

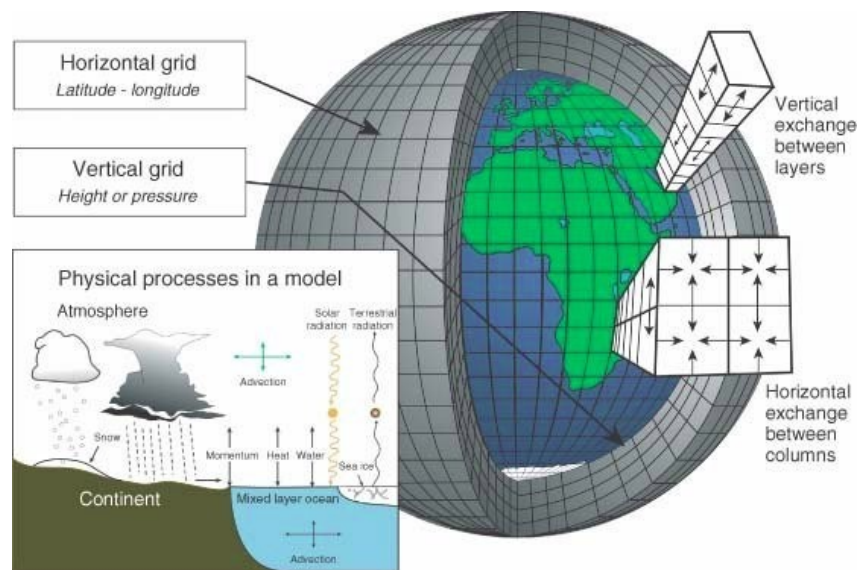
Fizyka procesów klimatycznych

Wykład 04

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Ekstremalny sposób modelowania pogody i klimatu to budowa wirtualnej planety dzięki znajomości praw fizyki:



równania hydrodynamiki
równania termodynamiki
prawa transferu radiacyjnego
własności składników atmosfery i oceanu
wymiana atmosfera-ocean-biosfera
oddziaływanie z podłożem
+ przemiany chemiczne

układ równań modelu

- * „zakłęcie” w kod numeryczny
- * uwzględnienie danych
- * wielki superkomputer

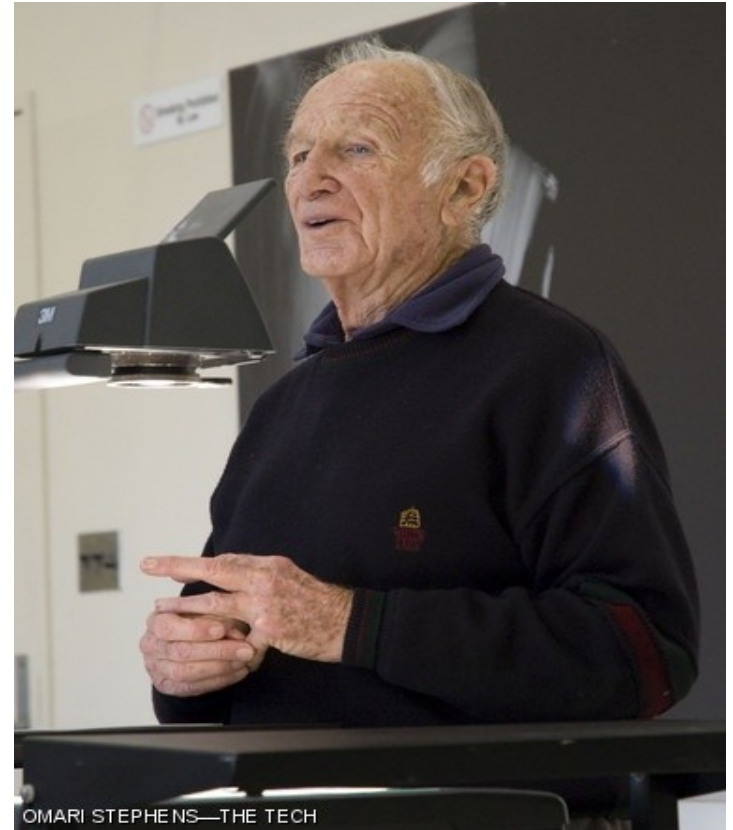
Edwards Paul N.. History of climate modeling. WIREs Clim Change
2011, 2: 128-139. doi: 10.1002/wcc.95

wirtualna rzeczywistość, w której
możemy symulować mechanizmy
klimatyczne i związki
przyczynowo-skutkowe.

Z doświadczenia wiemy, że mimo ogromnego postępu w nauce i technice prognozy numeryczne nie są doskonałe; można też udowodnić, że nie byłyby doskonałe nawet w przypadku znalezienia idealnego układu równań, opisujących procesy w atmosferze, i rozwiązania go niezwykle dokładnie.

Odkrycia tego dokonał w 1963 r. amerykański meteorolog Edward N. Lorenz.

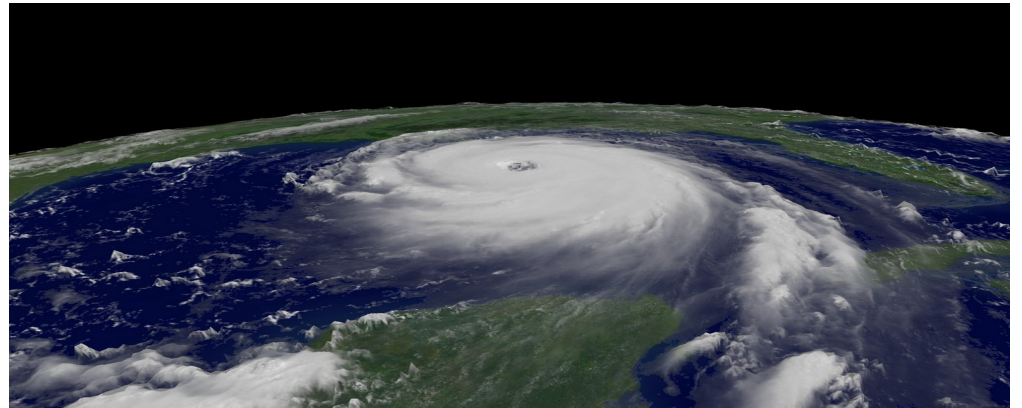
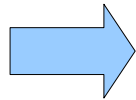
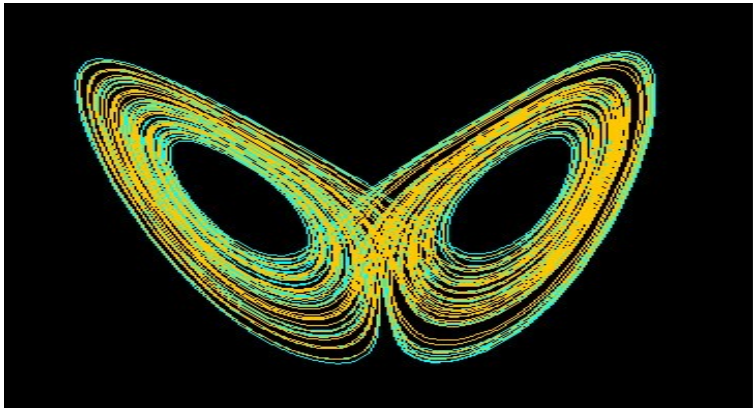
To odkrycie pozwala ulepszać prognozy w inny sposób niż przez coraz dokładniejsze przybliżenia i drobniejsze siatki.



