Valuable Foresight or Useless Arithmetic?

(Expectation Management in Decision Support)

12 April 2007

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Centre for the Analysis of Time Series, LSE

&

Pembroke College, Oxford

CATS sits between the mathematical modelling community, physical scientists and environmental decision makers, enhancing the interface through its ability to talk to all sides.

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Live Discussion Board NOW

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British Energy

Scottish and Southern Energy plc

National Grid

Risk Management Solutions RMS

LLOYD'S

SAIC

ONR

California ISO

METRA ENERGY

EDF ENERGY

ALSTOM

London Electricity

Live Discussion Board NOW

Instructions:

The symposium will address several major challenges in climate projection, including:

- The formulation of climate models F and $\tilde{F}$
- The process of downscaling from global to local scales
- The derivation of climate statistics and secular trends
- The interpretation of climate as a dynamical system
- The construction of risk analyses for climate impacts
- The extraction of climate information for decision making

"Stimulate Discussion"

Policy, Decision Support and Mathematical “preliminaries.”

The symposium will address several major challenges in climate projection, including:

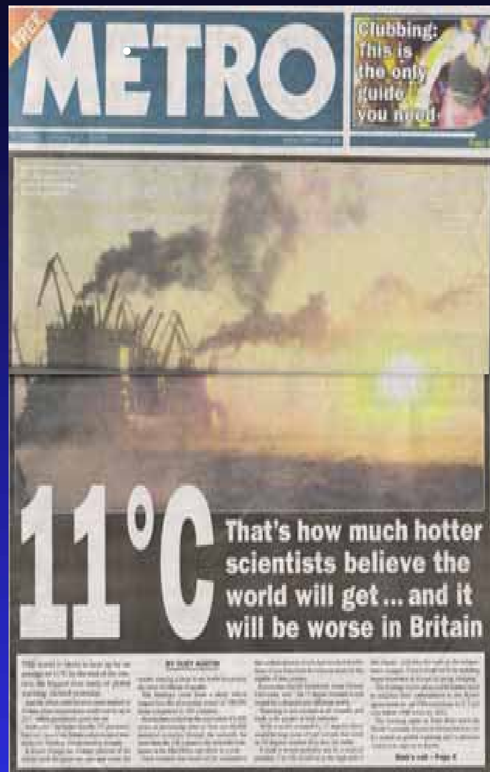
- The aims of climate models
- The relevance of downscaling from global to local scales
- The deriv
  of collections models nonlinear non-recurrent transient distinct
  Mathematical interpretation of climate as dynamical systems
  ^ ^ ^
- The construction of risk analyses for climate impacts
- Scientific identification of climate informa relevant decision making
  ^ in state of the art models.

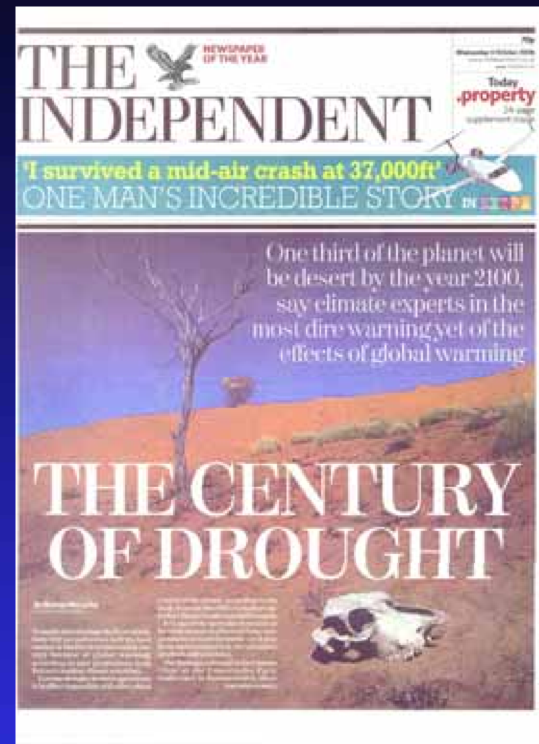
Decision makers are neither dumb (BP) nor naïve (EDF).
?will buy due diligence only once: nontrivial risk to credibility of science?
Qualitative interpretations of quantitative models desired (is more possible?)

Outline

- Knowledge Transfer and Expectation Management
- Ensemble Environmental Modelling and “Probability”
  - Weather and Climate : Models and Projection Operators
- *Known Inabilities, Unknown Unknowns & Unrealistic Aims (Sales)*
- ***Key Open Question:***
  - At what spatial and temporal scales do today’s models provide decision-support relevant information?
  - Can we build a better mathematical framework for discussing climate?
- Prognosis:
  - The ***lower*** bound on our range of uncertainty will remain large
  - “All climate is local”: weather forecasting is a win-win investment
  - Over-interpretation of models will lead to poor decision making
  - Realistic model/data interpretation will bring real rewards
  - Difficult tactical/strategic questions of resource allocation for decision support relevance (How often should one run/update large models?)

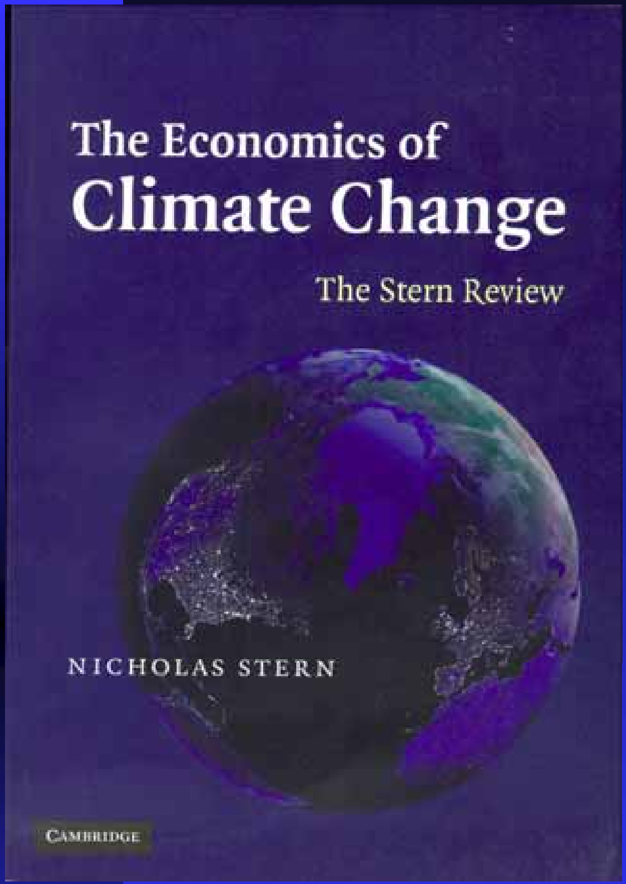
Knowledge does not transfer (well) by itself.

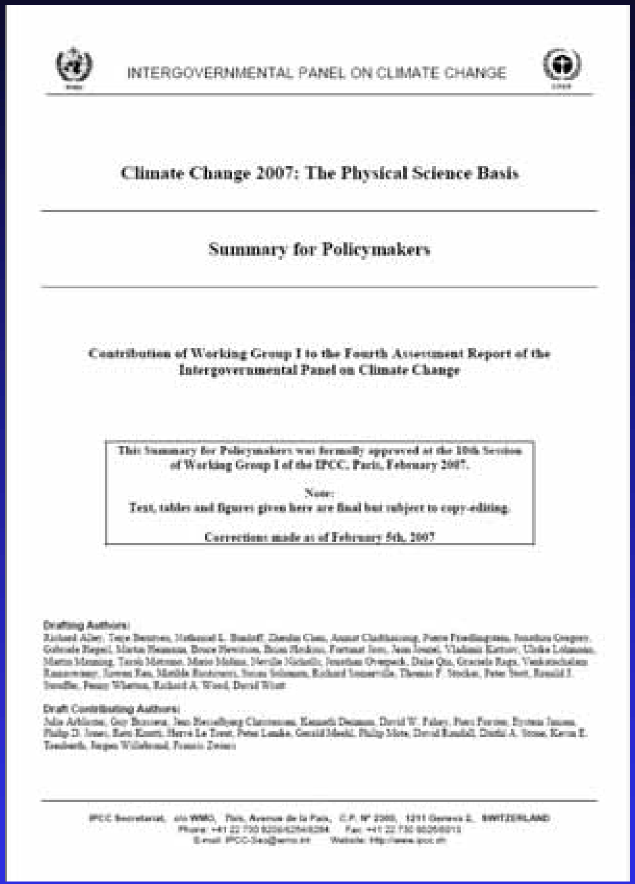




Especially when market share is valued more than reliability

Socio-economic | Science Summary





INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

Climate Change 2007: The Physical Science Basis

Summary for Policymakers

Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change

This Summary for Policymakers was formally approved at the 10th Session of Working Group I of the IPCC, Paris, February 2007.

Note:
Text, tables and figures given here are final but subject to copy-editing.

Corrections made as of February 5th, 2007

Drafting Authors:

Draft Contributing Authors:

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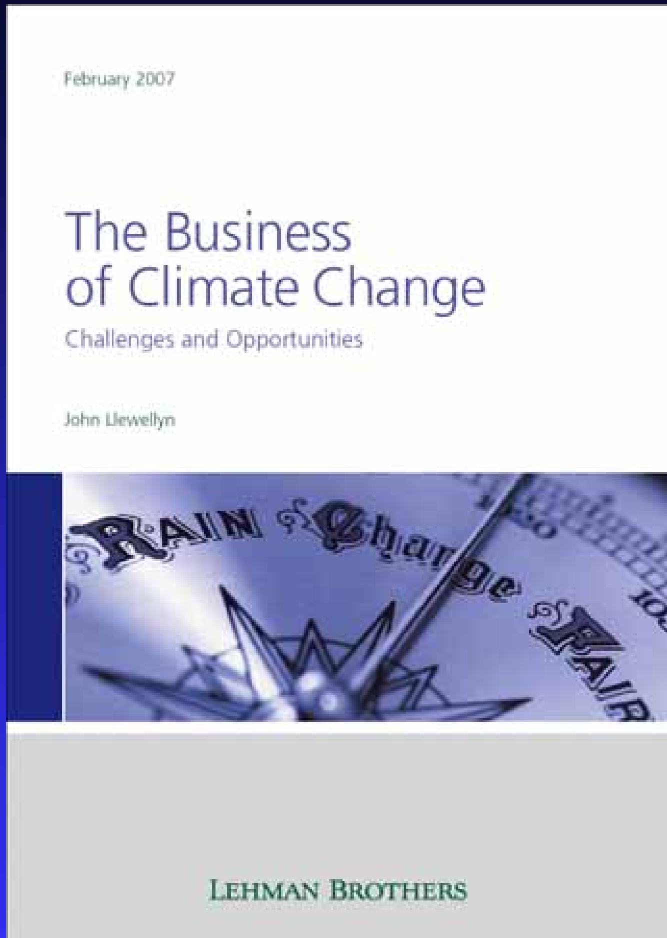
Science Base

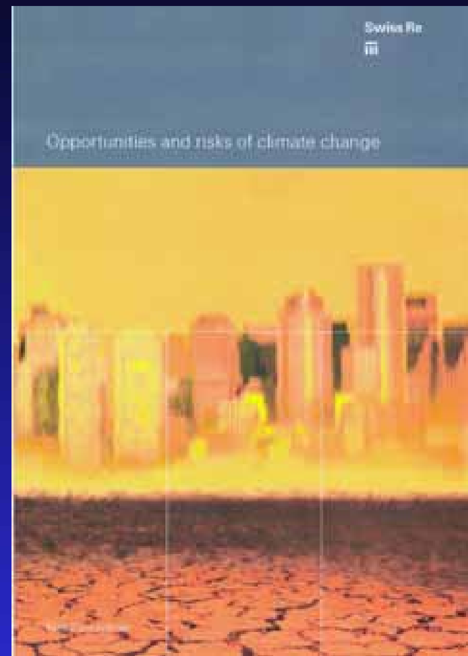
Climate Change also calls for a new mix of truly multidisciplinary knowledge transfer.

At present, model output tends to be over-interpreted. X

?mis-?

