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WCRP World Climate Research Programme

World Climate Research Programme

Strategic Plan

2019-2028

WCRP Publication No. 1/2019

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Preface

The World Climate Research Programme (WCRP) was established in 1980 to answer two questions: (i) to what extent can the global climate be predicted, and (ii) how have humans influenced the climate? To address these questions, the international scientific community organized itself to understand the complex relationships among the different components, and the physical, biological and chemical processes, of the Earth system. The answers, arrived at by science, are clear and unequivocal: our climate has changed and will continue to change, and changes since the mid 20th century are largely due to human activities. This message, based on rigorous scientific investigations, has provided a foundation for international climate treaties and national policies.

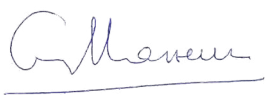
Today, the setting for climate research has changed. Solutions to address the causes and impacts of climate change must be based on collaborative dialogue among natural and social scientists, civil society, and political leadership at every level. As before, WCRP will continue to deliver the fundamental scientific evidence on the climate system and how it is changing.

At the same time, climate research, including the fundamental science of climate systems, is evolving rapidly in order to better understand and predict climate variability at time scales ranging from a few weeks to a few years. In this context, the role of WCRP is to facilitate the international coordination of climate research that is needed to support a more resilient society. A new generation of brilliant scientists representing different disciplines and working in a diverse and inclusive environment will be crucial for the success of this endeavor.

The WCRP Strategic Plan 2019-2028 is the result of many reflections within the scientific community after the Paris Agreement of 2015. The priorities that have been set are the result of extensive consultation with researchers across the entire Programme. They were deeply informed by the recommendations made by an external review chaired by Professor Dame Julia Slingo, by consultations with other research programmes within and beyond the World Meteorological Organization, and engagement with agencies and organizations worldwide. This Strategic Plan will be operationalized through an Implementation Plan that will be developed during 2019 and 2020.

We would like to thank all those who contributed to the preparation of the WCRP Strategic Plan 2019-2028, and particularly the members of the WCRP Joint Planning Staff. The ongoing support of WCRP's sponsors, the World Meteorological Organization, the Intergovernmental Oceanographic Commission of UNESCO and the International Science Council, is greatly appreciated. Helpful comments from WCRP's sponsors on an earlier version of the Strategic Plan are gratefully acknowledged.

Amanda Lynch
Vice-chair, 2018



Guy Brasseur
Chair, 2018

Helen Cleugh
Vice-chair, 2019

Detlef Stammer
Chair, 2019

World Climate Research Programme

Our Vision

A world that uses sound, relevant, and timely climate science to ensure a more resilient present and sustainable future for humankind.

Our Mission

The World Climate Research Programme (WCRP) coordinates and facilitates international climate research to develop, share, and apply the climate knowledge that contributes to societal well-being.

The World Climate Research Programme (WCRP) leads the way in addressing frontier scientific questions related to the coupled climate system — questions that are too large and too complex to be tackled by a single nation, agency or scientific discipline. Through international science coordination and partnerships, WCRP contributes to advancing our understanding of the multi-scale dynamic interactions between natural and social systems that affect climate. WCRP engages productively through these partnerships to inform the development of policies and services and to promote science education. Most critically, WCRP-supported research provides the climate science that underpins the United Nations Framework Convention on Climate Change, including national commitments under the Paris Agreement of 2015, and contributes to the knowledge that supports the 2030 Agenda for Sustainable Development, the Sendai Framework for Disaster Risk Reduction, and multilateral environmental conventions.

WCRP is co-sponsored by the World Meteorological Organization, the Intergovernmental Oceanographic Commission of UNESCO, and the International Science Council.

Globally coordinated climate system science requires investment in human capacities.

Our Engagement

The vibrant WCRP research community is geographically, disciplinarily, culturally, and socially diverse. Training, capacity building, higher education, and facilitated collaboration are of paramount importance to sustain and grow this community, particularly through opportunities for early career, underrepresented, and developing country researchers.

Joint strategic planning, joint execution of coordinated experiments, and the sharing of data and information require a well networked research community. Furthermore, our mission to facilitate science in support of society demands broad enabling of natural-social science collaborations and globally coordinated citizen science.

Open engagement with civil society, governments, and the private sector – across regions and in United Nations processes, programs, and activities – is central to the activities conducted by WCRP. Effective communication of scientific advancements, with a variety of stakeholders, is also key, as are high-level and vigorous research dialogues through widely inclusive and open science conferences.

Our Strategic Partners

Partnerships across science communities are critical to meet the challenges and to take advantage of the opportunities that will arise with current and future climate variability and change.

To advance our fundamental understanding of the climate system, deliver meaningful guidance in support of regional and global climate prediction, support multilateral conventions and frameworks, and improve the usability and use of climate science across all space and time scales, WCRP proactively collaborates with regional and global research and operational groups, observational coordination bodies, national academies, and scientific associations.