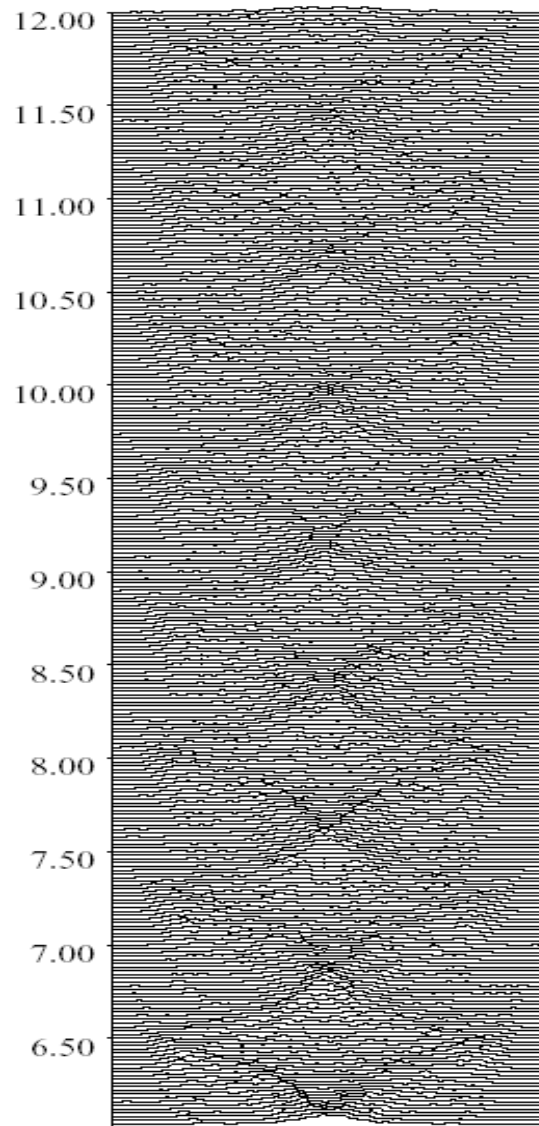
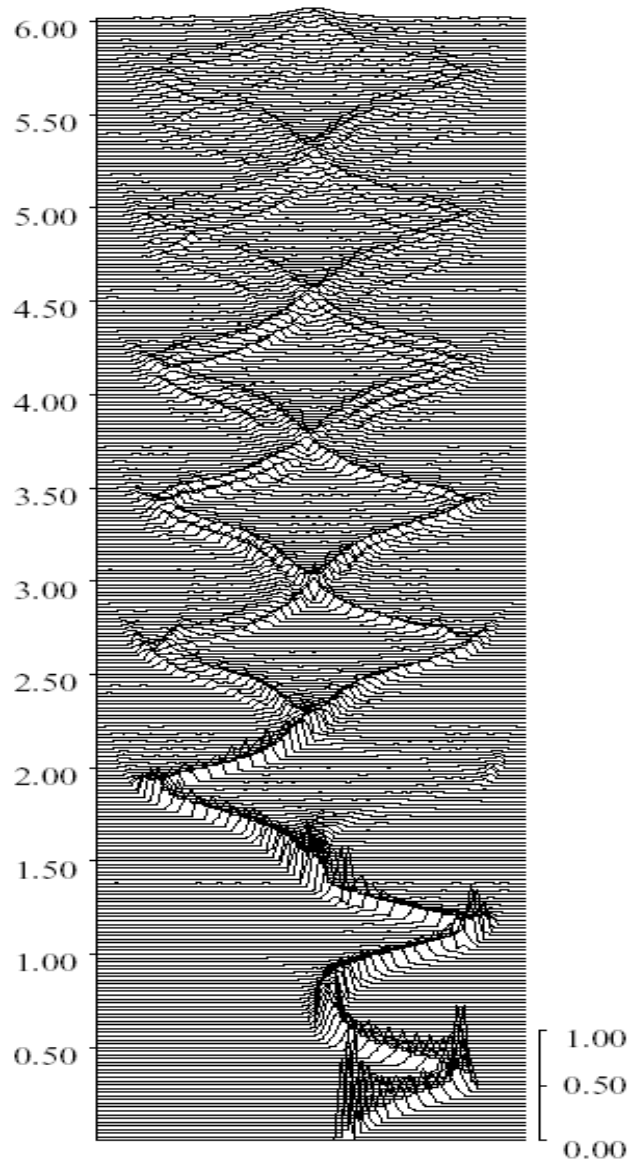
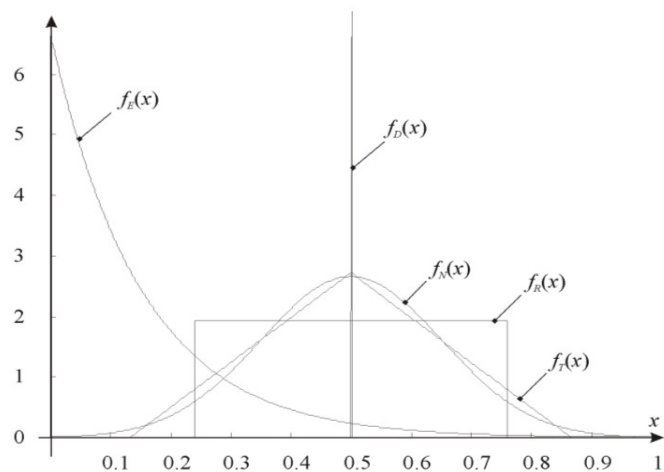
Równanie Naviera–Stokesa, które jest podstawowym równaniem dynamiki atmosfery, jest nieliniowe, co oznacza, że jego rozwiązanie (wynik obliczeń) jest najczęściej niezwykle wrażliwe na niewielkie zmiany warunku początkowego, od którego rozpoczyna się obliczenia.

Cechę tę ma też cały układ równań opisujący przepływy atmosferyczne. Innymi słowy wynik ekstrapolacji w czasie (prognoza pogody) jest bardzo czuły na dokładność, z jaką określamy początkowy stan atmosfery.

Niewielka przyczyna: fluktuacja temperatury czy wiatru, może po krótkim czasie wywołać ogromny skutek. To są najistotniejsze wnioski z odkrycia Lorenza, które sam autor na jednym z odczytów opisał poetycko: trzepot skrzydeł motyla w amazońskiej puszczy może wywołać huragan na Atlantyku.

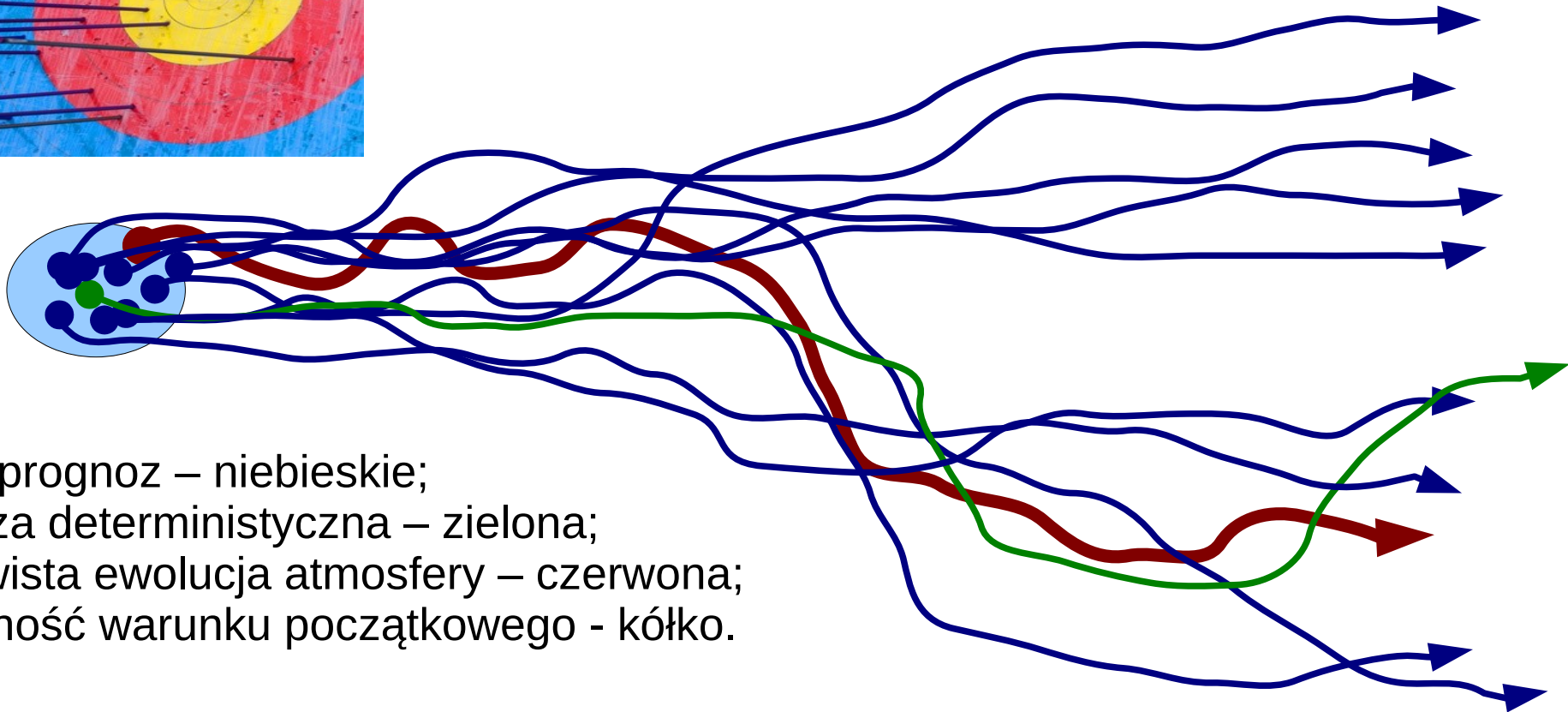


Odkrycie Lorenza
można zilustrować w
języku teorii
prawdopodobieństwa,
ściślej mówiąc
analizując tzw. rozkład
prawdopodobieństwa.

