Objecting to Models: A Typology of Non-experts' Critiques of Models of Human-Natural Systems

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ABSTRACT: Cooperation between scientists and local stakeholders on building models requires scientists to listen to lay objections. This paper develops a typology of objections based on discourse analysis of a participatory modeling exercise examining causes and potential solutions to flooding in a Midwest watershed. Four principle objections are examined, together with ways scientists can address them.

KEYWORDS: science communication, rhetoric of science, public participation, models, participatory modeling, hydrological modeling, agent-based modeling, trust

1. INTRODUCTION

In the global movement to involve citizens more deeply in decision-making on complex issues, one emerging approach brings communities together to model the domain in question. Especially prominent in decision-making about water resources—indeed, required in the EU— "cooperative modeling" (Cockerill, Passell, & Tidwell, 2006), "companion modeling" (Barreteau et al., 2003) or "participatory modeling" (Daniell, 2012), as it is variously called, unites stakeholders, scientists and decision-makers in building a model of their watershed. Such models show promise as boundary objects mediating interactions within and between the diverse groups (White et al., 2010). Participatory modeling can help lay participants gain a systems-level view of their watershed and an understanding of the points of view of other stakeholders, can help experts learn about community concerns and benefit from community knowledge, and can help decision-makers identify novel policies and make better-informed decisions that will be perceived as legitimate by the broader community (Jones et al., 2008).

The scholarly literature has grown in parallel with the practice. Some of this work has been of the "manifesto" variety, urging more widespread adoption of the approach (e.g., Olsson & Andersson, 2006), while a "craft literature" gives practical advice about how to carry it out (reviewed in von Korff, D'Aquino, Daniell, & Bijlsma, 2010). Numerous case studies have documented the successes and limitations of participatory modeling across a broad variety of local settings (e.g., Gaddis, Falk, Ginger, & Voinov, 2010; Gurung, Bousquet, & Trébuil, 2006; Liu, Gupta, Springer, & Wagener, 2008). More recently, syntheses across cases have advanced typologies of approaches and principles of good practice (Barreteau, Bots, & Daniell, 2010; Daniell et al., 2010; Hare, 2011; Voinov & Bousquet, 2010). While these make a good start, one of the goals of this conference is to push the conversation forward. At the macrolevel, we can ask: what factors promote the success of a participatory exercise? Complementing this approach, we

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can also pursue studies at the microlevel, and ask what participatory exercises *mean* to the individual agents involved. The present essay contributes to this second goal.

Participatory modeling promises to build trust among citizens, scientists and managers. But as the climate debates have often revealed, non-experts find it easy to distrust models and model results. What are "the actual experiences of using models" (Shackley, 1998) that lie behind citizen resistance? A series of studies have documented the reasons even professional water managers give to justify their failure to use available models (Borowski & Hare, 2006; Rayner, Lach, & Ingram, 2005; White et al., 2010). Olsson and Berg (2005) have extended this line of work to examine the objections non-expert stakeholders raised in the course of a participatory modeling exercise focused on water quality in Sweden. They found stakeholders concerned that the model missed some sources of pollution, incorporated unreliable measurements and generalizations, failed to account for natural variations, and did not adequately analyze the effectiveness of possible solutions.

Having summarized these objections, Olsson and Berg then go on to ask "how the lack of acceptance [of the model] could be overcome," examining the factors that lead stakeholders to challenge models. This is, after all, a typical response to situations where science communicators have failed to achieve their goals. The tendency is to try to see through non-experts' recalcitrance in order first to diagnose and then to cure the misunderstanding on which it is assumed to be based. There is, however, another way to look at recalcitrance. Moments of dissonance between scientists and citizens are also moments where scientists might learn something. Participatory modeling is intended to allow an "extended peer community" (Funtowicz & Ravetz, 1993; Yearley, 2006) to review the model, simultaneously ensuring its quality and enhancing its public legitimacy. That can only occur if the model is vulnerable to critique from the extended community, and that in turn can only occur if non-experts' objections are taken at face value, as serious questions that deserve to be addressed, not diagnosed and cured.

