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

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

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

Fitzroy, 1862

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

www.cccep.ac.uk

How does the diversity in our models inform us about the uncertainty in our future?

?Expected Uncertainty -or- Big Surprise?

Leonard Smith

With Ana Lopez, Dave Stainforth,

Ed Tredger & Roman Binter

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

Living With Environmental Change LWEC

Münchener Rück Munich Re Group

LSE The London School of Economics and Political Science

University of Leeds


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One-Minute World News

News Front Page

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South Asia
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Northern Ireland

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

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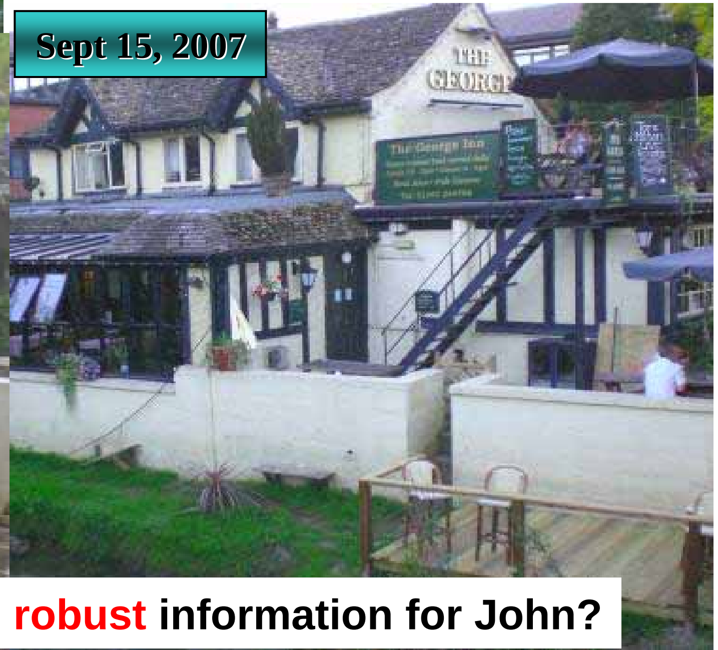
England smoke ban to start 1 July

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

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

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



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

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

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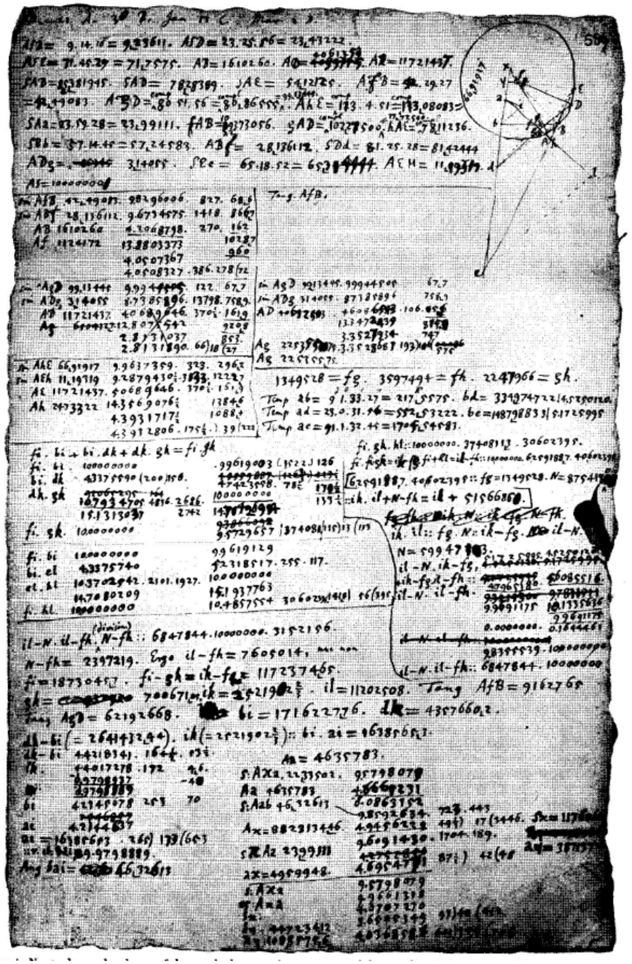
Overview

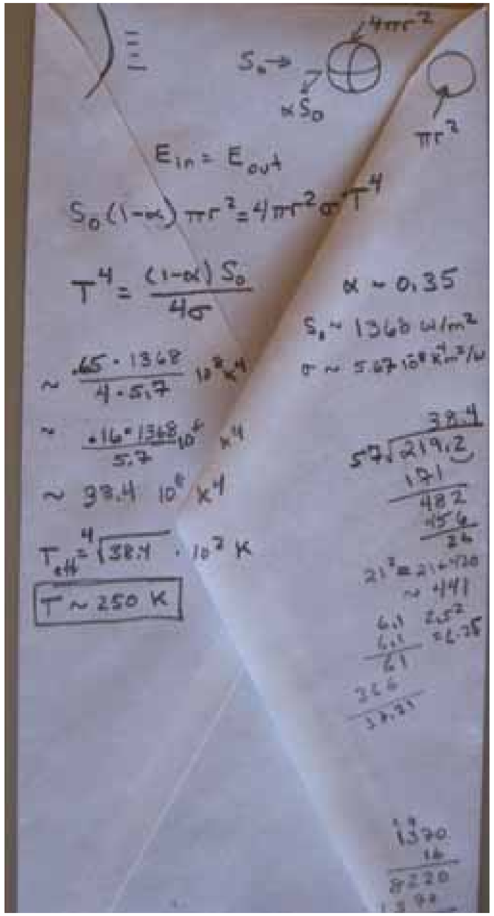
- Models as a basis for evidence-based decision making
- Complex models interpreted within the understanding of science
  - Detailed example of a simple (and amazingly useful) climate model
- What are ensembles?
  - How do they aid our insight?
  - Where can we expect “surprises”?
- What is a “Big Surprise”?
- Challenges to interpreting today’s state-of-the-art models
- Expectations from the Munich Re Programme and/in Grantham

Back of the Envelope Calculations



Newton

Computing the orbit of Hadley's comet for Hadley



Smith

Reproducing an estimate for the temperature of the Earth

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The amazing thing about models is that they give us so much!

Science, Models, and Parameters

The simplest(?) climate model:

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

energy in = energy out

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

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Science, Models, and Parameters

The simplest(?) climate model:

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

Area of a sphere
SB constant
Effective Temperature

Albedo
Area of a disk
Solar constant

energy in = energy out

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

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Science, Models, and Parameters

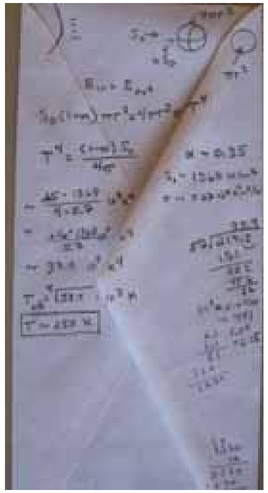
The simplest(?) climate model:

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

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

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

Solving for T_{eff} gives an answer to within about 10% of the Earths average surface temperature, And does even better for the moon!



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	MERCURY	VENUS	EARTH	MOON	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Mass (10^{24}kg)	0.330	4.87	5.97	0.073	0.642	1899	568	86.8	102	0.0125
Diameter (km)	4879	12,104	12,756	3475	6792	142,984	120,536	51,118	49,528	2390
Density (kg/m^3)	5427	5243	5515	3340	3933	1326	687	1270	1638	1750
Gravity (m/s^2)	3.7	8.9	9.8	1.6	3.7	23.1	9.0	8.7	11.0	0.6
Escape Velocity (km/s)	4.3	10.4	11.2	2.4	5.0	59.5	35.5	21.3	23.5	1.1
Rotation Period (hours)	1407.6	-5832.5	23.9	655.7	24.6	9.9	10.7	-17.2	16.1	-153.3
Length of Day (hours)	4222.6	2802.0	24.0	708.7	24.7	9.9	10.7	17.2	16.1	153.3
Distance from Sun (10^6 km)	57.9	108.2	149.6	0.384*	227.9	778.6	1433.5	2872.5	4495.1	5870.0
Perihelion (10^6 km)	46.0	107.5	147.1	0.363*	206.6	740.5	1352.6	2741.3	4444.5	4435.0
Aphelion (10^6 km)	69.8	108.9	152.1	0.406*	249.2	816.6	1514.5	3003.6	4545.7	7304.3
Orbital Period (days)	88.0	224.7	365.2	27.3	687.0	4331	10,747	30,589	59,800	90,588
Orbital Velocity (km/s)	47.9	35.0	29.8	1.0	24.1	13.1	9.7	6.8	5.4	4.7
Orbital Inclination (degrees)	7.0	3.4	0.0	5.1	1.9	1.3	2.5	0.8	1.8	17.2
Orbital Eccentricity	0.205	0.007	0.017	0.055	0.094	0.049	0.057	0.046	0.011	0.244
Axial Tilt (degrees)	0.01	177.4	23.5	6.7	25.2	3.1	26.7	97.8	28.3	122.5
Mean Temperature (C)	167	464	15	-20	-65	-110	-140	-195	-200	-225
Surface Pressure (bars)	0	92	1	0	0.01	Unknown*	Unknown*	Unknown*	Unknown*	0
Number of Moons	0	0	1	0	2	63	60	27	13	3
Ring System?	No	No	No	No	No	Yes	Yes	Yes	Yes	No
Global Magnetic Field?	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Unknown
	MERCURY	VENUS	EARTH	MOON	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO

Mean Temperature (C or F) - This is the average temperature over the whole planet's surface (or for the gas giants at the one bar level) in degrees C (Celsius or Centigrade) or degrees F (Fahrenheit). For Mercury and the Moon, for example, this is an average over the sunlit (very hot) and dark (very cold) hemispheres and so is not representative of any given region on the planet, and most of the surface is quite different from this average value. As with the Earth, there will tend to be variations in temperature from the equator to the poles, from the day to night sides, and seasonal changes on most of the planets.

Black-body temperature (K) 274.5 254.3

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http://nssdc.gsfc.nasa.gov/planetary/factsheet/moonfact.html

Uncertainty and Inadequacy

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

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

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

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

We do not expect uncertainty in the parameters to reflect model error!

