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# Model Guidance for Adaptation Planning: Is CMIP the way forward?

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Actionable Science and CESM, Boulder, CO

# What is this talk about?

- CMIP, the Coupled Model Intercomparison Project, has been and is one of the most important parts of the climate science community. It has promoted controlled experimentation and supported a culture of extraordinary evaluation. CMIP is at the foundation of us having historically unique knowledge of our future, which gives humanity the opportunity to affect our future in ways to establish positive outcomes.
- I will make a case that CMIP simulations are not the right type of simulations for adaptation planning.

# Framing and Definitions 1

- Scientists often maintain that the research and products, the knowledge, that they generate are “useful.”
  - This is often used when seeking funding.
  - But are they usable and, in fact, used? (“Knowledge providers”)

- Usable is defined by those who need and, actually, use the knowledge. (“Knowledge users”)

Our research and practice focus on usability and the development of knowledge systems to accelerate the incorporation of climate knowledge into, especially, adaptation planning and management.

# Framing and Definitions 2a:

## Legitimacy, Credibility, & Salience (Cash et al., 2003)

- Credibility is an attribute of scientific adequacy.
- Legitimacy is an attribute of objectivity, fairness, and a lack of political bias.
- Salience requires that information be relevant to the problem to be addressed.

# Framing and Definitions 2b:

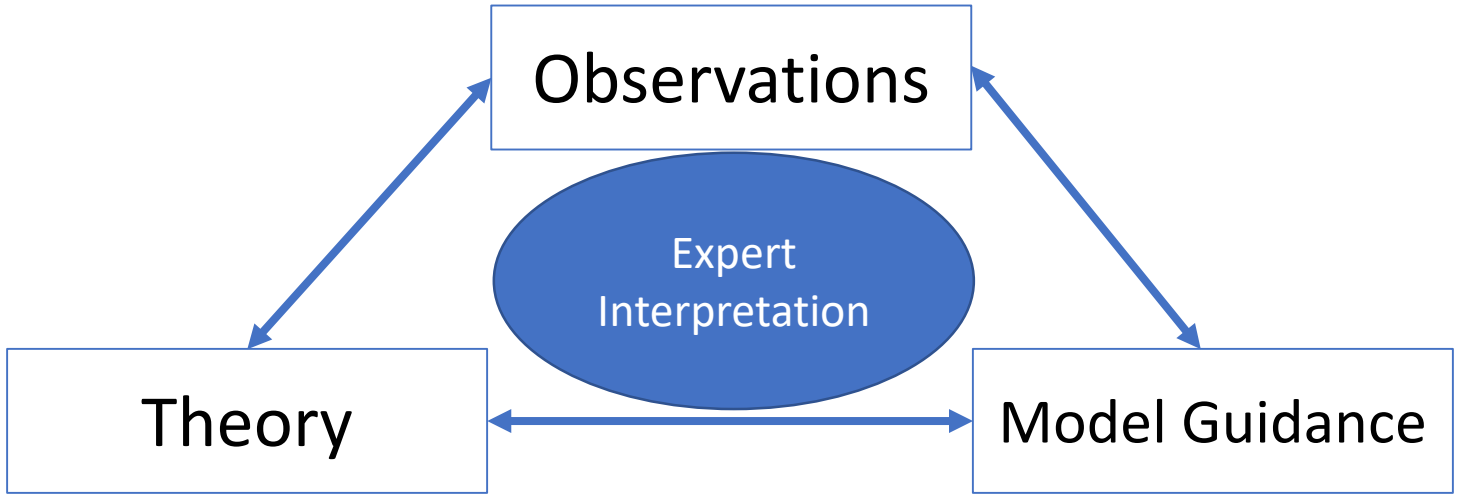
## Plausible, Ethical, and Trustworthiness

- Plausible scenarios of the future are physically consistent or realizable.
  - We seek a set of plausible futures, rather than focusing on a probable future.

