With funding from the:

Federal Ministry
of Research, Technology
and Space

ESMO
Earth System Modelling
and Observations

WCRP
World Climate
Research Programme

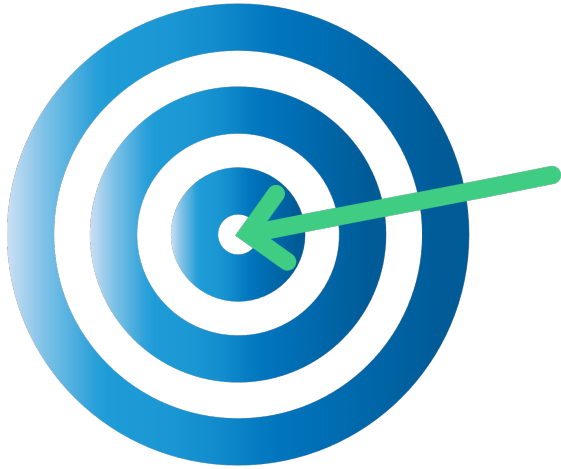
ESMO – Earth System Modelling and Observations

WCRP Core Project

Fanny Adloff
WGNE 40, CMA, CEMC, Beijing, China

What is ESMO?

One of the 6 WCRP Core projects



Mission

Coordinate, advance and facilitate modelling, data assimilation and observational activities within WCRP.

Address critical gaps in our ability to monitor, predict, and forecast the climate across different time and spatial scales.

Our Objectives

Advancing predictions and projections of the Earth System

on time scales from weeks to centuries and furthering model-observation integrated frameworks

Improving monitoring, understanding and attribution of climate system changes and impacts

with robust uncertainty quantification through the synthetic use of models and observations

