On Hawkmoths and Horses: Epistemic issues in modelling complex systems

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- What is the Hawkmoth Effect?
- What is a good model?
- Example: climate models
- P(Horse)
- Are all models Horses?
- What does that mean?

The Hawkmoth Effect

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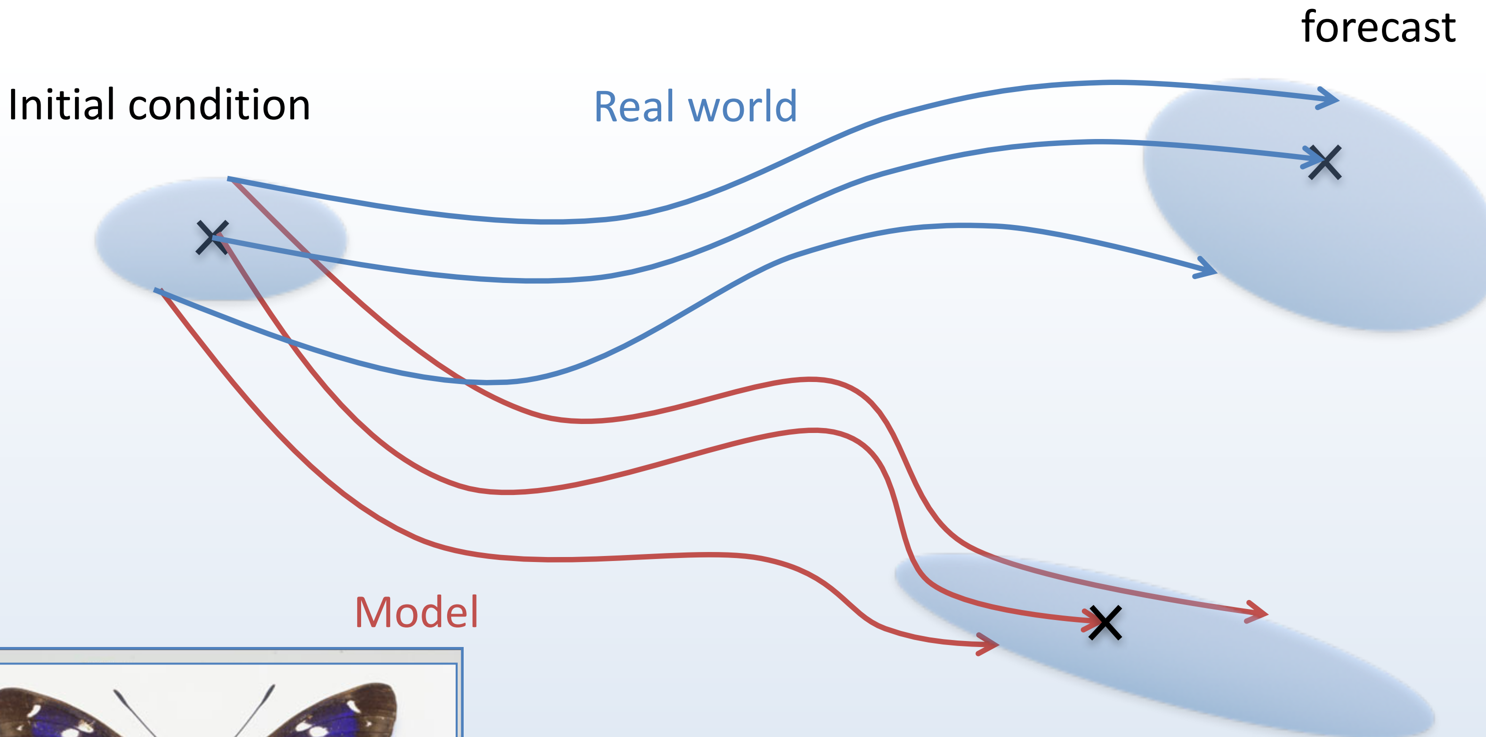

“the butterfly effect”
“the Hawkmoth effect”

The Hawkmoth Effect

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- Your equations can be *arbitrarily close* to the "correct" equations, and still get completely the wrong answer

real world: $\mathbf{y} = f(\mathbf{x})$

model: $\mathbf{y} = f(\mathbf{x}) + \varepsilon(\mathbf{x})$

- Trajectories (may) differ by *much more* than ε

What is a good model?

- Right answer?
- Right answer for the right reasons?
- What do we mean by the right reasons?
- Right dynamics?

	Right reasons	Wrong reasons
Right answer	Good model	Horse
Wrong answer	Unlucky?	Dead Horse

Model development:

bad → good → better → best ??