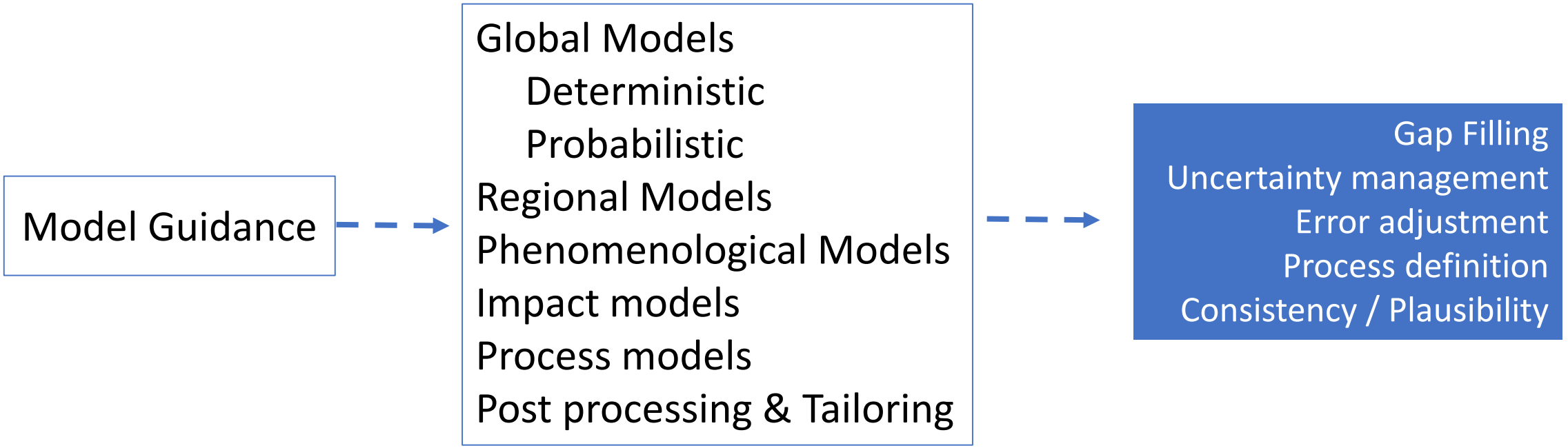
- Ethical considerations include:
  - Recognition and consideration of issues of equity and social justice
  - Scientists strive to neither understate or overstate our confidence (uncertainty).

# How are models used in defining future scenarios? Consider the paradigm of weather forecasting

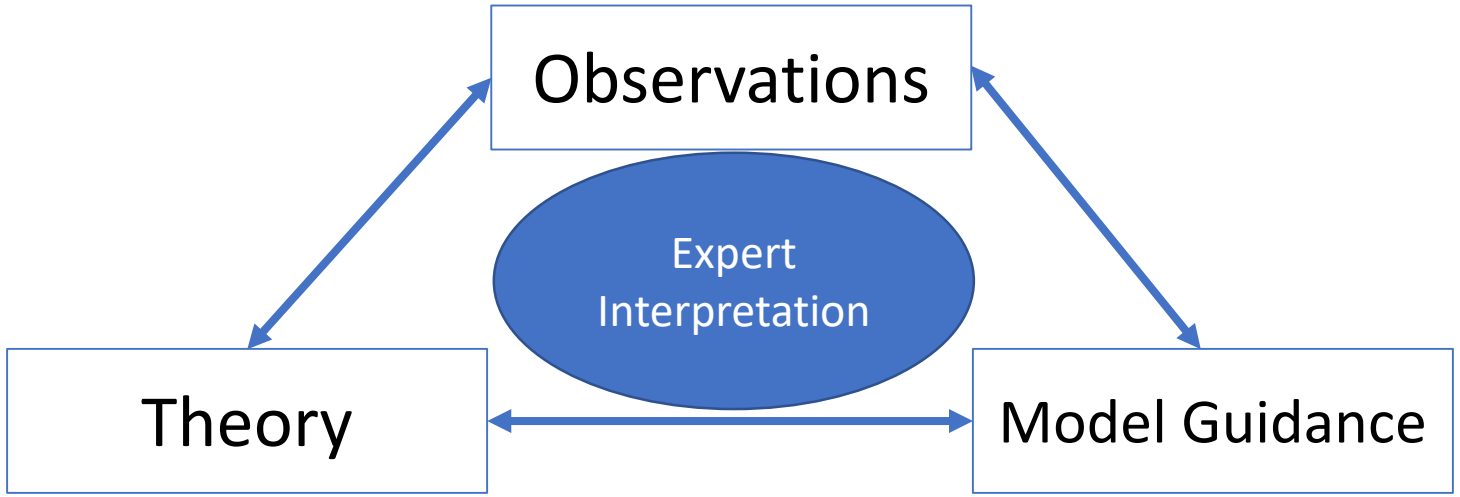
Models provide guidance. They do not provide “predictions” or “projections.”



