



# Characterizing Uncertainty in Applications of Ecological Models

Jeremy Littell, USGS  
Alaska Climate Science Center





# Summary

- Model output  $\neq$  forecast or prediction *the way managers think about those terms*
- Outside science, **useful** models are those that make projections **used by** decision makers, managers
- Useful means managing and describing uncertainty in ways that allow model output to be put into the decision context
- That is, action depends on translating output and science into information
- Multiple models “bolted together” is not necessarily a recipe for a ***cascade of uncertainty***! If choices to constrain uncertainty are made in the construction and application of models, then uncertainty – in both reality and perception - can be decreased.

**What's the utility of  
ecosystem modeling  
in a global change era?**



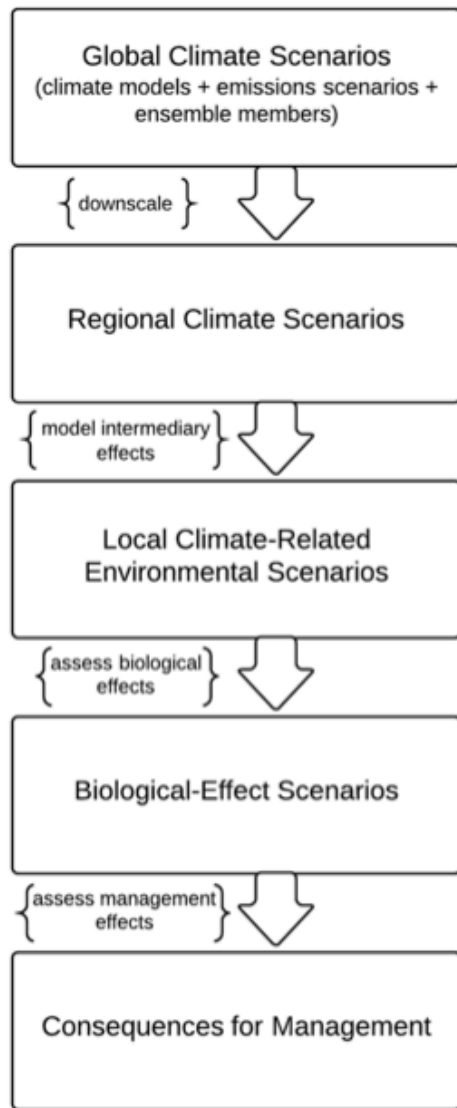
# What's the utility of ecosystem modeling in a global change era?

Increasingly, models built for purely scientific purposes are pressed into service for projecting future conditions relevant to resource management.

Whether those projections are ***predictions*** or ***forecasts*** is a key distinction for utility in decision making.

A prediction has clearly stated contingencies; a forecast has a probability.

Most climate and ecosystem models produce *neither*.



*Figure 1. A common method of assessing the consequences of climate change for natural systems is a top-down impact assessment, which links, in turn, projections of global climate, regional climate, regional effects, biological effects, and responses.*