Climate has stimulated work at the science-industry interface



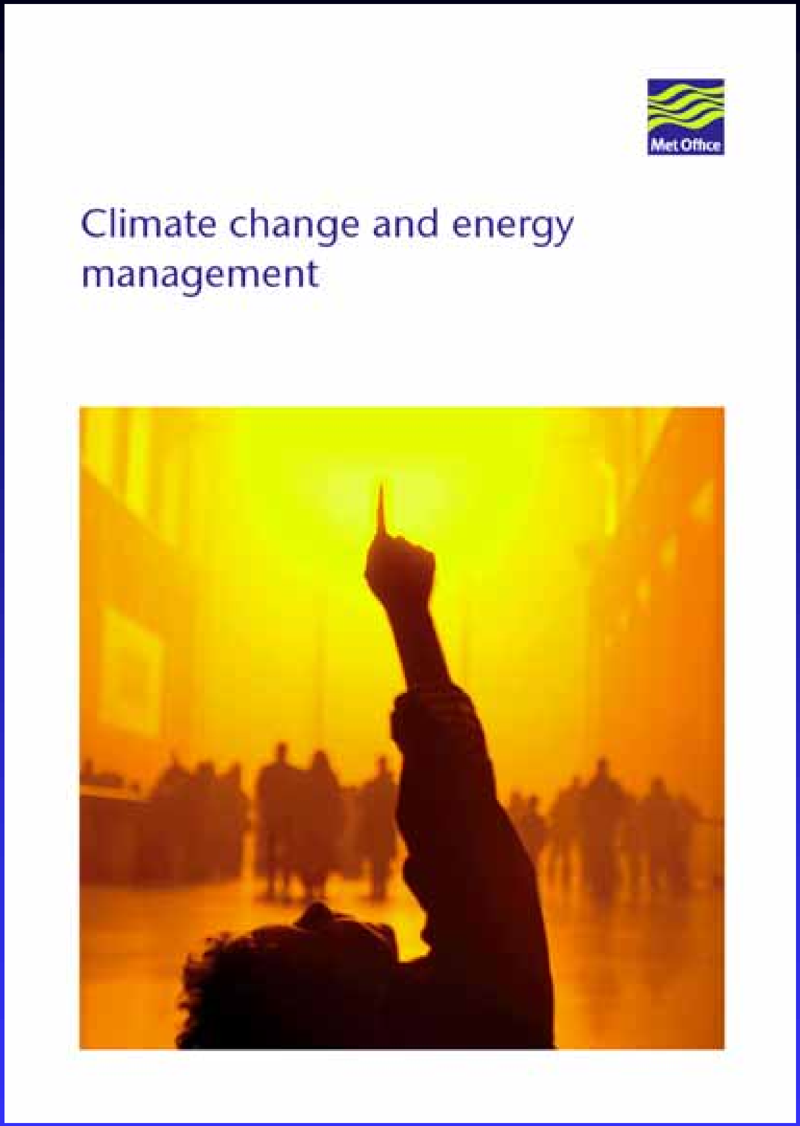


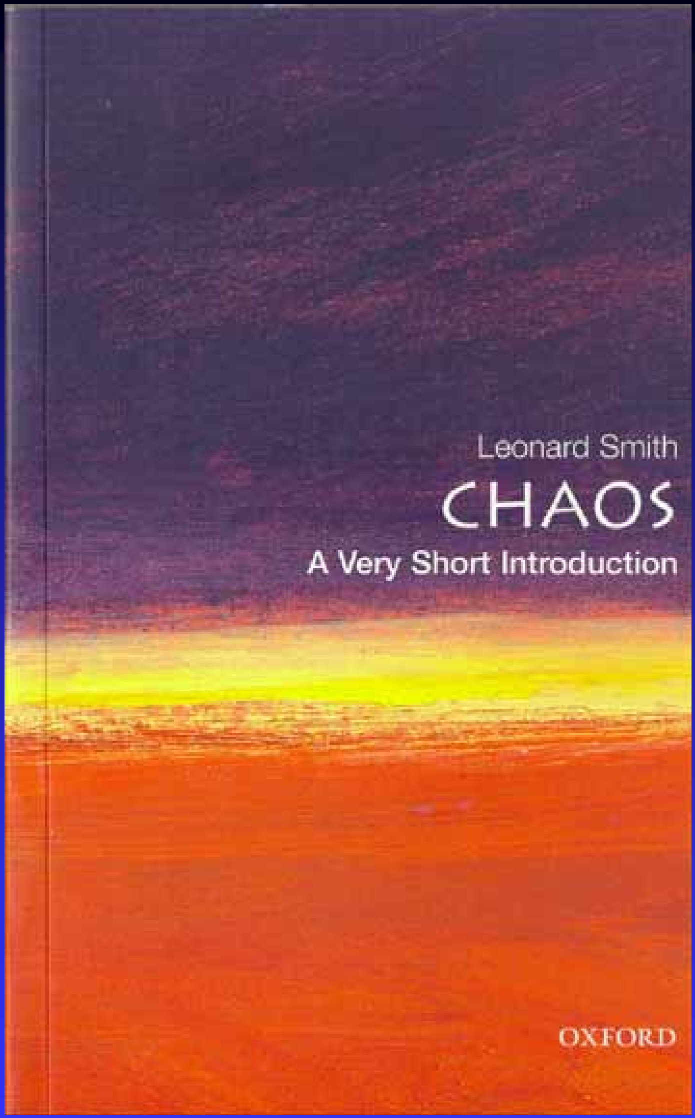
Climate Change Working Party

Making **financial** sense of the **future**

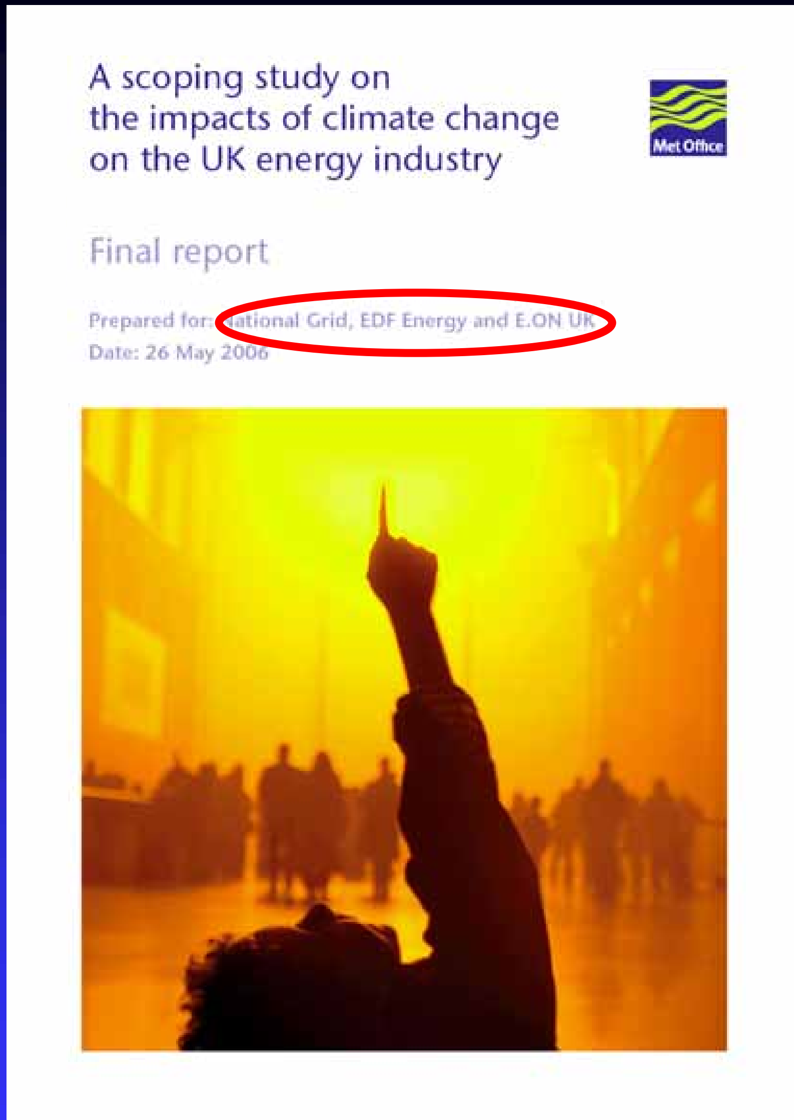
http://climatechange.pbwiki.com/

Huge need for expectation management and sanity checking





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

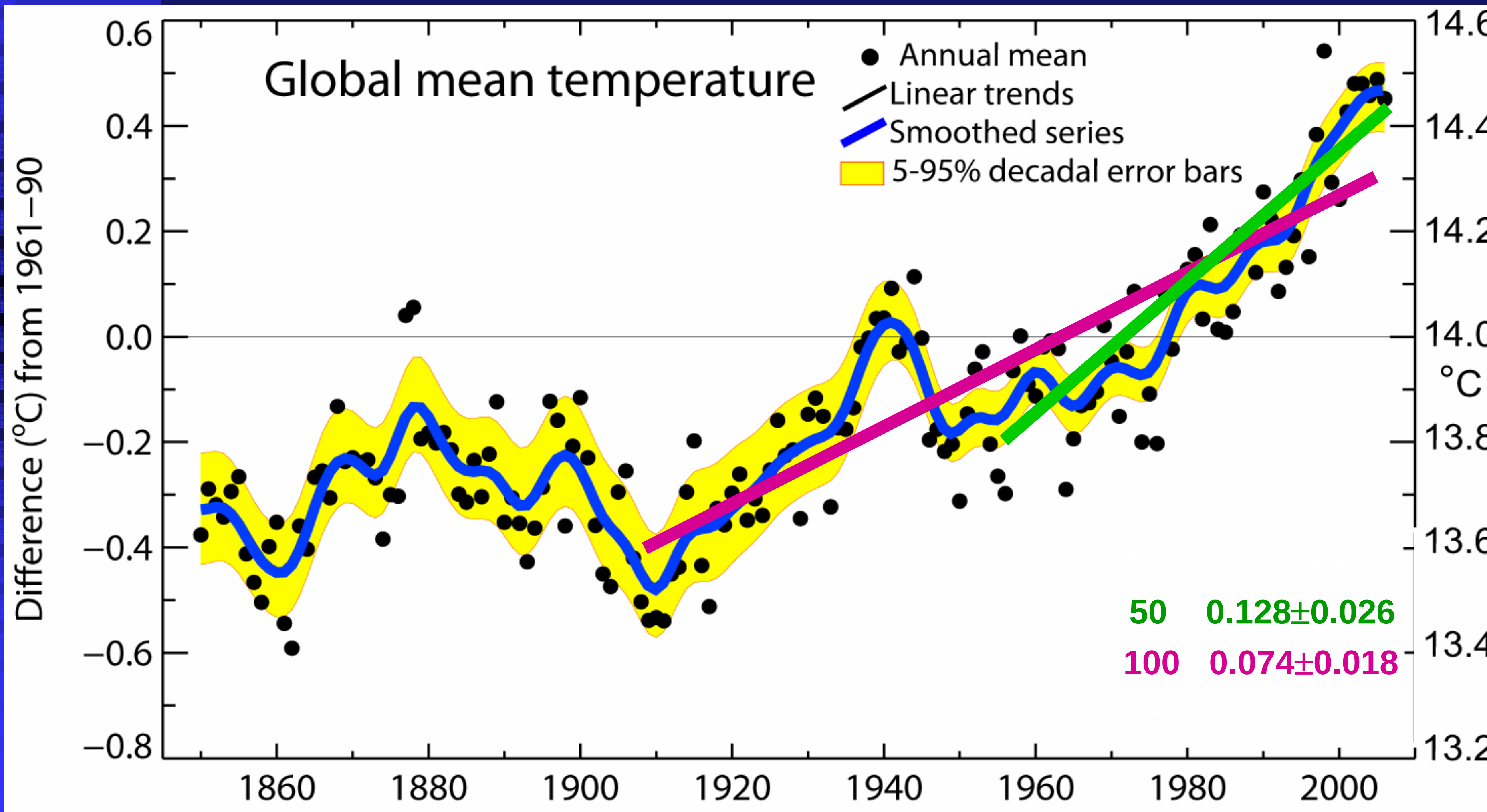


Supporting good policy and decision making requires informed criticism of the "best available information."

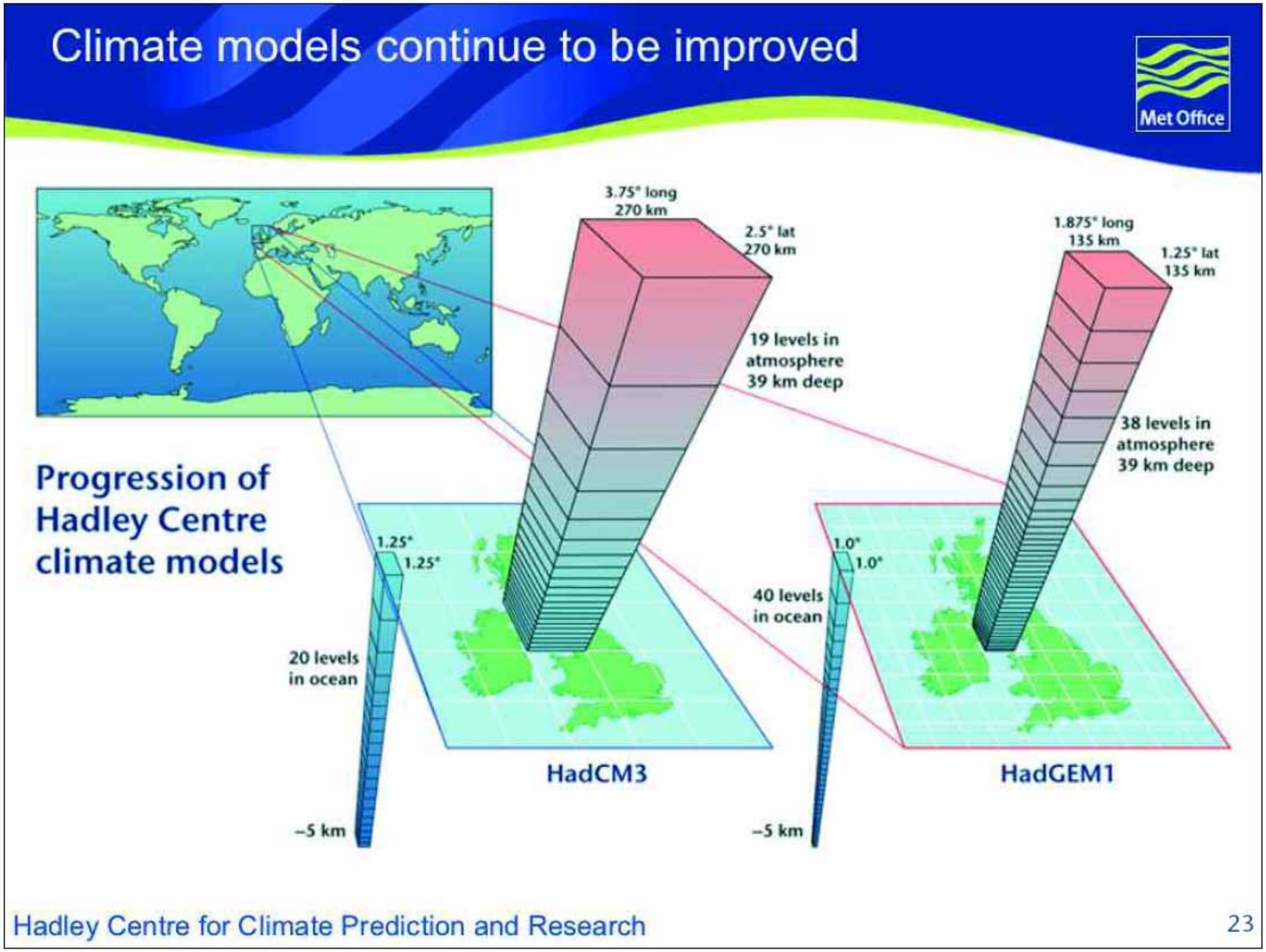
Ideally answering *only* the answerable questions, and never providing the "best available answer" when it is ***not*** decision support relevant.

