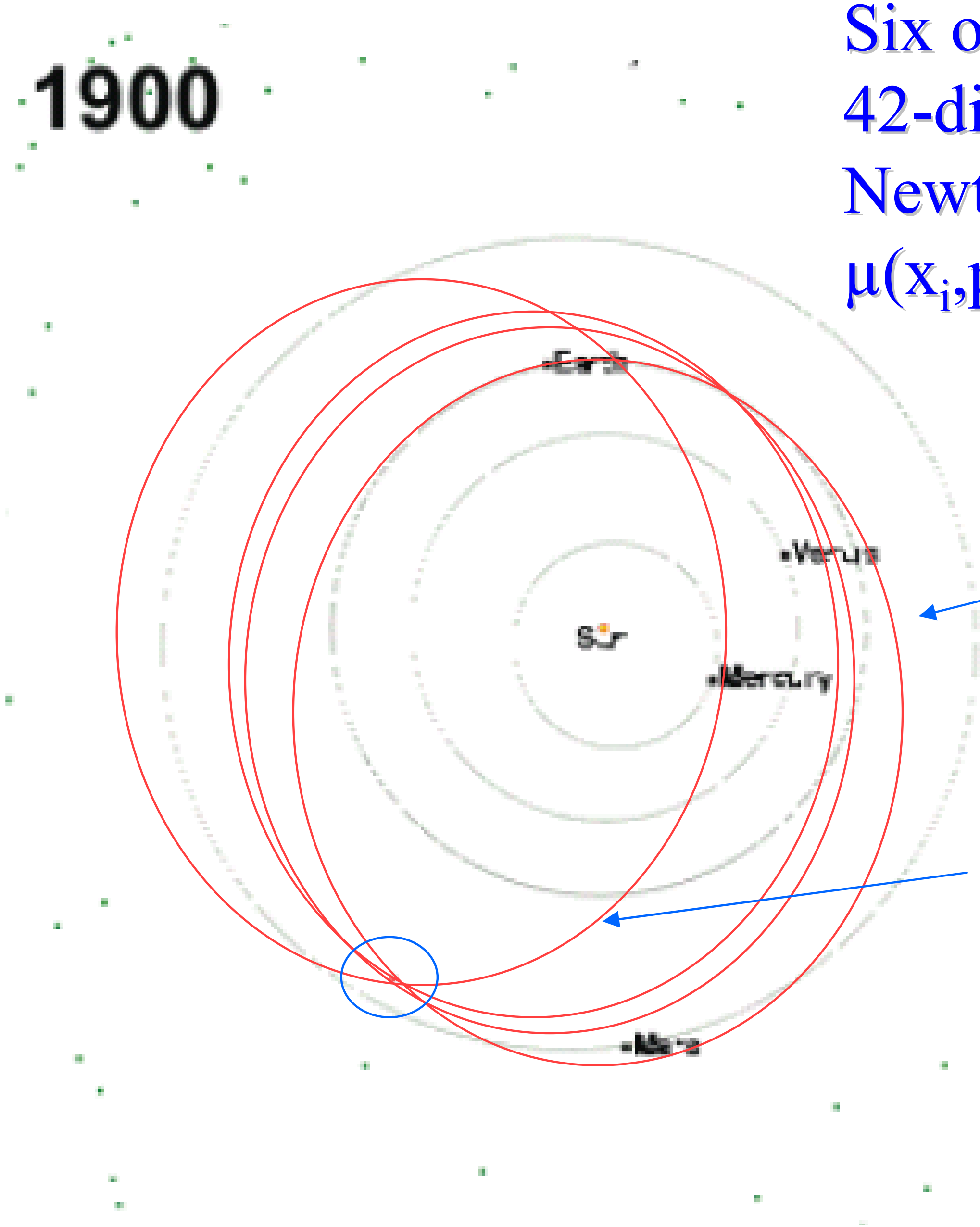


Figure 3. History of Asteroid Discoveries

Lets go back to 1900…



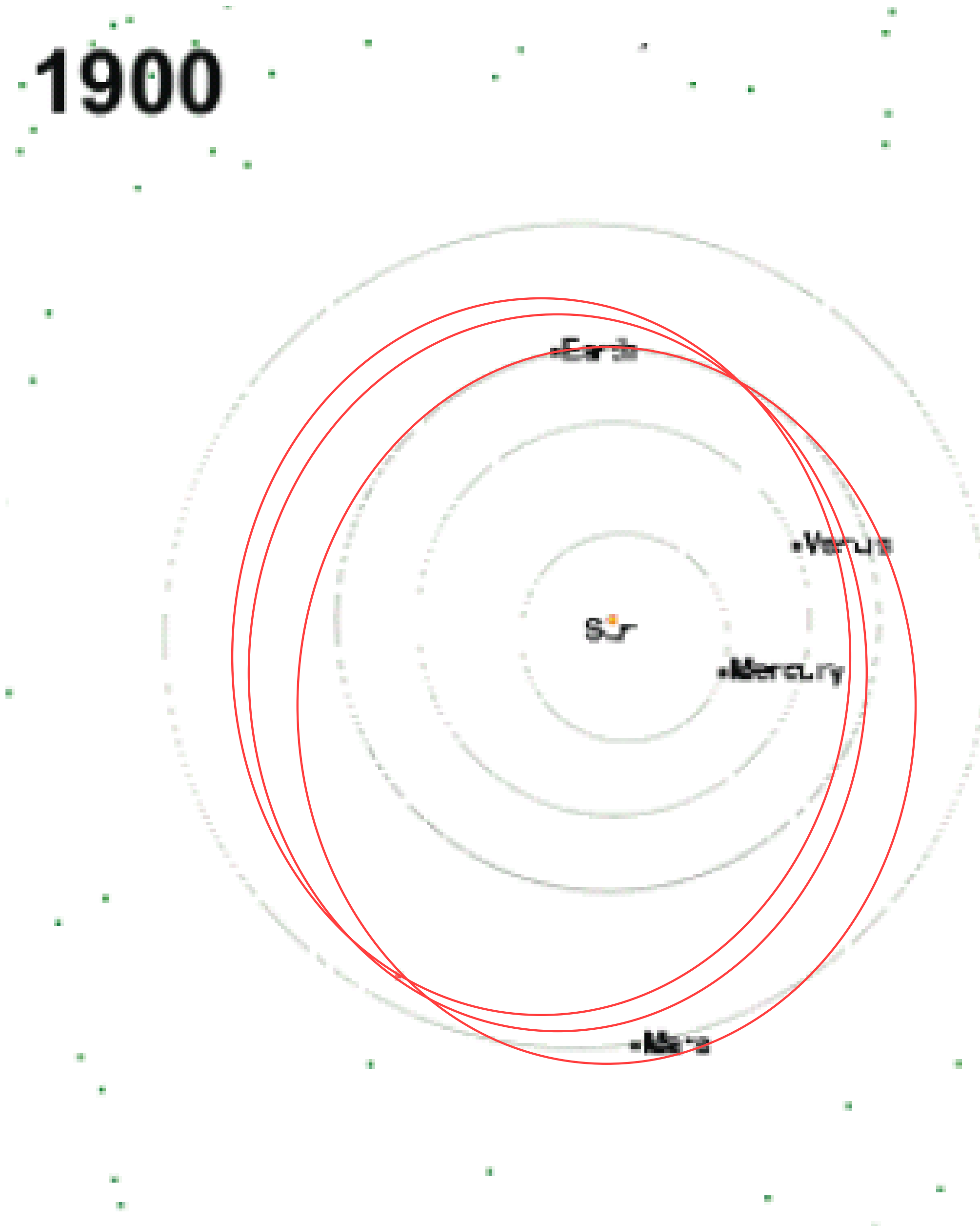
Six objects,
42-dimensional space,
Newton's Laws
$\mu(x_i, p_i, m_i, G)$
"Real solutions" live on a
m < 42 -d manifold



Six objects,
42-dimensional space,
Newton’s Laws
$\mu(x_i, p_i, m_i, G)$

This one scares me

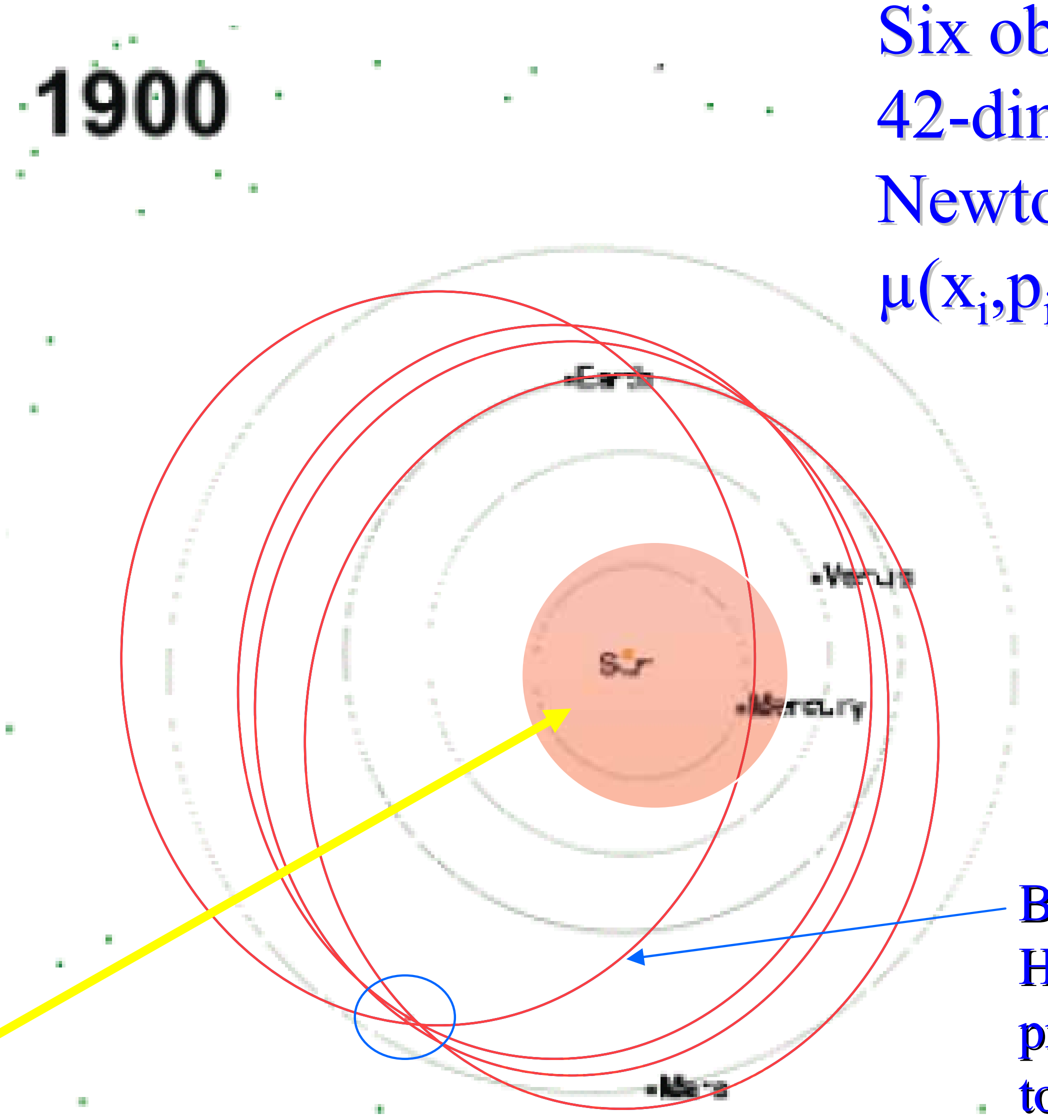
But that one scares me mor



As long as "that one" does not appear, I am very happy to interpret a large Monte Carlo sample as informative and decision support relevant.

But why here and not for pub kitchens?
Newton's Laws are not perfect?

Newton fails too close to the sun or where mercury might be!



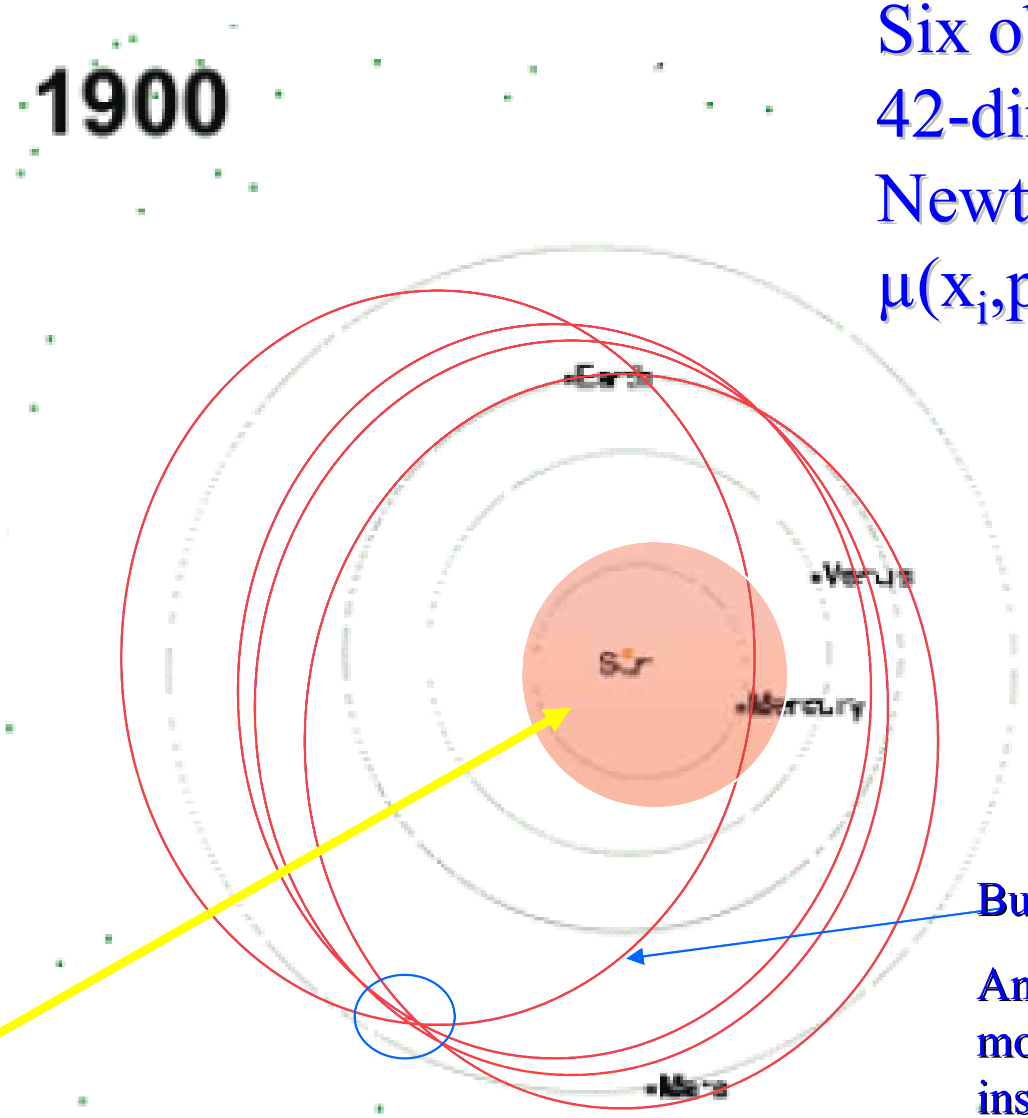
Six objects,
42-dimensional space,
Newton's Laws
$\mu(x_i, p_i, m_i, G)$

But that one scares me more. How do we account for the probability mass "lost" due to individual simulations (trajectories) which sample regions of state space where we know our model is woefully inadequate?