*Snover et al. 2013, Conservation Biology*



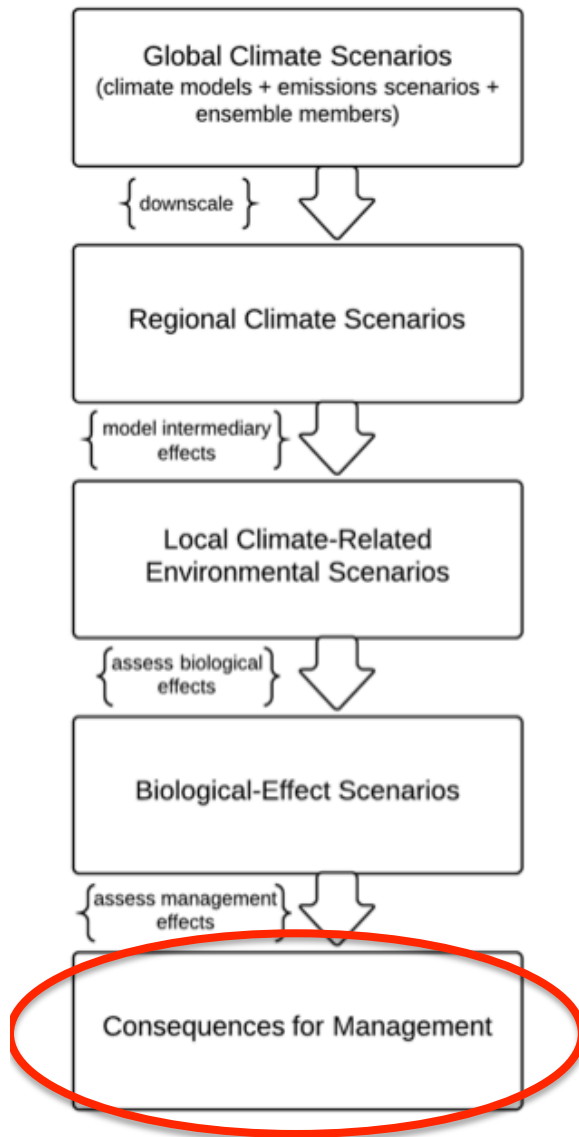
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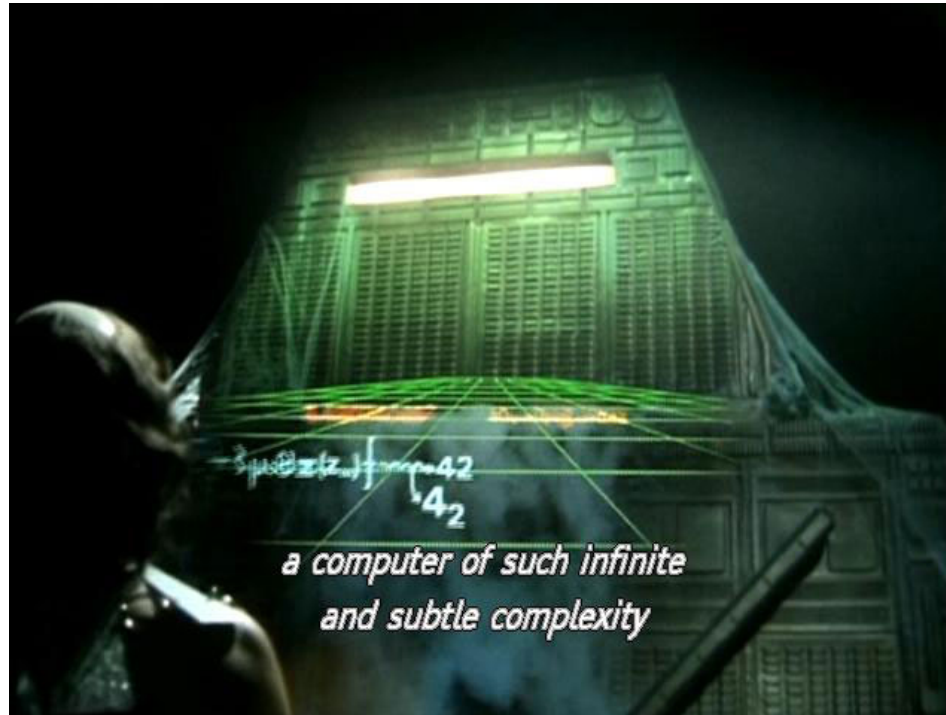
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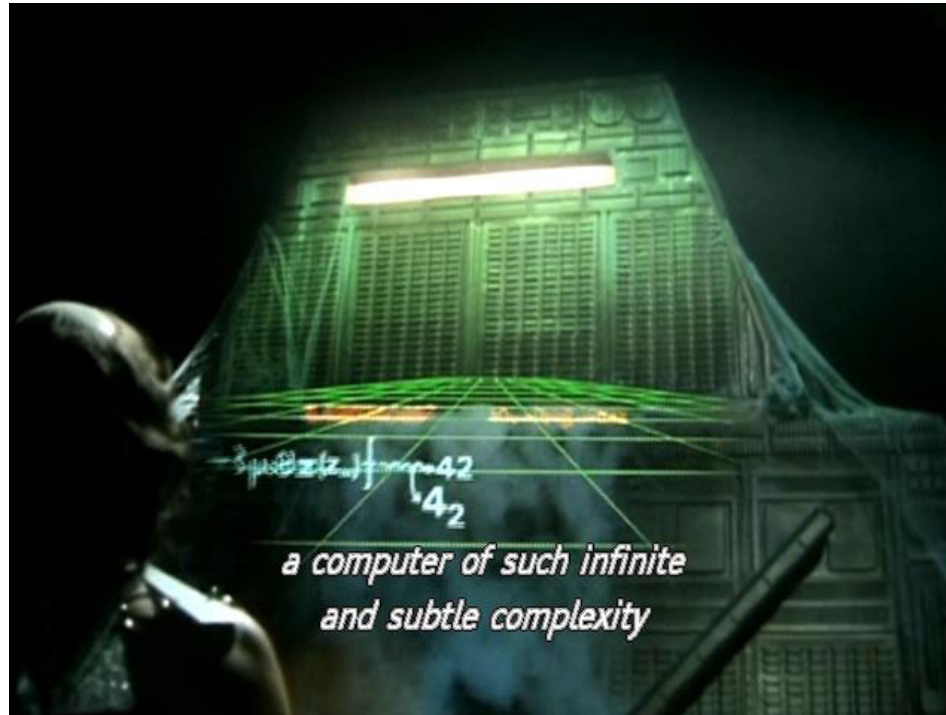
“I have \$11B of infrastructure to manage and \$11B more to plan. I ask you, how actionable is your science?”

