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Developing high quality regional climate projections: a framework, applications and recommendations

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Outline

- Quality framework: why, what and applications to UKCP18
- Using the framework to produce guidance for higher quality projections: methods and results.

- Framework: why, what and applications to UKCP18
- Using the framework to produce guidance for higher quality projections: methods and results.

Why a quality assessment framework?

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- Long-term regional climate information is increasingly important for supporting climate change adaptation.
- This information is difficult to assess:
  - non-stationarity of the system and forward-looking model simulations.
  - nature and scope of ensemble experiments.
  - excessive focus on uncertainty quantification.
  - escape from "model land".
- The related uncertainty makes a quality framework an important tool given the high stakes of climate change adaptation decisions.

Baldissera Pacchetti, M., Dessai, S., Bradley, S., & Stainforth, D. A. (2021). Assessing the quality of regional climate information. *Bulletin of the American Meteorological Society*, *102*(3), E476-E491

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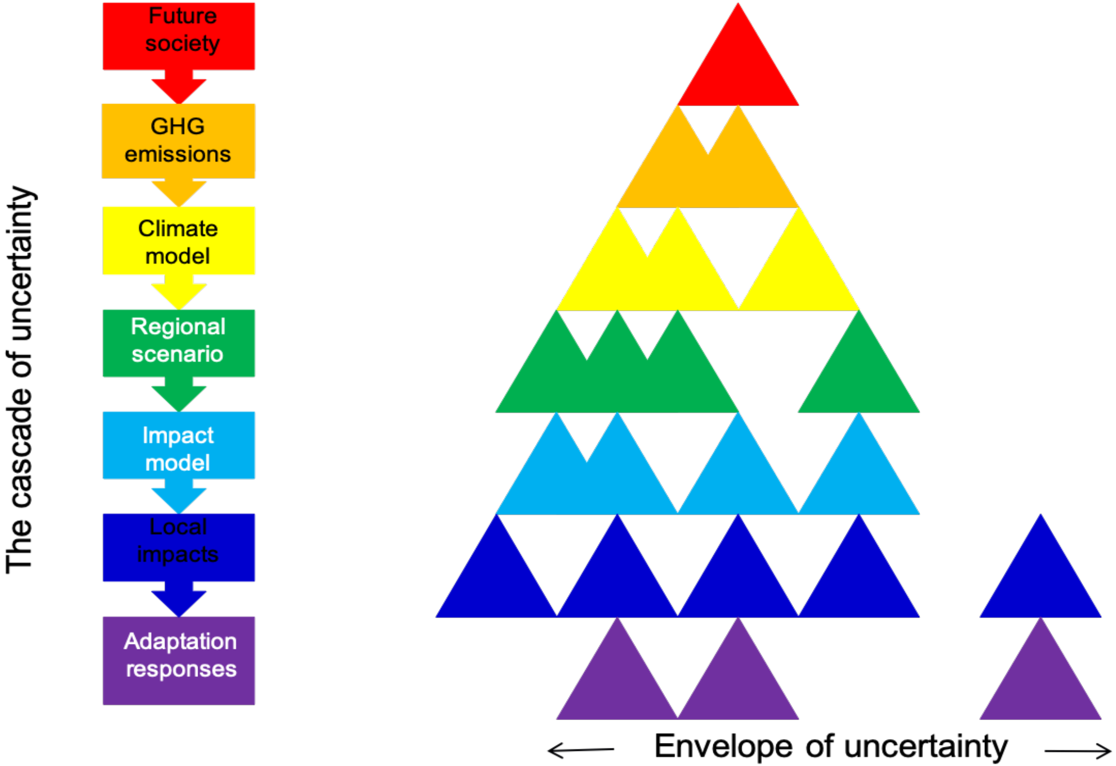
Why a quality assessment framework?



Adapted from Wilby and Dessai (2010)

Why a quality assessment framework?