# A portfolio of models



# Models as guidance in a knowledge system



# Laurentian Great Lakes

Photo credit: http://www.noaa.gov/resource-collections/great-lakes-eco-region

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# The Importance of Weather in Adaptation Planning

What Has Happened?

What Will Happen?

VULNERABILITY

# Framing and Definitions 2a:

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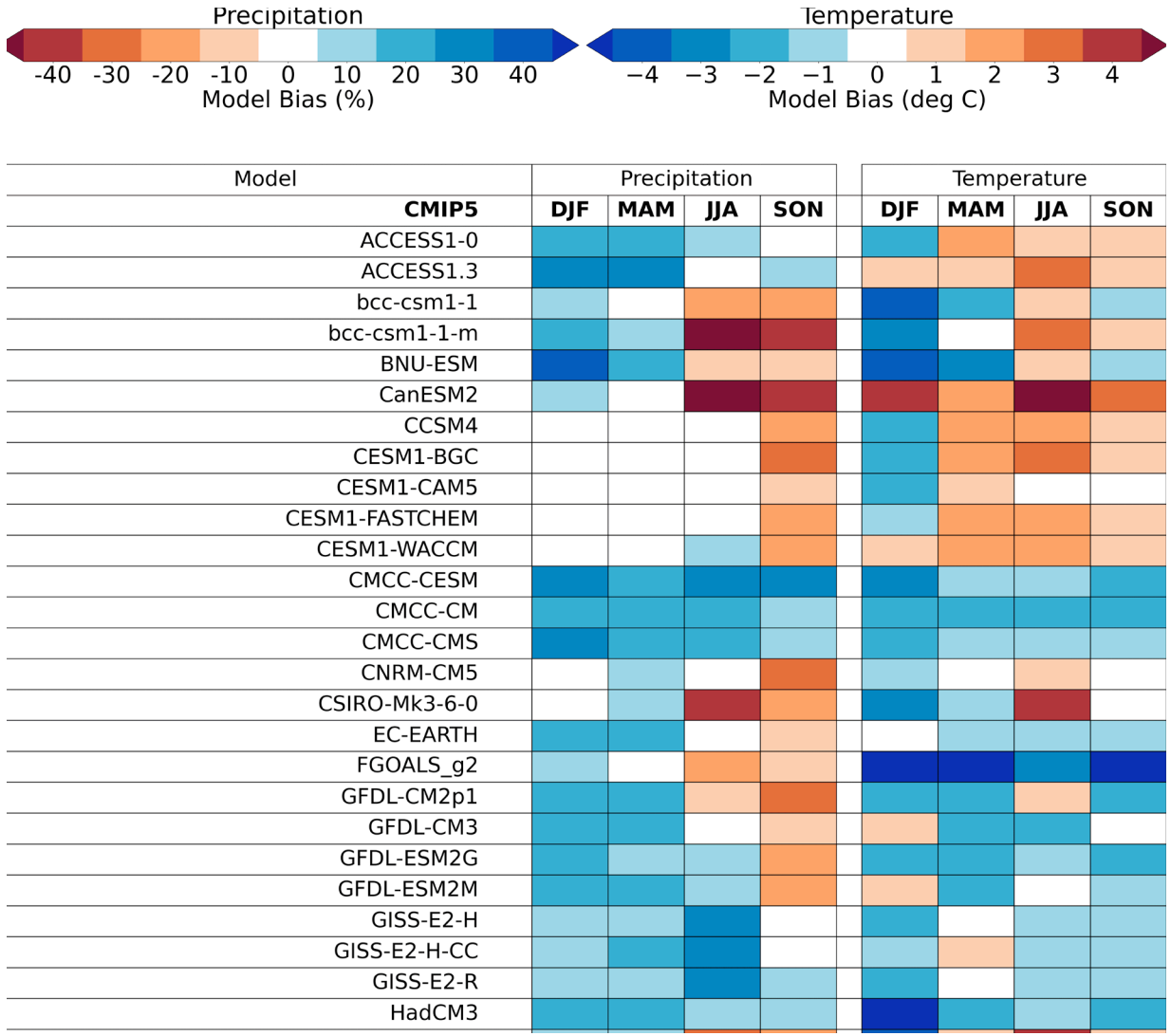
# Bias in climate models for Great Lakes Basin (by season)