I can easily know my model (class) is inadequate here, without knowing how/being able/ to improve it: what value do ensemble simulations add in this case?

Newton fails too close to the sun or where mercury might be!

Six objects,
42-dimensional space,
Newton's Laws
$\mu(x_i, p_i, m_i, G)$



But that one scares me more.

And **discrepancy** based on Y<1901 models **will not help** (at least not inside the simulation approach)

What do I do if I lose 12% of my simulations this way?

I can easily know my model (class) is inadequate here, without knowing how/being able/ to improve it: what value do ensemble simulations add in this case?

In the case PHO trajectories stay far from the Sun , it arguably makes sense to

- put “priors” on mass, positions and momenta (and G),
- exploit the simplicity of Newtonian dynamics, and
- verify it might apply to each trajectory it suggests.

as long as we <u>expect</u> Probabilistic Similarity between predictive distributions of the Newtonian model and those of General Relativity (or any future model).

Predictive distributions are useful even if I don’t believe they are precise probabilities!
My model can be a source of information, without a NR belief in simulations.

How can the Bayesian approach handle the “known unknown” trajectories?
How can we at least communicate that they exist?

“Prob(Big Surprise)”

The risk of an irrelevant Discrepancy:

The Climate-Bayesians reply is to take several models and compute the discrepancy:

- Runge-Kutta 6th order
- Runge-Kutta 4th order (smaller time step)
- Predictor-corrector
- Hamiltonian (numerically exact energy conservation scheme)

In the case of Newton's Laws, this is a misleading lower bound.
And was known to be so in 1920!

Might one rationally believe:
"relationships between *model errors* for different climate variables can reasonably be expected to follow relationships between *inter-model differences* for different variables." Murphy et al 2007
"are unlikely to be fundamentally compromised"
?@ 5 km, hourly extremes of precip in 2080? In Y2007 models?

I will next argue "no", first generically for Physics, then for Y2007 GCMs, and then suggest question areas for the SAMSI working group.

3 Construction of probabilistic climate projections

PX

Adobe Acrobat

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OK

Discrepancy in future variables increases the uncertainty associated with the projections, and mitigates the risk of making overconfident projections.

3.2.8 Structural model errors (discrepancy)

What is discrepancy, and why is it important?

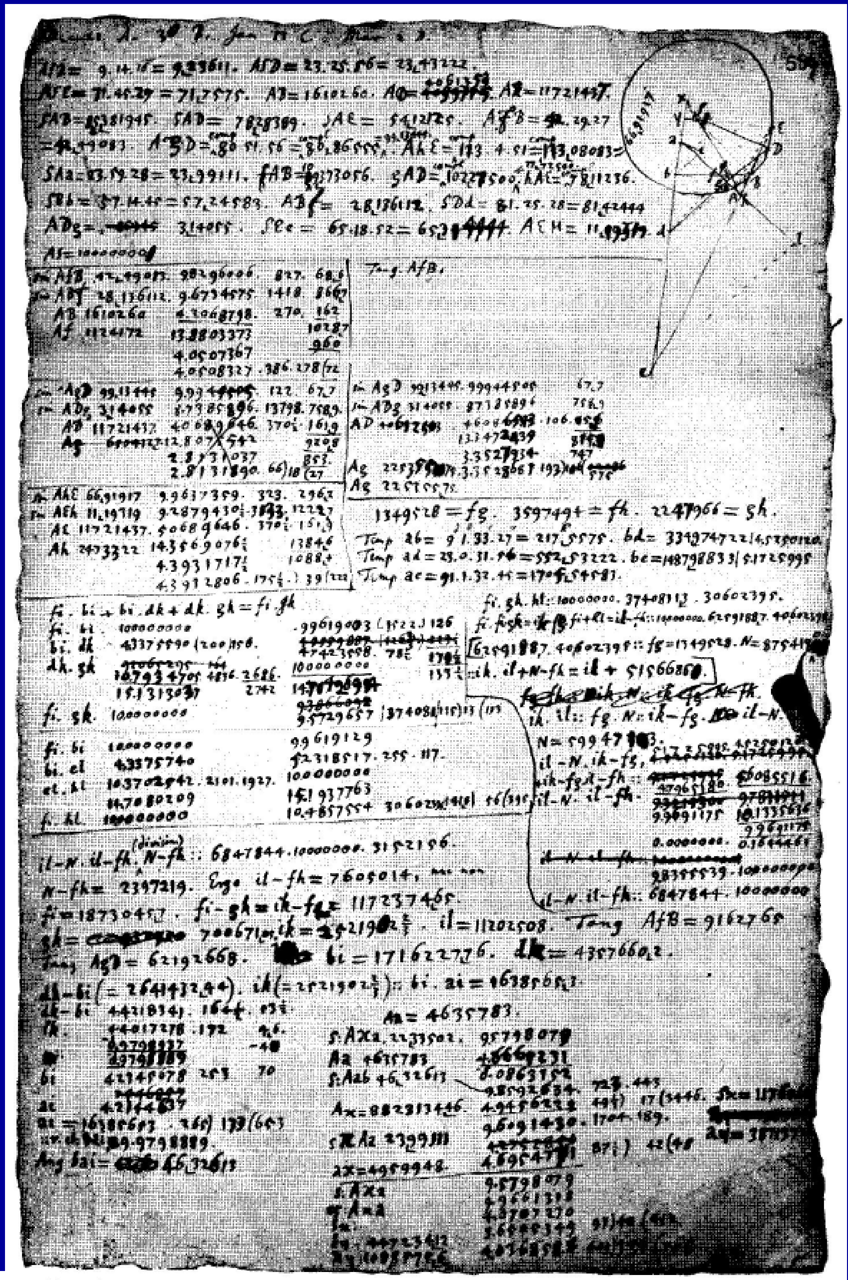
The discrepancy term, introduced in Section 3.2.7, is a measure of how informative the climate model is about the real world. Formally, it represents the mismatch we would find between the model and the real world if we could locate precisely the

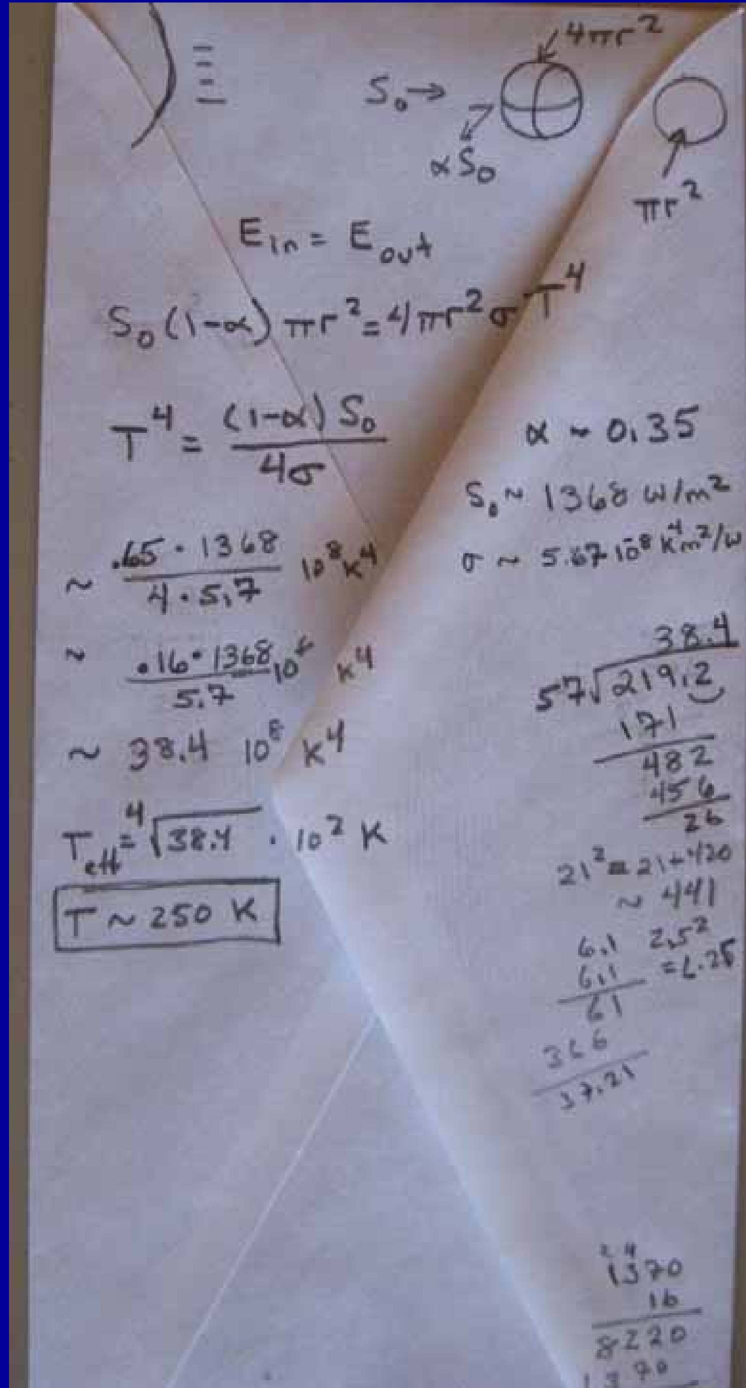
combination of model parameter settings giving the best overall simulation of climate that the model is capable of providing.

Centre for Climate Change Economics and Policy
The Munich Re Programme: *Evaluating the Economics of Climate Risks and Opportunities in the Insurance Sector*

http://ukclimateprojections.defra.gov.uk/images/stories/projections_pdfs/UKCP09_Projections_V2.pdf

Back-of-the-Envelop Calculations





The simplest(?) climate model:

$$(1-\alpha)(\pi r^2 S_0) = 4\pi r^2 \sigma T^4_{eff}$$

energy in = energy out

T_{eff} is the effective temperature of the earth, if it were a black body.

The simplest(?) climate model:

$$(1-\alpha)(\pi r^2 S_0) = 4\pi r^2 \, \sigma \, T^4_{eff}$$

Area of a sphere
SB constant
Effective Temperature

Albedo
Area of a disk
Solar constant

energy in = energy out

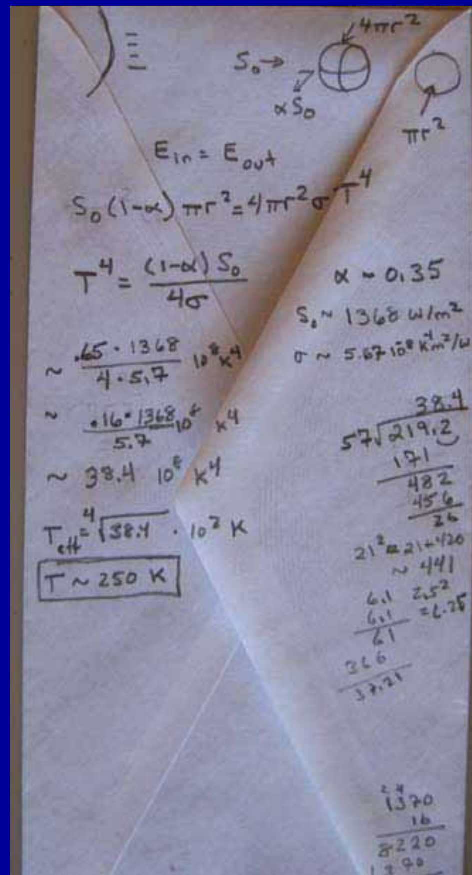
T_{eff} is the effective temperature of the earth, if it were a black body.

The simplest(?) climate model:

$$(1-\alpha)(\pi r^2 S_0) = 4 \pi r^2 \, \sigma \, T^4_{eff}$$

$$((1-\alpha)S_0)/(4\sigma) = T^4_{eff}$$

T_{eff} is the effective temperature of the earth, if it were a black body.



The simplest(?) climate model:

$$(1-\alpha)(\pi r^2 S_0) = 4\pi r^2 \sigma T^4_{eff}$$

$$((1-\alpha)S_0)/(4\sigma) = T^4_{eff}$$

T_{eff} is the effective temperature of the earth, if it were a black body.

One could compute the uncertainty in α, S_0, σ, (and 4, as the earth is not a sphere).
But we don't;
we know/knew the Earth is not a black body and that α, S_0 are functions of frequency (what would subjective "priors" mean?).

The model has served its purpose ("deriving" T to within 10%!) and so instead *we make a more complicated model.*

Besides, we also know T_{eff} is not only a model-land variable anyway!

So what does a physical model tell me?

(In what sense can we "get the average" right?)