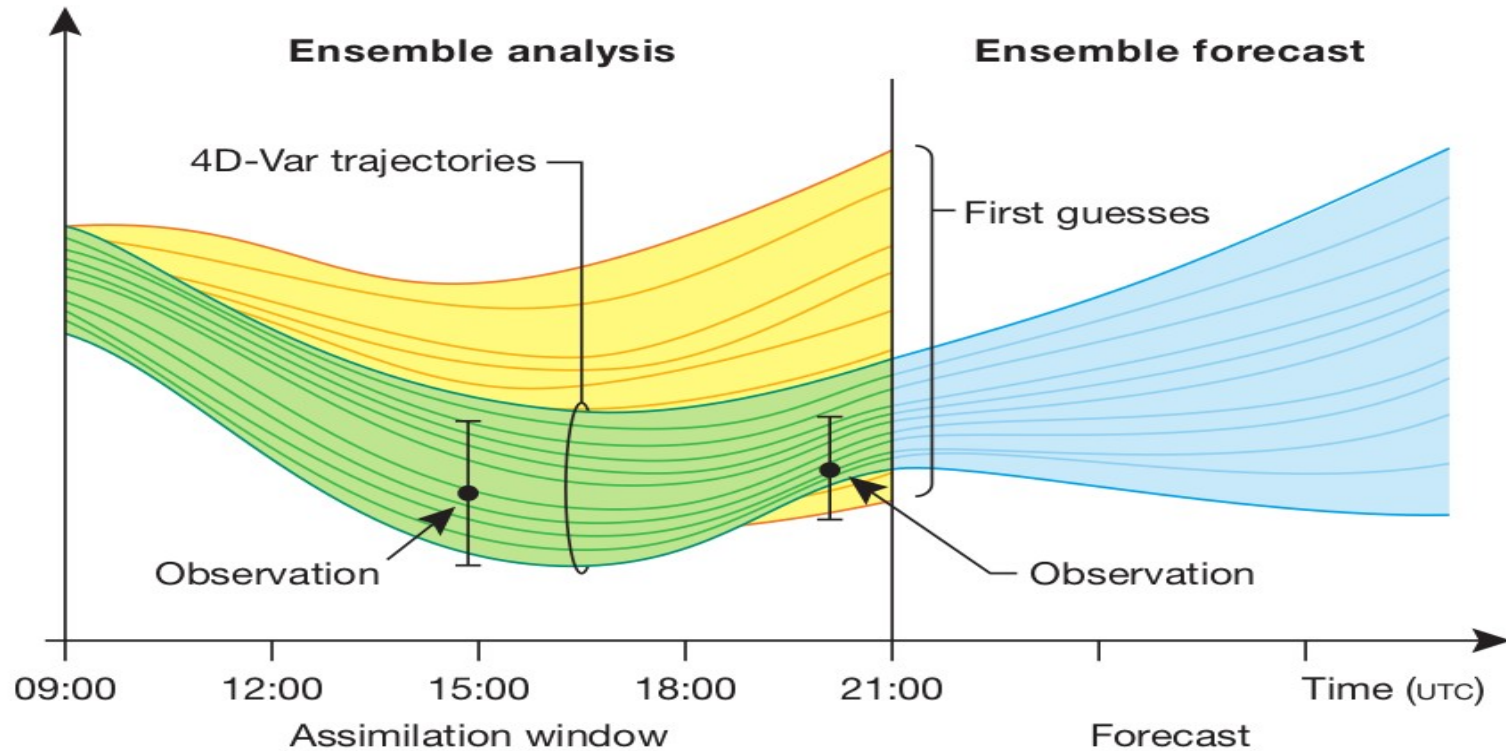


Wiązka prognoz pogody : równoległe prognozy pogody startujące z nieznacznie (w granicach błędu pomiaru) różnych warunków początkowych





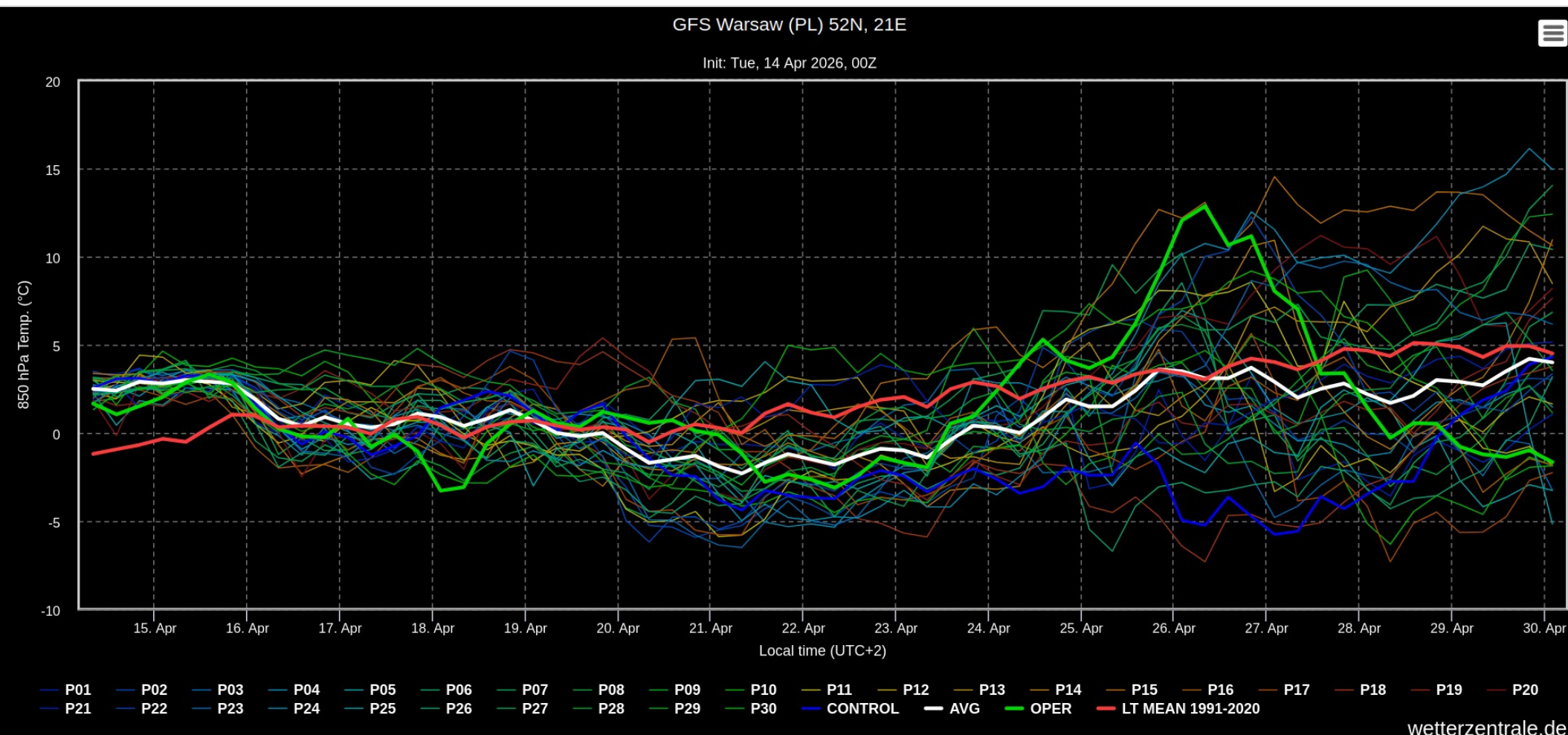
wiązka prognoz – niebieskie;
prognoza deterministyczna – zielona;
rzeczywista ewolucja atmosfery – czerwona;
niepewność warunku początkowego - kółko.