Example: climate models

- How would we know climate model is giving the "right answer"?

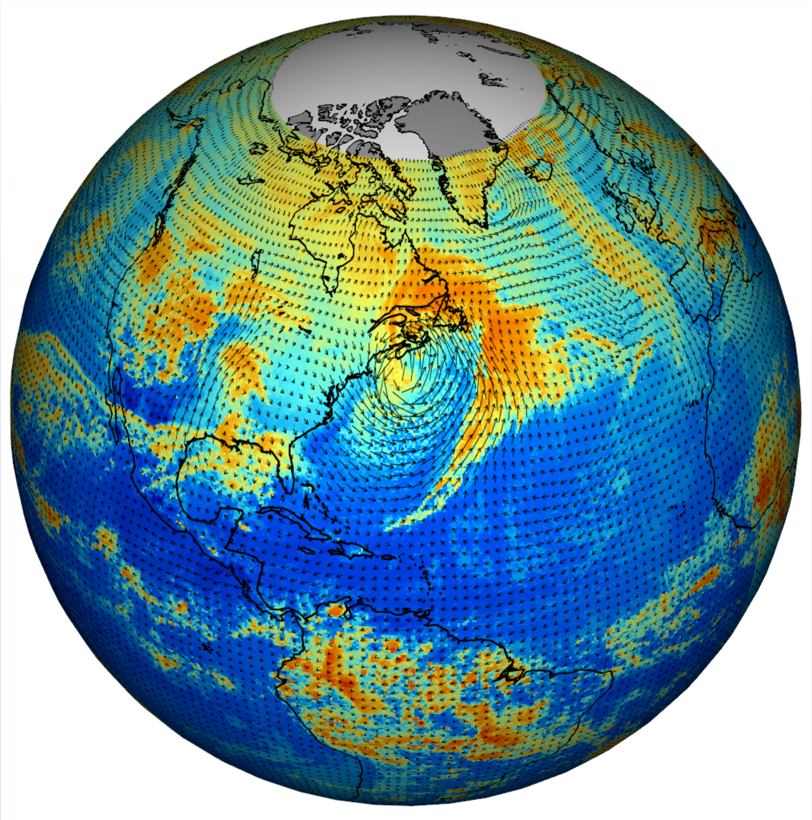
Agreement with other models?

Agreement with physical intuition?

Makes pretty pictures?

Looks plausible?

Out of sample: can't test it



Example: climate models

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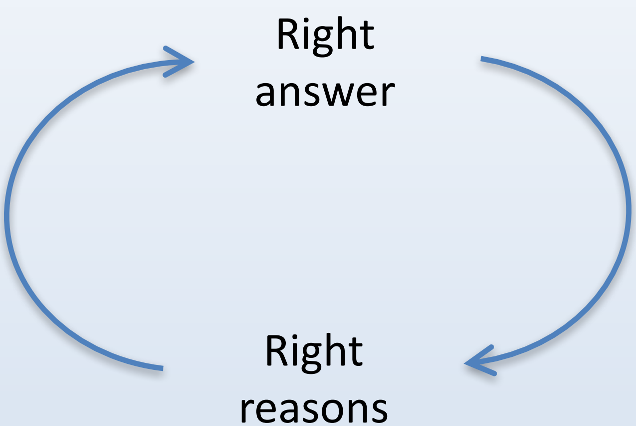
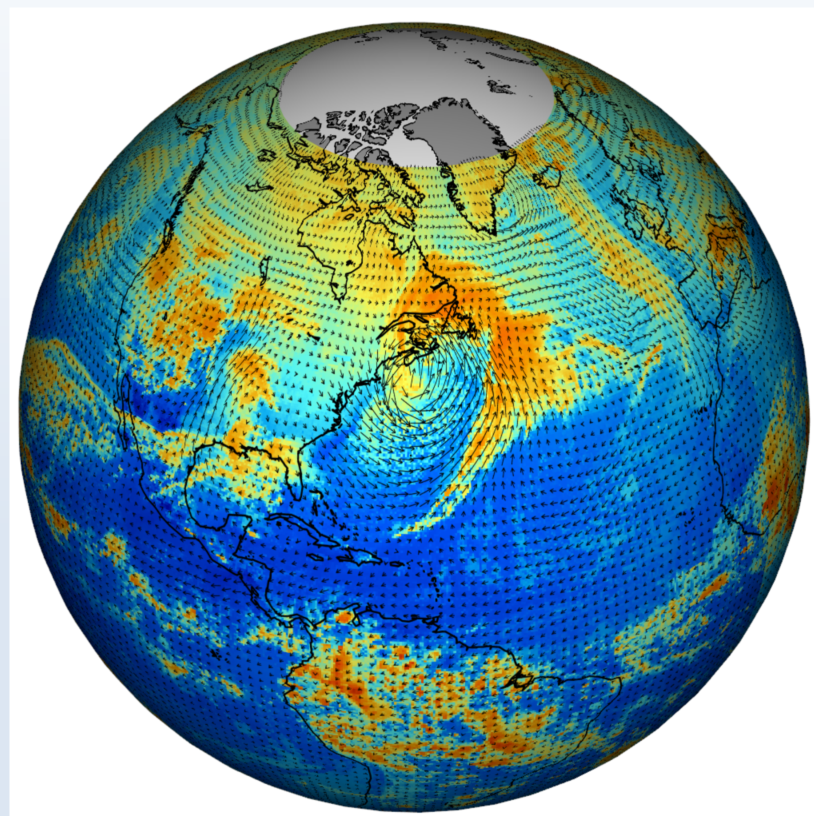
- How would we know climate model is giving the right answer for the “right reasons”?