Advancing and harnessing emerging technologies

in modelling and observations

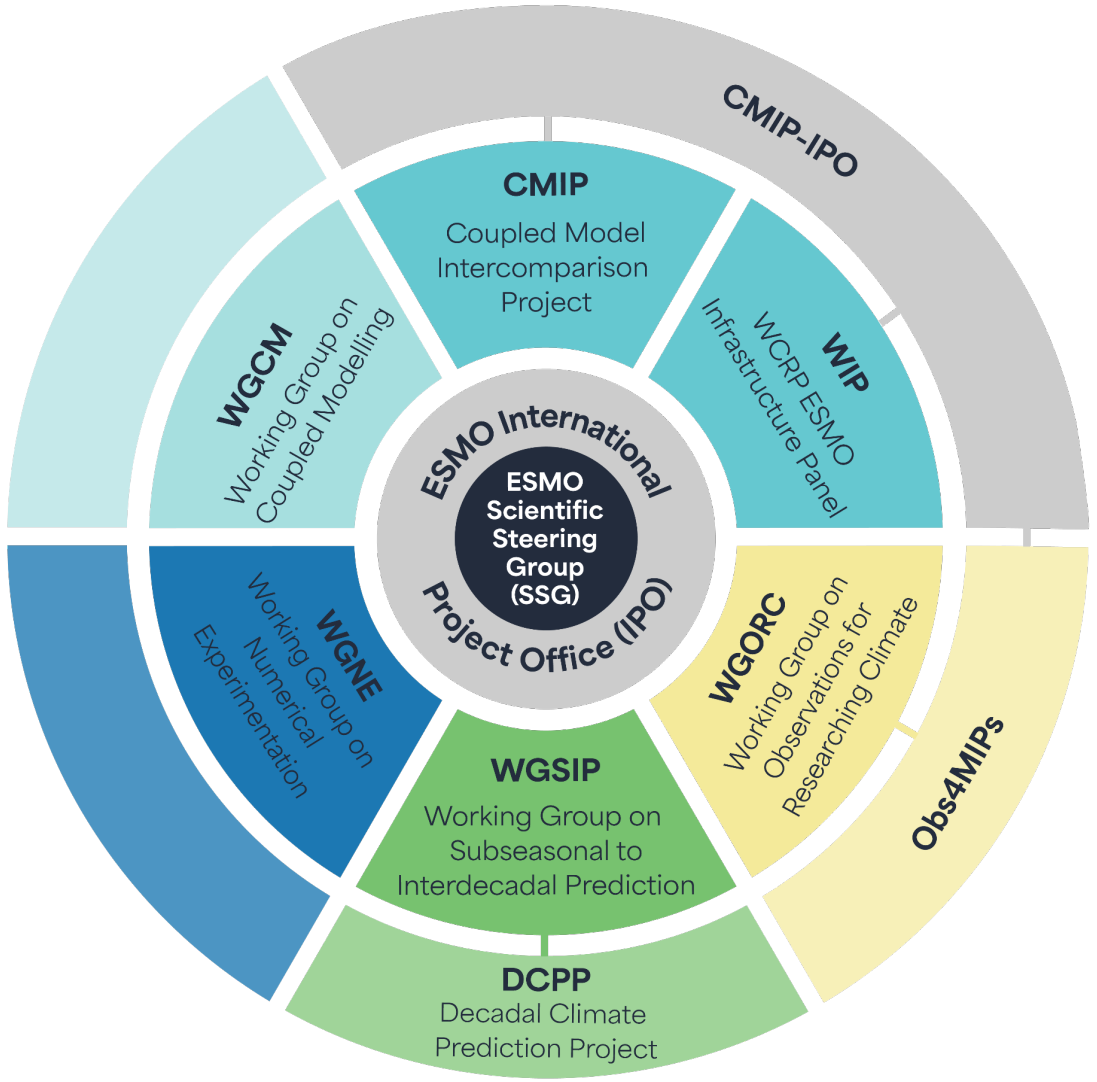
ESMO Structure

WORKING GROUPS

- Working Group on Coupled Modelling (WGCM)
- Working Group on Subseasonal to Interdecadal Prediction (WGSIP)
- Working Group on Numerical Experimentation (WGNE)
- Working Group on Observations for Researching Climate (WGORC) => **NEW!**