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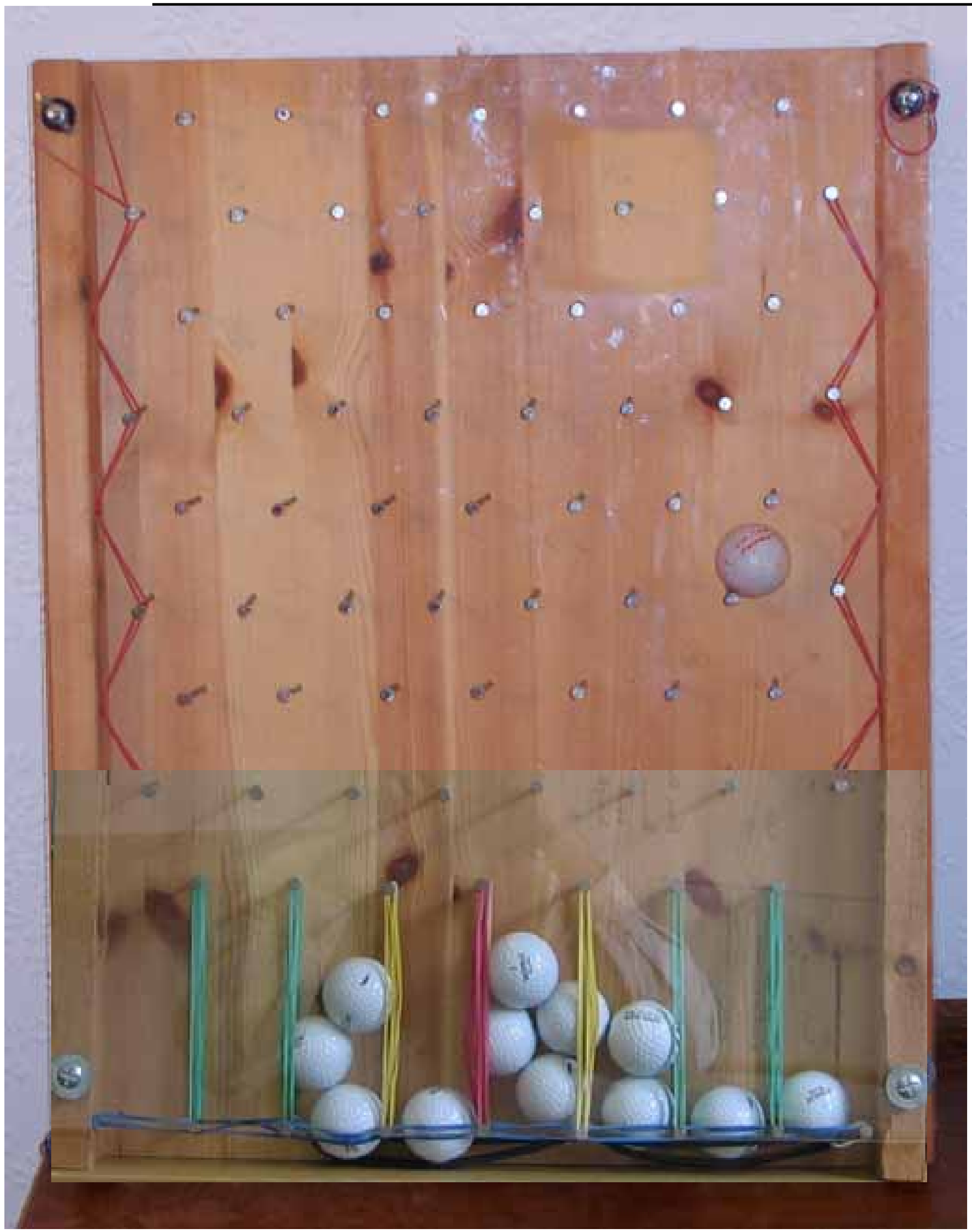
What is an Ensemble?

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…

Note that ensembles inform us of uncertainty growth *within our model!* *(It tells us about the next golf ball.)*

What is an Ensemble?



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 red ball archive: into the known-to-be-different unknown.

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

And anticipate "Big Surprises"

Information in Ensembles: Decision making


6 | News

Property slump

Under £200,000

New-build flats

Under £350,000

Conversion flats

Under £500,000

Terraced houses

Homeowers brace themselves for a cold front on the property market

▶ High-value houses may not be affected

▶ Last areas to boom could be first to fall

Will your home weather the storm?

Capital Economics

Scotland

North

Northern Ireland

North West

Yorkshire and Humberside

Wales

West Midlands

East Midlands

East Anglia

South West

South East

London


News | 7

Property slump

Under £750,000

Under £2m

Over £2m

Lenders may not pass on rate cuts

What do homeowners have to fear from the credit crunch?

An ensemble is nothing more than a collection of different forecasts for the same target!

Is seeing this diversity of value, even if reality might fall outside the RANGE of the forecasts?

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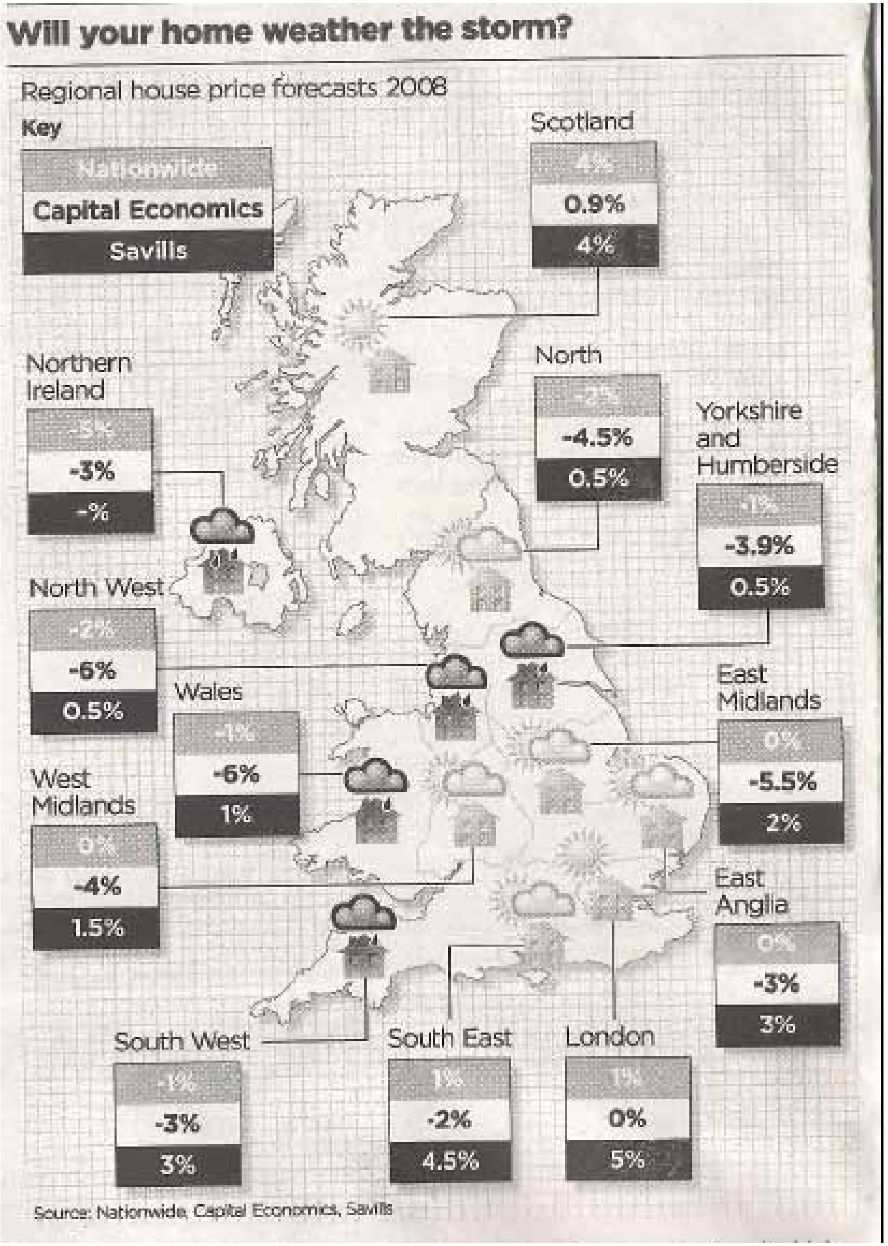
Ensembles: the value of knowing Diversity



Scotland: all forecasts positive.

London: None negative

Northern Ireland: one missing

All others mixed: positive and negative

All these issues are mirrored in climate modelling, including the fact that the forecasts are not really independent.

Do not confuse the diveristy of an ensemble forecast/projection with the uncertainty in our future!

Whitehead's 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.

Science and the Modern World. Pg 58/9

You don't have to believe everything you compute!

Or in terms of "trust":
We might "trust" our models in the way a parent trusts a child,
but never in the way a child trusts a parent!
This holds for all models, and does not damn climate models!

Science allows for "big surprises"!

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What is a "Big Surprise"?

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

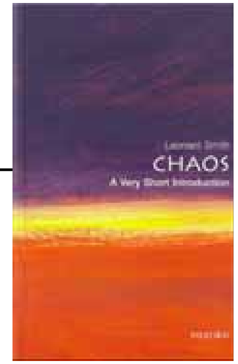
  (Science can tell us of things the red ball can do, that golf balls cannot do)

  (And warn of "known unknowns" even when the magnitude is not known)
- Big Surprises invalidate (not update) the foundations of model-based probability forecasts. (Arguably "Bayes" does not apply)

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

How might we communicate the useful information in ensembles?

(Then a bit on how we might use climate science to foresee big surprises)



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.)

