Framing Climate Science and Uncertainty in Adaptation Decision making

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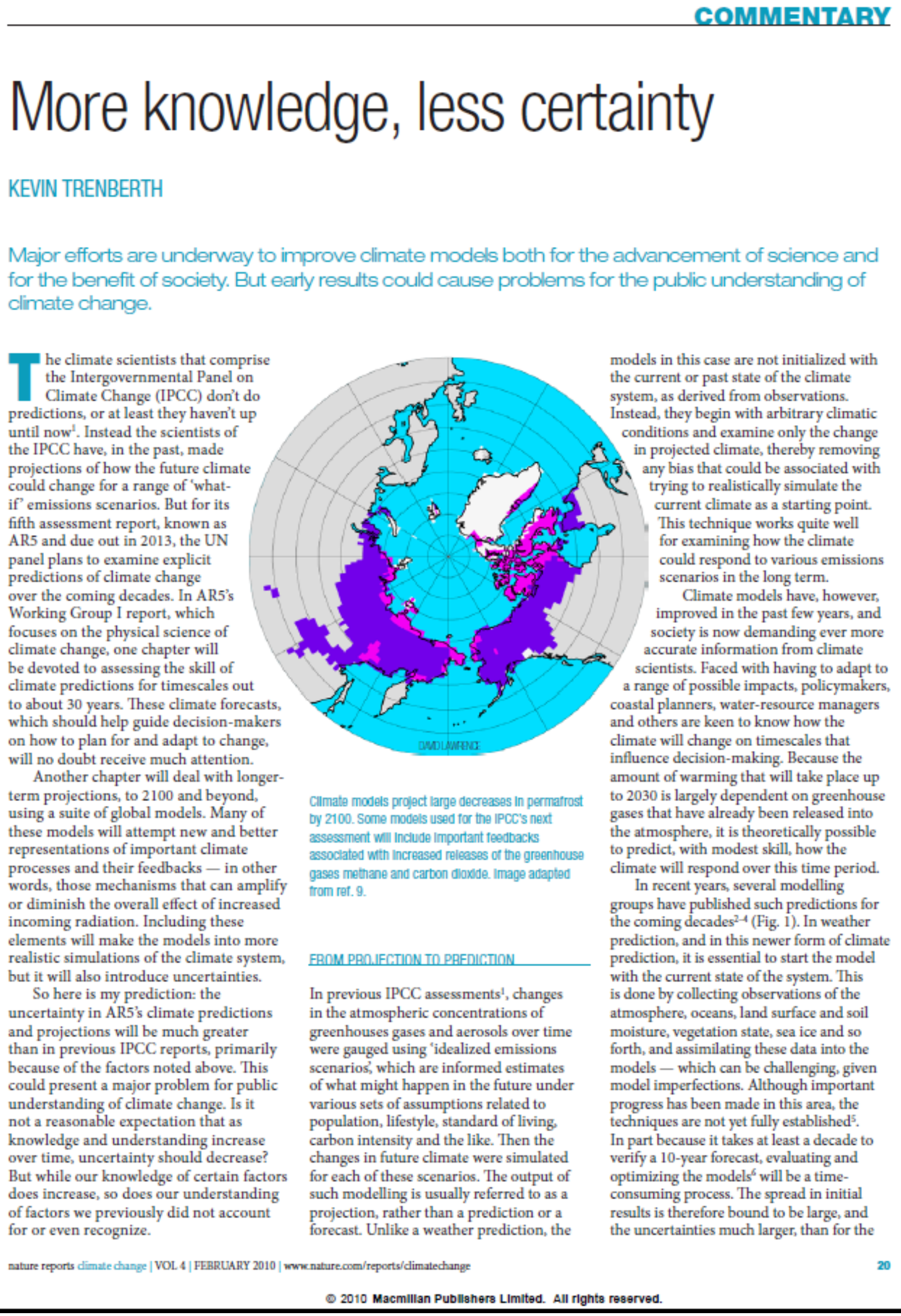
stakeholders increasingly recognize the need for innovative mechanisms for linking climate science and action in public policy decision making efforts to enhance the contributions of climate science to decision making, however, have met with mixed success one major challenge stems from differences in how scientists and decision makers understand, communicate and visualize uncertainty scientists tend to frame uncertainty in probabilistic terms and communicate uncertainty through statistical methods whereas decision makers may also frame uncertainty in political terms based on perceived costs of being wrong while uncertainty is being reduced in some climate science domains, uncertainty is increasing in other areas

“The uncertainty in AR5’s climate predictions and projections will be much greater than in previous IPCC reports…”



More knowledge, less certainty

KEVIN TRENBERTH

Major efforts are underway to improve climate models both for the advancement of science and for the benefit of society. But early results could cause problems for the public understanding of climate change.