Our partners include, but are not limited to, the Global Climate Observing System; the Global Ocean Observing System; the Group on Earth Observations and national space agencies; the World Weather Research Programme and the Global Atmosphere Watch of the World Meteorological Organization; Future Earth and its contributing projects and Knowledge Action Networks; the Global Carbon Project; sections and programmes of the Intergovernmental Oceanographic Commission; International Science Council member groups; the Belmont Forum; the United Nations Framework Convention on Climate Change; and national funding agencies.

WCRP will continue to sustain the scientific basis for the work of the Intergovernmental Panel on Climate Change and enhance support for the activities of weather and climate services and the efforts of the Global Framework for Climate Services. New opportunities will be explored for the co-production of project design and outcomes that are directly relevant to policy and decision makers.

Our Decadal Ambition

Understanding the sensitivity of climate stresses and how they could change in the future is critical in formulating policies to mitigate or adapt to climate change.

For almost 40 years WCRP has been a leading initiative dedicated to coordinating international climate research. The integral role of WCRP in developing knowledge of the climate system and our understanding of climate variability and change has been achieved as a result of the efforts of the international scientific community organized through core projects (CLIC, CLIVAR, GEWEX, SPARC), major initiatives (CORDEX, CMIP), working groups, grand challenges, and other activities.

WCRP strives to deliver relevant, accessible, inclusive, and salient scientific information on the climate system.

These efforts have transformed our understanding of the climate as a system and enabled us to predict near-term climate variability and anticipate the future trajectory of the system. This work has contributed fundamentally to the conclusion that human activities are responsible for the majority of the observed global climate change since the mid 20th century.

Society requires decision-relevant, evidence-based climate information to support mitigation strategies and adaptation choices. It therefore needs to address the challenges created by the pace of climate change and the emerging risks associated with climate extremes and hazards, which are being exacerbated by climate change. This climate information is based on new knowledge along with improved observations, process understanding, robust predictions, and scenarios of climate change, produced at increasingly fine spatial resolutions and over a wide range of timescales. While there are key scientific gaps, there are also new opportunities to advance scientific understanding through strategic partnerships. The fundamental climate science that has underpinned past achievements, embodied by disciplinary and interdisciplinary rigor, must now be further extended and applied in order to meet these new demands.

The next decade will bring challenges that can only be addressed through a worldwide coordinated effort conducted by a prepared scientific workforce. This effort must be supported by strong global partnerships. The task is formidable: not only is it scientifically and technically complex, but it also needs to be informed by societal needs at every level from local to global. However, there are clear opportunities: to develop new partnerships for research and operations, to promote exciting observational and computational technologies, to develop scientific capacities and collaboration across the globe, and to improve the cost-effectiveness of future investments in support of resilience and preparedness, mitigation and adaptation. To meet these new challenges and opportunities, WCRP has developed this Strategic Plan for the next decade to ensure that climate science provides the information necessary to achieve a more resilient, sustainable, and equitable world.

Research on the effects and consequences of carbon dioxide removal and solar radiation management is critical for identifying promising approaches and avoiding unintended consequences.

Our Terminology

The terminology used in this Strategic Plan is based on substantial consultation. Of particular importance is an understanding of what we mean by "climate system" and "Earth system" (Figure 1) and their numerical model counterparts – the "Global Climate Model" and the "Earth System Model (ESM)" (Figure 2, see also definitions below). These schematic figures underpin the definitions used in this plan and are consistent with the Intergovernmental Panel on Climate Change Fifth Assessment Synthesis Report (IPCC, 2014).

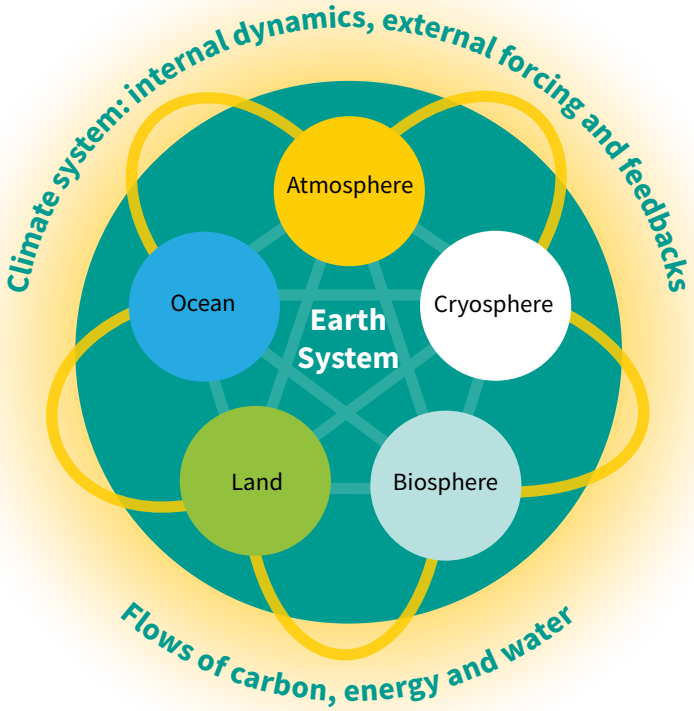


Figure 1: Climate relevant aspects of Earth system science as used in the WCRP Strategic Plan.