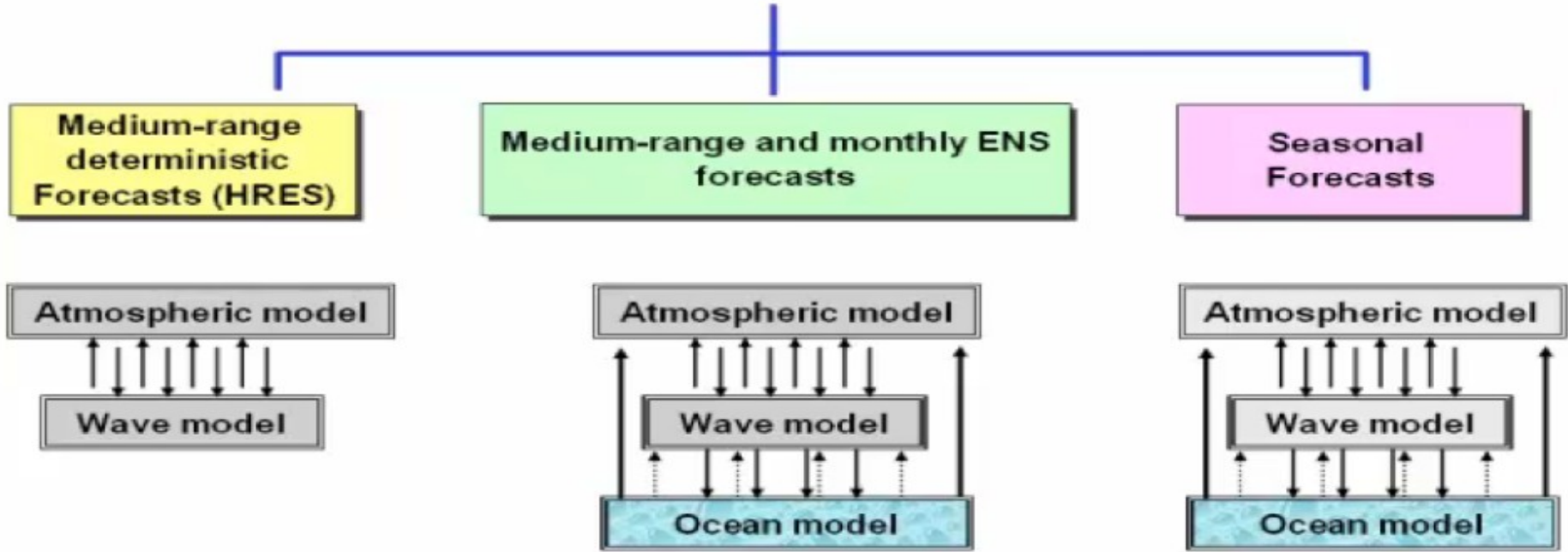
Schemat cyklu analizy i prognozy.

Poprzez minimalizację w czterech wymiarach z wykorzystaniem technik wariacyjnych, tworzone są lepsze oszacowania (trajektorie 4D-Var) są tworzone przy zmniejszonej odległości do obserwacji. Następny następny cykl prognoz ensemble jest inicjowany na podstawie tych udoskonalonych analiz.

W praktyce np. prognoza temperatury na wys. 850 hPa może wyglądać tak:



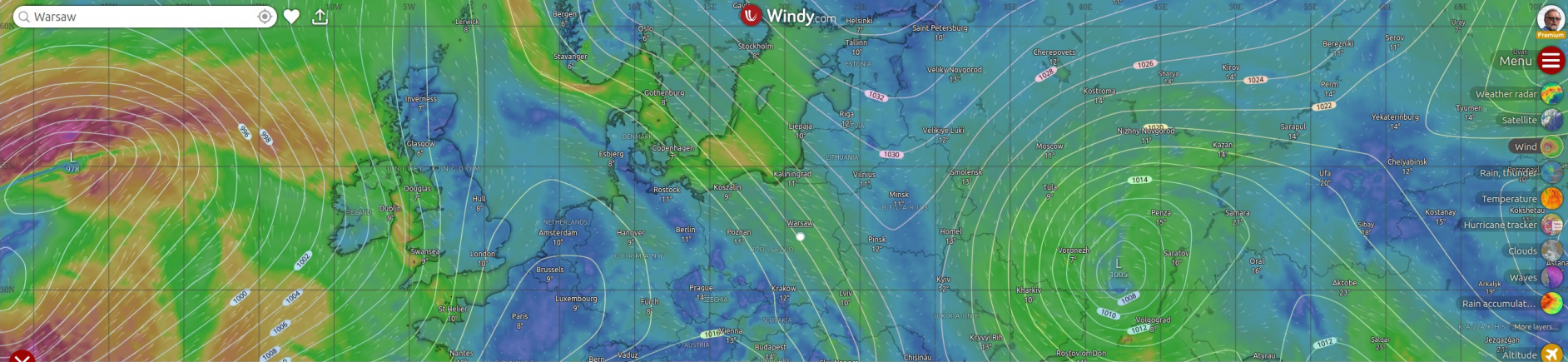
ECMWF forecasting system



Resolution

Resolutions in bold increased/changed from the previous operational IFS cycle.

	Component	Horizontal resolution		Vertical resolution [levels]
Atmosphere	HRES	O1280	~9 km	137
	ENS	O1280	~9 km	137
	ENS sub-seasonal (previously 'extended')	O320	~36 km	137
Wave	HRES-WAM	O1280	~9 km	-
	ENS-WAM	O1280	~9 km	-
	ENS-WAM sub-seasonal (previously 'extended')	O320	~36 km	-
Ocean (NEMO 3.4)	All components	0.25° ORCA	~28 km	75



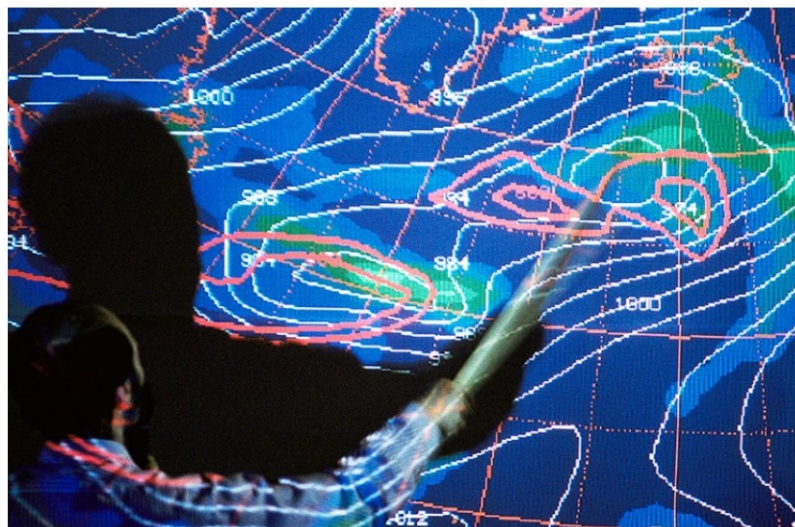
Compare forecasts Warsaw

	Tuesday 14	Wednesday 15	Thursday 16	Friday 17	Saturday 18	Sunday 19	Monday 20	Tuesday 21	Wednesday 22	Thursday 23																																																		
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DeepMind AI accurately forecasts weather – on a desktop computer

The machine-learning model takes less than a minute to predict future weather worldwide more precisely than other approaches.

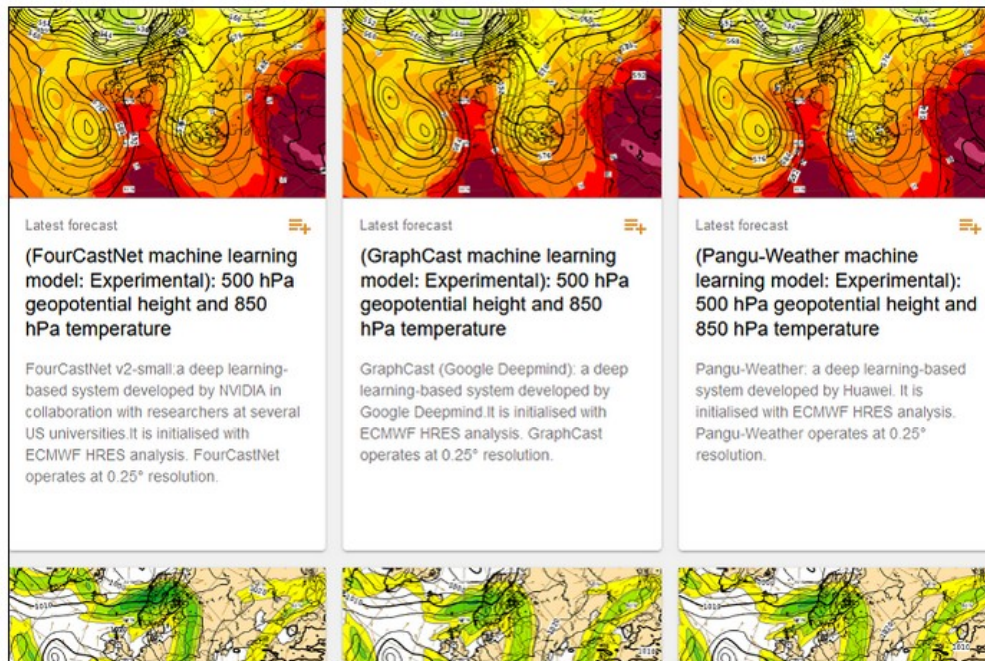
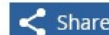
By [Carissa Wong](#)



Conventional weather forecasts are the result of intensive processing of data from weather stations around the world. Credit: Carlos Munoz Yague/Look At Science/Science Photo Library

How AI models are transforming weather forecasting: a showcase of data-driven systems

6 September 2023



Developments in machine learning are continuing at breathtaking pace, both inside and outside of weather forecasting. To help assess machine learning weather forecasts from different sources, we now show a range of them in [ECMWF's charts catalogue](#).