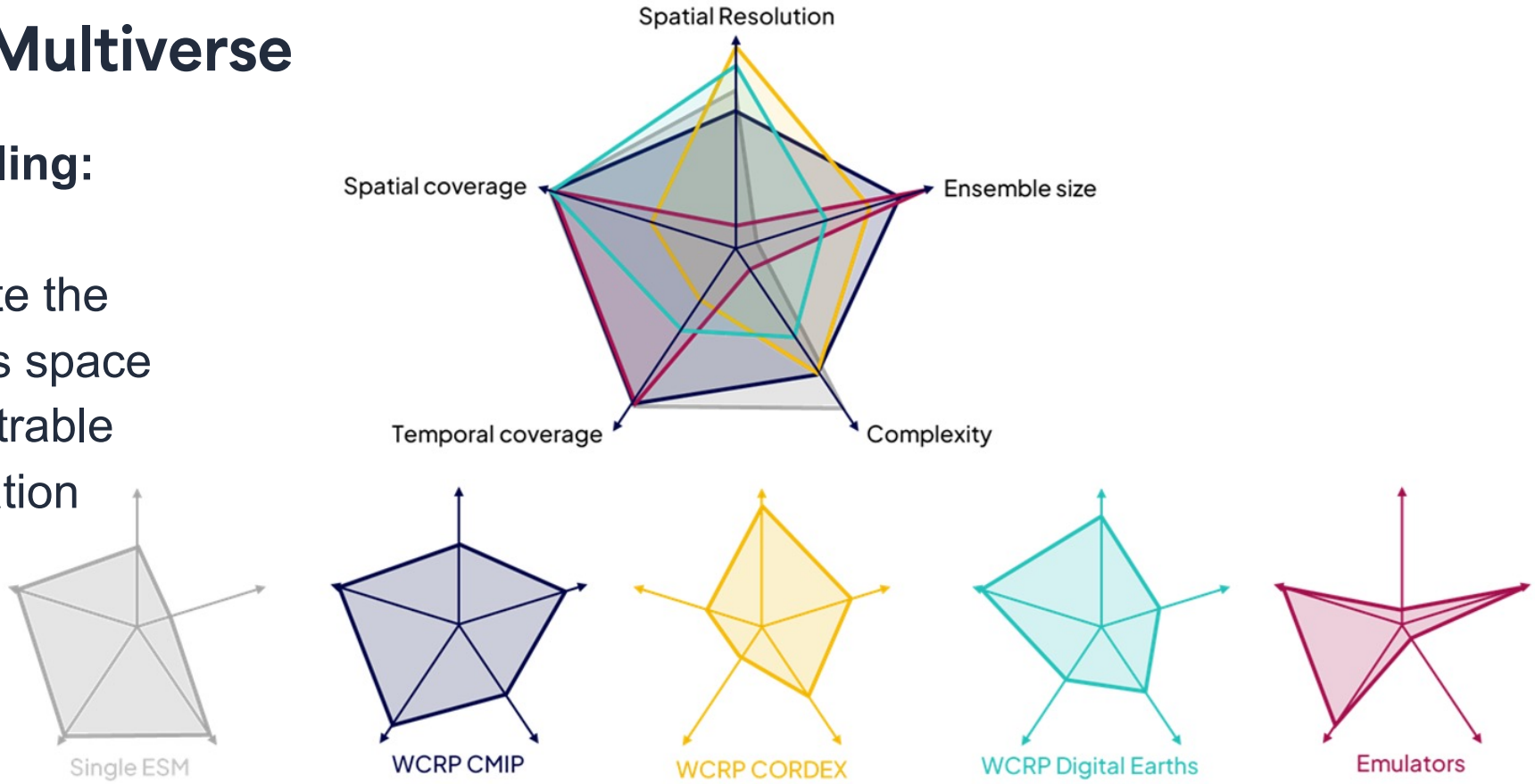
PROJECTS & PANELS

- Coupled Model Intercomparison Project (CMIP)
- WGCM infrastructure Panel (WIP)
- Observations for Model Intercomparisons Project (Obs4MIPs)
- Decadal Climate Prediction Project (DCPP)



The WCRP Modelling Multiverse

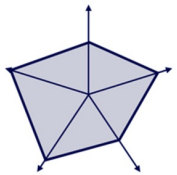
Challenges in climate modelling:
Accessible, reliable and useful modelling systems that simulate the Earth's climate system - across space and time scales - with demonstrable fidelity and process representation



Adapted from Dingley at al. 2023, https://zenodo.org/records/8047805

Approach: Explore all the dimensions of the modelling multiverse across WCRP activities and deliver the best tools to address current and future scientific and societal challenges.

Modelling community within ESMO



Working Group on Coupled Modelling (WGCM)

- Evaluation and development of coupled climate models

Working Group on Numerical Experimentation (WGNE)

- ESMs development (design, implementation, error diagnosis, revisions)

ESMO

Interactions

Coordination

Shared activities

Cross-cutting themes

New impulses

Coupled Model Intercomparison Project (CMIP)

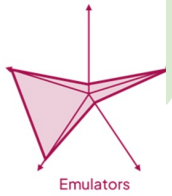
- Understanding of past, present and future climate changes
- Model performance evaluation

Working Group on Subseasonal to Interdecadal Prediction (WGSIP)

- Numerical experimentation for S2I variability and prediction

Task Team on Climate Emulators

- Brings together modeling experts interested in emulators
- Taxonomy paper in planning



Decadal Climate Prediction Project (DCPP)

- Prediction of annual, multi-annual to decadal timescales

km-scale climate modelling group - joint with Digital Earth

- Foster a global research network in km-scale modelling of the Earth system and individual components
- Isolate common biases/issues and ideally develop strategies