D. Behar, Deputy to the Assistant General  
Manager, Water Enterprise, San Francisco  
Public Utilities Commission



“We demand rigidly defined areas of doubt and uncertainty!” - Vroomfondel





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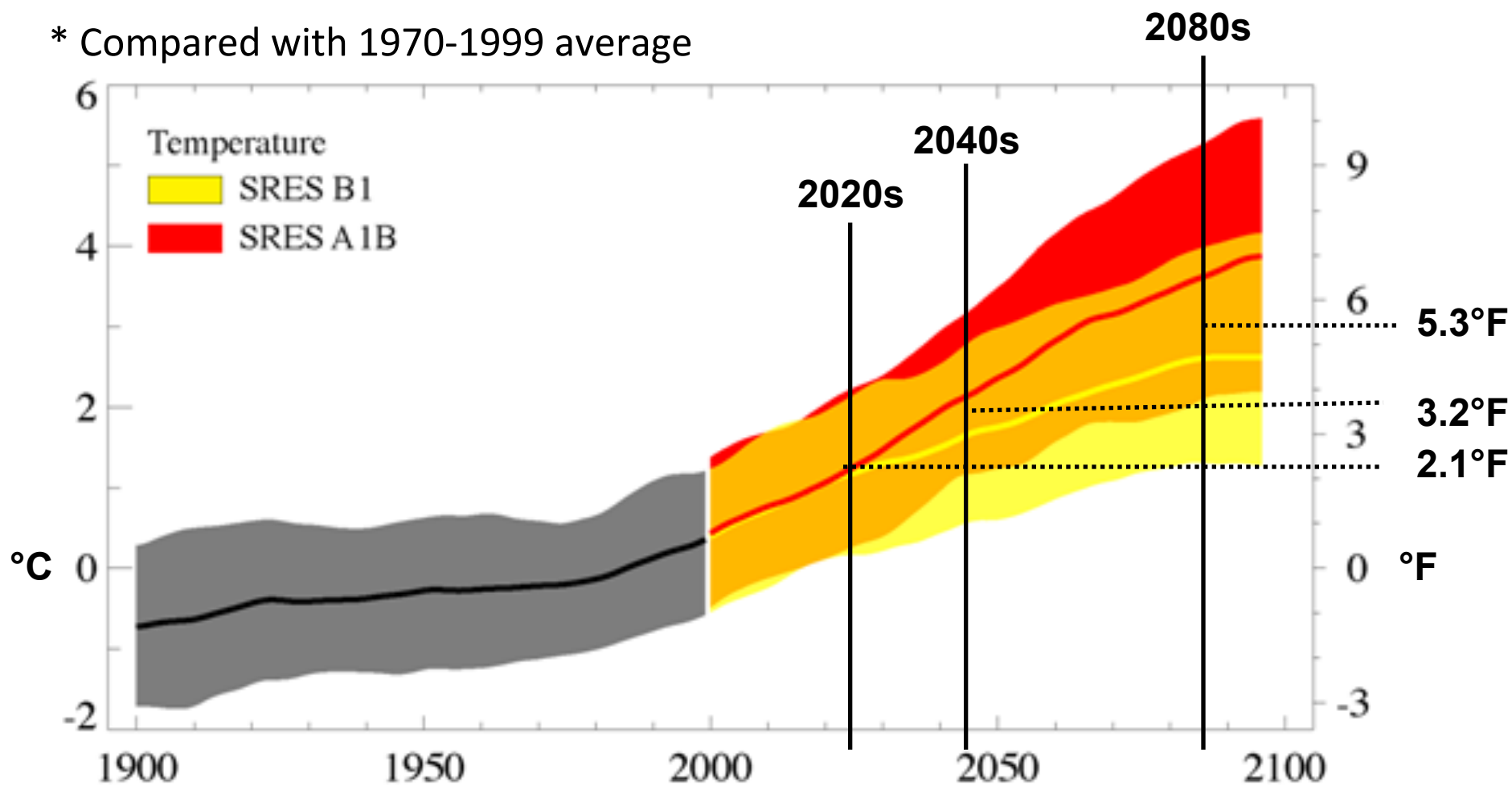