We are also exploring the use of machine learning models to produce [ensemble forecasts](#), which present the range of future weather possibilities.

Edward N. Lorenz (1917-2008) pokazał co to znaczy przewidywalność (ang. predictability) układu fizycznego.

„Deterministic nonperiodic flow”, 1963 (atraktor Lorenza, efekt motyla)

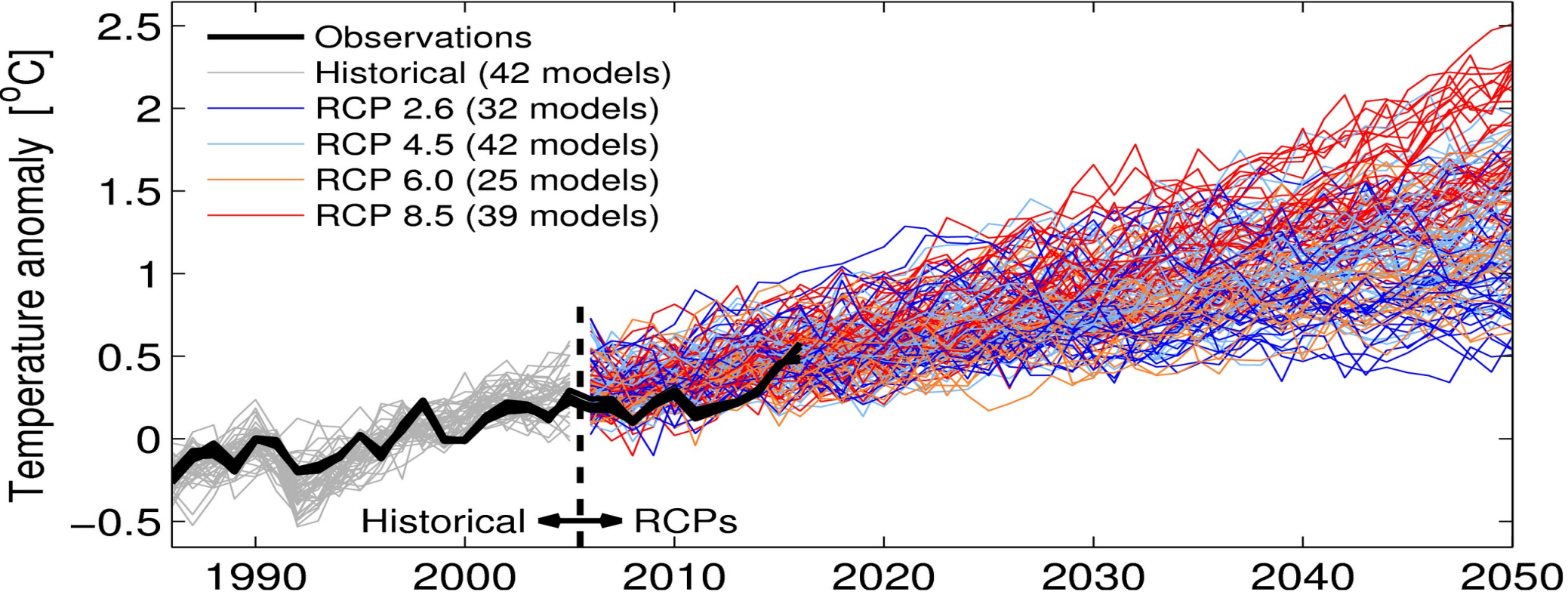
„The problem of deducing the climate from the governing equations”, 1964 (rozdzielenie między brakiem przewidywalności ze względu na nieznaną wartość stanu początkowego układu i ze względu na niepełną znajomość fizyki – równań – układu)

„Climatic change as a mathematical problem”, 1970 (nieprzewidywalność pogody -chaos- nie znaczy że klimat jest nieprzewidywalny)

„Predictability – a problem partly solved”, 2006 (bez komentarza :)

Przewidywalność klimatu: symulacje różnymi modelami

Global mean temperature near-term projections relative to 1986–2005



**Boundary
value problem**

Initial value problem



szczegóły przepływów
procesy „szybkie”

- bilans energii
- procesy „wolne”

oddziaływania między procesami lokalnymi i szybkimi
a globalnymi i wolnymi

Prognoza pogody:

prognoza pojedynczej realizacji procesu dynamiczno-stochastycznego, lub prognoza empirycznego rozkładu prawdopodobieństwa różnych realizacji.

Prognoza klimatu:

prognoza pewnych quasi-równowagowych statystyk realizacji procesów dynamiczno-stochastycznych przy ustalonych wymuszeniach zewnętrznych w stosunku do systemu klimatycznego.

Na granicy pogody i klimatu: reanaliza danych meteorologicznych. Asymilacja wszystkich danych meteorologicznych od 1940 roku do modeli globalnego o wyprodukowaniu a stani atmosfery zgodnego z obserwacjami i modelem co godzinę w każdym oczku siatki.

ERA5 hourly data on single levels from 1940 to present

Overview

Download

Documentation

Info

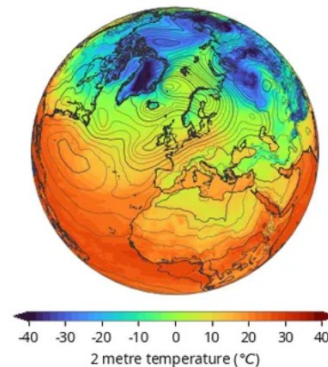
11 Dec 2025

Please note that a dedicated catalogue entry for this dataset, post-processed and stored in Analysis Ready Cloud Optimized (ARCO) format (Zarr), is available for optimised time-series retrievals (i.e. for retrieving data from selected variables for a single point over an extended period of time in an efficient way). You can discover it [here](#)

ERA5 is the fifth generation ECMWF reanalysis for the global climate and weather for the past 8 decades. Data is available from 1940 onwards. ERA5 replaces the ERA-Interim reanalysis.

Reanalysis combines model data with observations from across the world into a globally complete and consistent dataset using the laws of physics. This principle, called data assimilation, is based on the method used by numerical weather prediction centres, where every so many hours (12 hours at ECMWF) a previous forecast is combined with newly available observations in an optimal way to produce a new best estimate of the state of the atmosphere, called analysis, from which an updated, improved forecast is issued. Reanalysis works in the same way, but at reduced resolution to allow for the provision of a dataset spanning back several decades. Reanalysis does not have the constraint of issuing timely forecasts, so there is more time to collect observations, and when going further back in time, to allow for the ingestion of improved versions of the original observations, which all benefit the quality of the reanalysis product.

ERA5 2 metre temperature and Mean sea level pressure
1 January 2023 at 00:00 UTC



References

[Citation and attribution](#)

DOI: [10.24381/cds.adbb2d47](https://doi.org/10.24381/cds.adbb2d47)

Licence

[CC-BY licence](#)



Open-source tools for Earth sciences

[Dataset sample viewer](#)

[Launch example in JupyterHub](#)

