Future of Climate Modeling Workshop: Summary

Future of Climate Modeling: An online WCRP workshop
WCRP's Core Project **Earth System Modelling and Observations (ESMO)**
March 21-24, 2022

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On behalf of JSC Chairs and Workshop participants

44rd Session of the WCRP Joint Scientific Committee May 8-11, 2023

Need of The Hour

1. **Detailed, improved, and actionable climate change information** for the society and decision-makers to help
   a. Transition to **net-zero emissions**
   b. Make informed **adaptation, mitigation and CO_2 removal decisions** now and adequately insure against climate related losses
2. **Advancements in climate science**, including improved process understanding and enhanced model developments to help achieve #1

WCRP Workshop on Future of Climate Modeling

GOAL

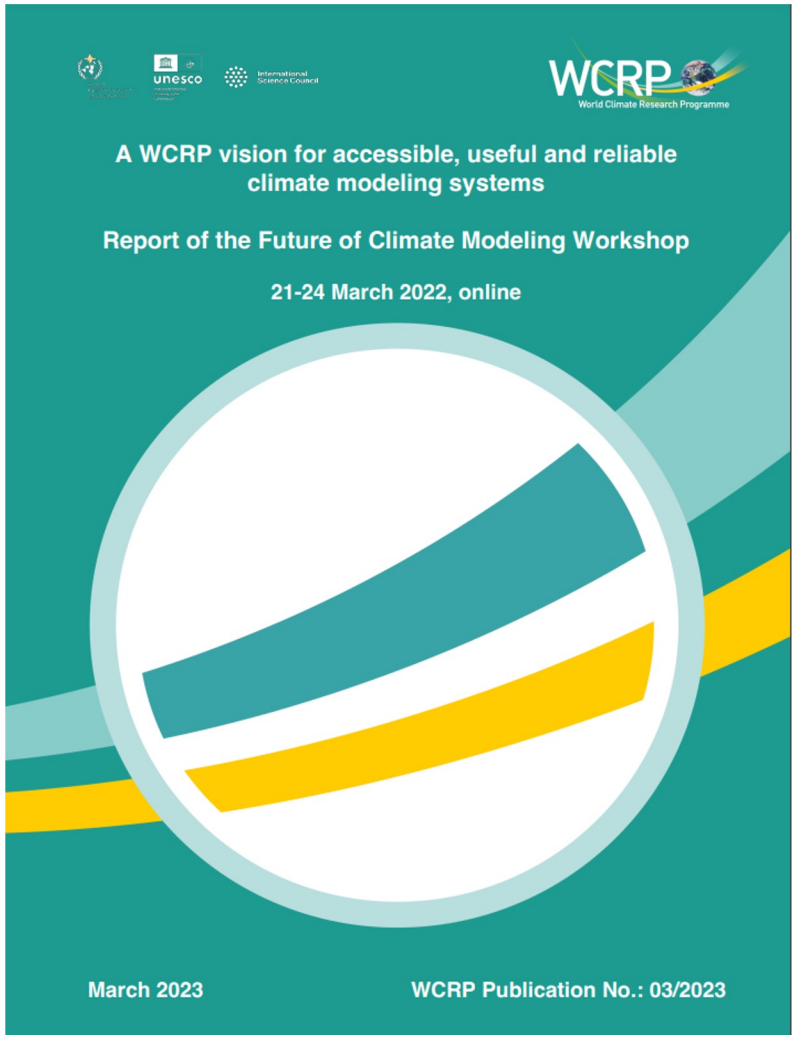
- Identify as a community the key **contemporary challenges for climate modelling**
- Create a **roadmap for reliable, accessible and useful climate model systems** that will allow climate science community to rise to major new challenges for climate research by exploring opportunities for climate modelling that exist now and into the coming decades