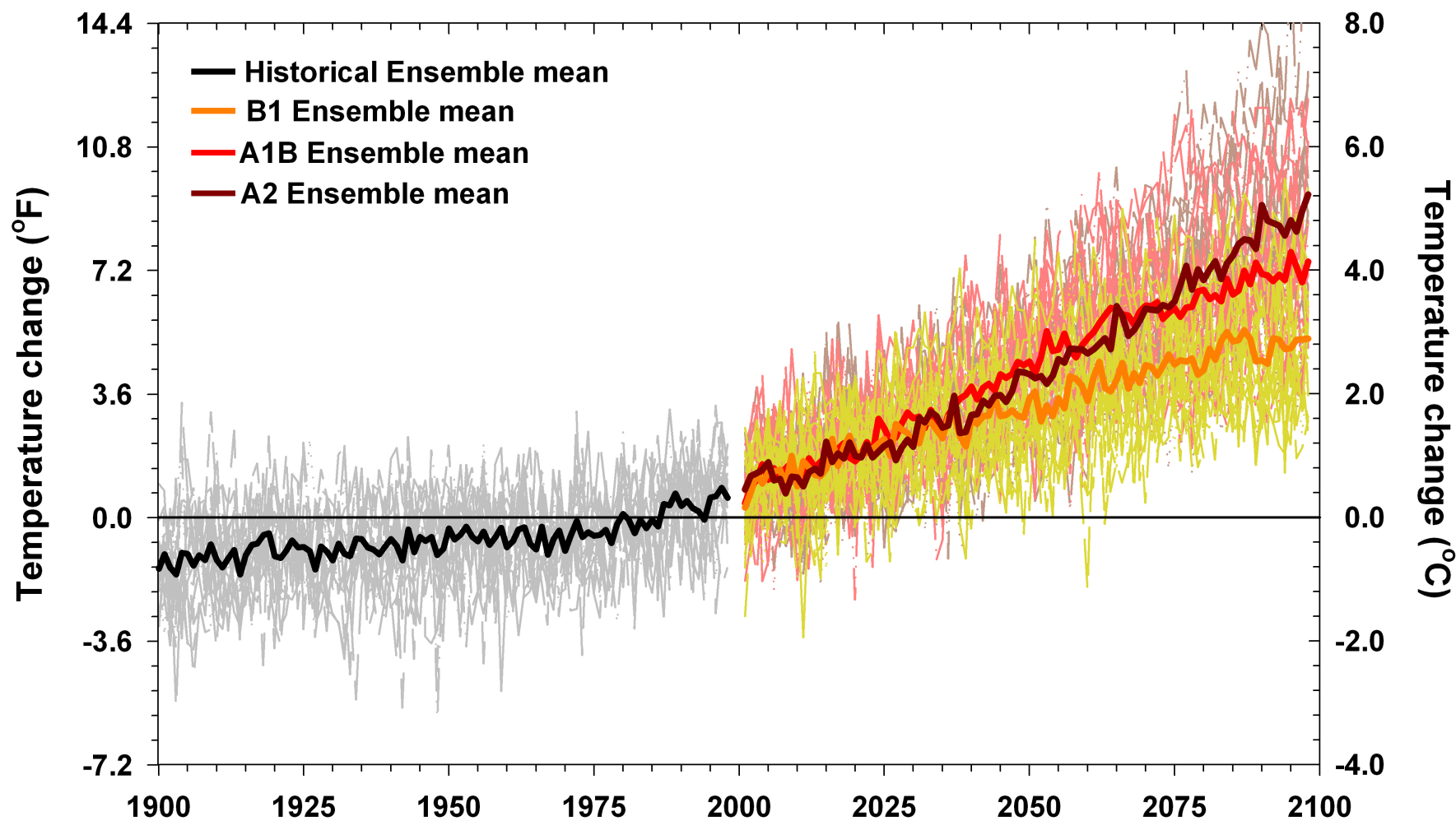
....we're scientists!



# Projected increases in annual temperature

\* Compared with 1970-1999 average





Northern Rockies historical and 2001-2099 (color).  
Heavy lines are ensemble (multiple climate model)  
averages for B1, A1B, and A2 emissions scenarios.



# **One rigidly defined view of uncertainty: The Rumsfeldian Taxonomy**

- Known knowns – the things you know you know
- Known unknowns – the things you know you don't know
- Unknown unknowns – the things you don't know you don't know

# One rigidly defined view of uncertainty: The (Expanded) Rumsfeldian Taxonomy

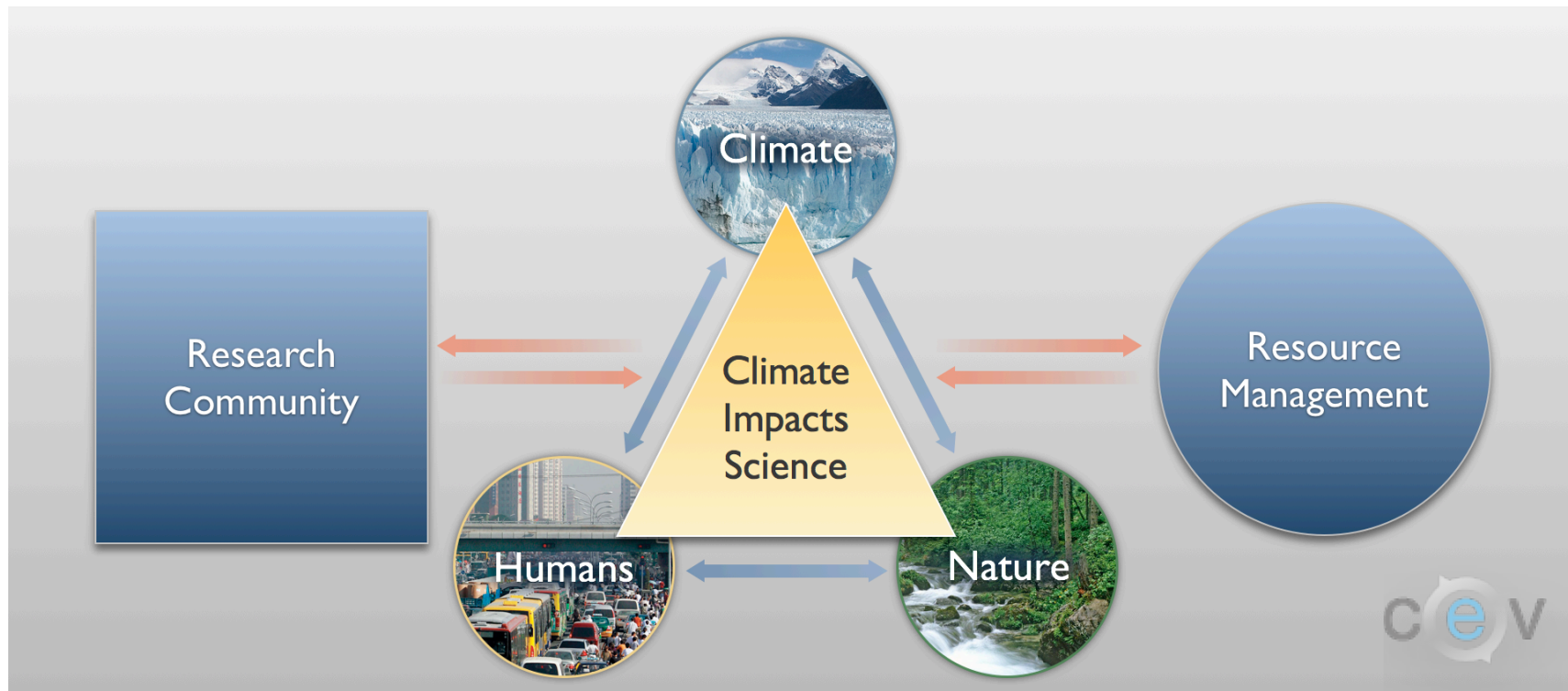
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- Known unknowns – the things you know you don't know
- Unknown unknowns – the things you don't know you don't know
- **Unknown knowns – “the things you do not like to know”,**  
e.g., elephants under the rug and  
gorillas in the room