Publication date

2018-06-14

Update date

2026-04-14

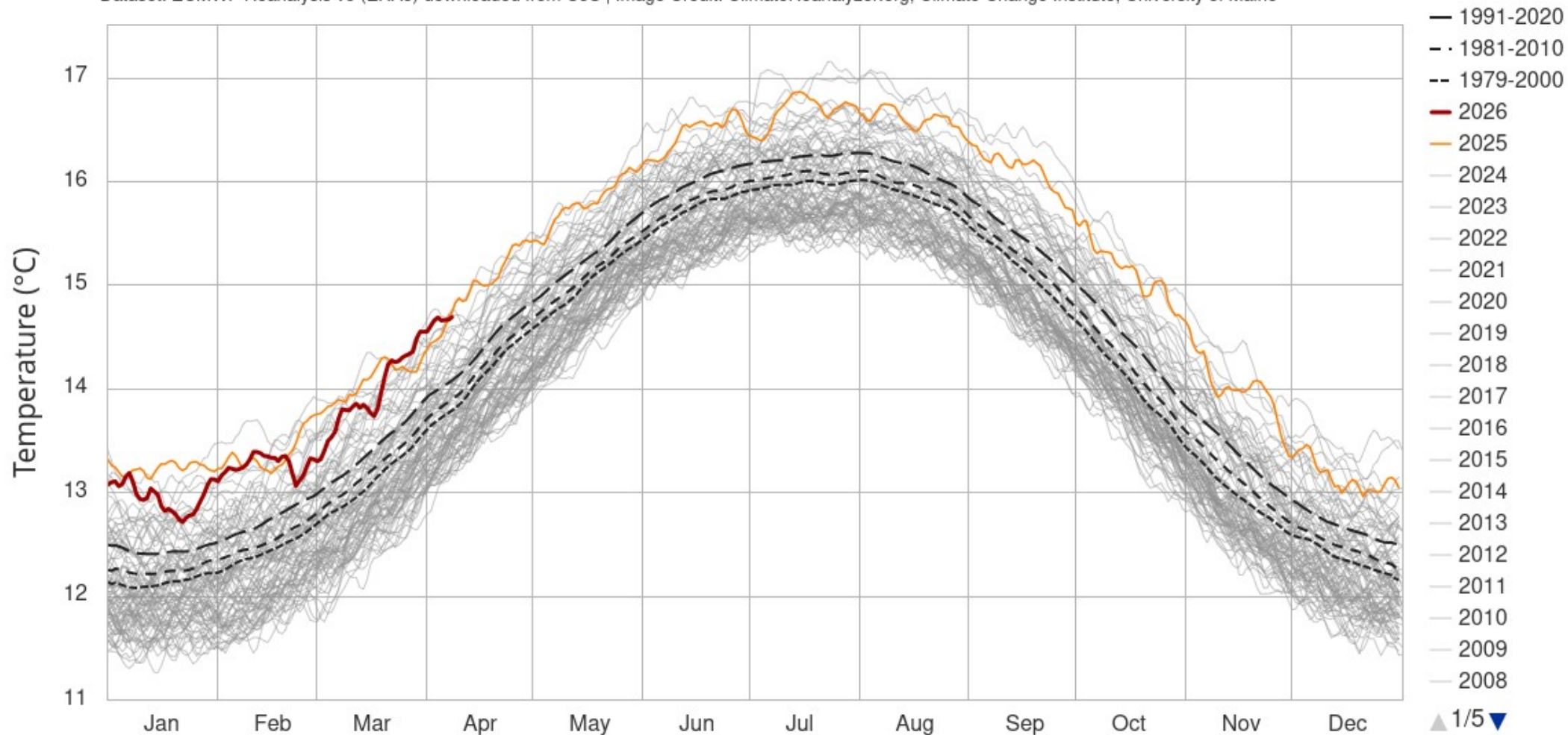
Standard metadata

[STAC](#) [↗](#)

[CSW](#) [↗](#)

Daily Surface Air Temperature, World (90°S–90°N, 0–360°E)

Dataset: ECMWF Reanalysis v5 (ERA5) downloaded from C3S | Image Credit: ClimateReanalyzer.org, Climate Change Institute, University of Maine



Ewaluacja modeli klimatu.

Wiązka symulacji przebiegu anomalii temperatury globalnej w XX wieku.

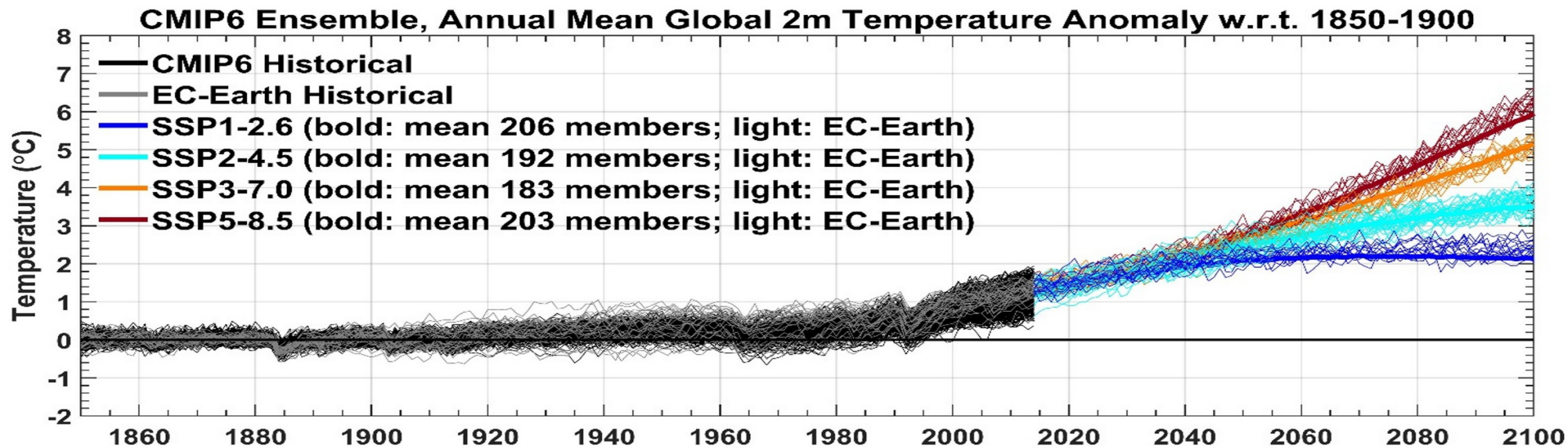
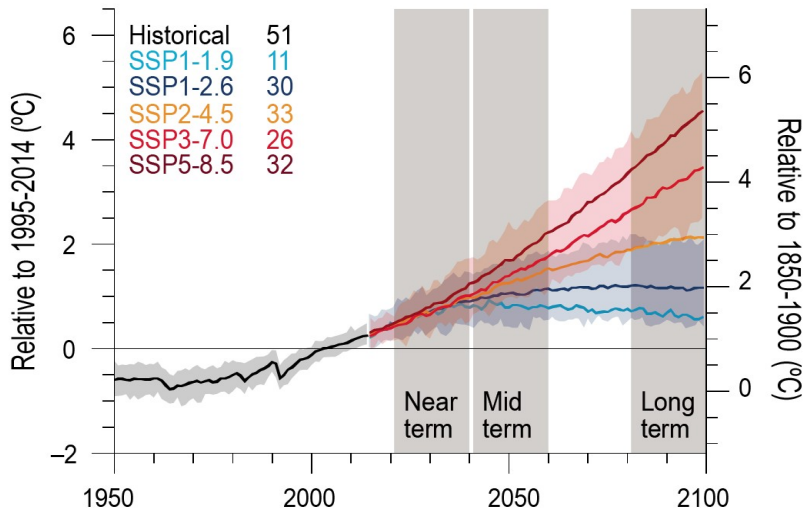
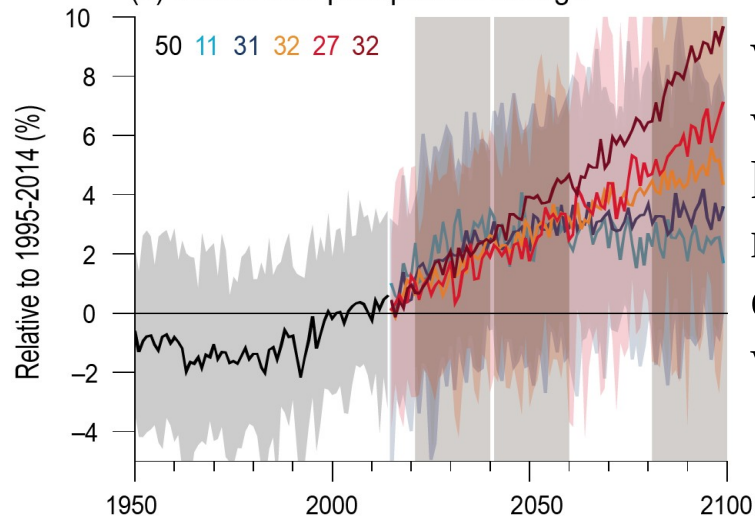


Figure 1. The CMIP6 global annual 2m temperature anomaly with respect to the 50-year mean 1850-1900. The EC-Earth ensemble members are presented alongside the CMIP6 mean to assess where the EC-Earth simulations fit within the full CMIP6 ensemble.