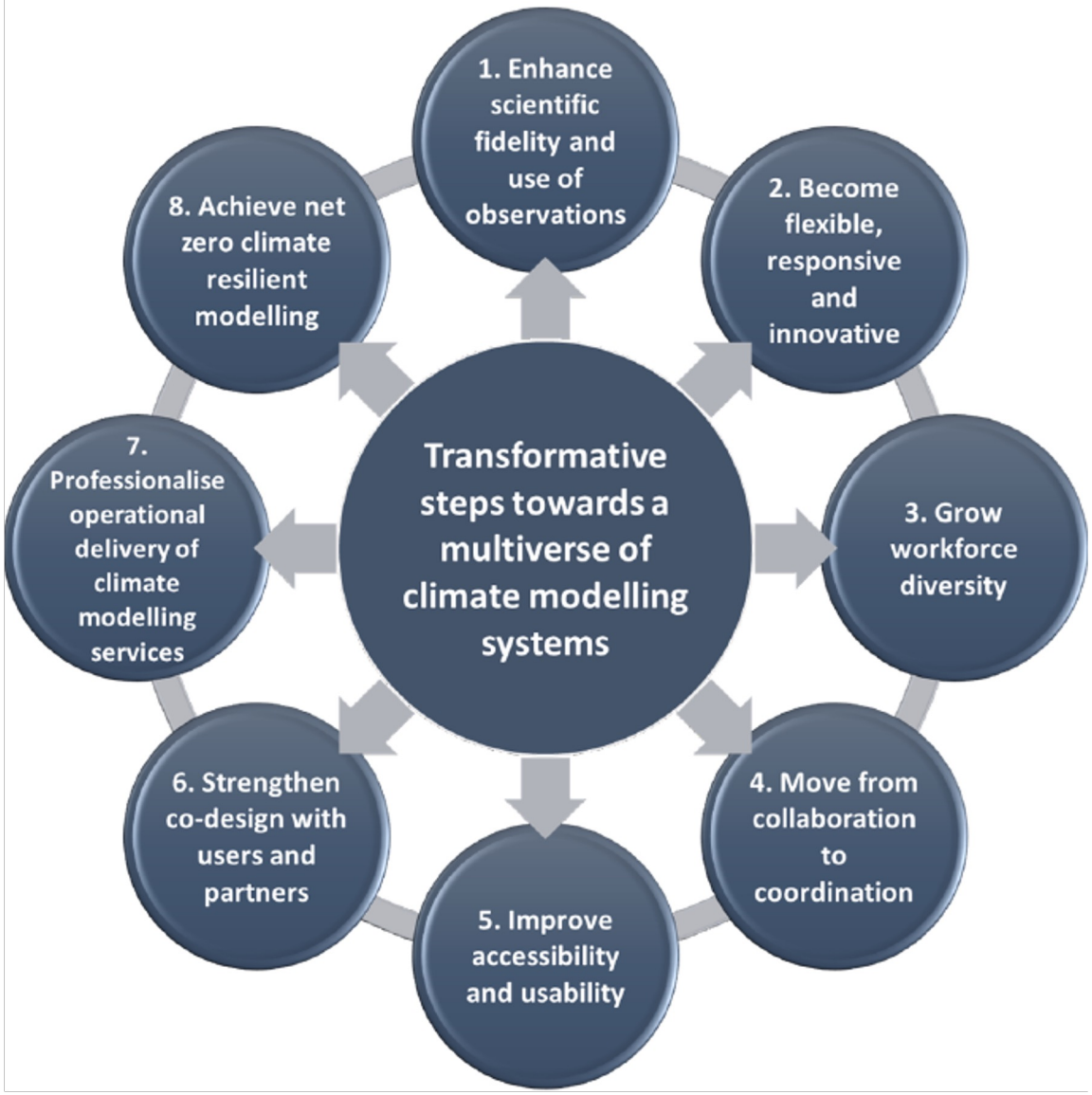
Participation

- Sessions consisted of invited presentations by a **diverse group of speakers** with different science and applications backgrounds, career stages and geographic regions, representing **state-of-the-art modelling efforts** from within and outside WCRP to provide a broad perspective and innovative views

- **Specific questions discussed during the workshop:**
  - What are the main priorities for climate model improvements and developments?
  - What are the main model requirements to cope with societal needs for climate information?
  - Which technical developments are required to cope with future hardware generations?
  - How does WCRP needs to adjust its modelling approaches to meet scientific and societal challenges?