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

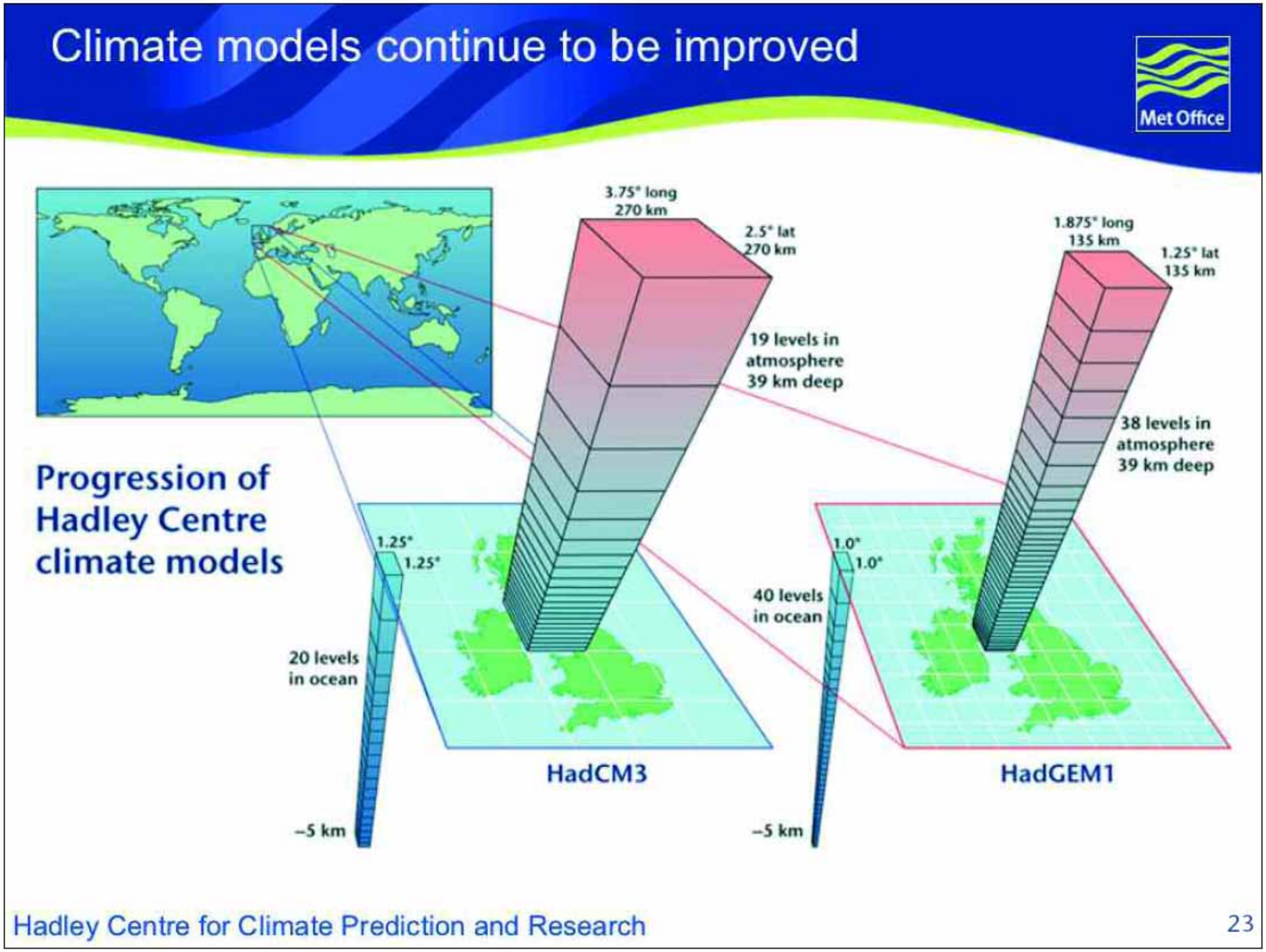
Global mean temperatures are rising faster with time



That is the past: What do we know about the future.
(Climate models will continue to be improved in every IPCC report!)

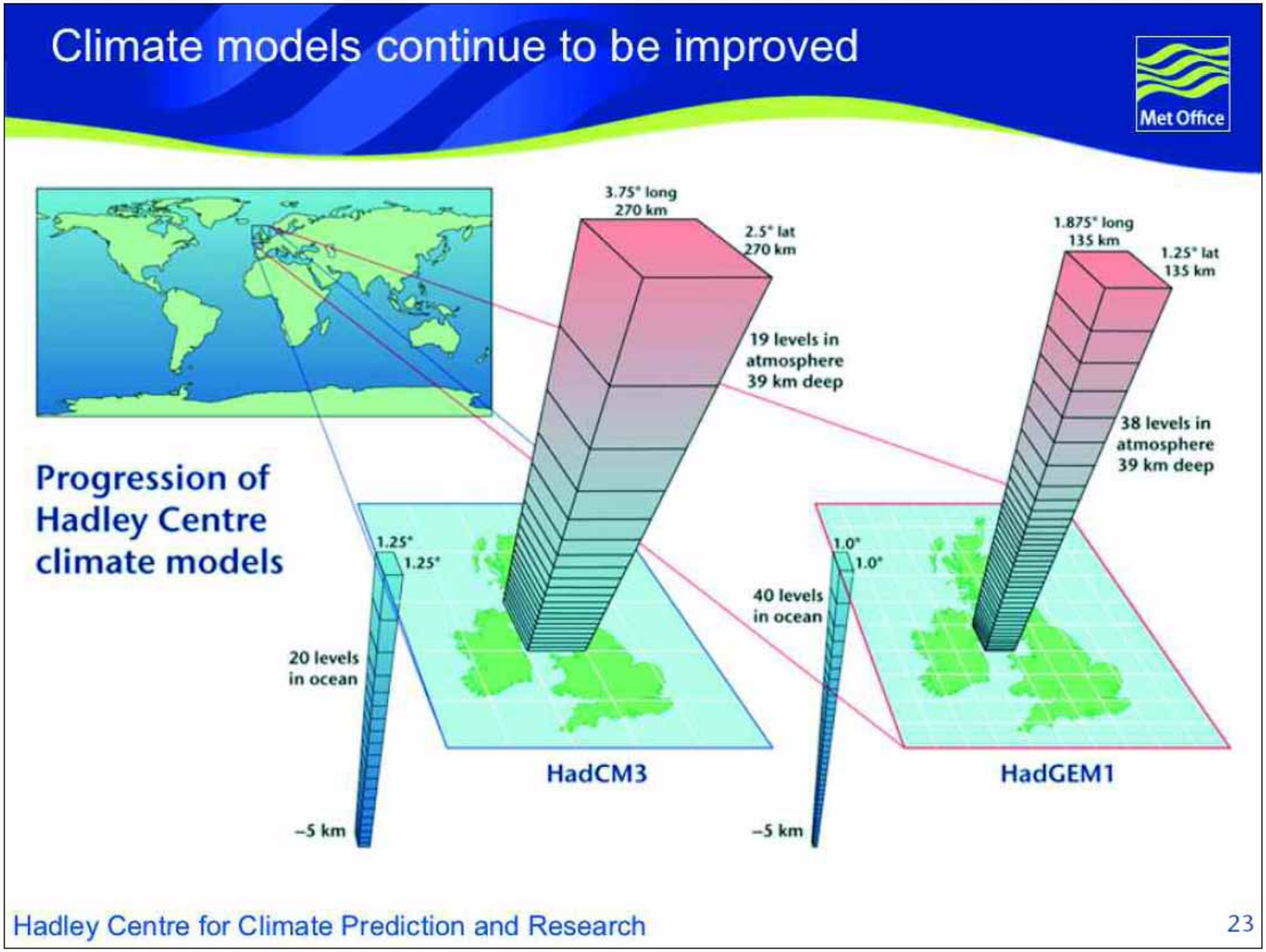


But on what space and time scales ***do*** we have decision-relevant information? Expectation Management!



Expectation Management!

UKCIP has been *instructed* on what it *will* provide.



(This is not a "AGW-denier" stance)

The credibility of science would profit from a realistic and mathematically coherent framework for massive modelling projects (more than just climate change, not all *extrapolations*).

How do we quantify model uncertainty in the absence of data?

AIDS deaths in South Africa in 1999 (Pilkey and Pilkey-Jarvis)

UNAIDS (model hindcast)	Total Recorded Deaths (in 1999)
250,000	375,000

(This is not a "AGW-denier" stance)

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How do we quantify model uncertainty in the absence of data?

Effective-percolation flux (rocks of Yucca Mountain)

1984	4 mm/year	(cores and simulation models)
1986	1 mm/year	(cores and simulation models)
1987	0.5 mm/year	(cores and simulation models)

Rates of 0.02 to 1 mm/year adopted for risk assessment simulation modelling

1996 Bomb test Cl^{36} detected in test tunnels implies 3000 mm/year "near seven faults"

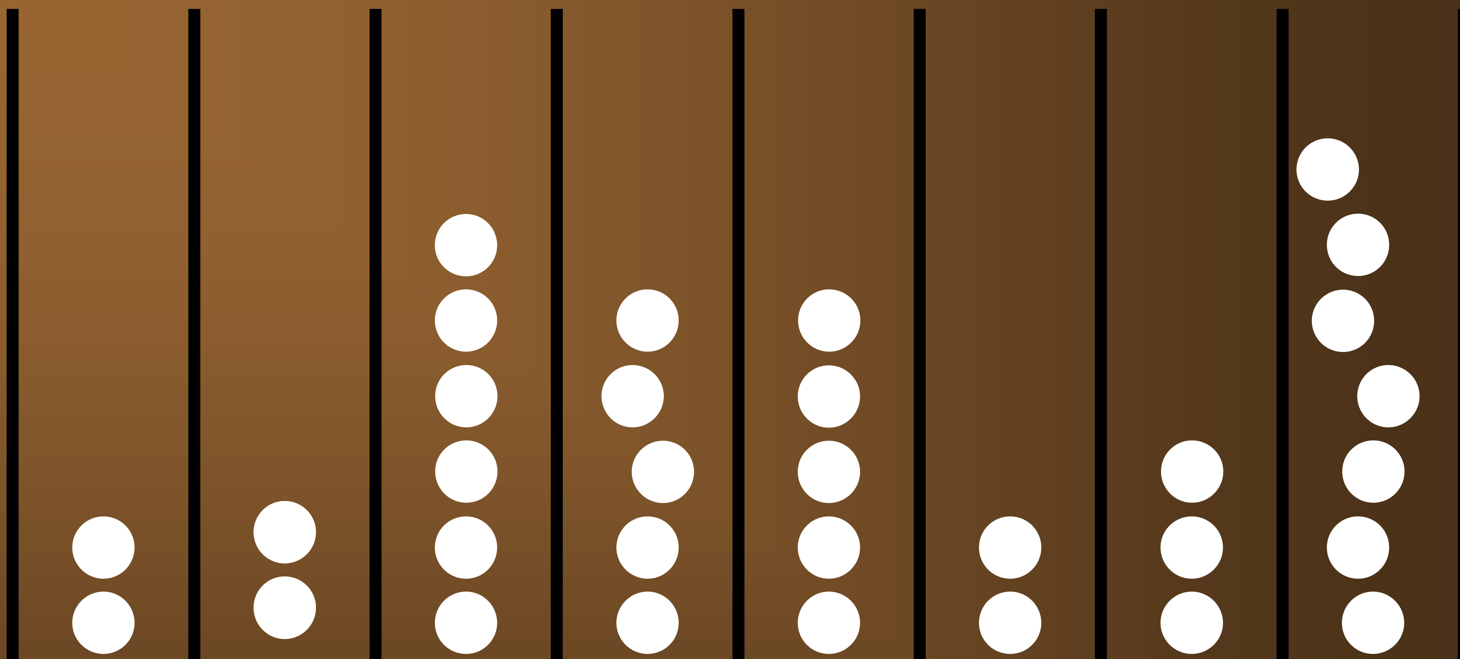
What is the decision support relevant number?
Given the resolution of the models, what is the "effective percolation flux"?
Is effective percolation flux merely unknown like the speed of light (was) or the half-life of the B meson? Non-statistical adjustments to both of these!
Or is it empirically vacuous like climate sensitivity and HADSM3's model entrainment coefficient?

