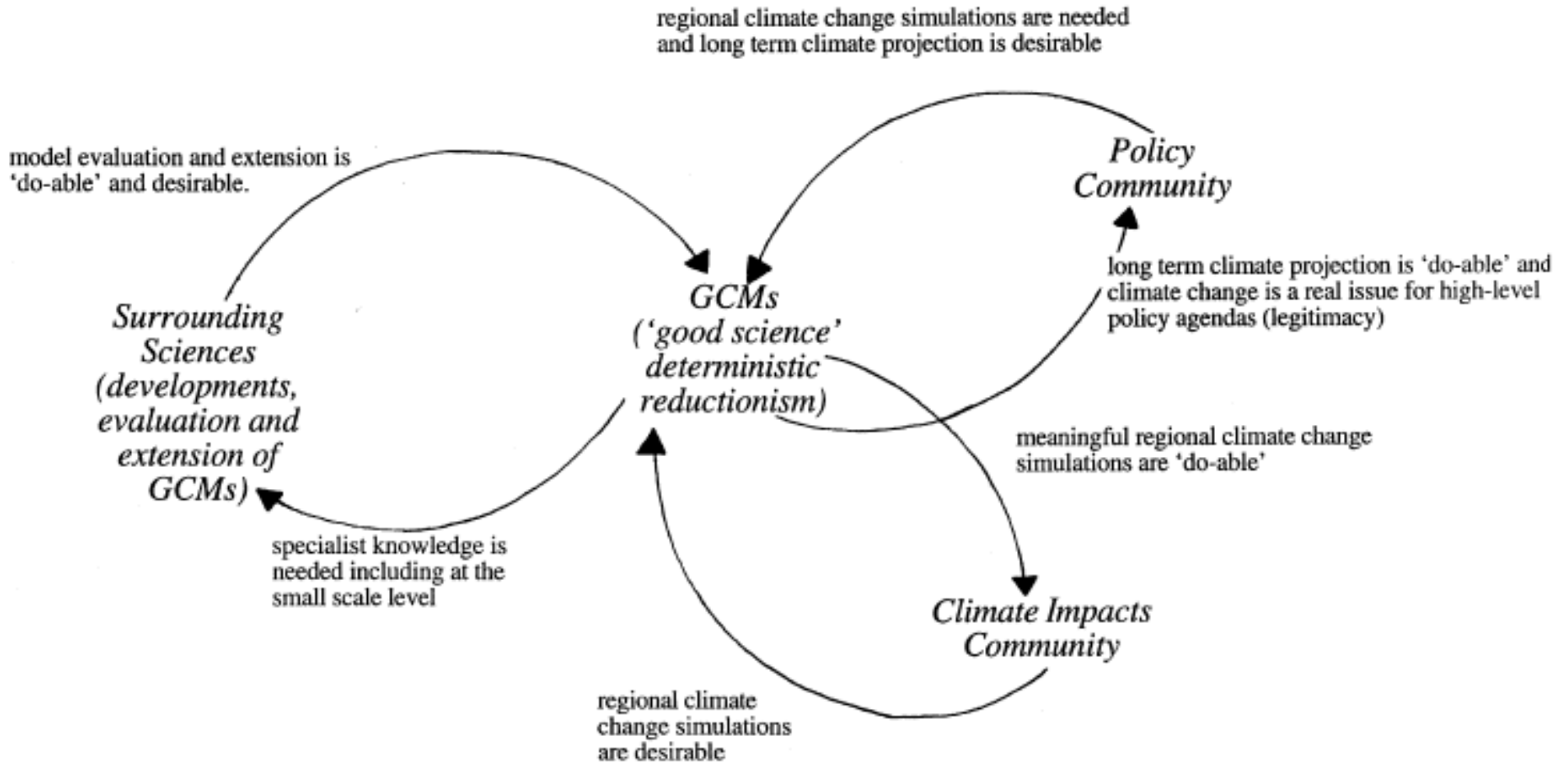


A 21st century perspective on climate models from a climate scientist

Judith Curry
Georgia Tech



Are GCMs the best tools?