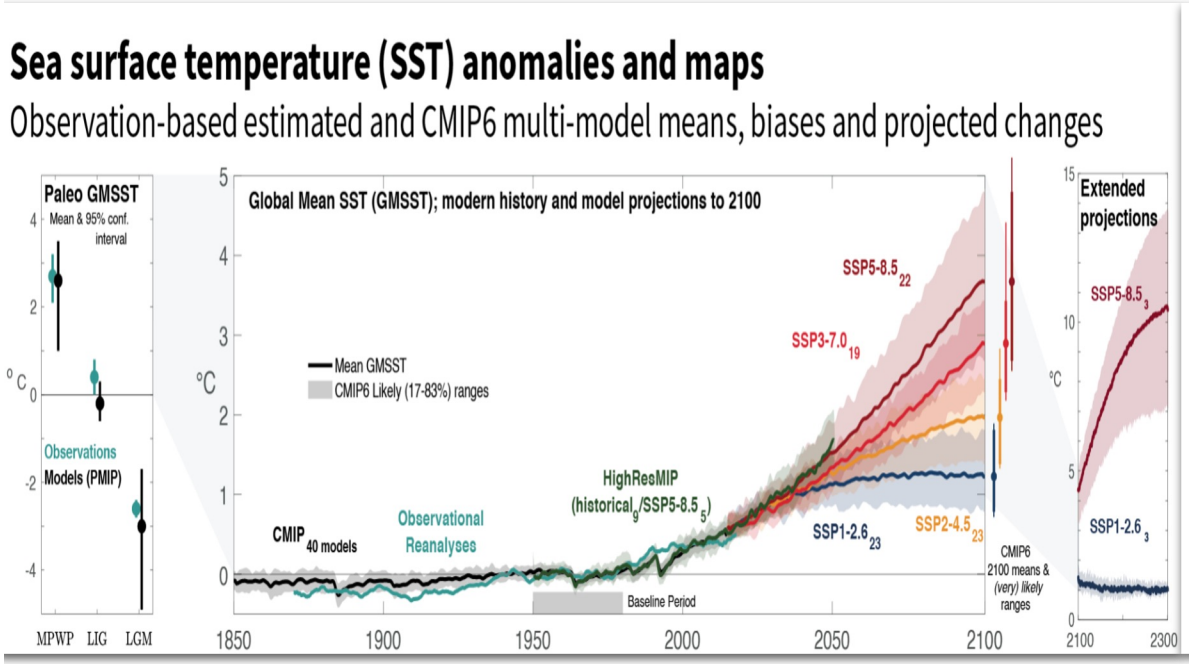
A ***multiverse* of climate models** (with associated infrastructure and a skilled workforce) that are **fit for purpose** to advance the **societally relevant and actionable science** needed for a sustainable present and future





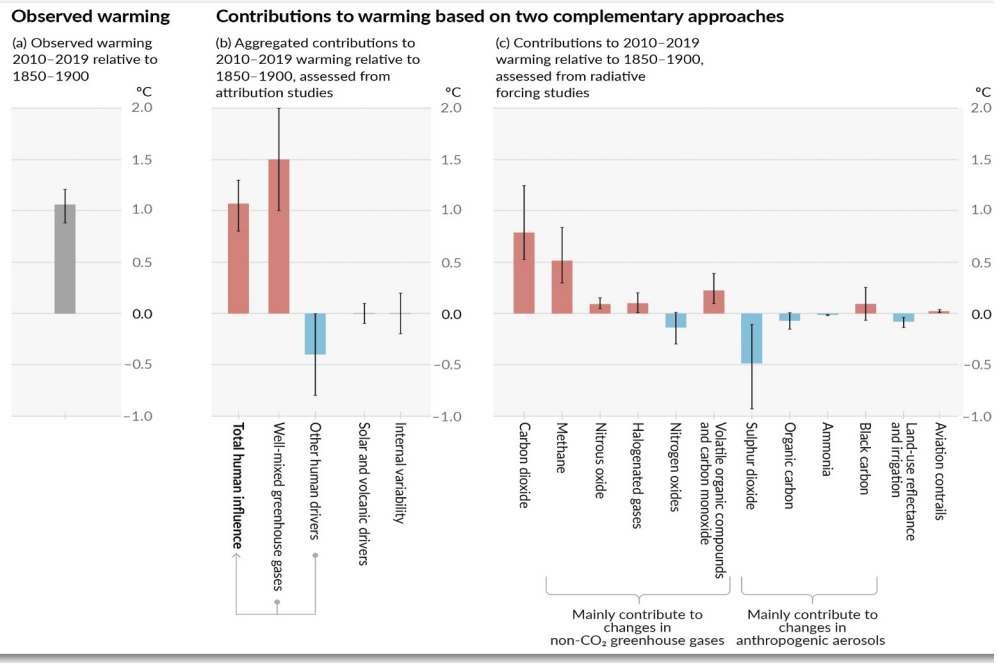
Examples of actionable climate science relying on a range of models