65 Total Models Evaluated
- CMIP 5
- NA-CORDEX
- U Wisconsin CM4

Temperature from
-5 ° C to 5 ° C

Precipitation from
-50% to 50%




| Model | Precipitation | | | | Temperature | | | |
|---|---|---|---|---|---|---|---|---|
| **CMIP5** | **DJF** | **MAM** | **JJA** | **SON** | **DJF** | **MAM** | **JJA** | **SON** |
| ACCESS1-0 | | | | | | | | |
| ACCESS1.3 | | | | | | | | |
| bcc-csm1-1 | | | | | | | | |
| bcc-csm1-1-m | | | | | | | | |
| BNU-ESM | | | | | | | | |
| CanESM2 | | | | | | | | |
| CCSM4 | | | | | | | | |
| CESM1-BGC | | | | | | | | |
| CESM1-CAM5 | | | | | | | | |
| CESM1-FASTCHEM | | | | | | | | |
| CESM1-WACCM | | | | | | | | |
| CMCC-CESM | | | | | | | | |
| CMCC-CM | | | | | | | | |
| CMCC-CMS | | | | | | | | |
| CNRM-CM5 | | | | | | | | |
| CSIRO-Mk3-6-0 | | | | | | | | |
| EC-EARTH | | | | | | | | |
| FGOALS_g2 | | | | | | | | |
| GFDL-CM2p1 | | | | | | | | |
| GFDL-CM3 | | | | | | | | |
| GFDL-ESM2G | | | | | | | | |
| GFDL-ESM2M | | | | | | | | |
| GISS-E2-H | | | | | | | | |
| GISS-E2-H-CC | | | | | | | | |
| GISS-E2-R | | | | | | | | |
| HadCM3 | | | | | | | | |

https://glisa.umich.edu/summary-of-model-biases/

# Bias in climate models for Great Lakes Basin

(Worst season in each model)

T with 2.5°C & P with 25% bias

Seasonal Temperature bias [deg C]