- Long-term regional climate information is increasingly important for supporting climate change adaptation.
- This information is difficult to assess:
  - non-stationarity of the system and forward-looking model simulations.
  - nature and scope of ensemble experiments.
  - excessive focus on uncertainty quantification.
  - escape from “model land”.
- Considerations around knowledge justification and uncertainty cascades makes a quality framework an important tool given the high stakes of climate change adaptation decisions.

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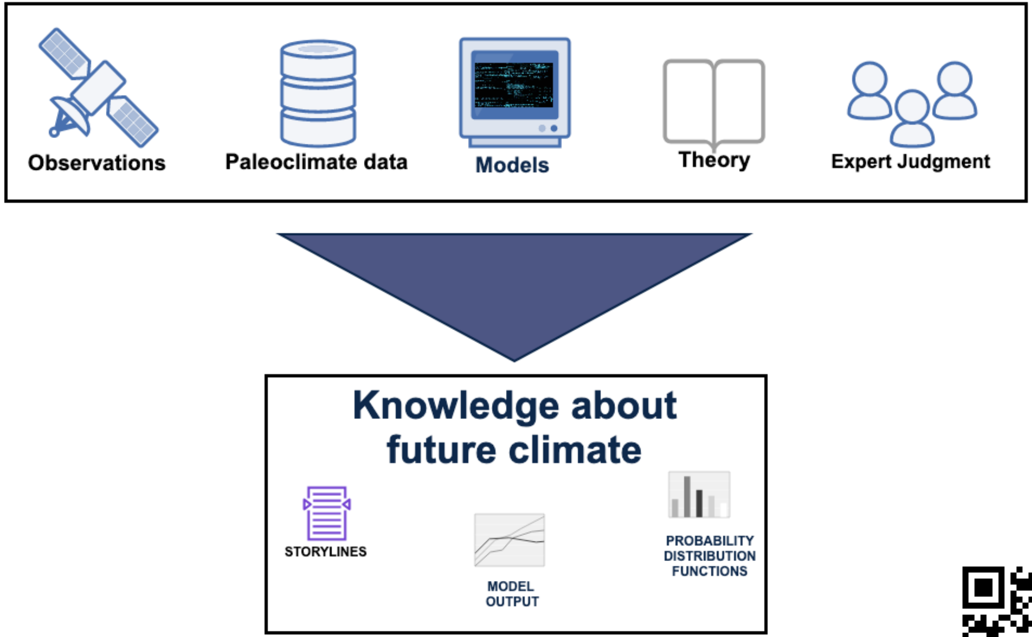
What our framework evaluates

Statements about future regional climate that are intended for adaptation decision support



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How we define quality

“Quality” = Epistemic reliability

Information is epistemically reliable if:

(i) It **adequately** represents the likelihood of different realizations of future regional climate **with respect to the purpose at hand**.

(ii) We can explain why (i) is the case.

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The framework

Quality dimension		What it does
Transparency		Assesses whether evidence and methodology are accessible and whether the other quality dimensions can be assessed.
Theory		Assesses the strength of the theoretical underpinning of the statement about future climate.
Diversity and Completeness	Independence	Assesses whether different types of evidence are independent from one another.
	Number	Assesses how many different types of evidence are taken into account.
	Comprehensiveness	Assesses whether individual lines of evidence are exhaustively explored.
Historical Empirical Adequacy		Assesses the empirical adequacy of the components relevant to the statement about future climate.

Qualitative descriptors for each quality dimension across a quantitative scale (0-4).