- **Climate system:** The part of the Earth system that is relevant to climate; that is the atmosphere, ocean, land surface, and cryosphere, their coupling processes and feedback mechanisms.
- **Earth system:** Earth's interacting physical, biogeochemical, biological, and human systems, including the land, the atmosphere, the hydrosphere, and the cryosphere.
- **Global Climate Model:** Represents the physical climate system components and considers biogeochemical and human systems as external forcing or impacts. Historically, these models were restricted to the physical aspects of the atmosphere and ocean.
- **Earth System Model (ESM):** Represents both the physical climate and the biogeochemical systems and their interactions as a single coupled system. In most ESMs, the human system is external as well as natural forcing (solar and volcanic eruptions).

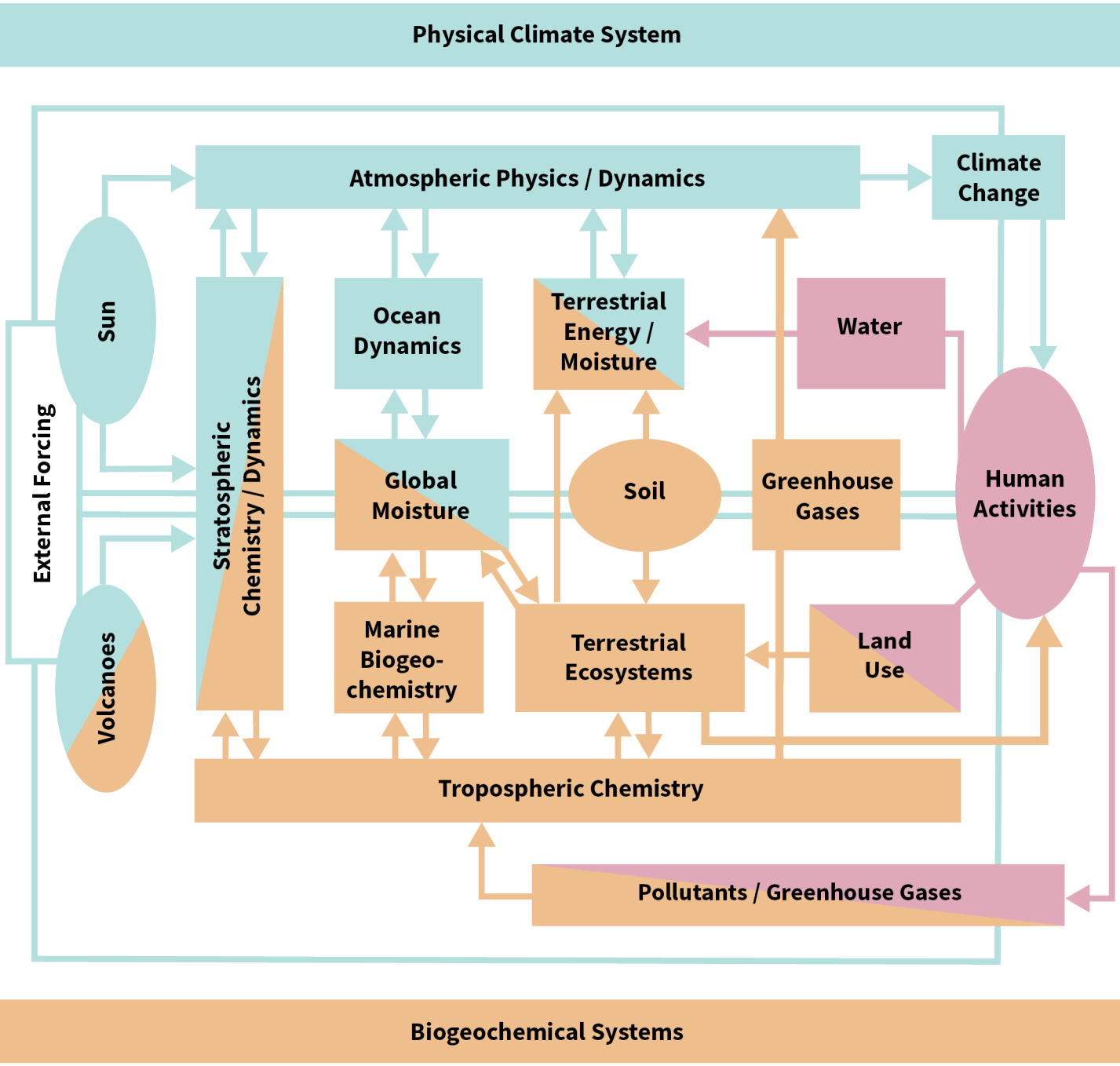


Figure 2: A schematic showing typical models of the physical climate system (in blue) and Earth System Models (orange and blue; but noting that the water component is often included in many contemporary Earth system and global climate models) (after National Research Council,1986).