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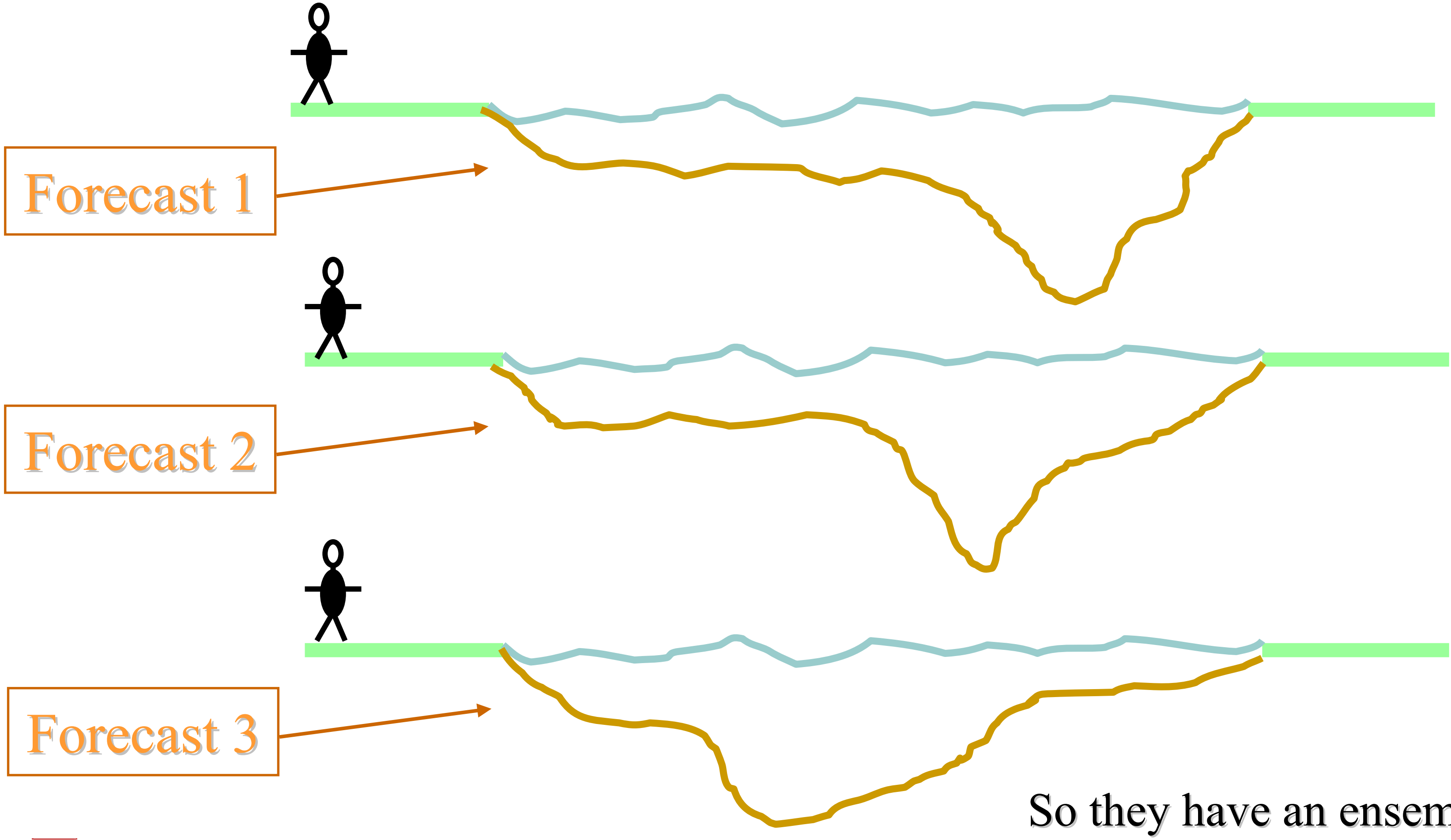
Three non-Floridian statisticians wish to cross a river

Each has a forecast of depth which indicates they will drown.



So they have an ensemble forecast,with three members

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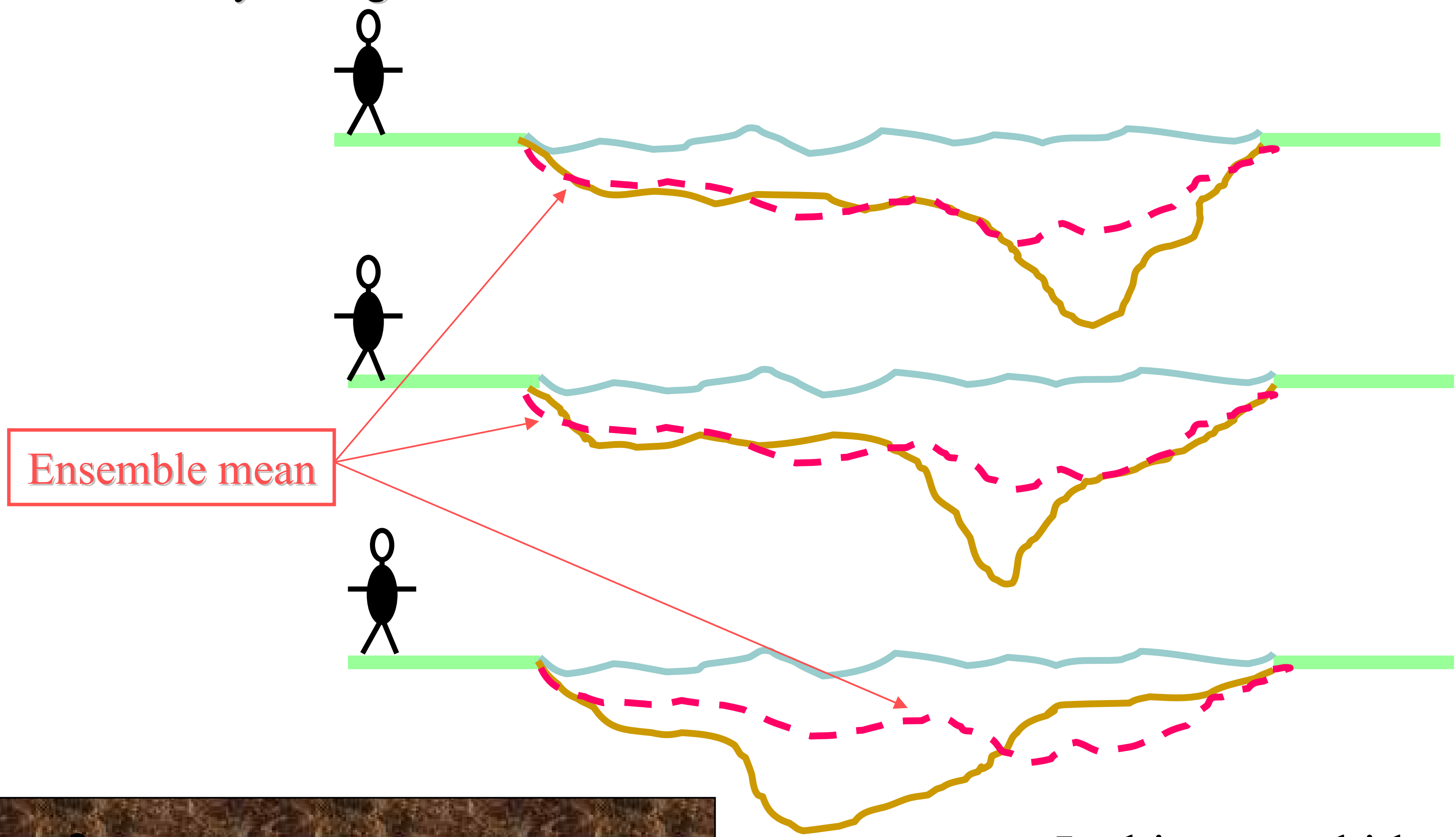
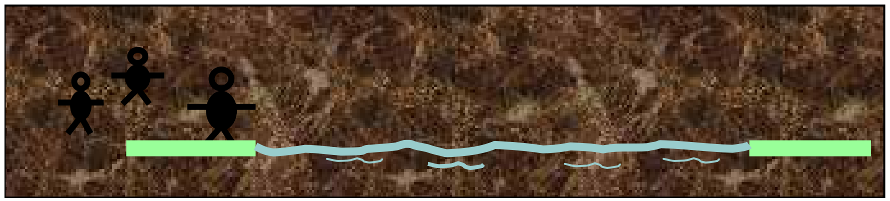
Three non-Floridian statisticians wish to cross a river.

Each has a forecast of depth which indicates they will drown.

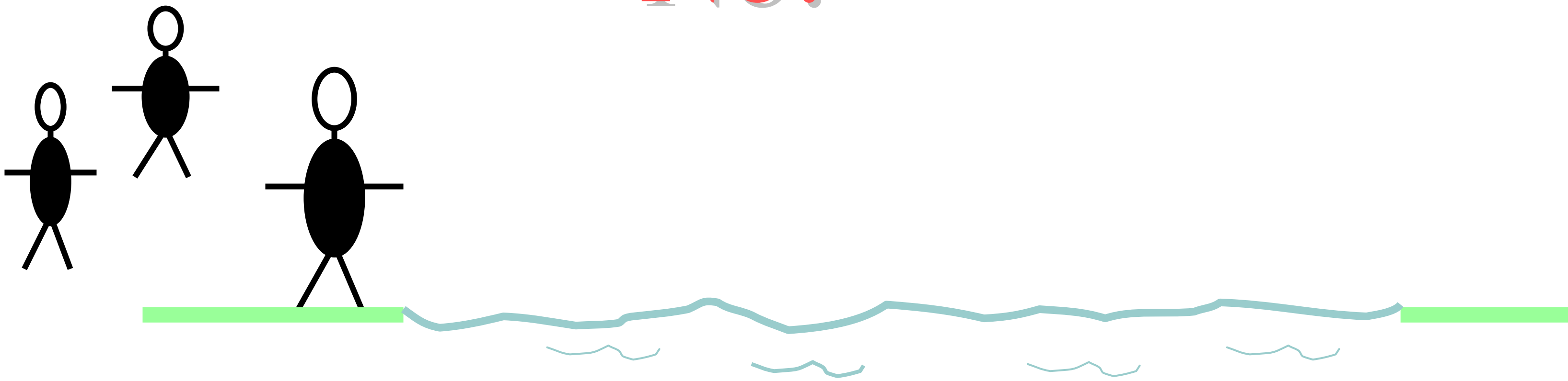
So they average their forecasts and decide based on the ensemble mean…





Is this a good idea?

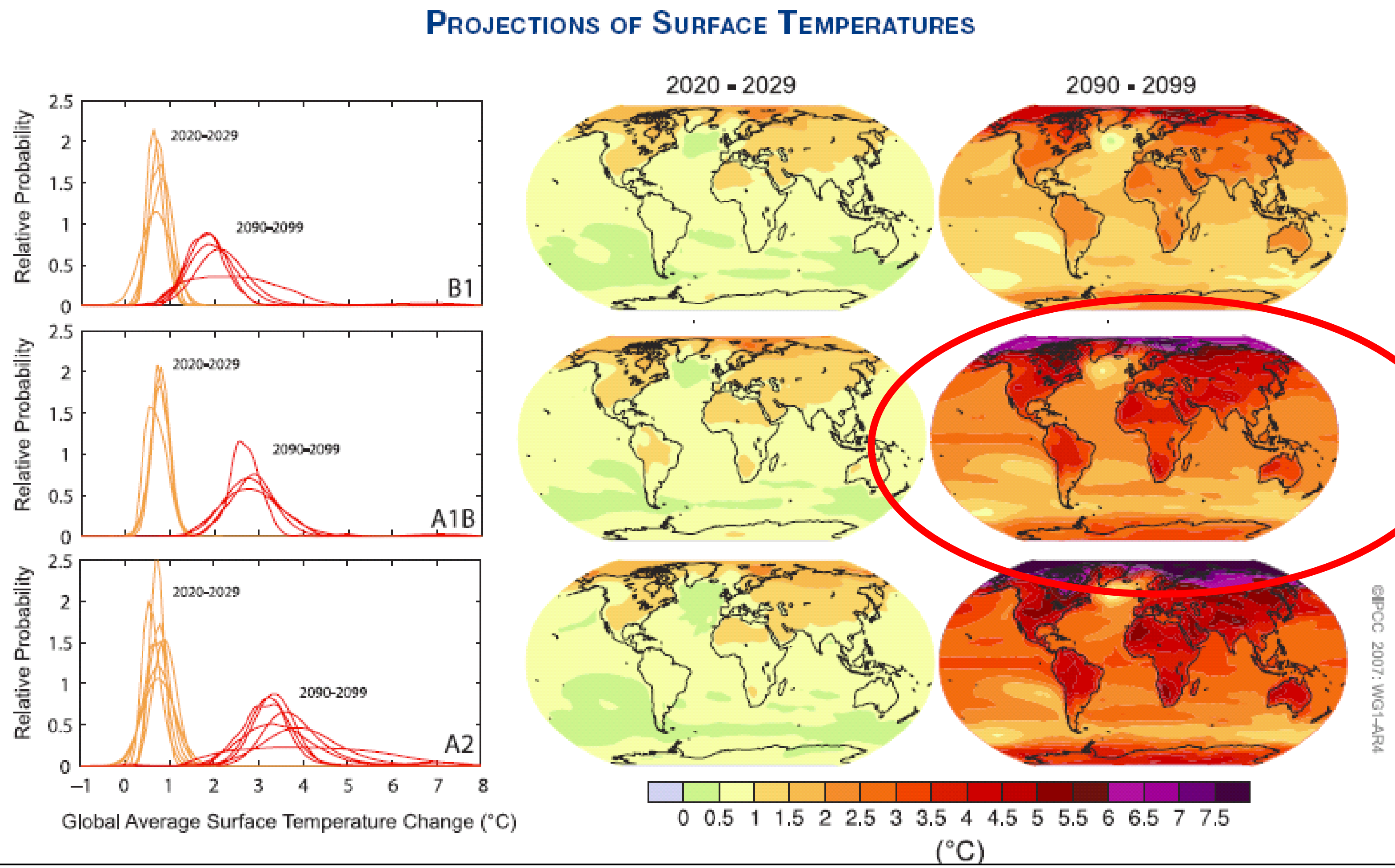
No!