Score	Qualifier	Transparency	Theory	Diversity and Completeness			Historical Empirical Adequacy
				Independence	Number	Comprehensivenes s	
0	Not satisfied	No access	No theoretical support that warrants X. Or Can't assess.	Only one type of evidence is taken into consideration to justify X. Or Can't assess	No (scientific) evidence is taken into consideration. Or Can't assess	No exploration of uncertainty within individual lines of evidence. Or Can't assess	No empirical tests (e.g. hincasts) for X. Or Can't assess
1	Minimally satisfied	Evidence and Methodology are mentioned but not well explained and not appropriately traceable.	Weak theoretical support that warrants X. (theoretical underpinning is weak, and doesn't justify the precision of X)	There is considerable overlap among the evidence.	Few of the available lines of evidence are taken into account.	Minimal exploration of uncertainty within individual lines of evidence.	Empirical tests are performed but only of few components relevant to X.
2	Somewhat satisfied	Evidence and methodology are somewhat accessible and traceable, but there are gaps.	Medium theoretical support that warrants X.	The evidence overlaps somewhat.	Multiple, but not most available lines of evidence are taken into account.	Partial exploration of uncertainty within individual lines of evidence.	Empirical tests are performed but not for all components relevant to X.
3	Generally satisfied	Evidence and methodology are well-explained, and all evidence is traceable.	Strong theoretical support that warrants X.	There is little overlap among sources of evidence.	Most available lines of evidence are taken into account.	Sufficient exploration of uncertainty within individual lines of evidence.	Extensive empirical tests are performed for all components relevant to X.
4	Satisfied	Evidence and methodology are well-explained, and all evidence is immediately available.	Theory unequivocally justifies X.	Completely independent types of evidence are taken into account.	All possible lines of evidence are taken into account.	Comprehensive exploration of uncertainty within individual lines of evidence.	All possible empirical tests for all components relevant to X.

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Application to state-of-the-art regional climate projections: UKCP18

	Probabilistic projections	Global projections	Regional projections
Description	Probabilistic changes in future climate based on a assessment of model uncertainties	A set of 28 climate futures with detailed data on how it may evolve in the 21st century ▪ 15 x Hadley Centre Model variants HadGEM-GC3.05 (PPE-15)‡ ▪ 13 x Other climate models (CMIP5-13)‡	A set of 12 high-resolution climate futures over Europe downscaled from the global projections (PPE-15) using Hadley Centre model HadREM-GARA11M
Period	1961-2100	1900-2100	1981-2080 for 12km 1981-2000, 2021-2040, 2061-2080 for 2.2km
Temporal resolution	Monthly Seasonal Annual	Daily Monthly Seasonal Annual	Subdaily for 2.2km Daily Monthly Seasonal Annual
Spatial resolution	25km	60km	12km 2.2km
Geographical extent	UK & regions	UK & regions Global	UK & regions Europe for 12km
Emissions scenarios	RCP2.6 RCP4.5 RCP6.0 RCP8.5 SRES A1B	RCP8.5	RCP8.5
Why should you use it?	▪ Explores emissions scenario uncertainty ▪ Explores uncertainty in key processes in climate models ▪ Helps characterise future extremes in risk assessment	▪ Long time series ▪ Spatially and temporally coherent* ▪ Direct access to 'raw' climate model data ▪ Met Office Hadley Centre global climate model HadGEM3-GC3.05	▪ Enhanced spatial detail ▪ Spatially and temporally coherent* ▪ Improved extremes ▪ Direct access to 'raw' climate model data

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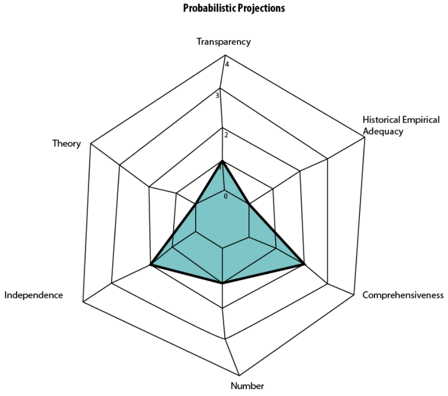
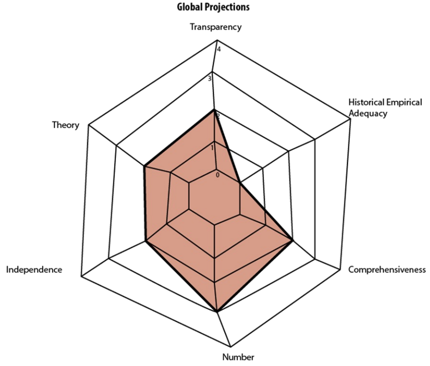
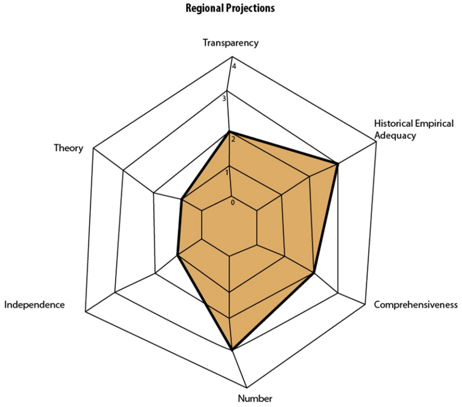
Application of the framework to UKCP18