The climate scientists that comprise the Intergovernmental Panel on Climate Change (IPCC) don’t do predictions, or at least they haven’t up until now[1]. Instead the scientists of the IPCC have, in the past, made projections of how the future climate could change for a range of ‘what-if’ emissions scenarios. But for its fifth assessment report, known as AR5 and due out in 2013, the UN panel plans to examine explicit predictions of climate change over the coming decades. In AR5’s Working Group I report, which focuses on the physical science of climate change, one chapter will be devoted to assessing the skill of climate predictions for timescales out to about 30 years. These climate forecasts, which should help guide decision-makers on how to plan for and adapt to change, will no doubt receive much attention.

Another chapter will deal with longer-term projections, to 2100 and beyond, using a suite of global models. Many of these models will attempt new and better representations of important climate processes and their feedbacks — in other words, those mechanisms that can amplify or diminish the overall effect of increased incoming radiation. Including these elements will make the models into more realistic simulations of the climate system, but it will also introduce uncertainties.

So here is my prediction: the uncertainty in AR5’s climate predictions and projections will be much greater than in previous IPCC reports, primarily because of the factors noted above. This could present a major problem for public understanding of climate change. Is it not a reasonable expectation that as knowledge and understanding increase over time, uncertainty should decrease? But while our knowledge of certain factors does increase, so does our understanding of factors we previously did not account for or even recognize.

DAVID LAWRENCE

Climate models project large decreases in permafrost by 2100. Some models used for the IPCC’s next assessment will include important feedbacks associated with increased releases of the greenhouse gases methane and carbon dioxide. Image adapted from ref. 9.

FROM PROJECTION TO PREDICTION

In previous IPCC assessments[1], changes in the atmospheric concentrations of greenhouses gases and aerosols over time were gauged using ‘idealized emissions scenarios’, which are informed estimates of what might happen in the future under various sets of assumptions related to population, lifestyle, standard of living, carbon intensity and the like. Then the changes in future climate were simulated for each of these scenarios. The output of such modelling is usually referred to as a projection, rather than a prediction or a forecast. Unlike a weather prediction, the models in this case are not initialized with the current or past state of the climate system, as derived from observations. Instead, they begin with arbitrary climatic conditions and examine only the change in projected climate, thereby removing any bias that could be associated with trying to realistically simulate the current climate as a starting point. This technique works quite well for examining how the climate could respond to various emissions scenarios in the long term.

Climate models have, however, improved in the past few years, and society is now demanding ever more accurate information from climate scientists. Faced with having to adapt to a range of possible impacts, policymakers, coastal planners, water-resource managers and others are keen to know how the climate will change on timescales that influence decision-making. Because the amount of warming that will take place up to 2030 is largely dependent on greenhouse gases that have already been released into the atmosphere, it is theoretically possible to predict, with modest skill, how the climate will respond over this time period.

In recent years, several modelling groups have published such predictions for the coming decades[2–4] (Fig. 1). In weather prediction, and in this newer form of climate prediction, it is essential to start the model with the current state of the system. This is done by collecting observations of the atmosphere, oceans, land surface and soil moisture, vegetation state, sea ice and so forth, and assimilating these data into the models — which can be challenging, given model imperfections. Although important progress has been made in this area, the techniques are not yet fully established[5]. In part because it takes at least a decade to verify a 10-year forecast, evaluating and optimizing the models[6] will be a time-consuming process. The spread in initial results is therefore bound to be large, and the uncertainties much larger, than for the