Consider this case:

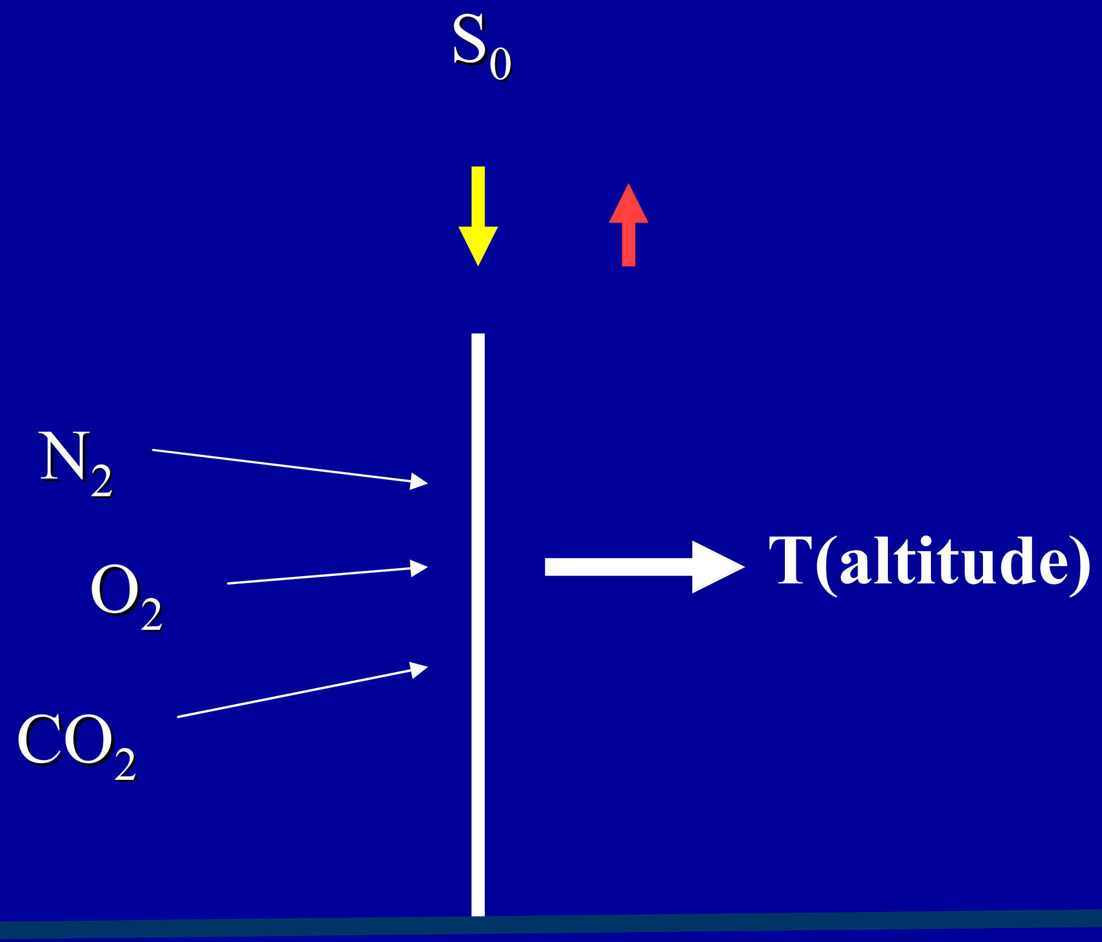
Physical simulation models do not tell us about our Earth, (they are far too simple), rather they tell us about properties the "average planet"; average over those even remotely like Earth are likely to share.

So the energy balance model applies equally well to the Mars, and very well to the Moon: the parameter values that change are not "fit" but specified.

Similarly: The robust properties of GCMs are those shared with planets like Earth but, say, without Iceland, or the Andes, or a highly variable ocean… or where ice is less interesting/more viscous…

The "better" the model, the more Earth-like the class of planets are; but it would be a fundamental mistake to take the diversity of these "planets" to reflect the uncertainty in our's in any detailed quantity. Especially as we know a priori that our Earth is an outlier in that set.
(without knowing exactly how/why)

One Dimensional models



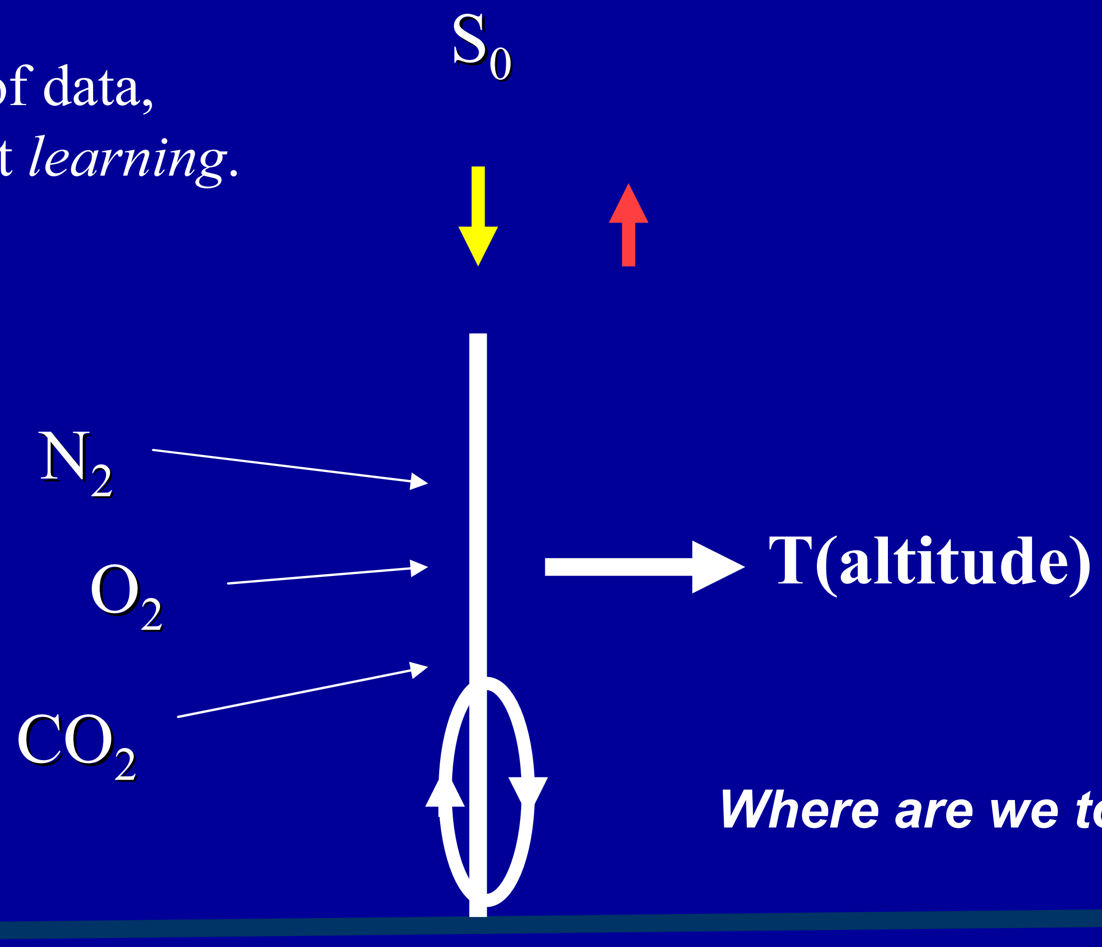
We put in gases and solar radiation, and get out a temperature profile… … which we see is not physically realistic!

? α ? X

? T_{eff} X

One Dimensional Radiative-Convective models

When we have lots of data,
this is *not* tuning, but *learning*.



Where are we today?

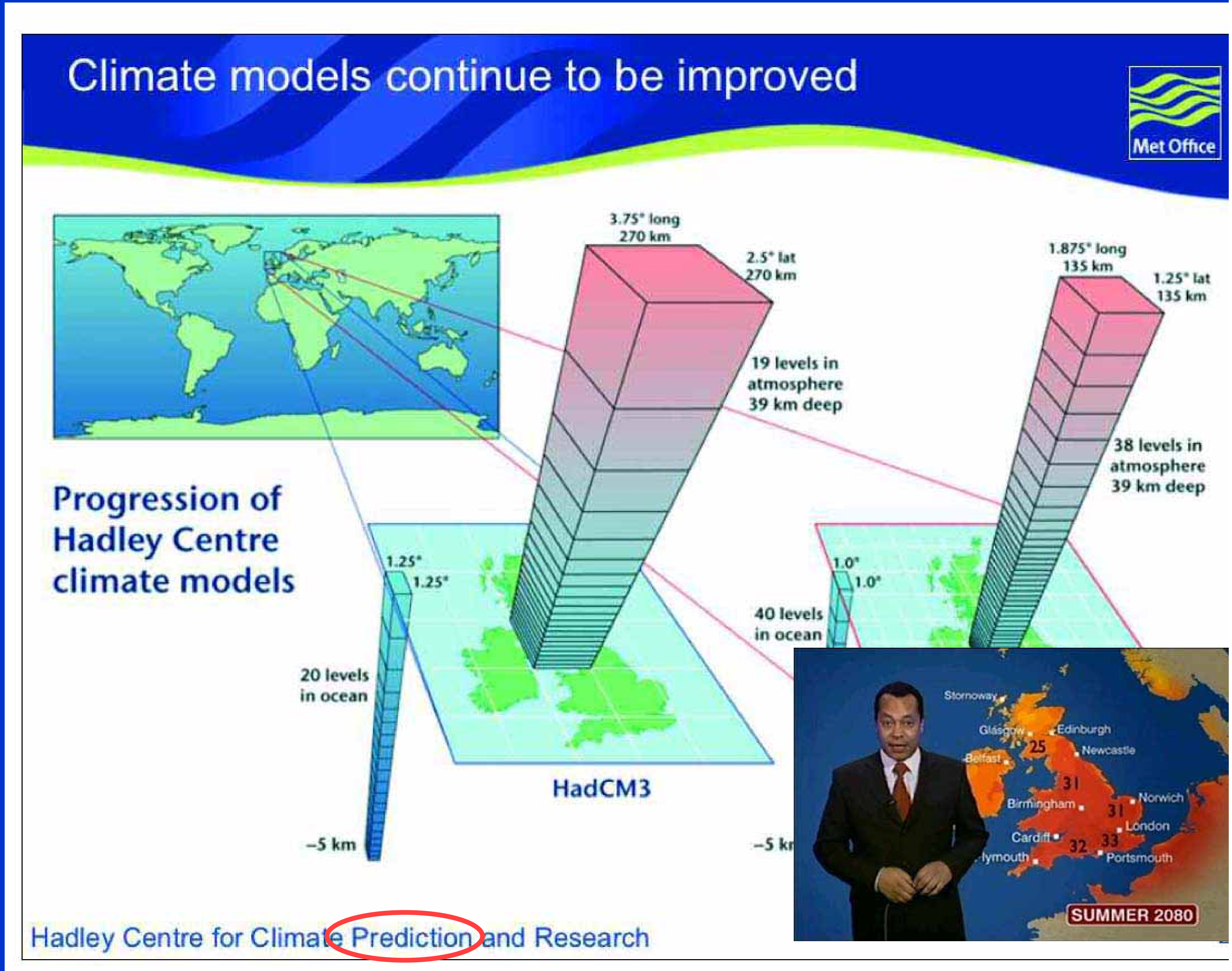
We put in gases and solar radiation,convection, and get out a temperature profile…

… which looks pretty good!

? ~~α~~ ?

? ~~T_{eff}~~

Models may get better and better, but always stay models!



Scientists need to be careful to communicate the limitations of current models.

Scientifically Relevant vs. Decision Support Relevant

Modellers sometimes understandably take offence when one complains that their model cannot do something that no model in the world can do:
In application, it would be useful to better distinguish a "best model in the world" from a "model that is fit for the purpose" at hand.

Science might usefully avoid "Plausible Deniability"

Model-land phrases like "improved", "better", "best", "includes", "state-of-the-art", "comparable", "simulates", "skill" ….

…should be immediately qualified at every use, unless they imply:

Robust, Relevant and in context Informative

Robust: Thought to be unlikely to change significantly (PDF).
Relevant: **All** meteorological drivers have been considered.
Informative: predictions on space-time-impact scales of the user.

UK CLIMATE PROJECTIONS

Annex 3: Strengths and weaknesses of climate models

Relevant Skill: Large Storms in the UK

(b) Anticyclones and blocking

The inconsistency of the three diagnostics makes it difficult to make a clear statement about the ability of the perturbed physics ensemble to simulate anticyclones, but in general the HadCM3 ensemble is competitive with other climate models.

Climate modellers, quite naturally, compare their model with other modellers models.

But being competitive is decision support irrelevant!

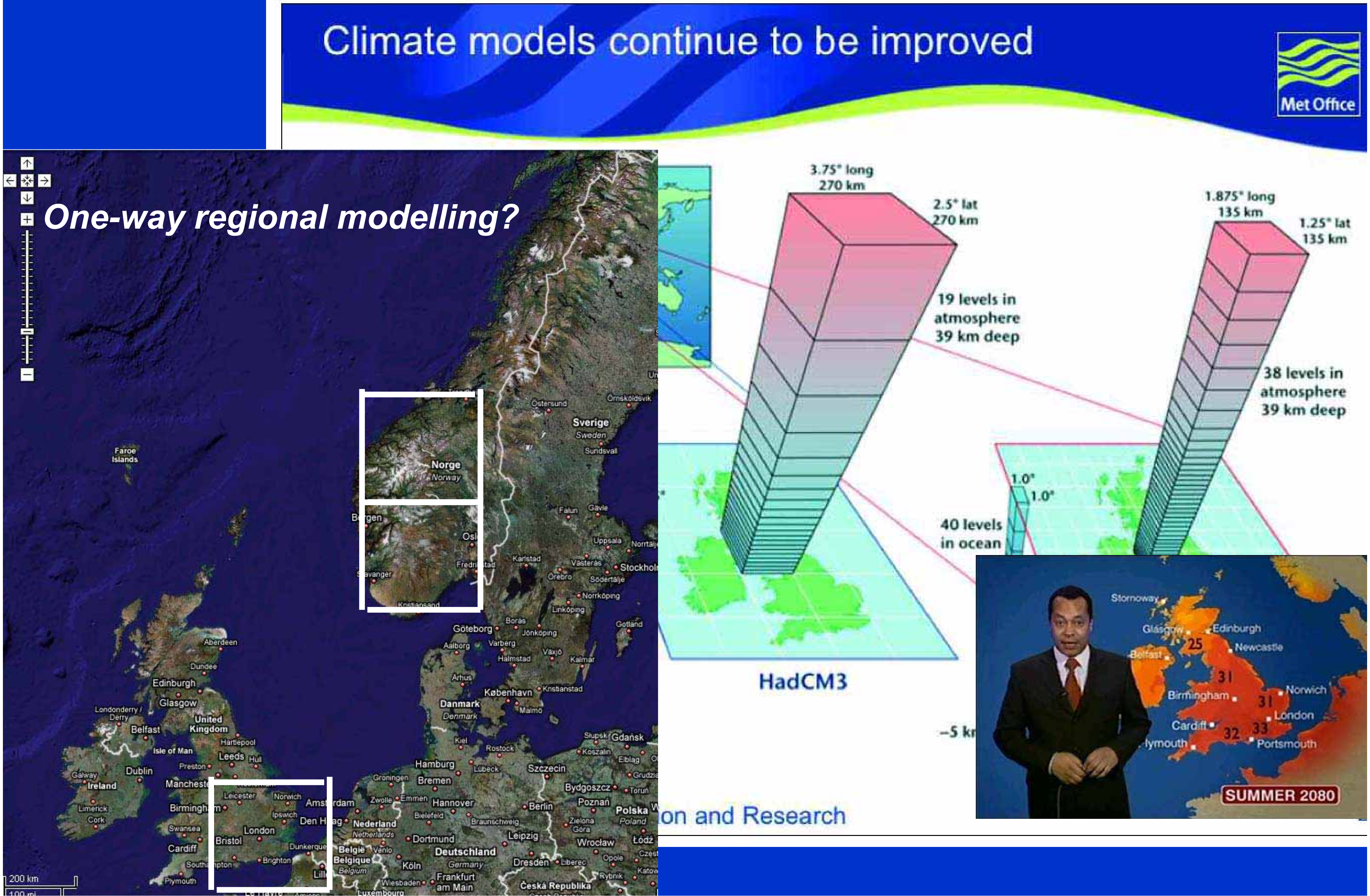
Is the model "fit for purpose" for a given decision/question?

