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Does VVUQ have a role in support of Climate Policy? Of Climate Science?

Leonard A Smith

LSE CATS/Grantham &

Pembroke College, Oxford

Verification, Validation and Uncertainty Quantification Across Disciplines
August 6, 2011 to August 13, 2011
The Canyons, 4000 Canyons Resort Drive, Park City, Utah

Not possible without:

H Du, K Judd, A Lopez, F Niehoerster, D. Stainforth & E Suckling

Grantham Research Institute on Climate Change and the Environment

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

© Leonard Smith

"Accurate interpretation is the real deficiency"

Claim: **(implication)**

The difficulty is not initial conditions (no "chaos" fix)

The difficulty is not parameter values (nc

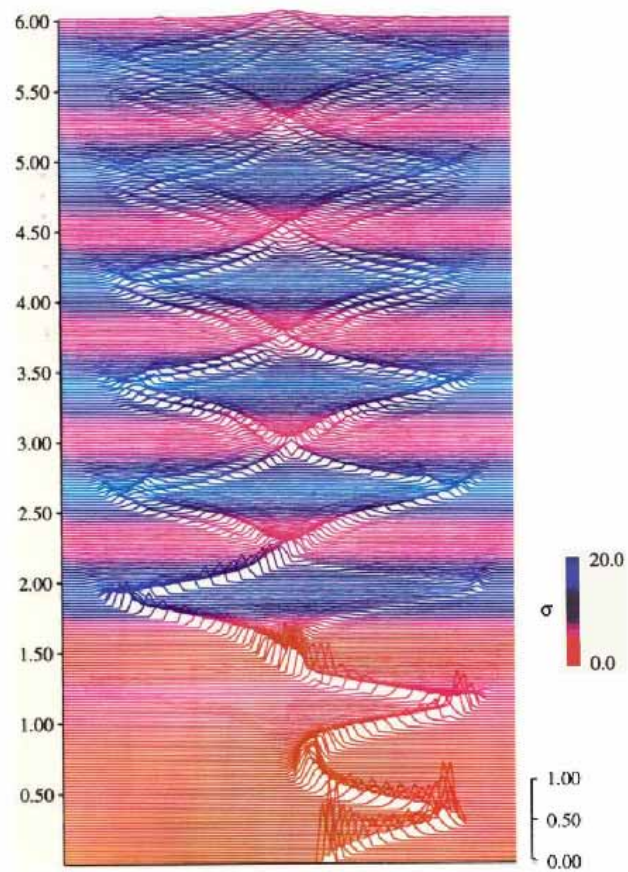
(empirically vacuous)

The difficulty is not determinism (n

The difficulty is not within today's model

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

In what year did climate prediction move beyond unde ;?



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

"Accurate interpretation is the real deficiency"

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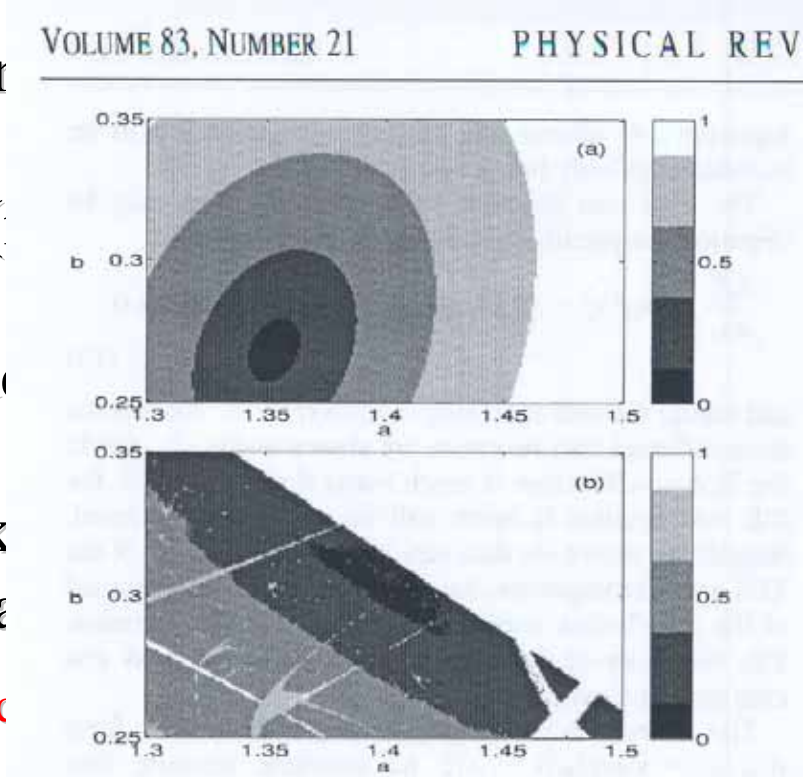

FIG. 4. Value of cost function in parameter space for a 2D delay reconstruction of the Hénon map for $a_0 = 1.4$, $b_0 = 0.3$, $N = 500$, and a noise level of 0.05: (a) C_{LS} and (b) C_{ML}.

"Accurate interpretation is the real deficiency"

Claim: **(implication)**

The difficulty is not initial conditions (no "chaos" fix)

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

(empirically vacuous)

The difficulty is not determinism (no "stochastic" fix)

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

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

In what year did climate prediction move beyond understanding to quantitative forecasting?

© Leonard Smith

Questions (mine)

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

(if so, what then is UQ?)

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

Is weighting models a nonsense?

Is a prior on a model parameter a nonsense?

In weather-like problems, is it rational to treat predictive distributions as probability density functions?

When might the Bayesian Way be the best available (in an *ad hoc* sorta way).

Can model-based probabilities provide sustainable odds?

Is the Bayesian Way treacherous?

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

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

- (•) Future Climate Change Only
- ( ) Future Absolute Climate Values

Variable

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

Smith

"Climate" has been changing…

Summary for Policymakers

The grey bands on the far right "the likely range." (semi-subjective)

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

These distributions do not respect the law of large numbers!

The grey band represents traditional observational uncertainty.

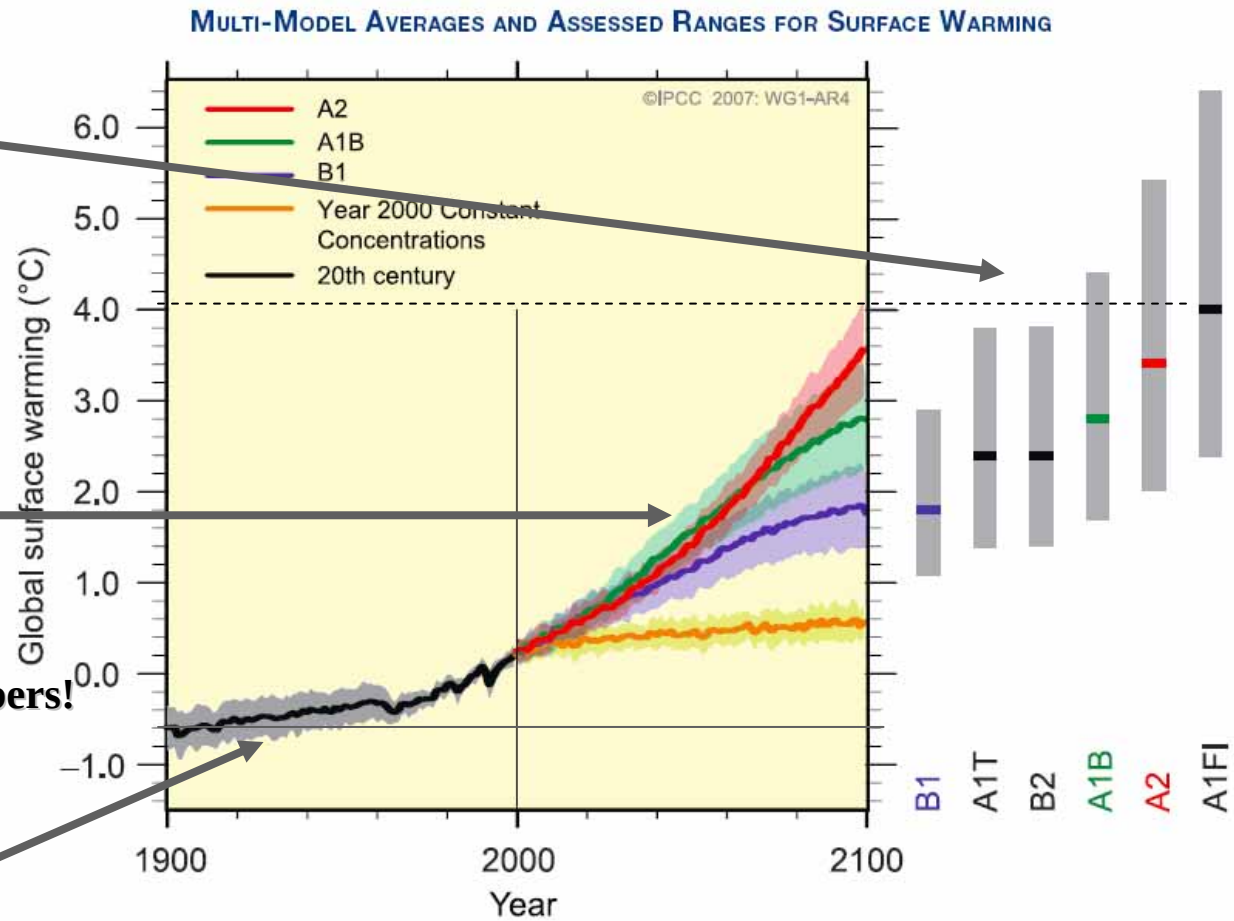

Figure SPM.5. *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the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

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

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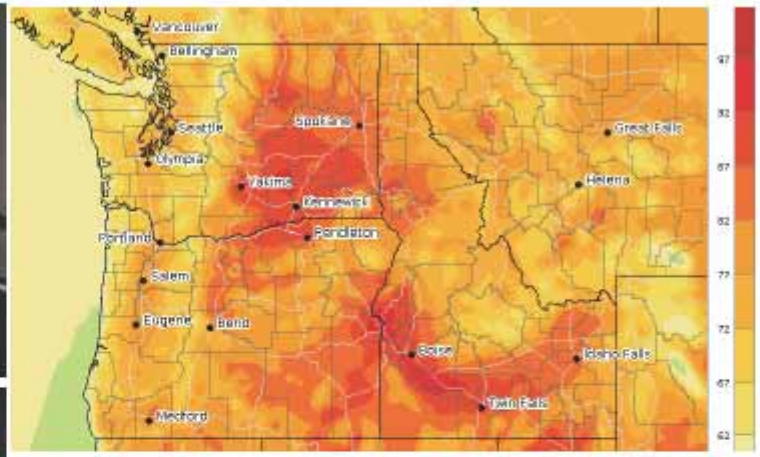
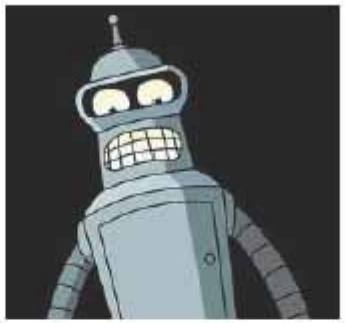
Model-based prediction & quantifying uncertainties

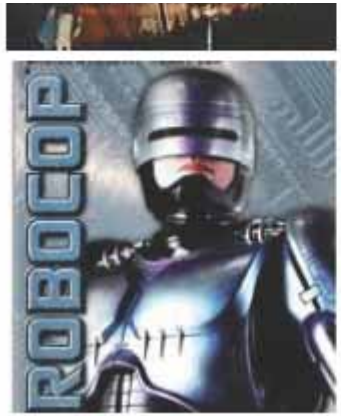


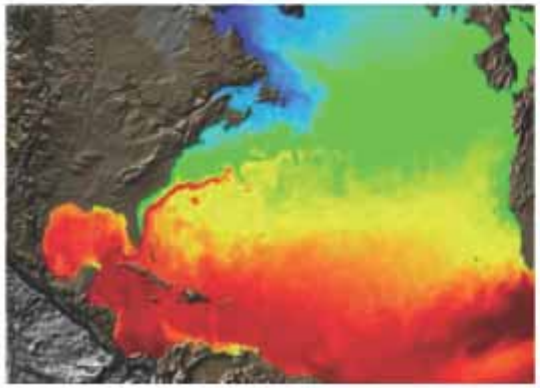


Combination of physical data & computational model

http://www.youtube.com/watch?v=hpFifHgZyrg

Estimate input settings & let it go





North Atlantic temperatures

Weather-like Challenges vs Climate-like Challenges

In "**weather-like**" challenges one has access to a large forecast-verification archive and decisions are being made frequently enough (every few seconds, daily, weekly …) so that out of sample evaluation is possible, and the pain of past mistakes remains fresh.

The temperature at LHR tomorrow noon
Natural Gas required to heat the UK next week
Generator failure on a National Grid (UK, Japan, W. Australia)
Day-trading automated systems

"**Climate-like**" challenges typically require one-off decisions either in unique circumstances or transient dynamics. There is no relevant large forecast-verification archive. Decisions are being made infrequently enough (years, decades, once) that the pain of past mistakes has faded, and the blame for any error today will probably fall on someone else (the next government, the guy that replaces you…)

Climate Change Mitigation (emissions pathway with 50/50 chance)
Climate Change Adaptation (damns, cables, buildings, power station cooling)
Nuclear Waste Disposal
The next flu pandemic

© Leonard Smith

Model-based prediction & quantifying uncertainties

http://www.youtube.com/watch?v=hpFifHgZyrg

Estimate input settings & let it go

In climate-like problems we are stuck with robots.

If we test them to destruction can we understand how the break?

Can we send them back over and over again, (so that we still love the early ones)

Thanks to Dave Higdon, LANL

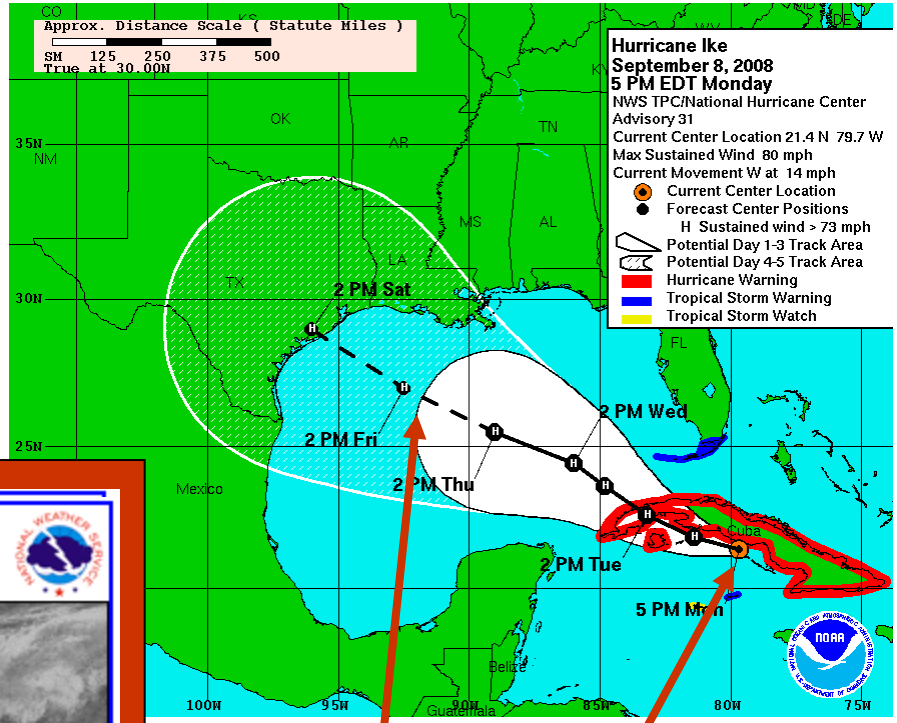
http://www.google.co.uk/imgres?imgurl=http://www.jpl.nasa.gov/images/spacecraft/ranger/ranger3-craft-browse.jpg&imgrefurl=http://www.jpl.nasa.gov/missions/index.cfm%3Fmission%3DRanger&usg=__b99CBKOa-QvjoCq6nzDnveO3=VO=&h=534&w=528&sz=31&hl=en&start=3&zoom=1&tbnid=TpmPEwJH23XLM:&tbnh=132&tbnw=131&ei=mRBTimeJcfu5gK3mKDTCQ&prev=/images%3Fq%3Dranger%28spacecraft%26N%3Den%26sa%3DX%26rlz%3D1T5GGLL_enUS253GB254%26tbm%3Disch&itbs=1

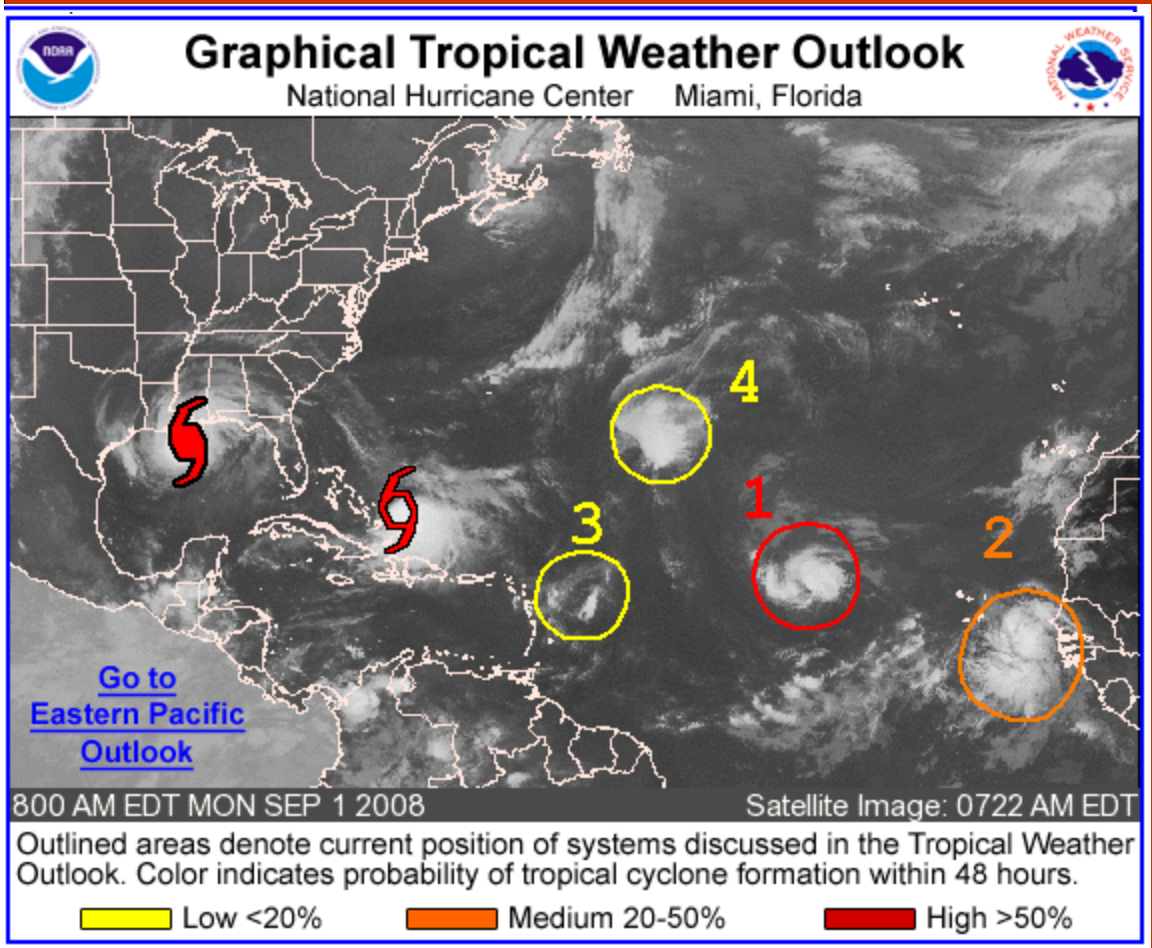
Distinguishing Weather & Climate

Weather-like Predictions

and

Climate-like Predictions?





Extreme weather

Weather forecast

Climate extreme

Climate forecast:

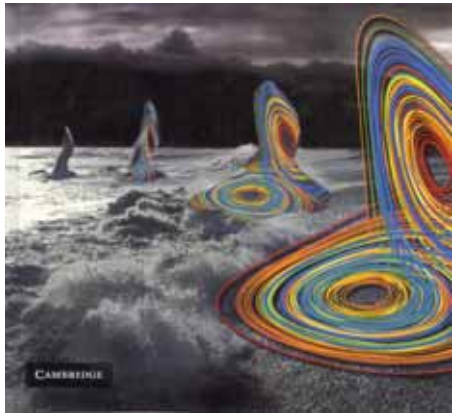
"We will see 6 active blobs more often in the 2030's."

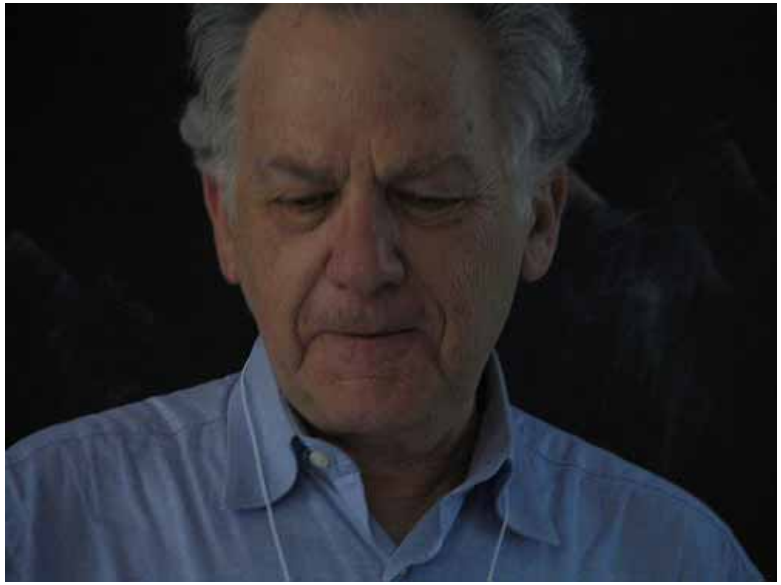
http://www.nhc.noaa.gov/archive/2008/graphics/al09/loop_5W.shtml

But what about chaos and ensembles?