This paper advances our understanding of participants' perspectives on participatory modeling by taking first steps towards a typology of objections to models. The typology is based on objections made by participants in a participatory process run in Spring, 2016 in an Iowa watershed. The upstream area in this watershed is dominated by corn and soy production, while urban area downstream is subject to periodic flooding. The science team set out to develop a modeling platform integrating various physical models (e.g., surface water hydrology) with agent-based modeling of land use decision-making in the watershed—and to do all this in cooperation with local stakeholders. The participatory process was intended both to improve the models and to advance well-informed and imaginative local planning to reduce flooding.

By the time of the participatory process, the modeling platform (from now on, referred to as "the model") had developed to a "proof-of-concept" stage. There were only two agents: a Farmer upstream and a City Manager downstream. Water flowed from the top to the bottom of the watershed in ways influenced by Farmer's land use decisions. To reduce flooding, the City Manager could decide to provide monetary incentives to the Farmer to convert some land to conservation practices that would slow the flow.

In a series of six meetings, the science team met with stakeholders in the watershed. An open recruitment process had produced volunteers who had relatively high interest in and experience with water issues in the watershed; between eight and eighteen were in attendance at meetings. In the first four meetings held jointly with the science team, the participants introduced themselves, shared knowledge and concerns about the watershed, and were introduced to basic principles of modeling. The fourth meeting culminated with participants selecting a general topic of interest: how land use practices affected flooding. In the fifth meeting, the science team presented some of the model's results on this issue, and received feedback from the participants. In the sixth and final meeting, the science team presented new results from the model which had been revised in response to participants' comments.

The typology developed in the following section is based on content analysis of the non-accepting responses to model results voiced by participants at the fifth meeting, with the data extended to include one incident at the sixth meeting. Participants' non-accepting responses ranged from questions to statements of skepticism, and were consistently accompanied by explanations of why it was reasonable for them to distrust the model, at least in some degree. I call such responses "objections," and identify four main types, before concluding the paper with a summary and remarks about what we can learn from this case for practice and theory.

2. FOUR TYPES OF OBJECTIONS

2.1 "We all know that realistically, you're not going to.... But what if..."

One of the most basic use of models is to ask "what if" questions—to project what might happen in a given scenario. The science team constructed several scenarios and presented the initial results at the meeting examined here; the participants in some cases questioned the scientists' choices. For example, in response to a scenario that imagined converting large portions of the watershed back to prairie, one participant asked:

> Looking at the subbasins, when [the scientist presenter] did his assumptions on the changes, it would have been good to have had a percentage of land in that subbasin. Say you took that subbasin that was all pretty much, like [subbasin number] 11 up there [on the map] for example, what would it be if 20% or 40% of that was now urban, or 40% or 20% of it was pasture, could you go to that level? And perhaps your initial [scenario], you know, just wasn't there, but that would have been...You assumption was…'OK, this one, if you turned it all into pasture.' OK, we all know that realistically, you're not going to have everybody in the watershed convert that to pasture. But what if you had 20% of it into pasture? Or something of that nature.

Probes of this sort were often phrased as true questions, asking for alterations of the "assumptions" based on the questioner's own experience of what is "realistic" in the watershed.

Scientists found it relatively easy to respond to these questions, since they could run the model with alternative scenarios. When the participant who made the "realistic" objection to the scenario expressed a half-serious concern about the amount of computer time the scientists had to try his alternatives, a scientist immediately responded: "Don't worry about computer time to try what you're thinking." But scientists did resist some suggestions. Sometimes the suggestion went beyond the current capacities of the model. For example, while science team members shared participants' interest in modeling what the impact of climate change, they simply let slide a comment asking "what if" on that subject. Scientists also resisted when their sense of "realism" diverged from that of participants. Thus a request to model a different flood was put aside when one of the scientists—backed by several of the lay participants—pointed out that it was actually less extreme than the flood which had been simulated. Finally, scientists resisted "realism" in itself, as less scientifically interesting than more "unrealistic" scenarios. A scenario combining diverse land uses (e.g., 20% pasture, 20% urban, 60% crop) might be more realistic, but the model results would be harder to interpret—there would be no way of telling which of the factors had the biggest impacts on flooding. Thus a scientist commented:

> Sometimes in simulations like this will go to some degree—it's an extreme we would not necessarily expect to happen, but it's a way of just seeing what the limits are in terms of what you can do.