Competitive, better, improving, even best are a distraction unless we expect Robust, Relevant, AND Informative.

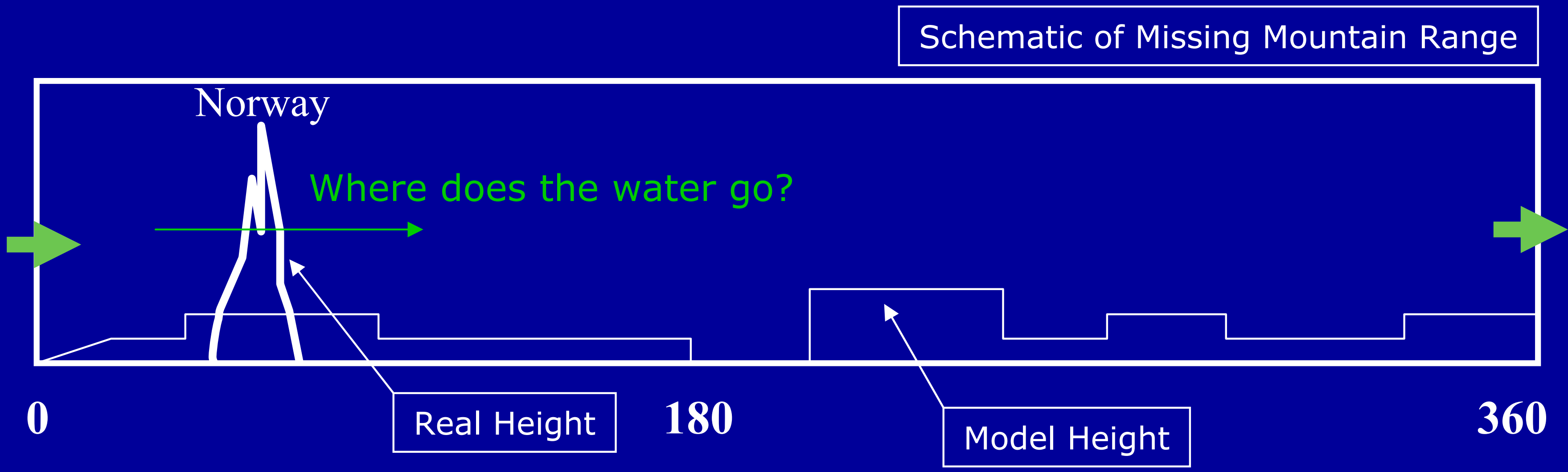
Centre for Climate Change Economics and Policy
The Munich Re Programme: *Evaluating the Economics of Climate Risks and Opportunities in the Insurance Sector*

http://ukclimateprojections.defra.gov.uk/images/stories/projections_pdfs/UKCP09_Projections_A3.pdf

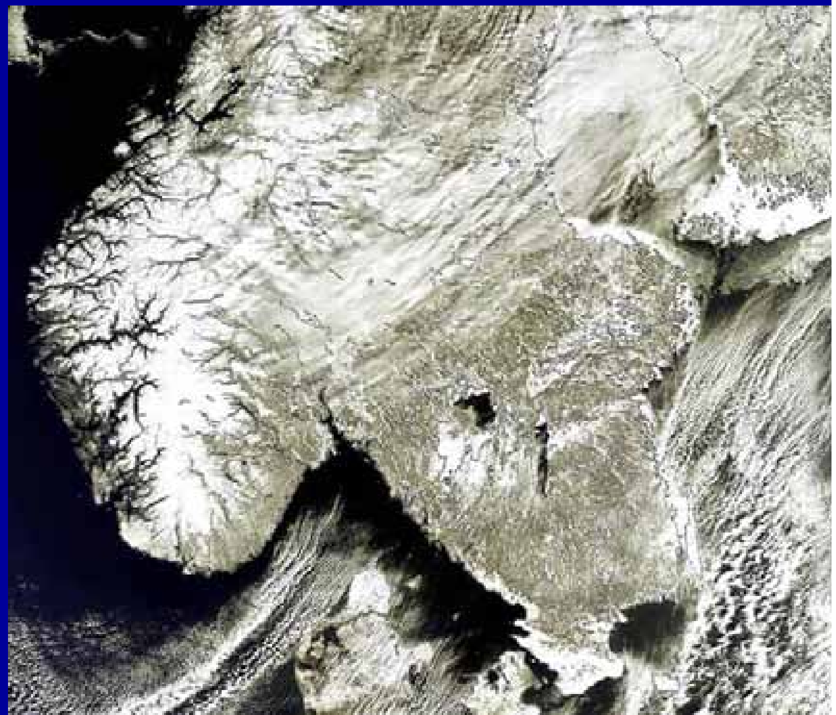
On what space and time scales *do* we have (robust) climate information?
(Much larger scales than the model's grid, at least!)

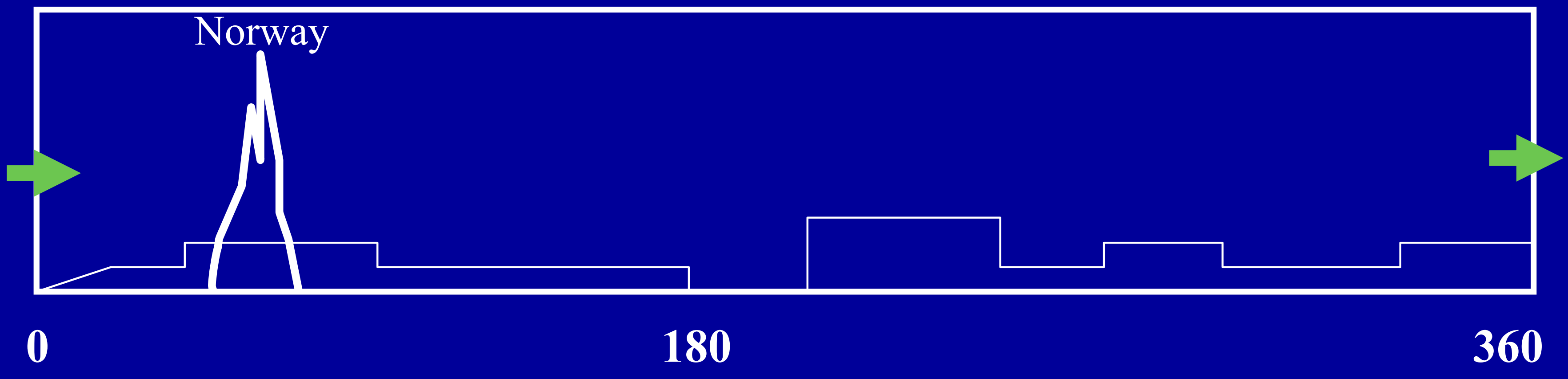


Science knows more than we can Model



If important, this leads to nonlocal effects.
(and the effective creation of water!)





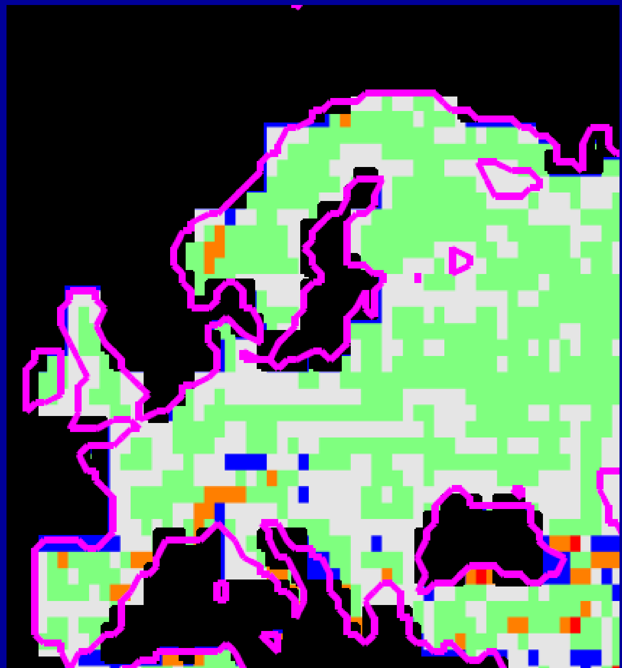
Before we start using phrases like "Laws of Physics" in public, can we:

A) check for internal consistency

B) Find necessary (not sufficient) conditions for this model to contain decision relevant information?

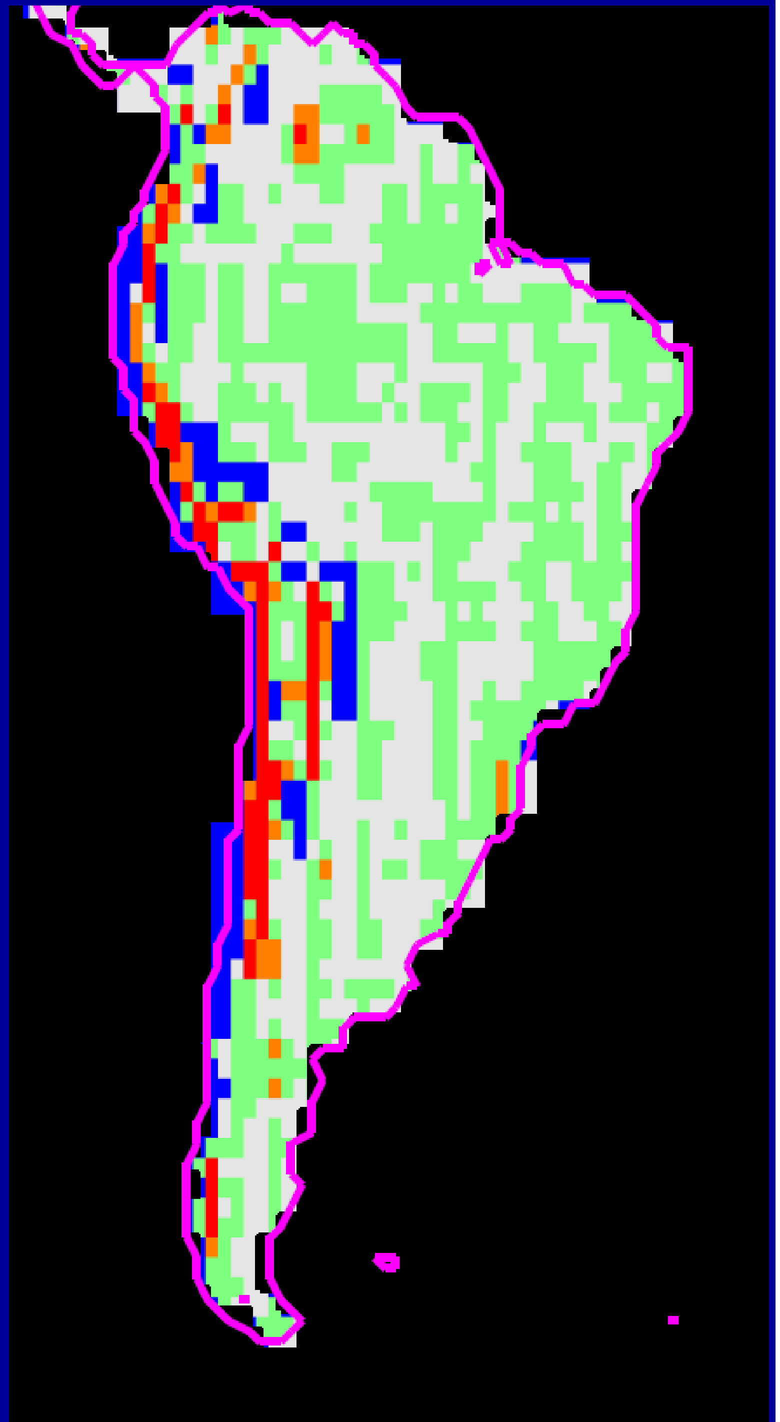
Not "how to downscale?" but "whether to downscale?" .

Missing Mountain Ridges



Blue < -500m
Grey > -500m
Green > 250m
Orange > 500m
Red > 1 km

Observed minus HADCM3 Height



Orange and red lines correspond to walls which water vapour must go over or around, walls which are missing in this climate model.

(Walls > 500m and > 1km!)

Resulting changes in the downstream dynamics cannot be "fixed" statistically.

Continent outlines: National Geophysical Data Center,NOAA 88-MGG-02.via matlab
Hadcm3 model topography http://www.ipcc-data.org/sres/hadcm3_topo.html
1x1 topography: http://www.ngdc.noaa.gov/mgg/topo/globe.html.

We know details of our planet are omitted from the models.
We know at some level details of the model output have no information, no connection, to our Earth.
We believe that models reflect properties of any planet "like" the Earth, "in some way".

For chaotic (perhaps generically for nonlinear) models, the better the model the worse the PDF! (I have a nice simple example of this…)

Should we have more faith in those model outputs which are robust across models, and deprecate attempts to combine over model structure?

Mathematically, we lack evidence that relevant PDEs are robust to infinitesimal perturbations (Clay Prize: Finite time blow up)

And how can we interpret graphs like:

The grey bands on the far right "the likely range."

SUBJECTIVE PROBABILITY

The coloured bands represent the widths of multi-model ensembles.

These distributions violate the law of large numbers!

DIVERISITY

The grey band represents traditional observational uncertainty.