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

Yet climate information is sometimes communicated as:

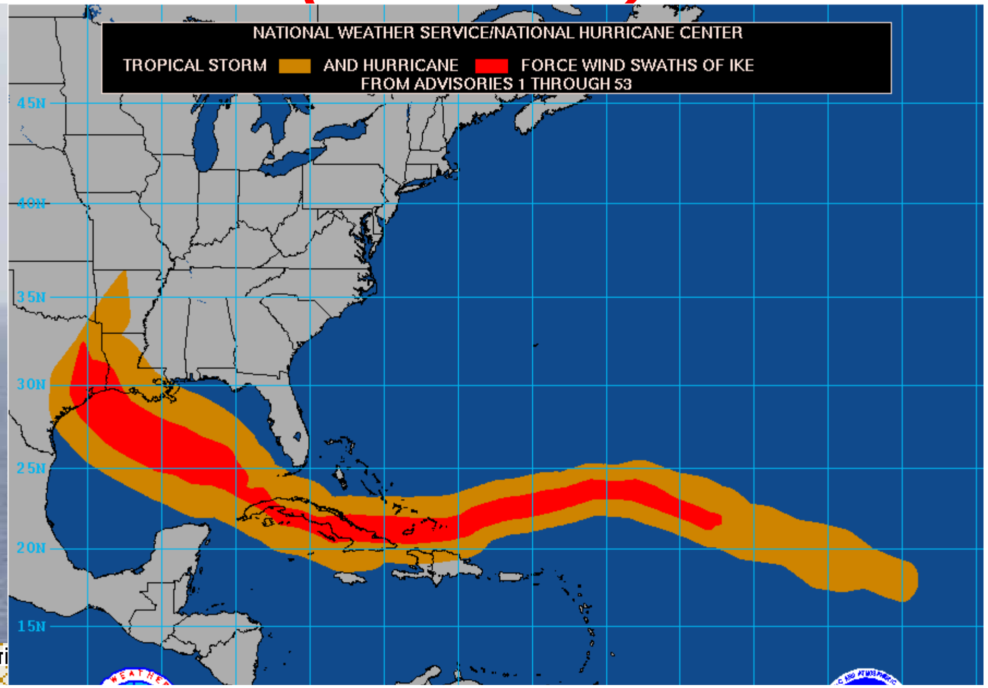
What does a (model) mean mean? For hurricanes?

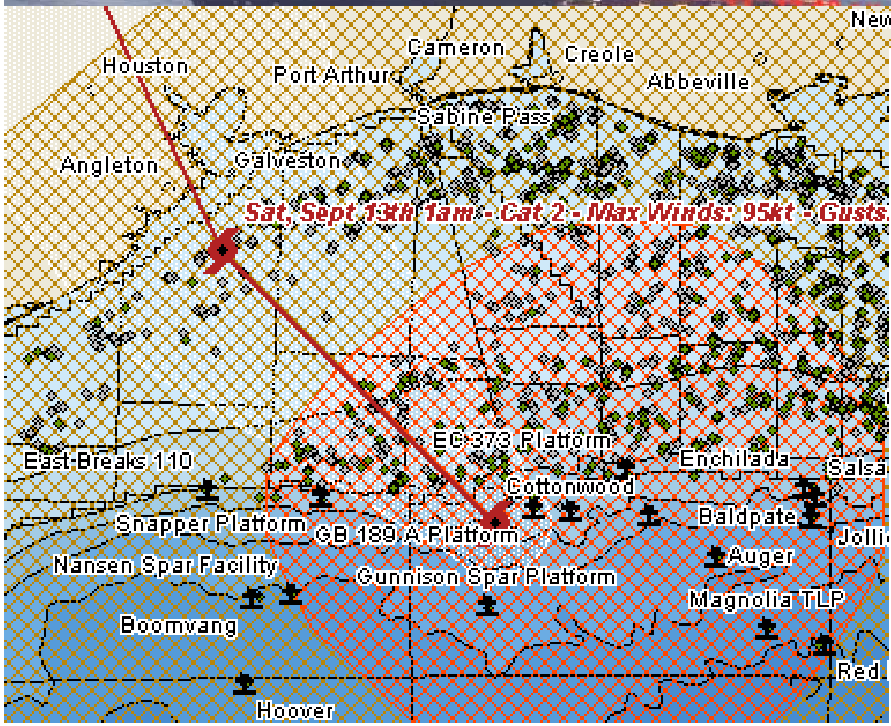


Today's state of the art climate models do not resolve things as small as a hurricane, but if the model temperatures were thought to be decision-support relevant, we could look at projected temperatures in the Atlantic and apply some experimental statistics…

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}

Hurricane Frequency is of Interest (This is Ike)





Wednesday, September 17, 2008

Offshore Rig Damage Caused by Hurricane Ike (Updated)

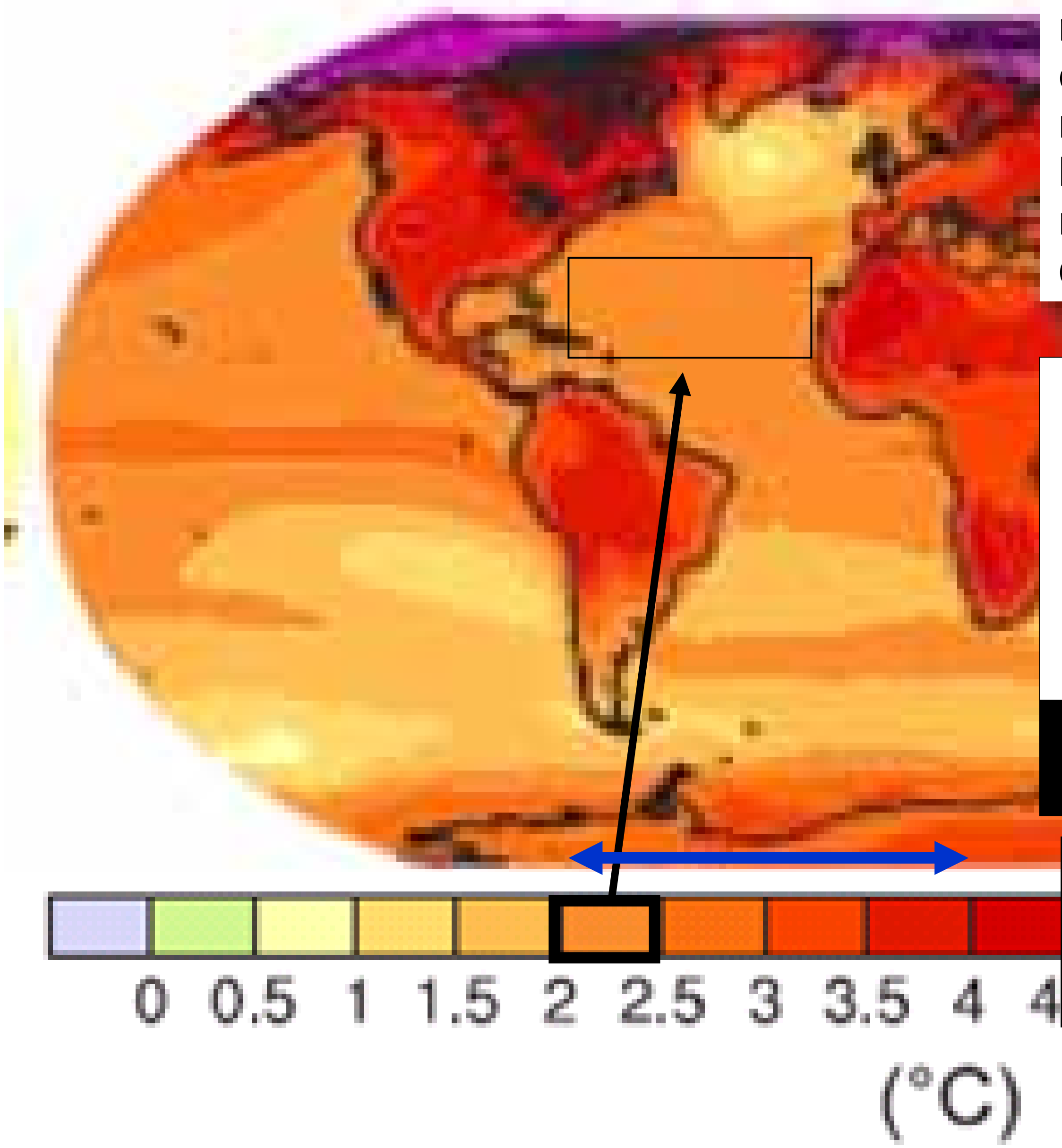
As companies evaluate their offshore assets and begin to report on their findings, it is quickly becoming apparent that Ike has dealt a harsh blow the Gulf of Mexico rig fleet. Thus far, 3 jackups and 1 platform rig have apparently been lost. In addition, another jackup has lost if drilling package and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

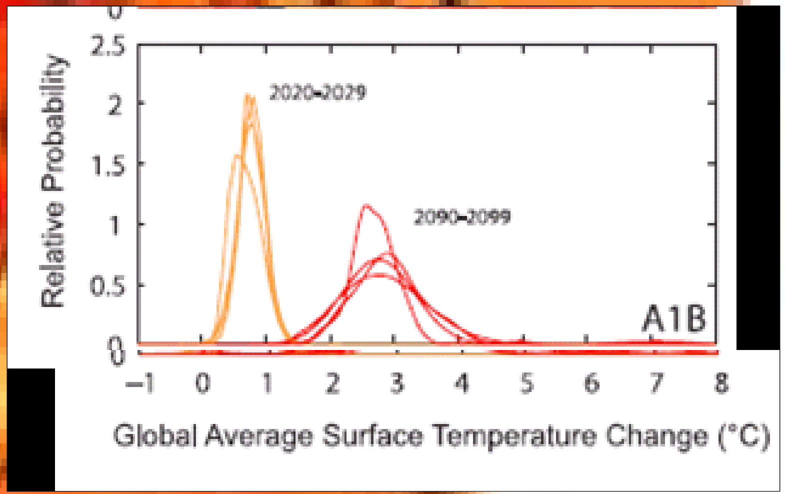
Rig Name	Manager	Rig Type	Built	Cost	Damage Assessment
ENSCO 74	ENSCO	375' ILC jackup	[illegible]	$84 million	Rig missing - probable total loss
Pride Wyoming	Pride	250' MS jackup	1976	$26 million	Rig missing - probable total loss
Rowan Anchorage	Rowan	250' ILS jackup	[illegible]	$9 million	Rig missing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

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

What does a mean mean?
Say, for changes in Atlantic hurricanes?