“development of global climate change science *and global environmental ‘management’* frameworks occurs concurrently and in a mutually supportive fashion”

Current path for climate modeling

- Increasing resolution and adding complexity
- Fully interactive earth system models (chemical, biogeochemical, land cryosphere); interface with human systems models
- Seamless prediction across timescales; data assimilation and initialization - PREDICTION
- Downscaling for regional applications

NRC: A National Strategy for Advancing Climate Modeling

Climate models are targeted at:

- Furthering scientific understanding of the climate system
- Needs of policy makers
- Needs of impact assessments communities

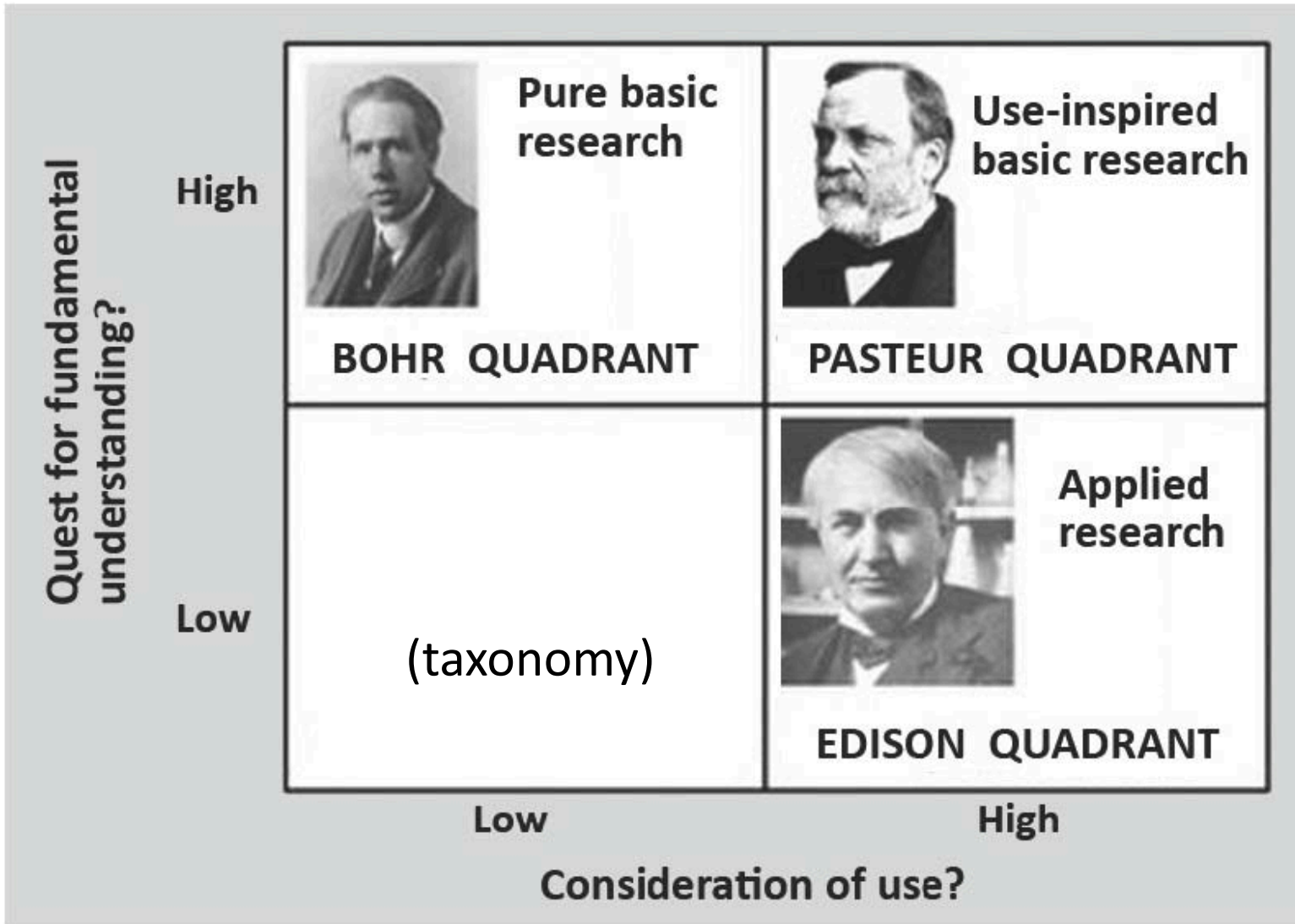
Are GCM climate models adequate for these needs?