| Seasonal Precipitation bias [%] | 0.5°C | 1.0°C | 1.5°C | 2.0°C | 2.5°C | 3.0°C | 3.5°C | 4.0°C | 4.5°C | 5.0°C |
|---|---|---|---|---|---|---|---|---|---|---|
| 5% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10% | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| 15% | 0 | 0 | 0 | 1 | 3 | 3 | 5 | 5 | 5 | 5 |
| 20% | 0 | 0 | 0 | 1 | 6 | 6 | 9 | 10 | 10 | 10 |
| 25% | 0 | 0 | 1 | 3 | 17 | 18 | 22 | 24 | 24 | 25 |
| 30% | 0 | 1 | 3 | 8 | 23 | 27 | 32 | 34 | 36 | 39 |
| 35% | 0 | 3 | 5 | 13 | 30 | 35 | 43 | 45 | 47 | 50 |
| 40% | 0 | 4 | 7 | 18 | 35 | 40 | 48 | 51 | 53 | 56 |
| 45% | 0 | 4 | 7 | 18 | 35 | 40 | 48 | 51 | 54 | 58 |
| 50% | 0 | 4 | 7 | 18 | 35 | 40 | 48 | 51 | 54 | 58 |
| 55% | 0 | 4 | 7 | 18 | 35 | 40 | 48 | 51 | 54 | 58 |
| 60% | 0 | 4 | 7 | 18 | 35 | 40 | 48 | 51 | 54 | 58 |
| 65% | 0 | 4 | 7 | 18 | 35 | 40 | 48 | 51 | 54 | 58 |
| 70% | 0 | 4 | 7 | 18 | 35 | 40 | 48 | 51 | 54 | 58 |
| 75% | 0 | 4 | 7 | 18 | 35 | 40 | 48 | 51 | 54 | 58 |
| 80% | 0 | 4 | 7 | 18 | 35 | 40 | 48 | 51 | 54 | 59 |
| 85% | 0 | 4 | 7 | 18 | 35 | 40 | 48 | 51 | 54 | 59 |
| 90% | 0 | 4 | 7 | 18 | 35 | 40 | 49 | 52 | 55 | 60 |
| 95% | 0 | 4 | 7 | 18 | 35 | 40 | 49 | 52 | 55 | 60 |
| 100% | 0 | 4 | 7 | 18 | 35 | 40 | 49 | 52 | 55 | 60 |

Of 65 Total Models Evaluated
5 did not meet these criteria of
5 ° C and 100 5 bias

Bias in the components of the net basin supply, the Lake's water budget, frequently exceed 100%

