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Effective communication of model uncertainty: moving towards decision-relevant communications.

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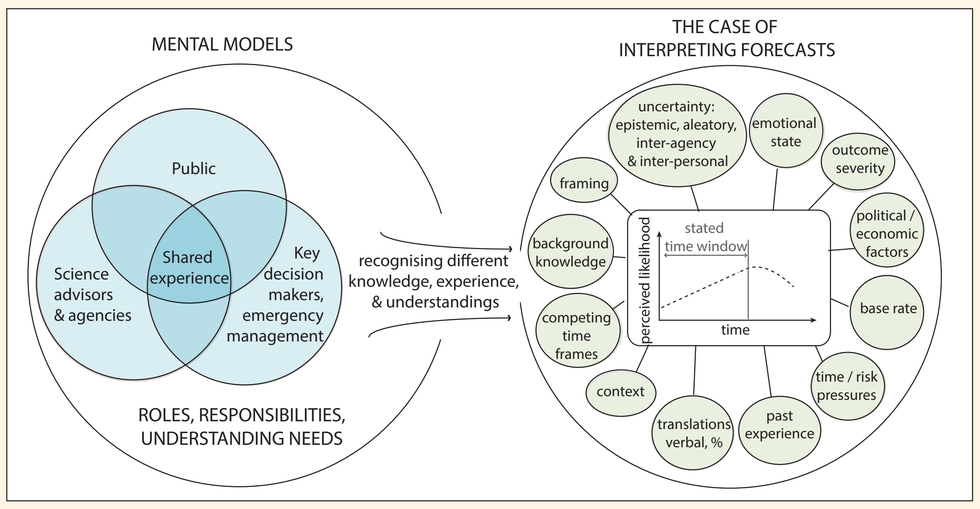
We present the results of a systematic thematic literature review into the effective communication of model uncertainty, and propose scientists move towards two-way and participatory approaches that identify decision-relevant uncertainty information needs pre-event, and adopt typology systems through shared uncertainty management schemes.



Successful emergency management decision-making during severe weather events is fundamentally dependent upon individual and team situation awareness (i.e., how selection, interpretation, and understanding of available information defines the problem and identifies solutions) while operating under high time and risk pressures. This depends upon information and advice from external experts, characterised by stochastic (system variability) and epistemic (lack of knowledge) uncertainty.

Non-communication of uncertainties is problematic as: a) it can limit decision-making capability; and b) interdependencies between uncertainties can result in much deeper uncertainties that can eclipse the simulated outcome. There is a need to identify effective ways to communicate uncertainties to maximise the usefulness of important analysis techniques.

Literature Review Method

1) Determine key issues and questions with practicing scientists and communicators.
2) Identify key search terms, synonyms, & inclusion and exclusion criteria from questions.
3) Peer review through expert colleague feedback on those search terms.
4) Initial search of the databases with those terms.
5) Refinement of search terms as appropriate depending on documents found.
6) Final dated search.
7) Reading abstracts to identify final documents via inclusion and exclusion criteria.
8) Full reading of chosen documents and thematic coding of text identifying key issues.
9) Final thematic analysis of documents.

- TITLE (uncertain* OR assumption* OR limitation*)
- AND TITLE-ABS-KEY (communicat* OR convey* OR represent* OR *visualis* OR *visualiz*)
- AND TITLE-ABS-KEY (model* OR simulat* OR comput* OR forecast* OR predict*)
- AND TITLE-ABS-KEY (hazard* OR fire* OR earthquake* OR aftershock* OR hurricane* OR volcan* OR tsunami* OR storm* OR flood* OR tornado* OR risk OR climate* OR medic* OR weather OR science OR scientific)
- AND TITLE (communicat* OR convey* OR represent* OR *visualis* OR *visualiz*) OR (model* OR simulat* OR comput* OR forecast* OR predict*)
- AND LANGUAGE (english)
- AND NOT TITLE-ABS-KEY (food OR finance OR financial OR gun OR injury OR oil)

The Scopus search string which returned 1,131 documents (807 articles or reviews) on 10th August 2015; 79 of these were chosen, plus another 32 from other databases, resulting in 111 for full thematic analysis.

Results

Documents came from a range of disciplines including psychology, policy, communication, law, climate change, health, geosciences, meteorology, risk analysis, and environmental management. Themes and sub-themes identified included: (# = number of documents).

Theme	#	Theme	#
Typologies, categories, and classification schemes for communicating uncertainty		**Methods and techniques for communicating specific uncertainties (e.g. graphs, probabilities), and complex uncertainties (e.g. confidence and consensus)**	
General typologies, taxonomies, and categorisations	35	Visualisation: maps, spatial, GIS, specific techniques	29
Typologies specifically for uncertainty in spatial visualisation	13	Novel techniques: sonification	3
Structural uncertainty definitions	17	Evaluation	8
Engagement processes, and the complexities that influence effective engagement		Particular Examples of Empirical investigations	5
Engagement and participatory approaches	10	Visualisation: graphs, tables, images	9
Trust	5	Probabilistic statements and terms	18
Epistemic differences and divides, philosophy of science, post-normal science	12	Timeframes	12
Psychology, mental models, individual beliefs	7	Ensembles	15
Ethics	4	Model confidence, confidence in evidence, bias	13
Articles that list a summary of recommendations and guidelines for communicating uncertainties		Consensus and dissensus	10
Specific recommendations/guidelines	20	**Other themes**	
Specific operational guidelines	4	Propagating and cascading uncertainties	7
Critique of IPCC guidelines	11	Decision making	26
General uncertainty communication	13		

Lessons

Fundamental to the effective communication of uncertainty is to first understand the needs of the decision-maker, through shared uncertainty management schemes. Scientists should then concentrate efforts on evaluating and communicating the uncertainties relevant to those specific decision needs and time frames, rather than communicate all uncertainties which can overwhelm a communication and decision making process.