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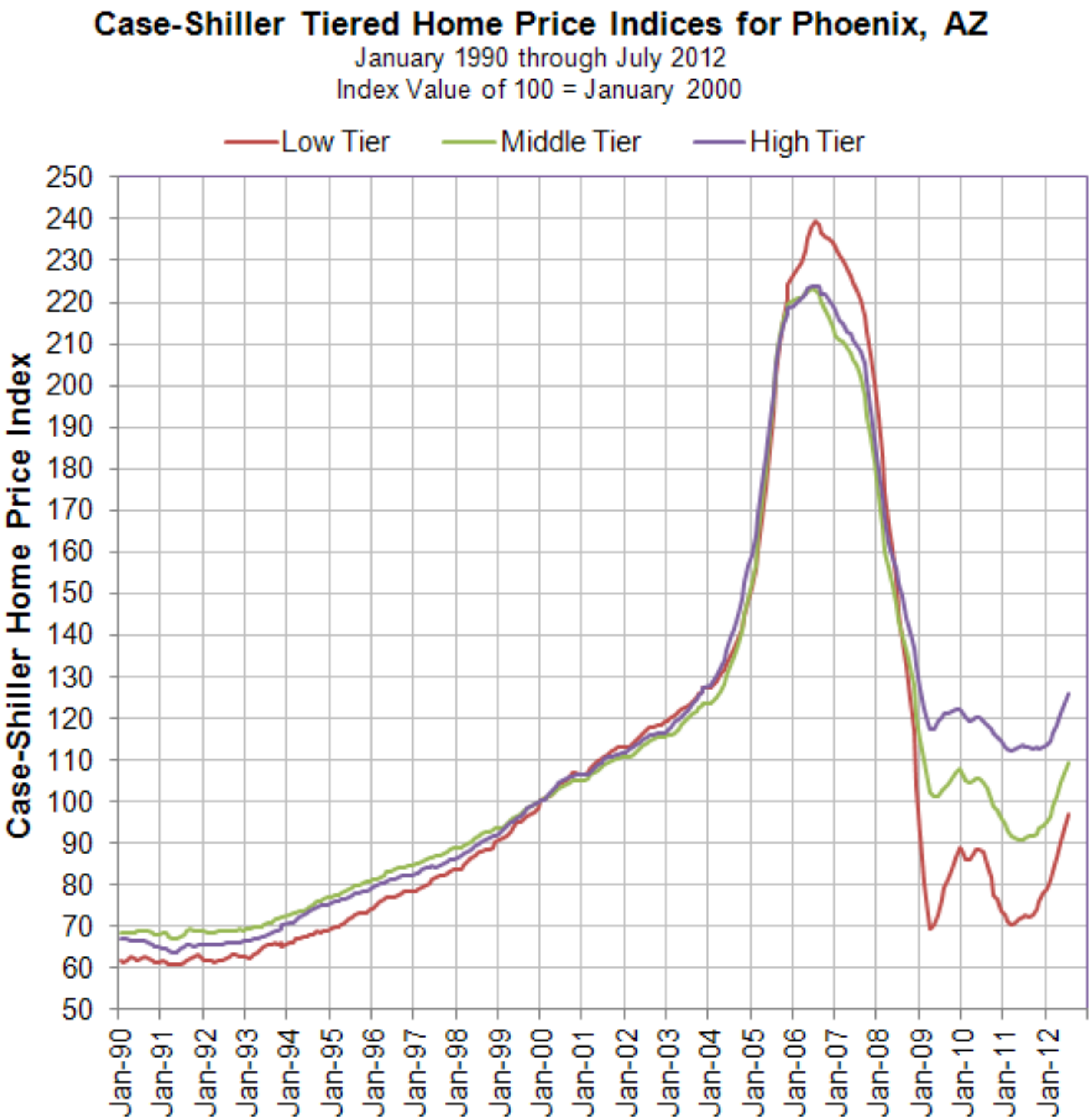
in addition to scientific uncertainty, decision makers must incorporate social, political and economic uncertainties