Are plans for GCM development likely to improve adequacy?

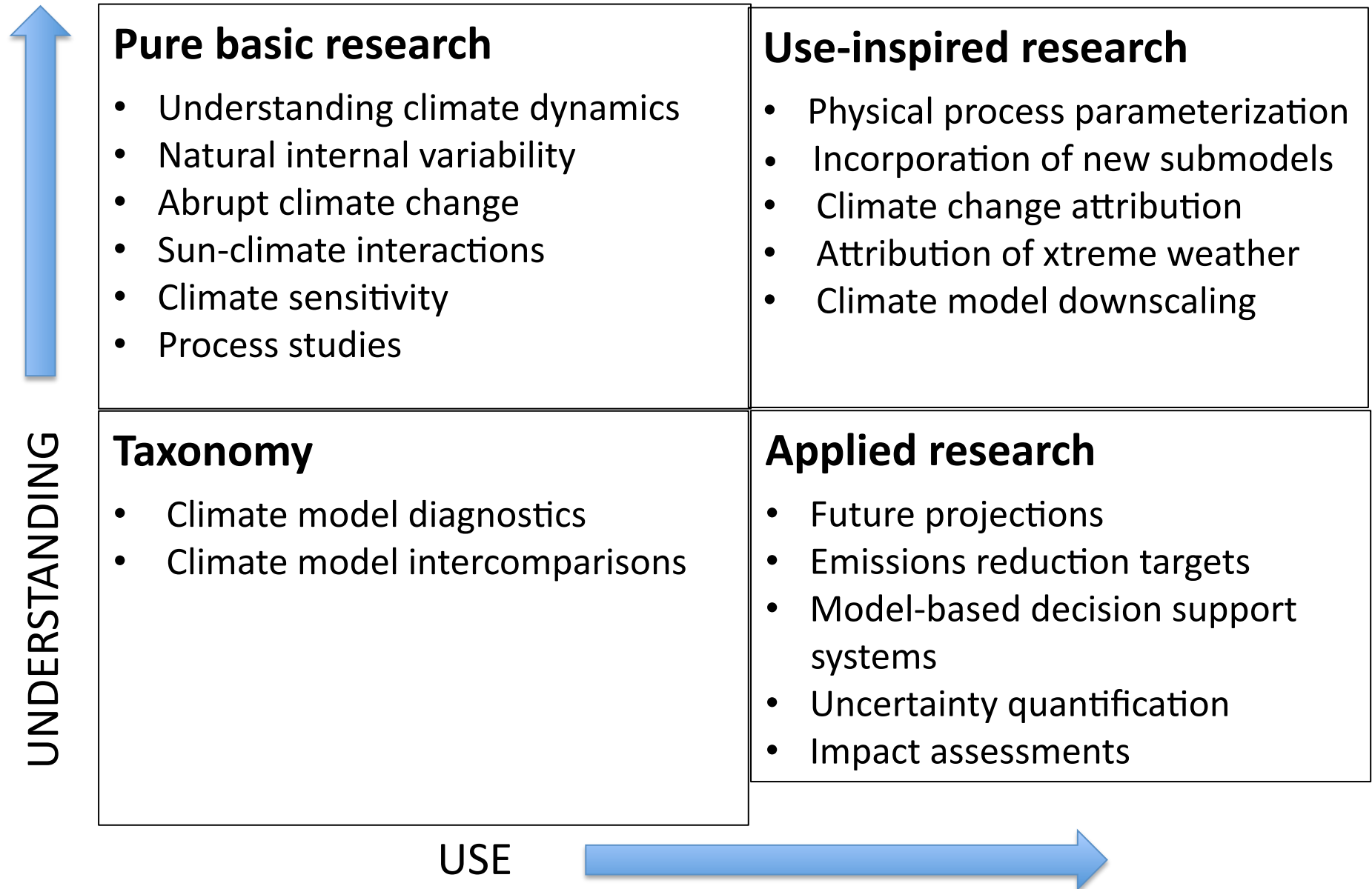
Are GCM climate models the best tools to address these needs?