P(Horse)

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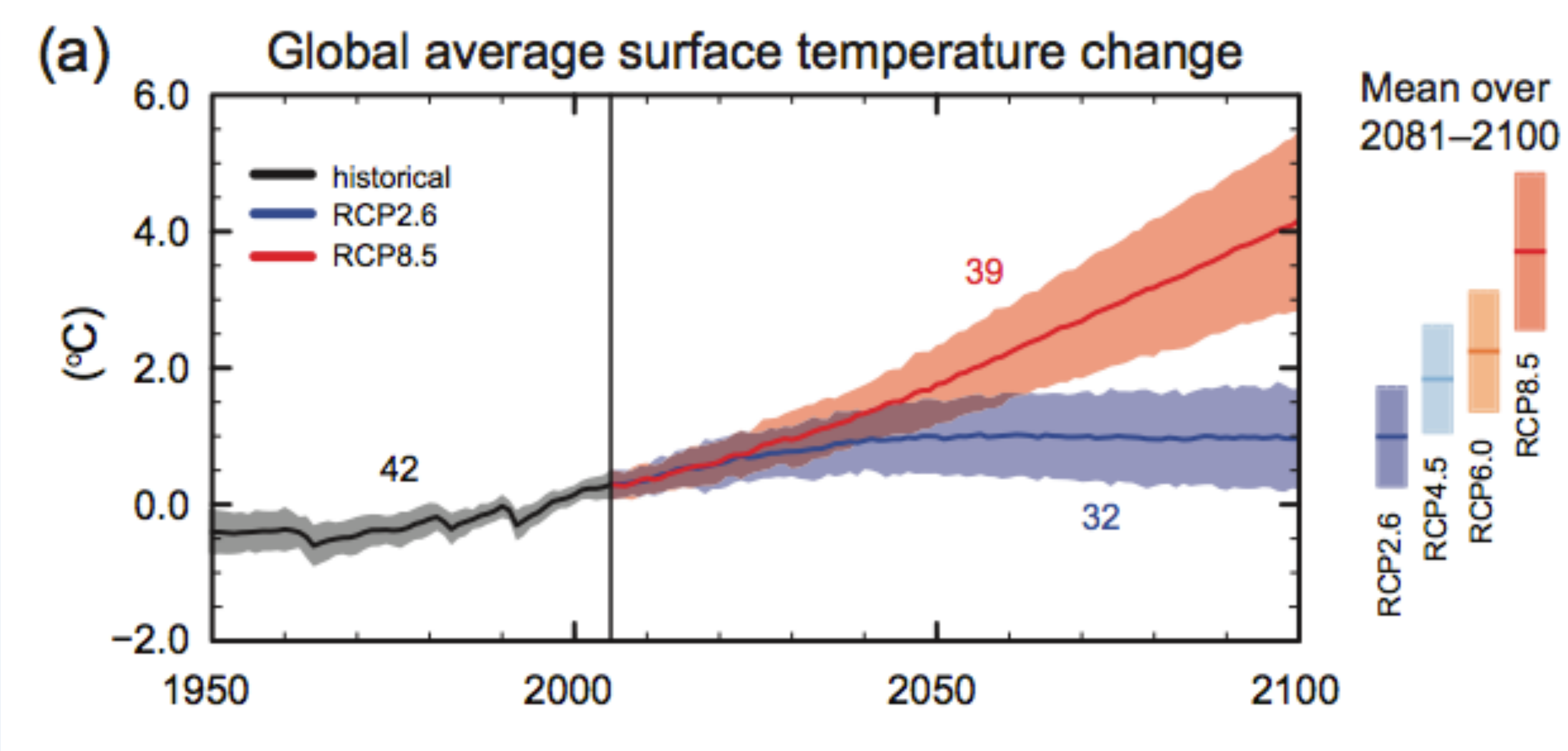
- The IPCC do effectively state the probability that climate models are Horses

- Anyone like to guess that probability?