Historical and future evolution of sea surface temperature



AR6 WGI Fig 9.3; Reanalysis, CMIP6, HighResMIP, PMIP, Emulators

Drivers of Observed Warming



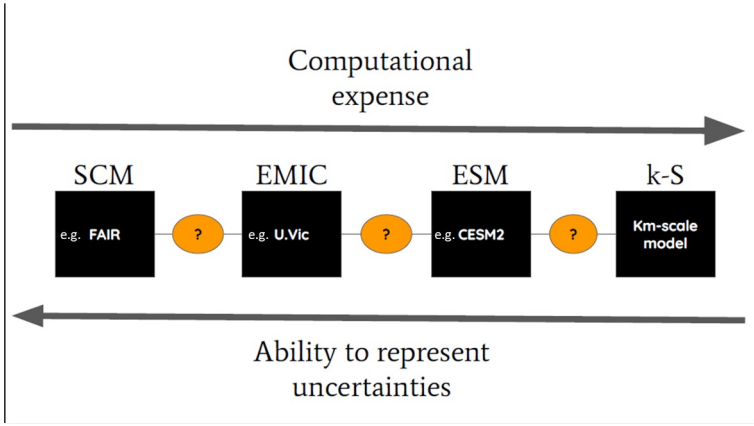
AR6 WGI Fig SPM2; Observations, CMIP6, DAMIP, AerChemMIP, Emulators

Recommendations for WCRP for a step change in climate modeling based on a whole-community approach

1. Assess **fitness-for-purpose of models** based on the requirements that the model should be scientifically useful, reliable, and feasible.
2. Play a coordinating role to **broaden** the global climate modeling effort and **enhance the diversity** of approaches for **climate modeling.**
3. Launch and coordinate a **process understanding campaign** with obs4MIPs to design and improve climate model fidelity.
4. **Capacity build the global south** climate scientists as future leaders.
5. **Lead on interacting with funders**, public and private, to support a wider set of climate modelling approaches.
6. Coordinate **uniform and interoperable model evaluation tools and metrics** for model-obs and model-model comparisons.
7. Promote **co-design and wider stakeholder input** by linking with other programs more effectively.
8. Launch a **World Climate Operational Modeling Programme.**
9. Take the lead in developing a **climate resilient net-zero emission pathway** for the global climate modeling community.

Placeholder: shared recommendations for climate modeling

- To address the scientific and societal challenges of adaptation and mitigation towards a net-zero future WCRP needs to coordinate and support a multiverse of modelling approaches from global and regional km-scale and ESMs to emulators and ML models.
- Rapid progress is being made towards global km-scale models that deliver a step change in model capability to simulate regional change and extremes. WCRP should support and coordinate global efforts to build capability, promote process understanding and exploit technological advancement.
- WCRP should focus its communities on utilising the model hierarchy where it can give unique scientific insights or robust policy advice.