If the answers are 'NO', could the power, authority and resources accumulating around GCMs be detrimental to both scientific progress and policy applications?

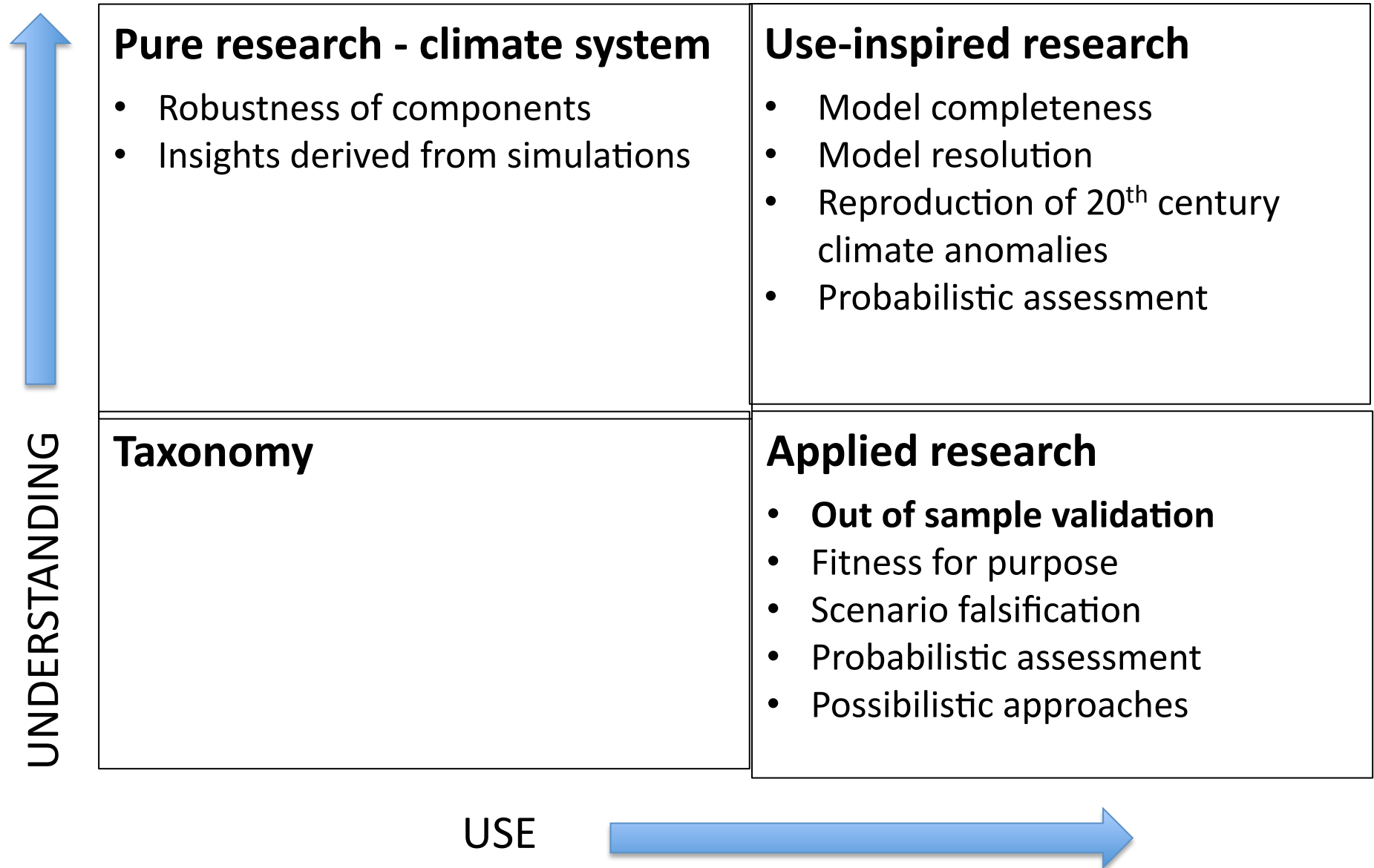
Pasteur's Quadrant



Uses of GCM Climate Models