Case-Shiller Tiered Home Price Indices for Phoenix, AZ
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Index Value of 100 = January 2000
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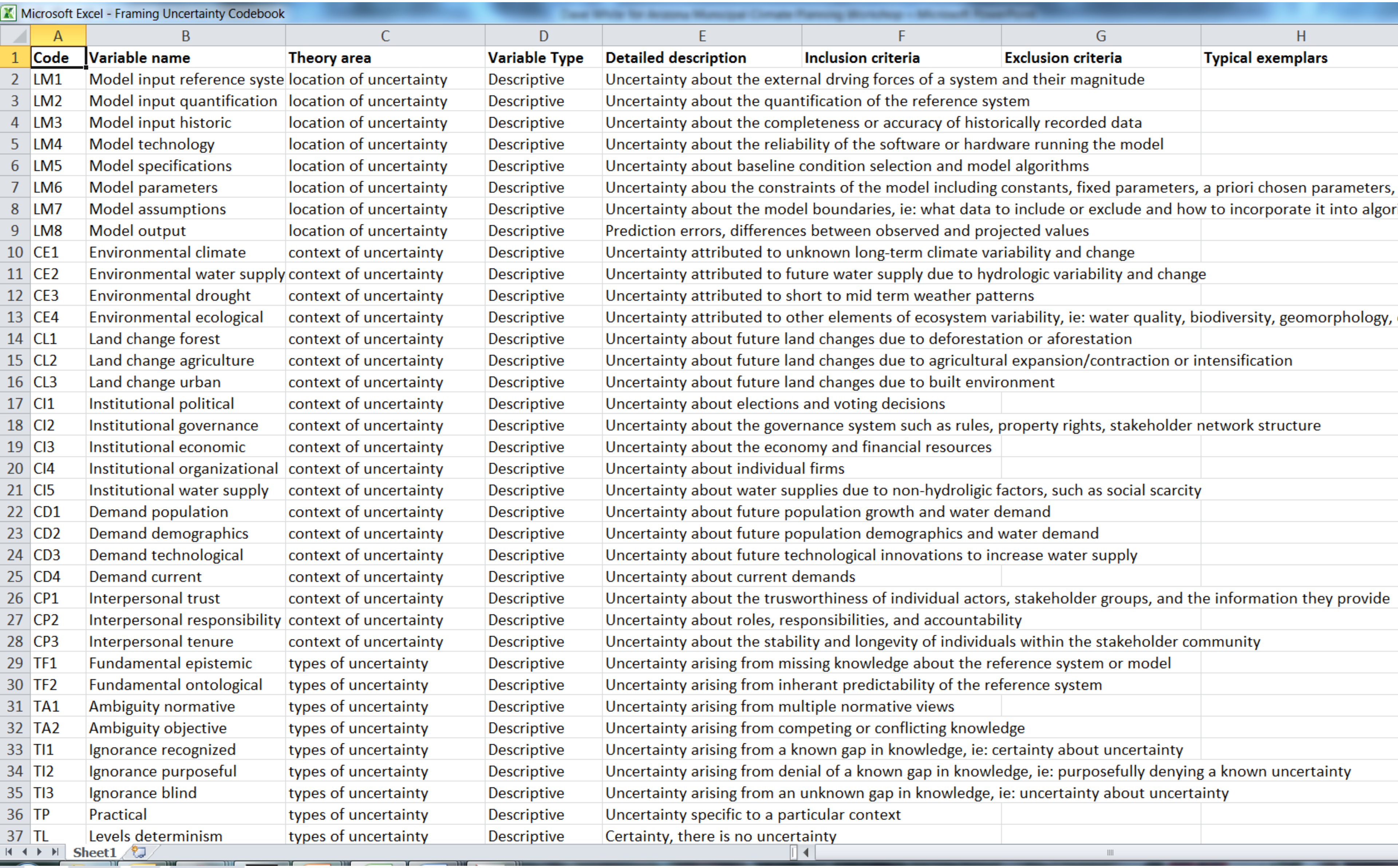