As there is no generally accepted definition of these important concepts and models, WCRP, as an international research program that represents the relevant scientific domains, accepts responsibility for developing a clearer definition for the community in the future through a consultation and defining task that will be initiated under the implementation of this Strategic Plan and that will involve our partner programmes.

Our Scientific Objectives

The WCRP Strategic Plan for the period 2019-2028 is based on four objectives that will underpin the next decade of climate science (Figure 3). As described in our mission (Page 1), these objectives are informed by the most pressing contemporary climate knowledge needs, as well as advancing the core science and capability needed to prepare for the challenges that society cannot yet foresee. These objectives are: (1) to advance fundamental understanding of processes, variations and changes in the climate system; (2) to predict the near-term evolution of the climate system; (3) to refine the ability to anticipate future pathways of climate system change; and (4) to support the development of theory and practice in the integration between natural and social sciences. Through these objectives, WCRP will contribute to progress in the foundations of climate physics and biogeochemistry, in the predictive skill across all climate system components, and in the improvement of simulations of the past and projections of the future.

Understanding the climate system as part of the Earth system is a foundation for meeting our decadal objectives. Earth system evolution is determined through complex interactions between and within the atmosphere, ocean, land, cryosphere, biosphere, and human activities, across space and time scales. Capturing the behavior of the climate system requires a detailed understanding of physical, dynamical, and biogeochemical processes on global and regional scales; of the internal modes of system variability; of the roles of teleconnections and feedback processes; and of the underlying mechanisms leading to extreme meteorological and hydrological events. Furthermore, it requires an understanding of – and insight into – the ways in which the natural sciences (physical, chemical, biological) can be usefully integrated. Indeed, none of these objectives can be achieved without enhancing existing programmes and without facilitating new partnerships to involve social sciences researchers.