As in the case of the three statisticians, rather than averaging first and then computing the impact on hurricane numbers, one should first compute hurricane numbers, and then (if you must) average. (or better still look at the distribution).





Prior to complicated statistical analysis, it would be useful if domain scientists believe these SSTs are robust, given that the GLOBAL ***model***-temperature range is >> 2 degrees…

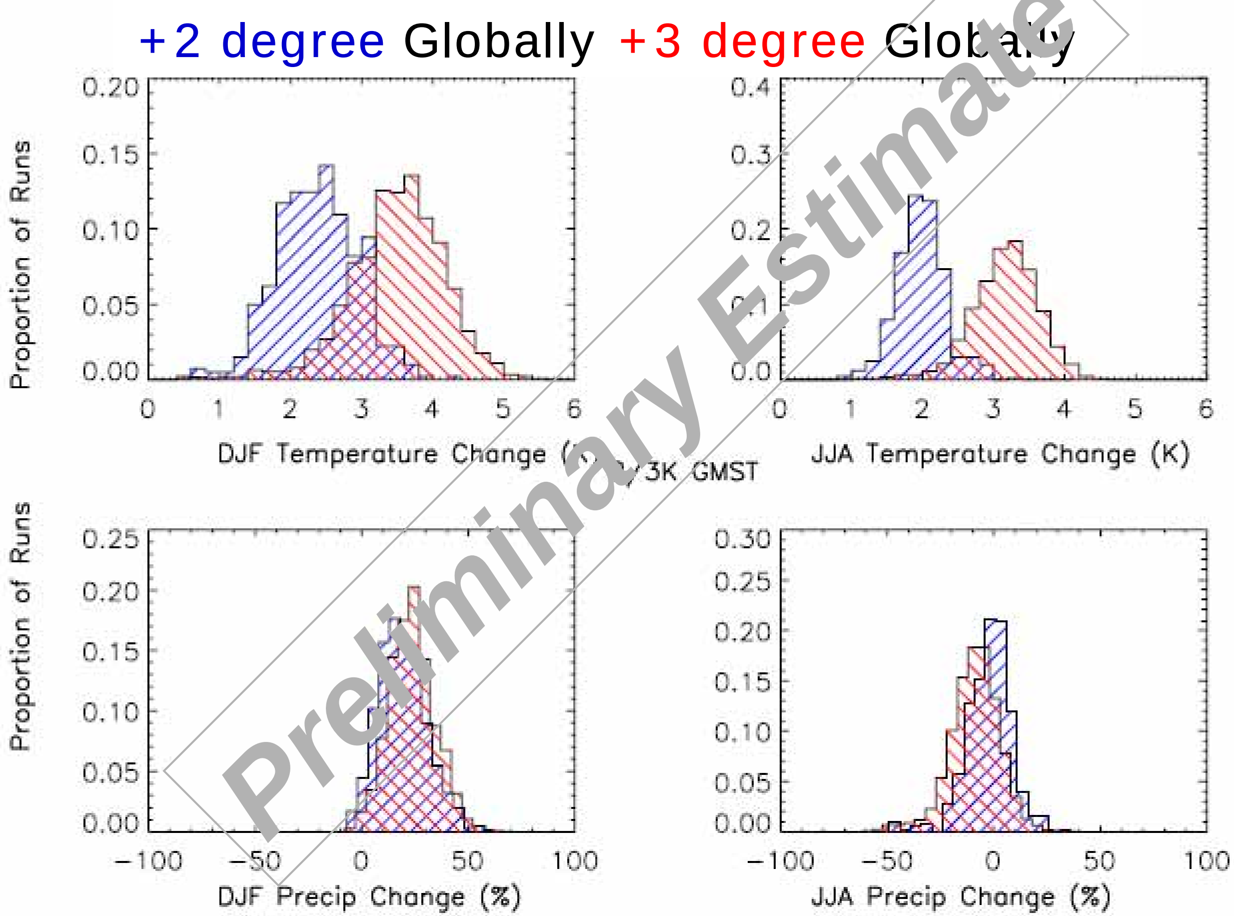
Ensembles can yield diversity within our models

Ensembles show the range of conditions our models propose we might observe, a "non-discountable envelope" of outcomes which the models suggest must be considered.

For example, what range of temperatures would the UK see in a model-world 2 degrees warmer, compared with a model-world 3 degrees warmer?

Ensembles can yield diversity within our models

Variations in UK seasonal temperature For fixed change in global mean temperature.



Here is the UK figure. 8 year mean seasonal p3-p2 uk temp and precip change for UK region (mean over 6 grid boxes as shown in uk_map.ps).

The overlap probabilities are :
DJF temp - 9%
JJA temp - 2%
DJF pr - 37%
JJA pr - 67%

Assuming the model is perfect!

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climateprediction.net

Surprises and our three non-Floridian statisticians.

As it turns out, the river is rather shallow.

Big Surprises come from Model inadequacy: things in the system that are not of the model.

We understand climate science well enough to expect non-statistical updates as the models improve.
While the basic science supports significant warming.

At present, the models do not agree (in distribution) on "decision relevant" length scales… how can the science help?

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Expecting Surprises

- Often, very well established science suggests we are over-interpreting the model output, and even suggests the sign of a likely surprise. Can we quantifying subjective probabilities here?
- We will look briefly at mountain ridges and the 1930's dustbowl to get an idea what our current models cannot do "accurately"
- This suggests we lower the bar of expectation

Avoiding Surprises for Users:

We are often told today's models are "better" without being told where they are believed to be quantitatively accurate (worth betting on).
Could we be told the probability of a "Big Surprise" for our target of interest?

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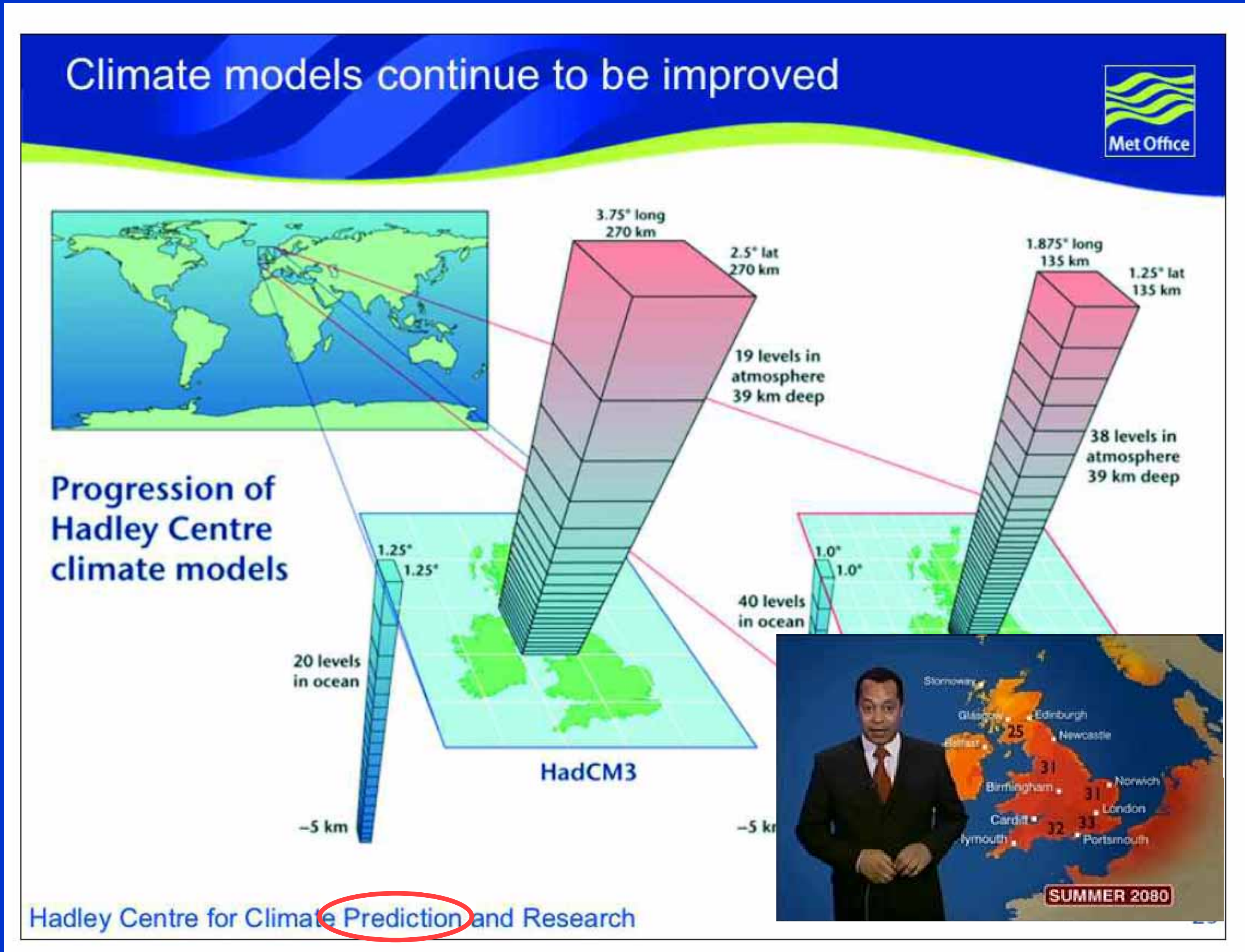
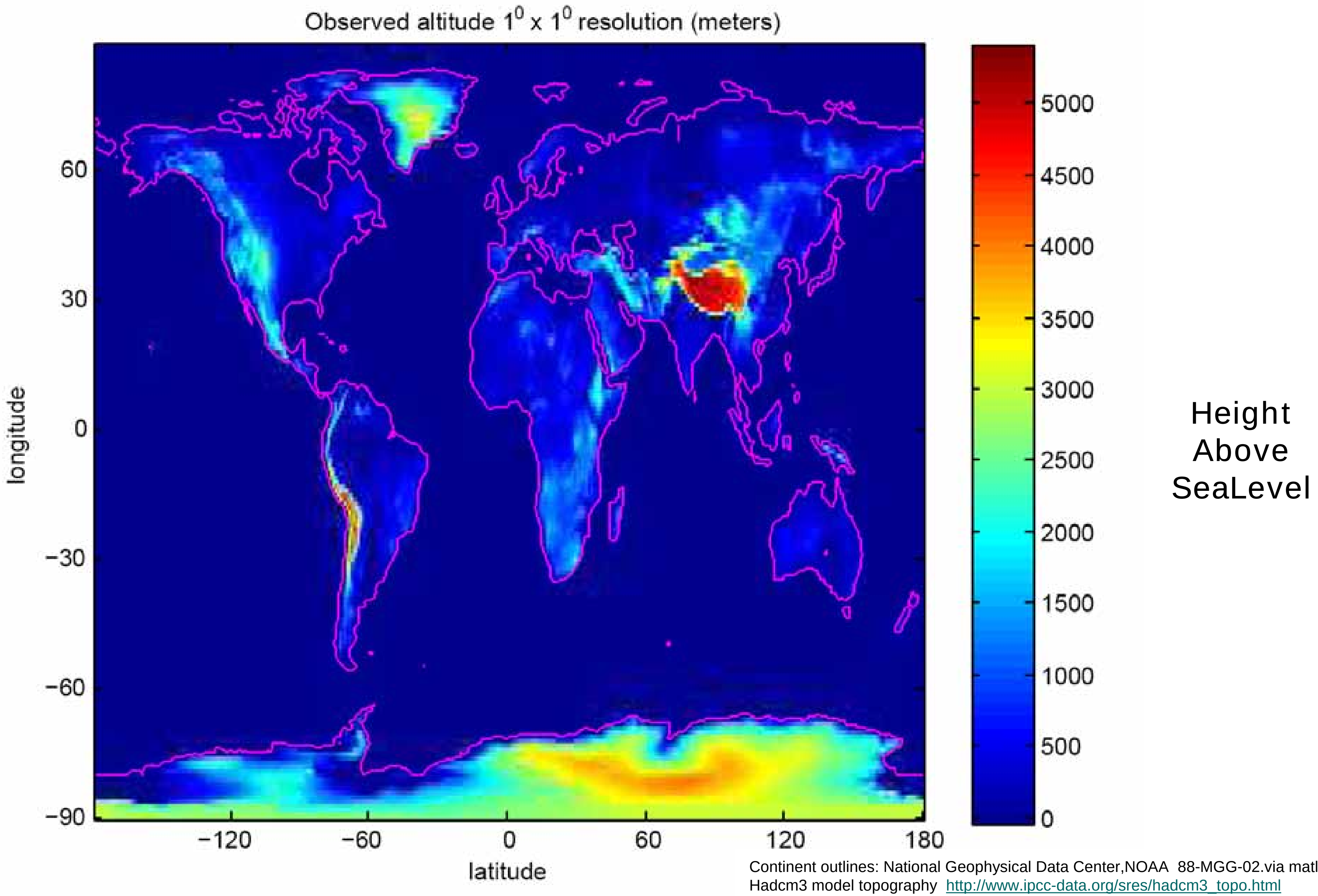
It is more useful to know where today’s models are robust!