24%

	Right reasons	Wrong reasons
Right answer	Good model	Horse
Wrong answer	Unlucky?	Dead Horse

IPCC projections



30+ big numerical models
All values displayed as change since baseline period 1986-2005, hence the scale
Range of model outcomes displayed as shaded area with mean as central projection

IPCC WG1 SPM-7

Projections

		2046–2065		2081–2100	
	Scenario	Mean	*Likely* range[c]	Mean	*Likely* range[c]
Global Mean Surface Temperature Change (°C)[a]	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
	Scenario	Mean	*Likely* range[d]	Mean	*Likely* range[d]
Global Mean Sea Level Rise (m)[b]	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82

Notes c and d: "Calculated from projections as 5−95% model ranges. These ranges are then assessed to be *likely* ranges after accounting for additional uncertainties or different levels of confidence in models."

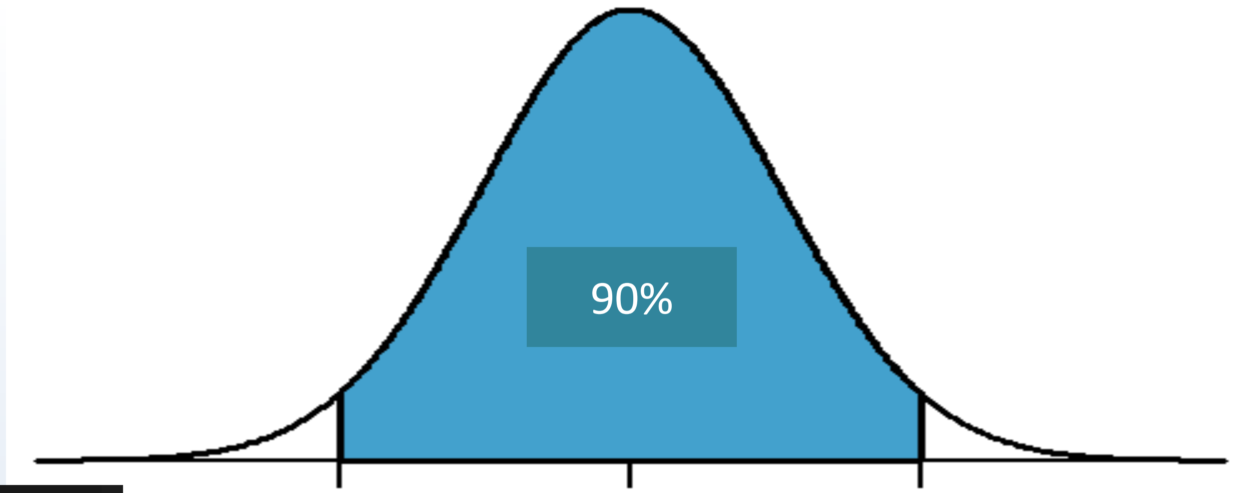
IPCC WG1 Table SPM.2

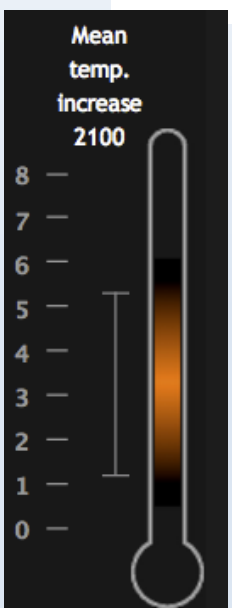
Communication

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

IPCC Guidance note on treatment of uncertainty

Confidence in models





90%: "Very likely"

66%: "Likely"

90% model range → "likely" assessed range

IPCC WG1 chapter 12

Are all models Horses?

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Two questions

- How do we know that all scientific models are not Horses?
  - Out of sample testing!
- If you have a model, and you test it out of sample, **and it works**, does a bit of equine DNA matter anyway?
  - Statistical models vs dynamical models
  - Perhaps it is still abstracting something informative

What does that mean?

- How can we know when models that cannot be tested out of sample are not Horses?
  - We can't know
  - In some sense they must all be Horses, as they are all prone to Hawkmoths and therefore can never be using "the right reasons"
  - But we can still make useful expert judgements about the quality of predictions made by the models

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