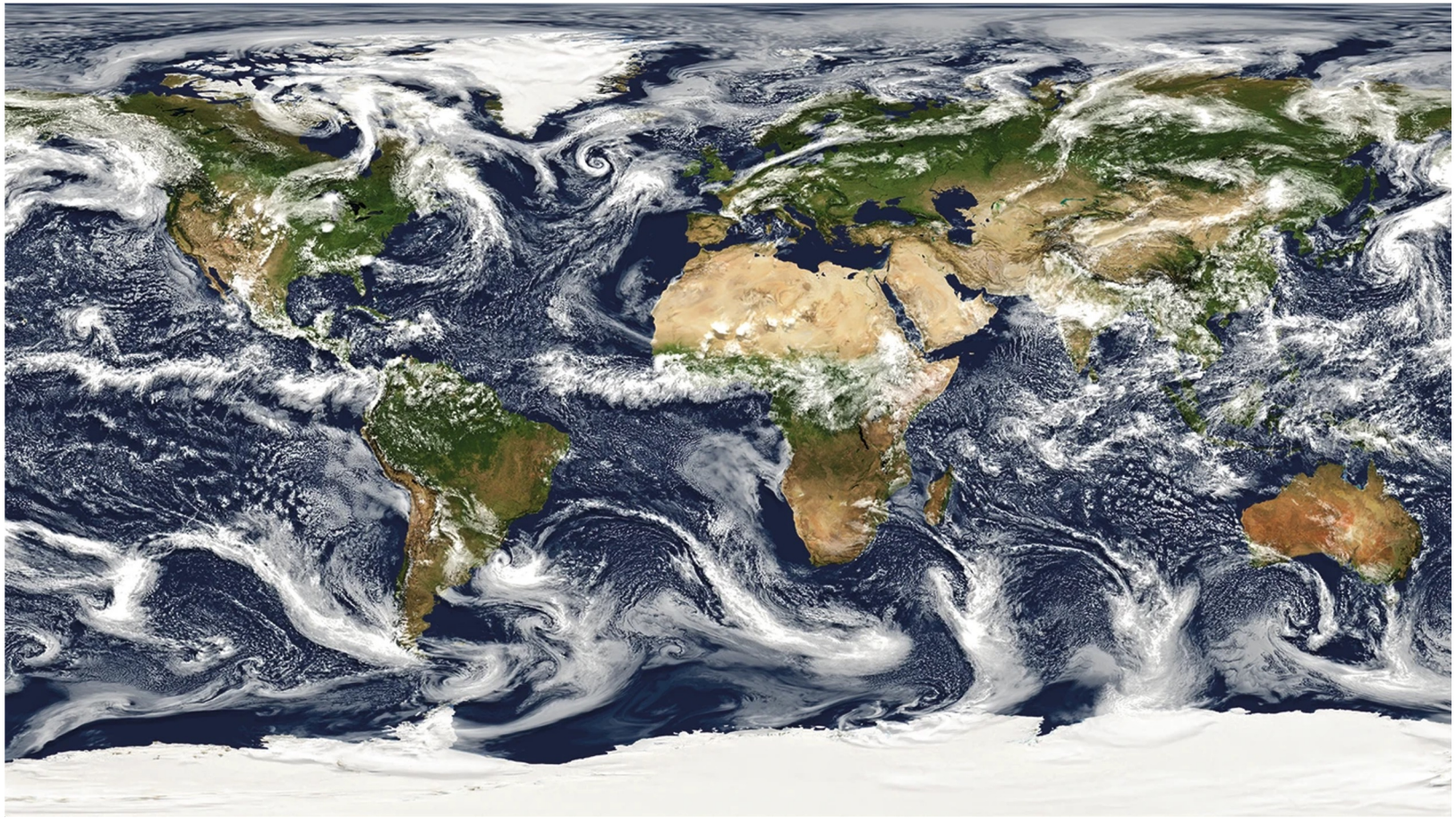


Extras

Questions for discussion and what is the ask to WCRP to focus on?