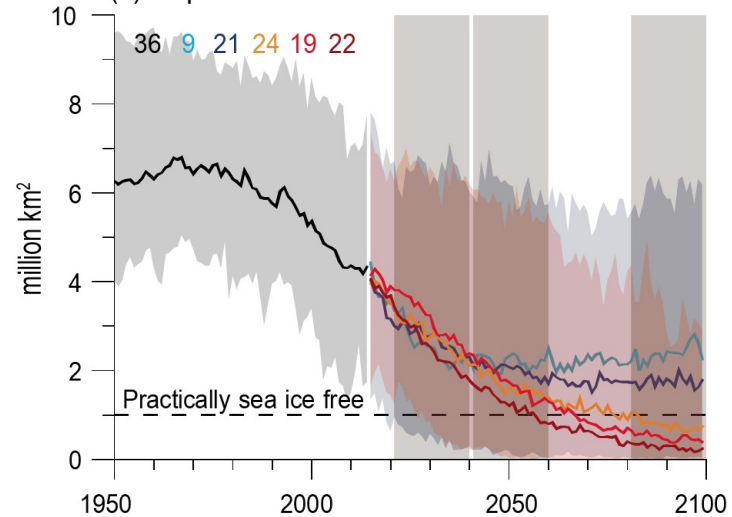
(a) Global temperature change



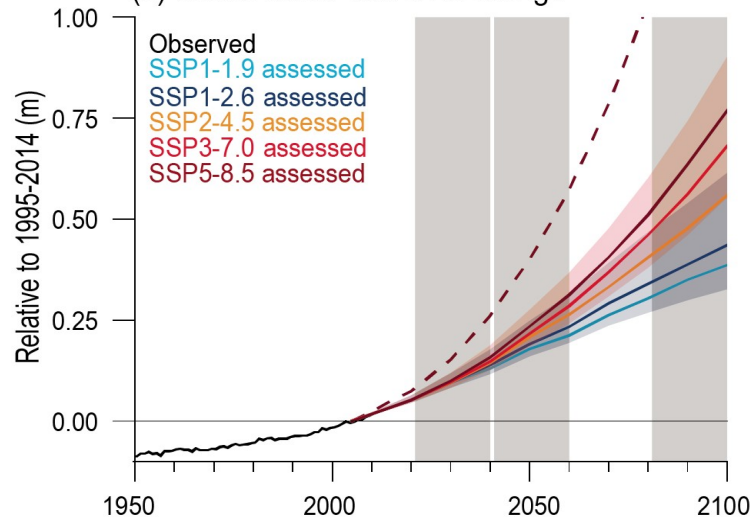
(b) Global land precipitation change



(c) September Arctic sea ice area



(d) Global mean sea level change



Wielomodelowe
wiązki projekcji
klimatu –
niepewność
odpowiedzi na
warunki graniczne

Prognoza pogody:

zależność od warunku początkowego, krytycznie ważna
możliwość śledzenia rozwoju pojedynczych niestabilności
w systemie, krytycznie ważne szczegóły dynamiki.

Prognoza klimatu:

badanie statystyki zachowań układu, krytycznie ważne
strumienie energii i spełnienie zasad zachowania w długim
czasie (warunki brzegowe).

CMIP Overview

On this Page

[What is CMIP?](#)

[History](#)

[CMIP Data](#)

CMIP is a project of the World Climate Research Programme (WCRP). Members of the [CMIP Core Panel](#) are currently working on developing the design of CMIP phase 7 (CMIP7). [Task teams](#) have been created to bring in expertise from across the climate science community, each tackling a different aspect of the design. [Click here](#) for updates on CMIP7 and for the pages on the [CMIP7 task teams](#). The data output for CMIP phase 6 (CMIP6) is available on the Earth System Grid Federation (ESGF). For more information on CMIP6, [click here](#).

What is CMIP?

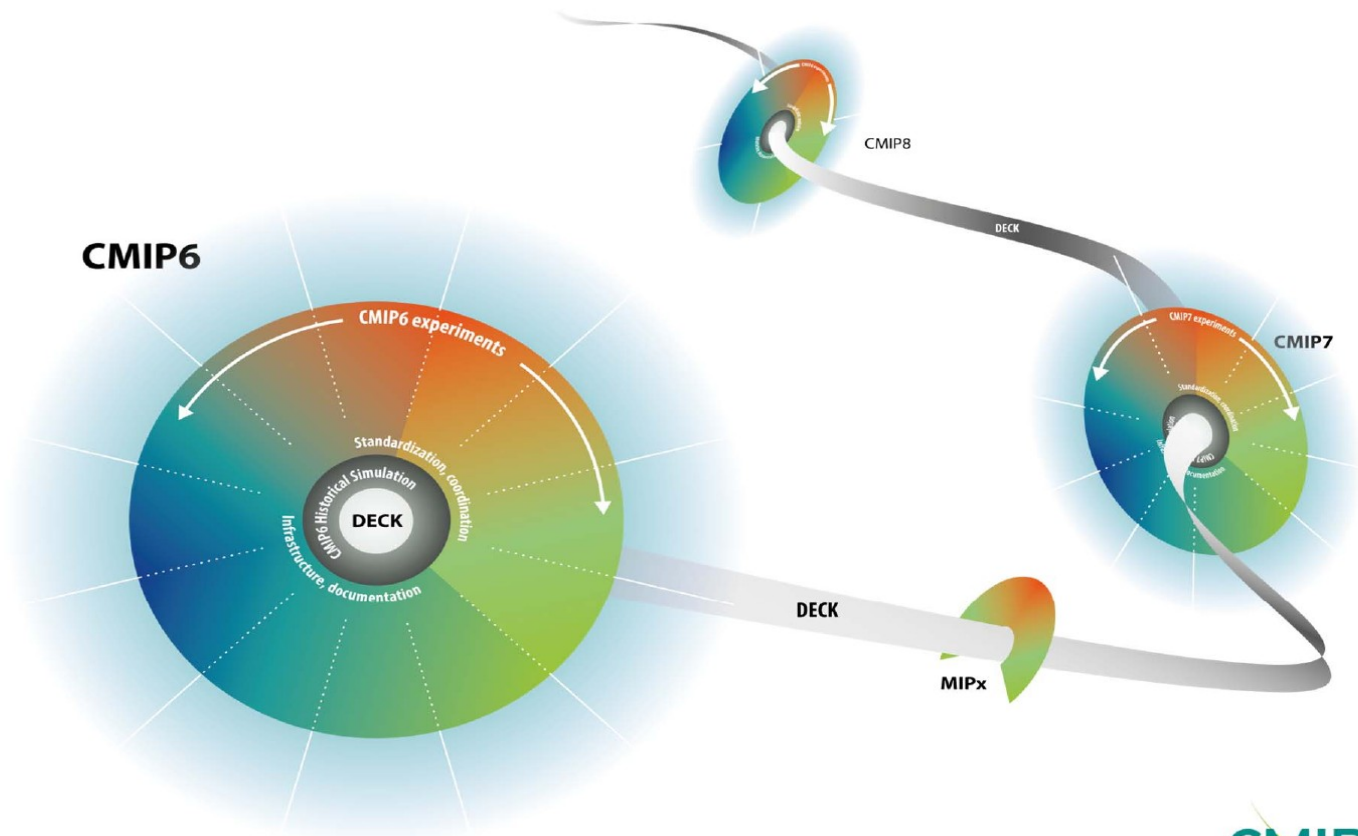
The Coupled Model Intercomparison Project (CMIP) is an international climate modelling project, designed to better understand past, present and future changes in the climate. A climate model is a complex computer code that creates a digital analogue to Earth. This model digitises the processes and interactions between parts of Earth's climate system: the atmosphere, ocean, land surface, cryosphere and biosphere. We use models to experiment how future changes in human activities will impact the Earth's future climate, how much it warms, how floods, droughts and other extremes will change. However, many processes in our climate occur on such small scales, that models are not able to exactly represent them in models, and therefore some simplifications are required. How we simplify the climate system is unique to each model. Therefore comparing simulations from different models is useful for understanding which results are consistent across models, and which results are less agreed upon. Since 1995, CMIP has been coordinating this model intercomparison across the climate science community. This multi-model approach helps to evaluate climate models, leads to improvements in the model simulations and provides a better understanding of past, present and future climates. One additional strength of CMIP lies in its global infrastructure which has gathered the data and gives open access for a growing global research community. CMIP has grown from a modest scientific research initiative in the early nineties to become a global enterprise: more than 50 modelling centres around the world are participating in the sixth phase of CMIP, CMIP6. Many hundreds of scientific papers have already been published and the results are taken into account for policy decisions. CMIP has been organised in different phases, each with new and improved climate model experiment protocols, standards, and data distribution mechanisms. [CMIP6](#) is the most recent phase to release its modelling output data for general use, whilst the latest phase, [CMIP7](#) is in its earliest organisational stages. CMIP is a project of the World Climate Research Programme (WCRP), providing climate projections to understand past, present, and future climate changes. It is part of the WCRP Earth System Modelling and Observations (ESMO) Core Project, which was formed to coordinate all modelling, data, and observation activities across WCRP and its key partners. Under the guidance and at the direction of the [Working Group on Coupled Modelling \(WGCM\)](#), CMIP activities are overseen by a coordinated pair of subcommittees: the [CMIP Panel](#) and the [WGCM Infrastructure Panel \(WIP\)](#). This continued collaboration of climate scientists has resulted in CMIP knowledge being extended across the world. As such, this website brings this together to provide a one-stop shop for key resources, events, news, and information for the CMIP community. If there is any information you cannot find on these webpages, please see our [FAQs](#) and [community-led Q&A forum](#).