NOISE

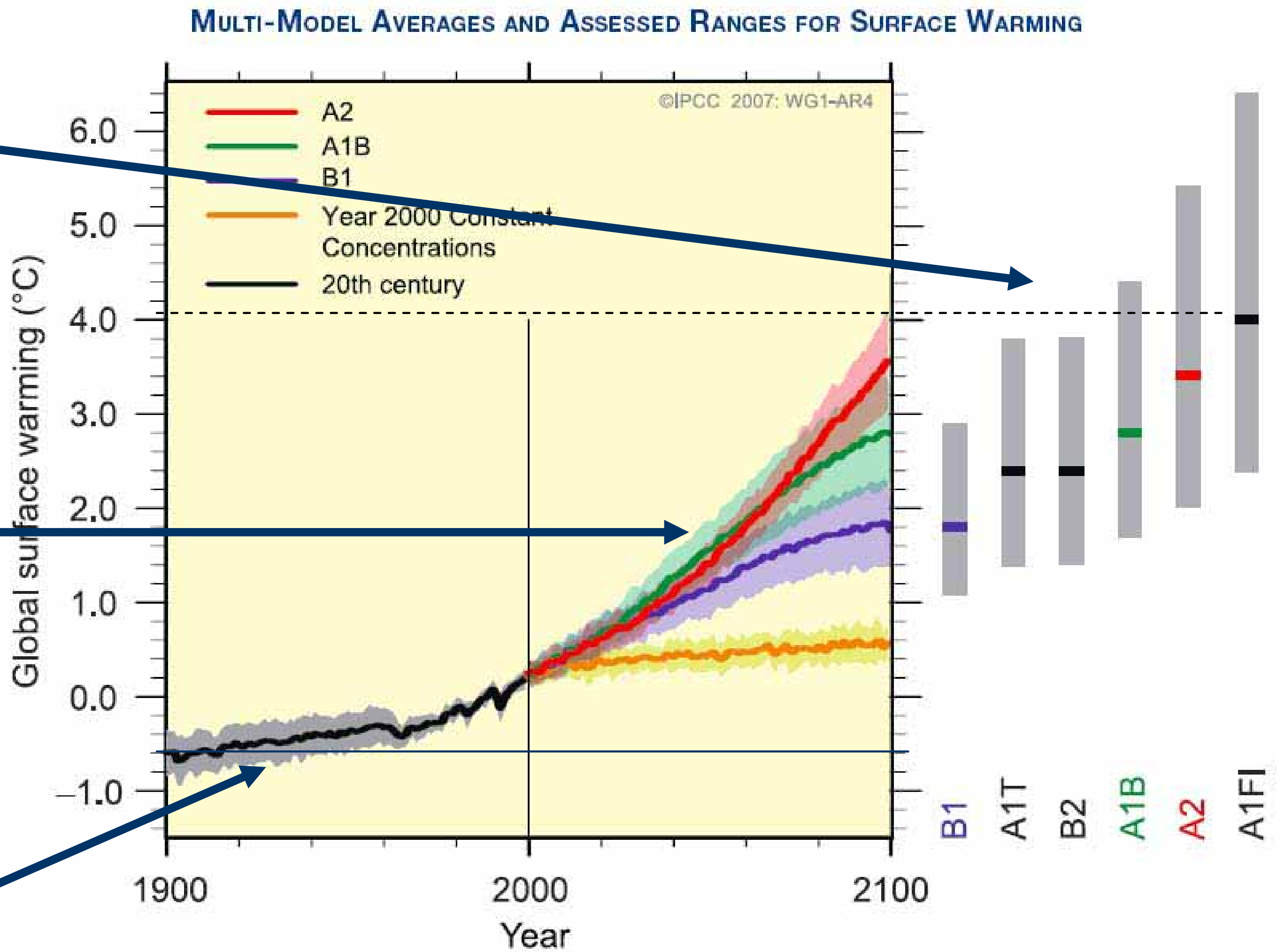


Figure SPM.5. *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the 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}*

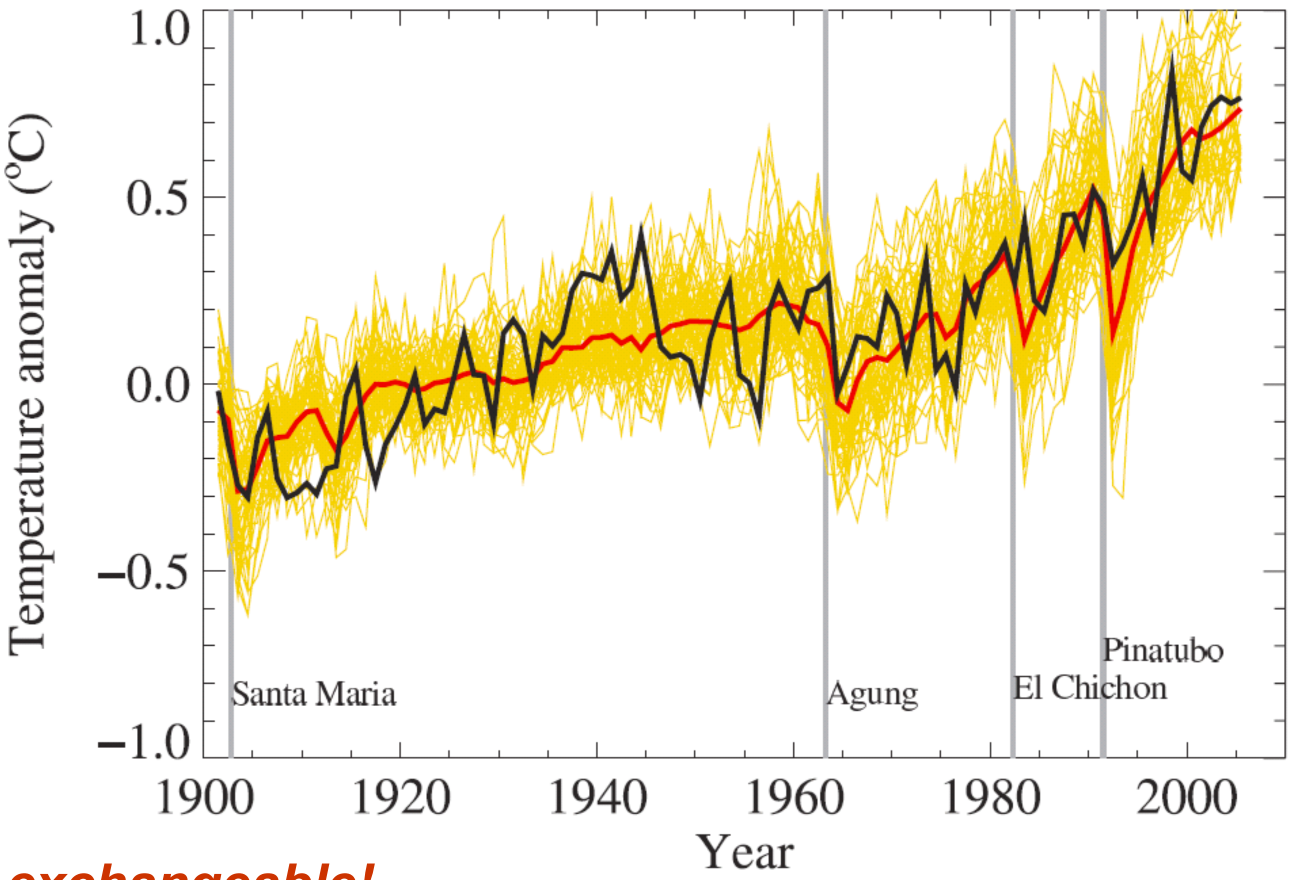
Colour central bar in grey bars and lettering to match A2, A1B, B1 curves as appropriate.
Drop model numbers and move to caption].

… uncertainty(s) play a key role in deciding how to react.

models to simulate important aspects of the current climate. Models are routinely and extensively assessed by comparing their simulations with observations of the atmosphere, ocean, cryosphere and land surface. Unprecedented levels of evaluation have taken place over the last decade in the form of organised multi-model 'intercomparisons'. Models show significant and

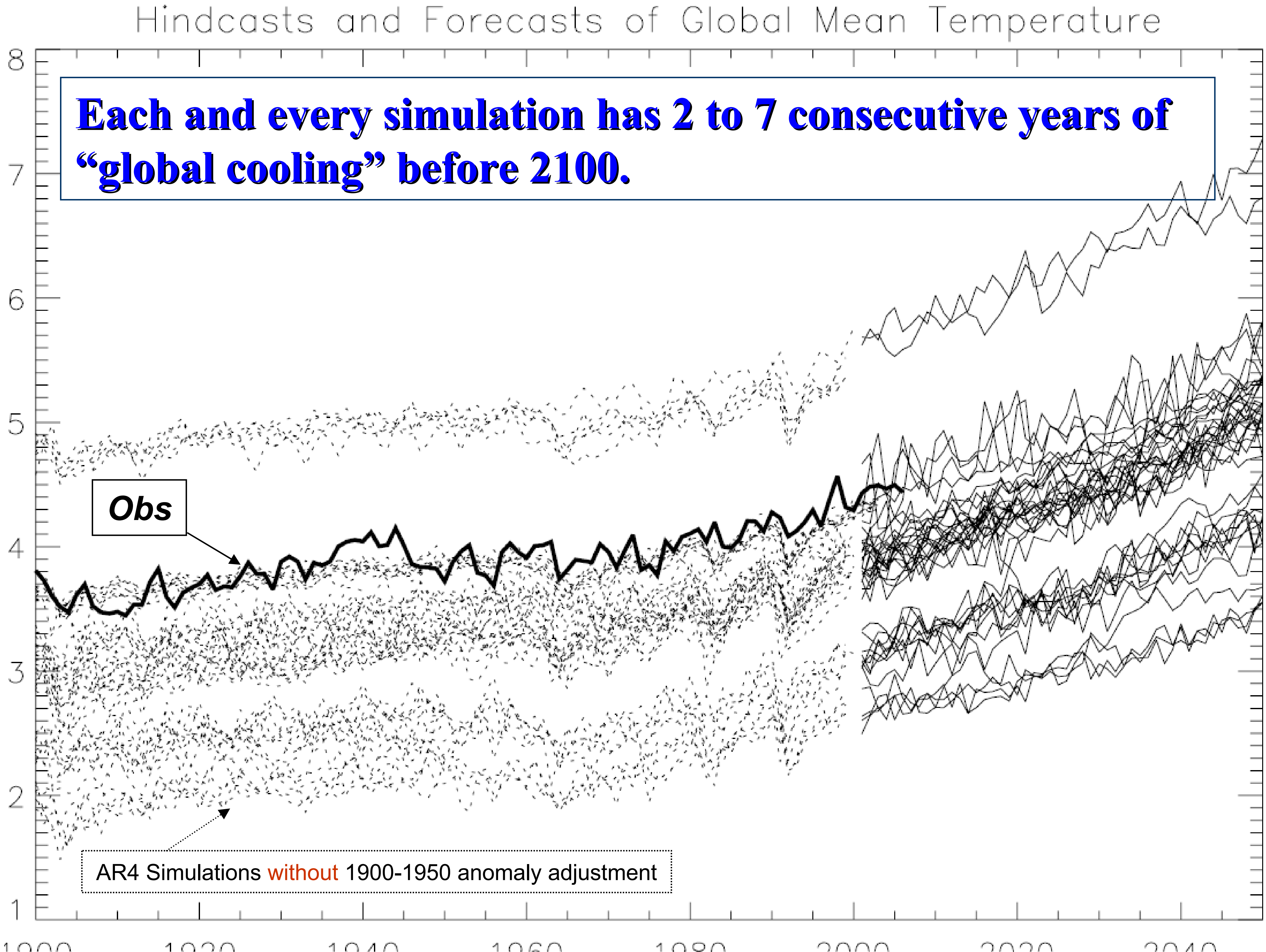
they represent the essential physical processes important for the simulation of future climate change. (Note that the limitations in climate models' ability to forecast weather beyond a few days do not limit their ability to predict long-term climate changes, as these are very different types of prediction – see FAQ 1.2.)

(continued)



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.)*

All yellow yet NOT exchangeable!


Hindcasts and Forecasts of Global Mean Temperature
Each and every simulation has 2 to 7 consecutive years of "global cooling" before 2100.
Obs
AR4 Simulations without 1900-1950 anomaly adjustment
8
7
6
5
4
3
2
1

Change in precip over a three month period (June, July, Aug)

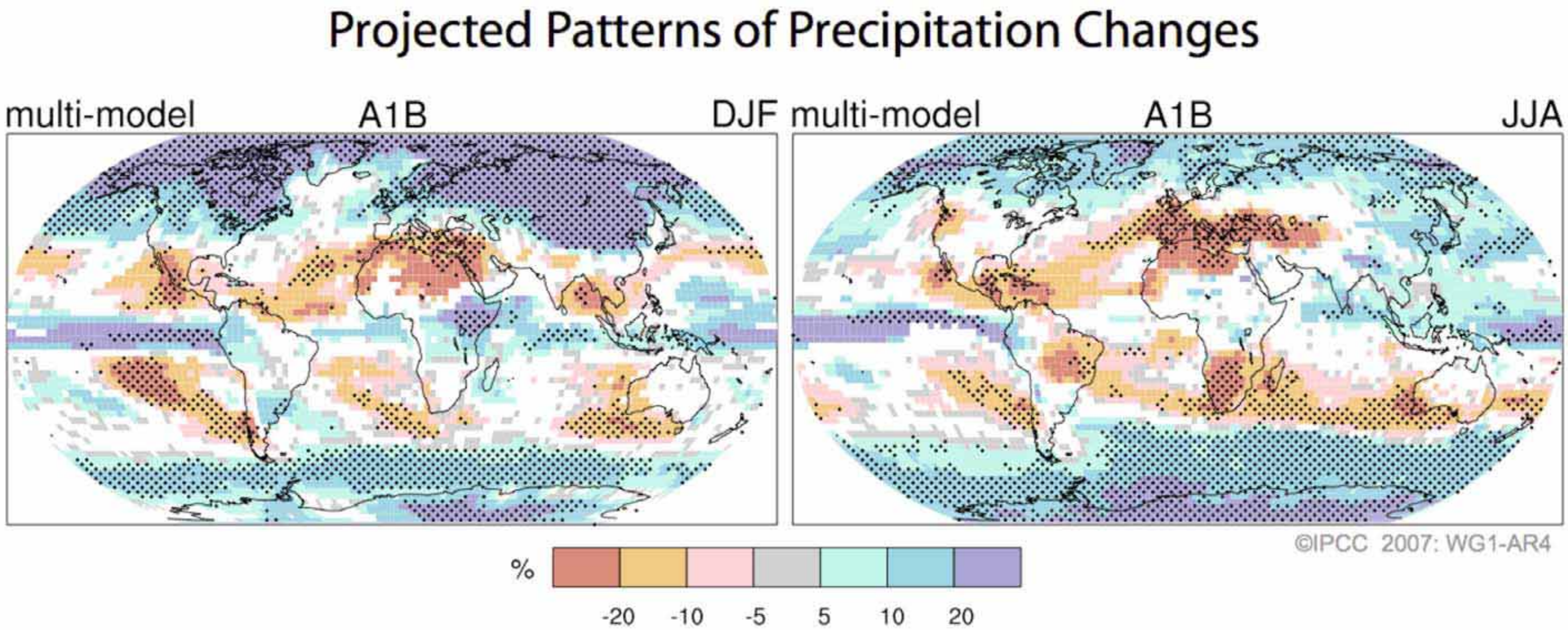
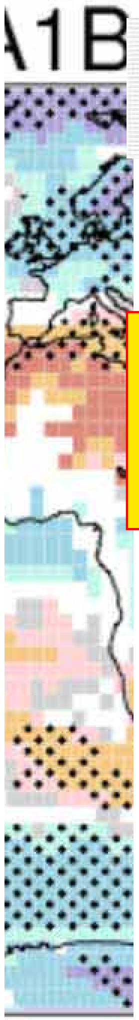
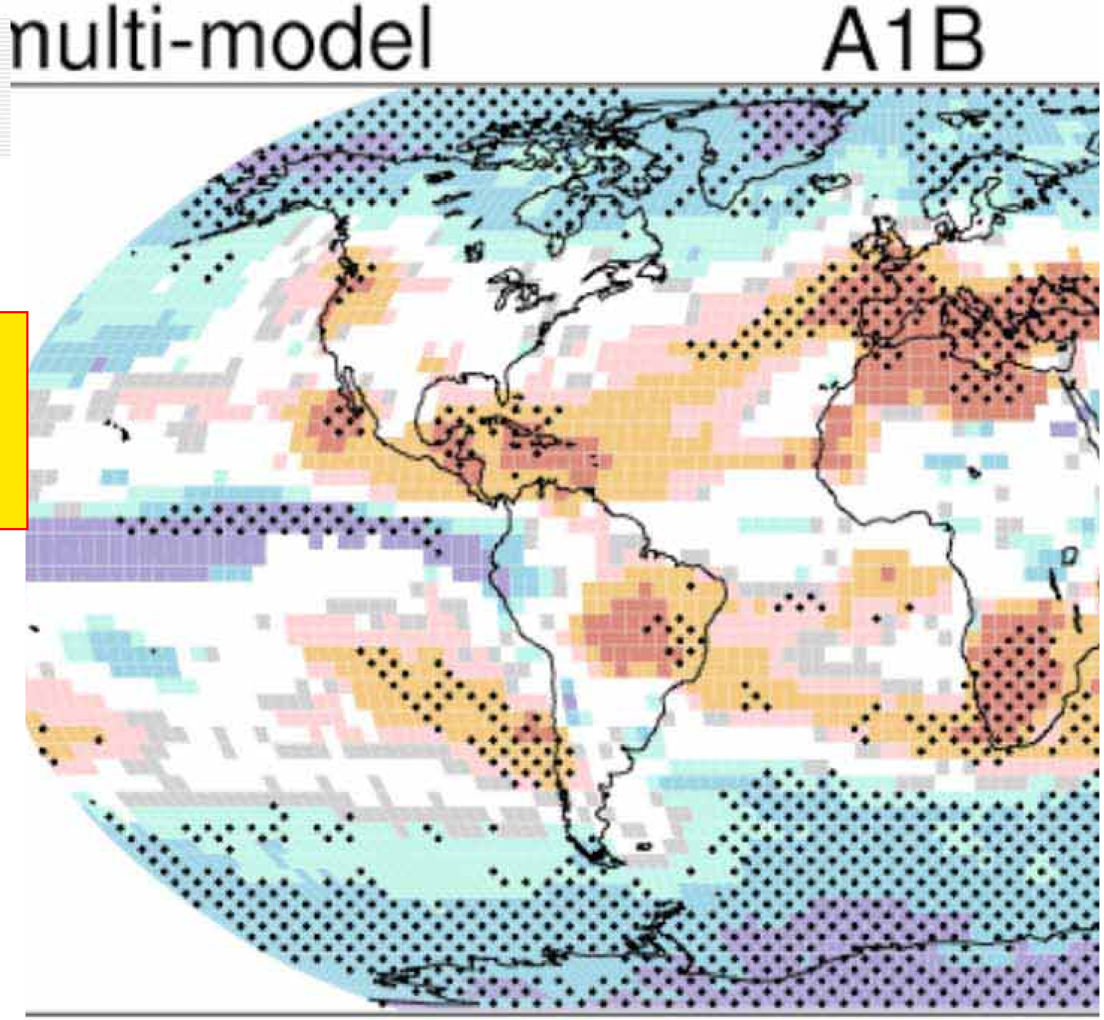


