Difficulties in constructing and assessing models: a philosophy of science perspective

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Why are some models a headache?

• There are straightforward, simple models

• And there are straightforward, complex models

• But sometimes models are confusing...
A climate model

• Model of global climate model (UCAR)
• Why is it so tough to ensure, and assess, reliability for our purposes?
Introduction

• Theories and models
• Familiar limitations of models
• Distinctive limitations of models
• Illustration in the case of climate models

Thesis: reliability and ease of assessment of models depends on the extent to which underlying theory guides model construction
Scientific models

- A model comprises:
  - a representation (simplified description) of a part of reality
  - a collection of rules (a theory) relating the representations variables
- But this applies to theories and, theories <> models
- A model also involves an application of theory/general principles to a special case (model of phenomena) (e.g. Newtonian model of the solar system)
Typical model ‘limitations’

- Typical model limitations:
  - Contextualised
  - Inadequate
  - Limited justification of imported theory
  - Other
- Physics, climate science, economics, management science, etc.
Typical model limitations need not be a problem

• Newtonian model of the Earth-Sun system suffers from familiar model limitations

• When are contextualization and adequacy a problem?

• Newtonian mechanics also suffers from contextualisation and adequacy problems

• So what is special about the reliability of models?
When assessment & prediction are manageable

- General relativity, Newtonian mechanics, Newton's theory of gravity, etc. serve as guides to constructing an Earth-Sun model
- Generally, theory
  - guides model construction
  - helps ensure that models will sometimes work
  - gives us a good idea about how accurate models will be and where they will fail (Humphreys 2004).

Where theory provides solid constraints on model construction, models can sometimes be useful
When assessment and prediction is tough

- Often theory does not adequately guide model construction
- Need to compensate for limited theoretical resources
  - Empirically driven generalisations
  - Qualitative guide from theory
- These sources often do not wear their limitations on their sleeves!
- Known unknowns not modelled
  → where theory does not adequately constrain model construction, model predictions might be unreliable and assessment will be tough
Climate models and the effects of parameterization

- The climate system: processes underlying the behavior of temperature, humidity, atmospheric pressure, oceanic salinity etc.
- Climate models are used to study the long term statistics of the climate system
- Climate models comprise
  - applied basic physical theory
  - Parameterizations (e.g. cloud cover as function of humidity)
→ Theory limited constraint on climate model construction and assessment
Modelling internal variability of the climate system

• Internal variability: variability within the climate system that is not due to external factors (e.g. greenhouse gases, the Sun)

• Important patterns of observed climate variability include the Pacific Decadal Oscillation, the North Atlantic Oscillation, El Niño/La Niña Southern Oscillation

• We have no general, implementable quantitative theory of how such patterns collectively affect overall climate variability

→ So we lack an important resource for
  – ensuring model usefulness in predicting internal variability
  – assessing accuracy of model predictions that require reliable simulation of internal variability (e.g. inter-decadal predictions of global mean surface temperatures)
Compensating for limited theory: frequency testing

- Empirical evidence can compensate for limited guidance of theory in model construction
- e.g. weather model predictions can be repeatedly tested to
  - ensure reliability
  - facilitate assessment of reliability
- Often, this is not feasible (e.g. in the case of climate models)
Are probabilities a way out?

• Probabilities assigned to predictions either on the basis of theory or on the basis of empirical considerations
• In cases such as climate modelling, neither suffices to assign probabilities
• One can still produce them, but there is no reason to be bound by them
• Sometimes the best we can do is to establish real possibilities/assign relative rankings/assign degrees of plausibility
Conclusions

• Models involve the application of theory
• Often, theory constraints on model construction make construction and assessment difficult
• Where theory is strong enough, it allows providing precise estimates of model reliability/producing models which are sometimes useful
• Where theory is not strong enough to guide its application, we struggle to assess model reliability/to produce useful models
• Where do most models sit?
References

• Swanson, K. L., A. A. Tsonis (2009), "Has the climate recently shifted", *Geophysical Research Letters*, 36, L06711.