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- **Unknown knowns – the things you do not like to know**
- **Things you think you know that just ain't so**

**Science by design addresses these directly and iteratively moves facts from one portion of the taxonomy to others.**

**Increasingly, the world in which models are developed is not the world in which they are applied.**



**Traditional Products:**

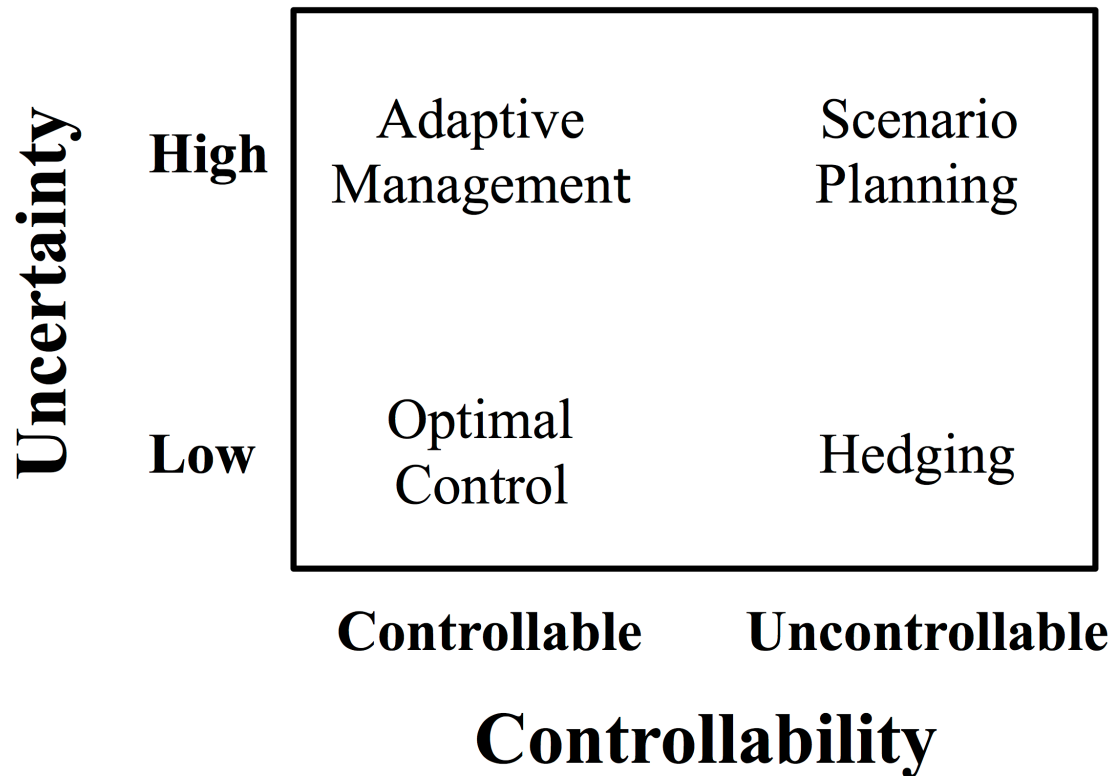
- Publications
- Forecasts
- Physical system models
- Theoretical models
- Case Studies
- Data

**Traditionally Operates in a world of:**

- Formal planning
- Regulatory requirements
- Limited technical resources
- Hierarchical mgmt. authority
- Balancing stakeholder interests
- Risk-averse decision-making