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

The Western Australian (1994)





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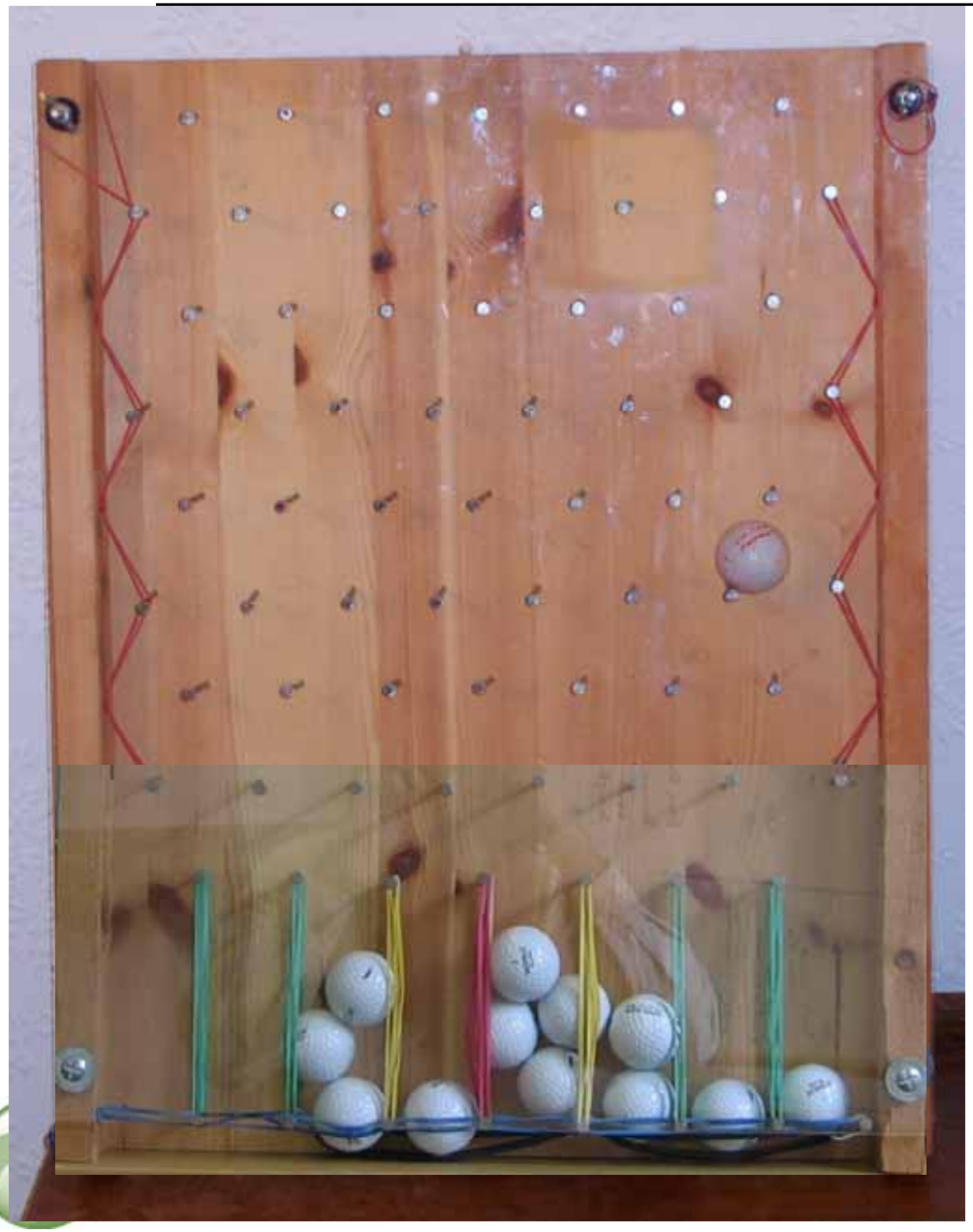
Enter Ensembles



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

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

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

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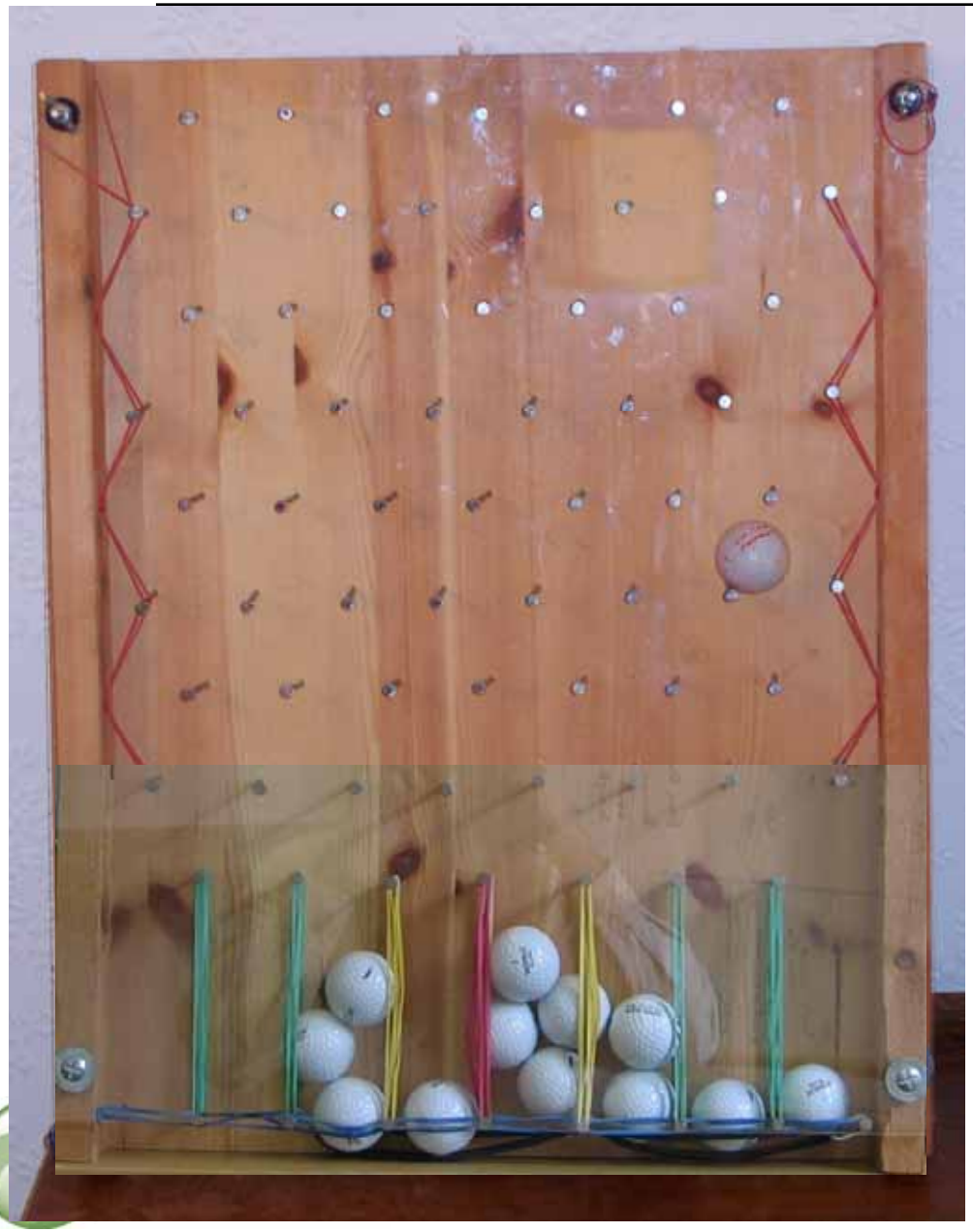
Science can expect surprises outside of model-land



In the NAG board, ensembles correspond to predicting with a collection (ensemble) of golf balls… but if reality is not a golf ball, then how do we interpret these distributions?

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

The best we can hope for is consistency between models (in distribution).

And anticipate "Big Surprises"

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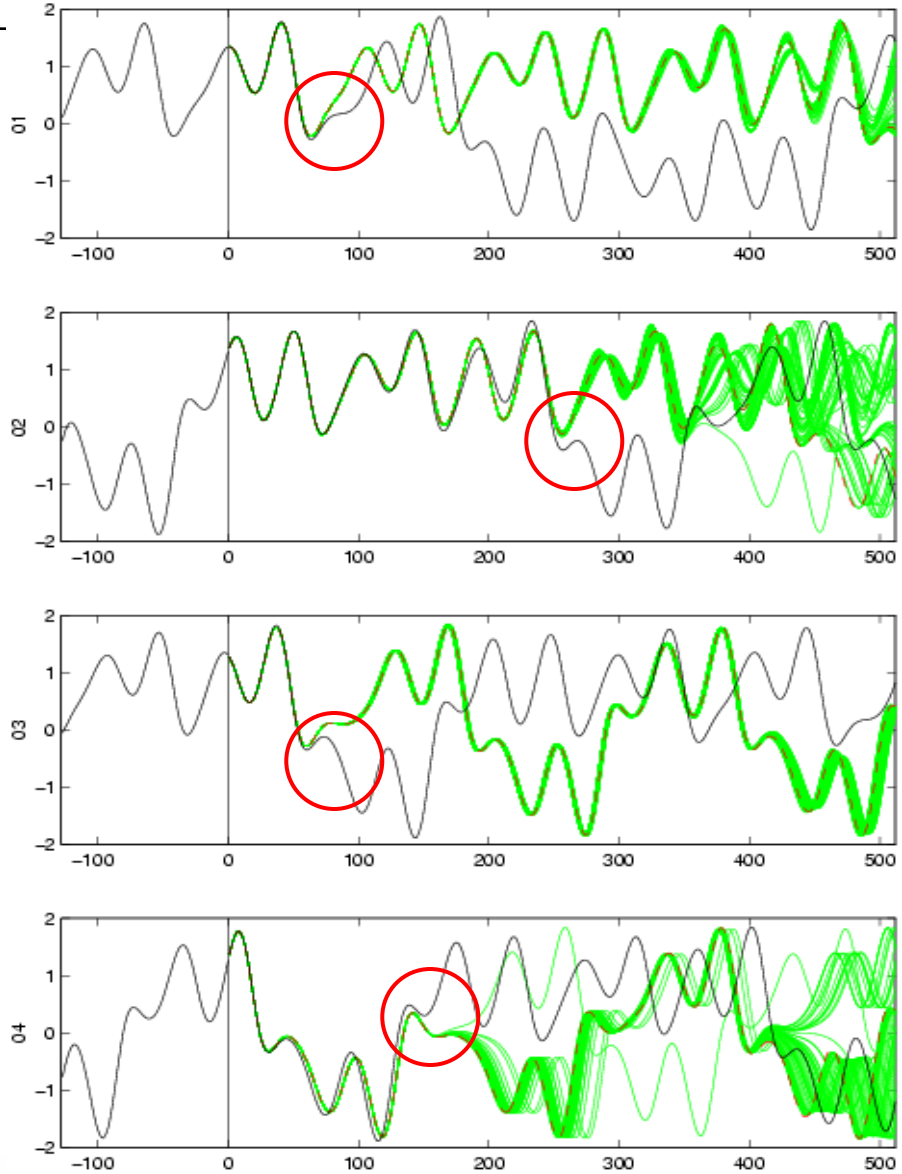
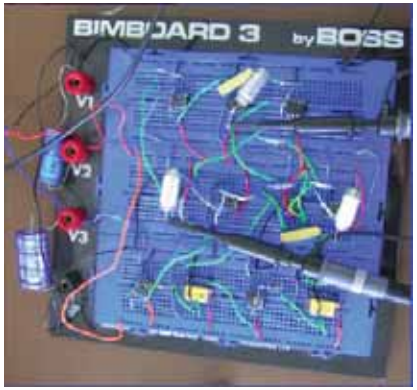
Forecasts busts in a Chaotic Circuit



512 member ensembles
Best known 1-step model
512 step free running forecasts

So wait until we know the future, then look for model trajectories that "shadow" the obs to within the noise.

(But what is noise, really?)



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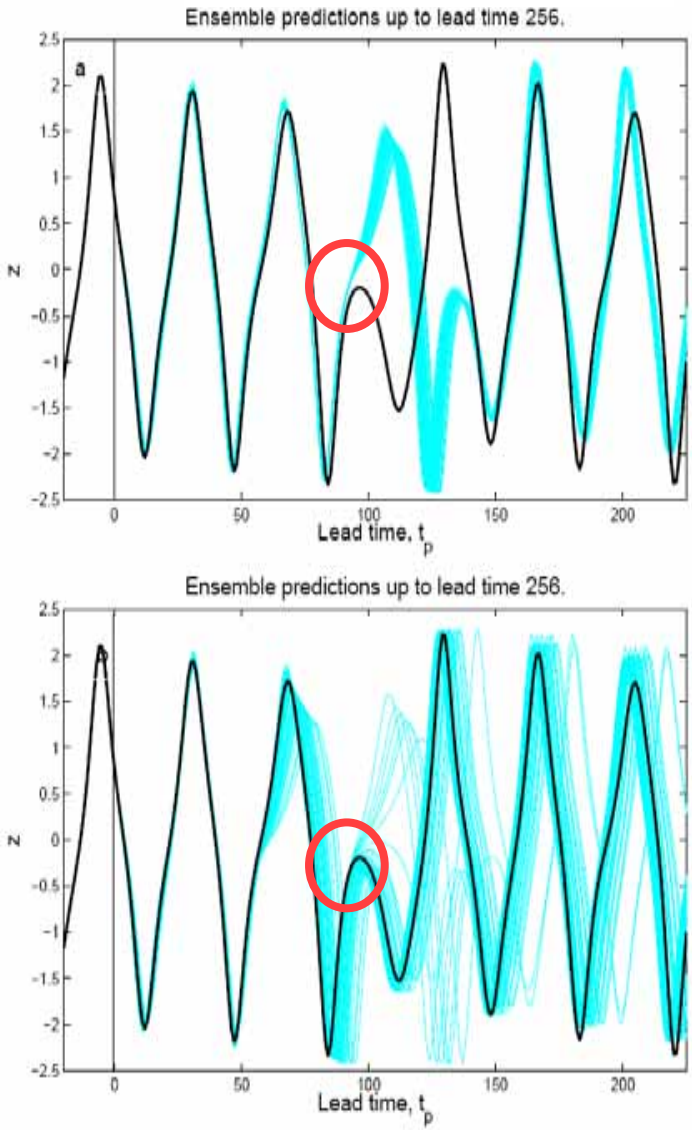
Moore-Spiegel Circuit (by Reason Machette)

One Initial State — **Another Initial State**

Model 1

Model 2



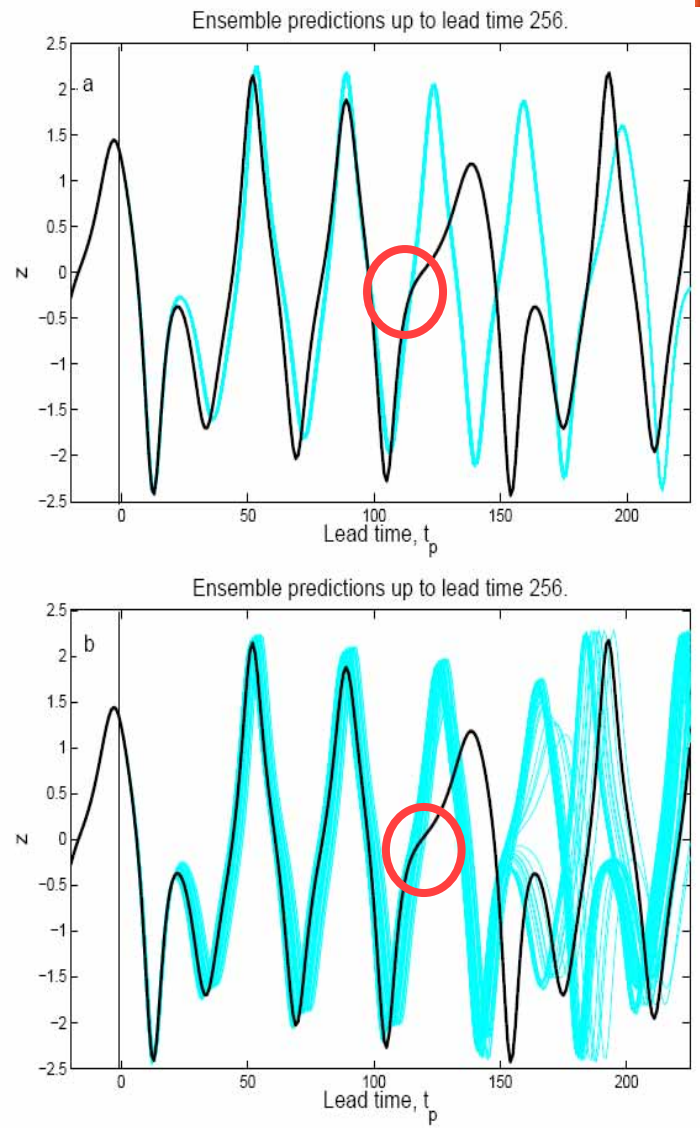


Figure 7: Ensemble predictions using (a) model 1 and (b) model 2. The

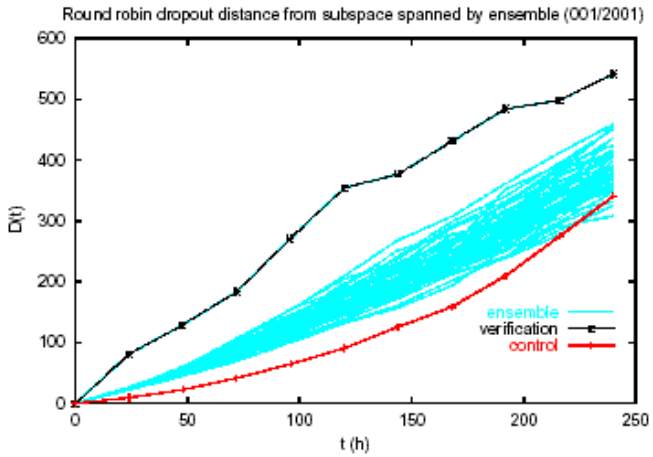
2: Ensemble predictions using (a) model 1 and (b) model 2. T

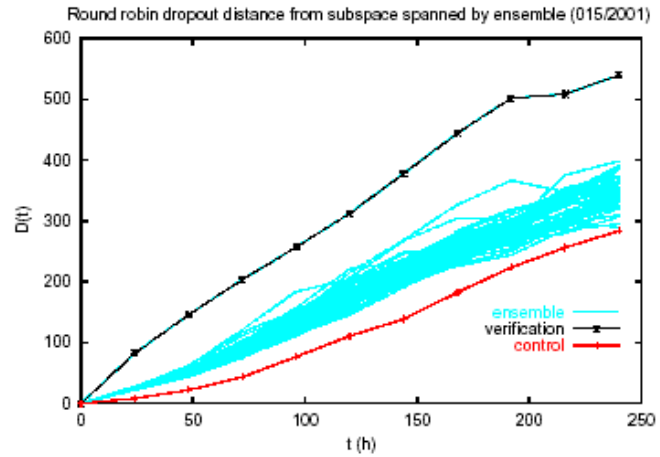
Weather Forecasting Lead times:

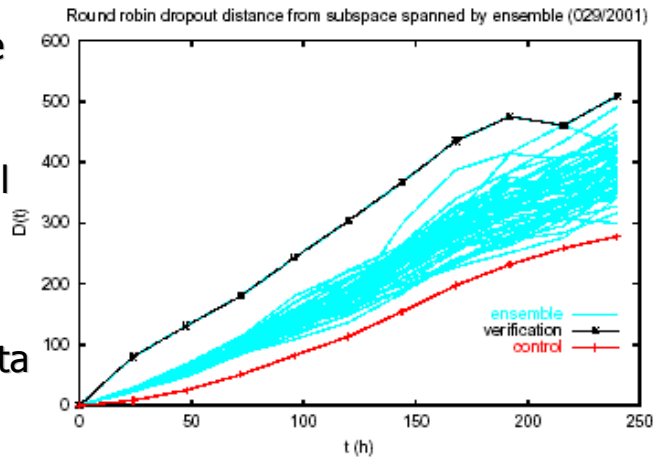
Bad Spread (with the correct magnitude)

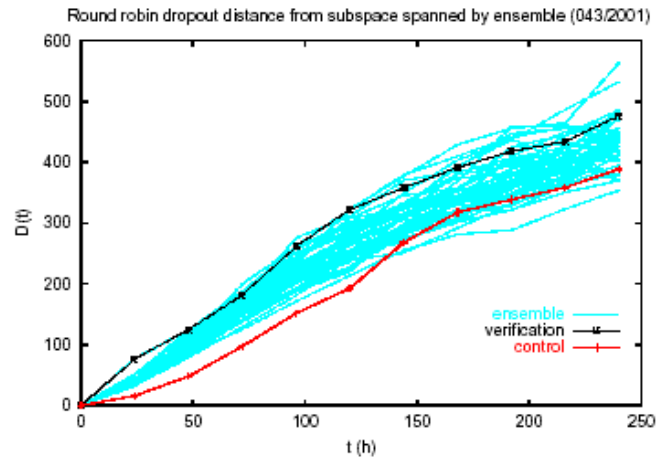
Evidence of nontrivial model error:

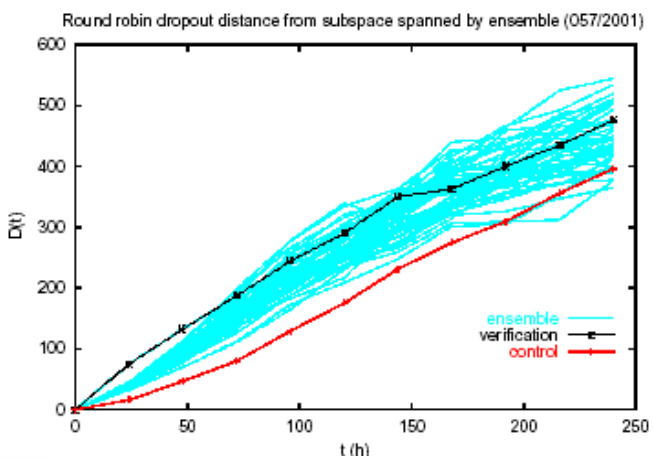
How then do I determine "good" data assimulation?

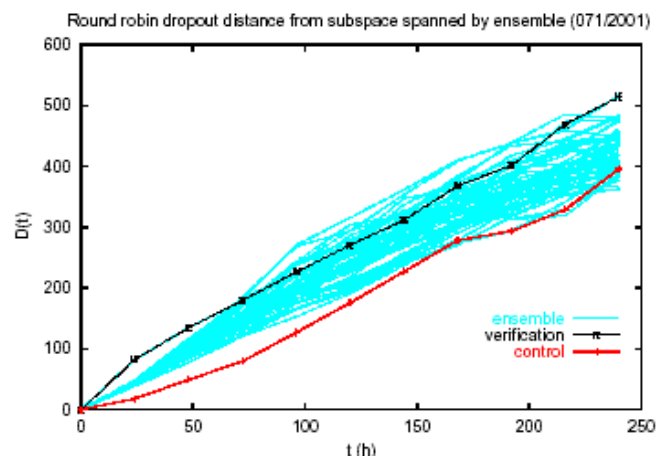












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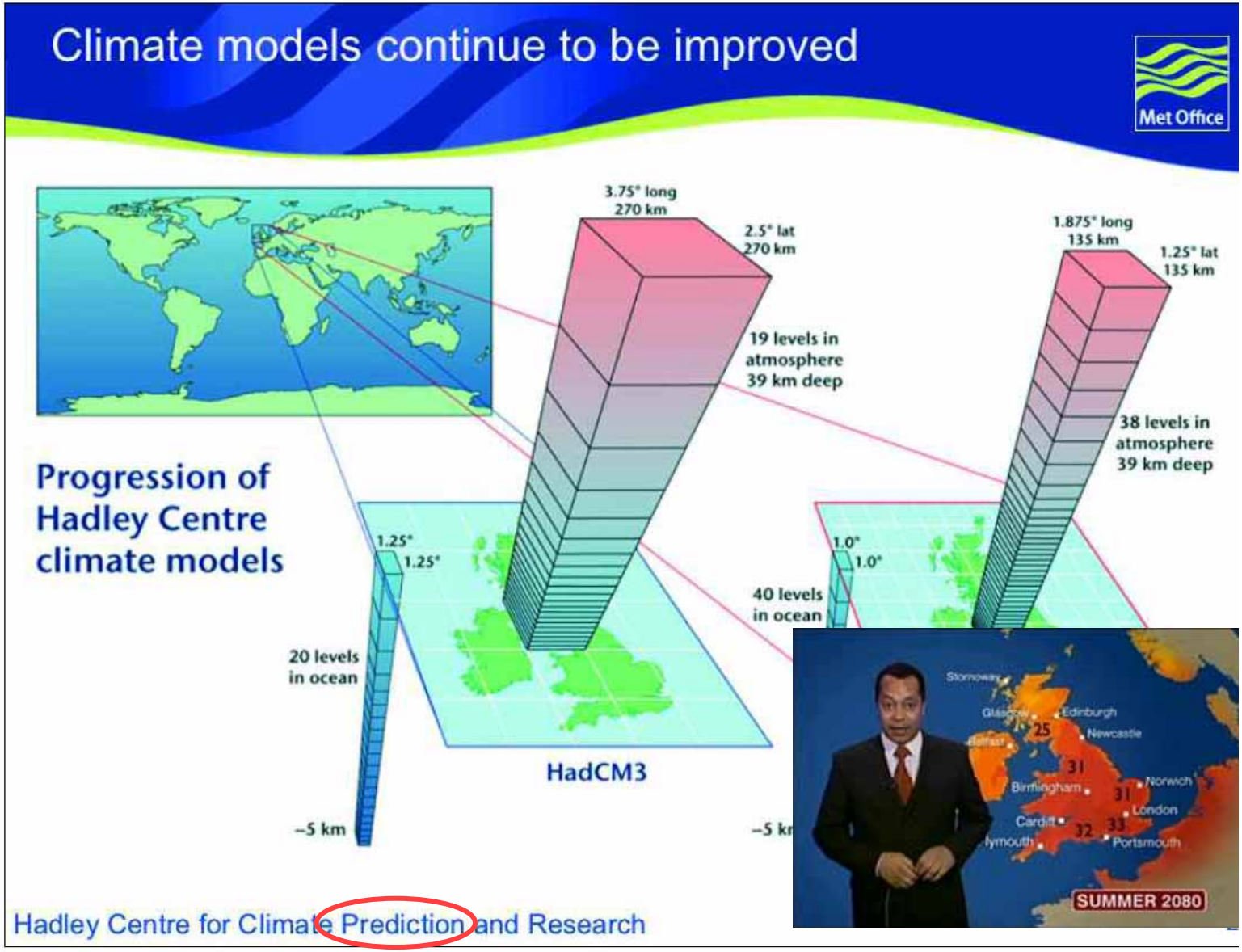
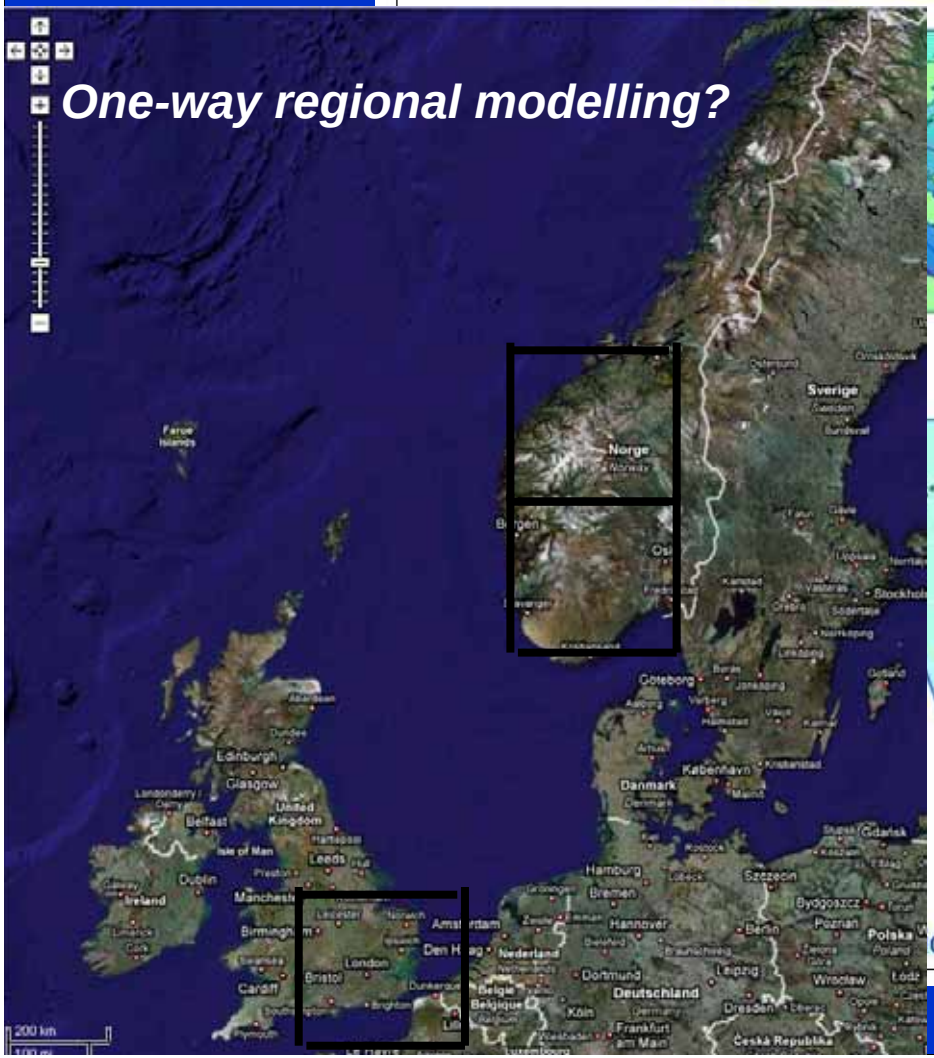
Models may get better and better, but always stay models!