Microsoft Excel - Framing Uncertainty Codebook

	A	B	C	D	E	F	G	H
1	**Code**	**Variable name**	**Theory area**	**Variable Type**	**Detailed description**	**Inclusion criteria**	**Exclusion criteria**	**Typical exemplars**
2	LM1	Model input reference syste	location of uncertainty	Descriptive	Uncertainty about the external drving forces of a system and their magnitude			
3	LM2	Model input quantification	location of uncertainty	Descriptive	Uncertainty about the quantification of the reference system			
4	LM3	Model input historic	location of uncertainty	Descriptive	Uncertainty about the completeness or accuracy of historically recorded data			
5	LM4	Model technology	location of uncertainty	Descriptive	Uncertainty about the reliability of the software or hardware running the model			
6	LM5	Model specifications	location of uncertainty	Descriptive	Uncertainty about baseline condition selection and model algorithms			
7	LM6	Model parameters	location of uncertainty	Descriptive	Uncertainty abou the constraints of the model including constants, fixed parameters, a priori chosen parameters,			
8	LM7	Model assumptions	location of uncertainty	Descriptive	Uncertainty about the model boundaries, ie: what data to include or exclude and how to incorporate it into algor			
9	LM8	Model output	location of uncertainty	Descriptive	Prediction errors, differences between observed and projected values			
10	CE1	Environmental climate	context of uncertainty	Descriptive	Uncertainty attributed to unknown long-term climate variability and change			
11	CE2	Environmental water supply	context of uncertainty	Descriptive	Uncertainty attributed to future water supply due to hydrologic variability and change			
12	CE3	Environmental drought	context of uncertainty	Descriptive	Uncertainty attributed to short to mid term weather patterns			
13	CE4	Environmental ecological	context of uncertainty	Descriptive	Uncertainty attributed to other elements of ecosystem variability, ie: water quality, biodiversity, geomorphology,			
14	CL1	Land change forest	context of uncertainty	Descriptive	Uncertainty about future land changes due to deforestation or aforestation			
15	CL2	Land change agriculture	context of uncertainty	Descriptive	Uncertainty about future land changes due to agricultural expansion/contraction or intensification			
16	CL3	Land change urban	context of uncertainty	Descriptive	Uncertainty about future land changes due to built environment			
17	CI1	Institutional political	context of uncertainty	Descriptive	Uncertainty about elections and voting decisions			
18	CI2	Institutional governance	context of uncertainty	Descriptive	Uncertainty about the governance system such as rules, property rights, stakeholder network structure			
19	CI3	Institutional economic	context of uncertainty	Descriptive	Uncertainty about the economy and financial resources			
20	CI4	Institutional organizational	context of uncertainty	Descriptive	Uncertainty about individual firms			
21	CI5	Institutional water supply	context of uncertainty	Descriptive	Uncertainty about water supplies due to non-hydroligic factors, such as social scarcity			
22	CD1	Demand population	context of uncertainty	Descriptive	Uncertainty about future population growth and water demand			
23	CD2	Demand demographics	context of uncertainty	Descriptive	Uncertainty about future population demographics and water demand			
24	CD3	Demand technological	context of uncertainty	Descriptive	Uncertainty about future technological innovations to increase water supply			
25	CD4	Demand current	context of uncertainty	Descriptive	Uncertainty about current demands			
26	CP1	Interpersonal trust	context of uncertainty	Descriptive	Uncertainty about the trusworthiness of individual actors, stakeholder groups, and the information they provide			
27	CP2	Interpersonal responsibility	context of uncertainty	Descriptive	Uncertainty about roles, responsibilities, and accountability			
28	CP3	Interpersonal tenure	context of uncertainty	Descriptive	Uncertainty about the stability and longevity of individuals within the stakeholder community			
29	TF1	Fundamental epistemic	types of uncertainty	Descriptive	Uncertainty arising from missing knowledge about the reference system or model			
30	TF2	Fundamental ontological	types of uncertainty	Descriptive	Uncertainty arising from inherant predictability of the reference system			
31	TA1	Ambiguity normative	types of uncertainty	Descriptive	Uncertainty arising from multiple normative views			
32	TA2	Ambiguity objective	types of uncertainty	Descriptive	Uncertainty arising from competing or conflicting knowledge			
33	TI1	Ignorance recognized	types of uncertainty	Descriptive	Uncertainty arising from a known gap in knowledge, ie: certainty about uncertainty			
34	TI2	Ignorance purposeful	types of uncertainty	Descriptive	Uncertainty arising from denial of a known gap in knowledge, ie: purposefully denying a known uncertainty			
35	TI3	Ignorance blind	types of uncertainty	Descriptive	Uncertainty arising from an unknown gap in knowledge, ie: uncertainty about uncertainty			
36	TP	Practical	types of uncertainty	Descriptive	Uncertainty specific to a particular context			
37	TL	Levels determinism	types of uncertainty	Descriptive	Certainty, there is no uncertainty			

we need knowledge, tools and strategies to understand and support decision making under uncertainty to implement these strategies we need to frame climate science and uncertainty for policy makers how science is framed by scientists, modelers, and agency staff for policy makers affects political opportunities and decision space

“Science-based decision making is perhaps the single most important principle we have. Given the deep divisions that exist and the stakes involved, we must stick to the science. If we do not, we will be rudderless, adrift without direction, and lost.”