FIGURE SPM-6. Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {Figure 10.9}





UK Climate Impacts Programme

UKCIP08 will provide climate change scenarios for the UK :

• for 25 x 25 km grid squares, plus some aggregated results for administrative regions and river catchments

- The weather generator will allow future time daily (and sub-daily) time-series to be simulated, which will be of use to any user who is interested in daily weather variables, thresholds and sequences or extreme events.

events:
• relative to a baseline period of 1961–1990
• including extra information such as marine scenarios and changes to river flows

UKCIP02

FIGURE SPM-7. Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {Figure 10.9}

UK CLIMATE PROJECTIONS

What is UKCP09? | UKCP09 Guidance | Key findings | Published material | Customisable output | About UKCP09 | Downloads | Contact us | search this site...

Climate change projections

Box 1.4: Confidence in climate projections

There is a cascade of confidence in climate projections. There is very high confidence in the occurrence of global warming due to human emissions of greenhouse gases. There is moderate confidence in aspects of continental scale climate change projections. 25 km scale climate change information is indicative to the extent that it reflects the large-scale changes modified by local conditions. There is no climate change information in the 5 km data beyond that at 25 km. All that can be produced is a range of examples of local climates consistent with current larger-scale

the probabilities cannot represent uncertainties arising from deficiencies common to all models, such as a limited ability to represent European blocking. The fact that the UKCP09 projections are presented at a high resolution for the UK should not obscure this,

not obscure this, and users should understand that future improvements in global climate modelling may alter the projections, as common deficiencies are steadily resolved.

It is not clear to me how to use UKCP PDFs in a decision context for extreme events known not to be represented in those PDFs.

Read the Boxes!

http://ukclimateprojections.defra.gov.uk/content/view/1924/517/

What is a “Big Surprise”?

Suppose there is an SAMSI meeting in 2109 to discuss the IPCC AR21

We have 2100 hardware, and knowledge of the “emission scenario”

We can reproduce (shadow) climate change from 1900 till 2100 with good fidelity relevant to the insurance sector (using 2100 hardware)

We contrast our 2100 results with climate models available in 2009: What is the chance that events of high impact on the insurance sector happened? Things that we then understand, but which UKCP09 simply could not have foreseen using the model **structures** available on the hardware available in 2009?

In short:

What is the probability of a Big Surprise (in 2012? 2040? 2090?) for UKCP users?

How is one to use UKCP numbers for quantitative decision support when Prob(BS) is not small?

(First note: climate scientists in 2009 can often say Prob(BS) is **not** small).

Schematic For Decision Relevance

- Clearly specify the Decision Question in terms of local environmental phenomena that Impact it (“hot dry periods”)
- Determine the larger scale “meteorological” phenomena that impact the local. (“blocking”)
- Identify all relevant drivers (known). (“mountains”)

Pose necessary (NEVER SUFFICIENT) conditions for model output to quantitatively inform prior subjective science based reflection.

- Are local phenomena of today realistically simulated in the model?
  - (If not: Are relevant larger scale (to allow “prefect prog”)). If not: P(BS)>>0
- Are drivers represented? (to allow “laws-of-physics” “extrapolation”)
- Are these conditions likely to hold given the end-of-run model-climate?

If one cannot clear these hurdles, the scientific value of the results does not make them of value to decision makers. They can be a detriment.

And claiming they are the “Best Available Information” is both false and misleading.

Are these just old unfair criticisms?

444 *Admiral Fitz-Roy* [March 28,

WEEKLY EVENING MEETING,

Friday, March 28, 1862.

JOHN PETER GASSIOT, Esq. F.R.S. Vice-President, in the Chair.

REAR-ADMIRAL FITZ-ROY, F.R.S.

An Explanation of the Meteorological Telegraphy, and its Basis, now under trial at the Board of Trade.

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.

No! (In fact I fall on Fitzroy's side of the "Storm warning" debate, as did Lloyd's).
The case against detailed 2007 "climate-proofing" differs in that:

(a) one can learn how to use storm warning, day after day.
(b) storm warning did in fact reflect the weather "thought probable."
(c) Fitzroy argued captains to be left entirely to their own judgement.

Advantages of unleashing the "Big Surprise"?

- Big Surprises arise when something our models cannot mimic turns out to have important implications for us.
- Climate science can (sometimes) warn us of where those who use naïve (if complicated) model-based probabilities will suffer from a Big Surprise.

  (Science can warn of "known unknowns" even when the magnitude is not known)
- Big Surprises invalidate (not update) the foundations of model-based probability forecasts. (Arguably "Bayes" does not apply, nor the probability calculus.)

(Failing to highlight model inadequacy can lead to likely credibility loss)

Including information on the Prob(BS) **in every case study** allows use of probabilities conditioned on the model (class) being fit for purpose without believing it is.

(or appearing to suggest others should act as if they do!)

"When you have eliminated all which is impossible, then whatever remains, however improbable, must be the truth."
Sherlock Holmes*, *The Blanched Soldier

"Whenever you have eliminated the impossible, whatever remains, however improbable, must be true." Spock

(or there was something we failed to think of eliminating: what is P(missed something)?

samsi

NSF ● Duke ● NCSU ● UNC ● NISS

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Fax: 919.685.9360
info@samsi.info

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2009-10 Program on Space-time Analysis for Environmental Mapping, Epidemiology and Climate Change

Opening Tutorials & Workshop

September 13-16, 2009

The Opening Workshop for the SAMSI program on Space-time Analysis for Environmental Mapping, Epidemiology and Climate Change will be held on Sunday-Wednesday, September 13-16, 2009, at the Radisson RTP in Research Triangle Park, NC.

The workshop program will focus on problems encountered in dealing with random space - time fields, both those that arise in nature and those that are used as statistical representations of other processes. Specific focus will be on the sub-themes of environmental mapping, spatial epidemiology, and climate change, which are interrelated both in terms of key issues in underlying science and in the statistical and mathematical methodologies needed to address the science.

samsi

NSF ● Duke ● NCSU ● UNC ● NISS

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info@samsi.info

2009-10 Program on Space-time Analysis for Environmental Mapping, Epidemiology and Climate Change

Opening Tutorials & Workshop

September 13-16, 2009

Session on Climate Change
Chair: **Michael Stein**, University of Chicago

Claudia Tebaldi, Climate Central/NCAR
Climate Model Ensembles

Lenny Smith, London School of Econom
The Science of Impacts and the Impacts
Forecasts and Adaptation in the United K

Co
Dis
Am
Mo
Ric

1:15-3:30

Session on Rand
Chair: **Dongchu**

Chris Wikle, Uni
Don't Forget the
Spatio-Temporal

Håvard Rue, No
Spatial Modeling

Discussion Sessi
Noel Cressie, O
Leo Held, University of Zurich
Alexandra Schmidt, Universidade Federa

4:00-5:40

New Researcher Session
Chair: **Jim Zidek**, University of British Columbia

Ethan Anderes, University of California, Davis
Estim

Dan
Mode
Simul

Cryst
Laten

Chris
The I
Spati

Hiuy
Baye

Wednesday, September 16, 2009
Radisson RTP

8:15-9:00 a.m.	Registration and Continental Breakfast
9:00-12:00	Session on Interface of Deterministic Modeling and Space-time Statistics Chair: **Montse Fuentes**, North Carolina State University **Mark Berliner**, Ohio State University *Combining Models and Observations: Bayesian Approaches* **Doug Nychka**, NCAR *Interpreting Geophysical Numerical Models using Spatial Statistics* Coffee Break Discussion Session **Susie Bayarri**, University of Valencia **Dave Higdon**, Los Alamos National Laboratory

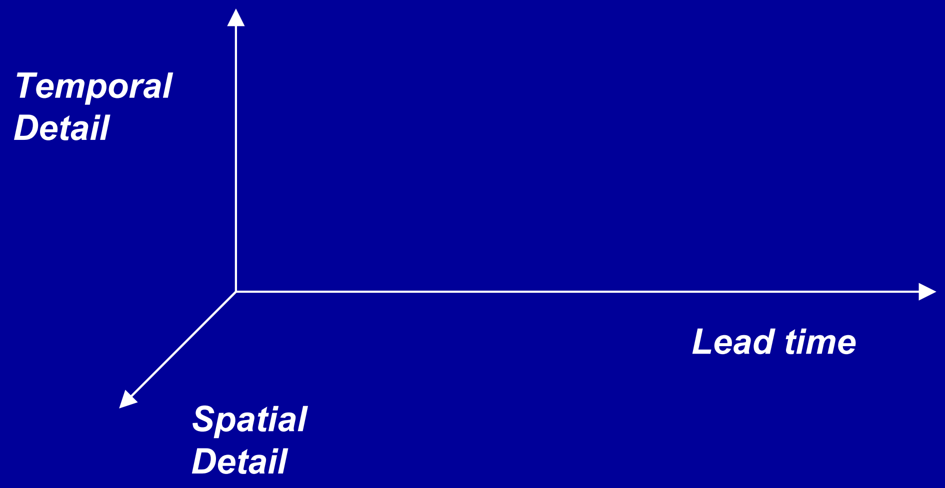
Is this a good idea?

Why?

How might we prevent studies done for laudable "Whys" (understanding, advancing statistical methodology, model improvement …) from being mis-employed as if they were decision support relevant?
Must we explicitly deprecate?

Centre for Climate Change Economics and Policy
The Munich Re Programme: *Evaluating the Economics of Climate Risks and Opportunities in the Insurance Sector*

Questions



What do contours of P(BS) look like?
Where does 100 km, weekly, rainfall in 2030 fall?

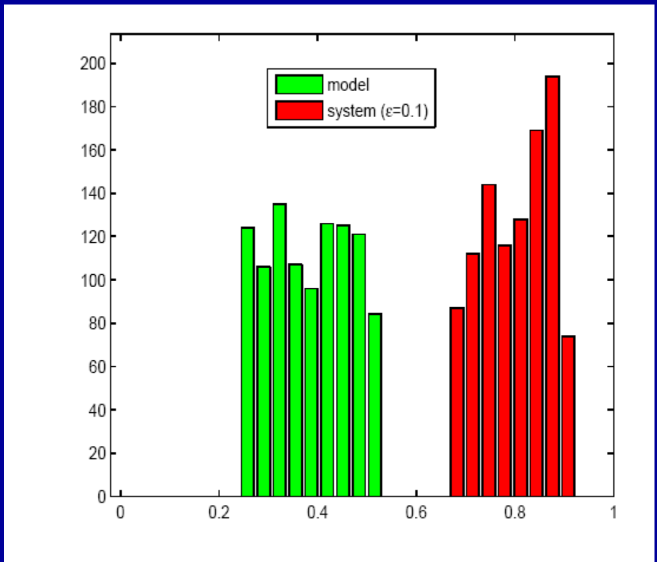


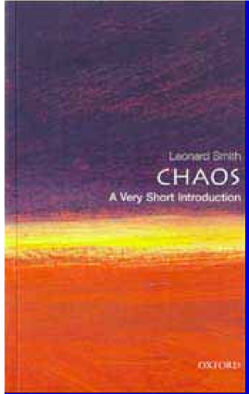
Figure 5: 8-step forecast using system and model, 1024 initial condition ensemble is constructed by random draw around 0.759 using $U(0, 2^{-10})$

Model Logistic Map: $l(x) = 4x(1-x)$
Quartic Map: $q(x) = \frac{16}{5}x(1-2x^2+x^3)$
System: $F(x) = (1-\epsilon)l(x) + \epsilon q(x)$ with $\epsilon = 0.1$

*Please accept for a moment that **Model Inadequacy** makes probability forecasting irrelevant in just the same way that **Chaos** made RMS error irrelevant. **If so:***

How might we guide progress?

How might we inform society?