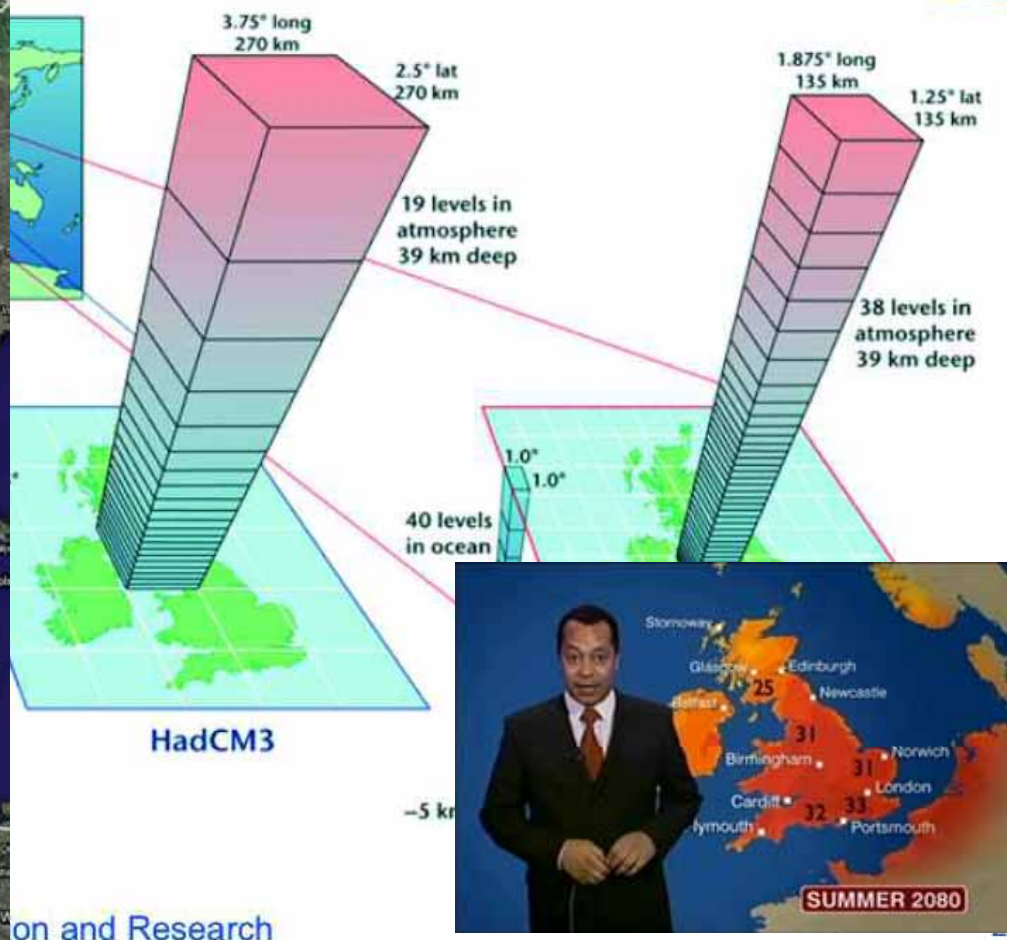


Scientists need to be careful to communicate the limitations of current models.

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

Climate models continue to be improved





on and Research

Verification, Validation, & Uncertainty

If fail verification tests should the code be run anyway?
Weather: yes, Climate: ?maybe/not?

Without clear evidence of validation, can UQ hope to provide anything more than sensitivity analysis?

Uncertainty Quantification: What is the deliverable? When might one expect anything other than the Probabilities regarding the next model run (which are uninformative in terms of decision making).

How should I approach UQ when the best available models are not empirically adequate?
?What year did climate prediction move beyond understanding to quantitative forecasting?

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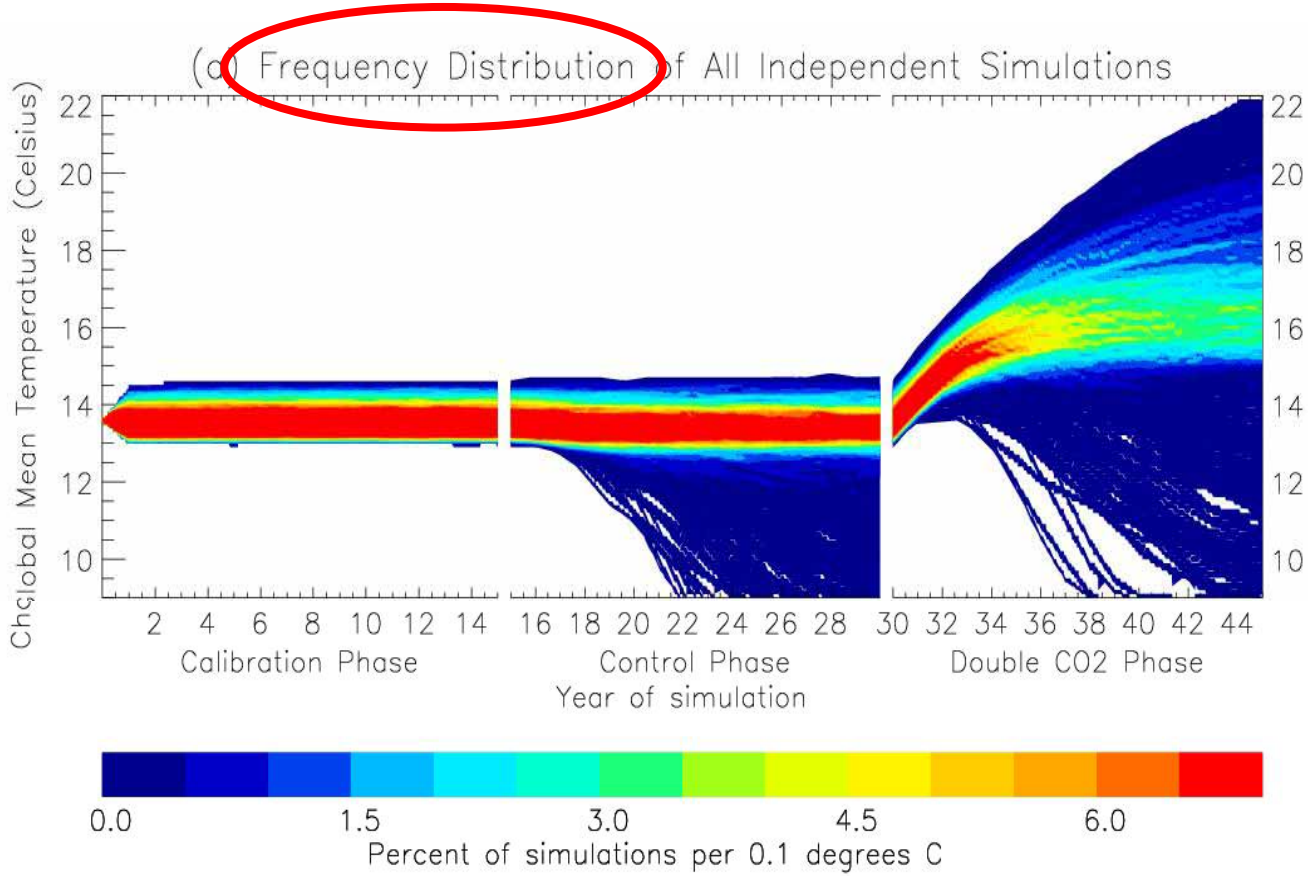
Ensembles reflect diversity within a model class; its decision relevance depends on the model class in hand.



A measure of model sensitivity?

or

A decision relevant probability?

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Probability and Weather-like Simulations

Here we usually have a “unconditioned distribution” called “climatology”

$$P_{clim}(x|\ \text{archive})$$

It is “unconditioned” inasmuch as it does not take into account our knowledge of the current state of the system.

In addition we have a number of model simulations that are conditioned on current observations, s, and of course on the model used.

$$P_i(x|\ s,\ M_i)$$

the subscript i denotes the model used

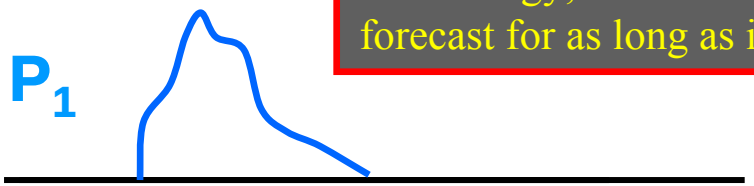
Given that we know the model is inadequate, this notation is already odd…

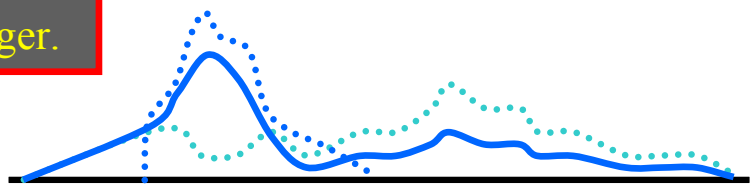
But in the weather case, we use the forecast-verification archive to determine when the model has less skill than climatology, and thereby cope with model inadequacy.

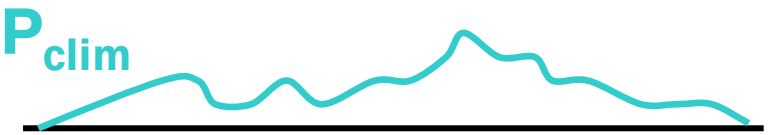
© Leonard Smith

Blending Predictive Distributions and Climatology

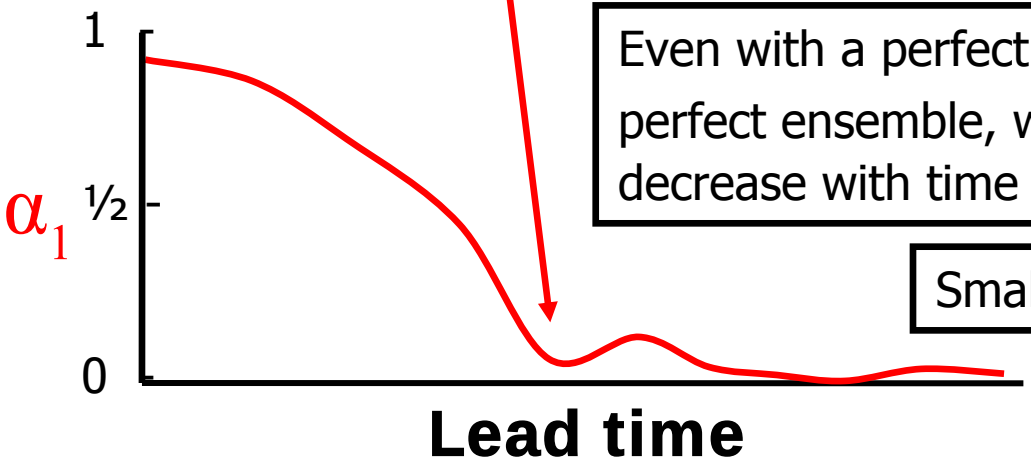
When $\alpha_1 \approx 0$ the forecast consists of pure climatology; the simulation informs the forecast for as long as it can, but no longer.







$$M_1 = \alpha_1 P_1 + (1-\alpha_1) P_{clim}$$



Even with a perfect model and perfect ensemble, we expect α to decrease with time for small n_{eps}

Small :: $n_{eps} << n_{clim}$

J Bröcker, LA Smith (2008) From Ensemble Forecasts to Predictive Distribution Functions *Tellus A* 60(4): 663.

© Leonard Smith

Probability in Climate-like Simulations

Here the problem is one of extrapolation, we have no relevant forecast-verification archive and we do not know the climatology (that being our aim!)

Arguably, the best we can hope for is agreement between our models (in distribution) which suggests the details do not (better: did not) matter.

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

We do not have that sort of agreement today, even for the planet's temperature.

And we have a hodge-podge of various types of "uncertainties" mixed together and shown to policy makers on the same graph:

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Scientific Uncertainty in GMT >> model range

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

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

Diversity NOT Uncertainty!
These distributions do not respect the law of large numbers!

The grey band represents traditional observational uncertainty.

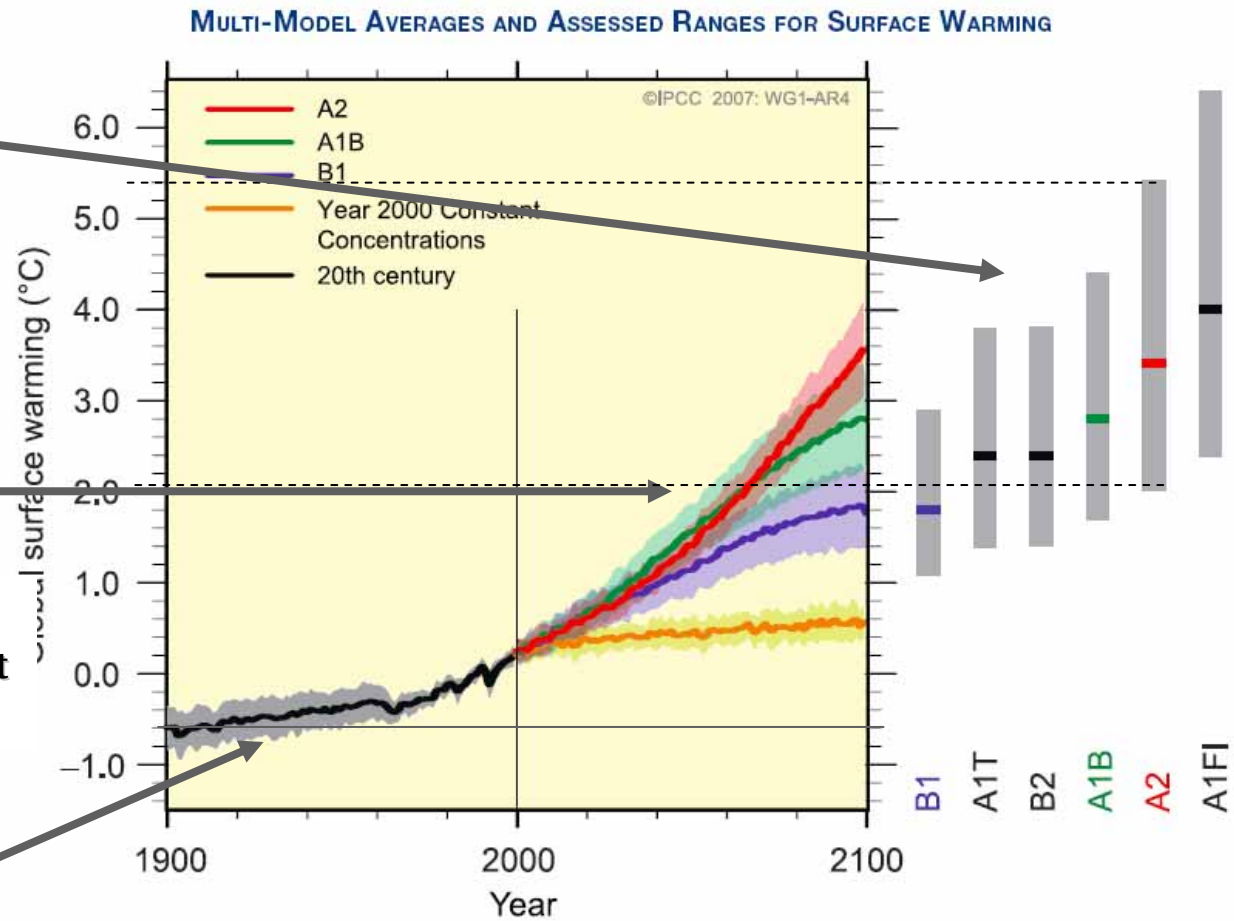

Figure SPM.5. *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the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

IPPC holds the model range too narrow even in GMT!

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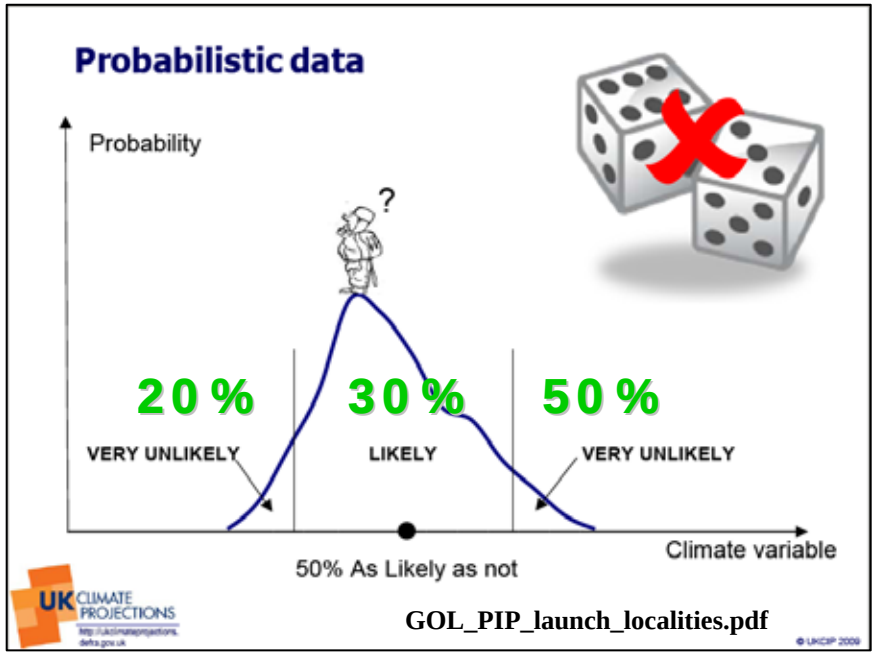
What is the chance of falling above the 90% line of model-PDFs?



A climate scientist can easily know that the probability of the real world falling above the 90% line of the UKCP PDF can be much **much** greater than 10%. Say > 50%

It is irrational to base decisions on a model-based PDF when known model inadequacy dominates the model-PDF ("blocking")!

(My subjective PDF is not constrained by any model-PDF when I know (aka believe) that the model is likely to be mis-informative!)

Diversity of My Models need not reflect Uncertainty in My Future

If I want a decision-relevant PDF I have to return to the Science

Sit and think <----------> Simulate and Count

When might Model-based PDFs be of value?

My goal here is similar to R. Cox's "Stable probability" (AJP, 1946)

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

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

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

SYUKURO MANABE AND RICHARD T. WETHERALD

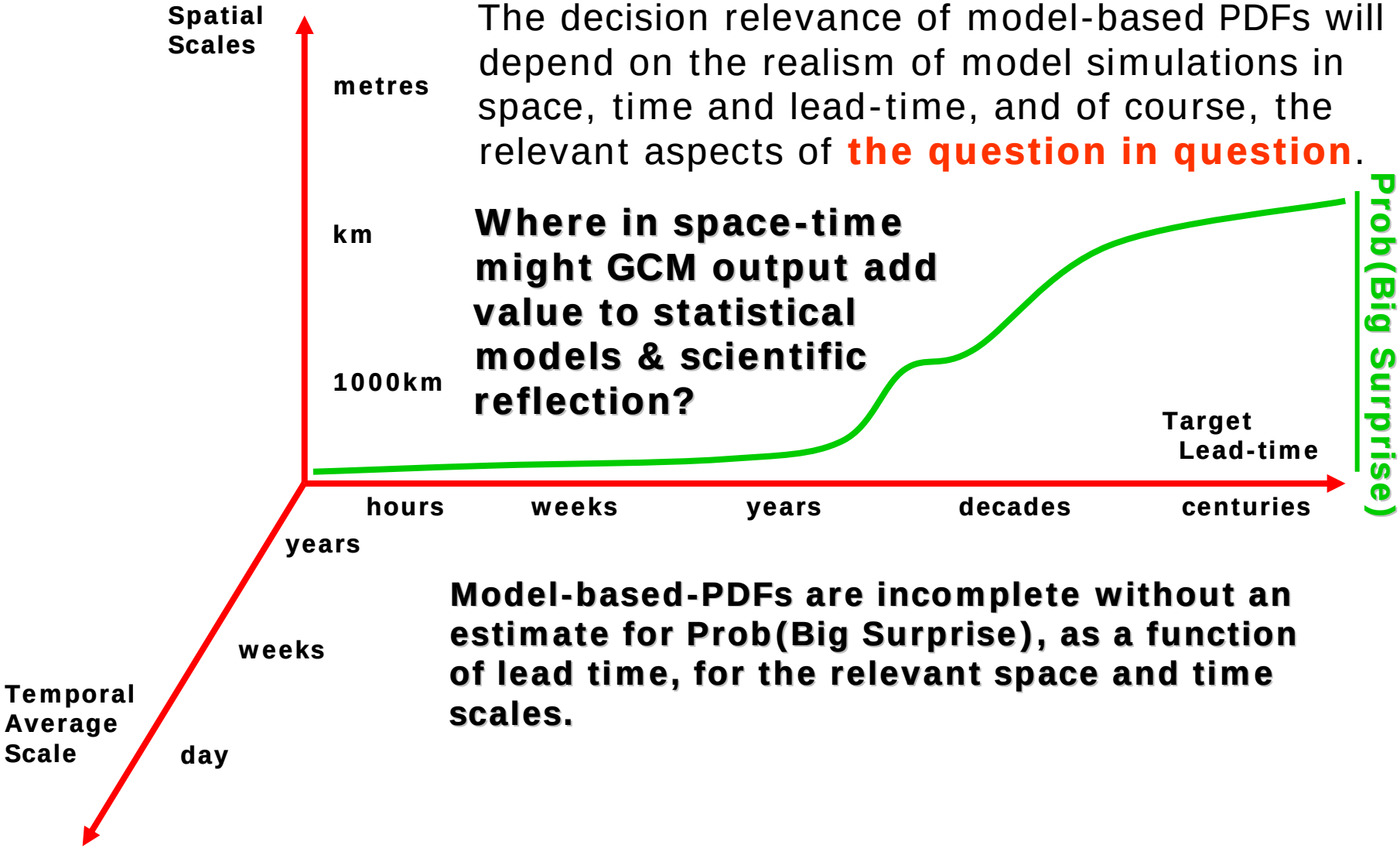
Geophysical Fluid Dynamics Laboratory/NOAA, Princeton University, Princeton, N.J. 08540

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

Mechanisms == Insight

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

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



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

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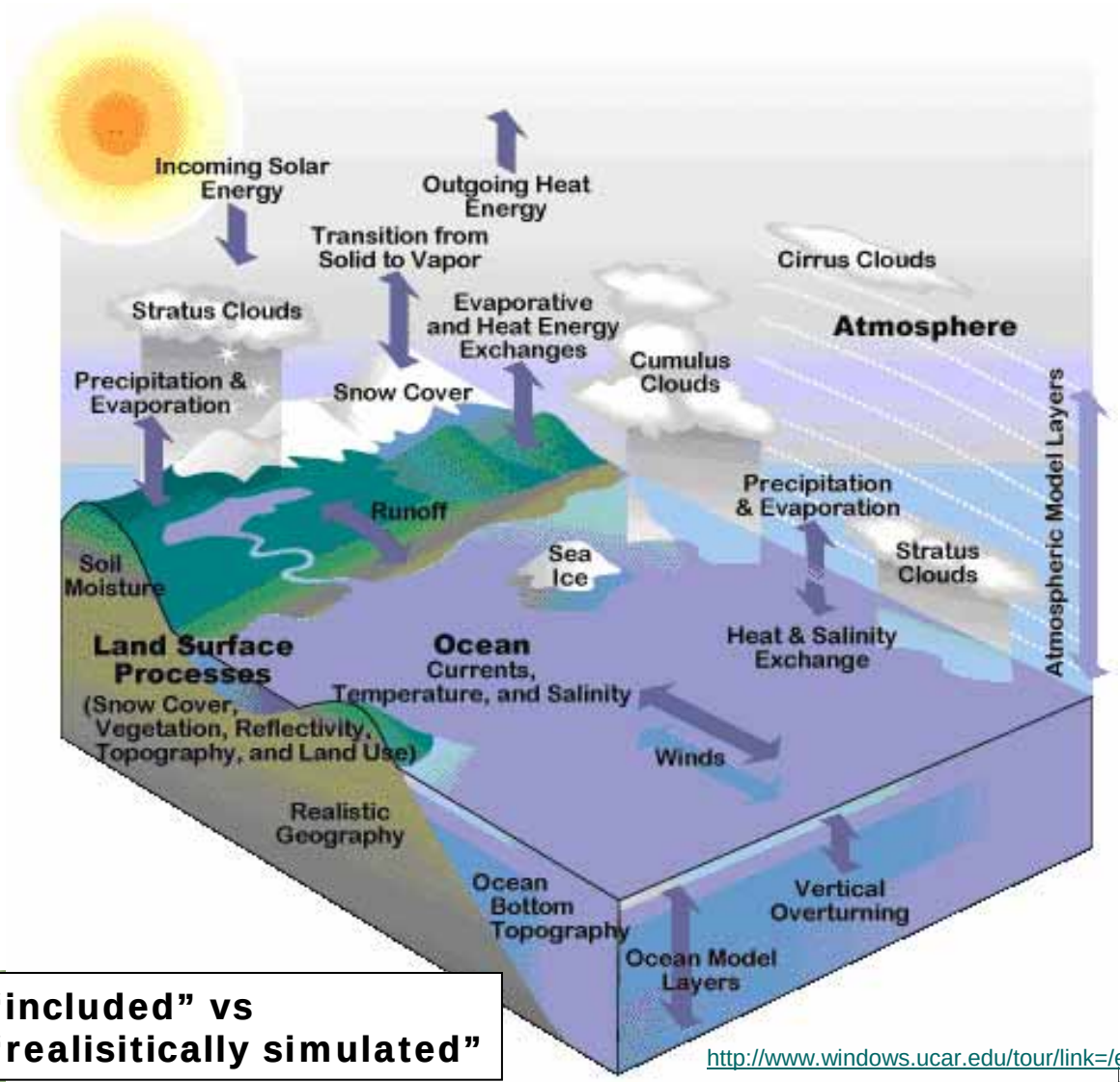
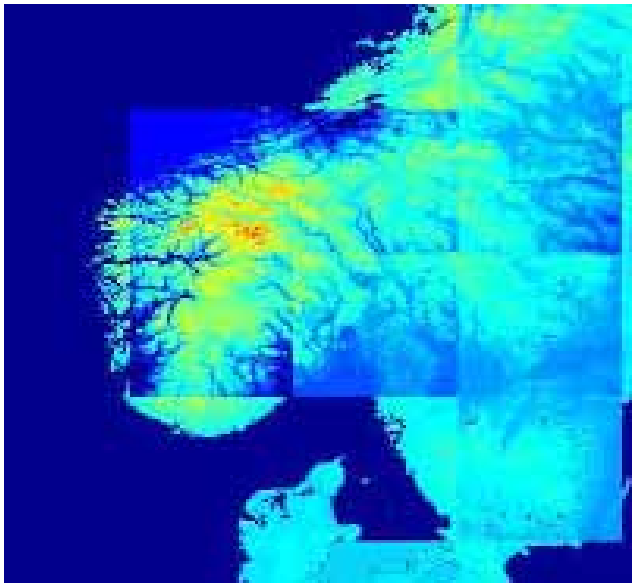
A dangerously schematic schematic

