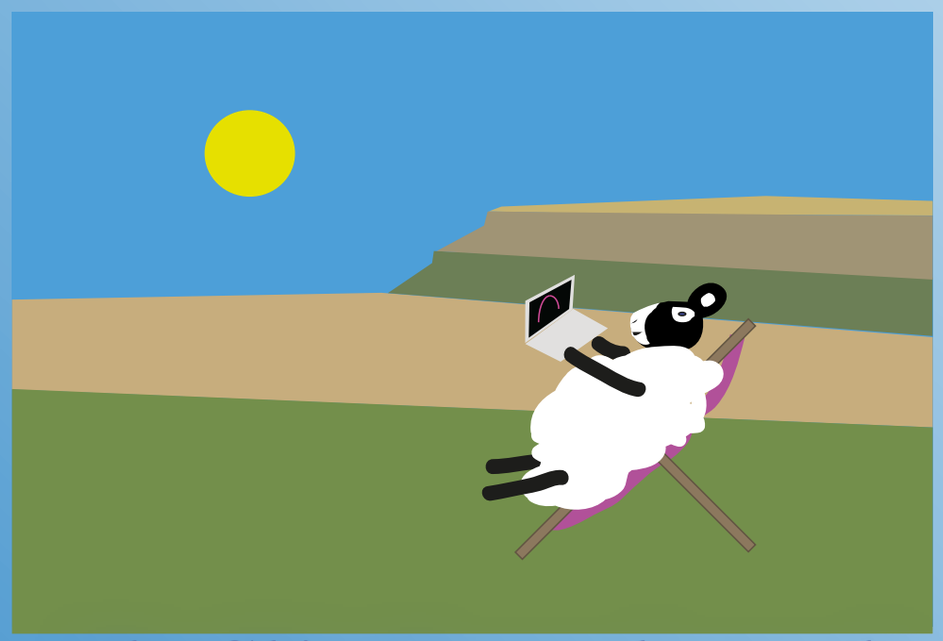
Model, models, models…

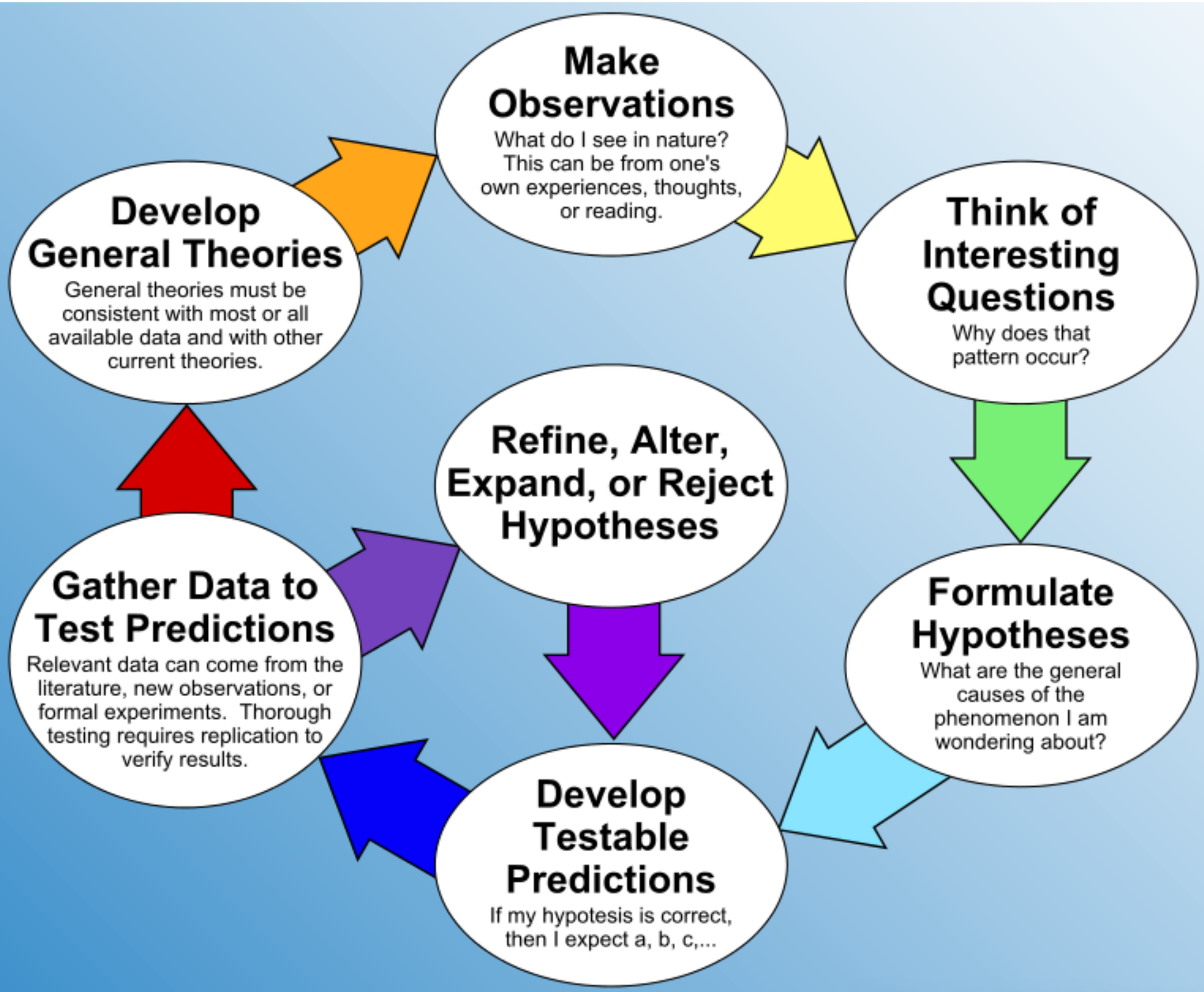
Julia Hargreaves, Chief Executive Editor of
Geoscientific Model Development and second best
Scientist at BlueSkiesResearch.org.uk