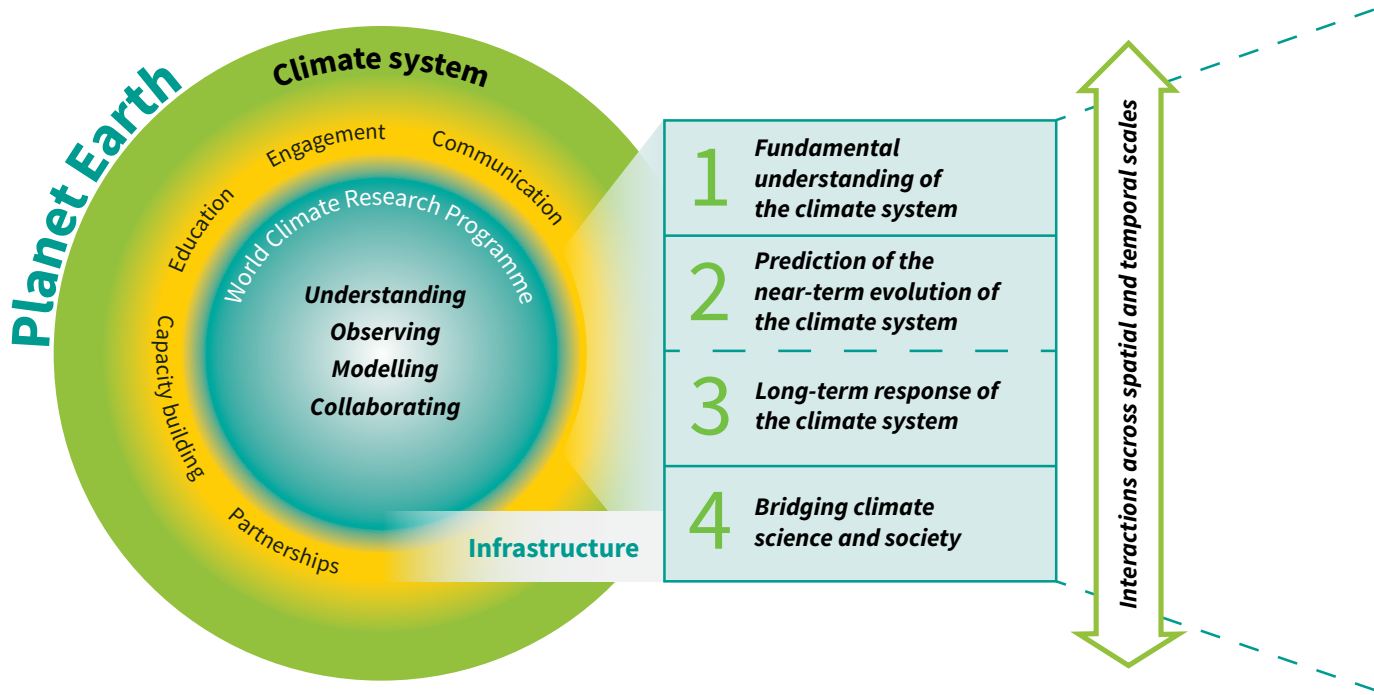
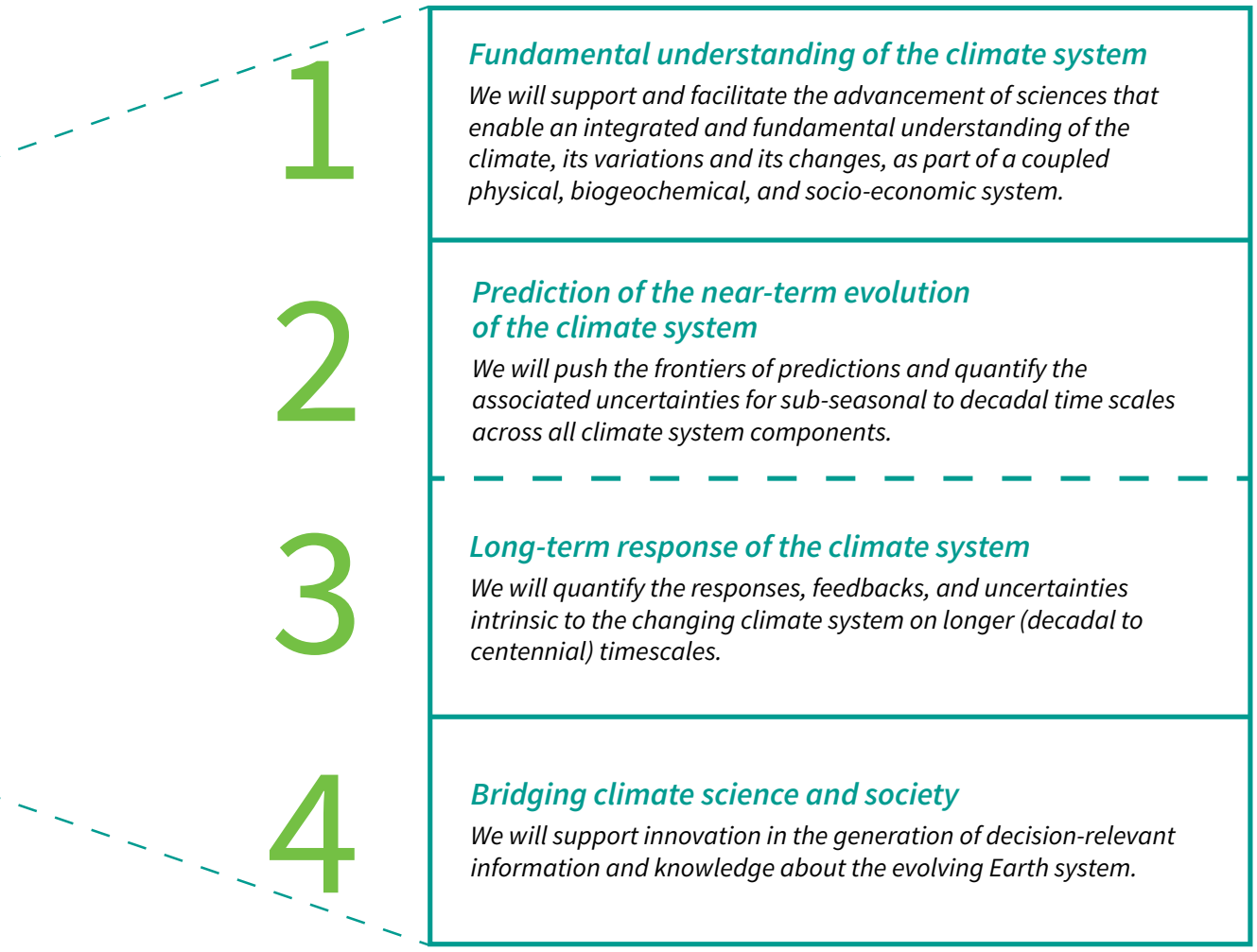


Figure 3: The four Scientific Objectives of the WCRP Strategic Plan 2019-2028 (above and in detail on Page 9) rely on the WCRP community working together to facilitate collaboration and advance understanding, observations, and modeling. WCRP research spans a range of spatial and temporal scales and depends on robust infrastructure to deliver its outcomes. WCRP connects with the wider science community and with a range of stakeholders through partnerships, capacity building, education, engagement, and communication.

