**Hawkmoth book**

[1. Model worlds and the real world 3](#_Toc15633846)

[1.1. One real world; infinitely many model worlds 3](#_Toc15633847)

[1.2. Motivation: Why do we construct model worlds? What is it all for? 3](#_Toc15633848)

[1.3. Some consequences: teaser examples, for later in-depth treatment (one per chapter???) 3](#_Toc15633849)

[1.4. Solutions: teaser/summary 3](#_Toc15633850)

[2. What do model worlds tell us? 3](#_Toc15633851)

[2.1. Abstraction and simplification 3](#_Toc15633852)

[2.2. Ontological status of variables/measurables 3](#_Toc15633853)

[2.2.1. Model-world variables are not the same as real ones 3](#_Toc15633854)

[2.2.2. Real world -> model world (eg freezing point of water) 3](#_Toc15633855)

[2.2.3. Model world -> real world (eg implied volatility, climate sensitivity) 3](#_Toc15633856)

[2.2.4. No true parameter set exists 3](#_Toc15633857)

[2.3. Complexity. Subtractability. Noise/music. 3](#_Toc15633858)

[2.4. Dynamical (process-based) models versus statistical models 3](#_Toc15633859)

[2.4.1. “explainability” 3](#_Toc15633860)

[2.4.2. Horses and Hawkmoths 3](#_Toc15633861)

[2.4.3. Note on “machine learning”? 3](#_Toc15633862)

[3. Butterflies and Hawkmoths 3](#_Toc15633863)

[3.1. Butterfly Effect. Initial condition ensembles. Solved. 3](#_Toc15633864)

[3.2. Hawkmoth Effect. Model structure ensembles? Unsolved. 3](#_Toc15633865)

[3.3. Ensembles 3](#_Toc15633866)

[3.3.1. Independence? 3](#_Toc15633867)

[3.3.2. Model groupthink 3](#_Toc15633868)

[3.3.3. So what does the ensemble range mean? 3](#_Toc15633869)

[3.3.4. A model asylum 3](#_Toc15633870)

[3.4. Consequences of the Hawkmoth Effect 3](#_Toc15633871)

[3.4.1. Things which are not included may not be negligible 3](#_Toc15633872)

[3.4.2. Models cannot be monotonically improved 3](#_Toc15633873)

[3.5. Mathematical treatment (easily skippable!) 3](#_Toc15633874)

[3.5.1. Andronov/Pontryagin 1937, Anosov, etc. Shadowing timescales and numerical approximations. Solution of PDEs. Ergodicity, existence/timescales of attractors, “statistical stability”? 3](#_Toc15633875)

[4. Confidence and uncertainty 4](#_Toc15633876)

[4.1. What is uncertainty? Types of uncertainty. Methods of quantifying uncertainty in the physical sciences. 4](#_Toc15633877)

[4.2. Predictability of phenomena. In-sample / out-of-sample. Reference class problem. Modelling. Timescales of predictability. Butterfly/Hawkmoth again. 4](#_Toc15633878)

[4.3. Constraints on quantification of uncertainty and predictability due to model error. 4](#_Toc15633879)

[5. The cat that looks most like a dog 4](#_Toc15633880)

[5.1. The cat that looks most like a dog 4](#_Toc15633881)

[5.2. Bayesian methods are not the answer because they imply that the true model is in the set considered: Bayes theorem does not apply. 4](#_Toc15633882)

[5.3. Methodology is epistemology 4](#_Toc15633883)

[5.4. Many other statistical methods have the same underlying problem 4](#_Toc15633884)

[6. Escaping from model-land 4](#_Toc15633885)

[6.1. Statements made about real world need to refer to the real world. How? 4](#_Toc15633886)

[6.2. Evaluation against past data 4](#_Toc15633887)

[6.2.1. Evaluation metrics (eg do we require propriety if models are never perfect?) 4](#_Toc15633888)

[6.2.2. Big Data 4](#_Toc15633889)

[6.2.3. Small Data (accounting for small-number problems) 4](#_Toc15633890)

[6.2.4. No data? The reference class problem 4](#_Toc15633891)

[6.3. Use of expert judgement 4](#_Toc15633892)

[6.3.1. IPCC statements in SPM 4](#_Toc15633893)

[7. Making decisions based on models 4](#_Toc15633894)

[7.1. The aim: getting “the right answer” or supporting a decision? 4](#_Toc15633895)

[7.1.1. Properties of good decisions 4](#_Toc15633896)

[7.1.2. Sometimes the skill of the model is unimportant (Mali farmers; Start; horoscopes; biodynamic planting…) 4](#_Toc15633897)

[7.1.3. Sometimes the confidence, even where reported honestly, is recalibrated by the audience (“ninety per cent” =/= 90%) 4](#_Toc15633898)

[7.2. Evaluation of models, evaluation of forecasts 4](#_Toc15633899)

[8. Conclusions and consequences 4](#_Toc15633900)

[8.1. The unreasonable effectiveness of mathematics in the natural sciences? 5](#_Toc15633901)

[8.2. Modelling for decision support 5](#_Toc15633902)

[8.3. Alternative strategies, find positive/constructive note to end on. 5](#_Toc15633903)