Climate Model Schematic



Climate Model (the squares)



HadCM3 missing elevation

2min x 2min obs – HadCM3

"included" vs "realisitically simulated"

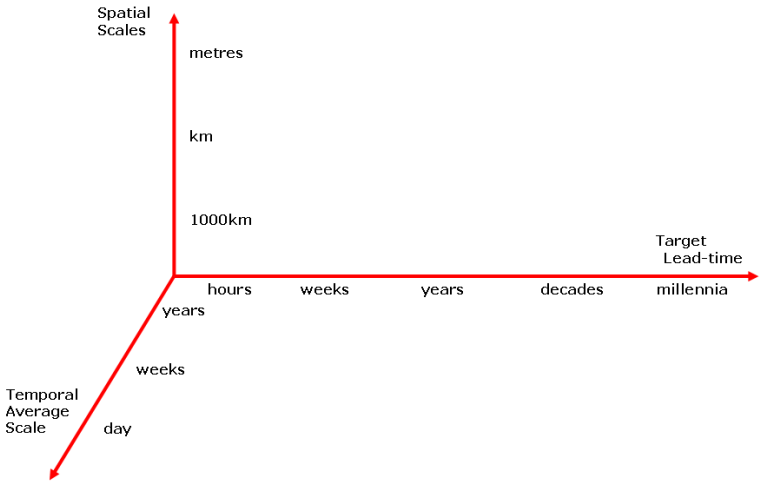
http://www.windows.ucar.edu/tour/link=/earth/climate/cli_models3.html

© Leonard Smith

Missing mountain ridges:

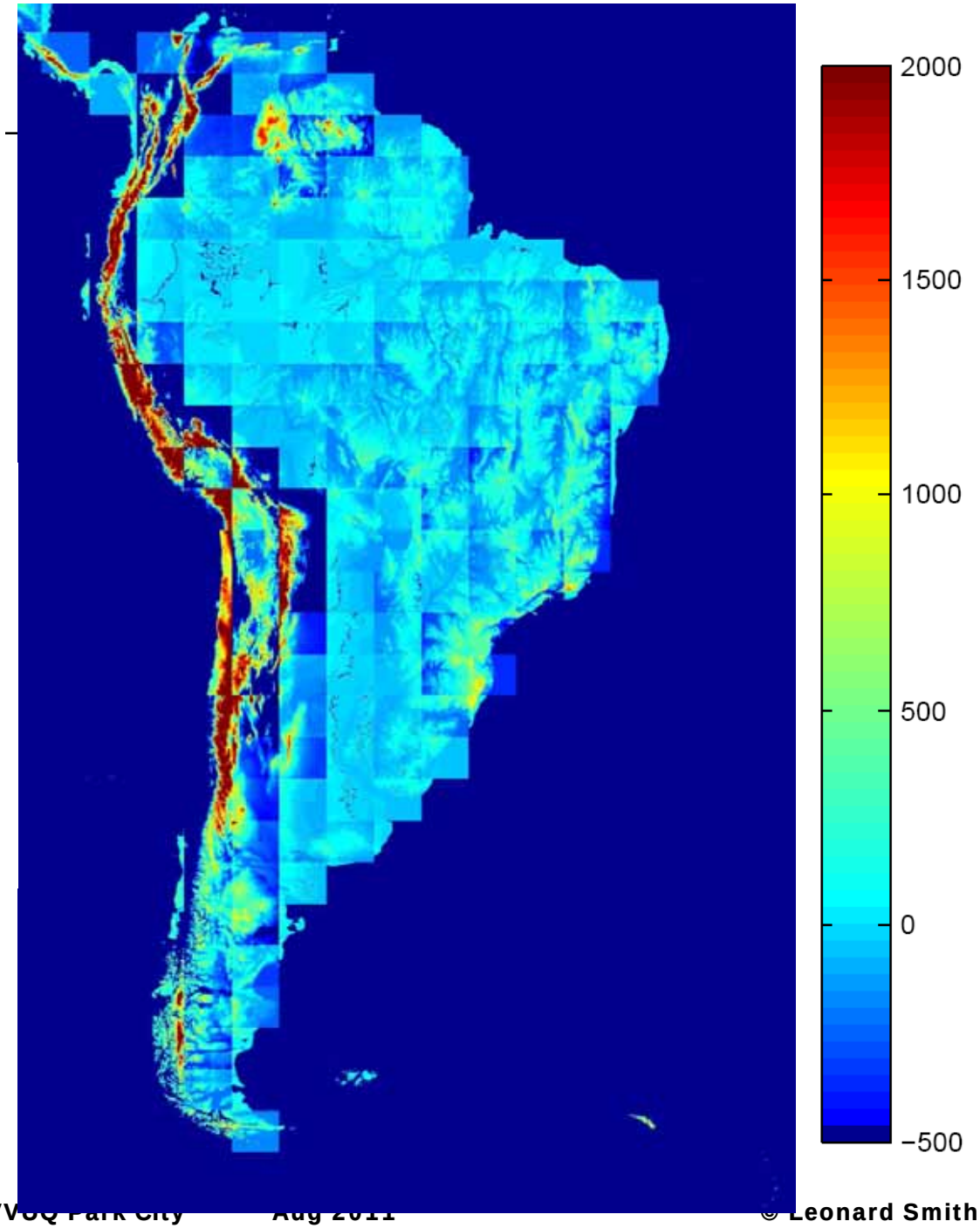
And long term feedbacks (bio-feed backs, albedo, …)

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



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

The Dust Bowl



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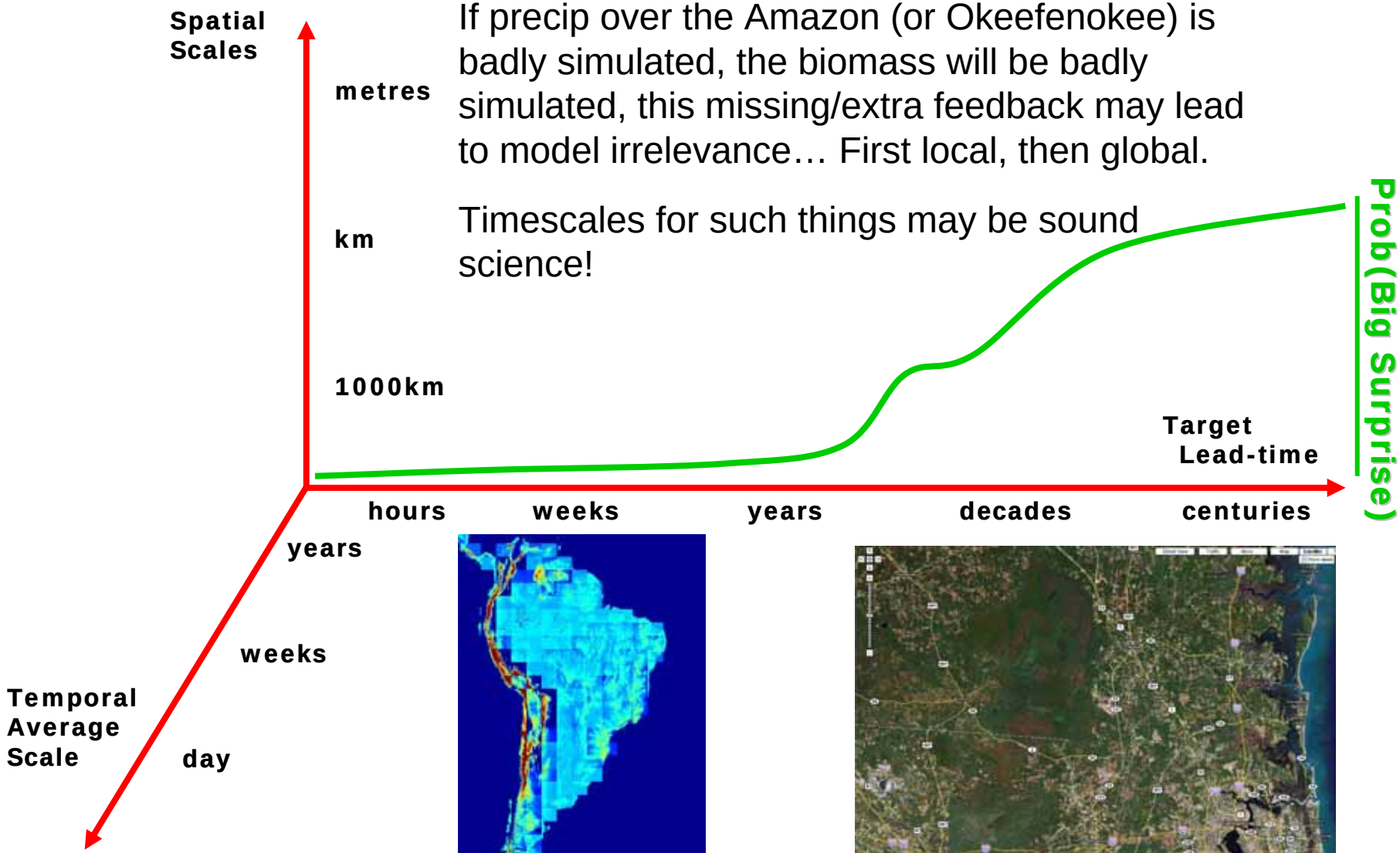
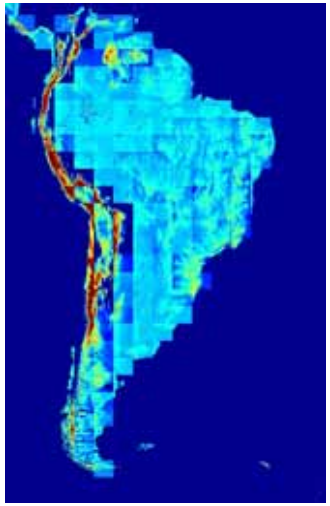
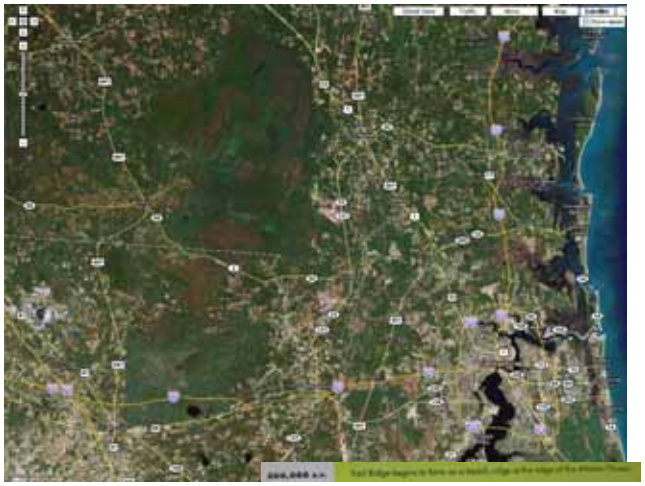
Model Relevance in Quantitative Decision Support

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

Timescales for such things may be sound science!







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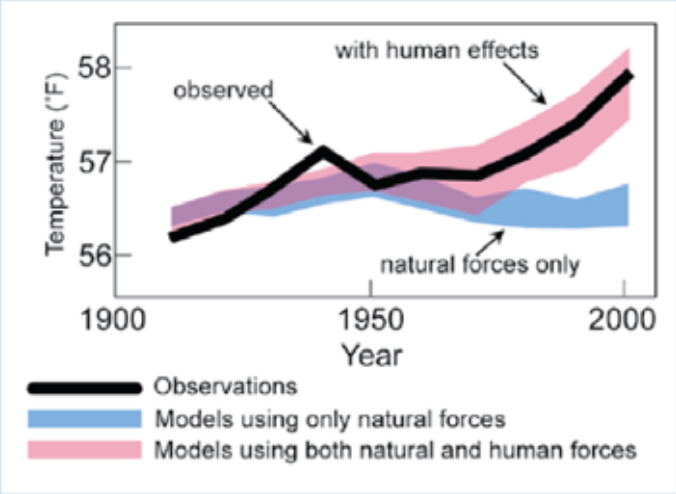
United States Global Change Research Program

Separating Human and Natural Influences on Climate



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

ipcc INTERGOVERNMENTAL PANEL ON climate change WMO UNEP

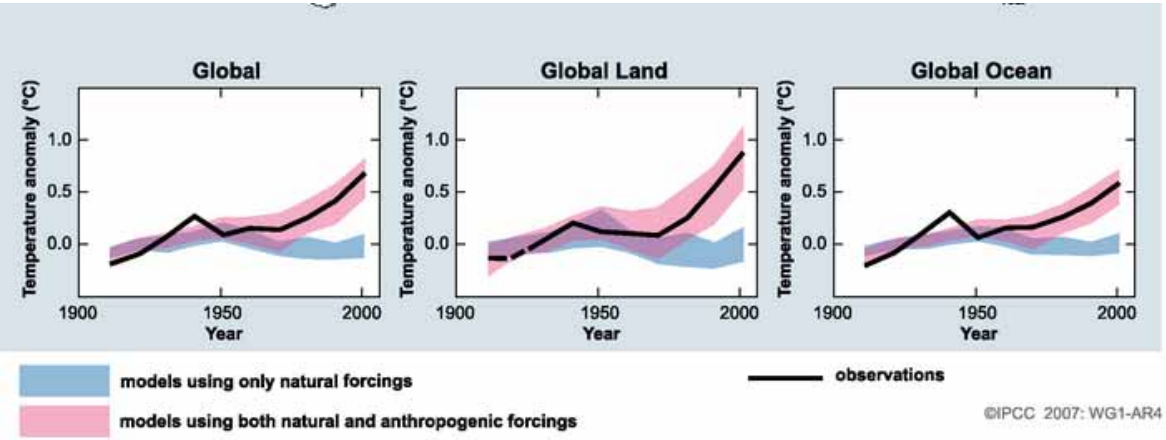


Figure SPM.4. Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906 to 2005 (black line) plotted against the centre of the decade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

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

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

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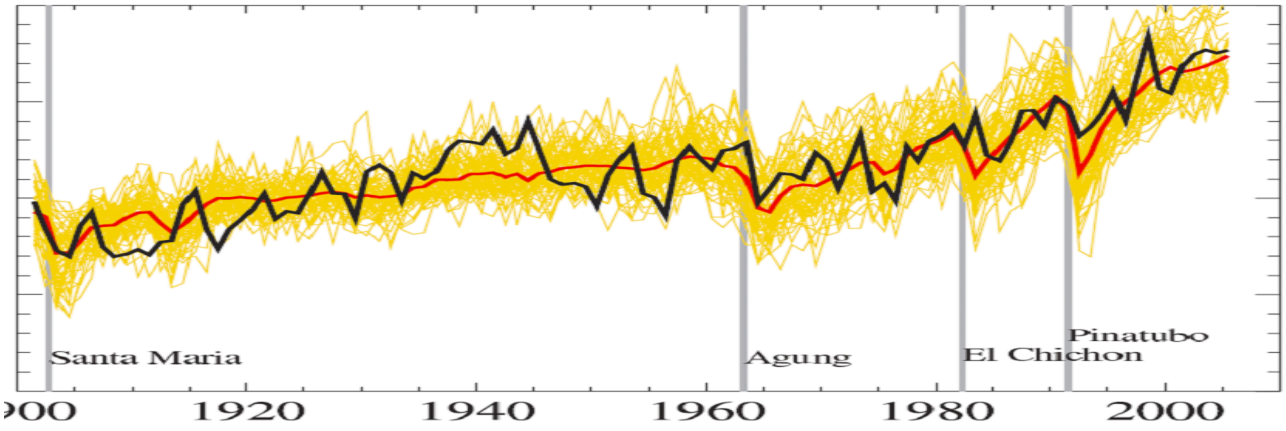
IPCC AR4:

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*



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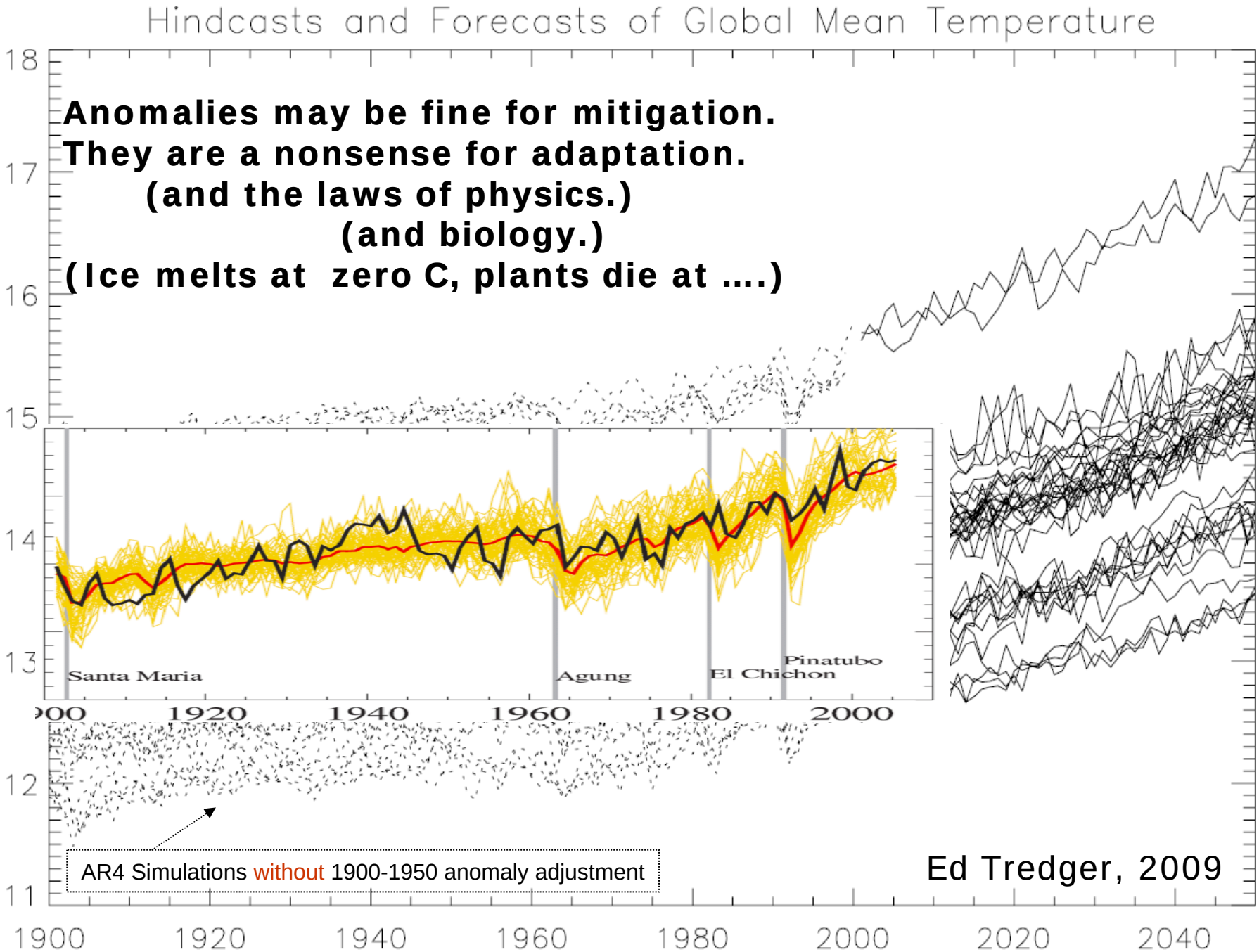
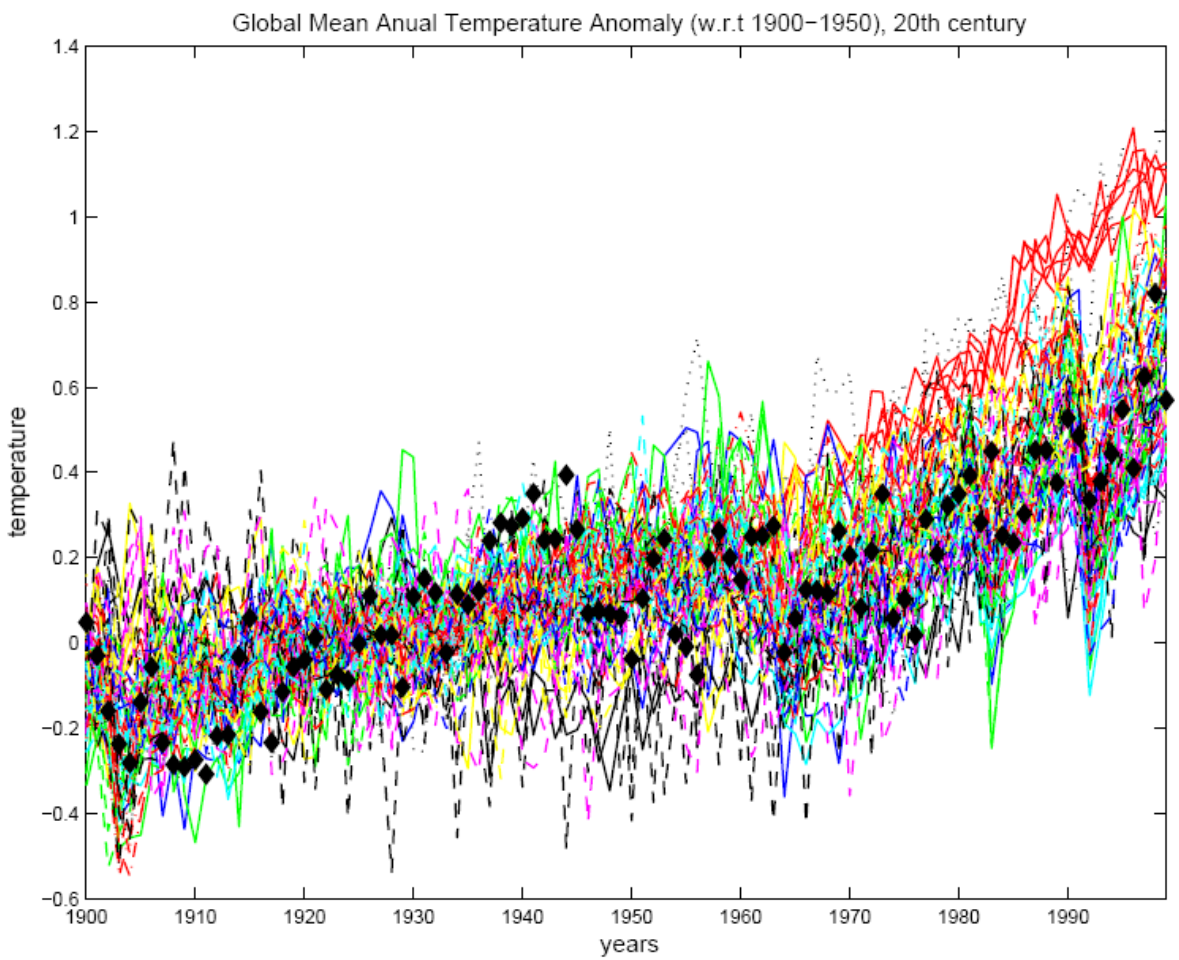

Hindcasts and Forecasts of Global Mean Temperature
Anomalies may be fine for mitigation.
They are a nonsense for adaptation.
(and the laws of physics.)
(and biology.)
(Ice melts at zero C, plants die at ....)
Santa Maria
Agung
El Chichon
Pinatubo
AR4 Simulations without 1900-1950 anomaly adjustment
Ed Tredger, 2009
18
17
16
15
14
13
12
11
1900
1920
1940
1960
1980
2000
2020
2040

What do we do given such systematic errors?