Similarly, scientists resisted a question asking why they didn't simulate the later stages of the flood that had been modeled, since modeling extremely bad conditions was uninteresting: there was going to be a flood no matter how humans used the land.

2.2 "Are you looking at…?"

A second set of participant questions focused on elements of model itself, and in particular, on aspects of the world that the model left out. A question of this type was the first to be asked after the initial presentation of model results at the first meeting:

> Are you looking at soil type, at slope, and at vegetation cover?

Any of these could affect the speed water runs off the land, and thus flooding downstream. Another physical factor that was mentioned several times was "tiling"—subsurface drainage systems installed to reduce wetness in fields. For example:

> How does your model include the drain tile run-off from farms?

Even more frequent, however, were questions about social factors that appeared to be left out of the model. Participants displayed a substantial appreciation of the complexities of interactions in the watershed. For example:

> Was he [the Farmer in the model] the landowner, or the [renter/]farmer? It makes a big difference.

> Have you ever modelled—in adding this into it, I'll throw you a nice curve, here—do you guys play poker? Some will take their pot and just put it all in and say, "there it is," and they hope they're going to win it....And others will join in, saying, "I've got a better hand than you do." And all they're—all you're laying out is this very similar situation. If it was all that easy, to make those three choices. So I guess what I've done, what I'm saying is that you've really oversimplified it. It's a matter of gambling here at this point.

In both these contributions, participants seem somewhat appalled at the way scientists have "oversimplified" the social situation through overlooking "big differences;" they recognize that they seem to be "throwing a nice curve" by asking for increased complexity. Overall, participants were interested in including in the model: different types of farmers (renters versus owners and risk-takers versus risk-averse, as above, and also women versus men), a broader range of farming practices (on-farm crop storage), more economic factors (crop insurance, international markets, futures contracts), more political factors (pressures on city politicians, city budgeting process), and more cultural factors (reluctance to participate in governmental programs). They suggested modeling the impact of non-monetary incentives such as awards, and social processes whereby farmers are influenced by the actions of their neighbors. In two cases, participants suggested novel feedback loops which could make the model more interesting: recognizing that conservation measures which slow down water flows also lead to soil health which improves farmer productivity, and the possibility that more productive farmers would spend more money in the city, increasing tax revenue and thus city well-being. Overall, participants wanted the model to have what they called "more details" to match their sense of the complex factors in the watershed that influenced land use decision-making and flooding; these were by far the most frequent responses to the model at the meetings.

The science team sometimes responded in an open way to these suggestions, framing them as additional factors that could be added to the model:

> [Scientist #1] I guess we've always implicitly assumed that the farmer owns—
> [Scientist #2] That's right, yeah.
> [Scientist #1] This actually brings out—
> [Participant] But how many do?
> [Scientist #2] Right. And so when we do this exercise, that would be something to add to the model, right, the ownership of the land.

At other times, however, the scientists resisted the requests. As with extremism in scenarios, simplicity in modeling was needed (at least at the beginning) to keep the model interpretable. The more working parts the model had, the harder it would be to figure out what was happening, one scientist explained:

> So one of the goals was just to keep everything as simple as possible to start off with, to make sure that we understand that before trying to build in a lot of complexity which could get in the way of actually understanding what is going on. The goal of using a model is to understand what is going on. Not simply—not this thing where you throw in data and it gives you back numbers and you just say, "Oh" you know, and you're just blindly accepting them.

Scientists also gave technical reasons for not incorporating some factors—basically, because it was too hard to do. Thus although several participants had mentioned the lack of subsurface drainage in the model, the scientists responded with a firm "no":

> So that's a very, very good question. And I have some unfortunate news: that almost every single model out there—not just talking about this one—almost no model takes into account tile drainage... It's very, very difficult to simulate that.