1. Where can biggest gains be made: near term predictions, hydrological cycle, machine learning, vulnerable regions, tipping points…
2. How best to connect across modelling approaches, observations and stakeholders: Digital Earths, Complex ESMs, emulators, co design with stakeholders, partnerships …
3. How many of the different model types do we need and where should they be, and who should run them?
   - Also how many digital earths, global climate models and emulators are needed? Over 50 global models and still counting!
   - Continental modelling hubs or distributed multinational single model collaborations feeding national climate service infrastructures?
4. Digital infrastructure and skills

A suggested solution: global k-scale climate model for reliable climate prediction



Slingo et al., Nature, 2022

However,…

- Investment in a bigger computer does not necessarily guarantee reliable climate prediction
  - Persistent biases in large scale circulation, climate sensitivity, aerosol-cloud interactions
  - Parameterizations still needed and error-prone
- Advances in Earth System processes and interactions using very high resolution models are challenging
  - E.g., slowly evolving processes
- Investment in a bigger computer in of itself may not help constrain projections or lead to capacity-building or a diverse workforce…

Initial draft of the WCRP report
A Roadmap for accessible, useful and realistic climate model systems

1. **Current Climate Modelling Landscape**

   Summary of sessions and breakout group compiled by session chairs and rapporteurs

2. **Our vision of where we want to be by [2030, 2050]**
3. **How do we get there?**
4. **Specific recommendations to WCRP**

Initial draft will be shared with the workshop participants to capture diversity and ensure cross-community consensus

WCRP report
A Roadmap for accessible, useful and realistic climate model systems

Design principles

- Make a clear recommendation to WCRP
- Be as transparent as possible: capture diversity and run a consultation
- Report itself should set an example and not be siloed into communities

Recommendations for a step change in climate modeling in a whole-community approach

1. **Enhance scientific fidelity and model evaluation**

use of observations, parameterisation development, Turing"/"Carslaw" tests, improved process modelling, uncertainty identification and reduction

1. **Become flexible, responsive and innovative**

Develop a multiverse of approaches; Agile suites of modelling tools; flexibility over who does what: national centres, international collaborative efforts, universities, private sector. Partnerships..

1. **Grow the diversity of workforce**

Agile and diverse workforce; meaningful partnerships with Global south that will lead to co-design and modelling capabilities, novel careers, skills…

1. **Move from collaboration to coordination**

WCRP play a coordination role to focus efforts and improve efficiencies; new partnerships to maximize science and societal benefits; better harness private sector

3. How do we get there?

5. Improve accessibility and usability

data protocols and model analysis tools working across suites of models, easy entry points, how to guides, health warnings, outreach….

6. Establish co-design

Ensuring we address societal relevant questions, timing of IPCC WGs, include human systems in modelling efforts, more coordination with Future Earth/impact modellers etc.

7. Professionalise operational aspects and climate services

better supported, longer timescale development cycle, increase transparency, improve emulators/downscaling, improve feedback into research, co-design

8. Achieve net zero climate resilient modelling

Set a leading example: monitor, report, pathway for modelling centres and researcher activities

2. Where do we want to be by [2030, 2050]? our vision

- “A “multiverse” of climate models (and associated infrastructure and a skilled workforce) that are fit for purpose to advance the societally relevant and actionable science needed for a sustainable present and future.”

OUTLINE FOR WCRP REPORT

Aim: A call for a step change in global coordination of the climate modelling effort for impactful, urgent and net zero science delivery that meets the needs of global society