Observational community in WCRP

Topic-specific observational groups in core projects

GSOP
- CLIVAR Global Synthesis and Observations Panel

GDAP
- GEWEX Data and Analysis Panel

GASS & GLASS
- GEWEX Global Atmospheric System Studie
- GEWEX Global Land-Atmosphere System S

APARC activities on
- Stratospheric ozone
- Temperature Trends

CLiC activities on
- Sea Ice Processes
- Permafrost Carbon Network

External Partners

GAW
Global Atmosphere Watch Programme

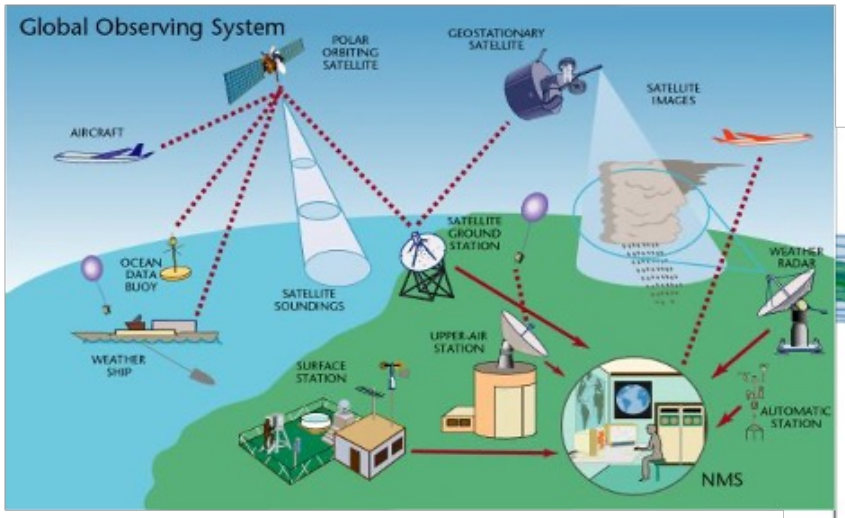
GCOS
Global Climate Observing System

GOOS
Global Ocean Observing System

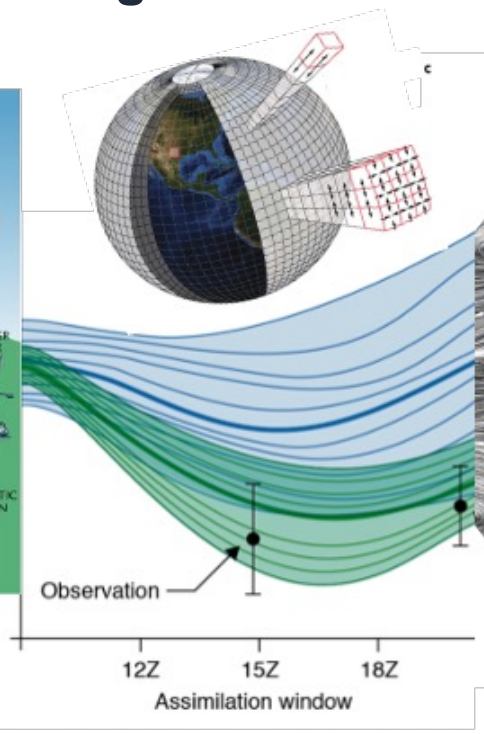
CEOS/CGMS WG Climate
Committee for Earth Observation Satellites / Coordination Group of Meteorological Satellites