Whereas limited "computer time" was not viewed as an obstacle to running a different scenario, technical limitations were put forward as reasons for declining to even consider incorporating a new element into the model.

2.3. "There are some assumptions…"

Participants raised questions not only about the factors left out of the model, but also about the generalizations built into the model about how those factors influenced each other. In particular, the model's reliance on curve numbers—a standardized measure of the speed of run-off from different land uses—received detailed scrutiny from several participants:

> There are some assumptions, like I think you said the numbers, maybe some of those numbers come from not Iowa? So, like, a pasture in Iowa might be different than from wherever those numbers came from?
>
> I would add, personally...if you used any data that was developed by the NRCS thirty or forty years ago what they were using for pasture and row crop, for example, would be not very accurate or very current, because today's farming methods are different…. A lot of that old information is out of the window.

In these interventions, participants express scepticism that generalizations based on data from different times and places ("not Iowa"—"forty years ago") would apply to the Iowa here and now.

Curve numbers also didn't capture specific vegetation types ("forbes is different from grasses"), seasonal variations ("the stage of the crop") or new land use regulations ("storm water detention requirements")—all of which require "going into a lot further detail than what you have at this point." A similar complaint emerged after an extended discussion of crop insurance:

> Each of us has a different opinion of how insurance, for example, is sold and measured and how the government's giving away or selling at a fair price or farmers are ripping off somebody. We all have a different opinion of what level there is there. Some accuracy would be good [laughter] if at all possible. If you [the scientist]'re not in the ag world, and neither is he, you know, so as we all think to blame farmers for whatever it is, we should have some accuracy in this if at all possible.

Notice that the participant here lumped both lay experience and scientists' disciplinary knowledge into the category of "opinion," since no one in the room had the knowledge that would have been derived from being in the "ag world." The whole meeting found it amusing that a non-scientist is calling on a scientist to improve his "accuracy"—but at the same time, such accuracy was seen as vital when real interests could be affected ("blame farmers").

Scientists' common response to this type of question could perhaps best be characterized as tepid. Changes in basic assumptions were possible—but also unlikely. For example, consider these three responses to requests for more accurate curve numbers.

> It's definitely—I don't know, I guess it'd be something to look at….
>
> Theoretically—I mean, maybe the data—I kind of assumed is, there'll probably be some run-off data out there for maybe plots that they have planted, like switchgrass. So then with that data, you could derive these curve numbers directly. So it'd be something to look at.
>
> Yeah, it's probably a good point that you make that most curve numbers could change throughout the year. There's basically—I don't know, I haven't seen many studies that look at that effect.

Note that each of these responses provides only a qualified endorsement of the request—it is "theoretically" possible that the curve numbers might be wrong; some that "probably" or "I guess" might be looked at. There "might" be existing data that could be used to (laboriously) re-calculate the numbers—or there might not, since "I haven't seen" it. The sense here is that any model must rest on assumptions derived from prior work, and that it is not going to be worthwhile to re-open questions that already have well-established answers in the discipline.

2.4. "But I'm not sure…"

A final category of participant response focuses not on what goes into the model, but on what comes out. These comments are phrased not as questions, but as statements of distrust in model results, albeit presented in highly hedged forms—almost to the point of uninterpretability.

There was only one instance of such total resistance at the meeting where the model was initially presented. It arose from a model result that suggested that changing land use practices far upstream had little impact on flooding in the city at the end of the watershed. One participant commented:

> So in this particular watershed, the peak—I mean we're talking twelve hours from the time usually from the water drops until they get it out to the exit. So when you talk about "flashy subbasins," people think it is extremely flashy when it comes to watersheds. So, I didn't want to—The model sort of discounts the upper reaches, but I'm not sure—it would—but maybe in such a flashy watershed it would be effective…

> In a much bigger watershed, I think, I would agree with discounting the upper part of it; in such a flashy watershed I would not necessarily be willing to say, "naw, let's not look at that other part."