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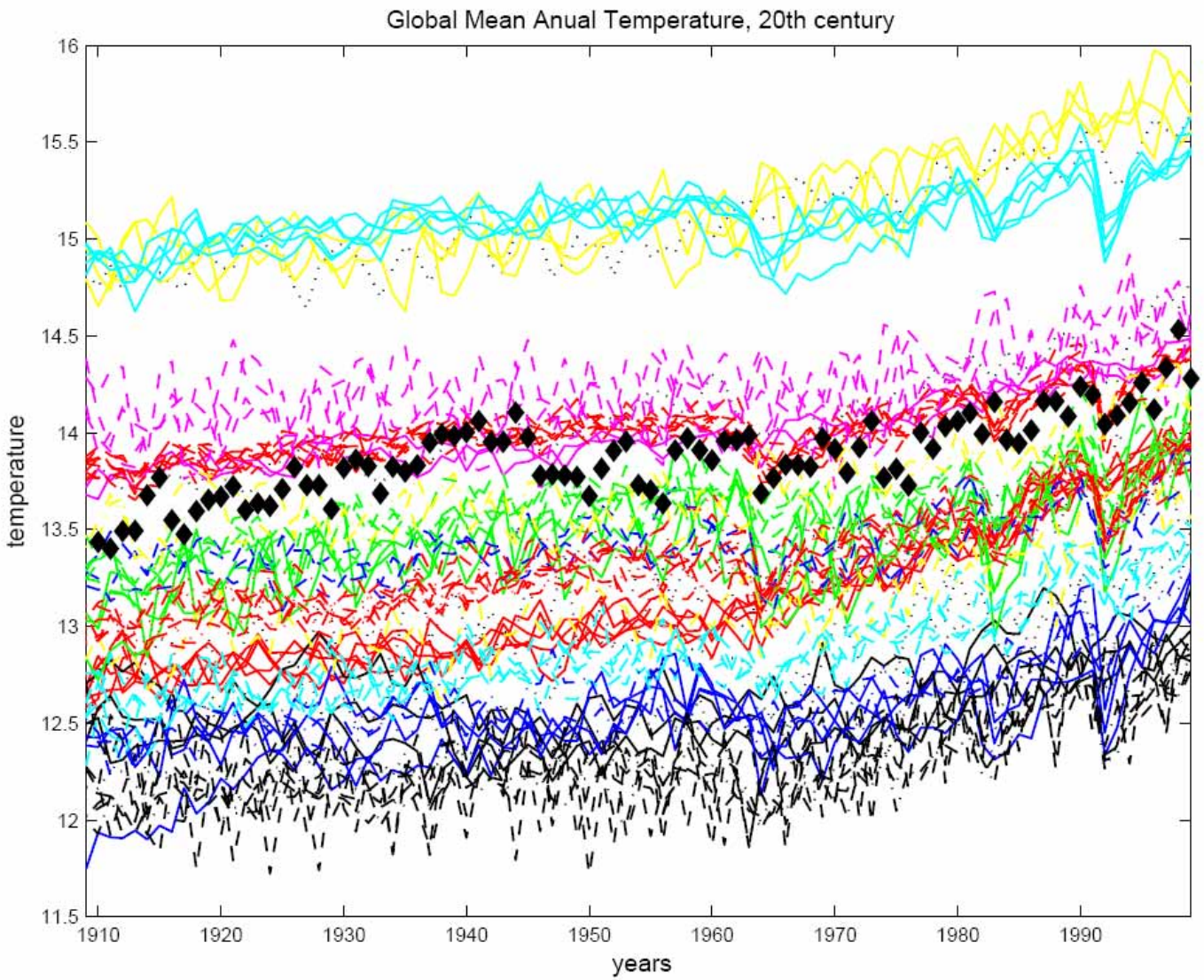
"Pink Runs"

WCRP CMIP3 Multi-Model Data

Home Data About ESG Login



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Probably Wrong: How Model-based PDFs go bad

If there is a high probability that model inadequacy dominates the model-PDF, then the decision-relevance of model-based PDFs must be evaluated in terms of the science.

At some lead-time, for a given target, the model-PDF will be classed as no longer decision-support relevant…

Let's consider using Newton's Laws as our model, and ask the question:

"What is the location of the Earth 1000 years from today?"

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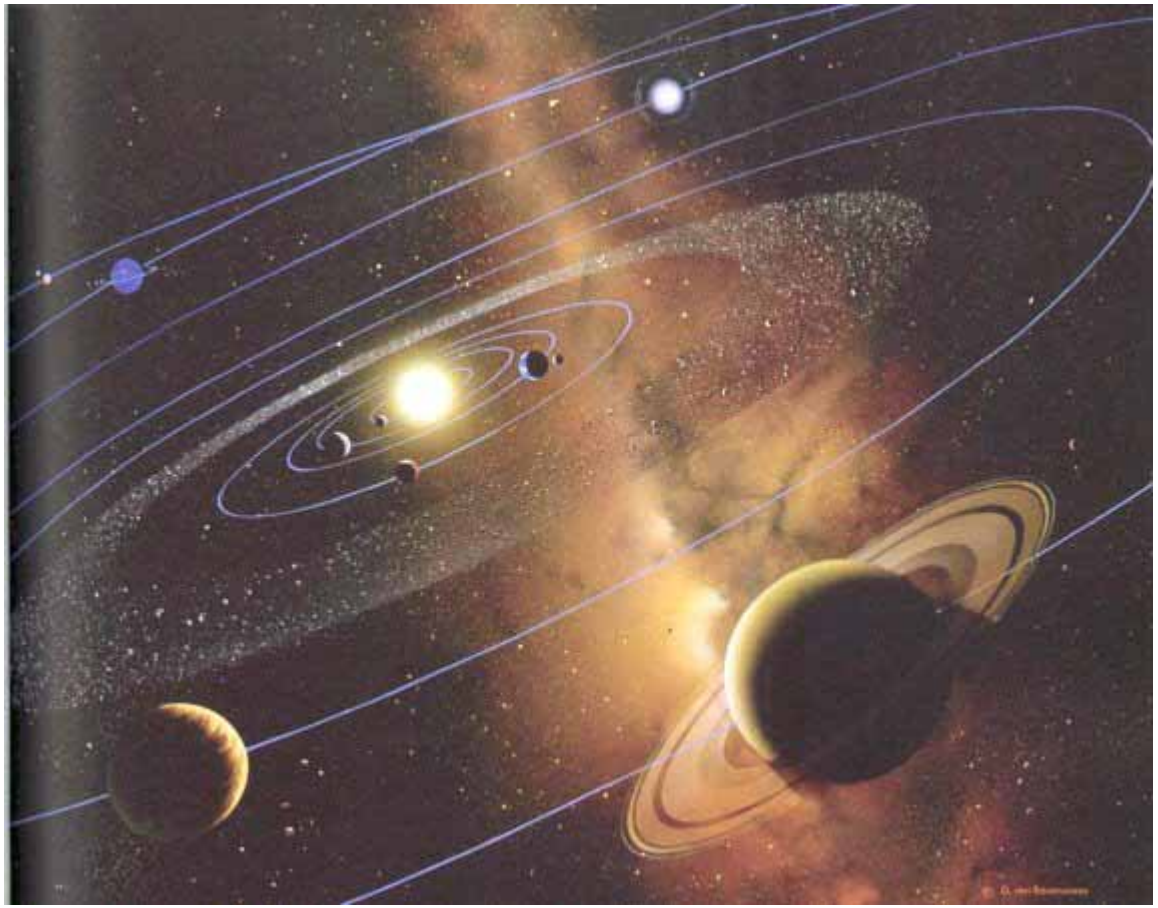
Model Relevance and the Location of the Earth

If our computer model is based on Newton's Laws, and the Question is the location of the Earth in 1000 years….

Monte Carlo sampling of from a prior distribution of initial condition and mass of each major planet will yield a final time distribution one thousand years hence, from which we can form a sensible PDF.



Bayesian Discrepancy terms, based on different integration schemes, compilers and computer hardware **may yield valuable information**.

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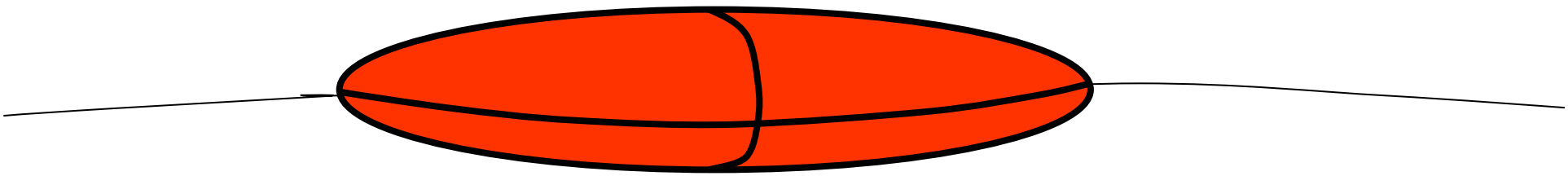
The Probability of being outside the 99% level?

Our models allow us to draw a balloon in space that captures 99% of the model-earth trajectories.



And our/my subjective probability that our Earth will fall outside that corresponding real-world balloon might rationally be ~1%

The orange balloon corresponds to a probability contour for capturing the Earth.

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SUN

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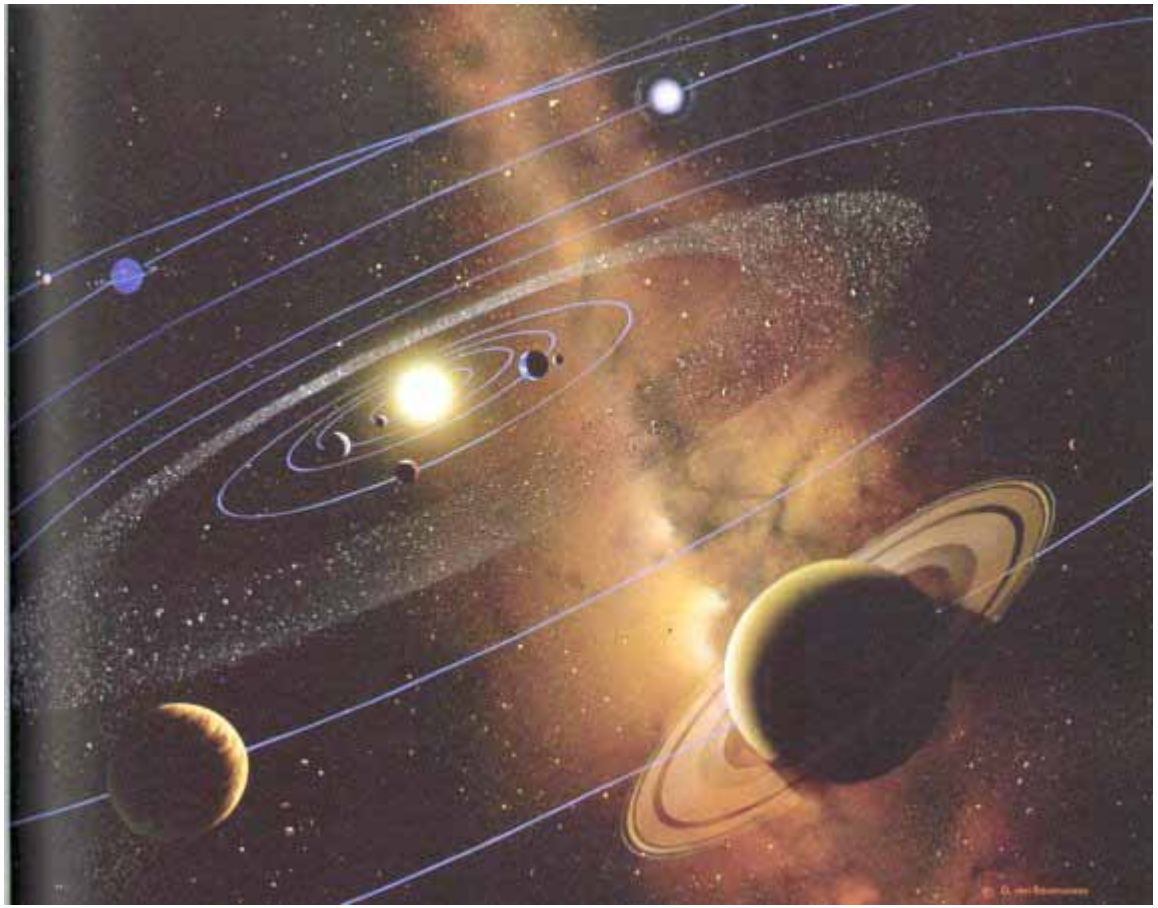
Model Relevance and the Location of Mercury

If our computer model is based on Newton's Laws, and the Question is the location of Mercury….

Then this approach is absurd.

Newton's Laws are long known to fail for Mercury.

And science could warn us the Newtonian-PDF was misleading long before General Relativity provided an empirically adequate model!



Discrepancy based on different integration schemes, etc, will lead to over-confidence, belief in spurious accuracy and bad decision making!

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The Probability of being above the 99% level?

And for Mercury?
Our subjective probability that the real Mercury will fall outside the real-world balloon corresponding to the volume that captures 99% of our model-Mercury trajectories… might be **say, ~90%!**

For Mercury, relevant science is more informative than the Newtonian model.

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Sit and think, don't just simulate and count!

SUN

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More transparency urgently needed:

And not in the PDFs

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Report from the Review of the Methodology used for the UKCP climate change projections

13 and 14 January 2009

The focus on UK-scale climate change information should not obscure the fact that the skill of the global climate model is of over-whelming importance. Errors in it, such as the limited current ability to represent European blocking, cannot be compensated by any downscaling or statistical procedures, however complex, and will be reflected in uncertainties on all scales.

(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.

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

THIS IS NOT ABOUT BEING COMPETATIVE BUT ABOUT BEING USEFUL!

Structural Uncertainty is Noted in the IPCC AR4:

Summary for Policymakers

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

10

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

Although quantitative statement of the systematic errors on the previous slide are not easily found…

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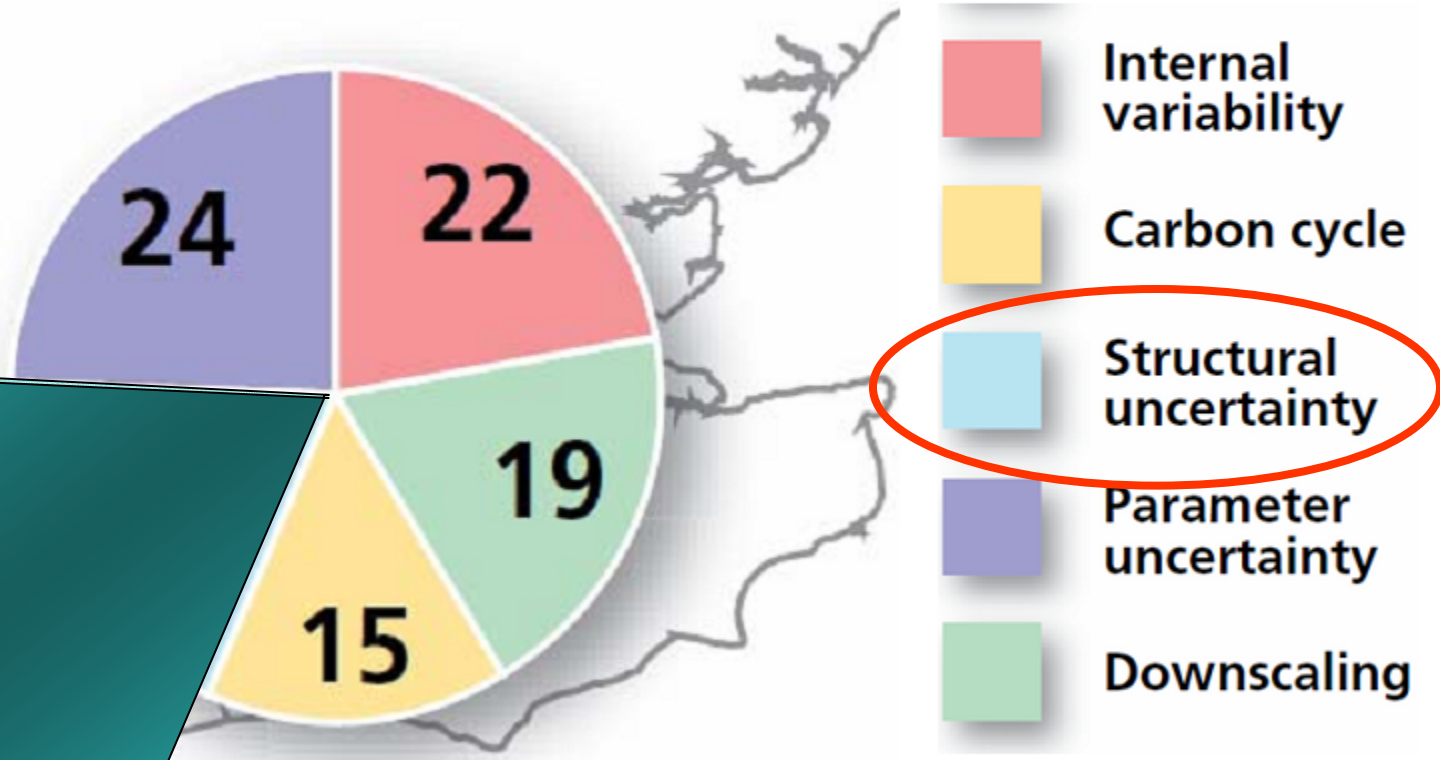
How important are different sources of uncertainty?

- Varies, but typically no single source dominates.



r precipitation changes for the 2080s relative to
box in SE England

Source: Met Office

?What year did climate prediction move beyond understanding to quantitative forecasting?

The basic insight here is not new

***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

Dr. Platzman

I may add to this another point mentioned by Dr. Charney, a somewhat philosophical comment concerning model experiments. I think that I agree with Dr. Charney's suggestion that machines are suitable for replacing model experiments. But I think it is also necessary to remember that there are in general two types of physical systems which one can think of modeling. In one type of system one has a fairly good understanding of the dynamical workings of the system, involved. Under those conditions the machine modeling is not only practical but probably is more economical in a long run. Typical examples of this kind, I think, are problems where you are concerned, let's say, with wave action in harbors, in general a whole class of engineering problems of that kind. But there is another class of problem where we are still far from a good understanding of the dynamical properties of the system. In that case laboratory models, I think, are very effective and have a very important place in the scheme of things.

PROCEEDINGS
OF
THE INTERNATIONAL SYMPOSIUM
ON NUMERICAL WEATHER
PREDICTION IN TOKYO

NOVEMBER 7–13, 1960

Because of the various simplifications of the model described above, it is not advisable to take too seriously the quantitative aspect of the results obtained in this study. Nevertheless, it is hoped that this study not only emphasizes some of the important mechanisms which control the response of the climate to the change of carbon dioxide, but also identifies the various requirements that have to be satisfied for the study of climate sensitivity with a general circulation model.

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

SYUKURO MANABE AND RICHARD T. WETHERALD

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

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

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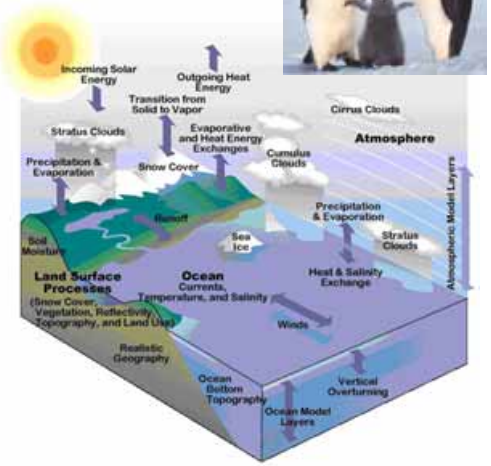
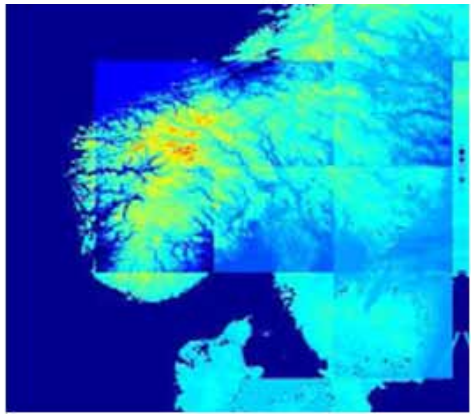
Moving Forward:
Plausible Planets or Implausible Eart



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

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

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



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

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

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And for Application: Robust, Representative and Relevant

Robust: not fragile, meteo PDFs are not expected to change substantially (a) as models undergo incremental development or (b) under slight changes in the analysis or (c) given the evidence suppressed. "Cox-Stable"

Where E = (EC U ES)

Representative: each meteo driver known to play a significant role in the question of interest is thought to be adequately represented (realistically simulated) to the extent that **each** simulation is fit to inform this question.

Relevant: in a form that users can use/exploit for the decision of interest using tools they like, spatial and temporal resolution and so on.

This is an ordered list:

First relax **relevant**, as other useful questions might be answered. Impact PDFs are only decision-relevant if **robust** and **representative**.

Next relax **representative**: a set of simpler questions might still be addressed, given only a subset of the meteo drivers, as long as PDFs of those meteo phenomena were **robust**.

Without **Robust**, arguably the model-PDF is not a subjective PDF for the phenomena at all. (Recall Manabe and Wetherall, 1975)

(doesn't someone have to believe it for it a Bayesian to count it as a PDF?)

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Watch out for the Penguin Effect

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

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

When selecting a thesis problem: should you go after something important, like understanding cloud dynamics (better)?

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

THERE IS NO PENGUIN EFFECT

(My prior on this effect is zero)

It is a joke regarding climate, but sadly not careers!

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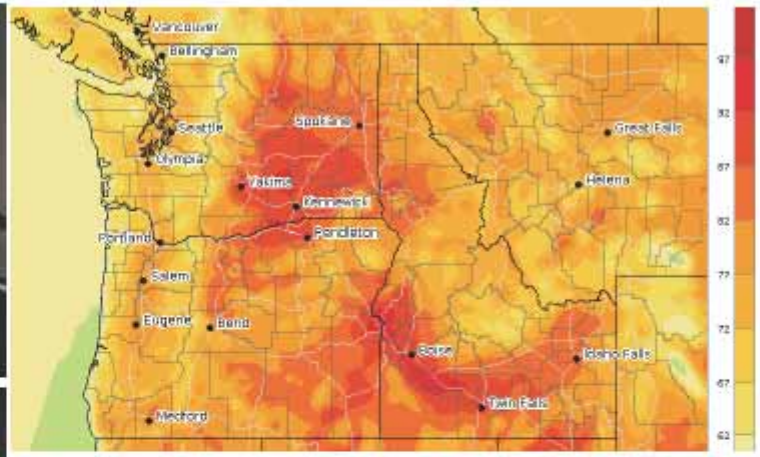
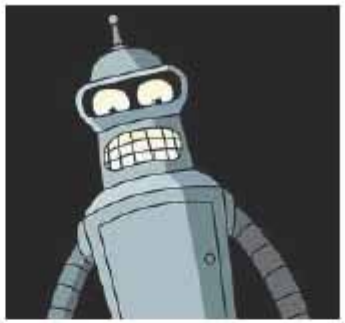
Model-based prediction & quantifying uncertainties

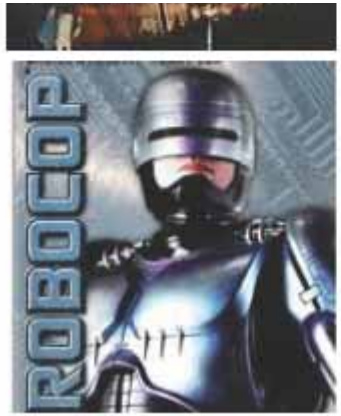


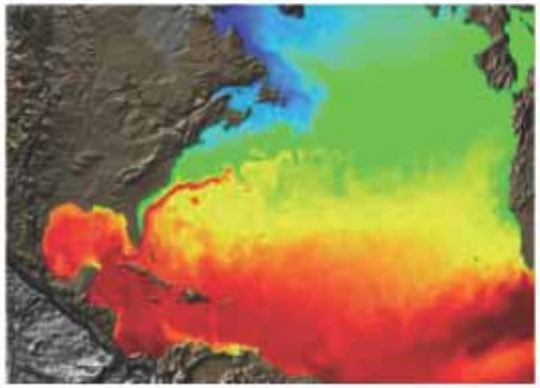


Combination of physical data & computational model

http://www.youtube.com/watch?v=hpFifHgZyrg

Estimate input settings & let it go





North Atlantic temperatures

Model-based prediction & quantifying uncertainties

http://www.youtube.com/watch?v=hpFifHgZyrg

Estimate input settings & let it go

In climate-like problems we are stuck with robots.

If we test them to destruction can we understand how the break?

Can we send them back over and over again, (so that we still love the early ones)

Thanks to Dave Higdon, LANL

http://www.google.co.uk/imgres?imgurl=http://www.jpl.nasa.gov/images/spacecraft/ranger/ranger3-craft-browse.jpg&imgrefurl=http://www.jpl.nasa.gov/missions/index.cfm%3Fmission%3DRanger&usg=__b99CBKOa-QvjoCq6nzDnveO3=VO=&h=534&w=528&sz=31&hl=en&start=3&zoom=1&tbnid=TpmPEwJH23XLM:&tbnh=132&tbnw=131&ei=mRBTimeJcfu5gK3mKDTCQ&prev=/images%3Fq%3Dranger%28spacecraft%26N%3Den%26sa%3DX%26rlz%3D1T5GGLL_enUS253GB254%26tbm%3Disch&itbs=1

In Climate-like problems we have to deal with robots

Isaac Asimov's "Three Laws of Robotics"

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

http://www.auburn.edu/~vestmon/robotics.html

1. A computer simulation must not mislead a policymaker, or through inaction, allow a decision maker to be mislead.

2. A computer simulation may be post processed using state-of-the-art statistics/graphics expect where such post-processing would conflict with the First Law

3. A simulation may be improved (towards the Laws of Physics) so long as funding such improvement does not conflict with the First or Second Law.

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In Climate-like problems we have to deal with robots

Isaac Asimov's "Three Laws of Robotics"

0. A robot may not harm humanity, or, by inaction, allow humanity to come to harm.

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.