Background

LA Smith(2002) *What might we learn from climate forecasts?* P. Nat. Acad. Sci (99)
LA Smith (2003) *Predictability Past Predictability Present. Predictability and Weather Forecasting* (ed. Tim Palmer, CUP).
LA Smith (2000) *Disentangling Uncertainty and Error*, in Nonlinear Dynamics and Statistics (ed A.Mees) Birkhauser.
Stainforth et al (2005) *Uncertainties in Prediction of Climate response*. Nature.
Stainforth et al (2007) *Uncertainty & Decision Support*. Phil Trans Roy. Soc. A,1098

LA Smith (2007) *A Very Short Introduction to Chaos*. OUP

Nancy Cartwright (1983) *How the Laws of Physics Lie*. OUP

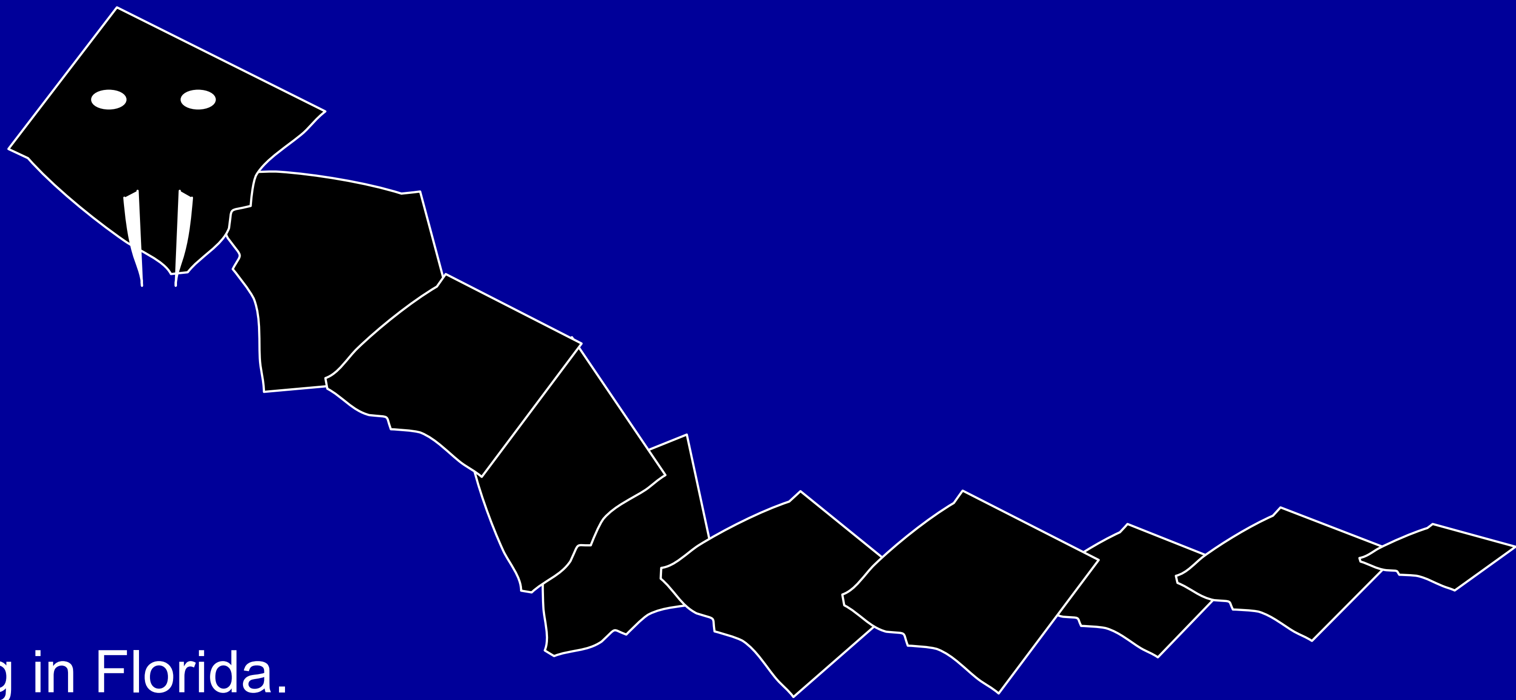
www.cccep.ac.uk

L.Smith@lse.ac.uk

When in doubt, distrusting the indications, or inferences from them (duly considered on purely scientific principles, and checked by experience), the words " *Uncertain*," or " *Doubtful*," may be used, without hesitation.

Fitzroy, 1862

Centre for Climate Change Economics and Policy
The Munich Re Programme: *Evaluating the Economics of Climate Risks and Opportunities in the Insurance Sector*



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.

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 interested of an epoch."

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

You don't have to believe everything you compute!

Or in terms of "trust":

we might "trust" our models in the way a parent trusts a child, but never in the way a child trusts a parent!

This holds all models, and does not damn climate models!

I am flying to the UK tomorrow.
If an engineer says my plane will fall out the say over the Atlantic tomorrow, I do not ask her "where exactly".
And I certainly do not plan to fly unless she can tell me!
I plan not to fly.

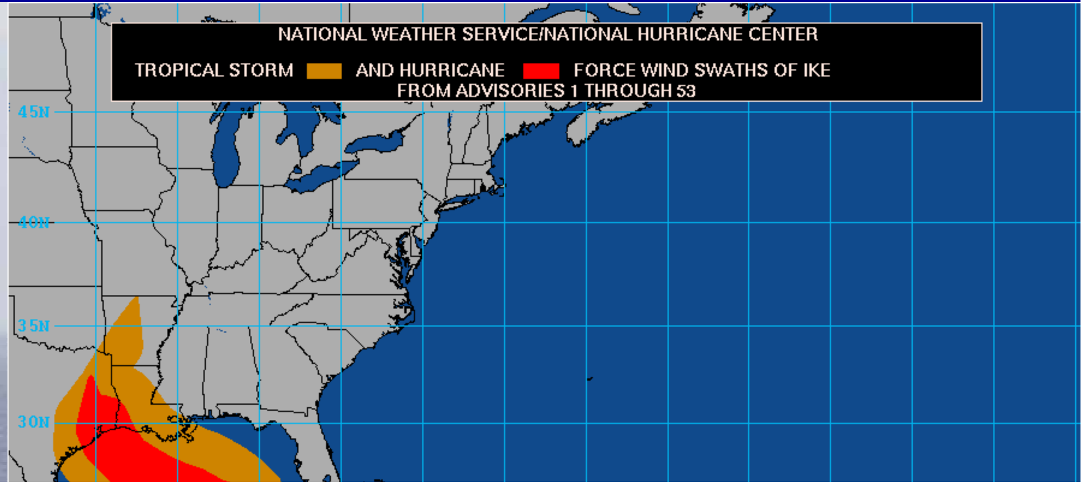
And if I must fly?
If she tell me that at a cost of twice my ticket, she can cut the probability from 10% to 1%,
or from 1% to 0.1%
or from 0.000000001% to 0.0000000001% ?

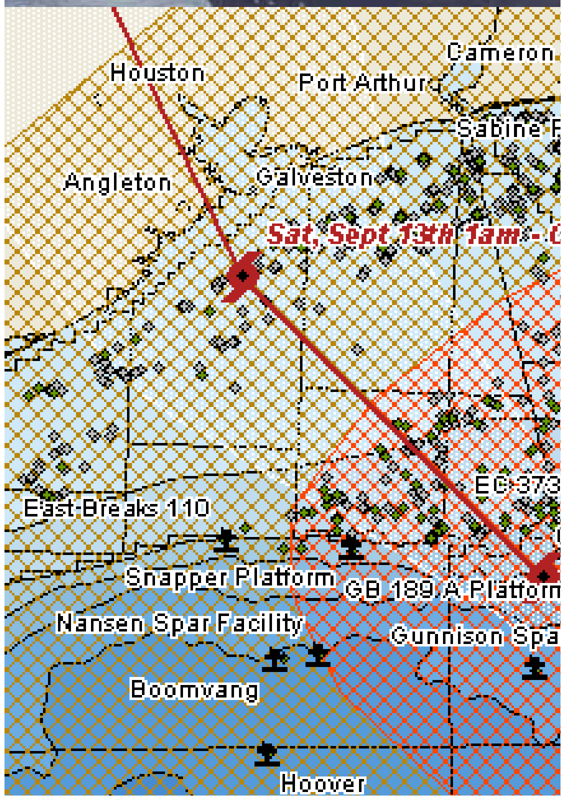
Do I care if she is not sure whether it is from 50 to 5, or if it is from 10 to 1?

No, as long as the chance is not vanishingly small already!
And there are huge costs (to me) associated with waiting:

The Cost (to me) of doing something once my plane has taken off is much higher than doing something now.

Multi-billion dollar extremes (Ike)





Wednesday, September 17, 2008

Offshore Rig Damage Caused by Hurricane Ike (Updated)

As companies evaluate their offshore assets and begin to report on their findings, it is quickly becoming apparent that Ike has dealt a harsh blow the Gulf of Mexico rig fleet. Thus far, 3 jackups and 1 platform rig have apparently been lost. In addition, another jackup has lost if drilling package and derrick, and two others suffered damages while in the shipyard. Four moored semisubmersibles sustained damage to their mooring systems and submersible rig was pushed off of its prestorm location.

Rig Name	Manager	Rig Type	Built	Cost	Damage Assessment
ENSCO 74	ENSCO	375' ILC jackup	1999	$84 million	Rig missing - probable total loss
Pride Wyoming	Pride	250' MS jackup	1976	$26 million	Rig missing - probable total loss
Rowan Anchorage	Rowan	250' ILS jackup	1972	$9 million	Rig missing - probable total loss
Ocean Tower	Diamond	350' ILC jackup	1972	$10 million	Lost drilling package, including derrick
Mad Dog	Pride / BP	Platform Rig	2004	n/a	Derrick collapsed & sunk
Transocean Marianas	Transocean	7,000' Semisub	1998	$224 million	Mooring system damaged, rig moved
Noble Amos Runner	Noble	8,000' Semisub	1999	$152 million	Broke moorings & set adrift
Noble Paul Romano	Noble	6,000' Semisub	1998	$118 million	Broke moorings & set adrift
Noble Lorris Bouzigard	Noble	4,000' Semisub	1975	$31 million	Mooring system damaged, maintained station
Hercules 78	Hercules	85' Submersible	1983	$34 million	Moved 600' during storm
Rowan Mississippi	Rowan	400' ILC jackup	2008	$165 million	Struck by vessel in shipyard, not expected to delay delivery
Blake 208	Blake Offshore	250' MC jackup	1977	n/a	damaged in shipyard, may delay avail.

For an overview of the locations of rigs affected by Hurricane Ike, take a look at our **Offshore Damage Map**.

Frequently Asked Question 8.1

How Reliable Are the Models Used to Make Projections of Future Climate Change?

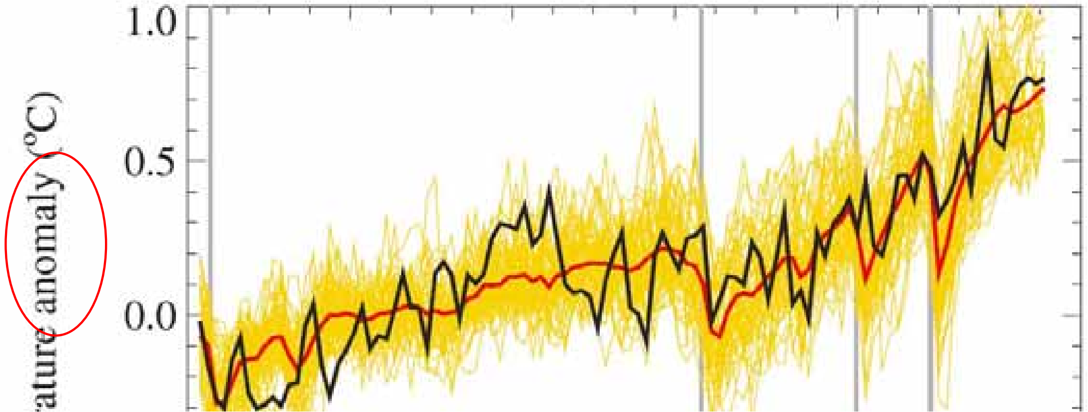
There is considerable confidence that climate models provide credible quantitative estimates of future climate change, particularly at continental scales and above. This confidence comes from the foundation of the models in accepted physical principles and from their ability to reproduce observed features of current climate and past climate changes. Confidence in model estimates is higher for some climate variables (e.g., temperature) than for others (e.g., precipitation). Over several decades of development, models have consistently provided a robust and unambiguous picture of significant climate warming in response to increasing greenhouse gases.

Climate models are mathematical representations of the climate system, expressed as computer codes and run on powerful computers. One source of confidence in models comes from the fact that model fundamentals are based on established physical laws, such as conservation of mass, energy and momentum, along with a wealth of observations.

A second source of confidence comes from the ability of models to simulate important aspects of the current climate. Models are routinely and extensively assessed by comparing their simulations with observations of the atmosphere, ocean, cryosphere and land surface. Unprecedented levels of evaluation have taken place over the last decade in the form of organised multi-model 'intercomparisons'. Models show significant and increasing skill in representing many important mean climate features, such as the large-scale distributions of atmospheric temperature, precipitation, radiation and wind, and of oceanic temperatures, currents and sea ice cover. Models can also simulate essential aspects of many of the patterns of climate variability observed across a range of time scales. Examples include the advance and retreat of the major monsoon systems, the seasonal shifts of temperatures, storm tracks and rain belts, and the hemispheric-scale seesawing of extratropical surface pressures (the Northern and Southern 'annular modes'). Some climate models, or closely related variants, have also been tested by using them to predict weather and make seasonal forecasts. These models demonstrate skill in such forecasts, showing they can represent important features of the general circulation across shorter time scales, as well as aspects of seasonal and interannual variability. Models' ability to represent these and other important climate features increases our confidence that they represent the essential physical processes important for the simulation of future climate change. (Note that the limitations in climate models' ability to forecast weather beyond a few days do not limit their ability to predict long-term climate changes, as these are very different types of prediction – see FAQ 1.2.)