-Northwest Regional Director, NMFS

“NMFS is unbridled by the democratic process or the principles of republican forms of governance. Ridiculous, you say? When NMFS and the U.S. Fish and Wildlife Service vote, who may vote them down? When they enforce the flawed and often ruinous law, who may veto them? To whom are these people accountable?”

- Representative, Forest Products Industry

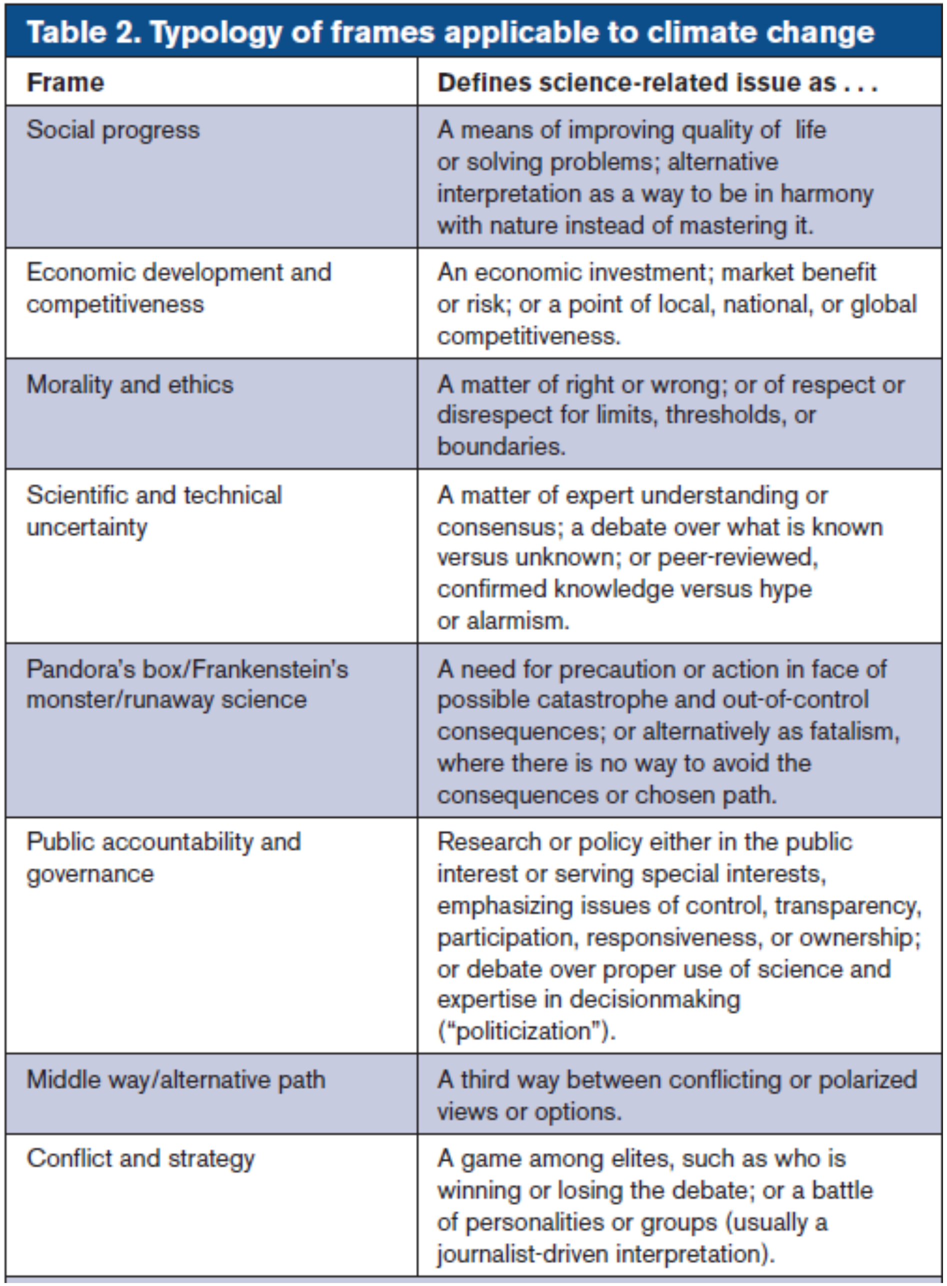
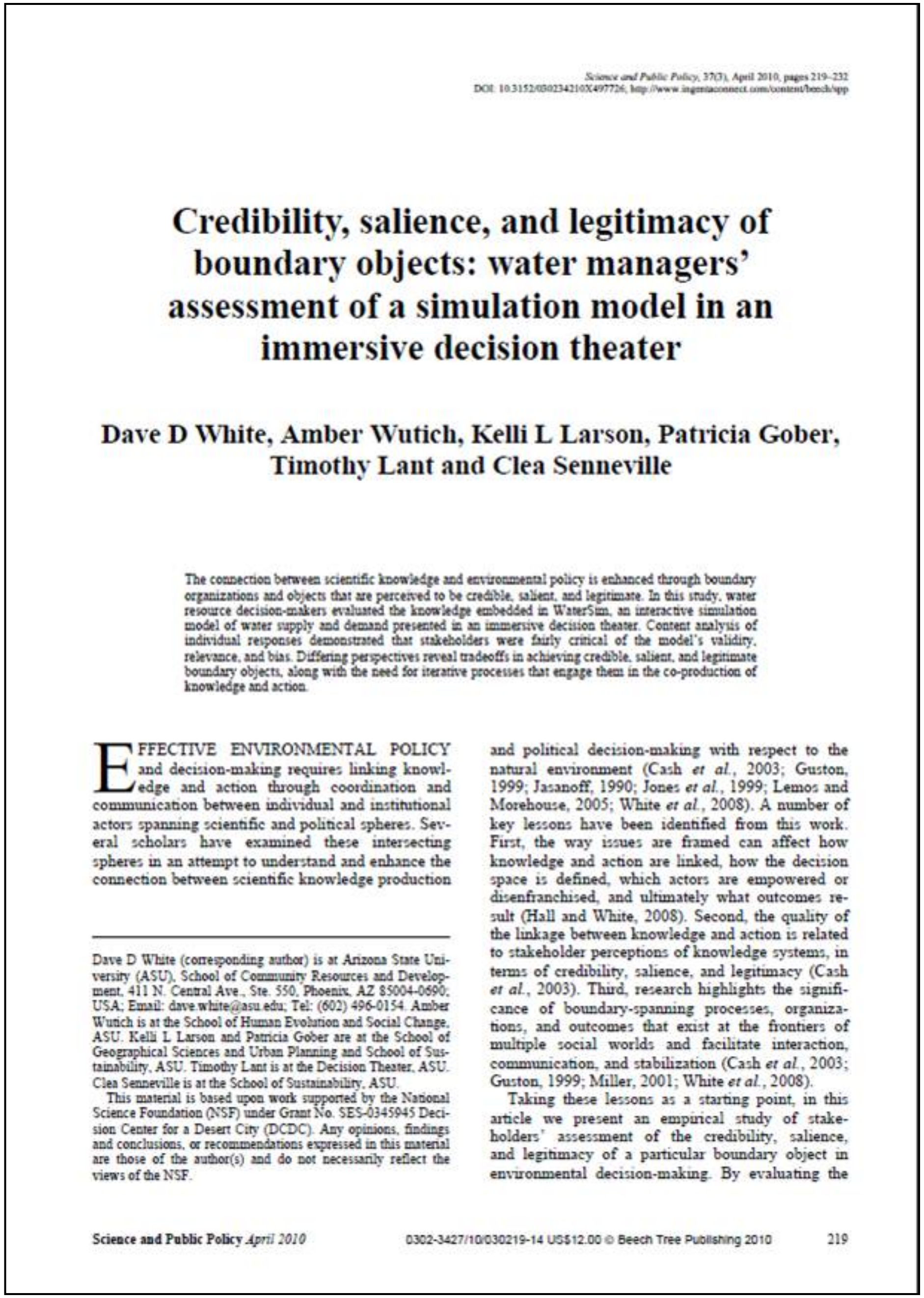