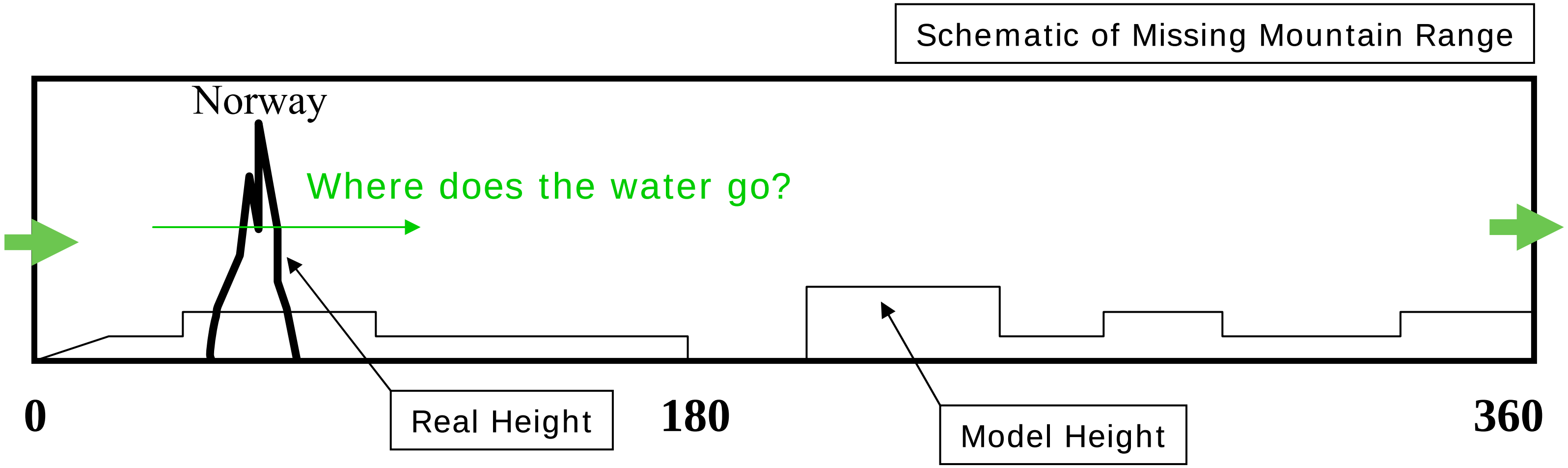
As scientists we need to be careful to communicate the limitations of current models.

The surface of the earth at “high” resolution



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

Sciences knows more than we can Model



Before using phrases like "based on the Laws of Physics" to defend hi-resolution predictions, we might check for internal consistency (quantitative).

Or better: find necessary (not sufficient) conditions for this model to contain decision relevant information.

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

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Sciences knows more than we can Model

This insight is not new:

In some countries, where the wind blows almost constantly in one direction, vegetation is abundant on the side against which the wind blows from the ocean, an inexhaustible source of moisture, while on the other side there is scarcely any vegetation at all; as in Peru, Patagonia, parts of Arabia and Africa, various islands, parts of Asia and of Australia, where all the moisture from the sea winds has been condensed and extracted: and in passing across extensive land, the other sea side, as in Peru, receives only dried air from the land, and the country is more or less barren.

BOARD OF TRADE.

1859.

COMPILED BY REAR ADMIRAL FITZROY, F.R.S.