- Different products have different strength and weaknesses
- Some weaknesses are inherited (e.g. regional projections inherit weaknesses from global projections)
- There is room for improvement of the epistemic quality of the national projections

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- Framework: why, what and applications to UKCP18
- Using the framework to produce guidance for higher quality projections: methods and results.

Using the framework to produce guidance for higher quality projections: methods

- Focus on key variables: temperature, precipitation and wind.
- Perform literature review for precipitation (multidecadal temporal scale, regional scale) + quick assessment using framework.
- Identify key experts and select interviewees by controlling for institutional background, focus (modelling, observation, attribution, etc.), career stage and gender.
- Interviewed 9 key experts from UK on UK regional precipitation.
- Interview followed semi-structured protocol which loosely follows the framework.
- Interviews coded according to the dimensions of the framework.

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Results (precip)

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Transparency

More code and data sharing.

Meaningful comparison of lines of evidence and results.

Translating methods assumptions and results.

Physical explanations of drivers of change and variability and uncertainty

How and when to integrate different types of information.

Theory

Necessary for meaningful comparison of model output and observations, including identifying gaps.

Evaluate code or model output? Both? (no consensus)

Model complexity and adequacy for purpose.

Need a better framework for rigorously comparing different lines of evidence.

How to translate information for different audiences?

Historical Empirical Adequacy

Test for raising possible issues rather than gaining confidence in the model: it's only a partial assessment of model's reliability.

Should be done for multiple variables that express meaningful physical relationships.

Scepticism about the usefulness of bias correction.

Quality control of observational data.
Uncertainty in observational data.

Use multiple types of datasets.

Sample statements: physical interpretation of model output for rainfall in the UK

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Given the extrapolatory nature of claims about future regional climate change, it is unclear how to test deviations from the ideal representation of the climate. Due to this limitation, many interpretations are unconstrained.

While the code does represent our (albeit imperfect) physical understanding, when it is run to produce a simulation, it can provide the basis for the interpretation of "emergent" properties that can further advance our understanding.

"theory has to be understandable, you understand why A leads to B. So when people say the models encapsulate theories I don't know what they mean because you don't know why a particular model choice leads to a particular outcome." If there is no explanation of how and why certain (emergent) properties arise, and in most cases there is not, then there is no clear way in which theory can be assessed or advanced.

Results (cont'd)

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Diversity

- Models are only one "tool" of the "toolbox"
- Different sources of evidence have different strength and weaknesses: need to evaluate each for a proper assessment of the envelope of uncertainty

Completeness

- Difficult to achieve, especially with resource intensive lines of evidence
- Exploration of uncertainty within different of lines of evidence should be guided by theoretical and empirical considerations.

Independence

- Identify relationships between different lines of evidence.
- Systematic exploration of differences in model structure.

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Upshots

Dimensions are interrelated but point at different areas that could be improved.

“Theory” dimension raised the most diverse set of responses.

“Transparency” is the least controversial dimension.

Recommendations

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Transparency

- Code, data and platform sharing, maximize comparability of model runs.
- Commonly accepted standard for physical interpretation of model output.
- Framework for communicating information to non-experts.
- Guidance for non-experts on how to evaluate, compare and aggregate different lines of evidence.