This participant had had substantial job-related experience in tracking flooding. Drawing from her repeated experiences of what happens "in this particular watershed…usually," she believes it to be "flashy," i.e. one in which water tends to move quickly. By contrast, the model seemed to predict that water moved more slowly. Although she surrounds her statement with qualifications ("I didn't want to [say]," "sort of discounts," "I'm not sure," "maybe," "I would not necessarily be willing"), it seems clear that she doesn't credit what the model is telling her.

A similar rejection occurred in the follow-up meeting, where the science team presented a new set of model results incorporating some participant suggestions from the first meeting. One set of results suggested that putting as little as 10% of the land into conservation practices would achieve almost as much flood reduction as taking the whole watershed back to prairie, if the 10% were well selected. One participant expressed his skepticism:

> Well, you know there's a strange thing, because—I've been told, I've been going to some of these different training sessions on this stuff—the days before we really started farming here it was all prairie, and there were a lot of criks and things that were not there now but that there were...there then. And it seems like, I don't know, I just would have expected it to be a lot lower. But—I don't know!... But I have, you know, growing up as a child in this area—I lived away from here a long time, but up until you know I was eighteen—and comparing what's on the farm now—when I was very young my Dad could drive a tractor across a slow crik, and now it's about six feet deep.... There's big change, and this is because it looks to me like it's because we got rid of the hay and the pasture, and we've got all row crops, I guess.

This participant claims authority both because he had attended other "sessions" focused on the watershed, and because of his personal experience. Although repeatedly avowing that "I don't know," he narrates a story of how water moved on the landscape when he was young as the basis for his "expectation" that changing back to those conditions would produce a larger impact than the model shows.

In both cases, participants claim a form of expertise based on both local experience and more disciplined study that authorizes them to disbelieve model results. The science team has no compelling way to respond to such disbelief. Eight seconds of silence followed the first participant's statement, until the participant herself followed up with a question about how the model calculated the time it took for water to move from the top to the bottom of the watershed; this initiated a detailed discussion of elements of the model The second participant's story elicited a general reminder about the limitations of any model:

> You know, and again, that's, that's a good—you know, there is, you know, uncertainty in the model.

As with the first instance, this then led into a discussion of the model features (no tiling, no water storage on the landscape) that could have produced the unexpected result.

3. DISCUSSION AND CONCLUSION

The following table summarizes the four categories of questions participants in this modeling exercised raised against the model they were co-developing with scientists.

Table: A Typology of Non-experts' Objections to Models

Type	Typical Discourse	Nature of Objection
1	"We all know that realistically, you're not going to…. But what if..."	Challenges a scenario because it does not envision a plausible world in participants' experience.
2	"Are you looking at…?"	Challenges the absence from the model of a feature of the system deemed important in participants' experience.
3	"There are some assumptions…"	Challenges a generalization built into the model as inapplicable to the participants' immediate situation.
4	"But I'm not sure…"	Challenges model results as implausible in participants' experience.

Similar critiques have been noted by previous work on lay responses to models, with types 2 and 3 being especially prominent. Olson and Berg's study (2005) of participant responses to water quality modeling noted objections both to "which sources of pollution were included and which were not when producing the model-generated data" (type 2) and to "generalizations, such as standard values for different land uses and soil types, were also seen as a problem" (type 3). Yearley (1999) of stakeholders' responses to models used in air pollution planning similarly found "public views about gases and other substances omitted from the monitoring programme" (type 2), and concerns that "the model was so dominated by the assumptions" about traffic (type 3) that it was untrustworthy. Shackley's (1997) early review of case studies found model users both asking for "greater detail" (type 2) and questioning "the numbers for specific variables" (type 3). This is some indication that the typology presented here may be robust across cases.