New challenges and opportunities for observation-model synergies

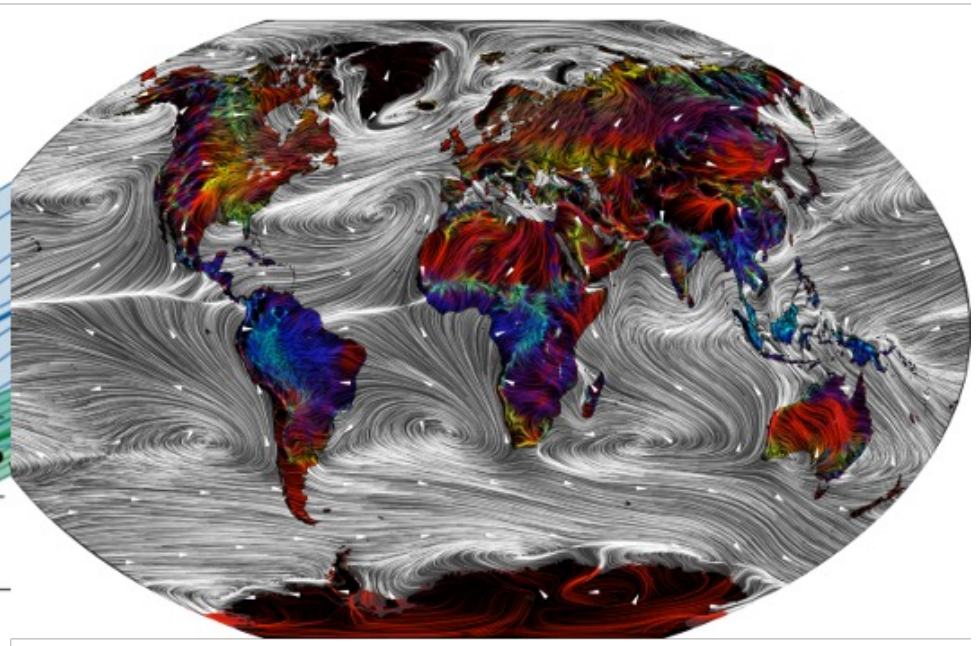
- Data-fusion for climate
- Emerging technologies
- Data-driven modelling
- Reanalysis and data assimilation



WMO Global Observing system



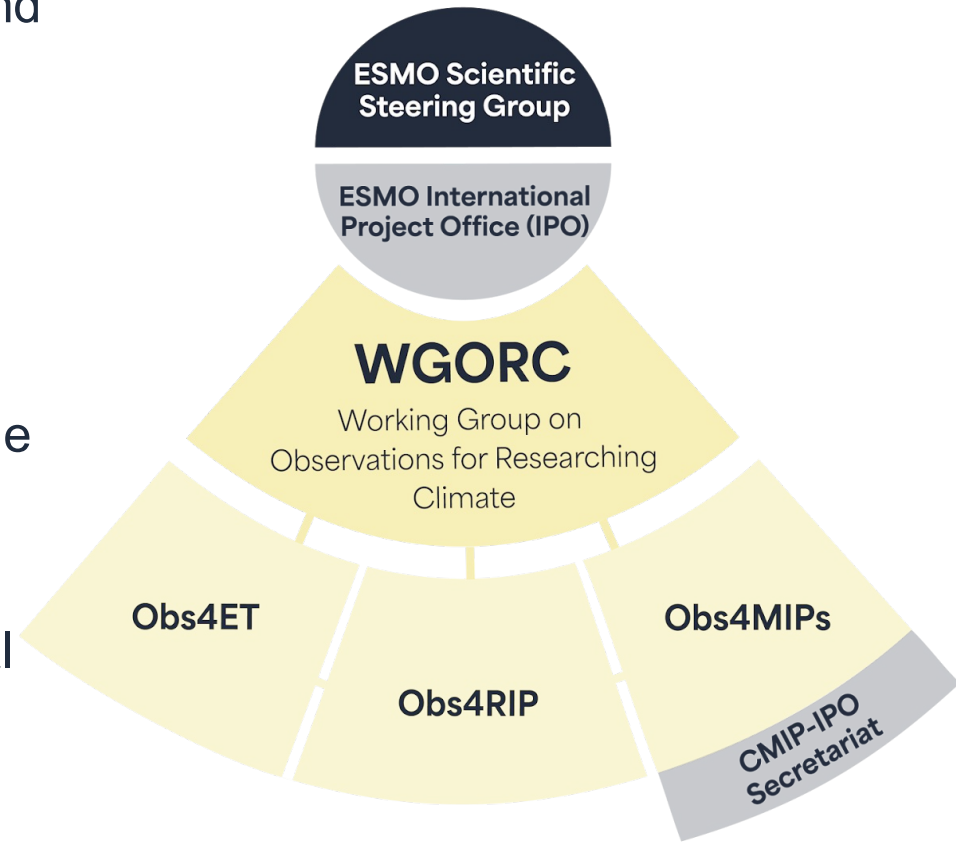
Cambridge University Press Climate Model and ECMWF Data Assimilation schematic