https://glisa.umich.edu/summary-of-model-biases/

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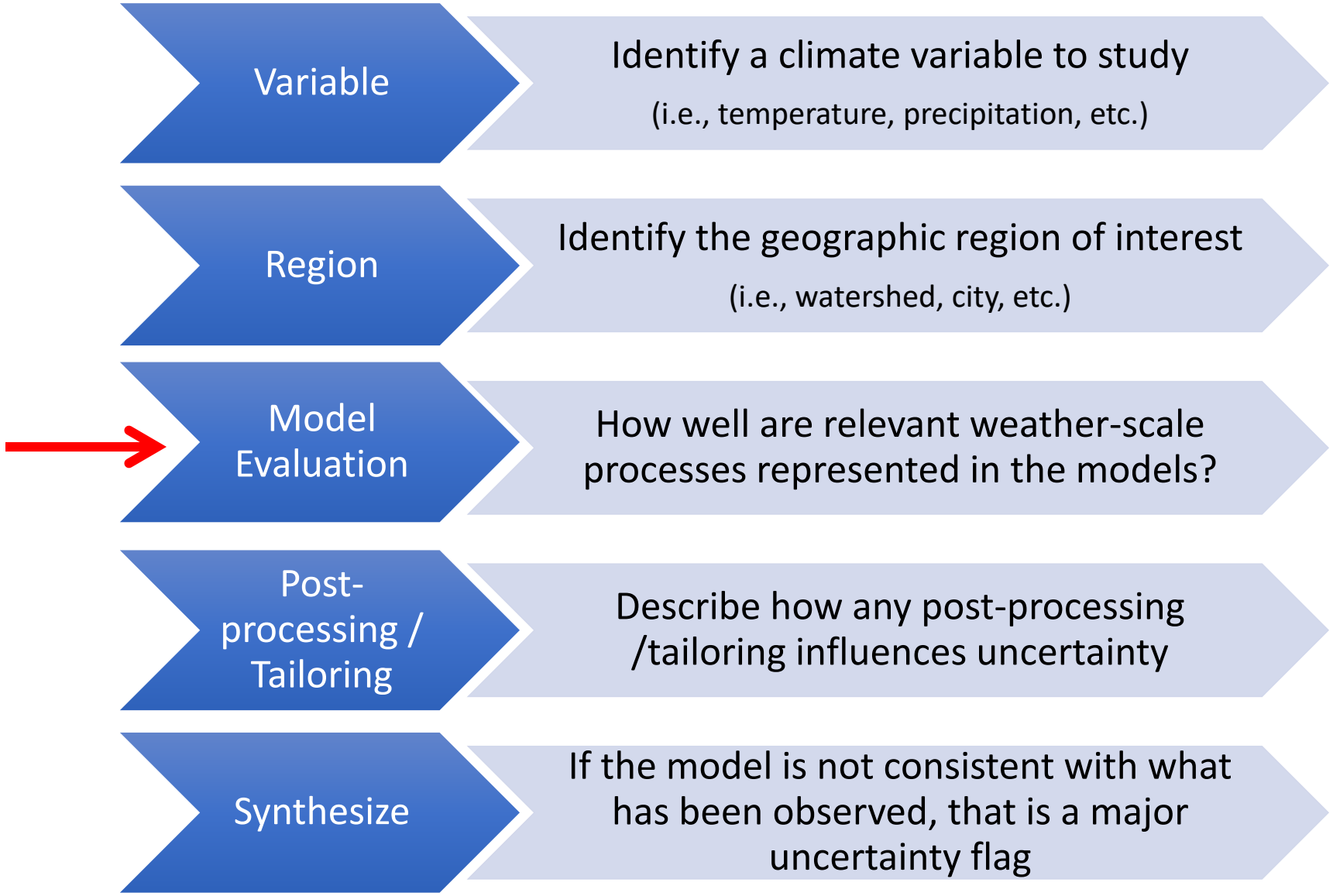
# Applying Climate Projections: Weather

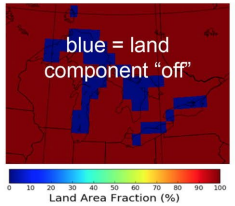


# Applying Climate Projections: Structure (Lake-Finding Decision Tree)

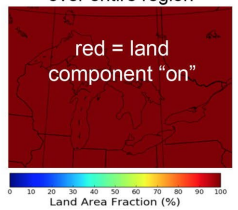
**Step 1. Is the land component turned "on" over the lakes?**

The land component is "on" over grid cells where the land area fraction (variable name sftlf) is >0%.

**NO**
land component is "off" over the lakes




**YES**
land component is "on" over entire region




**Step 2a. Is the ocean component turned "on" over the lakes and does it spatially fill the gaps where the land component is "off"?**

A map of sea surface temperature or sea ice (shown in blue below) can be used to identify where the ocean component is "on."

**YES**
ocean component is "on" and spatially fills land area gaps

Lakes are treated as dynamic and interactive[1] oceans

**NO**
ocean component is "on" but does not spatially fill land area gaps

**NO**
ocean and land components are "off" over the lakes

These models lack evidence for a consistent treatment of the lakes between the land and ocean components. Important lake-land-atmosphere feedbacks are likely compromised.

[1]Lakes that are dynamic (meaning fluxes are modelled in horizontal and vertical space) and interactive (meaning fluxes are coupled to other components, like the atmosphere) offer the greatest potential to represent important lake-land-atmosphere interactions.

**Step 2b. Is there documentation for the land component that describes the treatment of lakes?**

**YES**

**Step 3a. Are the lake grid cells classified as lakes in the land surface classification scheme?**

Search for the map or database that describes the type of surface (e.g., vegetated, lake, urban, etc) assigned within each grid cell.