To be effective, scientists, communicators and other stakeholders should actively collaborate with users through engagement and participatory approaches to co-develop typologies or taxonomies of uncertainties suitable for their needs and the hazard modelling and communication situation, including how events evolve over time.

- A typology system guides a scientist communicator through a process of identifying and classifying, articulating, and prioritising critical uncertainties. It prevents assumptions that the statistical output provides a comprehensive account of uncertainty.
- The choice of typology depends on the context, and many general systems exist. Multiple typologies may be required for individual decisions, or throughout the process.

a) Column categories

Walker et al. (2003)	**Level**			**Nature**							
	Statistical Uncertainty	Scenario uncertainty	Recognised ignorance	Epistemic Uncertainty		Variability uncertainty					
Kwakkel et al (2010)	**Level**				**Nature**						
	Level 1: Shallow uncertainty	Level 2: Medium uncertainty	Level 3: Deep uncertainty	Level 4: Recognised ignorance	Ambiguity		Epistemology		Ontology		
Janssen et al (2005)	**Level of uncertainty (from determinism, through probability and possibility, to ignorance)**			**Nature of uncertainty**		**Qualification of knowledge base**			**Value-ladenness of choice**		
	Statistical uncertainty	Scenario uncertainty	Recognition ignorance	Epistemic	Variability	-	0	+	-	0	+
Höllermann & Evers (2015)	**Level: Fundamental**			**Level: Procedural**							
	Uncertainty	Ambiguity	(Recognised) Ignorance	Norms and regulations	Resources	Competence		Knowledge transfer	Risk perception	Strategic liability and responsibility	

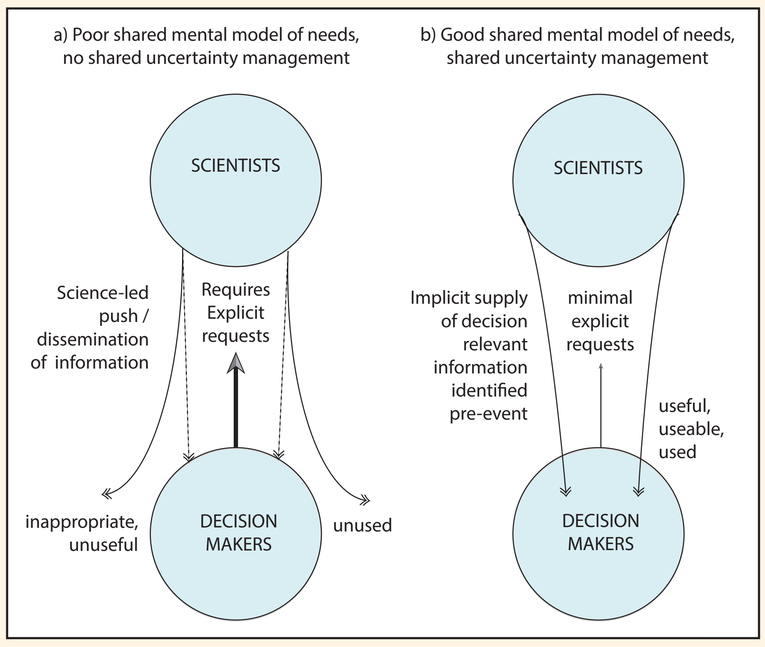
b) Row categories

Walker et al. (2003)		Kwakkel et al 2010		Jannssen et al (2005)		Höllermann & Evers (2015)	
Context	Natural, technological, economic, social and political representation	System boundary		Context		Location: Fundamental	Boundary conditions
Model	Model structure	Conceptual model		Expert Judgment			Data
	Technical Model	Computer model	Model structure	Model Inputs	Structure		Model output
Inputs	Driving forces		Parameters inside the model		Implementation		Parameter
	System data		Input parameters to the model		Parameters		Expert Judgement
Parameter		Input data			Inputs	Location: Procedural	Political framework
Model outcomes		Model implementation		Data			Financial and human constraints
		Processed output data		Outputs			Peer-review
							Culture of communication
							Relevance
							Conflicting interests and ownership

Example typology matrices, illustrating alternative categories. Table a) lists the column categories used in these matrices representing the *Level* and *Nature* of uncertainty, and the qualification and value-ladenness as appropriate. Table b) lists the row categories representing the *Location* of uncertainty.

- Typology schemes can help bridge epistemological and cultural differences between disciplines, enabling the creation of a system of shared uncertainty management that acknowledges and accounts for different priorities and perspectives.
- A typology system can be advanced by including scores for the qualification of the knowledge base and for the value-ladenness of any assumptions, as well as the value-ladenness inherent to practical aspects, epistemic, disciplinary-bound epistemic, and socio-political issues.
- A code of practice should be developed to encompass the uncertainty estimation, engagement process, and translational discourse, which considers funding, leadership and ethical standards, including increasing decision-making uncertainty tolerance.

Concluding Remarks



Engagement processes also help develop shared mental models that enhance all communications.

a) When understanding of needs is weak, communication is dominated by non-specific disseminated information, and time and resource intensive explicit requests.

b) When understanding of needs is good, and decision and uncertainty information needs are identified ahead of time, communication is dominated by implicit supply of tailored useful information.

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Further and related readng: https://tinyurl.com/doyle-papers Doyle, Johnston, Smith, & Paton (2018) International Journal of Disaster Risk Reduction (33) 449-476; Hudson-Doyle, Paton & Johnston (2018) Proceedings of the ISCRAM Asia Pacific Conference, Wellington, NZ, 2018; Doyle & Paton (2017), Advances in Volcanology. doi: 10.1007/11157.

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