WCRP Scientific Objectives



We need fundamental climate system science to prepare society for unforeseen challenges.

1 Fundamental understanding of the climate system

Our Goal

We will support and facilitate the advancement of sciences that enable an integrated and fundamental understanding of the climate, its variations and its changes, as part of a coupled physical, biogeochemical, and socio-economic system.

Coupled climate processes are fundamental to understanding, for example, variations in atmospheric and oceanic circulations; fluctuations and change in temperatures, salinity and precipitation; the trajectories of regional and global sea level rise; the ways in which extreme events are manifest in a non-stationary climate; the cycling of carbon and other chemical species between atmosphere, land and ocean; the dynamical, radiative and chemical interactions from the uppermost layers of the atmosphere to the deep oceans; and the evolution of regional climates. Closing the energy, water, and carbon budgets of these systems is integral to observing, assessing, and simulating climate change and variability, regionally and globally. Research focusing on laboratory science, instrument development, field experiments, paleoclimate proxy analyses, remote sensing technologies, and model innovation substantially contributes to the understanding of processes and mechanisms in every component of the climate system.

Our Scientific Emphases

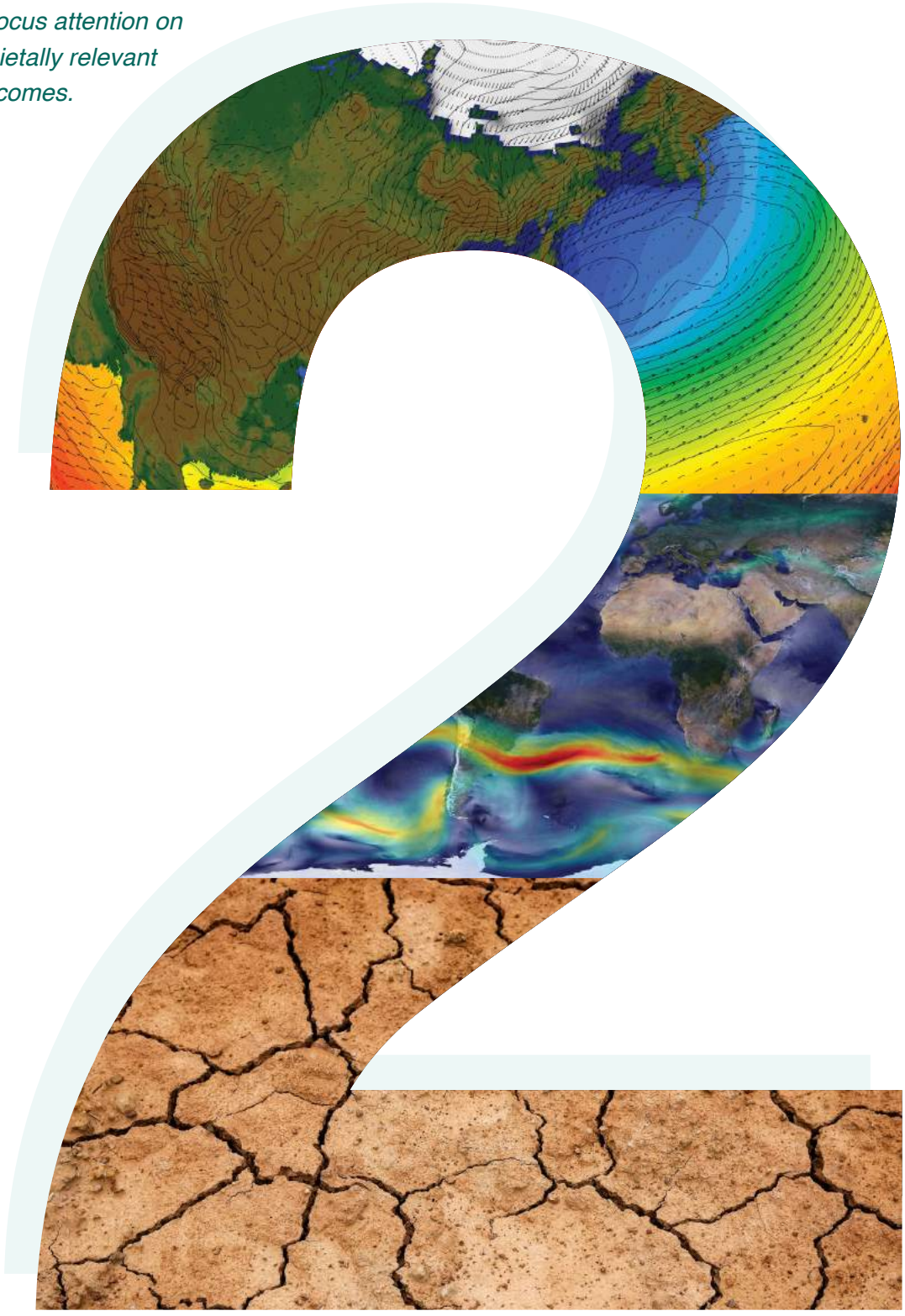
Climate dynamics

In order to better understand the past evolution of climate and to anticipate future changes, we will improve our understanding of the drivers, interactions, and feedbacks that lead to global and regional changes in oceanic and atmospheric circulations. The profound nonlinearities of these systems continue to present critical emerging questions at a range of scales, from local to global.