Lorenz PDF evolution

How might ensembles help us understand uncertainty. Consider the Not A Galton (NAG) Board.
It is neither stochastic or chaotic; but at least it is!

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

White Pin



Pick One	A	B	C	D	E	F	G	H
Prob	5%	5%	20%	15%	15%	5%	10%	25%
Odds	20x	20x	5x	6⅔ x	6⅔ x	20x	10x	4 x
Your Bet(s)								

Distribute a total bet of one £ (100 pennies) however you like.

Decision support given a relevant probability distribution is straight-forward.

Lorenz PDF evolution

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

How do we “verify” what a distribution of golf balls tell us about the single passage of the red ball of reality?

On weather timescales, we have a valuable forecast-verification archive (~2^8,2^{10}).
(& it appears more decision-support valuable if we focus on *information content*: no **scenario** interpretation!)

White Pin

How/Would you change your bets on learning reality was a red ball?

Who changed their bets on the second round (Reality)? Why? (How?)
Of 100 WMO forecasters, roughly half switched;
roughly half of those improved their score (sample over only 3 drops).

Prob	5%	5%	20%	15%	15%	5%	10%	25%
Odds	20x	20x	5x	6⅔ x	6⅔ x	20x	10x	4 x
Your Bet(s)								
Pick One	A	B	C	D	E	F	G	H

Distribute a total bet of one £ (100 pennies) however you like.

Decision support given a relevant probability distribution is straight-forward.

As a dynamical system, even weather is non-recurrent

We need a relevant jargon for non-recurrent nonlinear dissipative dynamical systems useful on finite time-scales:

attractor, mixing, chaotic

Coupled to unknowable single snap-shot systems:

shadowing, predictability,assimilation

Under transient parameter change (climate & seasonal)

structural stability, natural measure (unconditioned distribution)

And accepting multiple model structures of different state spaces connected only via *projections* into observation space.

We currently lack the language discuss such things clearly.

We'll not see two similar medium range PDFs before the sun dies

What sort of verification tools would help users with the Red Rubber Ball, noting that we never see the same initial condition twice?

Lorenz PDF evolution

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

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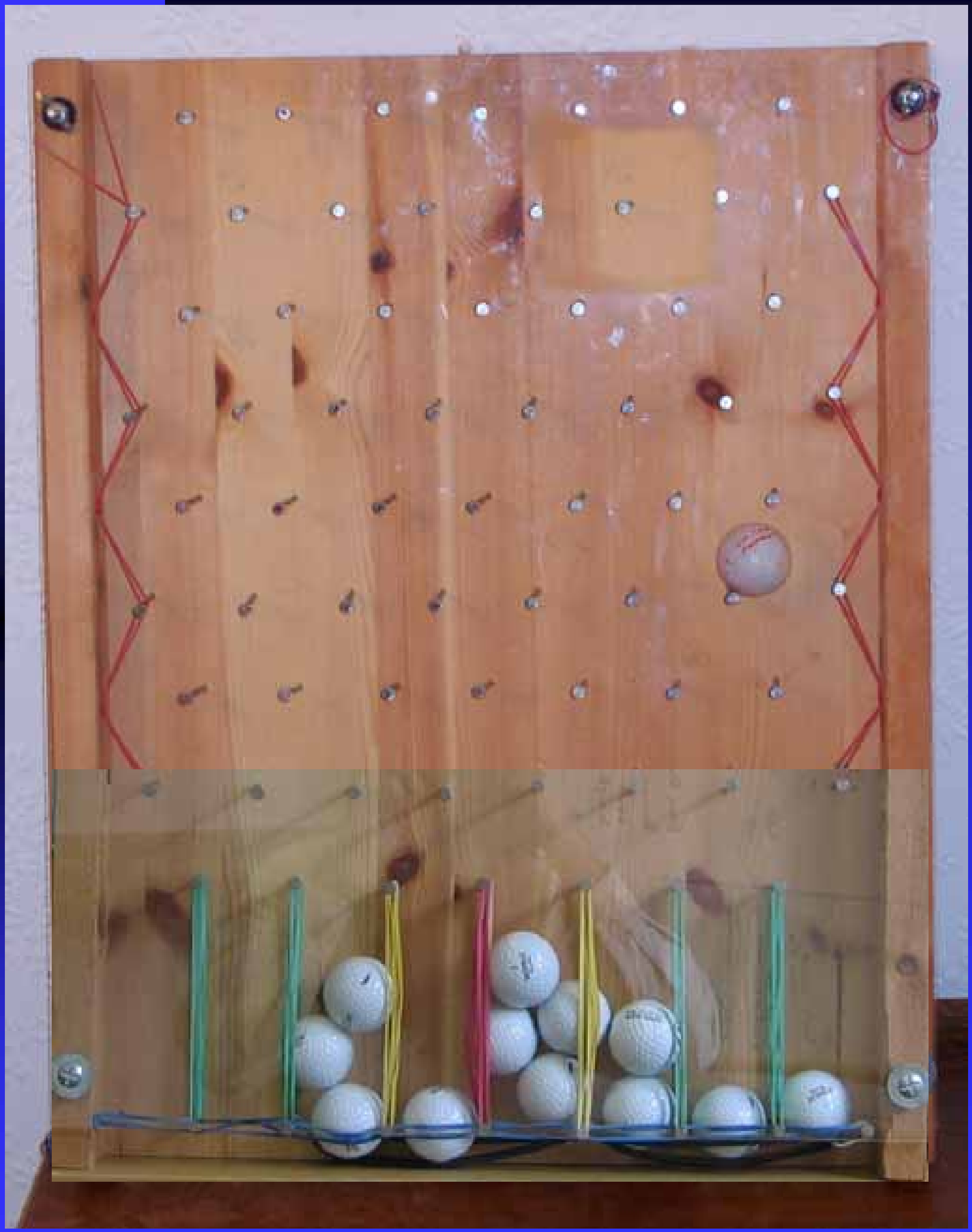
On seasonal timescales: a small forecast-verification archive (~2^4,2^5).

(Models disagree in IC distribution. How to blend if model skill varies?)

Lorenz PDF evolution



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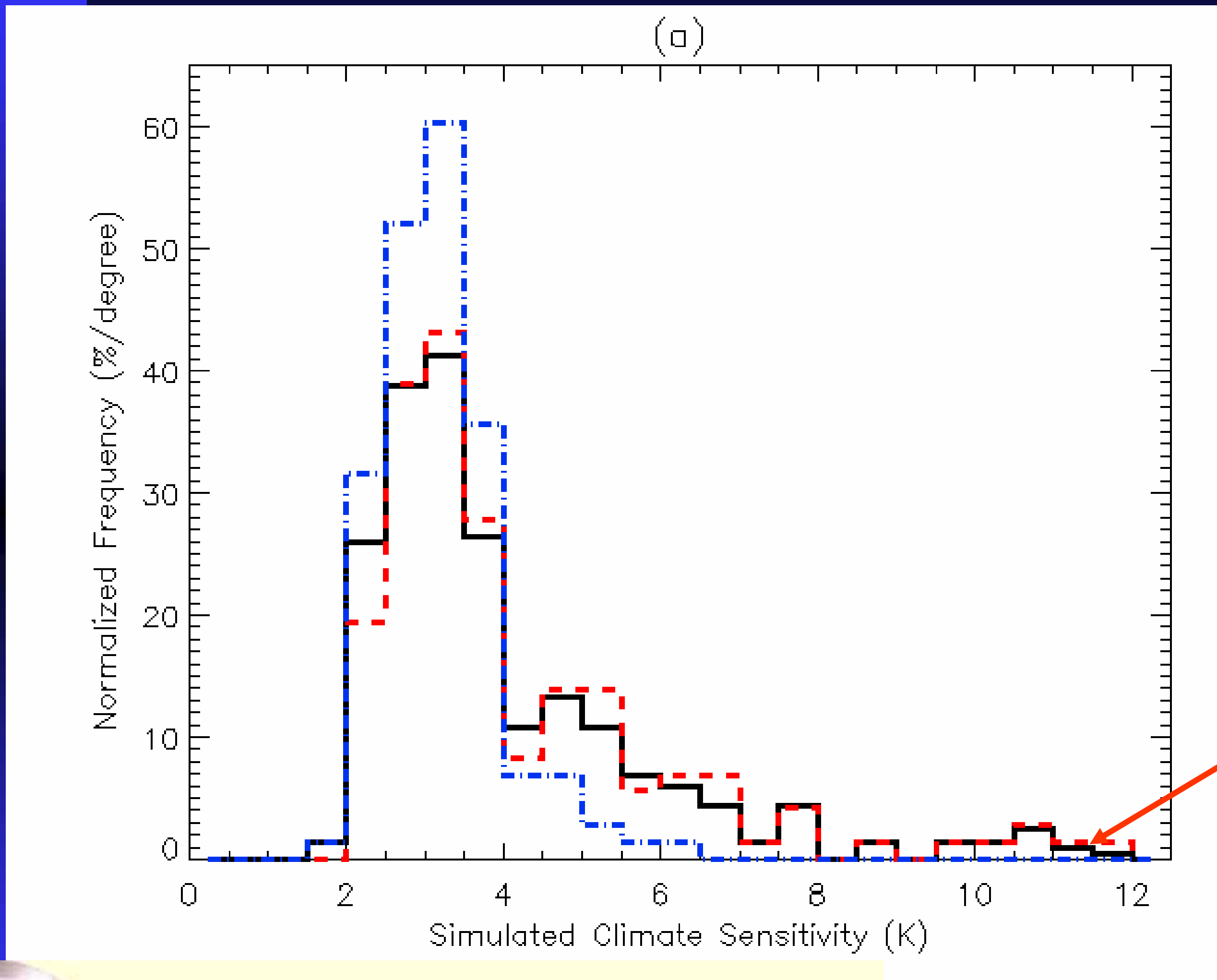
How do we "verify" what a distribution of golf balls tell us about the single passage of the red ball of reality?

Climate projection requires extrapolating out of red ball archive: into the known to be different unknown.

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

Frequency Distribution of Climate Sensitivity



% > 8°

Black: 4.2

Red: 4.9

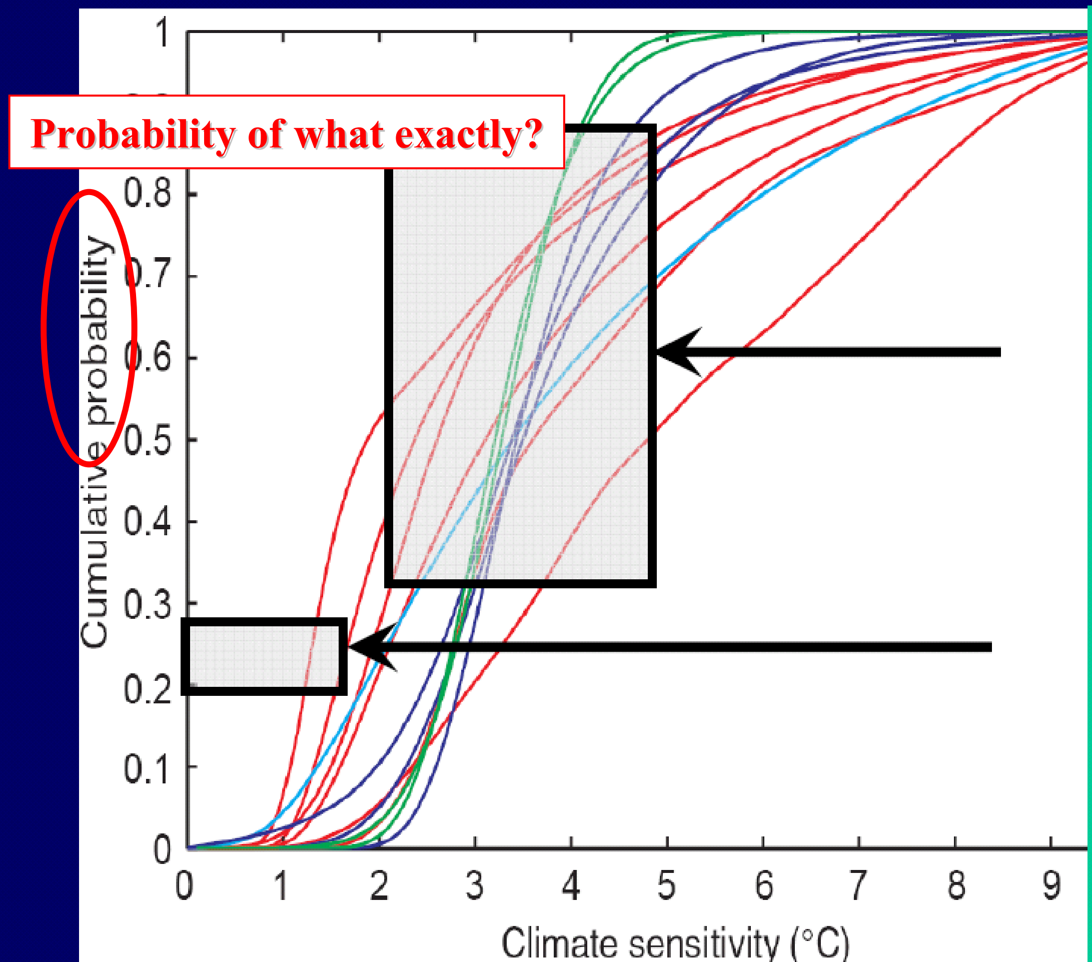
Blue: 0.0

Only one model structure.
One global averaged variable.