Outline
(the product of a fevered mind)

- What are models, anyway?
- Perceived problems with models
- Models through the GMD filter
- Conclusions

A model of the scientific method (from Wikipedia)



schematic by Archon Magnus

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Alternatively: "Science is the process of gathering, comparing, and evaluating proposed models against observables." (also from Wikipedia)

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Documenting model development

- In GMD a model is the computer code that is run with certain boundary conditions to make the prediction - same meaning as assumed in this session(?)

Where do models fit into the Geosciences?

Notice something

Think of Interesting Questions

Formulate Hypotheses

Develop Testable Predictions

Gather Data to Test Predictions

Refine, Alter, Expand, or Reject Hypotheses

Develop General Theories

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- As well as model descriptions, GMD also publishes papers about practically any sort of code related to numerical models, some of which could also be thought of as models:
  - data analysis - transforming measurements into understood variables - for model input or comparison with output
  - evaluation methods
  - visualisation methods
  - data assimilation methods

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- Models that GMD does not (usually) publish
  - Models that are trivial to code and that can be fully described in the same paper as the results
  - Physical, Chemical or Biological models - like wave tanks, lab coccoliths or lab rats
  - Mathematical models - models expressed in maths (there are some of these in GMD!)
  - Conceptual models - models expressed in words and pictures

Geoscience according to GMD!

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Make Observations

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Geoscience according to GMD!

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- Model Development
- Numerical Models

Design and run Experiment

- Model boundary conditions

Gather Data to Test Predictions

- Data Analysis Methods
- Data Assimilation Methods

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Mathematical Models

Numerical Models

Model Development

Physical, Chemical and Biological Models

Problems of large models

We get stuck in one or two pentagons, and don't have time for the other stuff that makes it science.

> "The fundamental goals of Science are to formulate generalizations based on observations and testable hypotheses (induction), and to use these generalizations to make statements about particular cases (inference), in support of decision-making."

Many models are so complex that no one person can understand them.

More problems?

- Multitudes of: data, approaches for building and testing of models and ways to estimate and handle uncertainty.
  - Obstructs communication across disciplines and with it the building of interdisciplinary models to address interdisciplinary questions.
- Progress towards a commonly applicable framework for model building and application along the following questions:
  - • How to evaluate the appropriateness (generality, parsimony) of models in a generalized way?
  - • How to evaluate the interplay of data-, model structure- and predictive uncertainty, i.e. the flow of information from data through models to decision-makers?
  - • How to learn from the encounter of models and data; i.e. how to detect, diagnose and correct model structural errors?
  - • How to build complex interdisciplinary models that remain falsifiable?
  - • How to assess limits of predictability of models and the underlying theoretical concepts?

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- But you can check that your model behaves as expected (In GMD, this is called “evaluation”).
- And you can compare models to observations of past and present and to each other to adjust your confidence in your model’s ability (these papers mostly in GRL, JClim, ClimDyn, CP etc).

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- -> diversity of approaches depending on the problem.

Geoscientific Modelling through the filter of GMD

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  - Approaches to modelling, Evaluation of models and Interdisciplinary collaboration

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- Tone of almost all GMD papers is encouraging others to collaborate and to use the code that is presented. Many suggest their code is useful for varied applications.