**Who will do what differently because  
you did some science?**



*After Peterson et al. 2003*



## ***Uncertainty, Models, and Adaptation***

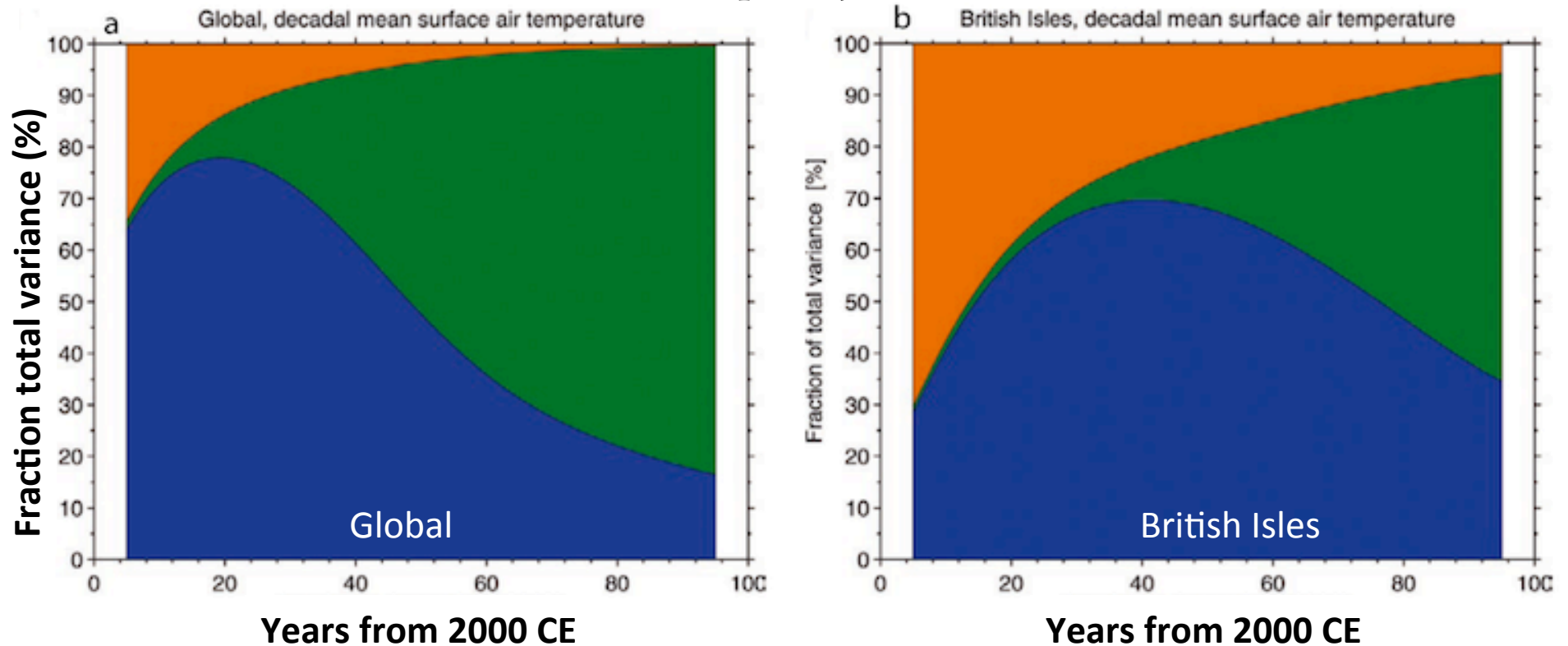
*Whether model output is **useful** depends on where uncertainty comes from, how big it is, and how it is handled.*

*The way decision makers think about “actionable” – what is possible, what is risky, what is vulnerable, and what to do about it – is based on how large or small they think the uncertainty is.*