climateprediction.net

Equilibrium Climate Sensitivity

Surface warming following a sustained doubling of CO_2 concentrations



Best estimate 3°C;

likely 2-4.5°C;

very unlikely less than 1.5°C;

higher values not ruled out

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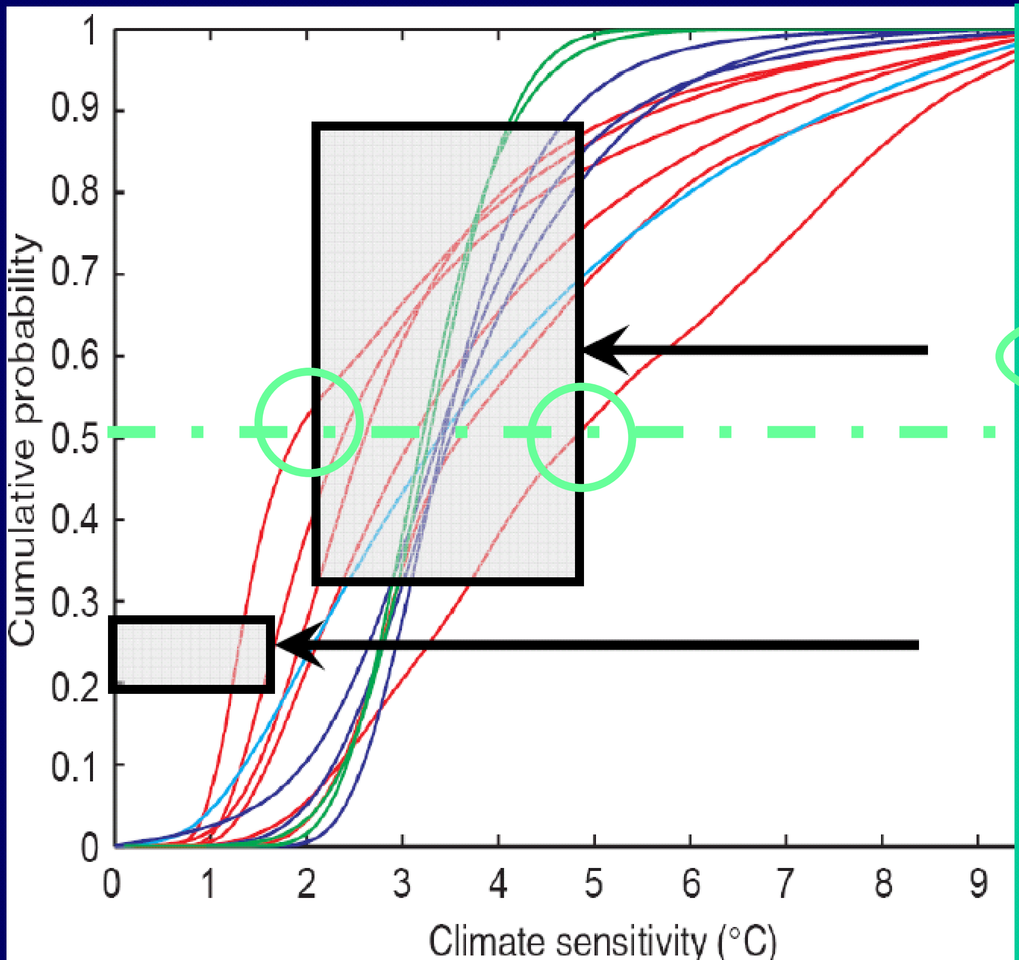

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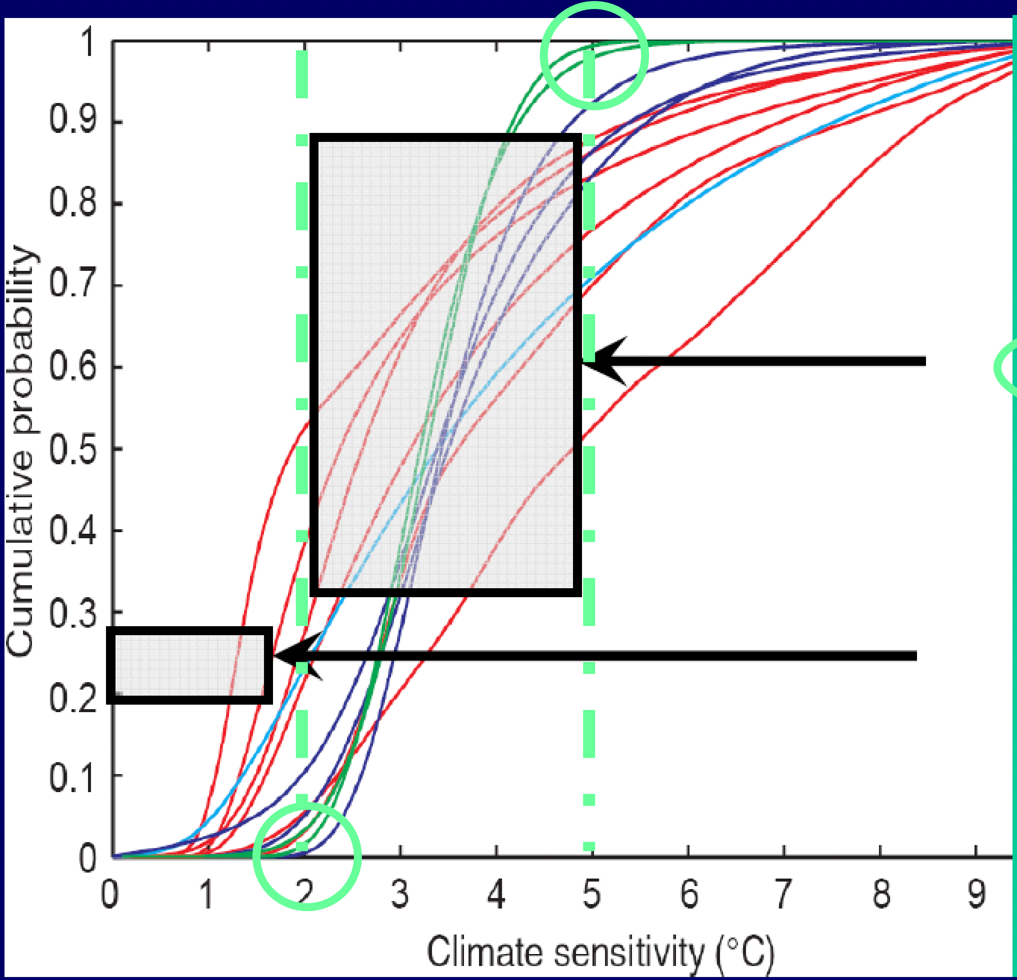

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likely 2-4.5°C;

very unlikely less than 1.5°C;

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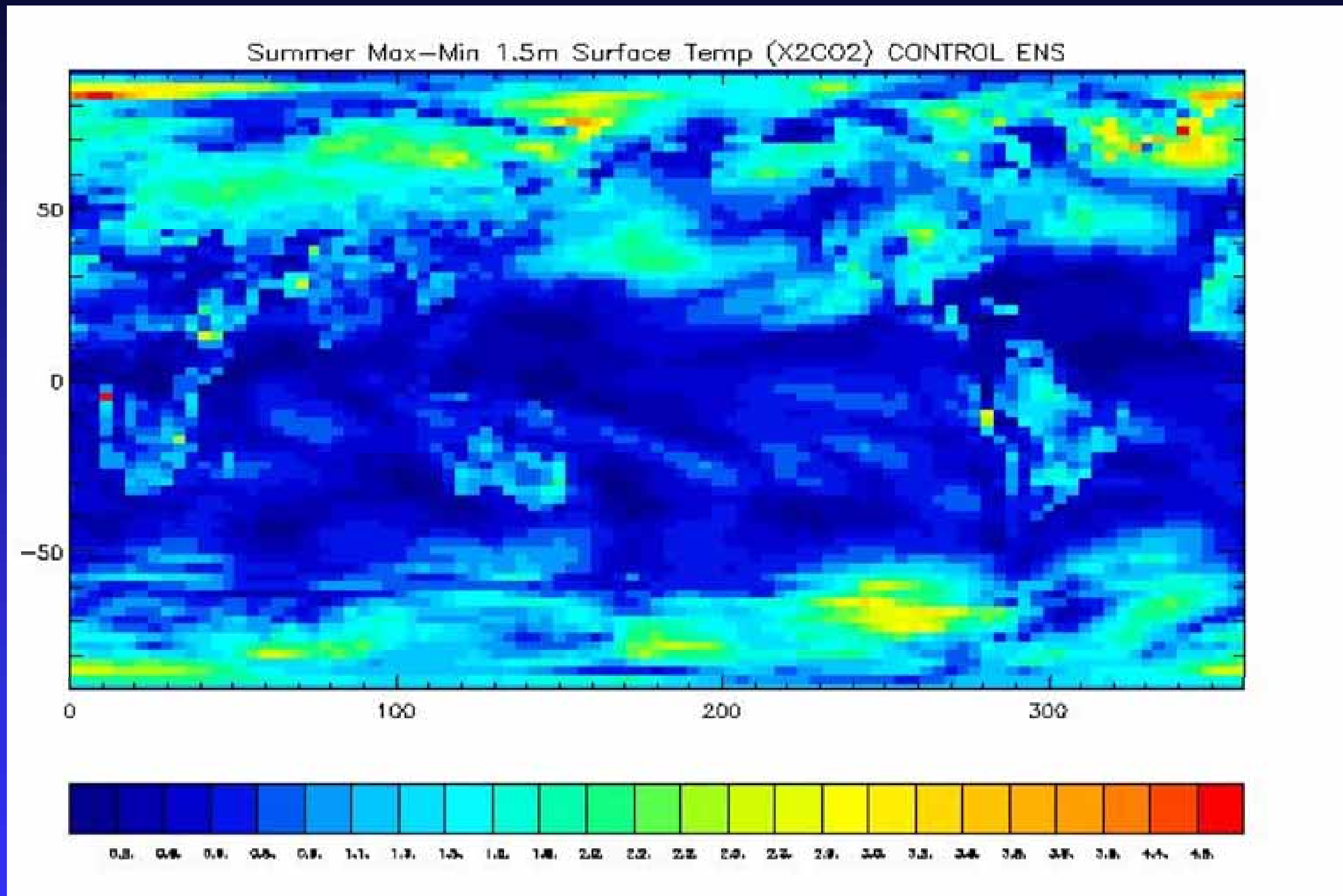
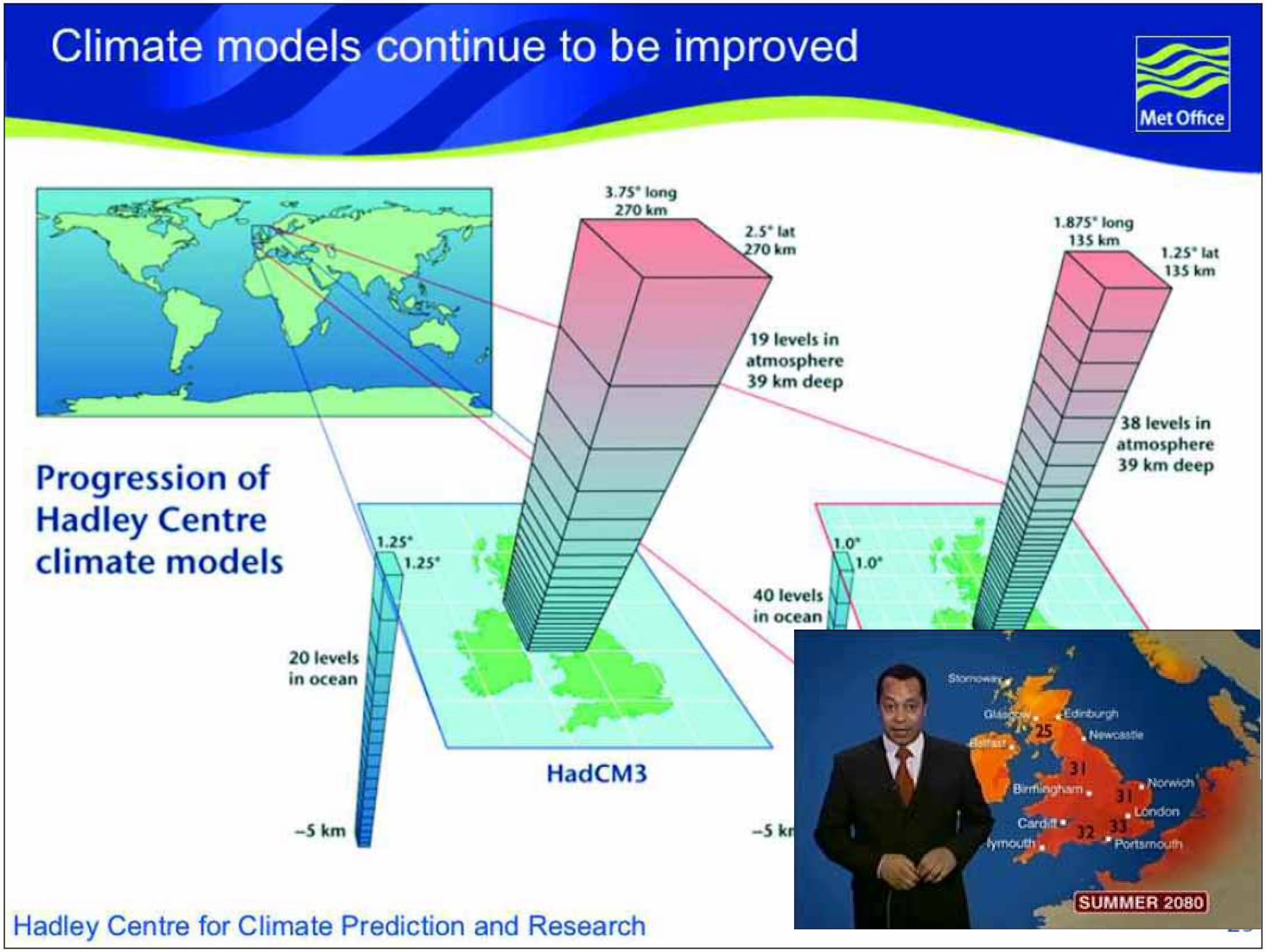
Range of Regional Results: *one* state-of-the-art model