Confirming Climate Models



Out-of-sample validation

IPCC Prediction:

Global mean Ts change for 2016 to 2035 likely 0.4C to 1.0C.

What IF:

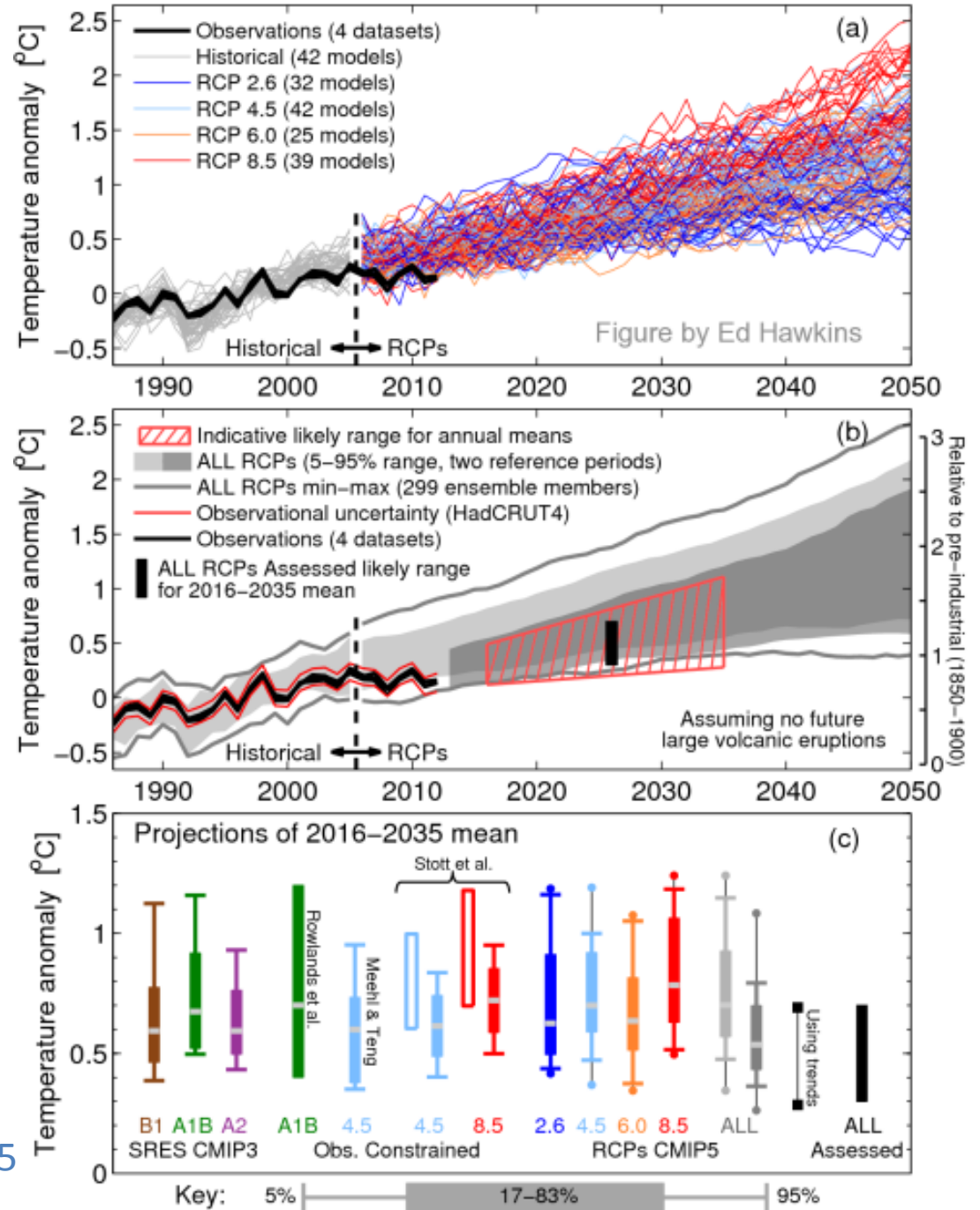
Global mean Ts remains the same or cools through 2035