***How do we effectively communicate uncertainty?!?***



# Sources of uncertainty in climate projections



Climate variability

Emissions scenario uncertainty

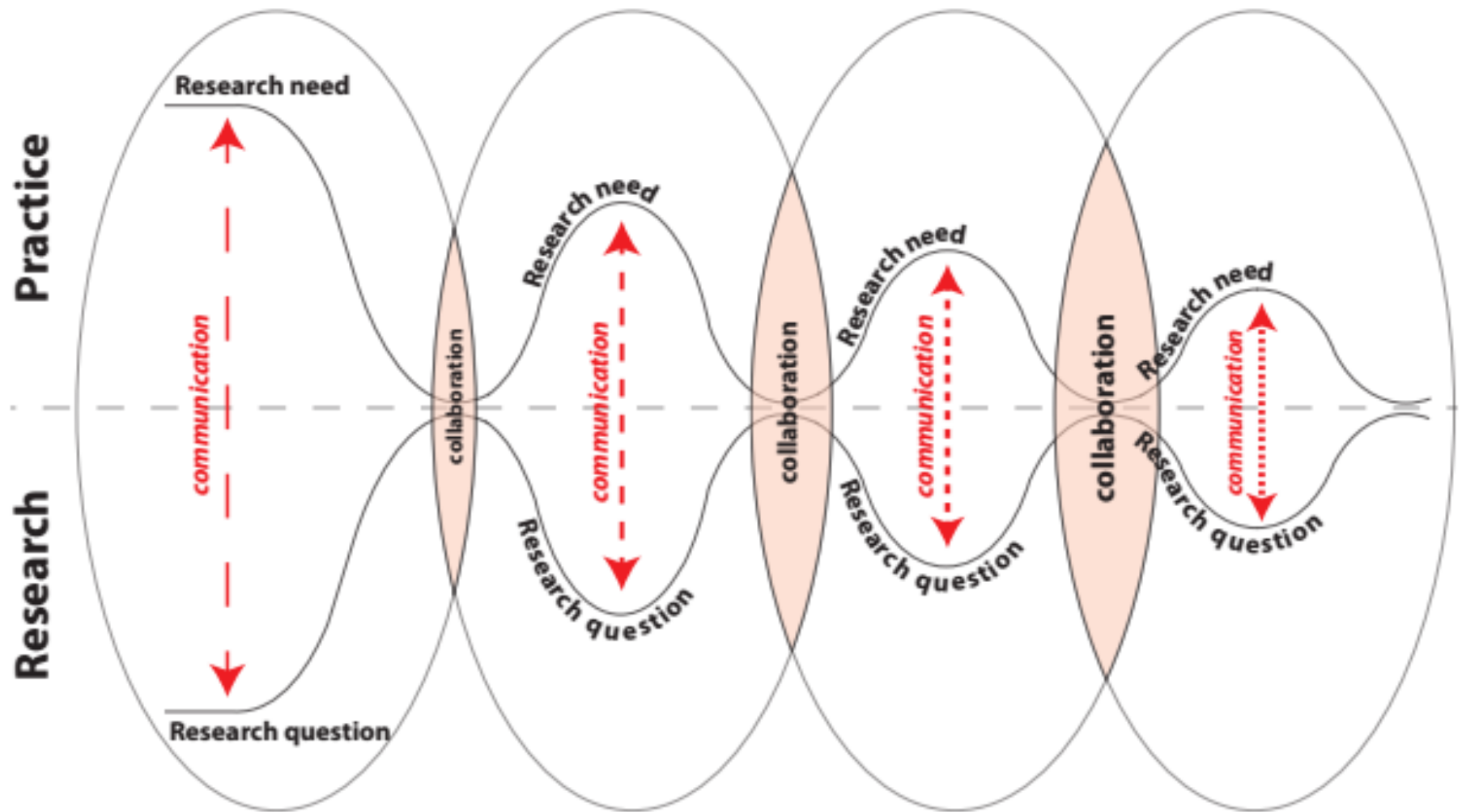
Climate model uncertainty

*Hawkins and Sutton, BAMS 2009*

# Managing uncertainty in climate projections in a decision context

- **Choosing scenarios** Multiple scenarios, multiple GCMs or ensemble mean + scenarios?
- **Model skill:** Fidelity to 20<sup>th</sup> century observations at regional scales?
- **Outliers:** Can models be objectively eliminated, or should all outcomes be considered equally plausible?
- **Scale of decision:** Spatial and temporal scales of the climate information appropriate to planning or decision making?
- **Using scenarios:** Models and emission scenarios selected match risk framework (risk tolerant vs. risk averse)?
- **Downscaling:** Is the added detail both necessary and realistic?
- **Scale of model linkages:** How does the scale of climate information match the ecosystem model being used?

**What's important compared to what – clearly, repeatedly, iteratively....and competently.**



Ferguson, Daniel B., Jennifer Rice, and Connie Woodhouse. 2014. Linking Environmental Research and Practice: Lessons from the Integration of Climate Science and Water Management in the Western United States.