Kling and Ackerly, 2020

New Working Group on Observations for Researching Climate (WGORC)

- Identify and address **research gaps in climate observation data** and act as a facilitator for **collaboration across diverse research and industry sectors.**
- Focus on advancing both the use and development of **reanalysis, initialization, and prediction (RIP)** data to improve climate models and enhance future forecasting capabilities.
- Explore how **emerging technologies (ET)**, such ML, AI and km-scale models & observations, can enhance the use and application of climate data.
- **obs4MIPS** as WGORC panel enhances accessibility to observational data for climate model evaluation, development, and research by aligning datasets with CMIP standards.



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Working Groups

WGCM
Working Group on Coupled Modelling

WGNE
Working Group on Numerical Experimentation

WGORC
Working Group on Observations for Researching Climate

WGSIP
Working Group on Subseasonal to Interdecadal Prediction

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Working Group on Subseasonal to Interdecadal Prediction

WGSIP

WG on Sub-seasonal to Interdecadal Prediction

Research priorities for next 5-year cycle:

- ML/AI (including participation in WGNE WP-MIP)
- Sources of Predictability
- Ensemble information across timescales
- Land-atmosphere interactions
- Climate Information for Decision-Makers

WGSIP

Current work

- Establishment of an **S2S Panel** within WGSIP
- Continued engagement with ET-OPCS (Expert Team on Operational Climate Prediction System)
- New activity on ML models for S2S prediction
- Continue supporting concrete aspects of the WMO **Regional Climate Outlook Forums**
  - e.g. collaboration with ICPAC on Greater Horn of Africa Climate Outlook Forum (GHACOF), African Centre of Meteorological Application for Development (ACMAD), potential collaboration with Regional Climate Centers in South America.
- Upcoming WCRP School on Prediction Across Timescales (Buenos Aires, Argentina, February 2026)
- Preparing for S2S2D conference (Reading, UK, Sept 2026)

ML models for sub-seasonal and seasonal prediction

WGSIP
Working Group on Subseasonal to Interdecadal Prediction

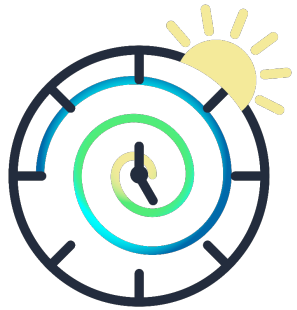
What is the purpose?

- **Synthesising existing research**, mapping the current landscape, fostering knowledge exchange and building a community around the potential of ML models for sub-seasonal and seasonal prediction.

What is the end goal?

- Improved understanding of the capabilities of ML models for sub-seasonal and seasonal prediction
- Synthesis of emerging findings from both coordinated intercomparisons and institutional efforts, contributing to shared knowledge and future research directions
- Enhanced community engagement around the development, evaluation, and application of ML models for sub-seasonal and seasonal prediction.
- Stronger connections and active collaboration with relevant WMO groups on the developments, trends and best practices in ML for sub-seasonal and seasonal prediction.