Implications:

If model-obs discrepancy is assoc with multi-decadal natural internal variability, then potentially serious model structural problems

IPCC AR5 WG1, Fig 11.25

Global mean temperature near-term projections relative to 1986–2005



Implications of growing discrepancy between GCM simulations and observations

- A period of disconcerting negative learning

	$p_1(x^*) < p_0(x^*)$ ~ increasing bias	$p_1(x^*) > p_0(x^*)$ ~ decreasing bias
$\sigma_1 < \sigma_0$ = decreasing uncertainty	Reassuring Negative Learning	Reassuring Progressive Learning
$\sigma_1 > \sigma_0$ = increasing uncertainty	Disconcerting Negative Learning	Disconcerting Progressive Learning

Increased focus on: solar variability and indirect effects; natural internal variability; vertical transfer of heat in the ocean and ocean heat storage, etc

Are GCMs the best tool?

- **Explore scientific understanding of the climate system**

GCM disadvantages:

- Computationally expensive; many problems don't require high resolution, complex physical parameterizations
- Resources spent primarily on climate model development and IPCC production runs; little time and \$\$ left over for understanding
- Diminishing returns on understanding from GCMs

Other approaches:

- Lower order models, larger ensemble size, parametric sensitivities
- Plurality in climate model structural form
- Semi-empirical methods
- Theoretical advances are needed

Are GCMs the best tool?

- **Developing scenarios of plausible future states**

Challenges:

- current GCMs inadequate for simulating of natural internal variability on multidecadal to century time scales
- GCMs incapable of predicting counterintuitive, unexpected surprises
- computational expense precludes adequate ensemble size

Other approaches:

- GCMs may be less effective than a plurality of lower order models
- Semi-empirical approaches
- Creative generation of scenarios, scenario falsification (Betz)

Are GCMs the best tool?