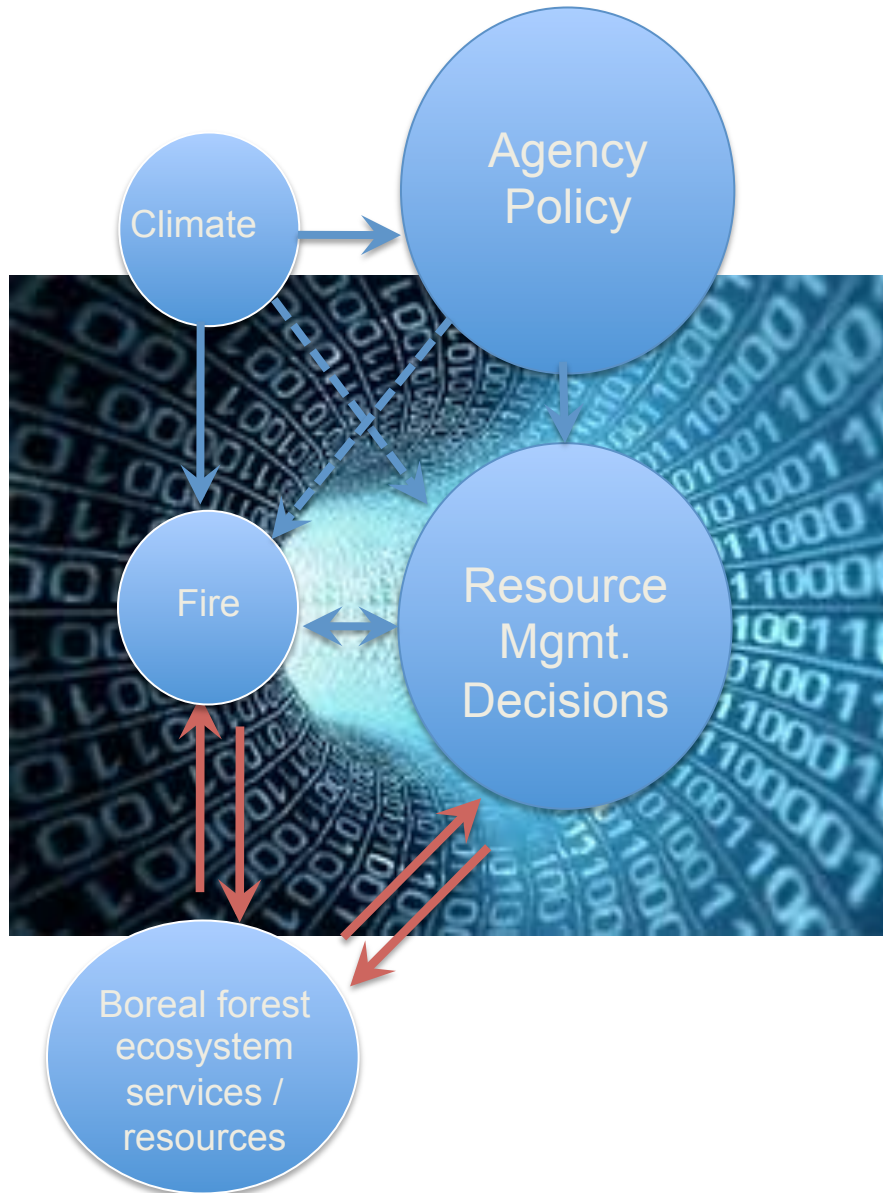


# Model world vs. Decision context



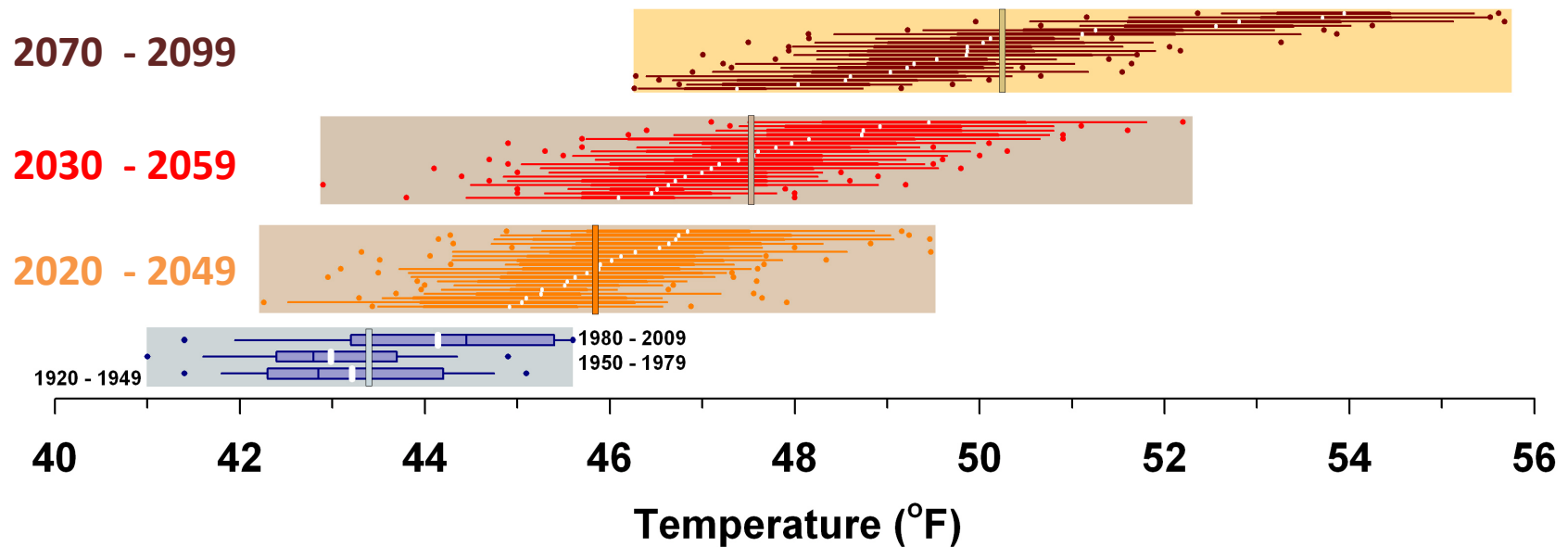
- **Model world:**  
Systems knowledge and target knowledge are rolled into models that describe or project
- **Decision context:**  
Projections *can* be used to plan, alter policy, or change management.  
But *will* they?

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## Northern Rockies Regional Projections, A1B (19 GCMs),



Historical 2020s 2040s 2080s A1B