2. A robot must obey orders given it by human beings except where such orders would conflict with the First Law.

3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

0. A simulation must not harm the credibility of science, or, through inaction, allow the credibility of science to come to harm

1. A computer simulation must not mislead a policymaker, or through inaction, allow a decision maker to be mislead.

2. A computer simulation may be post processed using state-of-the-art statistics/graphics expect where such post-processing would conflict with the First Law

3. A simulation may be improved (towards the Laws of Physics) so long as funding such improvement does not conflict with the First or Second Law.

(With thanks to Ken Judd for the zeroth law.)

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Questions (mine)

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

If our model class does not admit an empirically empirically-adequate model …

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

The "truth" is out there -vs- there is no "truth". (There is no true model-state)

Is weighting models a nonsense?

We can extract insight, but not numbers. (IPCC model democracy is a distraction)

Is a prior on a model parameter a nonsense?

If the model parameter is empirically vacuous or the model class inadequate…

In weather-like problems, is it rational to treat predictive distributions as probability density functions?

No clear examples yet.

When might the Bayesian Way be the best available (in an *ad hoc* sorta way).

Do we have any laboratory experiments where Bayesian odds could survive?

Can model-based probabilities provide sustainable odds?

And if not? Non-probabilistic odds?

Is the Bayesian Way treacherous?

Costing us valuable insight, risking the public credibility of science, and introducing a new "spurious accuracy"

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

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Publications

http://www.lse.ac.uk/collections/cats/publications.htm

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Papers

R Hagedorn and LA Smith (2009) Communicating the value of probabilistic forecasts with weather roulette. *Meteorological Applications*16 (2): 143-155.

K Judd, CA Reynolds, LA Smith & TE Rosmond (2008) The Geometry of Model Error (DRAFT). *Journal of Atmospheric Sciences* 65 (6), 1749--1772.

K Judd, LA Smith & A Weisheimer (2007) How good is an ensemble at capturing truth? Using bounding boxes for forecast evaluation. *Q. J. Royal Meteorological Society*, **133** (626), 1309-1325.

J Bröcker, LA Smith (2008) From Ensemble Forecasts to Predictive Distribution Functions *Tellus A* 60(4): 663.

J Bröcker, LA Smith (2007) Scoring Probabilistic Forecasts: On the Importance of Being Proper *Weather and Forecasting* 22 (2), 382-388.

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Bayesian's Burden

Rev. T. Bayes

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

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

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

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

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

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

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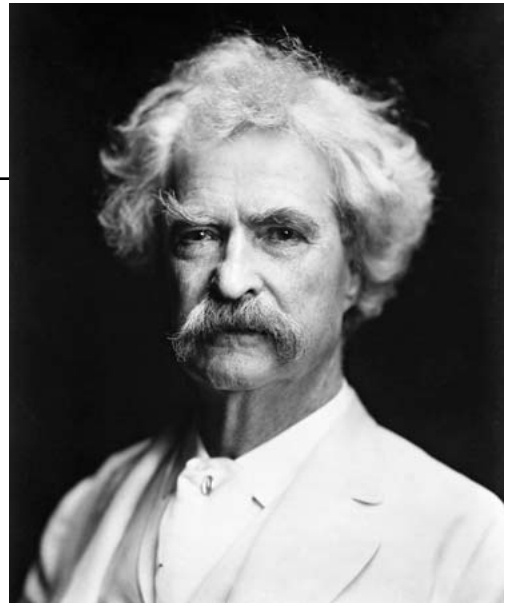
To the Physicist Sitting in Darkness



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

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

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

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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*

Columbus **(GA)** ***Enquirer*****, September 30, 1886**
ANOTHER AWFUL PROPHECY.
Mark Twain Comes to the Front With a Terrible Prediction.

WASHINGTON, September 29. - Mark Twain has entered the field of prediction and publishes in the *New York Sun* today the following:

As a result of the most careful observation of the aspect of the fixed stars during the past two months as affected by the remarkable changes now going on in the great nebula Cassiopeia, I am able to state with absolute certainty that by far the most awful disaster that has ever befallen the globe since its creation will occur on the 3d of October at 9:42 in the evening. The agent will be a meteoric stone -- a meteoric world, indeed, since its mass will be one-eighth as great as that of our own sphere. It will first come in sight about half way between the constellation of the Great Bear and the North Star, and will make the circle of the southern skies, and then sweep northward with immeasurable rapidity, turning the night of this whole Continent into a red glare of the most blinding intensity. As it approaches Canada it will make a majestic downward swoop in the direction of Ottawa, affording a spectacle resembling a million inverted rainbows woven together, and will take the Prophet Wiggins right in the seat of his inspiration and lift him straight up into the back yard of the planet Mars, and leave him permanently there in an inconceivably mashed and unpleasant condition. This can be depended on.

MARK TWAIN.

HARTFORD, Monday.

http://www.twainquotes.com/Prophecy.html

Don't never prophesy: If you prophesies right, ain't nobody going to remember and if you prophesies wrong, ain't nobody going to let you forget.
Attributed by Chis Chatfield (Time Series Forecasting ISBN 978-1-58488-063-9)

© Leonard Smith

See also Radio 4's GQT!

What is climate?

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

Robert Heinlein (1973)

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

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

Summary for Policymakers

Drafting Authors:

Draft Contributing Authors:

This Summary for Policymakers should be cited as:

GLOSSARY OF METEOROLOGY

Edited by RALPH E. HUSCHKE

Sponsored by

U. S. Department of Commerce Weather Bureau

U. S. Air Force Air Weather Service, MATS and Geophysics Research Directorate AFCRC, ARDC

U. S. Army Signal Corps

U. S. Navy Office of Naval Research

AMERICAN METEOROLOGICAL SOCIETY Boston, Massachusetts 1959

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

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

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(Re)Defining Climate

This definition more or less rules out many physically interesting "extreme events" a priori.

GLOSSARY OF METEOROLOGY

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- **climate**—The slowly varying aspects of the atmosphere–hydrosphere–land surface system.
  It is typically characterized in terms of suitable averages of the climate system over periods of a month or more, taking into consideration the variability in time of these averaged quantities. Climatic classifications include the spatial variation of these time-averaged variables. Beginning with the view of local climate as little more than the annual course of long-term averages of surface temperature and precipitation, the concept of climate has broadened and evolved in recent decades in response to the increased understanding of the underlying processes that determine climate and its variability. *See also* climate system, climatology, climate change, climatic classification.

- **variability**—Mathematically, same as spread.

- **spread**—1. (Also called variability.) The general departure of individual values from central tendency.
  Spread is reflected geometrically in the probability curve as the width of the region over which the probability density is appreciable. *See* scatter, variance. 2. Popular contraction for dewpoint spread.

- **central tendency**—In statistics, the general level, characteristic, or typical value that is representative of the majority of cases.
  Among several accepted measures of central tendency employed in data reduction, the most common are the arithmetic mean (simple average), the median, and the mode.

http://amsglossary.allenpress.com/glossary/search?id=climate1

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CATS CENTRE FOR THE ANALYSIS OF TIME SERIES

Are Projections just Predictions?

All predictions are conditioned on something(s); if we ran2011 models in 2050 would they admit shadowing trajectores?

Met Office

Hadley Centre
for Climate Predictions and Research

http://www.metoffice.gov.uk/publications/HCTN/HCTN_20.pdf

GLOSSARY OF METEOROLOGY

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- **climate prediction**—The prediction of various aspects of the climate of a region during some future period of time.

  Climate predictions are generally in the form of probabilities of anomalies of climate variables (e.g., temperature, precipitation), with lead times up to several seasons (*see* climate anomaly). The term "climate projection" rather than "climate prediction" is now commonly used for longer- range predictions that have a higher degree of uncertainty and a lesser degree of specificity. For example, this term is often used for "predictions" of climate change that depend on uncertain consequences of anthropogenic influences such as land use and the burning of fossil fuels.

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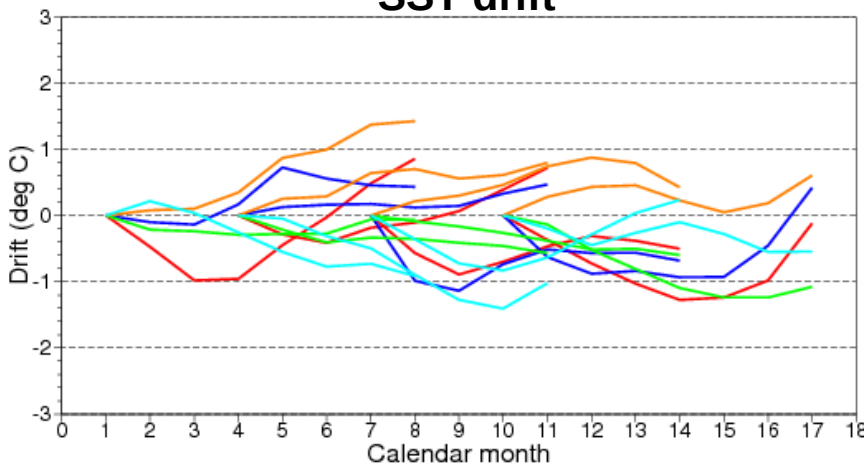
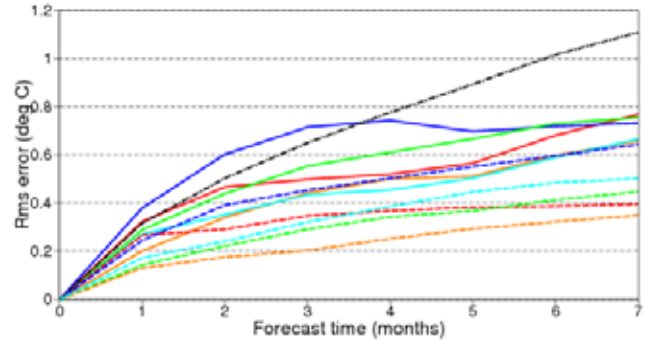
In practice, systematic errors in seasonal forecasting ("drift") are significant: about one degree, while the seasonal range of **Niño3** is only ~4 degrees!

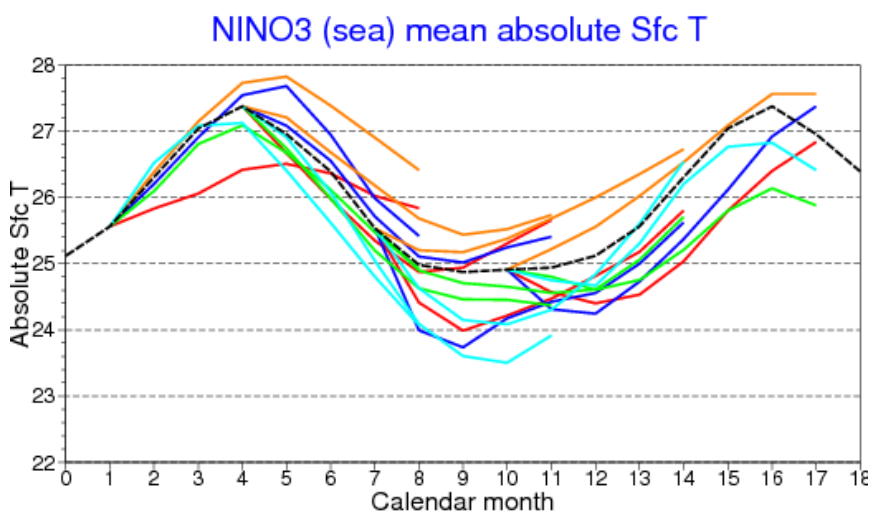
Météo France
IfM Kiel
INGV
ECMWF
Met Office

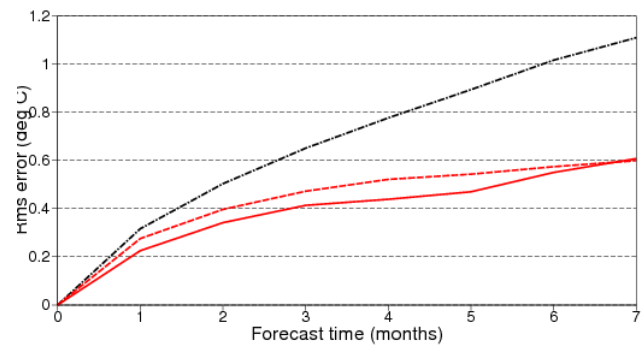
SST drift





RMSE and ensemble spread





multi-model RMSE

ensemble spread

persistence forecast

ENSEMBLES multi-model: Niño3 SST

Thanks to Antje Weisheimer

Demonstrations of local skill against climatology on EQUIP timescales (months).

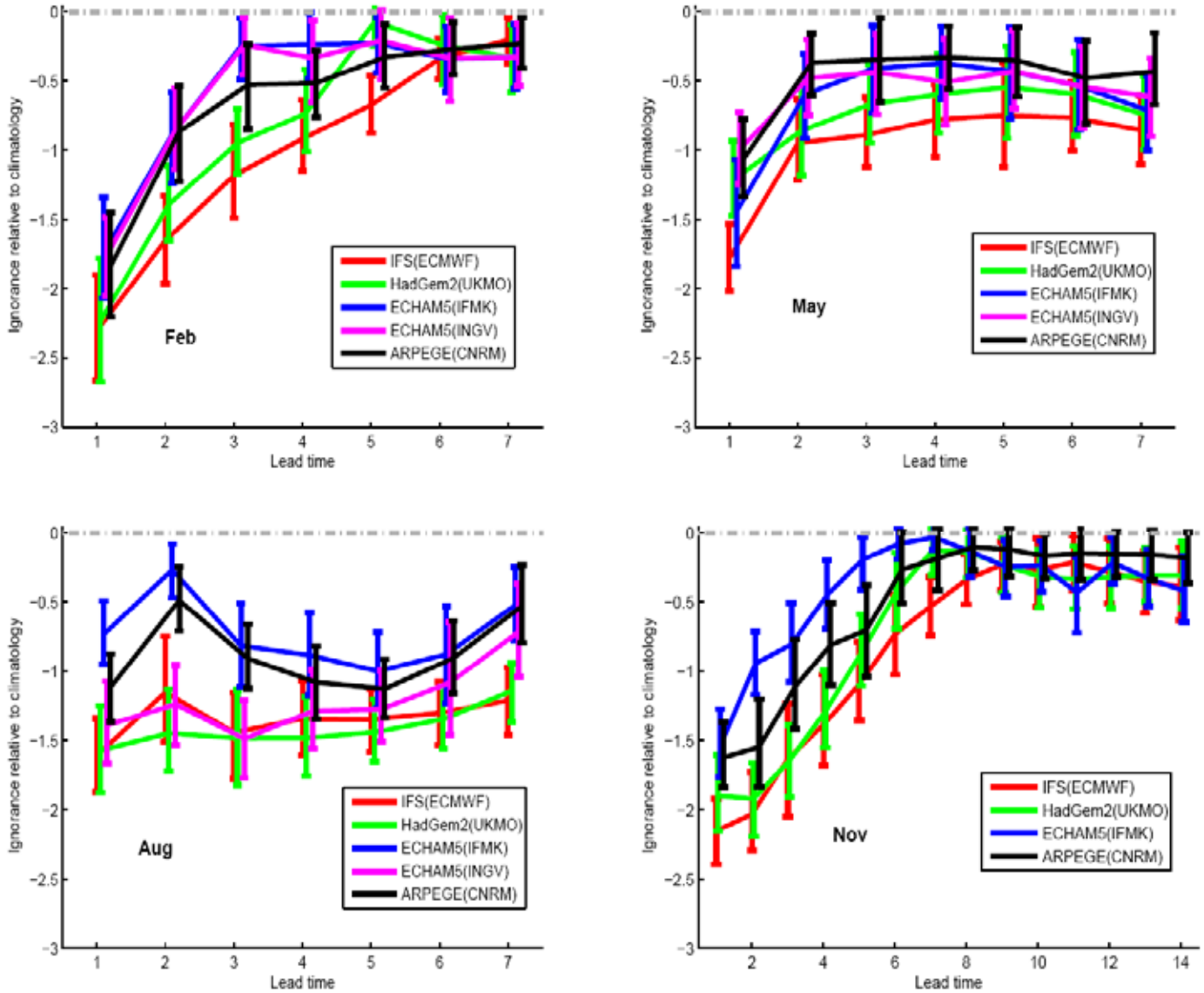


Fig 1: Ignorance score of each model forecast of SST in the Nino3.4 region

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Demonstrations of local skill against climatology on EQUIP timescales (months).

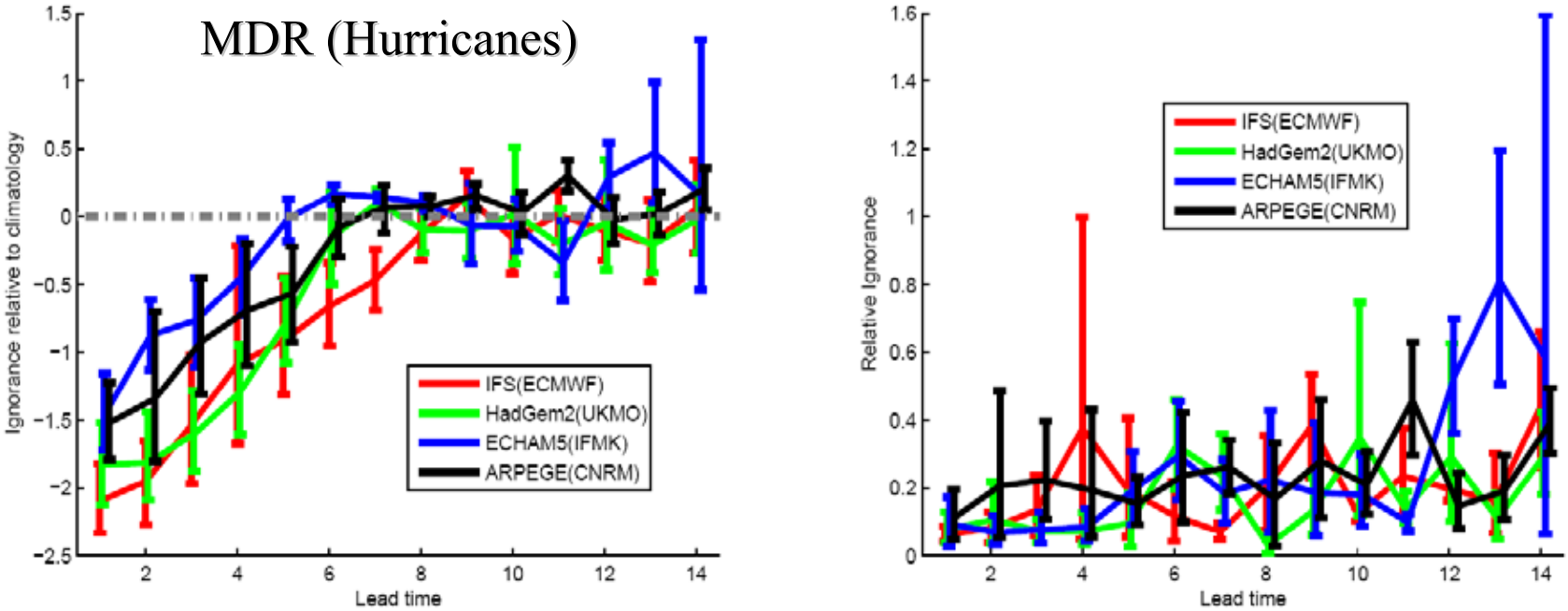


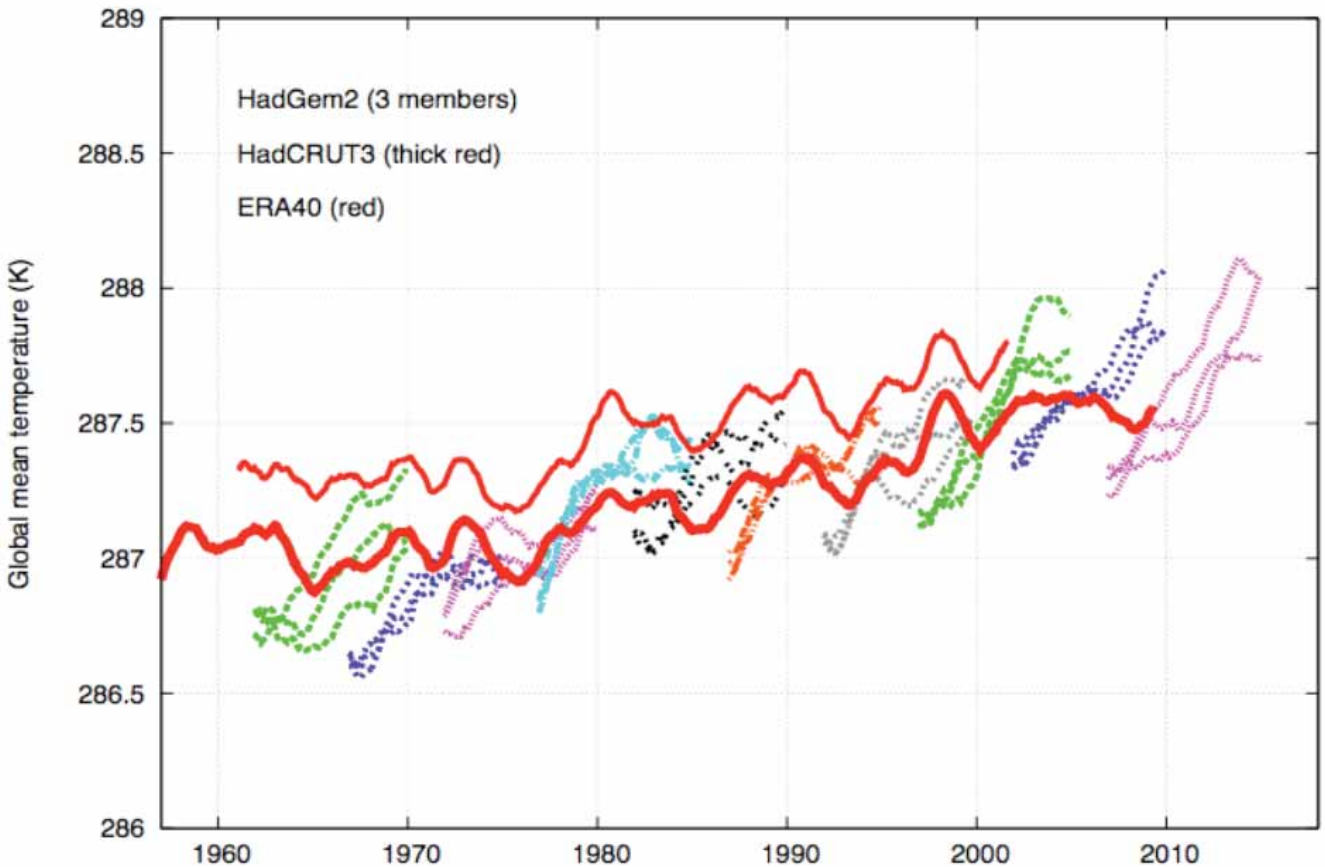
Fig 4: a)Ignorance score of ECMWF ensemble forecasts relative to climatology using truly leave one out cross-validation, b) Ignorance score of ECMWF ensemble forecasts, true leave-one-out cross-validation relative to leave one out cross-validation.

Even on seasonal scales, forecast-outcome pairs are precious.

("Information contamination" happens in CATS, statistical good practice is required.)

RMS is an actively misleading evaluation statistic for probabilistic skill.

Decadal Forecasting *at global scales.*



Back off on "Laws of Physics" justification if post processing is required.
Transparent forecast evaluation in empirical units of interest.
Careful (true) cross-validation. (And some *arguably* true out-of-sample)
Quantitative documentation of historical forecasts (for intercomparison)

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PDFs from dressed decadal forecasts

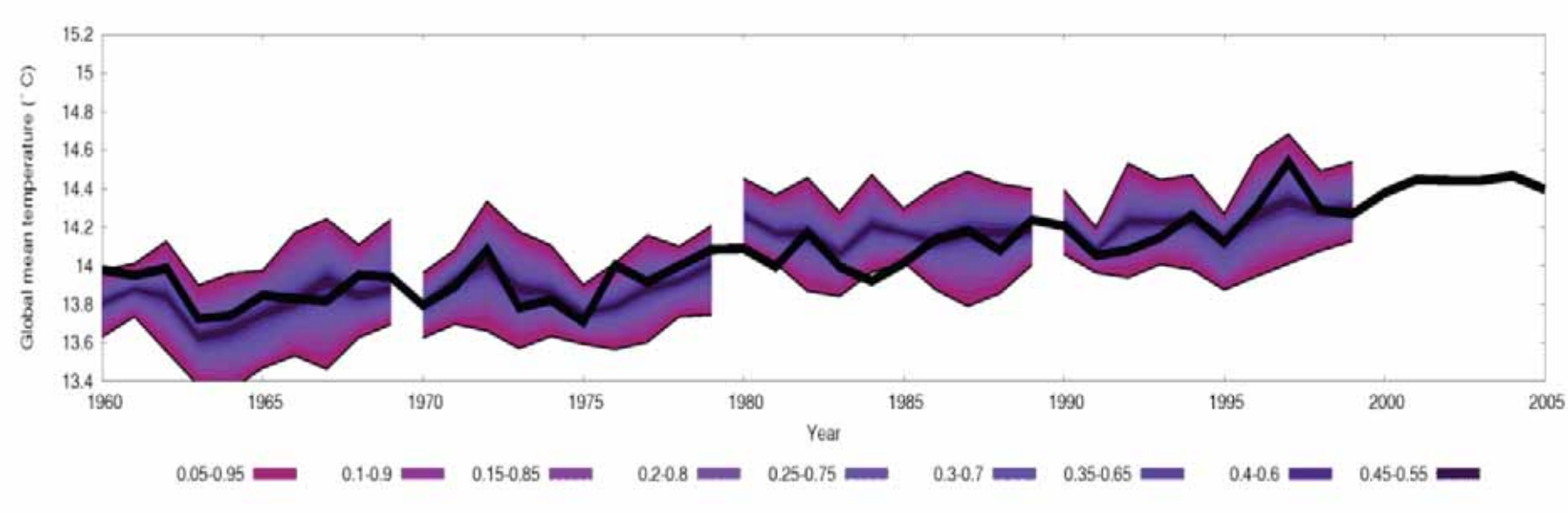

Figure 2: Predictive distributions (percentile ranges as indicated) of global mean temperature for the HadGEM2 model from the ENSEMBLES decadal simulations for launch dates at 10 year intervals.

