Overview of coupled modelling: CMIP and higher resolution models

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CMIP6 and plans for CMIP7
CMIP: driving science, informing policy

CMIP6: biggest yet!
- 24 endorsed MIPs
- 26 countries
- 48 institutions
- 131 models
- 322 experiments
- Nearly 25 PB of CMIP6 data
- 30+ ESGF data nodes

(b) Model complexity

(b) Annual mean temperature change (°C) relative to 1850–1900

IPCC AR6 WGI SPM Fig. 2

IPCC AR6 WGI TS Fig 2
CMIP data in action

Combining different MIPs, producing ensemble projections
CMIP6 Community Survey: Priorities for CMIP7

- No big structural change from CMIP6 but evolution.
- Retain alignment to IPCC in some form – prioritisation of core MIPs/experiments.
- Reduce burden on modelling centres.
- Need for greater focus on climate impacts and adaptation relevant experiments (including updated scenarios).
- Need for critical elements to become operational (e.g., forcings).
- Less centralized coordination of specialist MIPs, potentially decoupled from IPCC timeline.
- Build on substantial CMIP6 data infrastructure progress to support improved, and more user friendly, data access.
- Continue and enhance active community input to the experimental design process.
- Nurture the future CMIP community and promote young and global South scientists.
Questions for CMIP7

How many of the CMIP6 simulations/models can we reuse?

How many/which MIPs/scenarios do we really need?

How many ensemble members do we need?

How many high resolution simulations?

Do we need all modelling groups to do everything with their State-of-the-Art model?

How can we optimise data storage, analysis and access?

Can we reduce CMIP7 CO₂ emissions by 50% relative to CMIP6?
The Task Teams

CMIP Task Teams have been established to drive forward definition of CMIP7 in an open and collaborative manner.

- Data access (Robert Pincus and co-lead tbc)
- Data citation (Martina Stockhause and Sasha Ames)
- Data Request (Martin Juckes and Chloe Mackallah)
- Forcings (Paul Durack and Vaishali Naik)
- Model benchmarking (Birgit Hassler and Forrest Hoffman)
- Model documentation (David Hassell and Guillaume Levavasseur)
- Strategic ensemble design (Ben Sanderson and Isla Simpson)
Potential CMIP7 structure

The **DECK** - remains as an entry card to CMIP supporting model characterisation

A **Core** set of streamlined policy focused MIPs/experiments aligned with key policy/decision making timelines (e.g., IPCC)

Community experiments/MIPs could operate on timeline driven by scientific and model development advances but can benefit from working with Core MIPs/experiments (aligning experiment design and data requirements, e.g. requesting variables from CMIP7 piControl and historical simulations).
Supporting continuous activity (CMIP6+)

- Leveraging the CMIP6 infrastructure (CMIP6 compatible experiments).
- New and ongoing MIP activities can request guidance and limited support.
- Enable responsive activities (e.g., CovidMIP).
- Support CMIP evolution and potential operationalisation of components (e.g., testing next generation forcings).
Proposed DECK and Core timeline (for discussion)

- Definition of experimental design
- Forcing dataset generation and testing: ≈ 3 years
- Data request process: ≈ 2.5 years
- CMIP7 MIP identification
- Simulations start?
- Earliest IPCC data deadline (for Core simulations)?

Timeline:
- 2022
- 2023
- 2024
- 2025
- 2026
- 2027 (IPCC 2028 WG1)
- 2028
- 2029
- 2030

Global Stocktake
Community discussion and feedback opportunities

We are looking for wider engagement and feedback from the community like today, and with future:

- Surveys and consultations.
- Workshops.
- Monthly drop in sessions.
- EGU23 Town Halls (Future CMIP and CMIP ECR views).
- Direct interaction with TT Co-leads, TT members and the IPO.
What about resolution?

Minobe et al. 2008

Ocean Resolution of Global Models

IPCC Reports

CMIP6

HighResMIP

Climate Prototype

Ocean Prototype

Submesoscale resolving

Meso-scale resolving

Boundary layer resolving

Horizontal Grid Spacing (km)

Year

1980 2000 2010 2020 2030 2040 2050
Resolution hierarchies

Roberts et al, 2016; Chassignet and Xu, 2017; Hewitt et al., 2017, 2022
SST errors due to topographic steering

Response: (1) meridional heat advection by a mean wind anomaly; (2) meridional heat advection by the transient eddies; and/or (3) ascent and the associated adiabatic cooling over the western boundary currents (WBC) and their extensions

3 dominates in these experiments

Atmosphere response to SST errors

Rainfall %age change, DJF, 2030-50 - 1960-80 over Europe 20W-30E, 40-65N from different multi-model ensembles

Result needs both atmosphere and ocean resolution

Moreno-Chamarro et al., ERL, accepted; Grist et al., GRL, 2021.
Pushing the frontiers to the kilometric scale

- Building on regional modelling, k-scale is being developed for global atmosphere models – many challenges both modelling and data storage/exploration

- More challenges for ocean, sea ice and coupling

- Met Office science theme on Pathway to High Resolution (Lead: Cath Senior)

- WCRP and other international efforts to move to k-scale
K-Scale climate development:

- **New** 10-year (2-years so far) RAL3 Maritime Continent coupled to NOC regional ocean model
- Comparison with Atmosphere only show:
  - No drift
  - Cold bias off SW coast of Sumatra that develops during JJA reaching peak magnitude in SON.
  - Stronger surface winds in corresponding to cooler SSTs in coupled model - more upwelling?
- Planned: Developing coupled LAM and CTC capability based on ORCA12
- Planned 4.4km CTC 10-year simulations (Atmos only+4k, coupled)
Summary

• CMIP has rapidly expanded in terms of number of models and the complexity of models

• Increases in resolution haven’t progressed as fast as we might have expected 20 years ago

• Resolution is needed in both ocean and atmosphere to capture mesoscale air-sea interactions

• Computing costs/capability for higher resolution has limited our ability to assess how important resolution is for both the mean and the changing climate

• Should CMIP7 support more higher resolution models? What are the implications for the DECK? Should it interface to higher resolution efforts?