Quantifying uncertainty in predictions of climate and its impacts

The EQUIP project developed methods for generating predictions of climate and its impacts that carefully quantify uncertainty. Our main foci were crops, heatwaves, droughts and marine ecosystems. We also developed understanding of how to communicate uncertainty better, and how uncertain information should be interpreted and used. Our main conclusions fall under five headings.

Improved quantification of uncertainty

EQUIP made both specific methodological advances and broader conclusions on good practice:

- Not all uncertainties are equally important. For example, greenhouse gas emissions are more important than model initial conditions for predicting changes in hot extremes (Hanlon et al., 2013a). We also developed methods to quantify sources of uncertainty, including assessments of which aspects of climate and crop simulation contribute most to predictive uncertainty (Watson and Challinor, 2013).
- EQUIP identified sources of uncertainty that are often ignored when assessing climate impacts, for example the choice of bias correction method (Hawkins et al., 2013).

Good practice: we all agreed that all ensemble members should be used – there is no sub-sampling of ensembles in any EQUIP papers.

Expert judgement

Quantification of uncertainty, in climate or impacts, is not simply a matter of data processing but requires expert judgement.

- Quantitative estimates of uncertainty are contingent on chosen assumptions. Those assumptions can significantly affect the interpretation of the predictions. We developed a common uncertainty reporting format (Wesselink et al., 2014) in order to make these dependencies explicit.
- We also recommend reporting of multiple, rather than single, assessments of the confidence placed by experts in particular predictions. Such reporting would make explicit the potentially wide range of judgements made by experts (Wesselink et al., 2014).

Good practice: the assumptions made when quantifying uncertainty, and full range of expert interpretations, should always be reported.

Evaluation

Predictions are of limited value unless they contain information about their accuracy. Such information is obtained by evaluating past performance.

- Evaluation can guide how predictions are used, and enable improvements in future predictions. Are uncertainty ranges too wide to be useful (even if they are accurate), or misleadingly narrow (i.e. inaccurate)? Evaluation methods should be tailored to the ensemble prediction methods (Fricker et al., 2013).
- EQUIP work showed how we can train ourselves to improve our judgements of predictive performance (Otto et al., 2013).

Good practice: the performance of predictions should be assessed and reported using methods tailored to the prediction methods.

Informing adaptation

Whilst we have to accept that our climate and impacts predictions will be good for some times and places and not so good for others (Hanlon et al., 2013b), uncertainty does not preclude action.

- The interdependence of the sectors and regions affected by climate variability and change can be useful. For example, skill in the prediction of agricultural impacts outside of the UK (Challinor et al., 2010) might lead to skill in knowing likely impacts on UK food prices.
- There are a range of approaches to informing adaptation using uncertain information, each with their own strengths and weaknesses. Some of these uncertainty analyses can be focused on the timing of particular adaptation needs, such as systemic or transformative shifts (Vermeulen et al., 2013).

Good practice: uncertainty methods for adaptation should be selected on a case-by-case basis, and the interdependence between sectors should be explored.

Communicating uncertainty

From our interactions with users we learnt that the multiplicity of sources of climate information causes problems. Which source should be chosen for any given application? The fact that there is disagreement amongst experts about uncertainty ranges makes communication crucial; predictions cannot be conveyed with numbers alone. Stakeholder-focused ways of analysing and presenting uncertainty that were developed within EQUIP include:

- Consequence statements that describe processes (Wesselink et al., 2014). For example: 'warmer temperatures will reduce the time to maturity of crops, thus reducing yield. Model results suggest that increases in rainfall will compensate for this in 40-60% of cases.' This is better than simply providing a range without giving any information on the trade-offs inherent in the uncertainty estimate.
- Presentation of uncertainty in ways that focus on *when* particular changes are expected, rather than what the expected changes are for any given future time. Uncertainty can be calculated as temporal ranges (Vermeulen et al., 2013) or expressed visually as a time evolution of scientific consensus for given changes (Challinor et al., 2014).

Good practice: engaging with users, understanding their decision-making processes, and jointly developing research questions and analyses.

About us

The EQUIP consortium included scientists from the Universities of Leeds, Exeter, Edinburgh, Oxford, Reading, Liverpool, Newcastle, and from the Plymouth Marine Laboratory and the London School of Economics. For more information visit www.equip.leeds.ac.uk where you will find a link to our forthcoming special issue of Climatic Change.

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