**YES**

*Option 1*: A lake model is included and/or interactive lake dynamics (i.e., lake-atmosphere coupling) are described.

Lakes are interactive[1] but details of dynamics vary by model

*Option 2*: Lakes only have a surface classification (e.g., "lake" or "water") and are not dynamic.

Lakes are highly simplified in the GCM, and lake-land-atmosphere feedbacks may be poorly represented.

**NO**

Lakes are not represented

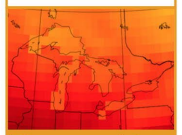
**NO**

**Step 3b. Do model simulations show an environmental effect of lakes?**

The user should select one or more variables (e.g., surface temperature) that would show a signature of lakes if they exist in the model.

**YES**

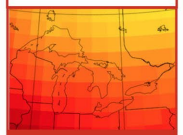
There is a clear distinction in surface temperatures over the Great Lakes



There are lakes in the GCM, but they may or may not be dynamic and interactive[1]

**NO**

There is no distinction of surface temperatures over the Great Lakes



There is no evidence for lakes in the GCM

# Synthesis and Conclusion 1

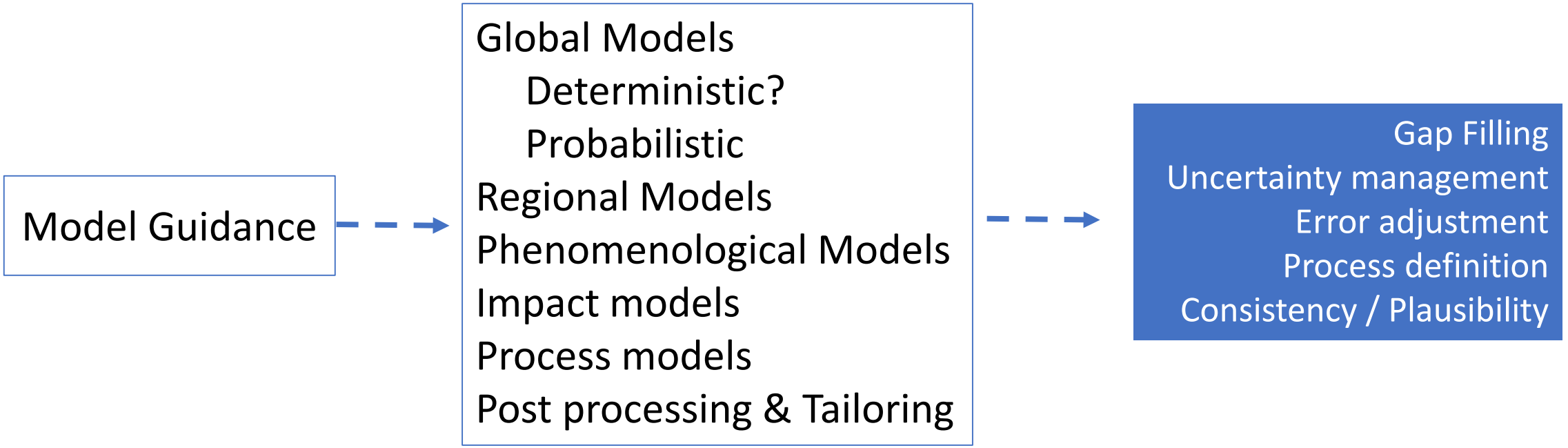
- The science-based use of models requires that models are built for purpose; that is, an application.
  - This allows decisions to be made in the development process to address that purpose.
  - This supports model evaluation (validation) by metrics that inform how well the model addresses its purpose.
  - For example, models used in weather forecasting have quite narrow purposes to provide specific contributions to the total guidance.
- CMIP models are built for ”understanding.”
  - This is a broad purpose, and it is open-ended when understanding is reached.

# Synthesis and Conclusion 2

- My opinion is that this capacity is not met by increasing resolution, complexity, and comprehensiveness.
- Such adaptation models are not the CMIP models, and I do not feel they are rationally incorporated into the CMIP paradigm and culture.