1. Current Climate Modelling Landscape

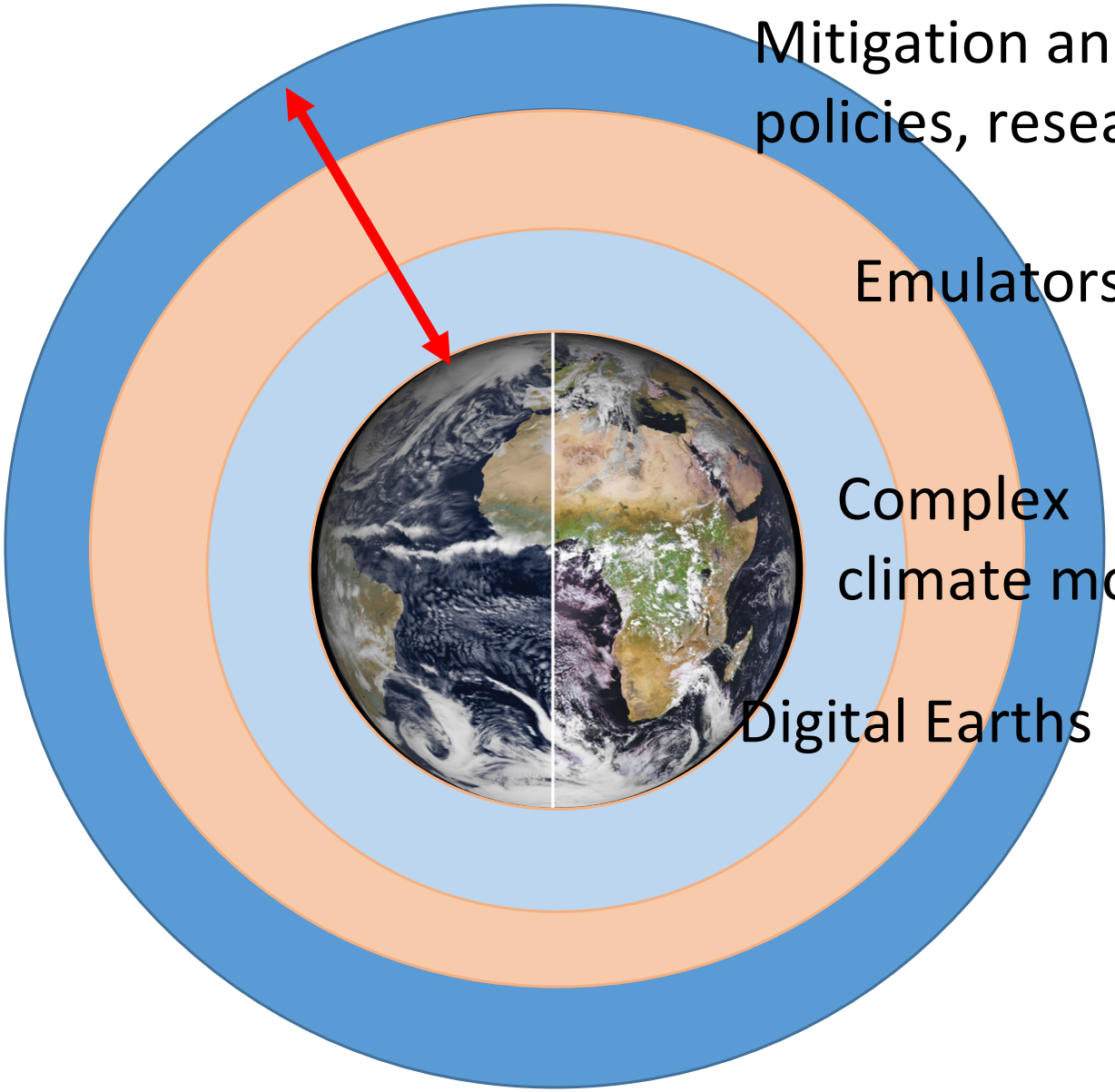
   Sessions and BOGs will become sections: chairs, speakers rapporteurs to author + others as necessary