Take home message: Uncertainties are large under even a single sensitivity;
We need to avoid over-interpreting pretty pictures of local impacts.

But on what space and time scales do we have decision-relevant information?
Expectation Management!



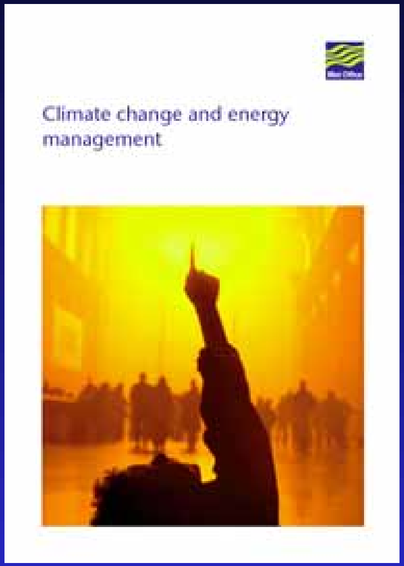
It is difficult for salesmen to lead with their uncertainty.

2.6.

Regional climate models are useful tools for assessing the impacts of climate change on the energy industry because they provide a comprehensive, physically consistent, prudent projection of future climate. Their main weaknesses are that their horizontal resolution is currently at best about 10 km, they are not integrated with energy industry infrastructure, e.g. water abstraction and there are uncertainties in the predictions.

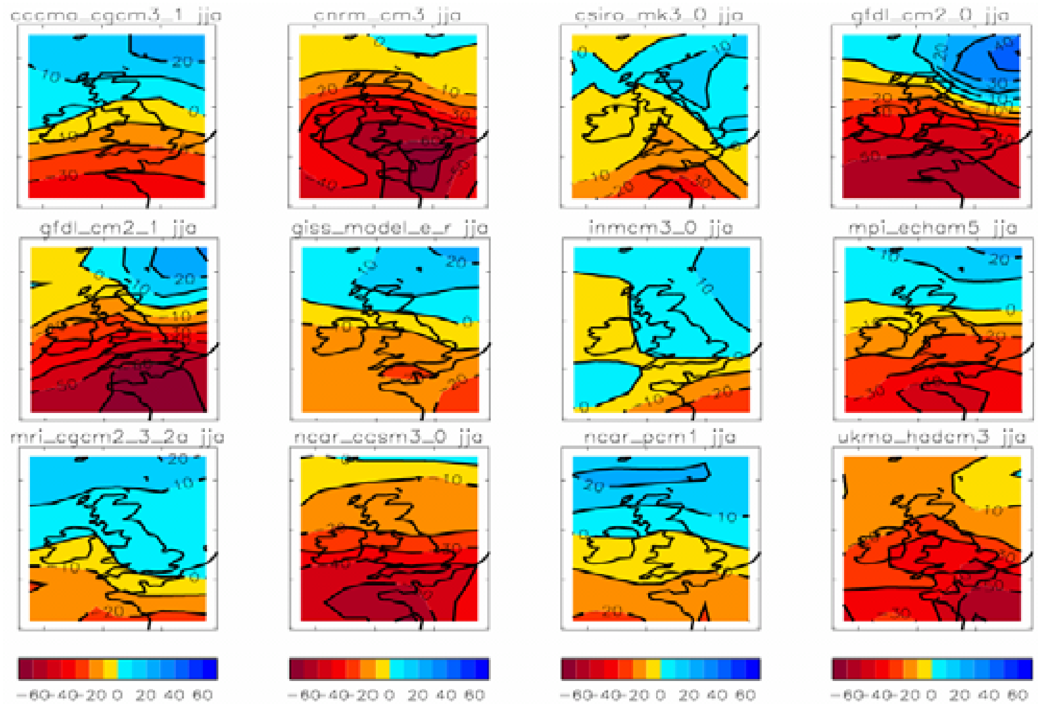
2.7.

A wide range of climate prediction data are available but have significant uncertainties and require expert interpretation. The uncertainties arise from lack of predictability of future emissions, uncertainties about climate model design, and natural climate variability.



Modelling uncertainties – IPCC 4AR (2007)

Met Office



Problem: we do not know the relative likelihood of each prediction

Met Office Hadley Centre

15

Global models differ substantially, decision-relevant regional details are not on offer even as probabilities.

It is difficult for salesmen to lead with their uncertainty.

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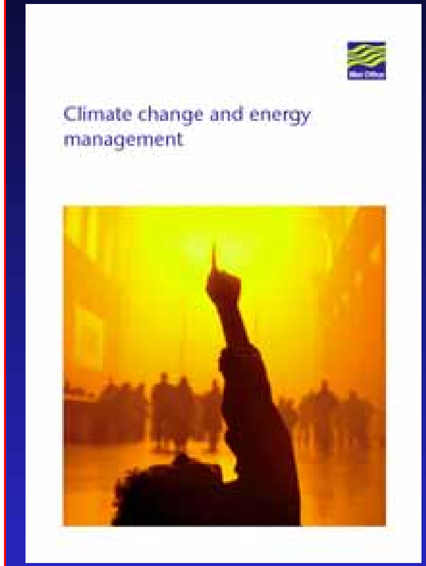
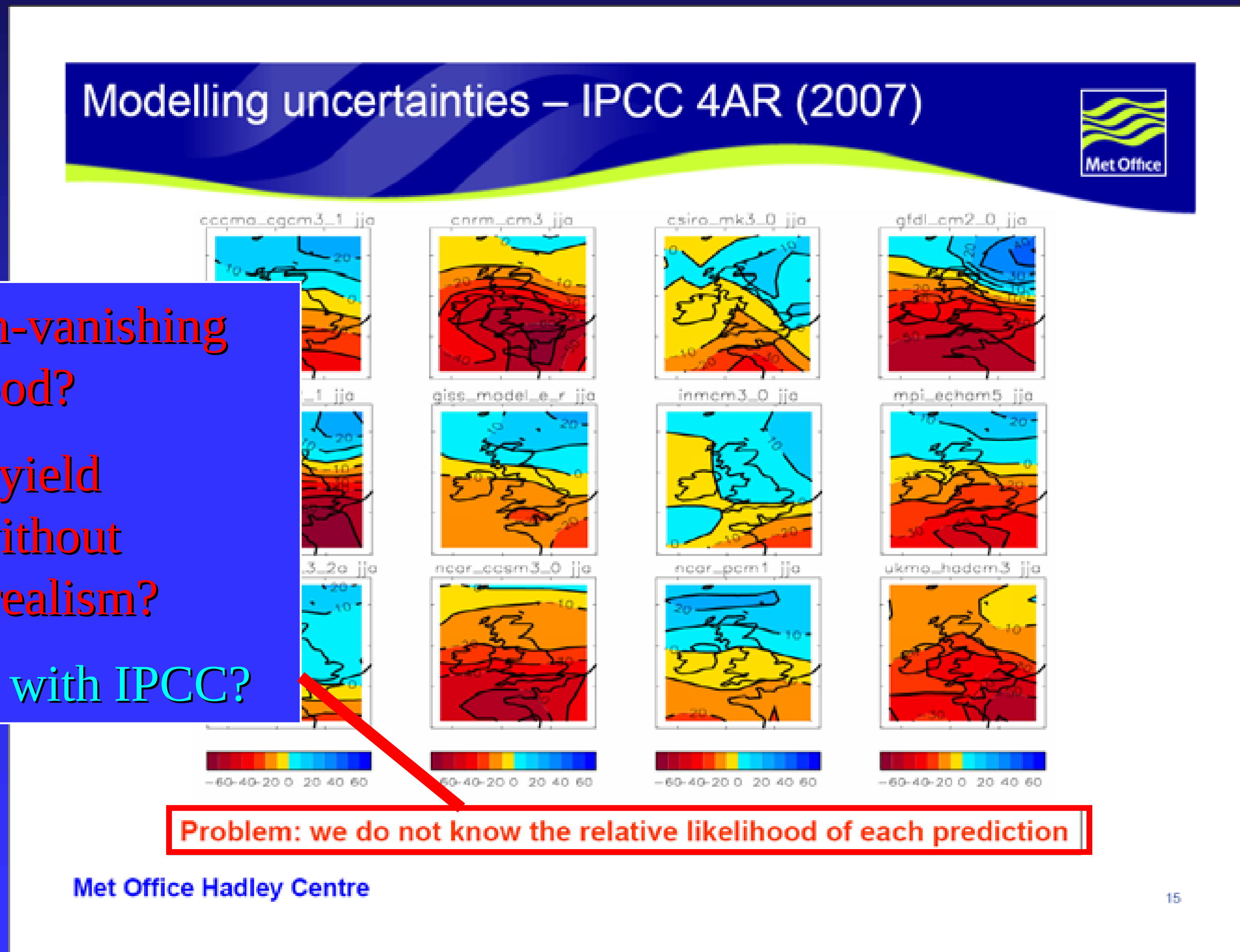


Mathematical/Statistical interpretation of decision support relevance of the means in IPCC chapter 10.

What does a multi-model mean mean in cases like this?



Do any have non-vanishing absolute likelihood?

Can our models yield understanding without probabilities or realism?

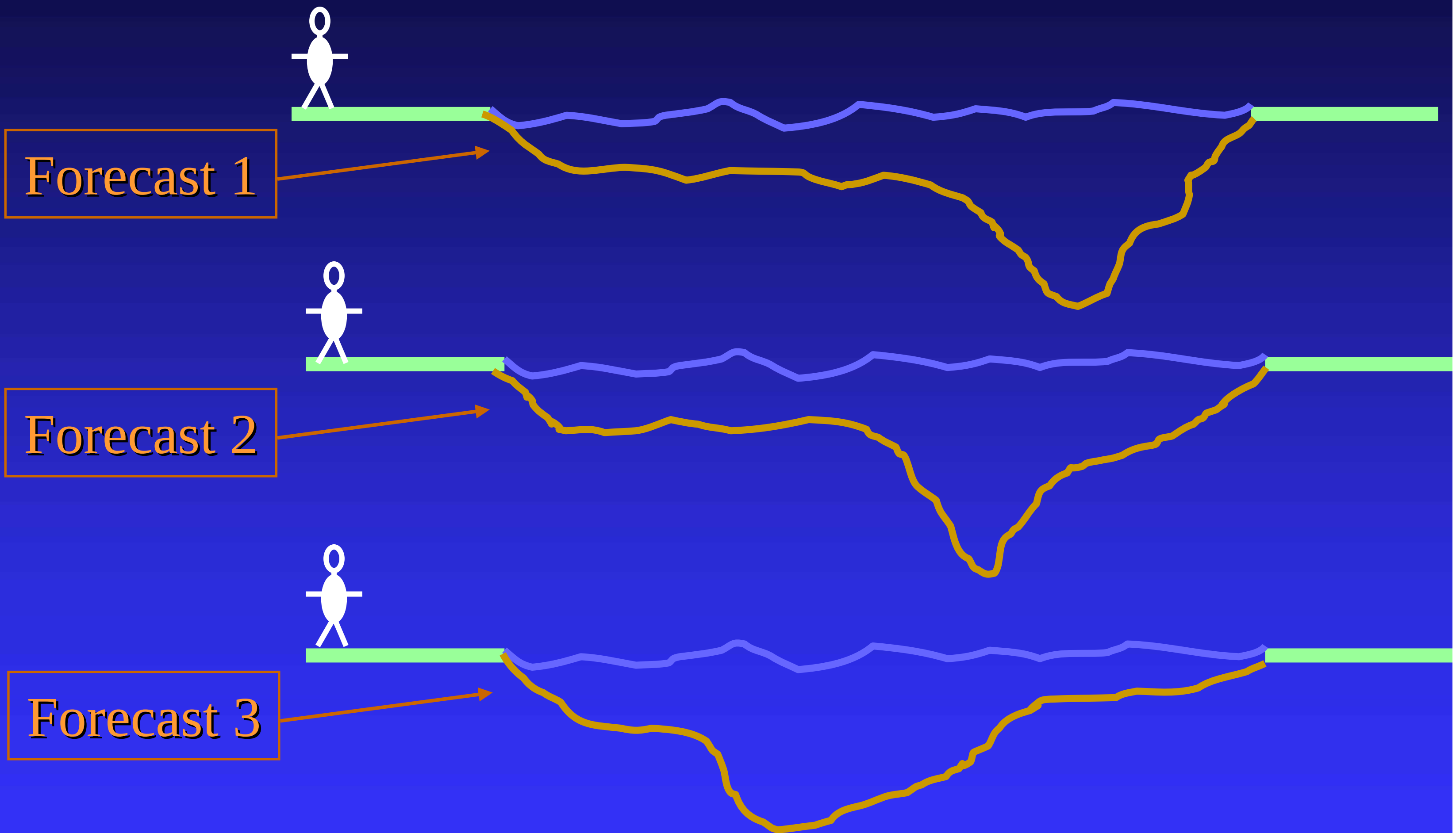
A Users Manual with IPCC?