Post processing is required even at global scales (more than a map from model space!)

RAP is a simple analogue-based method, above ALL analogues are used (untuned).
Does the greater skill of a GCM cover its cost? (Does it have greater skill?)

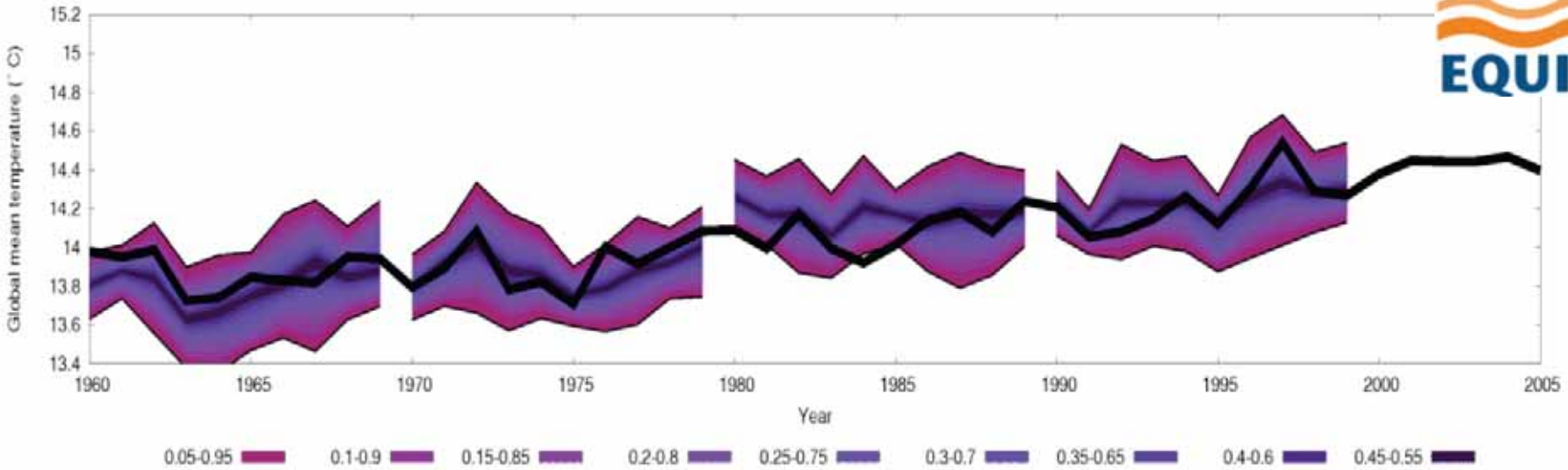

Figure 2: Predictive distributions (percentile ranges as indicated) of global mean temperature for the HadGEM2 model from the ENSEMBLES decadal simulations for launch dates at 10 year intervals.

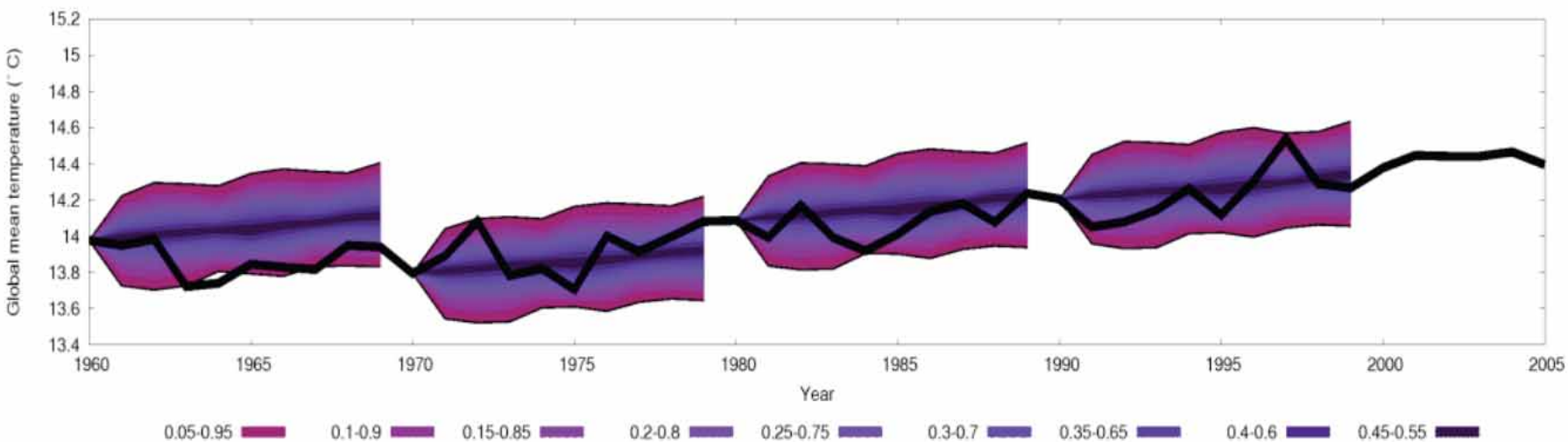

Figure 3: Predictive distributions for global mean temperature using the direct RAP model.

ith

The Value of GCM output is not overwhelming *even at global scales*.

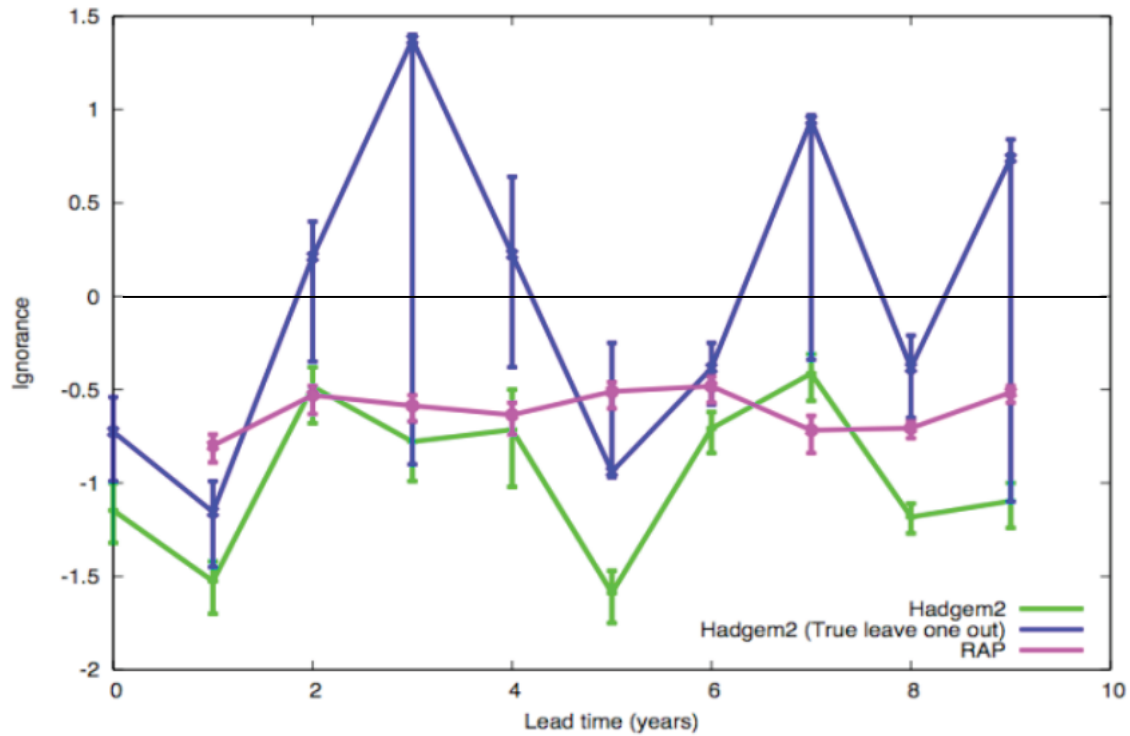

Figure 4: Ignorance as a function of lead time for the HadGEM2 and RAP models. The uncertainty bars are the 70th percentile from re-sampling from the forecast set. Lower values indicate better skill.

If GCM outperforms RAP on GMT by about one bit (that is twice the prob mass).

For which questions does the greater skill of a GCM cover its cost?
Does it really have greater skill? (Better Statistical Practice?)

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As we move to smaller spatial scales, when, where and at what lead-times will simulation models lose their relative skill?

As more and more statistical models are tested, how do we quantify the statistical significance of the nth model?

(What level of performance can we expect in real time?)

Good experimental design is required (i.e. specifying the order of locations examined) if statistical significance is to be assigned to local predictions.

(Scanning the globe for regions of skill is a nonsense)

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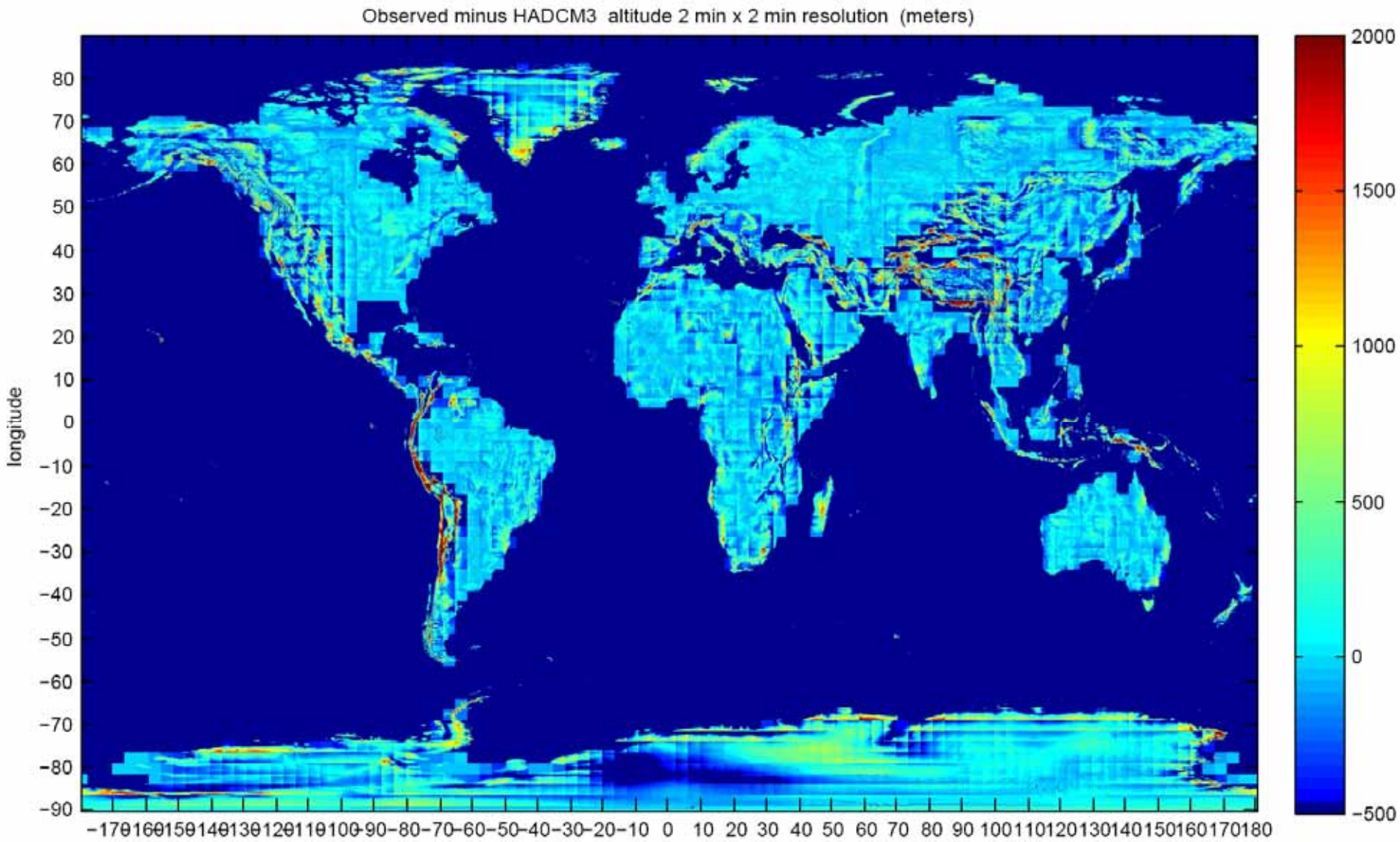
Common, nontrivial, systematic errors



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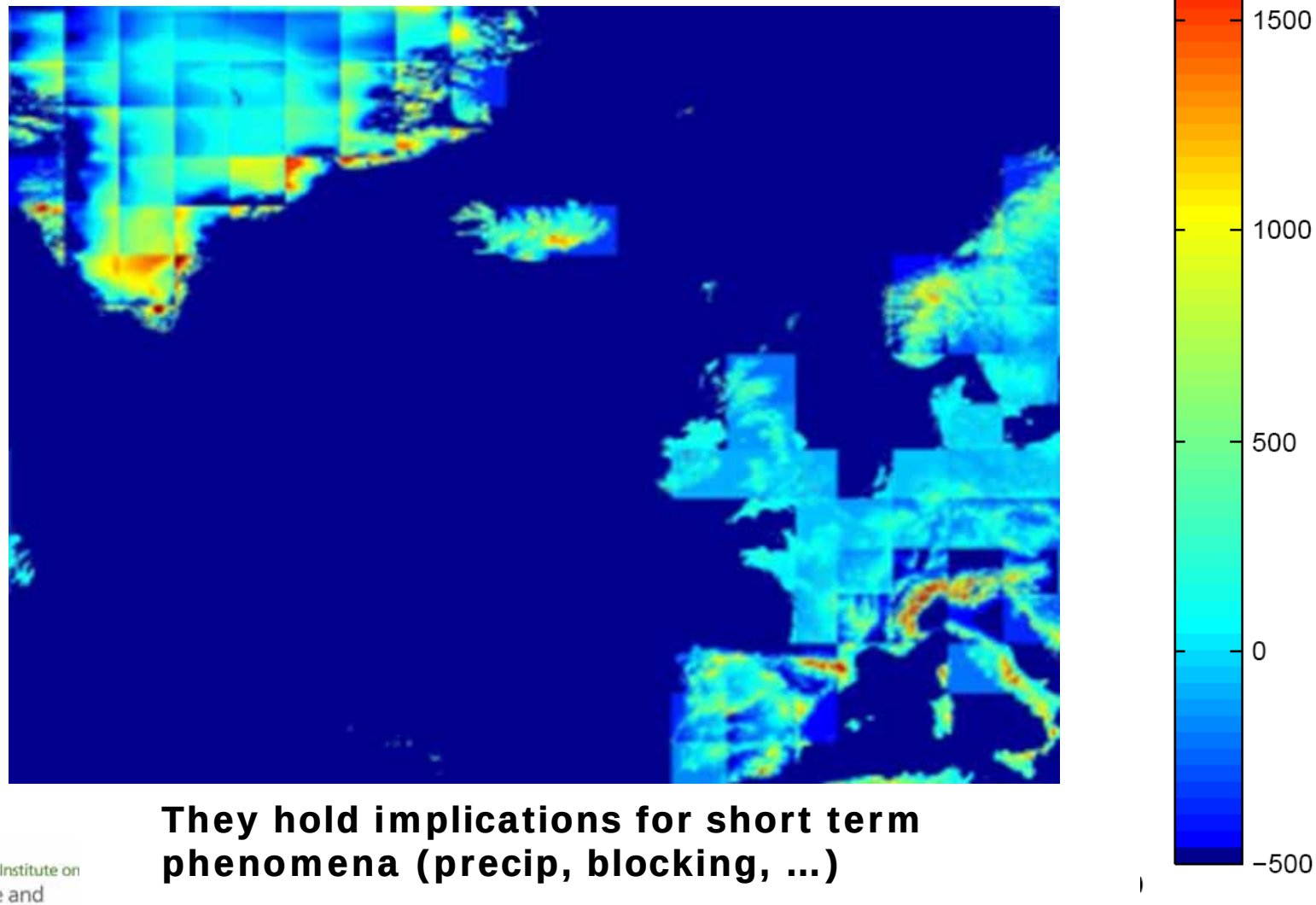
Missing Mountains: The fine structure shows what is missing.
Each AR4 model suffers from related inadequacies

© Leonard Smith

These are not small errors. Sometimes over one kilometre !
And they are shared by all (today's) models!



They hold implications for short term phenomena (precip, blocking, …)

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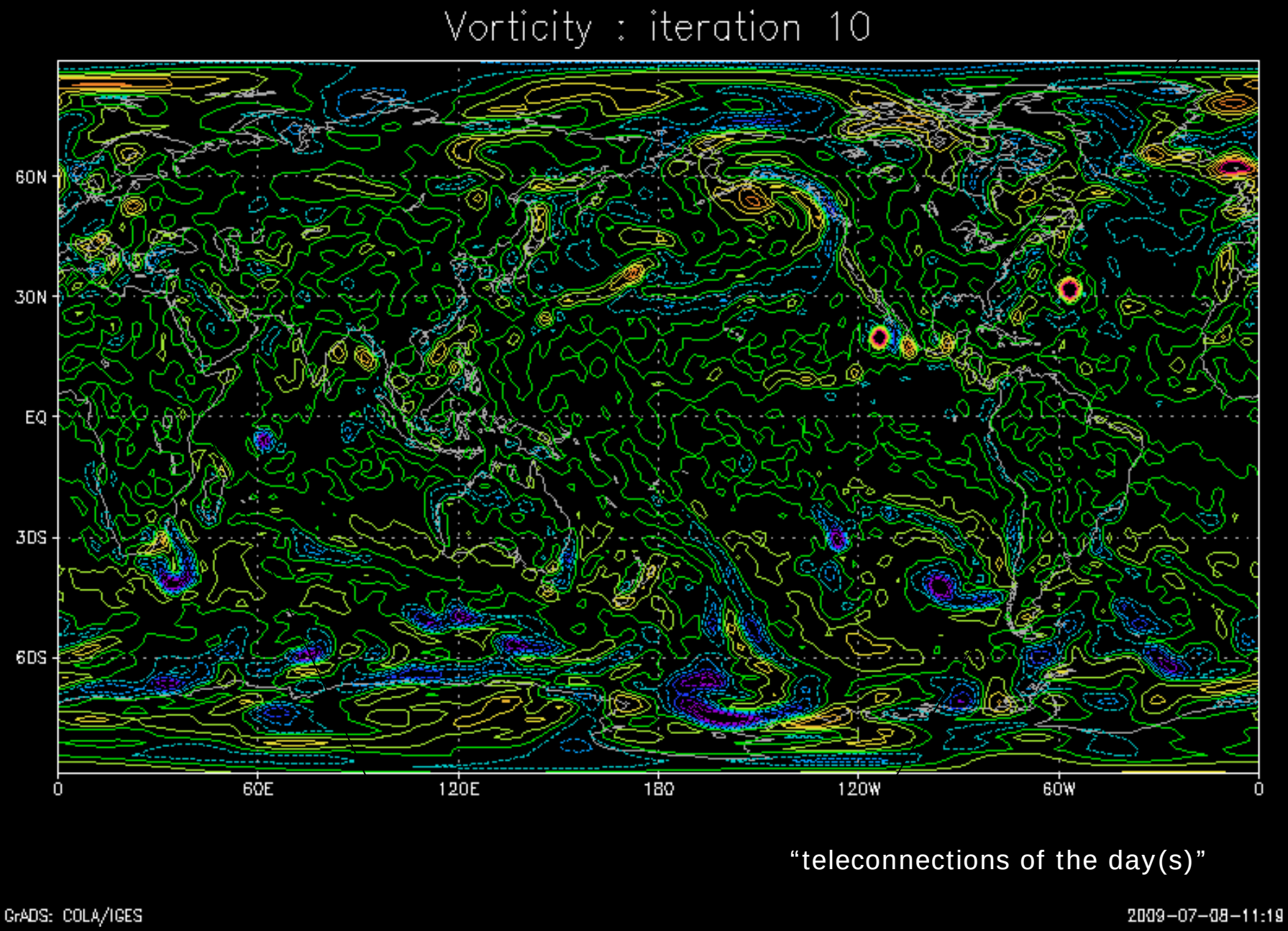
Thanks to Kevin Judd



“teleconnections of the day(s)”

There is no stochastic fix:

After a flight, the series of control perturbations required to keep a by-design-unstable aircraft in the air look are a random time series and arguably are Stochastic.

But you cannot fly very far by specifying the perturbations randomly!

Think of WC4dVar/ ISIS/GD perturbations as what is required to keep the model flying near the observations: we can learn from them, but no "stochastic model" could usefully provide them.

With the Eurofighter Typhoon, in subsonic flight the pressure point lies in front of the centre of gravity, therefore making the aircraft aerodynamically unstable, and is why Eurofighter Typhoon has such a complex Flight Control System – computers react quicker than a pilot.

When Eurofighter Typhoon crosses into supersonic flight, the pressure point moves behind the centre of gravity, giving a stable aircraft.

The advantages of an intentionally unstable design over that of a stable arrangement include greater agility – particularly at subsonic speeds - reduced drag, and an overall increase in lift (also enhancing STOL performance).

Which is NOT to say stochastic models are not a good idea:
Physically it makes more sense to include a realization of a process rather than it mean!
But that will not resolve the issue of model inadequacy, even as it give us a better model class!

It will not yield decision-relevant PDFs!

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Can we be more transparent on inadequacy?

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Report from the Review of the Methodology used for the UKCP climate change projections

13 and 14 January 2009

. It should give very firm guidance as to the uses that should and should not be made of the data, with concrete examples where possible. In particular it should include

probabilities (discussed in detail in the technical documentation), and detailed discussion of how the projected probabilities should be interpreted, and what they can and cannot be used for. Examples of analyses using projection products based on more traditional

http://ukclimateprojections.defra.gov.uk/images/stories/Other_images/UKCP09_Review.pdf

---

. Careful evaluation of such diagnostics from the RCM simulations and the weather generators is recommended in cases where such variability is important to the individual user.

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

LAS: "If one is sensitive to the duration, intensity and frequency of "blocking events" then the UKCP PDFs should not be used (as PDFs)in expected utility analysis.

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How is a User to judge if UKCIP PDFs are informative?
A Schematic of a Test For Quantitative Decision Relevance

- 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 (which are 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")).
- Are all 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.

Sit and think will trump Simulate and Count

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Moving Forward

We need to lower the bar. Clearly state that:

- We have very little robust quantitative information for adaptation decisions
- The level of systematic model inadequacy in today's GCMs implies we will have to make decisions without robust or representative PDFs
  - Climate science may play a larger role than climate modelling
- Planners using UKCP PDFs as PDFs can expect "big surprises"

Can we find a constructive way to

- Review and critically evaluate UKCP worked examples. **[Prob(Big Surprise)]**
- Evaluate and advertise the challenges to interpreting state-of-the-art models in support of adaptation.
- Pose methods to clarify that deep uncertainty at the local space and time scales relevant adaptation does not suggest uncertainty in the need for mitigation of global warming.

These challenges exist in other countries too: the UK can lead the world in addressing the limitations of the science without fear of the sceptics!

© Leonard Smith

Hard tasks: Depreciating Oversell

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

UK CLIMATE PROJECTIONS

UKCP09 in practice: Good practice

UKCP09 Guidance
Getting started
Data sources
Products
UKCP09 in practice
Good practice
Case study
Table of worked examples
Inappropriate uses
FAQ
Glossary

Using UKCP09 to...

Keywords	Data source used	Organisation	Probability level	Emission scenario
Provide guidance on how to prepare for climate change				
Defra, government, communication	• Probabilistic climate change projections (land)	Defra	10 to 90	Low, medium, high
Assess adaptation measures				
Built environment, adaptation	• Probabilistic climate change projections (land)	CIBSE/ARUP	10, 50, 90	Medium, high
Investigate impacts & implications for management policies				
Impacts, management policies, coastal, habitats, visitors	• Probabilistic climate change projections (land) • Storm surge • Sea level rise	Pembrokeshire Coast National Park	10 to 90	Low, medium, high
Perform a local climate impacts profile (LCLIP)				
LCLIP, vulnerability, city council	• Weather Generator	Leeds City Council	N/A	Medium
Inform integrated land use planning				
Under development	• Under development	Macaulay institute	Under development	Under development
Inform sector-specific capacity building				
Cider, capacity building	• Probabilistic climate change projections (land) • Weather Generator	National Association of Cider Makers	N/A	Medium
Perform a marine spatial assessment				
Marine, spatial assessment	• Probabilistic climate change projections (marine) • Multi-level ocean projections	CEFAS	10,50,90	Medium
Model impacts 1				
RCM, impacts, river flow	• 11-member RCM	CEH / Met Office Hadley Centre	N/A	Medium
Model impacts 2				
Forestry, modelling impacts	• weather generator	Forestry Commission	N/A	Medium
Inform strategic investment & adaptation policy (storm surge)				
Under development	• Under development	Risk Management Solutions	Under development	Under development
Inform strategic investment & adaptation policy (inland flooding)				
Adaptation, strategy, flood, model	• Probabilistic climate change projections (land)	Risk Management Solutions	10, 50, 90	Low, medium, high
Perform an impacts & opportunity analysis				
Under development	• Under development	South West Tourism / Environment Agency / SWCCIP	Under development	Under development

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Having raised expectations, these promises cannot just vanish from the website.

But perhaps we could rate each of the worked examples separately on

Robust,
Representative
Relevant

They would each score high on Relevant, and provide a better guide for good practice…

…and illustrate likely value added by the models using the evaluation schematic?