Reservoirs and flows

The mechanisms responsible for radiative, hydrologic, cryospheric, and biogeochemical changes determine our ability to quantify the reservoirs and flows of energy, water, carbon, and other climate-relevant compounds. We will advance this quantification, within and between the sub-systems of the Earth system, as an important check on our evolving understanding of fundamental processes.

Understanding predictability in the climate system helps to focus attention on societally relevant outcomes.



2 Prediction of the near-term evolution of the climate system

Our Goal

We will push the frontiers of predictions and quantify the associated uncertainties for sub-seasonal to decadal time scales across all climate system components.

This objective supports the capacity of Earth system scientists to engage with society in the context of climate change in the decade ahead. Furthermore, the objective focuses attention on societally relevant outcomes such as meteorological, oceanic, and hydrological extremes, including compound events. Achieving the objective requires an ability to quantify uncertainties, limits, and capacities of prediction systems. It requires advances in the foundational mathematics of predictability of the climate as a system and of components of that system. At the same time, this objective provides many opportunities for the development of new scientific knowledge regarding the whole Earth system.

Our Scientific Emphases

Advancing prediction capabilities

Advances in climate simulations depend crucially on the quality of modelled system components and their coupling. Improvements are critically required in representations of the water, carbon, and energy cycles, of clouds and precipitation, oceanic eddies and waves, sea ice dynamics, and river flows. Rigorous and systematic verification of each component is essential to evaluating the fidelity of these simulations. These advances will require innovative science – deterministic, statistical and machine learning approaches; advanced model-data fusion methods including data assimilation techniques; complex networks; and ensemble generation methods. We will collaborate with the forecasting communities to advance coupled model initialization techniques.

Predicting extreme events

Climate variability influences the frequency and intensity of extreme events, in ways that affect the environment and society. To improve our predictive skills, climate research will determine the processes responsible for the existence of regional climate hotspots, as well as the potential for crossing thresholds and manifesting surprises. The ways in which the non-stationarity of the Earth system interacts with “fast” (such as hurricanes) and “slow” (such as droughts) extremes will be a key focus.

3 Long-term response of the climate system

Our Goal

We will quantify the responses, feedbacks, and uncertainties intrinsic to the changing climate system on longer (decadal to centennial) timescales.

A fundamental scientific understanding of non-linear processes and internal variability, and of system sensitivities to imposed forcing, such as fossil-fuel emissions, land use change, volcanic eruptions, and solar variability, can inform improved climate projections and scenarios. Moreover, developing ideas on emergent constraints in the system promises useful information on longer time horizons. Reducing uncertainty in model projections and climate sensitivity will provide salient information for climate change on these timeframes. This objective has the potential to support the consideration of longer-term mitigation and adaptation alternatives.

Our Scientific Emphasis

Simulation capabilities

The ongoing development of integrated Earth system models that account for the slowly varying interactions and highly non-linear processes will underpin scenarios of the long-term evolution of the climate system. Many significant challenges remain in our ability to make these projections, including, for example, the detailed representation of complex interactions between aquifers, vegetation and soil carbon, or between permafrost, glaciers, and ice sheets, as well as human activities influencing the Earth system.

Future projections of the climate system require approaches that recognize the limits of predictability of the climate system and that effectively convey associated uncertainties.

Interpretation and use of climate information presents tremendous opportunities to collaborate with civil society, governments, and private industry to safeguard lives and valued assets.

4 Bridging climate science and society

Our Goal

We will support innovation in the generation and delivery of decision-relevant information and knowledge about the evolving Earth system.

Our Scientific Emphases

Interactions with social systems

Collaborative research involving WCRP's natural sciences and the social and economic sciences of other programmes will lead to rapid advances in answering complex questions associated with the dynamics of the Earth and societal systems. Social processes have intrinsic roles in the Earth system, and human communities and institutions cannot be separated in any meaningful way from the physical, chemical and biological systems that support them.

To understand the complex interactions and feedbacks between climatic and socioeconomic systems, we will participate in collaborative research on responses to natural and human-induced forcing. New and fundamental aspects of emergent behaviors will be incorporated into a comprehensive understanding of the profoundly coupled Earth system.