?Some increase, some decrease, none unchanged: average ~ unchanged?

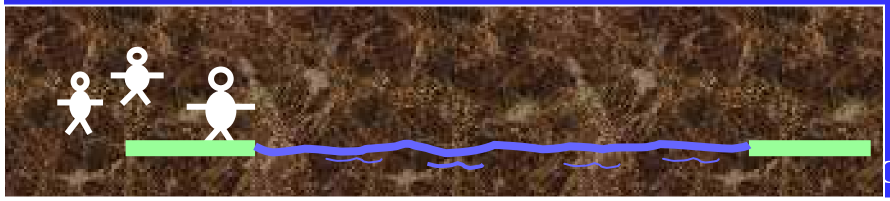
The parable of the three statisticians.

Three non-Floridian statisticians come to a river, they want to know if they can cross safely. (They cannot swim.)

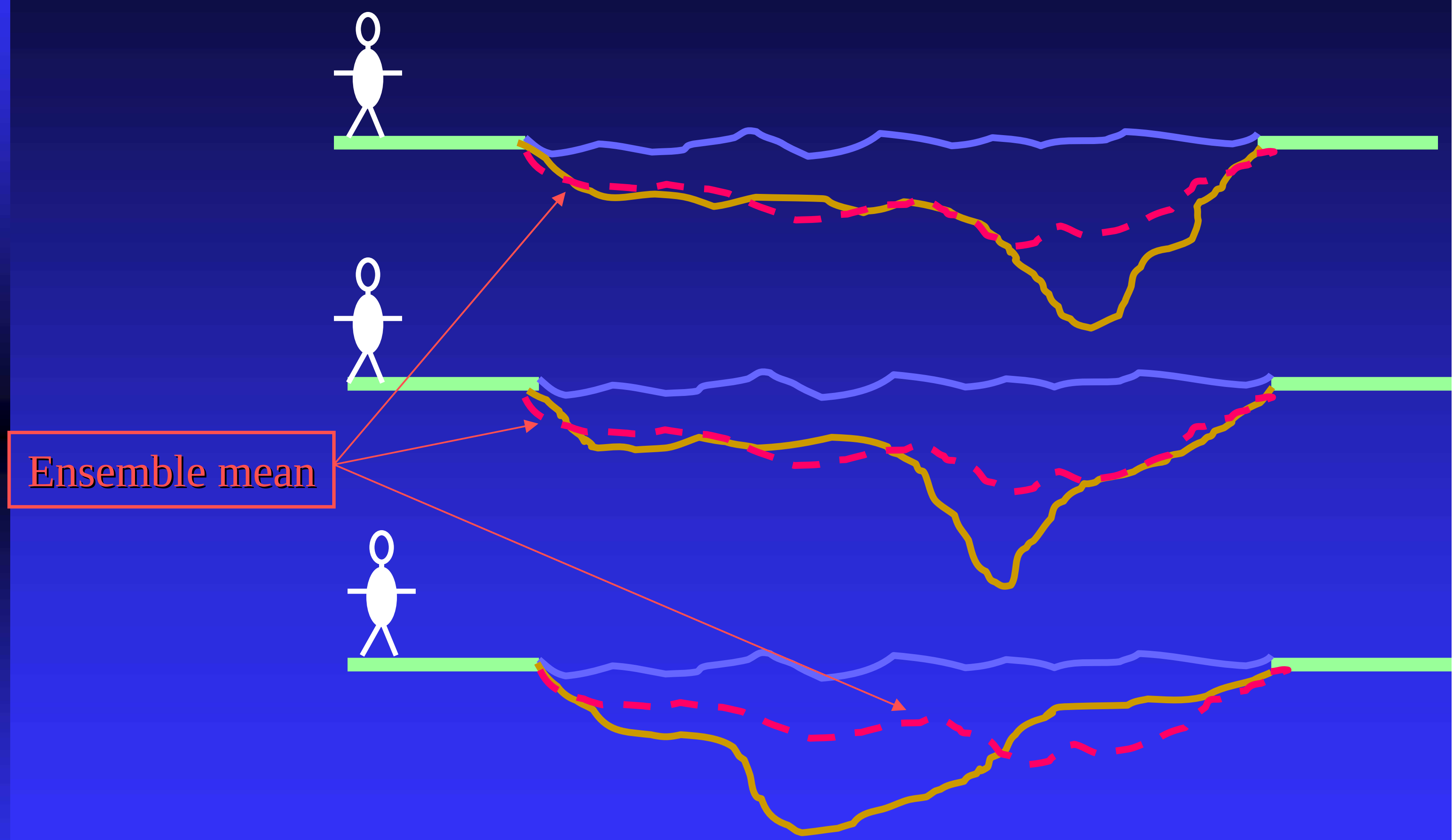
Three non-Floridian statisticians wish to cross a river.
Each has a forecast of depth which indicates they will drown.



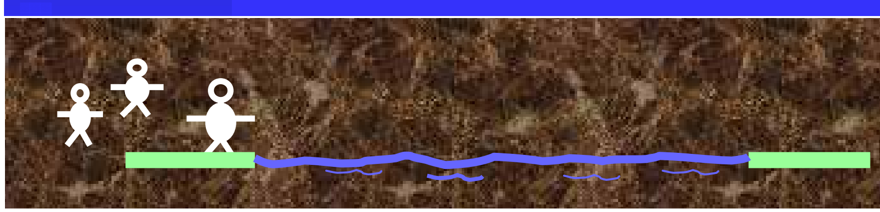
So they have an ensemble forecast,with three members



Three non-Floridian statisticians wish to cross a river.
Each has a forecast of depth which indicates they will drown.
So they average their forecasts and decide based on the ensemble mean…



Is this a good idea?



No!

Ensembles contain information, we must be careful not to destroy or discard it!

How do we even address these questions?

How to respect physically distinct distributions over
initial conditions ("mixing"),
parameter values ("non-mixing"),
model structure (defined how? And in what space?).

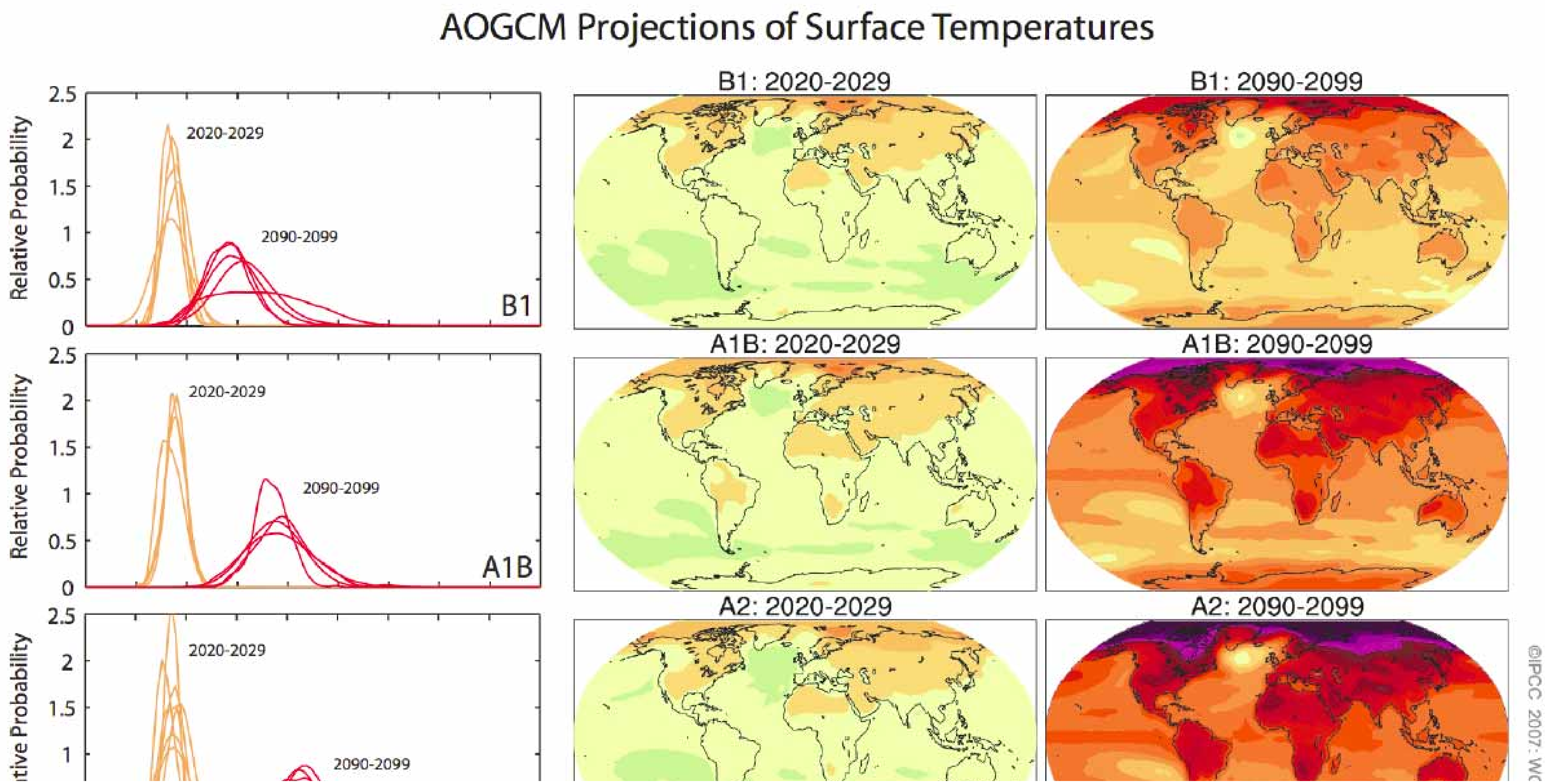
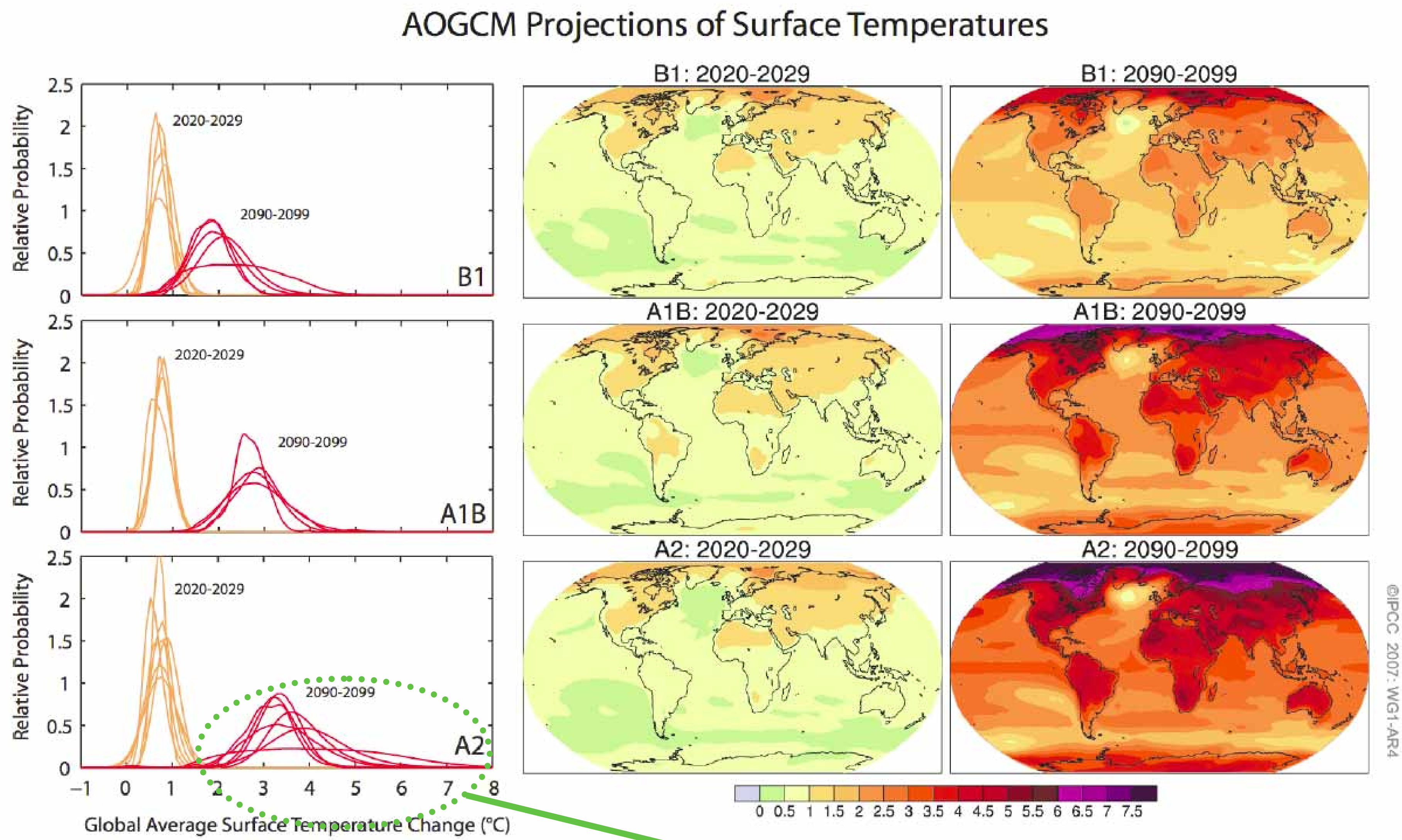
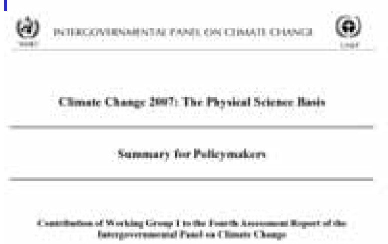