Table 2. Typology of frames applicable to climate change

Frame	Defines science-related issue as . . .
Social progress	A means of improving quality of life or solving problems; alternative interpretation as a way to be in harmony with nature instead of mastering it.
Economic development and competitiveness	An economic investment; market benefit or risk; or a point of local, national, or global competitiveness.
Morality and ethics	A matter of right or wrong; or of respect or disrespect for limits, thresholds, or boundaries.
Scientific and technical uncertainty	A matter of expert understanding or consensus; a debate over what is known versus unknown; or peer-reviewed, confirmed knowledge versus hype or alarmism.
Pandora's box/Frankenstein's monster/runaway science	A need for precaution or action in face of possible catastrophe and out-of-control consequences; or alternatively as fatalism, where there is no way to avoid the consequences or chosen path.
Public accountability and governance	Research or policy either in the public interest or serving special interests, emphasizing issues of control, transparency, participation, responsiveness, or ownership; or debate over proper use of science and expertise in decisionmaking ("politicization").
Middle way/alternative path	A third way between conflicting or polarized views or options.
Conflict and strategy	A game among elites, such as who is winning or losing the debate; or a battle of personalities or groups (usually a journalist-driven interpretation).

Nisbet, M. C. (2009). Communicating Climate Change Why Frames Matter for Public Engagement. *Environment, 51(2), 12-23.*

focus on science that is credible and salient to decision makers



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Credibility, salience, and legitimacy of boundary objects: water managers' assessment of a simulation model in an immersive decision theater

Dave D White, Amber Wutich, Kelli L Larson, Patricia Gober, Timothy Lant and Clea Senneville

The connection between scientific knowledge and environmental policy is enhanced through boundary organizations and objects that are perceived to be credible, salient, and legitimate. In this study, water resource decision-makers evaluated the knowledge embedded in WaterSim, an interactive simulation model of water supply and demand presented in an immersive decision theater. Content analysis of individual responses demonstrated that stakeholders were fairly critical of the model's validity, relevance, and bias. Differing perspectives reveal tradeoffs in achieving credible, salient, and legitimate boundary objects, along with the need for iterative processes that engage them in the co-production of knowledge and action.

EFFECTIVE ENVIRONMENTAL POLICY and decision-making requires linking knowledge and action through coordination and communication between individual and institutional actors spanning scientific and political spheres. Several scholars have examined these intersecting spheres in an attempt to understand and enhance the connection between scientific knowledge production and political decision-making with respect to the natural environment (Cash *et al.*, 2003; Guston, 1999; Jasanoff, 1990; Jones *et al.*, 1999; Lemos and Morehouse, 2005; White *et al.*, 2008). A number of key lessons have been identified from this work. First, the way issues are framed can affect how knowledge and action are linked, how the decision space is defined, which actors are empowered or disenfranchised, and ultimately what outcomes result (Hall and White, 2008). Second, the quality of the linkage between knowledge and action is related to stakeholder perceptions of knowledge systems, in terms of credibility, salience, and legitimacy (Cash *et al.*, 2003). Third, research highlights the significance of boundary-spanning processes, organizations, and outcomes that exist at the frontiers of multiple social worlds and facilitate interaction, communication, and stabilization (Cash *et al.*, 2003; Guston, 1999; Miller, 2001; White *et al.*, 2008).

Taking these lessons as a starting point, in this article we present an empirical study of stakeholders' assessment of the credibility, salience, and legitimacy of a particular boundary object in environmental decision-making. By evaluating the

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the boundaries between science, planning, management and policy should be actively managed by individuals, social networks and institutions

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Water Managers' Perceptions of the Science–Policy Interface in Phoenix, Arizona: Implications for an Emerging Boundary Organization

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A potential water supply crisis has sparked concern among policymakers, water managers, and academic scientists in Phoenix, AZ. The availability of water resources is linked to population growth, increasing demand, static supply, land use change, and uncertainty. This article examines the perceptions of water managers working at the science–policy interface in Phoenix and discusses the implications of their experiences for the development of an emerging boundary organization: the Decision Center for a Desert City. Qualitative analysis of data generated through in-depth interviews with water managers uncovers two understandings of the intersection of science and policy: One perspective is a traditional, linear model with sharp conceptual distinctions between the two spheres, and the other is a recursive model recognizing fluid boundaries. Managers describe uncertainty as inescapable, but manageable. A prescriptive model for the science–policy interface for Phoenix water management is presented.

Keywords climate change, drought, environmental policy, uncertainty, urban water resources, Western water management

According to the U.S. Bureau of Reclamation (2003), Arizona is at the center of a geographic region facing a potential water supply crisis by 2025: Existing water supplies may not be adequate to meet future demands for society or the environment. This potential crisis is tied to a convergence of factors including explosive population

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