Overall, the four types of objections present increasing levels of threat to the scientists responsible for building the model. Dealing with a variety of scenarios is precisely what models are designed to do. Adding new elements is somewhat more difficult; any model draws a boundary specifying what in the system will be included and what excluded. But it should be possible to re-negotiate that line, and the exploration of the pros (such as increase in fit with participant experience) and cons (such as technical difficulties) should be enlightening to both expert and lay participants in the modeling process. Tinkering with the generalizations built into the model can be more difficult yet. It would be impossible to build a model if results of previous research couldn't be taken for granted; no inquiry afford to defend assumptions "all the way down." At the same time, Wynne's classic case study (1989) is a good reminder that sometimes scientific generalizations do not apply in the here and now of a particular situation. In the worst case, the rush to achieve closure on challenging questions can lead to a model that does nothing more than recirculate the assumptions on which it is based (Shackley, 1997). This suggests that scientists should remember that generalizations hold "other things being equal"—but that other things are *never* equal. Scientists should thus be open in principle to re-examining some of the assumptions they have relied on. Finally, global skepticism about model results is impossible to address directly, although as will be discussed below there may be indirect ways to respond.

Can heeding participants' objections improve the model, as the idea of extended peer review suggests? Even in the small case at hand, there is evidence that listening to participants' critiques contributed to better science. After the first meeting, the science team made several changes in the model and took the new results back to the participants at the final meeting. In response to objections to their scenarios, they ran the model assuming that the areas closest to the city were converted from cropland to developed land. Interestingly, although previous model runs had suggested that flooding was most sensitive to changes downstream, paving over the neighborhoods nearest the city had little impact on flooding. In response to objections about missing elements, crop insurance was incorporated into the social model. The scientists were impressed by the complexity of the crop insurance system—a clear demonstration that "more work is needed"—although the result of incorporation was not surprising: farmers did a little bit better when insurance was available. Finally, one member of the science team had actually just completed a separate project calculating the curve numbers of carefully positioned conservation measures, based on long-term data from Iowa farms. Using these more locally adapted curve numbers in place of the generally accepted ones previously built into the model produced results suggesting that well-placed conservation measures would have a more significant impact on flooding than the model had previously shown.

Given that participants' contributions can improve the model, how should scientists respond to objections made in the course of participatory modeling exercises? A good practice would seem to be "yes," or "yes, but." The scientist should acknowledge that many choices were made in selecting scenarios, selecting system features, and selecting background generalizations. Those choices could have been made otherwise. Participants' objections voice relevant reasons for alternative choices. Scientists may have countervailing reasons—technical limitations or limitations of scientific knowledge that make participants' preferred choices difficult or impossible; these reasons too deserve consideration. Still, scientists should be aware that their own assessments of how difficult or bothersome it would be to make changes may not be entirely accurate. "I don't want to do it" is not equivalent to "it can't be done."

Responding to objections of type 4—global objections to model results—is more difficult. In that case, good practice would seem to be to explore whether the participant's reason for distrust can be converted back into an objection of type 1, 2 or 3. What would have to change about the model for it to be trustworthy? If there is nothing that could be changed in the model that would induce the participant to accept—or at least, seriously consider—model results different from his or her expectations, then the participant is not going to be able to learn from the model. In that case, the conversation might better be directed to the "meta" question of whether model development is useful at all, and if so, for what (Bots, Bijlsma, von Korff, Van der Fluit, & Wolters, 2011).

The typology proposed here is based on only a single case; validation across other cases would be useful, and especially testing whether the typology is effective as a coding scheme for participatory modeling exercises more generally. Such a coding scheme could be a valuable resource for more "macro" investigations of participatory modeling. For example, there is an open question about the relationship of model complexity to the success of the participatory modeling process. In the case at hand, as in other cases (White et al., 2010; Yearley, 1999), participants' type 2 objections were particularly prominent. Heeding these objections would result in more system features being incorporated into the model; in other words, an increase in model complexity seems the necessary cost of increasing model trust. In contrast, one study (Webler, Tuler, & Dietz, 2011) of modelers' and outreach professionals' views found that technical complexity was thought to be a significant barrier between models and their lay users. And the companion modeling process advocated by Barreteau and others (2003) intentionally emphasizes relatively simple models constructed by the participants themselves. Does resolving type 2 objections lead to increase trust in the model? Is there an eventual trade-off between complexity and trust? Or is complexity not the right focus—perhaps, as suggested by the scientists at several points in the present case, it is not complexity but interpretability that influences trust. In any case, these and similar questions need to be tackled by both "macro" and "micro" investigations if we are to advance our understanding of the participatory modeling process.

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