Theory

- Improve the way in which theory is used to improve observational networks and identification of key metrics.
- Develop a theoretical framework for rigorously and flexibly combining different sources of evidence, both quantitative and qualitative.
- Clarity of aims of producing climate information (quality standards may differ depending on aims).

Historical Empirical Adequacy

- Promote physically meaningful evaluation of empirical adequacy of model output, e.g. by focusing on multiple variables that express physically meaningful relationships.
- Promote empirical evaluation of model using multiple datasets.
- Always accompany bias correction with explanation of why it is necessary and what it accomplishes

Diversity, completeness and independence

- Recognize that models are just one tool out of a large toolbox.
- Selection of models for use in ensembles should be guided by process understanding.
- Always consider relationship between different lines of evidence to evaluate their independence

Better integration of research communities working on weather, climate and observation (measurement).

Priorities?

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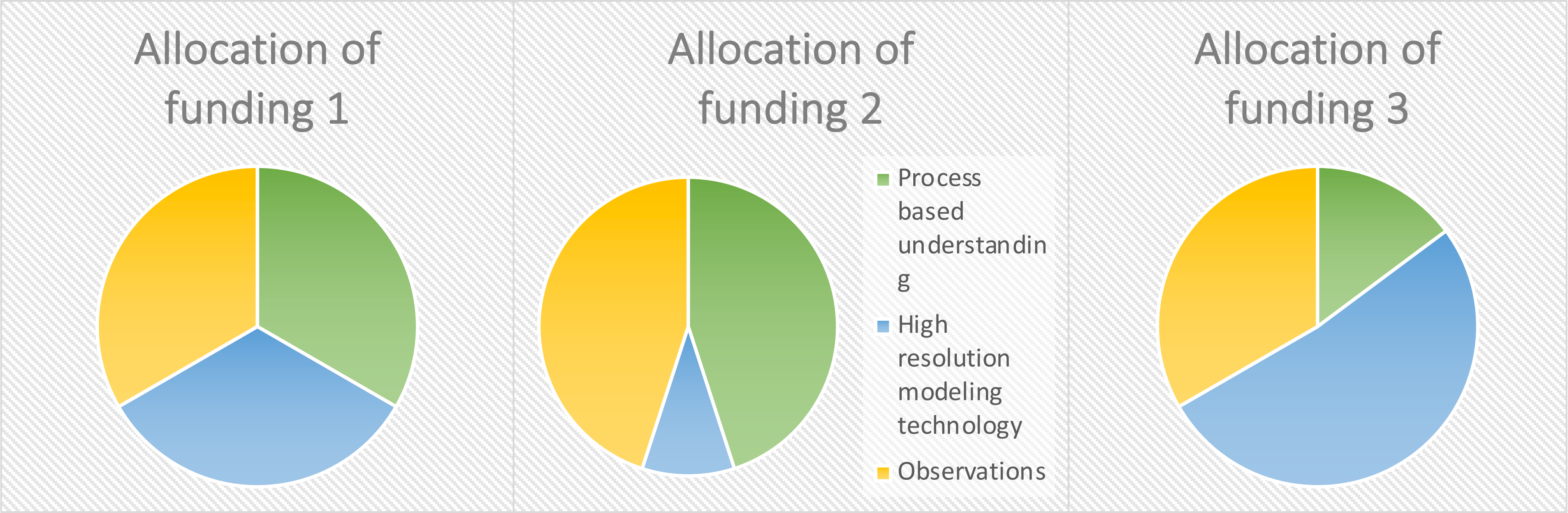
How would you distribute a fixed amount of funding among research towards process-based understanding, the development of high-resolution modeling technology (hardware and software), and/or improving observation methods and observation quality assurance?



Missing: funding for integration of communities

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Thank you!

Some key references:

Wilby R. L., Dessai S. (2010) .Robust adaptation to climate change. *Weather* 65:180–185

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