WCRP School on Predictions Across Timescales



WCRP School on Climate Prediction Across Timescales

WGSIP
Working Group on Subseasonal to Interdecadal Prediction

- 23-27 February 2026 in Buenos Aires, Argentina

- **Theme**: *Predictability Assessment and Communication of Uncertainty for Applications in Environment and Society*

Objectives:

- Foster understanding of key concepts including predictability, forecast skill, sources of predictability, and cross-timescale interactions
- Provide an overview of novel tools to determine the predictability and assess forecast skill.
- Introduce emerging tools in machine learning and AI for forecasting.
- Develop practical skills through interactive lab sessions focused on real data

S2S2D Conference 2026

7-11 September 2026 in Reading, UK

Theme: *Advancing climate predictions from weeks to decades to benefit society*

<u>What topics will be discussed?</u>

- Climate Services for Decision Making
- Predictability and Prediction Skill
- Physics-based Prediction Systems
- Machine-Learning Methods in S2S2D

Abstract submission will open in December 2025

WGSIP
Working Group on Subseasonal to Interdecadal Prediction

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Working Groups

WGCM
Working Group on Coupled Modelling

WGCM

WG on Coupled Modelling

- Recently restructured with many new panel members
- Starting WGCM model forum
  - Wider discussion platform for leads / contacts from several modelling centres worldwide
  - Addressing common issues, both technical and scientific
  - Potential for future WGNE collaboration
  - Launch event @ CMIP workshop (Kyoto, Japan, March 2026)

WGCM Modelling Forum Launch

CMIP 2026
COMMUNITY WORKSHOP
9-13 MARCH
KYOTO JAPAN

(as part of the CMIP community workshop 2026)

- Will **bring together modelling centres** from across the global climate science community
- The Forum will provide a dedicated platform for **enhanced collaboration** and knowledge transfer among model developers, users, and researchers worldwide.
- Special emphasis will be placed on **creating pathways for smaller and emerging modelling centres** to engage with the broader community.

WGCM

- Also discussing launch of new activities on:
  - Process complexity
  - Carbon Cycle and Human interaction coupled in ESMs
  - Potential summer school on climate model development
    - Would seek WGNE support

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WGORC
Working Group on Observations for Researching Climate

WGORC

WG on Observations for Researching Climate

- New WG, launched this summer
- Kick-off meeting soon (Reading, UK, DEC 2025)
- Planning establishment of subpanels, potentially on:
  - Emerging Technology (AI/ML) and data readiness
  - Reanalysis
  - Data standards and Quality control
- Also setting up an extended panel with key partners (CEOS-WGClimate, GCOS, GOOS, GAW, other core projects)
- Supporting Obs4MIPs and Rapid Evaluation Framework

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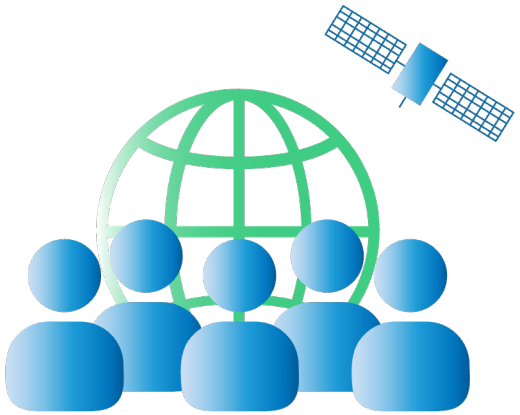
ESMO Project and Panels

CMIP
Coupled Model Intercomparison Project

WIP
WGCM Infrastructure Panel

obs4MIPs
Observations for Model Intercomparison Projects

DCPP
Decadal Climate Prediction Project



CMIP

Coupled Model Intercomparison project

Key objectives

✅ **Advance Climate Science** – Facilitate multi-model experiments to address key climate questions.

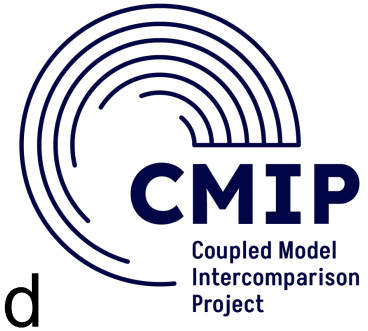
🔬 **Support Global Assessments** – Provide essential climate projections for the IPCC and other national and international reports.