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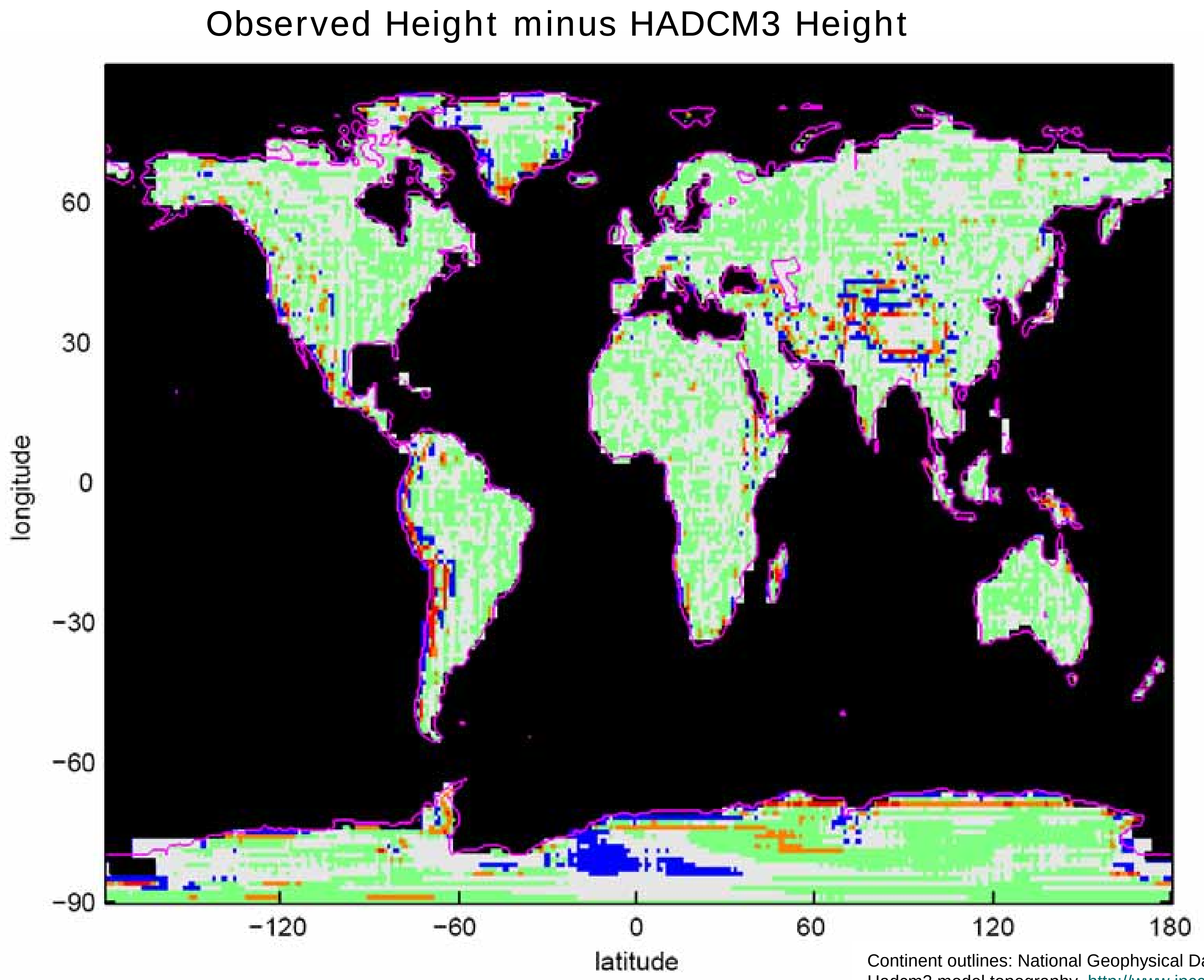
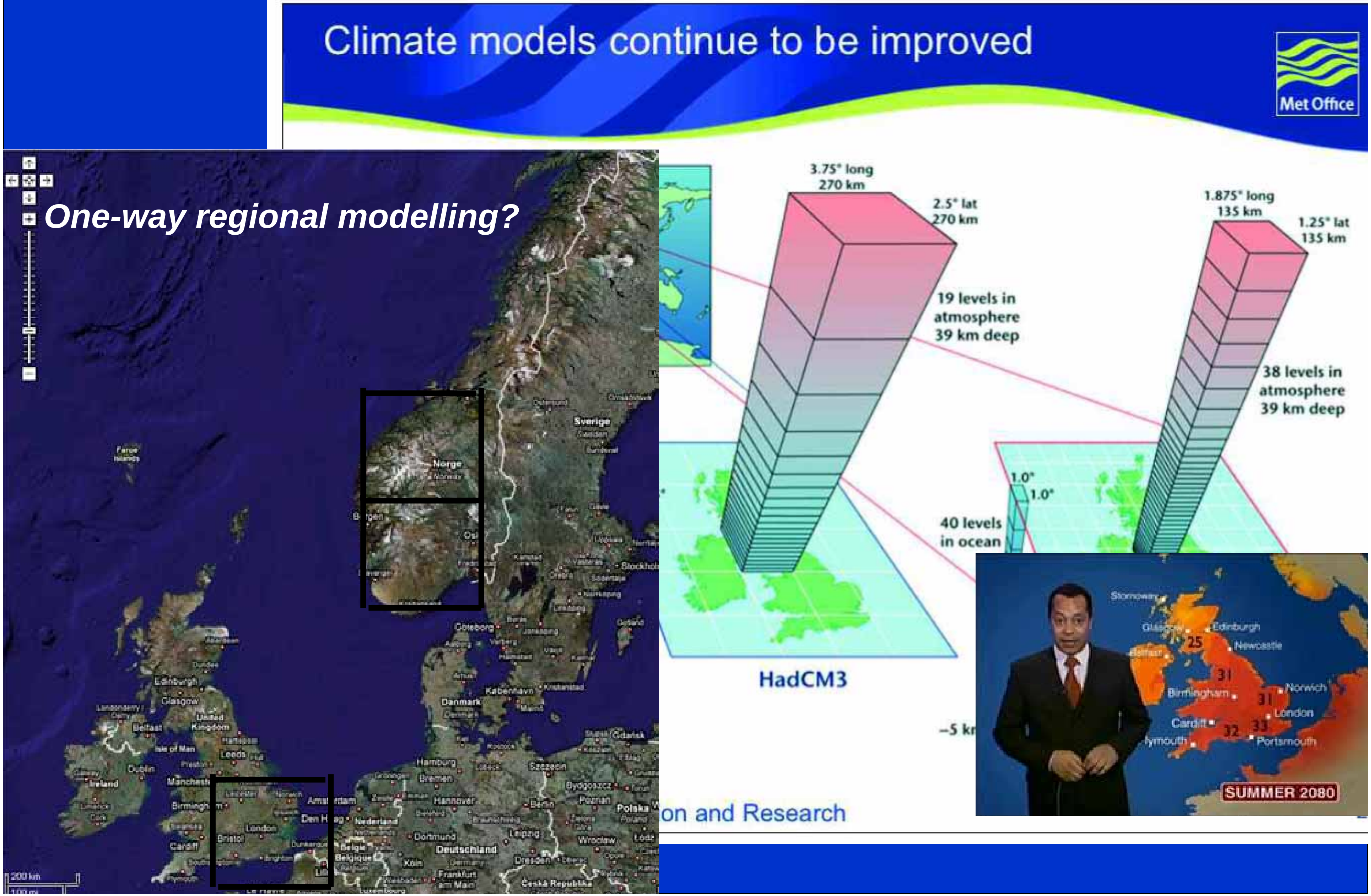
Missing Mountain Ridges



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

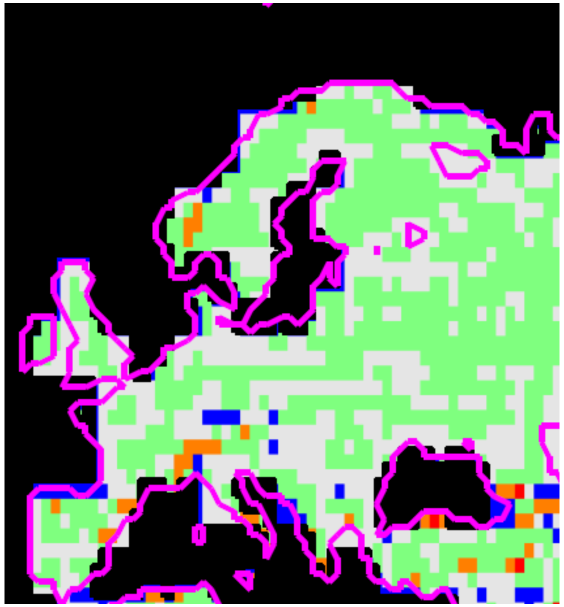
Continent outlines: National Geophysical Data Center,NOAA 88-MGG-02.via matlab
Hadcm3 model topography http://www.ipcc-data.org/sres/hadcm3_topo.html
1x1 topography: http://www.ngdc.noaa.gov/mgg/topo/globe.html.

On what space and time scales ***do*** we have (robust) climate information?
(The usual numerical arguments require m uch larger scales than the model's grid, at least!)



Missing Mountain Ridges

Observed minus HADCM3 Height

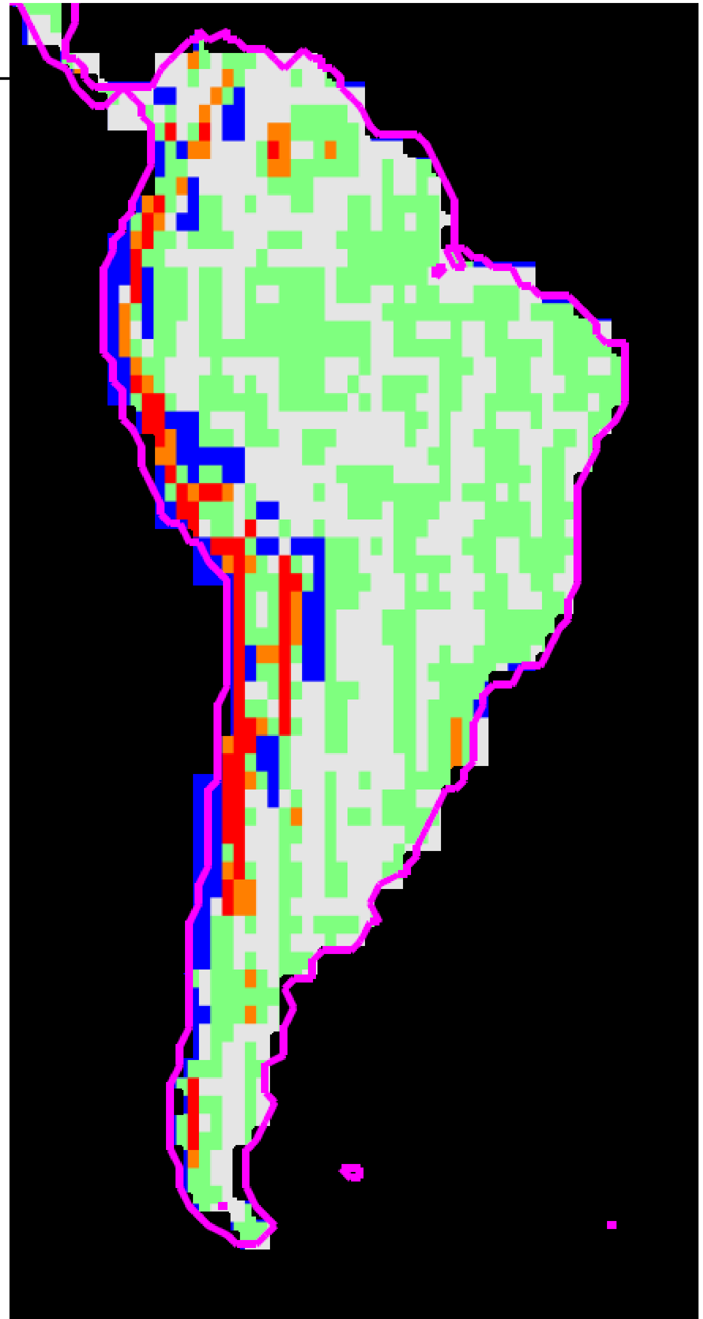


Blue < -500m
Grey > -500m
Green > 250m
Orange > 500m
Red > 1 km

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

(Walls > 500m and > 1km!)

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



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

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Things we know cannot model: The 1930’sDust bowl

Would Advance Knowledge of 1930s SSTs Have Allowed Prediction of the Dust Bowl Drought?*

RICHARD SEAGER, YOCHANAN KUSHNIR, MINGFANG TING, MARK CANE, NAOMI NAIK, AND JENNIFER MILLER

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(Manuscript received 3 July 2007, in final form 30 October 2007)

ABSTRACT

Could the Dust Bowl drought of the 1930s have been predicted in advance if the SST anomalies of the 1930s had been foreknown? Ensembles of model simulations forced with historical observed SSTs in the global ocean, and also separately in the tropical Pacific and Atlantic Oceans, are compared with an ensemble begun in January 1929 with modeled atmosphere and land initial conditions and integrated through the 1930s with climatological SSTs.

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Temperature Observations

Model Ensemble means with misc **observed** Sea Temperatures

Even given the SSTs, the drought is too weak and in the "wrong place."