FIGURE SPM-5. Projected surface temperature changes for the early and late 21st century relative to the period 1980–1999. The central and right panels show the Atmosphere-Ocean General Circulation multi-Model average projections for the B1 (top), A1B (middle) and A2 (bottom) SRES scenarios averaged over decades 2020–2029 (center) and 2090–2099 (right). The left panel shows corresponding uncertainties as the relative probabilities of estimated global average warming from several different AOGCM and EMICs studies for the same periods. Some studies present results only for a subset of the SRES scenarios, or for various model versions. Therefore the difference in the number of curves, shown in the left-hand panels, is due only to differences in the availability of results. {Figures 10.8 and 10.28}




INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

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With this range of uncertainties in the global mean, how is one to interpret the patterns above?

Model Inadequacy and our three non-Floridian statisticians.

As it turns out, the river is rather shallow.
Model inadequacy covers things in the system that are not of the model.

The decision-relevant question was could they make it across, the depth of the river was only one component…

Investing in models: personal expectations for the next 20 years.

I hope AO+GCM climate model forecasts to converge (in distribution), hopefully without the distributions themselves becoming narrow (an indication of forced agreement via over-tuning). Odds on this happening before by ~ 2080 (DARPA extrapolation)?

I expect significant changes as the science advances (as in changes in the Atlantic storm track or blocking frequency or …)

I expect (*to see*) significant improvement in seasonal forecast models, with (realistic) converge in distribution and ensemble distributions with significant skill over climatology.

I expect (*to see*) surprisingly good improvement in probabilistic "weather" forecasts (now-casting to week three) which allow unexpected advances in adaptation and exploitation.

Economic value of NUMB weather will become obvious.

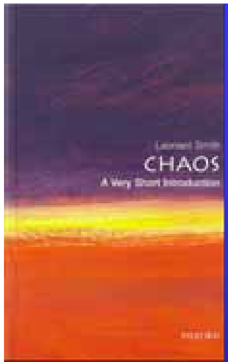
Overview

Models are our best tool for understanding; consistency will improve!

- Model inadequacy limits even probabilistic regional information
- Hurricanes, Atlantic SST gradient, Tropical rainfall, Sea breezes…

- Agreement between models (in distribution) would boost confidence
  - *Even* while leaving *unknown unknowns* untouched
- Climate Science needs to be presented so that the expected future advancements of science are seen as a "good thing" by decision makers.
- Prognosis:
  - The ***lower*** bound on our range of uncertainties will remain large
  - "All climate is local": weather forecasting is a win-win investment
  - Over-interpretation of models will lead to poor decision making
  - Moving to a model's information-content timescales will benefit all

Accepting this inconvenient ignorance will help us to deal with the inconvenient truth of global warming.



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K. Judd & LAS(2004) *Indistinguishable States: Imperfect Model Scenario*, *Physica* D

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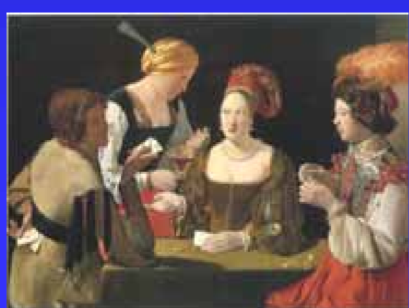

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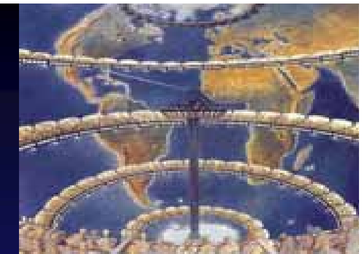
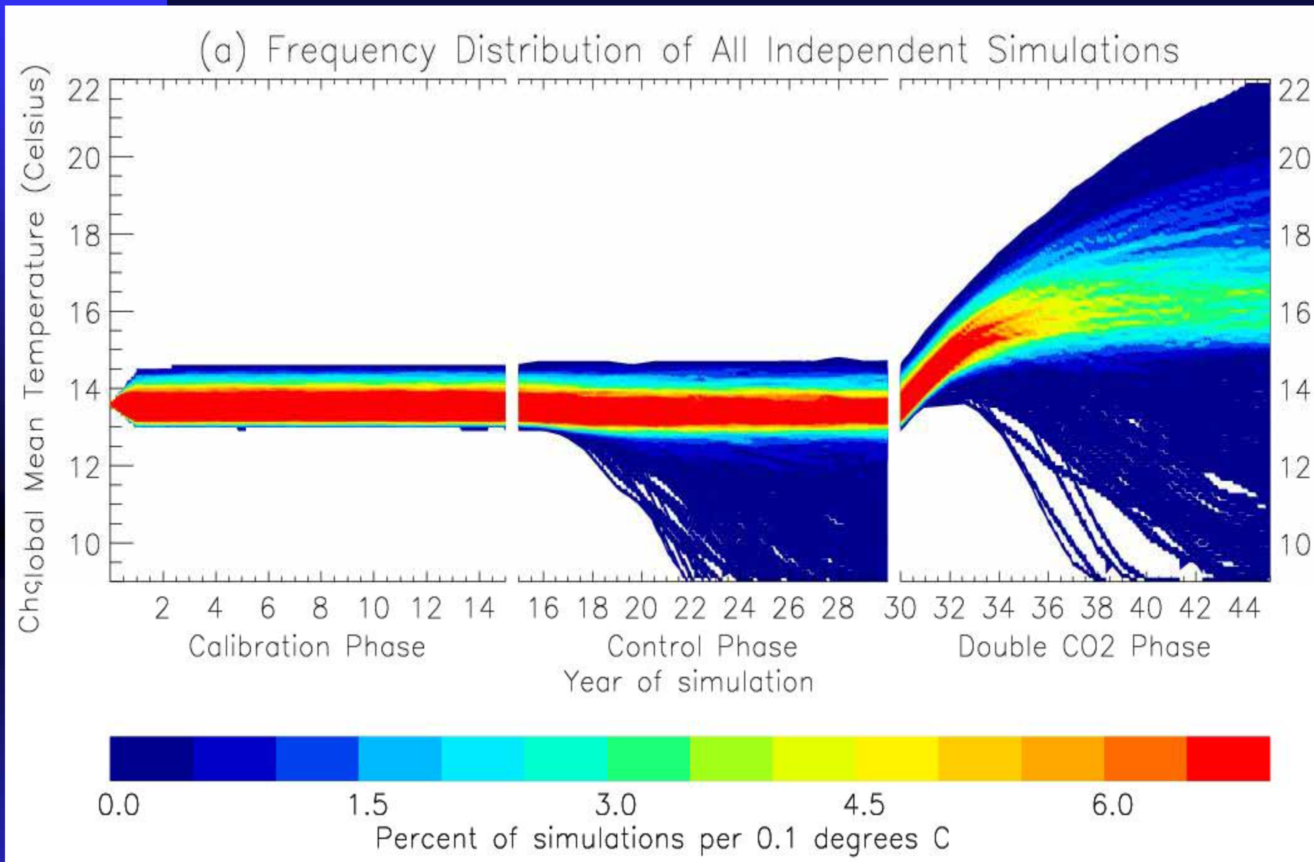
Live Discussion Board

MSRI Questions (Mine) :

- Framework/concepts for transient nonlinear systems
- Framework for transient system/model pair(s)
  - How long can state-of-the-art climate models shadow?
    - Do p-orbit mismatch vectors show systematic "needs".
  - How to project between obs space and model state space(s)?
  - Beyond Best: An interpretation of distributions (IC, P, & structure) of useful state-of-the-art models (in which no one "believes").
- How to determine decision-relevant space-time scales?
- How to *better* identify skill in the absence of observations?
- Can our models yield understanding without probabilities or realism? (Qualitative info from quantitative models)
- How to respect physically distinct distributions (IC, P, M)?
- Can we ensure scientific progress is seen as a "good thing"?

An ensemble of climate "models."





This is the range of 2xCO2 global average temperature in one model!

It tells us nothing about summer temperatures in London.

Except through global things like sea level

> 100,000 participants from 150 countries
> 70,000 simulations (each 45 years long)
> 8,000 years of computing time

Projections of Future Changes in Climate

Projected Patterns of Precipitation Changes

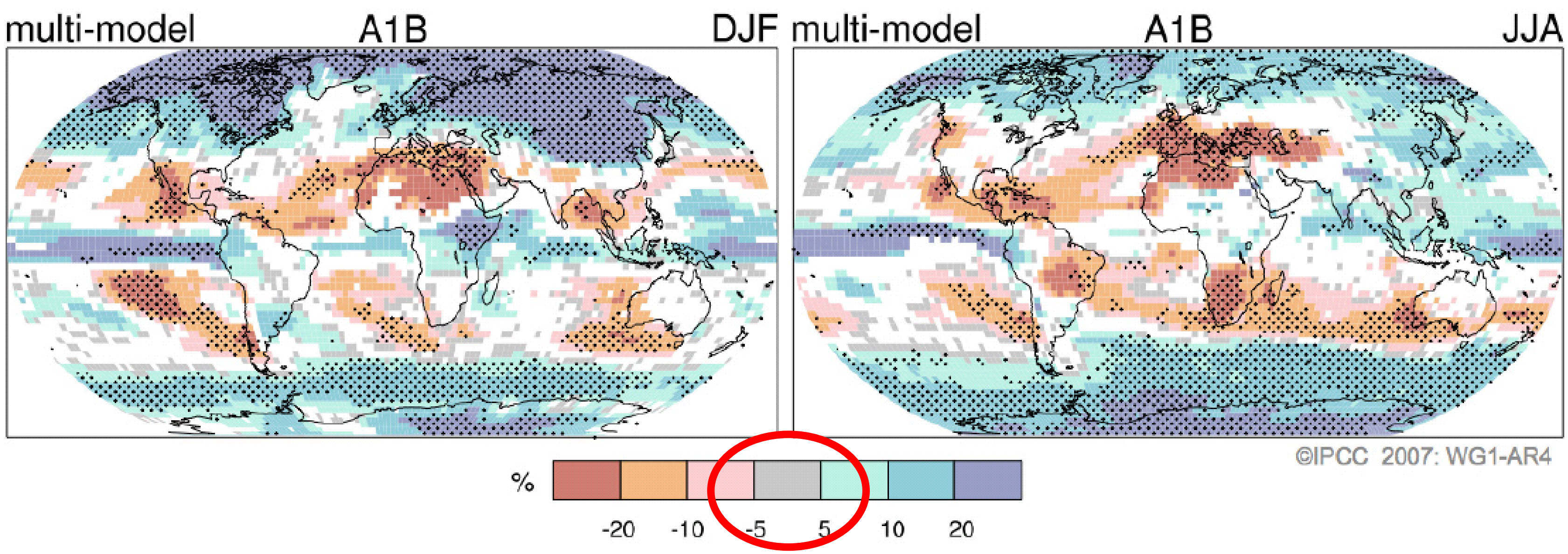


FIGURE SPM-7. Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign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