🌎 **Enhance Data Infrastructure** – Maintain a shared, standardized platform for climate modeling research.

📊 **Inform Policy & Adaptation** – Deliver actionable insights to scientists, policymakers, and climate adaptation practitioners.

CMIP Community Workshop 2026

- 9-13 March 2026 in Kyoto, Japan



Workshop Themes:

- Progress in understanding historical climate variability and change
- Understanding climate system responses, feedbacks, and thresholds
- Synthesising information across the multiverse of models
- ESMO side-event on WGORC

WIP

WCRP-ESMO Infrastructure Panel

Key objectives

✅ **Define CMIP Infrastructure** – Develop and implement the technical framework for each CMIP phase.

🔬 **Support Data & Services** – Construct essential information to enable climate modeling and data-sharing services.

🌍 **Ensure Efficient Data Access** – Optimize the infrastructure that allows researchers worldwide to access and analyze CMIP simulations.

DCPP

Decadal Climate Prediction project

Key objectives

✅ **Advance Near-Term Climate Prediction** – Organize experiments to improve climate forecasts on annual to decadal timescales.

🔬 **Evaluate Prediction Skill** – Investigate processes that contribute to successful predictions.

🌍 **Support Climate Science & Policy** – Promote the importance of decadal climate prediction for research and decision-making.

📊 **Develop CMIP7 Protocols** – Lead the design and implementation of decadal prediction experiments for CMIP7.

DCPP

Current work:

- Continue to develop DCPP CMIP7 protocol
  - Just agreed on final details of DCPP-A (hindcasts) and DCPP-B (forecasts)
  - Developing a protocol for DCPP-C (idealised simulations) by end of 2025 - currently the focus of a task-team led by Pablo Ortega
- Finalisation of DCPP CMIP7 protocol in 2025 => paper for the CMIP7 special issue (Robson et al.)

obs4MIPs

Observations for Model Intercomparison Projects

Key objectives

✅ **Provide Model-Compatible Observations** – Format observational products to align with CMIP model data.

🔬 **Support Climate Model Evaluation** – Enable direct comparisons between observations and climate simulations.

🌎 **Ensure Open Access** – Make gridded observational datasets available via the Earth System Grid Federation (ESGF).

📊 **Facilitate User Guidance** – Provide concise documentation to help researchers effectively use Obs4MIPs data.

obs4MIPS

Current work

- Data set proposal submission & review workflow established
- Support for non-gridded data sets (e.g. site-based in-situ)
- Many new datasets in preparation!
- Supporting the data requirements of the CMIP7 Rapid Evaluation Framework (REF)
- Update of the obs4MIPs data specifications

Climate Emulators

- Task team within ESMO to look at the use of Emulators in Climate research
  - Low cost application, specific use cases
  - Potentially helpful for development of forcing scenarios
- Currently working on a taxonomy review paper
- Considering further training activities, hackathon or summer school
- Possibility of WGNE engagement

Other ESMO activities

- **REF**: Rapid Evaluation Framework v1 launched by CMIP Model. Benchmarking Task team

  => fully integrate evaluation tools into the CMIP publication workflow.

  REF v1 provides diagnostics to characterise climate model performance and highlight model spread, diversity and differences
- Co-hosting the **Transient Climate Response to cumulative carbon Emissions (TCRE) activity** with Safe Landing Climate activity.
- Reinforcing ESMO's engagement with the km-scale community, in partnership with **Digital Earth LHA.**

WCRP Global Hackathon

The World Climate Research Programme
Global km-scale Hackathon
12-17 May 2025

Co-organised by ESMO IPO

DKRZ-node participants

Global Collaboration

Share best practices for process-based analysis of km-scale simulations

Enhanced Accessibility

Provide high-quality data resources and facilitate global access

Long term Impact

Develop sustainable workflows and promote accessible data-sharing

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Thank you!