(continued)

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.)*



Quantitative Projections Demand Quantitative Guidance

For *each* question asked, the users should expect and get:

- clear statements of known shortcomings and likely implications in terms of impacts
    Quantify: “very high confidence”, “moderate confidence”, “indicative”
- reputation binding statements on what is believed to be robust
- quantitative subjective estimate of a relevant “big surprise” probability *from climate scientists for every projection!*

Even the best methodology available can accompany “the answer” with a statement of confidence in its expected relevance to the question asked. Prob(BS)

And also get a rough idea of how fast model output is likely to improve

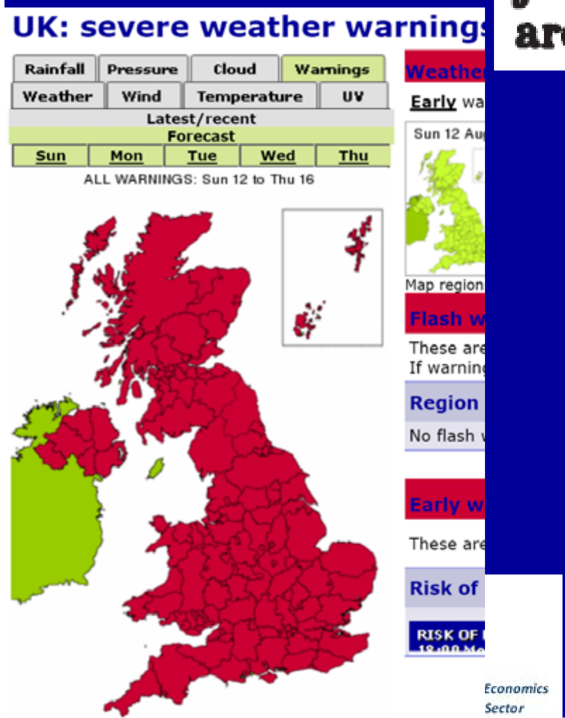
What misuses of UKCP09 are officially deprecated?

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



I believe these actions would be inappropriate even if UKCP distributions were decision relevant PDFs.

But is it appropriate to use UKCP PDFs as such?

Some UKCIP worked examples suggest yes…

Can we use UKCP PDFs in these three insurance sector relevant cases?

Extreme wind frequencies (?robust realistic storm track?)

Extreme rain (informative: flooding)

Extended dry periods (informative: subsidence)

Prob(BS) < 10%: Yes or no?

UK CLIMATE PROJECTIONS

What is UKCP09? | UKCP09 Guidance | Key findings | Published material | Customisable output | About UKCP09 | Downloads | Contact us | search this site...

UKCP09 in practice: Inappropriate uses of UKCP09 probabilistic projections

- UKCP09 Guidance
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  - Inappropriate uses of the UKCP09 Weather Generator
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Inappropriate uses of UKCP09 probabilistic projections

Below is a list with further details of identified inappropriate uses of UKCP09. This is by no means comprehensive, but reflects those that we have identified to date. They arise from using one of the products or data sources in a manner inconsistent with its intended use.

Limitations on the use of each product and data source are identified in the respective science report and within the sections of this User Guidance. It is recommended that users refer to and understand these limitations prior to deciding what to use and how.

Remember:
When using the UKCP09 probabilistic projections the following are inappropriate:

- **Assessing current and near-term vulnerability, impacts, risks and adaptation**
- **Using only the median or central estimate from the probabilistic distribution**
- **Interpreting the UKCP09 maps as weather maps**
- **Comparing a seasonal/monthly mean from a single year with seasonal/monthly mean values from the UKCP09 30-year mean projections**
- **Averaging probabilistic projections for different grid squares to produce a single probabilistic projection for this user-defined aggregated area**
- **Averaging CDF data for different temporal averaging periods (e.g. months, seasons, and 30-years periods)**
- **Exploring transient future climate or changes throughout the 21st century**
- **Overlaying GIS shapefiles for more than one variable**

Click here for a printable page or if you don't have javascript:

Show all

?

http://ukclimateprojections.defra.gov.uk/content/view/1793/510/

Funded by: defra | Department of Energy & Climate Change | Department of the Environment | The Scottish Government | Llywodraeth Cynulliad Cymru Welsh Assembly Government

Provided by: Met Office Hadley Centre | UK Climate Impacts Programme

1.4 Projections at a daily resolution over land

Changes in daily climate, such as the frequency of hot or very wet days, are likely to be more significant for many climate impacts than changes in monthly or seasonal averages. Whilst we are not able to project changes in storm tracks and anticyclones with confidence, we can project how the characteristics of daily time series could be affected by changes in the more basic aspects of future climate, such as monthly mean temperature and precipitation and other aspects of their distributions, which we have more confidence in projecting.

Our approach, therefore, is to provide a tool known as a weather generator, capable of providing plausible realisations of how future daily time series of several variables could look, consistent with changes in the characteristics of monthly-average climate sampled from the probability distributions. It does not provide a weather forecast for a particular day in the future; it gives statistically credible representations of what may occur given a particular future climate. Despite their limitations (for example, they assume that relationships between different variables remain unchanged in a future climate), we recognised the inevitability of (possibly different varieties of) weather generators being employed by many users, and the advantages for consistency between impacts studies that a single weather generator would bring. The UKCP09 weather generator was developed by the Universities of Newcastle and East Anglia, based on a previous version in use by the Environment Agency.

The UKCP09 Weather Generator provides synthetic daily time series of temperature (mean, maximum and minimum), precipitation, relative humidity, vapour pressure, potential evapotranspiration (PET) and sunshine (from which we also estimate diffuse and direct downward solar radiation) at a resolution of 5 km, for each of the three emission scenarios and each of the future 30-year time periods — 2020s, 2030s etc. It provides data over land but not for marine regions. The weather generator does not add any additional climate change information over that which is present in the 25 km probabilistic projections. However it does add local topographical information (e.g. hills, valleys) at the 5 km scale, as it is based on observed data which is representative of this scale. The Weather Generator is also able to construct synthetic hourly time series for precipitation, temperature, vapour pressure, relative humidity and sunshine for future time periods. This is a disaggregation of daily data and, again, does not provide any new climate change information at this level. The UK Climate Projections science report: Projections of future daily climate for the UK from the weather generator describes the weather generator in detail, with examples of its output, and also considers its limitations.

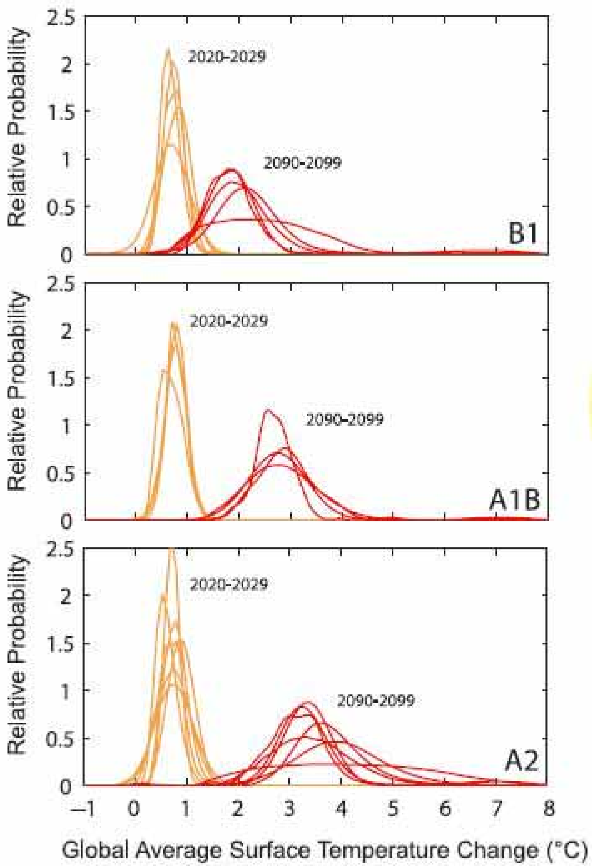
What does it mean to say you can provide "plausible realizations" or "statistically credible" hourly information on weather, after you have stated that the basic causes of many extremes of obvious interest (storms, blocking: flooding and heatwaves) are not included?

What is intended physically by the phrase "more basic aspects of future climate"? The rainfall in a month is the sum of the rain each day, the monthly average is not "more basic" in any sense.

Why might one think it better ("the advantages for consistency") for all users to see the same systematic errors?

This is not thought to be a good idea in the banking sector, for instance. (Or by the IPCC for global modelling!)

PROJECTIONS OF SURFACE TEMPERATURES



10

This risk of overconfidence is well known and well founded.

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.

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

UKCP distribution may provide insight into things that have not been "ruled out", but how exactly are we to use these distributions to assess risk, or support decisions in the Insurance sector, if the Prob(Big Surprise) is high?

Typical Errors suggest "Big Surprises" relevant to Insurance Sector Decisions

UK CLIMATE PROJECTIONS

Annex 3: Strengths and weaknesses of climate models

A3.4.2 Storm tracks and blocking

HadCM3 does simulate the main hemispheric pattern of storm tracks and some aspects of Atlantic-European blocking.

. The perturbations to HadCM3 do result in some spread in the position and intensity of the cyclone track between model versions, with ensemble members between 0 and 6 degrees too far south and

some having strengths as much as 20% too low. However, this spread is smaller than that seen in the CMIP3 multi-model ensemble, where the equivalent range is from 2 degrees too far north to14 degrees too far south, and range in intensity from 35% too low to 33% too high (Figure A3.6).

Centre for Climate Change Economics and Policy
The Munich Re Programme: *Evaluating the Economics of Climate Risks and Opportunities in the Insurance Sector*

Mat Collins, Simon Brown, Tim Hinton, and Tom Howard, Met Office Hadley Centre

Climate Science

Computer Modelling

Experimental Statistics

Extreme Economics

Decision Making

Un der stand ing

Uncertainty

Now that we know the policy question:
How many CO_2 levels were tested explicitly?

The red shading indicates a 60 per cent chance of exceeding the temperat[…] amber shading a 40 per cent chance; yellow shading a 10 per cent chance; […] shading a less than a 10 per cent chance.

Stabilisation Level (CO_2e)	Maximum	Hadley Centre Ensemble	IPCC TAR 2001 Ensemble	Min[…]
Probability of exceeding 2°C (relative to pre-industrial levels)				
400	57%	33%	13%	8[…]
450	78%	78%	38%	2[…]
500	96%	96%	61%	4[…]
550	99%	99%	77%	6[…]
650	100%	100%	92%	8[…]
750	100%	100%	97%	9[…]
Probability of exceeding 3°C (relative to pre-industrial levels)				
400	34%	3%	1%	1[…]
450	50%	18%	6%	4[…]
500	61%	44%	18%	1[…]
550	69%	69%	32%	2[…]
650	94[illegible]	94%	57%	4[…]
750	9[illegible]	99%	74%	6[…]
Probability of exceeding 4°C (relative to pre-industrial levels)				
400	17%	1%	0%	0[…]
450	34%	3%	1%	0[…]
500	45%	11%	4%	2[…]
550	53%	24%	9%	6[…]
650	66%	58%	25%	1[…]
750	82%	82%	41%	2[…]
Probability of exceeding 5°C (relative to pre-industrial levels)				
400	3%	0%	0%	0[…]
450	21%	1%	0%	0[…]
500	32%	3%	1%	0[…]
550	41%	7%	2%	1[…]
650	53%	24%	9%	5[…]
750	62%	47%	19%	1[…]

What Does a 2°C Target Mean for Greenhouse Gas Concentrations? 273

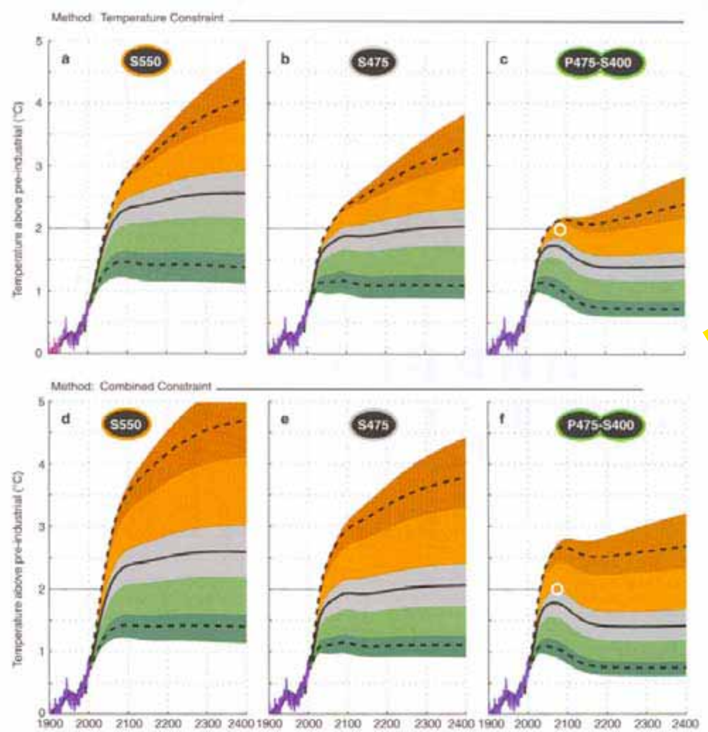

Figure 28.7 The probabilistic temperature implications for pathways that stabilize at (a,d) 550 ppm, (b,e) 475 ppm, and (c,f) 400 ppm CO_2 equivalent concentrations, based on the climate sensitivity PDF that is derived from the conventional IPCC uncertainty range 1.5°C to 4.°C (Wigley and Raper, 2001). The upper (lower) panels depict results when applying the maximum likelihood estimates for ocean mixing and sulphate aerosol forcing as derived by Method A (B). Shown are the median (solid lines), and 90% confidence interval boundaries (dashed lines), as well as the 1%, 10%, 33%, 66%, 90%, and 99% percentiles (borders of shaded areas). The historic temperature record and its uncertainty are shown from 1900 to 2003.

Economics and Policy

The Munich Re Programme: *Evaluating the Economics of Climate Risks and Opportunities in the Insurance Sector*

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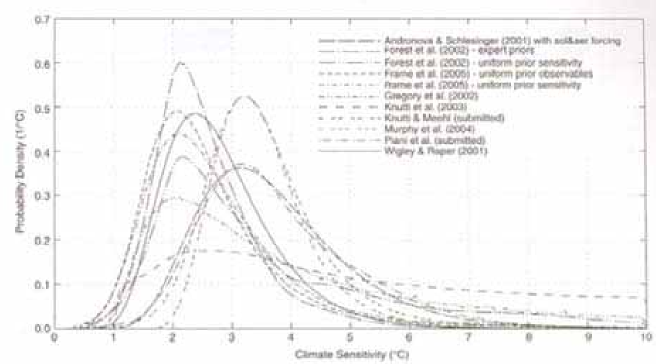

Figure 28.1 Probability density functions of climate sensitivity used in this analysis.

CHAPTER 28

What Does a 2°C Target Mean for Greenhouse Gas Concentrations? A Brief Analysis Based on Multi-Gas Emission Pathways and Several Climate Sensitivity Uncertainty Estimates

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Swiss Federal Institute of Technology (ETH Zurich), Environmental Physics, Department of Environmental Sciences, Zurich, Switzerland

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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

In general, such biases could arise from either missing processes or common limitations such as insufficient resolution or the widespread adoption of a deficient parametrization scheme. They introduce an important general caveat on the confidence that can be placed in ensemble predictions (Smith 2002).

. We believe it is preferable to include a lower bound for the effects of structural modelling errors than to ignore them altogether, since this will reduce the risk of providing policy makers with over-confident climate predictions.

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, precipitation and pressure at mean sea level (e.g. Lambert & Boer 2001),