- **Projections of future regional climate variation**

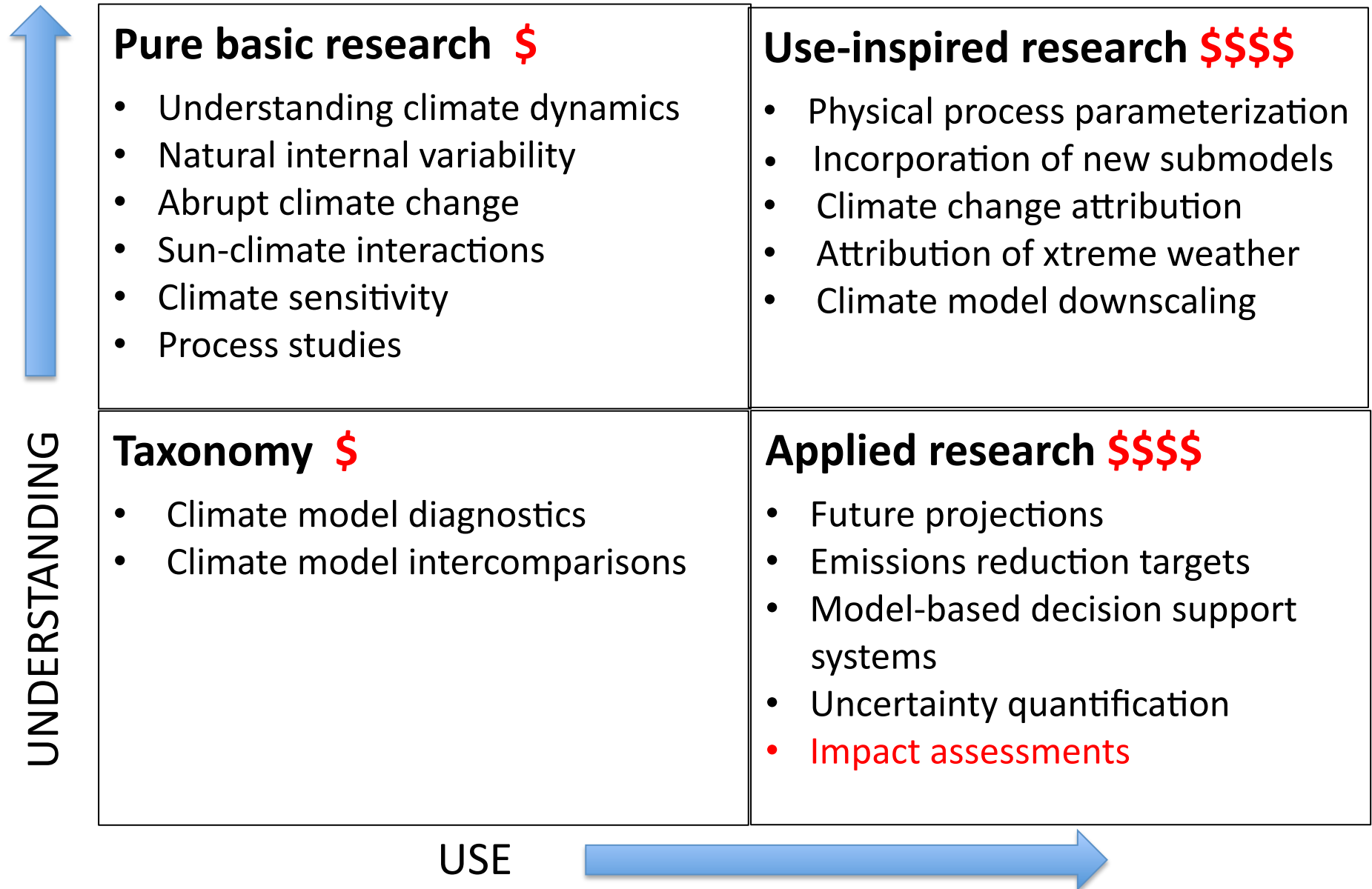
GCM challenges:

- GCMs currently have little skill in simulating regional climate variations; unclear how much increased resolution will help
- Dynamical & statistical downscaling adds little value, beyond MOS to account for local effects on surface variables

Other approaches:

- Improve understanding of historical/paleo regional climate dynamics and extreme weather/climate events
- Creative, regional approach to scenario development, including empirical and semi-empirical methods

Funding the climate model enterprise



Are GCM climate models the best tool?

A completely general, all encompassing climate model that is accepted by all scientists and is fit for all purposes as an idealistic fantasy

We need a plurality of climate models that are developed and utilized in different ways for different purposes.

For applied research and decision support, the GCM centric approach may not be the best approach

For growing scientific understanding, new model structural forms are needed

Given the compromises made for multiple purposes, GCMs are arguably not the optimal solution for any of these purposes