Model with Average Sea Temperatures

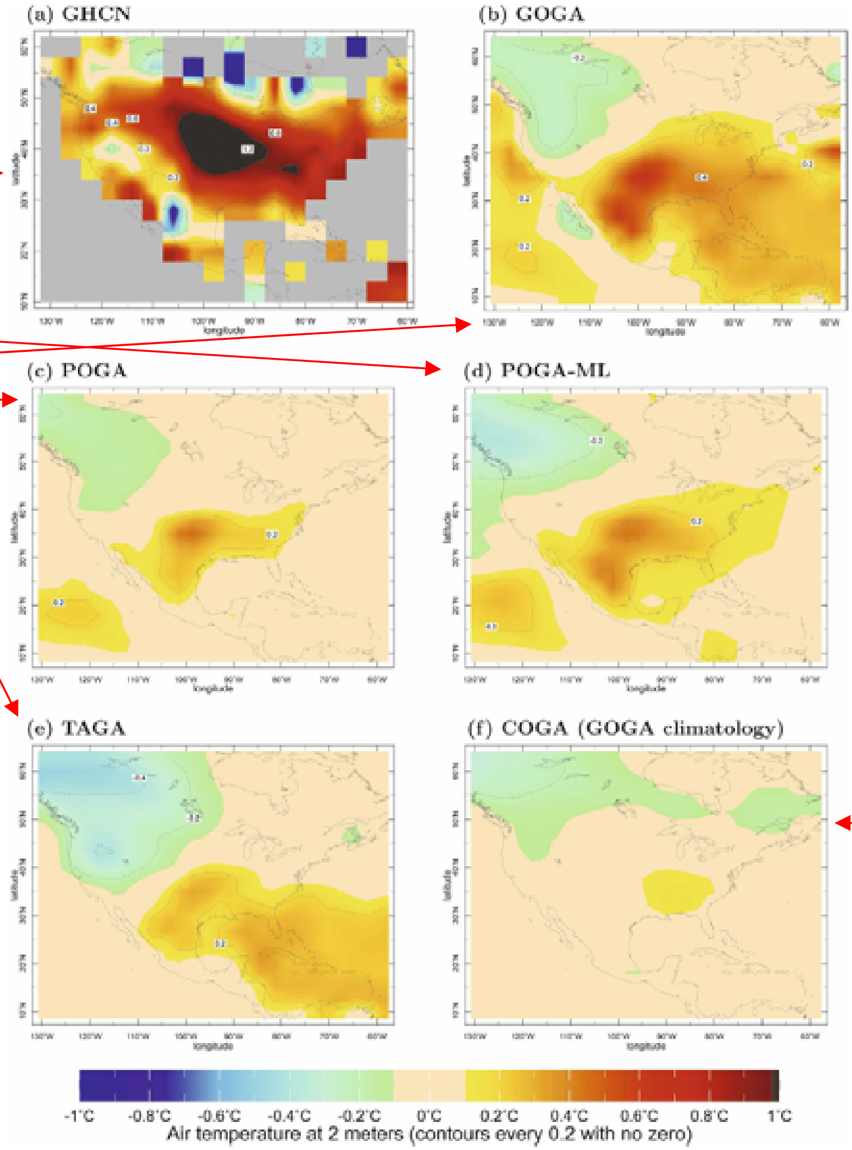

Fig. 4. Same as Fig. 2, but for temperature. The contour interval is 0.2 K.

Fig. 2. The (a) observed and (b)–(f) modeled precipitation anomalies (mm month^{-1}) during the Dust Bowl (1932–39) relative to an 1856–1928 climatology. Observations are from GHCN. The modeled values are ensemble means from the ensembles with (b) global SST forcing (GOGA), (c) tropical Pacific forcing (POGA), (d) tropical Pacific forcing and a mixed layer ocean elsewhere (POGA-ML), (e) tropical Atlantic forcing (TAGA), and (f) with land and atmosphere initialized in January 1929 from the GOGA run and integrated forward with the 1856–1928 climatological SST (COGA). The uneven contour interval is given at the base of the figure.

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This hypothetical drought prediction would have been of limited success because of differences in the modeled and observed patterns.

We should expect Big Surprises when using model-probabilities to anticipate future events similar to those our models do not capture well in the past (where the models have the historical Sea Surface Temperatures!)

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We see things we cannot model: Dust bowl

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As noted earlier, the overestimate of intensity of the modeled Dust Bowl drought in the southern plains and northern Mexico is attributable to model error. Errors in the temperature simulations are consistent with being the result of errors in the precipitation simulation.

It is extremely valuable for scientists to be this blunt about model error!

Quantitative Projections Demand Quantitative Guidance

- Move away from "better" "improved" and "included" towards "realistic" and "fit for purpose"
- Clear statement of known shortcomings and their likely implications in terms of impacts
  - Quantify: "very high confidence", "moderate confidence", "indicative"
- Reputation binding estimate on what is believed to be robust
- Quantitative subjective estimate of a relevant "big surprise" probability *from the domain scientists for every projection!*
- Rough idea of how fast model output is likely to improve
- Drop or explain how in projection mode, one can get the temperature usefully after 50 years of getting the precipitation badly wrong!

Three closing questions

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444 *Admiral Fitz-Roy* [March 28,

Are these just old unfair criticisms?

WEEKLY EVENING MEETING,

Friday, March 28, 1862.

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

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

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

an idea of the kind of weather thought *probable* cannot be otherwise than acceptable, provided that he is in no way *bound* to act in accordance with any such views, against his own judgment.

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

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

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For mitigation, do I always need to know the probability?

I am flying to the Germany next week..
If an engineer says my plane will fall out the say over Europe,
I do not ask her "where exactly".
And I certainly do not plan to fly if she cannot tell me where!!
I plan not to fly.

And if I must fly?
If she tells me that at a cost of twice my ticket, she can cut the probability from 10% to 1%,
or from 1% to 0.1%
or from 0.0000000001% to 0.000000000001% ?

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

No, as long as the chance is not vanishingly small already!

And there are huge costs (to me) associated with waiting:
The Cost (to me) of doing something once my plane has taken off is much higher than doing something now.

These facts ease mitigation decisions.

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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 do we hope do in the next 5 years...

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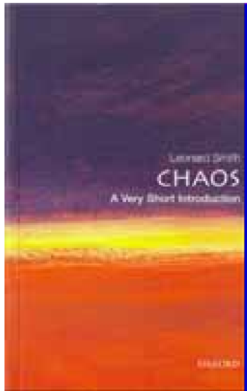
Expectations and Goals of Munich Re Program 5a

- To improve the mix between Science and Modelling in informing decisions
- To better propagate uncertainty to and through post-climate modelling (economics and impacts)
- Clarify the assumptions underlying popular climate products (Like assuming the climate changes and the weather stays the same)
- To "close the loop" with modelling, leading to experiments designed to be more informative to decision makers (rather than informative to modellers)
- To inform other programs across Grantham, the LSE, and beyond, with model output and insights on what is robust reliable information. (And ideally case dependent estimates of the probability and direction of the most likely "Big Surprise"!)



Background Reading:

LA Smith(2002) *What might we learn from climate forecasts?* P. Nat. Acad. Sci (99)

LA Smith (2003) *Predictability Past Predictability Present. Predictability and Weather Forecasting* (ed. Tim Palmer, CUP).

LA Smith (2000) *Disentangling Uncertainty and Error*, in Nonlinear Dynamics and Statistics (ed A.Mees) Birkhauser.

Stainforth et al (2005) *Uncertainties in Prediction of Climate response*. Nature.

Stainforth et al (2007) *Uncertainty & Decision Support*. Phil Trans Roy. Soc. A,1098

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

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

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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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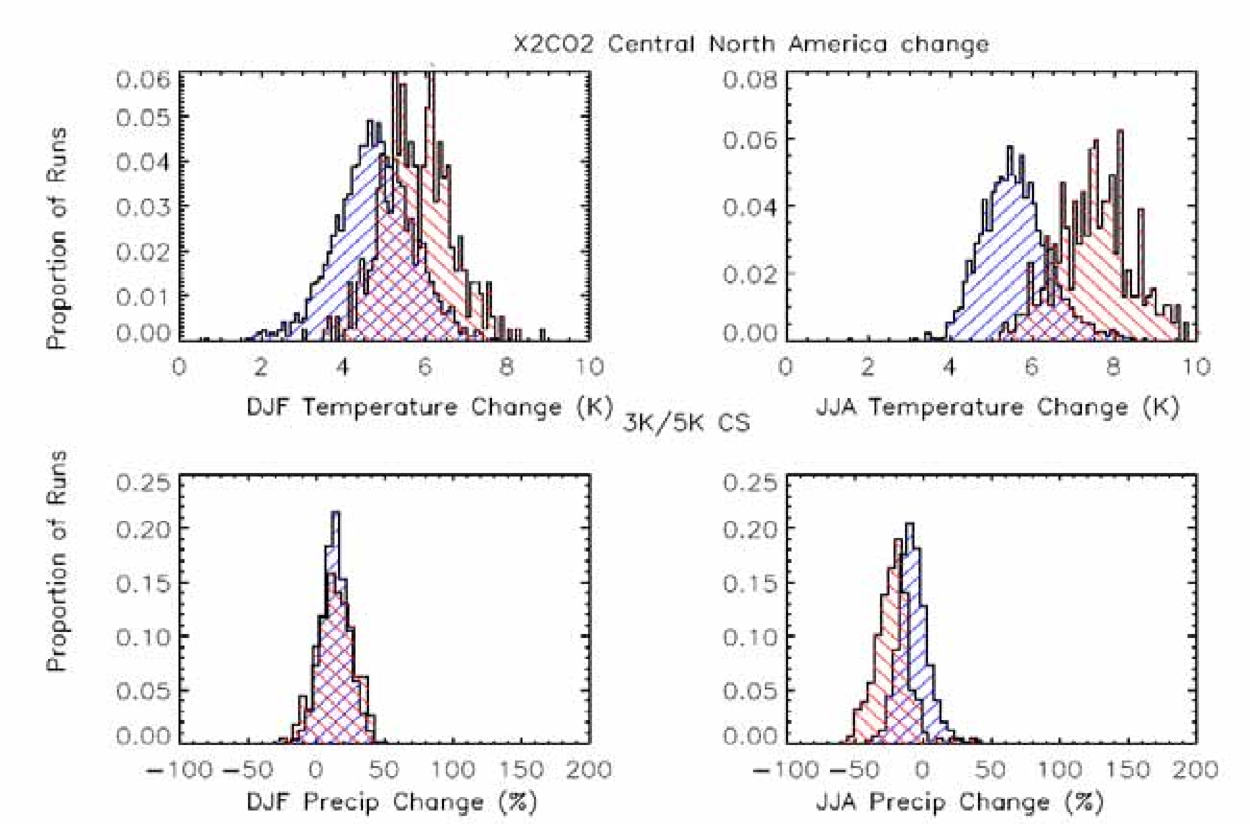
Quantitative Projections Demand Quantitative Guidance

Box 1.4: Confidence in climate projections

There is a cascade of confidence in climate projections. There is very high confidence in the occurrence of global warming due to human emissions of greenhouse gases. There is moderate confidence in aspects of continental scale climate change projections. 25 km scale climate change information is indicative to the extent that it reflects the large-scale changes modified by local conditions. There is no climate change information in the 5 km data beyond that at 25 km. All that can be produced is a range of examples of local climates consistent with current larger-scale model projections. The confidence in the climate change information also depends strongly on the variable under discussion. For example, we have more confidence in projections of mean temperature than we do in those of mean precipitation. The probabilities provided in UKCP09 quantify the degree of confidence in projections of each variable, accounting for uncertainties in both large scale and regional processes as represented in the current generation of climate models. However, the probabilities cannot represent uncertainties arising from deficiencies common to all models, such as a limited ability to represent European blocking. The fact that the UKCP09 projections are presented at a high resolution for the UK should not obscure this, and users should understand that future improvements in global climate modelling may alter the projections, as common deficiencies are steadily resolved.

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

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



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

Assuming the model is perfect!

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climateprediction.net

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