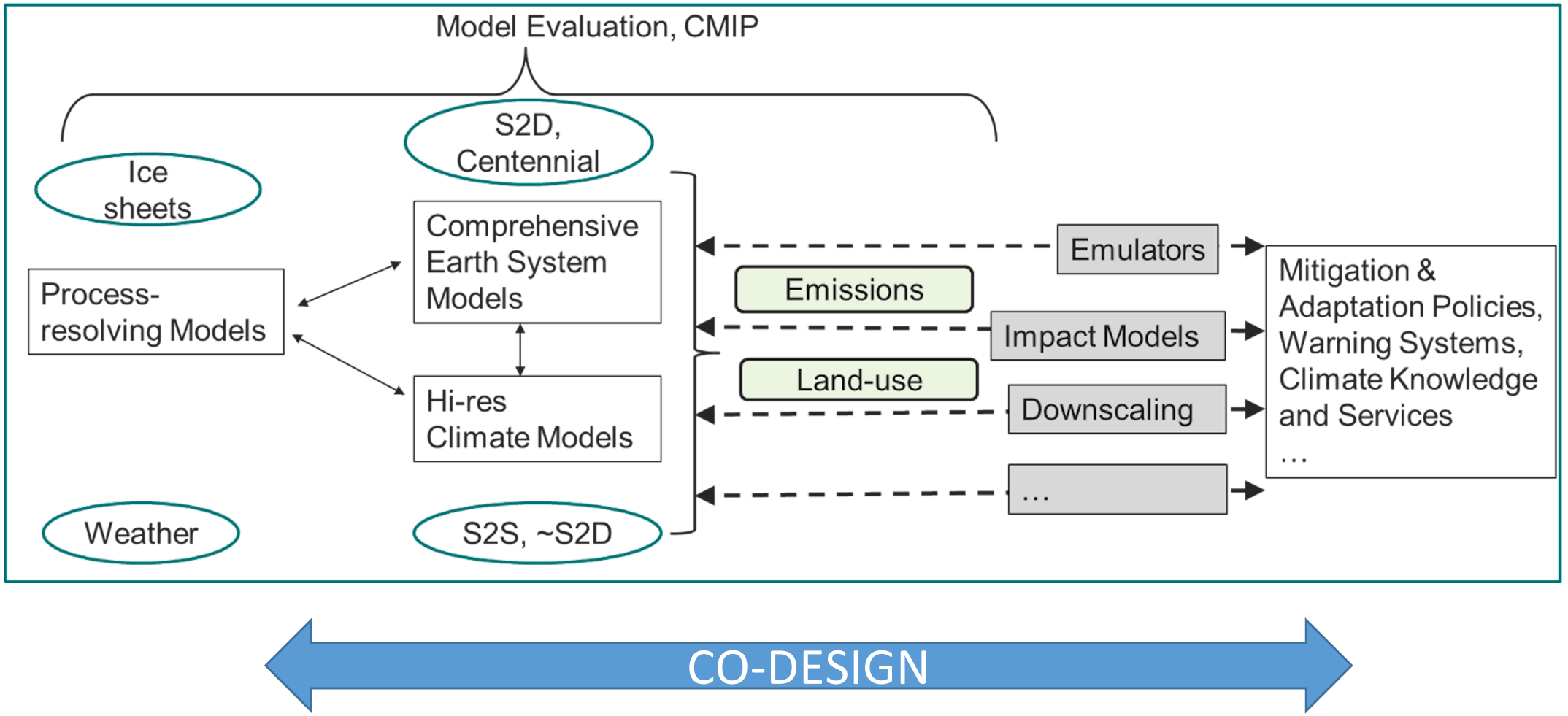
2. Where do we want to be by [2030, 2050]? our vision
3. How do we get there?
4. Specific recommendations to WCRP

Green is where we think we have good high-level agreement

The climate modelling multiverse

Observations, MIPS, model evaluation tools and people work across the multiverse; Co-design




Model Evaluation, CMIP
S2D, Centennial
Ice sheets
Process-resolving Models
Weather
Comprehensive Earth System Models
Hi-res Climate Models
S2S, ~S2D
Emissions
Land-use
Emulators
Impact Models
Downscaling
…
Mitigation & Adaptation Policies, Warning Systems, Climate Knowledge and Services
…
CO-DESIGN

3. How do we get there?

Step changes are needed

1. Accessibility; 2. Scientific fidelity; 3. Usability and usefulness; 4. Capacity building.

Develop a multiverse of approaches

System mindset, more cooperation between global modelling centres and/or a centralised model infrastructure

Become flexible, responsive and innovative

Agile suites of modelling tools; flexibility over who does what: national centres, international collaborative efforts, universities, private sector. Partnerships..

Improve capacity, diversity and career pathways

Global south led co-design and modelling capabilities, novel careers, skills…