# Synthesis and Conclusion 3

- We need modeling capacity, a portfolio of models, focused on adaptation (and, similarly, geo-engineering).
- A possible design concept for this is parallel to that for weather forecasting.



# Takeaways

- We need models that are designed for adaptation applications.
- We need models that are documented for adaptation applications.
- Effective design requires knowing how model guidance enters into problem solving and how that knowledge is used in planning and management.
- Such an effort might be framed as addressing environmental, economic, personal, and national security.

# Links to Papers & References

- 2017_Briley_Rood_Meteorological_Process_Uncertainty_TheorApplClimatol_2017 (Weather features)
- 2021_Briley_Rood_Large_Lakes_Climate_Models_JGreatLakesRes_2021 (Lake Finding)
- 2020_Briley_Rood_Climate_Model_Consumer_Reports_BAMS_2020 (Consumer Reports)
- Cash_Knowledge_Systems_Sustainability_PNAS_2003 (Knowledge Systems)
- 2014_Lemos_Rood_Crossing_Boundaries_WeaClimSoc_2014 (Boundary Chains)
- Coupled Model Intercomparison Project (CMIP)

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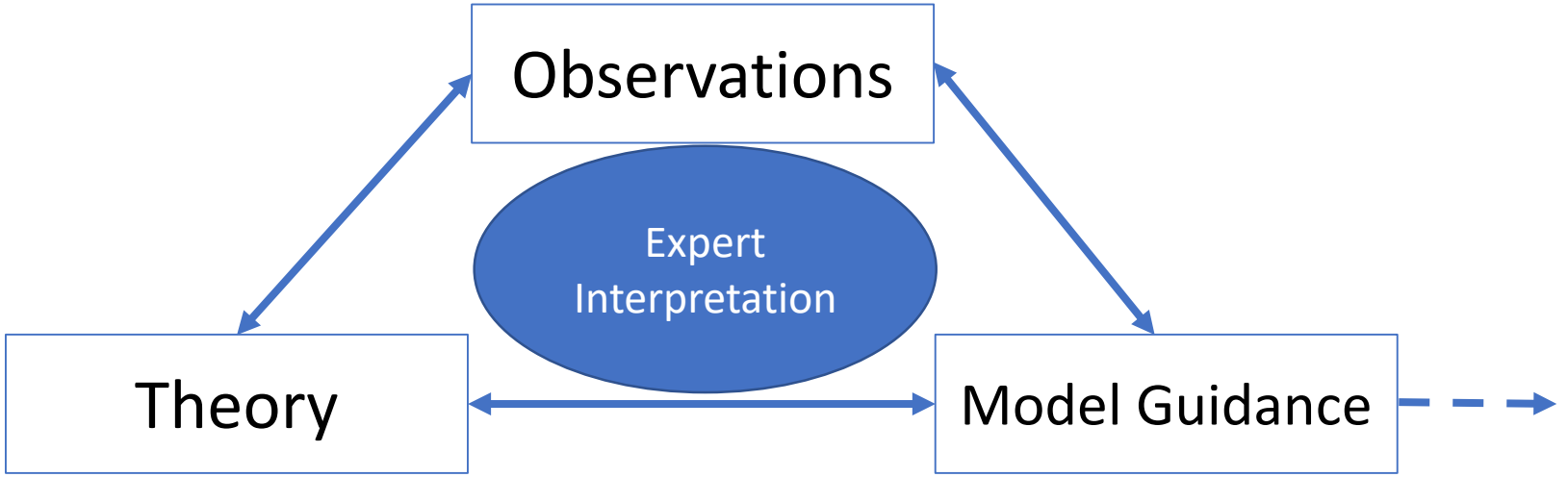


- Global Models
  - Deterministic
  - Probabilistic
- Regional Models
- Phenomenological Models
- Impact models
- Process models
- Post processing & Tailoring