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vvu

I do nothave time to discuss the UKCP worked examples…

UK CLIMATE PROJECTIONS

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- Products
- UKCP09 in practice
  - Good practice
  - Case study
  - *Table of worked examples*
  - Inappropriate uses
- FAQ
- Glossary

Using UKCP09 to...

Keywords	Data source used	Organisation	Probability level	Emissions scenario
Provide guidance on how to prepare for climate change				
Defra, government, communication	• Probabilistic climate change projections (land)	Defra	10 to 90	Low, medium, high
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Built environment, adaptation	• Probabilistic climate change projections (land)	CIBSE/ARUP	10, 50, 90	Medium, high
Investigate impacts & implications for managment policies				
Impacts, management policies, coastal, habitats, visitors	• Probabilistic climate change projections (land) • Storm surge • Sea level rise	Pembrokeshire Coast National Park	10 to 90	Low, medium, high
Perform a local climate impacts profile (LCLIP)				
LCLIP, vulnerability, city council	• Weather Generator	Leeds City Council	N/A	Medium
Inform integrated land-use planning				
Under development	• Under development	Macaulay institute	Under development	Under development

I do not have time to discuss the UKCP worked examples…
But each of these makes naïve realist assumptions

UK CLIMATE PROJECTIONS

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UKCP09 in practice: Leeds City Council

UKCP09 Guidance

UKCP09 in practice

- **Good practice**
- Table of worked examples
- **Inappropriate uses**

Keywords for this example:

LCLIP, vulnerability, weather generator, city council

Leeds CITY COUNCIL

UK Climate Impacts Programme

UKCP09 Guidance to perform a Local Climate Impacts Profile

Objectives: To assess Leeds city's current vulnerability to climate impacts and hence develop an adaptation plan for future climate change that draws on past experience about vulnerable areas.

- **How they used UKCP09 dummy data**
  - It was assumed that any winter month with wet soil conditions, followed by 50mm of rainfall in one day/night lead to fluvial flooding in the catchment
  - 100 runs of the weather generator were completed for both the baseline and future time periods.
  - The threshold detector was used to determine both the frequency of the known threshold (as outlined in step1) being exceeded in the baseline and how it may change in the future data.
- **What could they do next?**
- **What they learnt about UKCP09**

Contact details: David Cherry, Development Department, *Leeds City Council*

Selections made:

Data source: Weather generator

UKCP09 Product: Weather generator output, threshold detector

Other products: None

Climate variables: Rainfall

Emission scenario: Medium

Time period: 2040s

Temporal averaging: Seasonal (winter)

Spatial averaging: 5 km grid squares

Location: The Wyke beck catchment in the Leeds area

Probability level: N/A

Simulate and Count

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I do not have time to discuss the UKCP worked examples…
But each of these makes naïve realist assumptions

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UKCP09 in practice: Leeds City Council

UKCP09 Guidance

UKCP09 in practice

Good practice

Table of worked examples

Inappropriate uses

Keywords for this example:

LCLIP, vulnerability, weather generator, city council

Leeds CITY COUNCIL

UK Climate Impacts Programme

UKCP09 Guidance to perform a Local Climate Impacts Profile

Objectives: To assess Leeds city's current vulnerability to climate impacts and hence develop an adaptation plan for future climate change that draws on past experience about vulnerable areas.

- **How they used UKCP09 dummy data**
- **What could they do next?**
  - From the information gained for the threshold detector analysis, a cost-benefit risk assessment could be undertaken, possibly using the internal city council risk assessment approaches used for developing the community risk register.
  - The UKCIP Adaptation Wizard could be used to develop an adaptation strategy.
  - Might undertake a roadshow educating other groups of services within the Leeds City Council on how to conduct their own risk assessment.
- **What they learnt about UKCP09**

Contact details: David Cherry, Development Department, *Leeds City Council*

Selections made:

Data source: Weather generator

UKCP09 Product: Weather generator output, threshold detector

Other products: None

Climate variables: Rainfall

Emission scenario: Medium

Time period: 2040s

Temporal averaging: Seasonal (winter)

Spatial averaging: 5 km grid squares

Location: The Wyke beck catchment in the Leeds area

Probability level: N/A

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UKCP09 in practice: Defra

UKCP09 Guidance

UKCP09 in practice

Good practice

Table of worked examples

Inappropriate uses

Keywords for this example:

Defra, government, communication, guidance, probabilistic climate projections

UKCP09 Guidance to provide guidance on how to prepare for climate change

Objectives: To provide step-by-step guidance to farmers and land managers on how to use UKCP09. This work, which is part of Defra's new adaptation project in its Farming for the Future programme, will allow Defra to communicate the range of possible climate changes to farmers and land managers. They, in turn, will be able to use the information to identify their vulnerability to climate, assess their attitude to risk and make informed decisions about whether they might need to change their agricultural practices in response to climate change.

- **How they used UKCP09 dummy data**
  - Information from the Climate of the UK and Recent Trends Report were used to communicate to farmers, through summary statements, what climate changes the UK has experienced to date. This will allow the farmers to assess their current vulnerability to climate, if they are aware of their vulnerability thresholds.
  - The UKCP09 national key findings were used to provide farmers with the 10% – 90% probability ranges for future winter precipitation and summer temperature for the 2050s assuming all three emission scenarios. (These variables were used as an example as they will be of general relevance to all farmers and land managers. However, the process could apply to any variables that are of relevance to farmers and land managers). This will allow the farmers to assess the probability of a threshold of importance to them being exceeded for a given emission scenario (subject to the strength of evidence).

Selections made:

Data source: Probabilistic Climate Change Projections (land)

UKCP09 Product: Key Findings, Climate of the UK and Recent Trends Report, Cumulative Distribution functions

Other products: None

Climate variables: Precipitation (winter) and Temperature (summer)

Emission scenario: Low, Medium, High

Time period: 2050s

Temporal averaging: Seasonal (winter and summer)

Spatial averaging: 25 km grid squares

Location: UK

Probability level: 10 to 90

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UKCP09 in practice: Chartered Institute of Building Services Engineers

UKCP09 Guidance

UKCP09 in practice

- **Good practice**
- Table of worked examples
- **Inappropriate uses**

Keywords for this example:

Built environment, probabilistic climate projections, adaptation

ARUP

CIBSE

UK Climate Impacts Programme

UKCP09 Guidance to assess adaptation measures

Objectives: To consider how UKCP09 may be used in simulating the thermal properties of buildings under the future climate. The range of projections is used to explore overheating risk in a living room of a 1930s semi-detached house, both with and without adaptation measures.

- **How they used UKCP09 dummy data**
- **What could they do next?**
  - By modeling all three cases they would be able to compare the effectiveness of adaptation measures and the risk associated with each climate change projection.
  - Recommendations could be made on the most financially beneficial options.
- **What they learnt about UKCP09**

Contact details: Rachel Capon, *ARUP*, Anastasia Mylona, *CIBSE*

- Click here for full report (pdf, 215 KB)

Selections made:

Data source: Probabilistic Climate Change Projections (land)

UKCP09 Product: Customisable maps

Other products: None

Climate variables: Temperature

Emission scenario: Medium, High

Time period: 2050, 2080s

Temporal averaging: Monthly

Spatial averaging: 25 km grid squares

Location: London

Probability level: 10, 50, 90

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UKCP09 in practice: Forest Research

UKCP09 Guidance

UKCP09 in practice

Good practice

Table of worked examples

Inappropriate uses

Keywords for this example:

Forestry, probabilistic climate projections, practices

Forest Research

UK Climate Impacts Programme

UKCP09 Guidance to support change in management practice

Objectives: To assess whether current tree species choice will remain appropriate with climate change by considering the risk of damaging threshold moisture deficits being exceeded. The study aims to assess if and where drought sensitive species e.g. Sitka spruce, are likely to be affected by high summer moisture deficits (moisture deficits exceeding 180 mm).

- **How they used UKCP09 dummy data**
  - The impact of the change in future rainfall was calculated from the underlying data associated with the maps of UK summer rainfall for the time periods and probability levels specified alongside. Post-launch this data is available as the CDF data.
  - As evaporation data was not supplied with the dummy data, the 1961-90 baseline evaporation data was used to represent both the baseline and the future climate.
  - New maps were produced from a GIS analysis, and were used to show the future regional distribution of areas equal to or exceeding a moisture deficit of 180 mm.
  - The probability maps of moisture deficit were combined to show the distribution of the likelihood of areas considered too dry to plant drought sensitive tree species in the future climate.

Selections made:

Data source: Probabilistic Climate Change Projections (land)

UKCP09 Product: Pre-prepared maps, customisable maps

Other products: None

Climate variables: Precipitation

Emission scenario: Low, Medium, High

Time period: 2050s, 2080s

Temporal averaging: Seasonal (summer)

Spatial averaging: 50 km grid squares

Location: UK

Probability level: 10, 50, 90

Simulate and Count

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UKCP09 in practice: Forest Research

UKCP09 Guidance

UKCP09 in practice

Good practice

Table of worked examples

Inappropriate uses

Keywords for this example:

Forestry, probabilistic climate projections, practices

Forest Research

UK Climate Impacts Programme

UKCP09 Guidance to support change in management practice

Objectives: To assess whether current tree species choice will remain appropriate with climate change by considering the risk of damaging threshold moisture deficits being exceeded. The study aims to assess if and where drought sensitive species e.g. Sitka spruce, are likely to be affected by high summer moisture deficits (moisture deficits exceeding 180 mm).

- **How they used UKCP09 dummy data**
- **What could they do next?**
  - Using the resultant maps, forest managers could assess the degree of risk they are willing to accept in considering planting drought sensitive tree species for their area of management.
  - Strategic forest planners could also use the information to guide incentives to encourage climate change adaptation in tree species choice and in alternative forest management systems.
- **What they learnt about UKCP09**

Contact details: Duncan Ray, Ecology Division, *Forest Research*

- Click here for full report (pdf, 80 KB)
- Forest Research
- Forest Research Scotland
- Forest Research Wales

Selections made:

Data source: Probabilistic Climate Change Projections (land)

UKCP09 Product: Pre-prepared maps, customisable maps

Other products: None

Climate variables: Precipitation

Emission scenario: Low, Medium, High

Time period: 2050s, 2080s

Temporal averaging: Seasonal (summer)

Spatial averaging: 50 km grid squares

Location: UK

Probability level: 10, 50, 90

Simulate and Count

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UKCP09 in practice: Countryside Council for Wales

UKCP09 Guidance

UKCP09 in practice

Good practice

Table of worked examples

Inappropriate uses

Keywords for this example:

Defra, government, communication, guidance, probabilistic climate projections

Cyngor Cefn Gwlad Cymru
Countryside Council for Wales

UK Climate Impacts Programme

UKCP09 Guidance to investigate impacts

Objectives: To obtain location-specific information to explore the potential altitudinal changes in snowfall in the Snowdonia area under climate change.

- **How they used UKCP09 dummy data**
  - In order to cut down on resource requirements it was decided to use one weather generator grid square. Although the weather generator incorporates altitudinal information, an approach was taken to calibrate one weather generator grid square output for altitude based on observed lapse rates.
  - Meteorological observations were only available at 500m and sea level (0m) for the areas in question. From those stations, the lapse rate of 0.6°C/100m was determined in order to scale to different altitudes (Snowdonia is 1085m high). Additionally, a correction for the fact that it often rains at altitude in the mountains when it does not at the coast was incorporated.
  - The weather generator was run for one grid square 100 times for the baseline and the future to produce hourly data for both 30-year time periods. This data was then scaled to altitudes of 500m to 1000m at 100m intervals using the lapse rate and correction factor for rainfall determined through analysis of observed data.
  - The occurrence of precipitation and temperature less than 0°C was used to estimate snow cover during the day at different altitudes for both the baseline and the future. The hourly approach was taken to avoid overestimating the amount of snowfall in one day by using daily minima.

Selections made:

Data source: Weather Generator

UKCP09 Product: Weather Generator output

Other products: None

Climate variables: Precipitation, temperature

Emission scenario: Medium

Time period: 2080s

Temporal averaging: Seasonal (Winter hourly data)

Spatial averaging: 5 km grid squares

Location: Snowdonia

Probability level: N/A

Simulate and Count

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UKCP09 in practice: acclimatise

UKCP09 Guidance

UKCP09 in practice

- **Good practice**
- Table of worked examples
- **Inappropriate uses**

Keywords for this example:

Energy, sustainability, weather generator, threshold detector

acclimatise

UK Climate Impacts Programme

UKCP09 Guidance to perform a sustainability assessment

Objectives: To determine how many times in the future a known threshold might be crossed to ensure energy use sustainability in a school and perform a cost-benefit analysis on adaptation measures. The school is new-build so if operation of the school requires more energy than specified in the building contract then the contracting developer is held accountable.

- **How they used UKCP09 dummy data**
  - It is known that a persistently warm minimum temperature (exceeding 16° for three nights in a row) makes the building uncomfortably warm during the day.
  - This was used as a threshold for analysis in the threshold detector and was defined, in this case, as a *heatwave*. This is a user-defined heatwave and not the same as the pre-defined heatwave in the threshold detector.
  - By analysing the weather generator output with the threshold detector, an increase in frequency in comparison to the baseline climate was presented in a table showing the range of error in the threshold detector output and the average value, for each season (this is standard output from the threshold detector).
  - A number of adaptation measures were suggested to manage these climate risks.

Selections made:

Data source: Weather generator

UKCP09 Product: Weather generator output, Threshold detector

Other products: None

Climate variables: Temperature

Emission scenario: Medium

Time period: 2080s

Temporal averaging: Seasonal

Spatial averaging: 5 km grid squares

Location: Gordon Heights School (fictitious)

Probability level: N/A

Simulate and Count

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How do we reduce these risks?

Lower the bar: Openly admit the difficulty of quantitative support for adaptation decisions

Curtail the apparent aim for "Plausible deniability"
(embrace the insights of the Hoskin's review, do not reword around them)

Manage expectations: find ways for the advancement of science to be seen as a "good thing" by users.

Usual scathing scientific criticism of the overselling of current insights ("Climate Proofing" ...), especially by commercial enterprises and government departments.

> *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

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

How would a society learn to make such decisions?

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

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Overview(1)

Climate GCMs are large nonlinear models.

Robustness of warming to model structure is a plus.

It is a nonsense to assume anomalies are informative for local details
(if the laws of physics respected such transformations,
we would not need such big nonlinear models: water freezes at…)

Is it not a nonsense to assume such models can be scientifically informative on time scales where local feedbacks are nontrivial?

Presenting anomalies in such misleading ways begs misinterpretation.
(not to mention risking our credibility)

So what are we to do given such large systematic errors?

1) **Aim for insight, not numbers.**
2) **Quantify the probability of model irrelevance (with lead time).**
3) **Demonstrate that they can, in fact, shadow the obs. (after projection)**

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As of last week:

PCMDI - Program For Climate Model Diagnosis and Intercomparison

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CMIP5 *Coupled Model Intercomparison Project*

WCRP World Climate Research Programme

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CMIP5

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CMIP5 - Data Access - Getting Started

CMIP5 Data - Getting Started

Data not yet available. Expected arrival of first data: sometime in January 2011.

See also IPCC AR5 timetable for estimation of due dates for some AR5 activities.

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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

In the case of physical dynamical systems, probability forecasts based on model simulations provide excellent realisations of this fallacy, drawing comfortable pictures in our mind which correspond to nothing at all, and which will mislead us if we carry them into decision theory.

You don't have to believe everything you compute!

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Solvency II and Risk Management

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

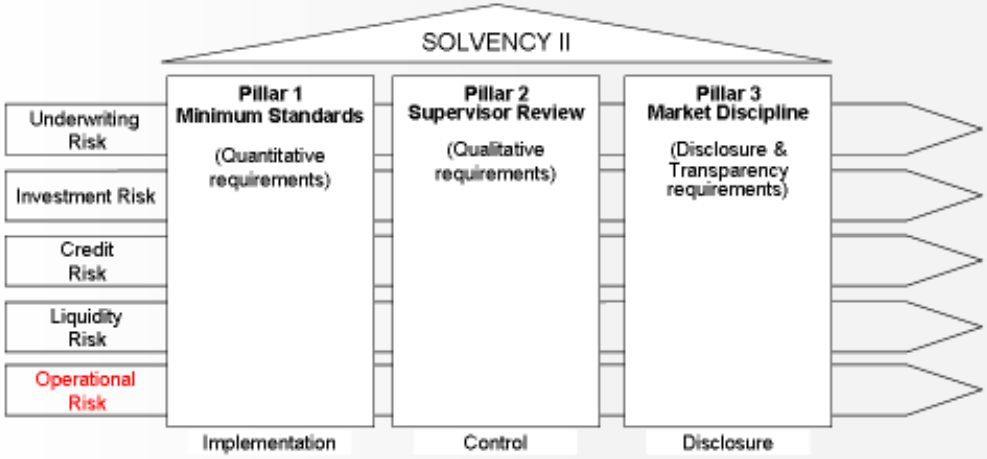
The aim here is not to integrate over all risks and opportunities to estimate the PDF of expected annual income but simply to ensure that insurers have sufficient "regulatory capital" to survive any (every) adverse event which has more than a 1 in 200 chance of occurring.

Question: Can climate science ascertain whether the probability of an outcome is

a) >> 1 in 200
b) ~ 1 in 200
c) << 1 in 200

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

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

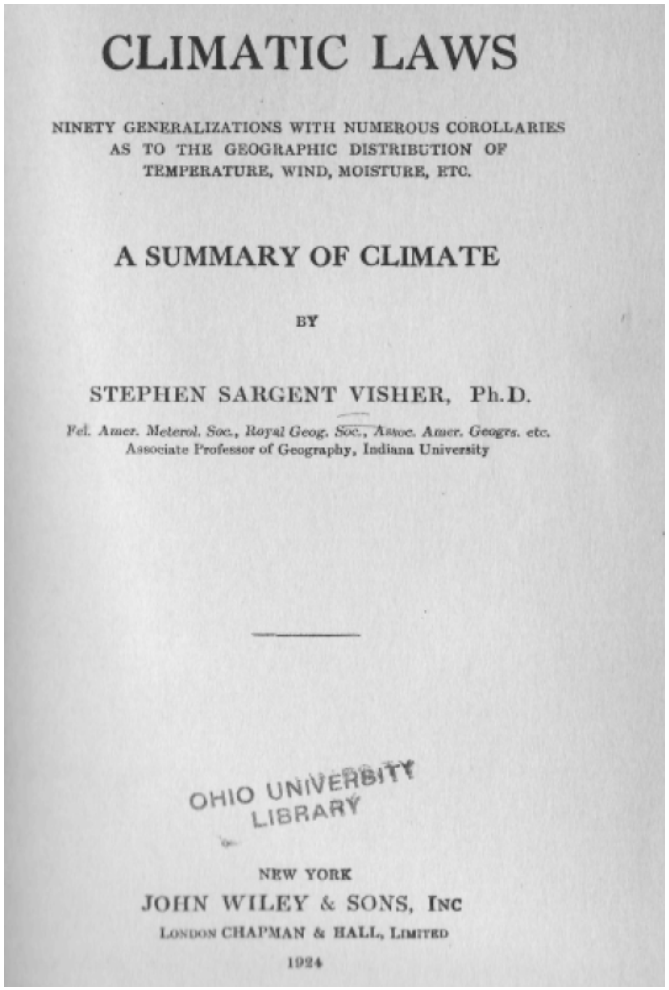


Solvency II (SII) is the updated set of regulatory requirements for insurance companies operating in the European Union. It revises the existing capital adequacy regime and is expected to come into force in 2012. It has a number of expected benefits, both for insurers and consumers. Although the most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

http://riskfriends.wordpress.com/2009/03/10/solvency-ii-dealing-with-operational-risk/

Grantham Research Institute on Climate Change and the Environment

The link between CO_2 and climate is not new!



CLIMATIC LAWS

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

A SUMMARY OF CLIMATE

BY

STEPHEN SARGENT VISHER, Ph.D.

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

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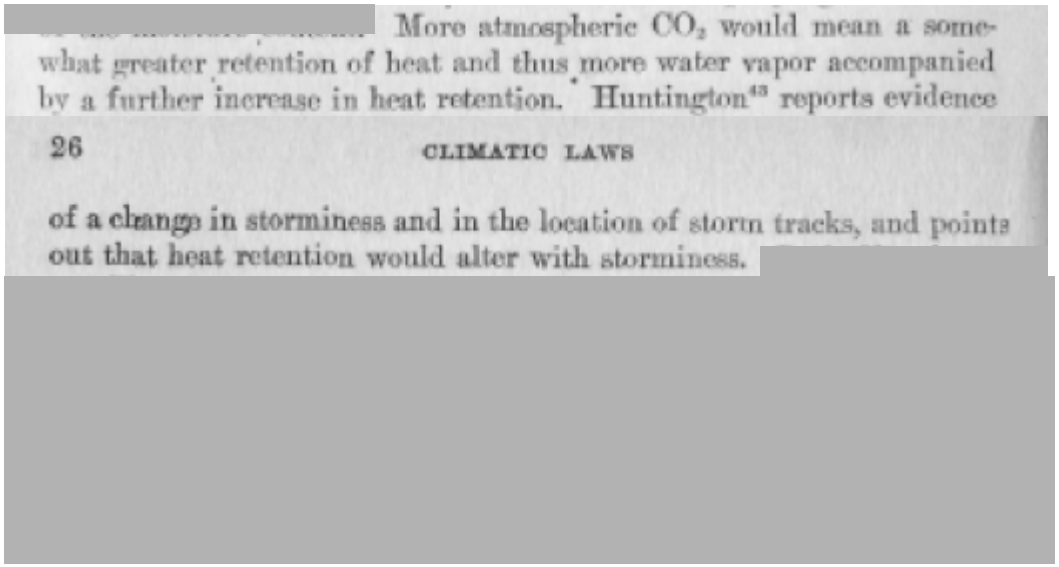

More atmospheric CO_2 would mean a somewhat greater retention of heat and thus more water vapor accompanied by a further increase in heat retention. Huntington[43] reports evidence

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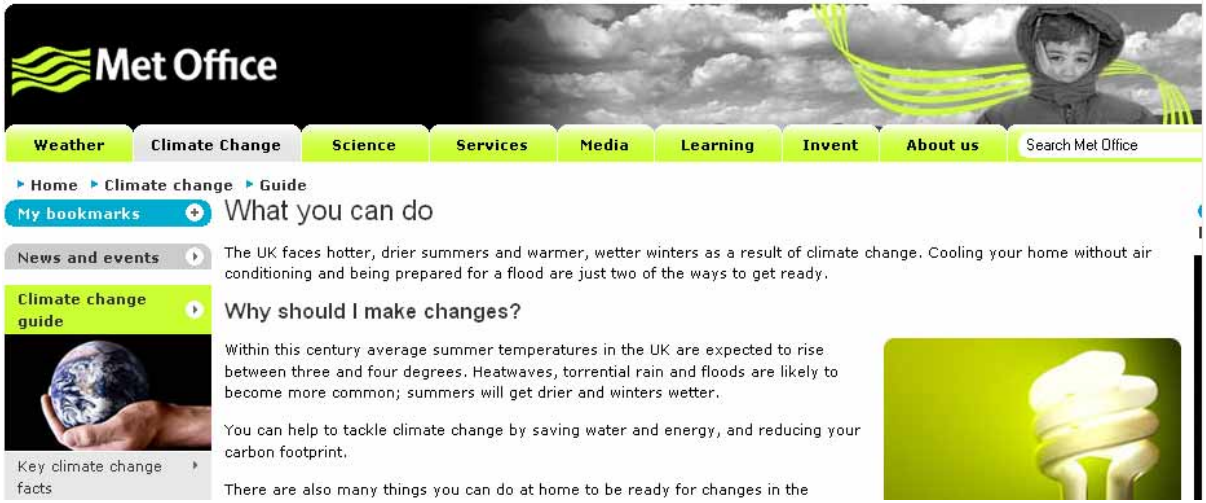
of a change in storminess and in the location of storm tracks, and points out that heat retention would alter with storminess.



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Climate change guide

Key climate change facts

What you can do

The UK faces hotter, drier summers and warmer, wetter winters as a result of climate change. Cooling your home without air conditioning and being prepared for a flood are just two of the ways to get ready.

Why should I make changes?

Within this century average summer temperatures in the UK are expected to rise between three and four degrees. Heatwaves, torrential rain and floods are likely to become more common; summers will get drier and winters wetter.

You can help to tackle climate change by saving water and energy, and reducing your carbon footprint.

There are also many things you can do at home to be ready for changes in the

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

Grantham Research Institute on Climate Change and the Environment

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Climate change detection, and forecasting (1937)

THE ARTIFICIAL PRODUCTION OF CARBON DIOXIDE AND ITS INFLUENCE ON TEMPERATURE

By G. S. CALLENDAR

(Steam technologist to the British Electrical and Allied Industries Research Association.)

(Communicated by Dr. G. M. B. Dobson, F.R.S.)

[Manuscript received May 19, 1937—read February 16, 1938.]

The radiation absorption coefficients of carbon dioxide and water vapour are used to show the effect of carbon dioxide on "sky radiation." From this the increase in mean temperature, due to the artificial production of carbon dioxide, is estimated to be at the rate of 0·003°C. per year at the present time.

It is well known that the gas carbon dioxide has certain strong absorption bands in the infra-red region of the spectrum, and when this fact was discovered some 70 years ago it soon led to speculation on the effect which changes in the amount of the gas in the air could have on the temperature of the earth's surface. In view of the much larger quantities and absorbing power of atmospheric water vapour it was concluded that the effect of carbon dioxide was probably negligible, although certain experts, notably Svante Arrhenius and T. C. Chamberlin, dissented from this view.

In the following paper I hope to show that such influence is not only possible, but is actually occurring at the present time.

That would be **1937**

© Leonard Smith

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?