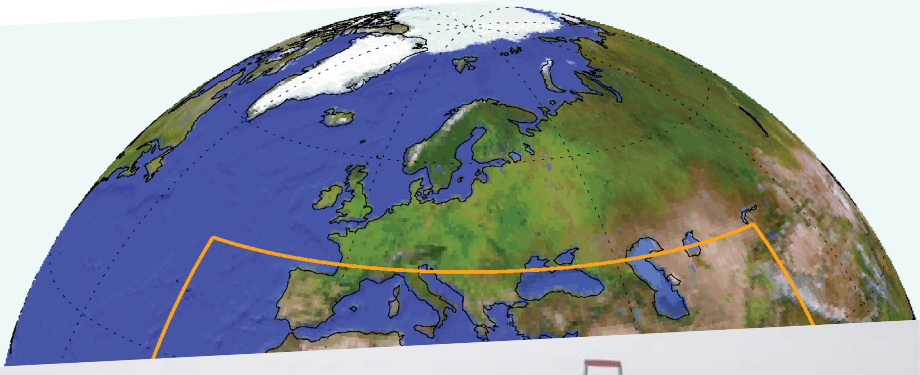
Engaging with society

A sustainable future for society presupposes a stable and amenable climate and requires salient and credible information on current and future states of the climate system. The timescales on which society requires this information range from near-term extreme events to long-range planning horizons, while spatial scales range from local to global. We will support the development of actionable climate information, scientific assessments, educational approaches, and public communication strategies that require collaborative efforts with multi-sectoral actors in all regions of the globe.

WCRP's partnerships with programmes within and beyond Future Earth will support the refinement of risk management and disaster response, economic and infrastructure planning, public communication, and education, as well as adaptation and mitigation strategies.

Critical Infrastructure

The infrastructure essential to implementing this plan in the coming decade requires commitment and investment across national and international programs, from the science community, funding agencies, and other partners. Most vital is enhanced support for a WCRP research community which embraces diversity, demands equality, and builds capacity for the future. This support must be interwoven with every implementation blueprint, every scientific activity, and every infrastructure enhancement as we take the Strategic Plan forward.



I. A hierarchy of simulation tools

We require a diversity of modeling and simulation approaches that span a range of complexity, a range of representations of processes, and a range of spatial resolutions, to drive progress and promote direct comparisons between different simulation approaches. Frameworks for model evaluation and uncertainty estimation are required, as is collaboration across model development communities. The potential for seamless and unified simulation tools, adaptive architectures, statistical methods, and machine-based learning is yet to be fully tapped. To advance support of climate services, progress will be further enhanced in dynamical and statistical downscaling tools to better represent regional and extreme phenomena.

II. Sustained observations and reference data sets

The development, collection, analysis, and archiving of multi-variate, multi-scale observations of the climate system is a foundation of climate system research. Sustained observations are needed to capture the evolving climate system. Observations are also critical to understand the climate system and to verify and improve climate simulations. We require well-coordinated international observational field and space-based programs, which have access to the most advanced sensors, platforms, and instruments. The development of synergies between disparate observing systems is critical, as is the characterization of bias and uncertainty in instruments and observational products. In addition, we require the co-design of new observations and indicators, sustained and quality-controlled climate system observational records, and the continuous improvement and timely availability of temporally consistent datasets, such as re-analyses. Common data formats, metadata requirements, and citation standards will improve the accessibility of datasets for all researchers.

III. Need for open access

To best serve stakeholders and to best advance scientific understanding, the global climate research community needs open access to scientific data (observations and model simulations), assessment products, and science results, with appropriate international standards for protecting publication rights, particularly for early career scientists and students. International standards for open access by researchers to publicly funded data collections and archives are critical. WCRP will support efforts to advance such standards and practices.

IV. High-end computing and data management

We require the technology and infrastructure to take advantage of progress in exascale computing and cloud-based systems and software. Technologies for big data, the exploitation of new hardware, improved modeling capabilities, and other computational advances are essential. Interoperable and reliable data management are also required.

Acronyms

CliC	Climate and Cryosphere (WCRP Core Project)
CLIVAR	Climate and Ocean - Variability, Predictability and Change (WCRP Core Project)
CMIP	WCRP Coupled Model Intercomparison Project
CORDEX	WCRP Coordinated Regional Climate Downscaling Experiment
ESM	Earth System Model
GAW	Global Atmosphere Watch
GCOS	Global Climate Observing System
GCP	Global Carbon Project
GEO	Group on Earth Observations
GEWEX	Global Energy and Water Exchanges (WCRP Core Project)
GFCS	Global Framework for Climate Services
GOOS	Global Ocean Observing System
FE	Future Earth
IOC	Intergovernmental Oceanographic Commission of UNESCO
IPCC	Intergovernmental Panel on Climate Change
ISC	International Science Council
KAN	Knowledge Action Network of Future Earth
SPARC	Stratosphere-troposphere Processes And their Role in Climate (WCRP Core Project)
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
WCRP	World Climate Research Programme
WMO	World Meteorological Organization
WWRP	World Weather Research Programme

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