GMD research areas

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Atmospheric Sciences
Climate and Earth System Modeling
Biogeosciences
Numerical Methods
Cryosphere
Hydrology
Oceanography
Solid Earth
Earth and Space Science Informatics
Solar-terrestrial Science
Total

GMD research areas

	number of papers published
Atmospheric Sciences	277
Climate and Earth System Modeling	245
Biogeosciences	88
Numerical Methods	48
Cryosphere	38
Hydrology	30
Oceanography	28
Solid Earth	14
Earth and Space Science Informatics	12
Solar-terrestrial Science	4
Total	784

GMD research areas

	number of papers published	percentage rejected/ withdrawn
Atmospheric Sciences	277	18%
Climate and Earth System Modeling	245	16%
Biogeosciences	88	17%
Numerical Methods	48	27%
Cryosphere	38	10%
Hydrology	30	30%
Oceanography	28	24%
Solid Earth	14	52%
Earth and Space Science Informatics	12	56%
Solar-terrestrial Science	4	0%
Total	784	20%

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- **CranSLIK v2.0: improving the stochastic prediction of oil spill transport and fate using approximation methods (Rutherford et al 2015)**
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- **The Met Office Global Coupled model 2.0 (GC2) configuration, (Williams et al 2015)**
  - Climate: **General Circulation Model;** Seasonal Prediction to Climate Prediciton

Translating between different models and data

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- **GO2OGS 1.0: a versatile workflow to integrate complex geological information with fault data into numerical simulation models (Fischer et al 2015)**
  - "**Conversion workflows** are needed as a way of communication between the diverse tools of the various disciplines. Our approach offers an **open-source**, platform-independent, robust, and comprehensible method that is potentially useful for a **multitude of environmental studies**."

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- **An open and extensible framework for spatially explicit land use change modelling: the lulcc R package (Moulds et al 2015)**
  - Breaking barriers with **open-source code.** "It is envisaged that lulcc will enable future model development and comparison within an open environment.

Interactions between models - coupling

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- **EwE-F 1.0: An implementation of Ecopath with Ecosim in Fortran 95/2003 for coupling and integration with other models (Akoglu et al 2015)**
  - For coupling and integration with biogeochemical and hydrodynamic models, "a base for **complex interdisciplinary modelling integrations**."

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- **Implementation of the Community Earth System Model (CESM) version 1.2.1 as a new base model into version 2.50 of the MESSy framework (Baumgaertner et al 2016)**
  - Building a Super-Model! The Modular Earth Submodel System, now has two alternative GCMs - CESM and ECHAM5!

Interactions between disciplines 1

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- **A fully coupled Atmosphere-Ocean Wave modeling system (WEW) for the Mediterranean Sea: interactions and sensitivity to the resolved scales and mechanisms (Katsafados et al 2016)**
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- Anthropogenic modelling: Agriculture in land surface models **(Wu et al 2016)** Wind farms in atmospheric models. **(Volker et al 2015)** Agricultural trees in ecosystem model **(Fader et al 2015)**

Interactions between disciplines 2

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- **Open-source modular solutions for flexural isostasy: gFlex v1.0 (Wickert 2016)**
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- **SHIMMER (1.0): A novel mathematical model for microbial and biogeochemical dynamics in glacier forefield ecosystems (Bradley et al 2015)**
  - **Biogeosciences+Cryosphere**: Ecosystem development in exposed glacier forefields

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  - Manage, aggregate, visualize, and share gridded data sets. Web-based, “It is hoped that it will inspire the future development of similar tools.”

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- **NCAR_Topo (v1.0): NCAR global model topography generation software for unstructured grids (Lauritzen et al 2015)**
  - **Open-source** tool for generating topography

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- Climate Model Inter-comparison Project: CMIP6 (special issue: **Coupled Model Intercomparison Project Phase 6 (CMIP6) Experimental Design and Organization**)
  - >20 MIPs plus data for forcing and comparison to models.

Data assimilation across Geoscience

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- **Development and application of the WRFPLUS-Chem online chemistry adjoint and WRFDA-Chem assimilation system (Guerrette et al 2015)**
  - Atmosphere - chemistry
- **Adjoint Global sensitivity analysis, probabilistic calibration, and predictive assessment for the data assimilation linked ecosystem carbon model (Safta et al 2014)**
  - Biogeochemistry - ecosystem
- **Streamflow data assimilation for soil moisture analysis (Warrach-Sagi et al 2010)**
  - Hydrology - streamflow
- **Physically Based Data assimilation (Levy et al 2010)**
  - Cryosphere - sea-ice as a test case
- **ECCO version 4: an integrated framework for non-linear inverse modeling and global ocean state estimation (Forget et al 2015)**
  - Ocean - state estimation using an adjoint

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  - These days, developers of cool code tend to be very open to collaboration - they want their code to be used and developed.
  - **Please join in: read the papers, and use the code!**