On this Page ↑

CMIP Continuity

A common suite of experiments for each phase of CMIP provides an opportunity to construct a multi-model ensemble using model output from various phases of CMIP



Dostęp do wyników symulacji modelami klimatu jest otwarty

CMIP - Overview - Mozilla Firefox

Instytut Geofizyki - Akt... CESM Models | CCSM4. MIT Integrated Framev MITgcm Wetter : Wetterzentral CMIP - Overview

cmip-pcmdi.llnl.gov zgodność

PCMDI - Program For Climate Model Diagnosis and Intercomparison PCMDI Home CAPT AMIP SMIP PMIP APE Contact

Denmark Norway Japan United Kingdom Italy
Russia S. Korea Germany France
The Netherlands China Canada
USA
Australia

CMIP Coupled Model Intercomparison Project
WCRP World Climate Research Programme

Home News CMIP3 CMIP5 Accomplishments Links Contact RSS

Home Overview

CMIP - Coupled Model Intercomparison Project - Overview

Under the [World Climate Research Programme \(WCRP\)](#) the [Working Group on Coupled Modelling \(WGCM\)](#) established the Coupled Model Intercomparison Project (CMIP) as a standard experimental protocol for studying the output of coupled atmosphere-ocean general circulation models (AOGCMs). CMIP provides a community-based infrastructure in support of climate model diagnosis, validation, intercomparison, documentation and data access. This framework enables a diverse community of scientists to analyze GCMs in a systematic fashion, a process which serves to facilitate model improvement. Virtually the entire international climate modeling community has participated in this project since its inception in 1995. The [Program for Climate Model Diagnosis and Intercomparison \(PCMDI\)](#) archives much of the CMIP data and provides other support for CMIP. PCMDI's CMIP effort is funded by the [Regional and Global Climate Modeling \(RGCM\)](#) Program of the [Climate and Environmental Sciences Division](#) of the U.S. Department of Energy's Office of Science, [Biological and Environmental Research \(BER\)](#) program.

Coupled atmosphere-ocean general circulation models allow the simulated climate to adjust to changes in climate forcing, such as increasing atmospheric carbon dioxide. CMIP began in 1995 by collecting output from model "control runs" in which climate forcing is held constant. Later versions of CMIP have collected output from an idealized scenario of global warming, with atmospheric CO₂ increasing at the rate of 1% per year until it doubles at about Year 70. CMIP output is available for study by approved diagnostic sub-projects.

Phase three of CMIP ([CMIP3](#)) included "realistic" scenarios for both past and present climate forcing. The research based on this dataset provided much of the new material underlying the [Intergovernmental Panel on Climate Change \(IPCC\)](#) Fourth Assessment Report (AR4).

Current Intercomparison - CMIP5

We are now beginning the process towards the IPCC Fifth Assessment Report and with it the [CMIP5](#) intercomparison activity. The CMIP5 (CMIP Phase 5) experiment design has been finalized with the following suites of experiments:

- I Decadal Hindcasts and Predictions simulations,
- II "long-term" simulations,
- III "atmosphere-only" (prescribed SST) simulations for especially computationally-demanding models.

Click on [CMIP5](#) tab to enter CMIP5 designated web-page

Coupled Model Intercomparison Project (CMIP)

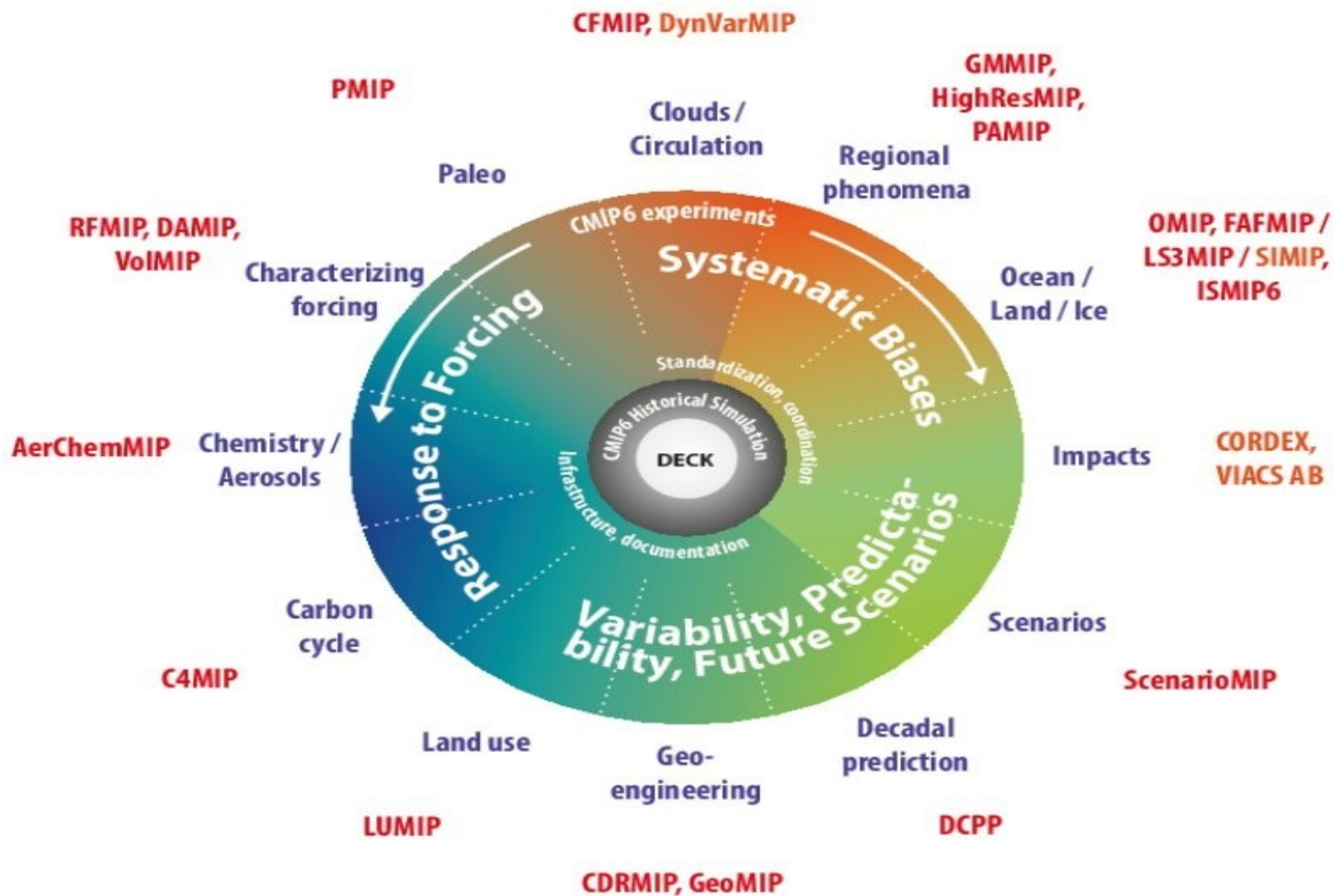
- Understanding past, present and future climate -

- CMIP is a project of the World Climate Research Programme (**WCRP**)'s Working Group of Coupled Modelling (**WGCM**).
- Since 1995, **CMIP** has coordinated climate model experiments involving multiple international modeling teams worldwide.
- CMIP has led to a better understanding of past, present and future climate change and variability in a **multi-model framework**.
- CMIP defines **common experiment protocols, forcings and output**.
- CMIP has developed in phases, with the simulations of the fifth phase, CMIP5, now completed, and the planning of the sixth phase, i.e. CMIP6, well underway.
- CMIP's central goal is to advance scientific understanding of the Earth system.
- CMIP model simulations have also been regularly assessed as part of the IPCC Climate Assessments Reports and various national assessments.

CMIP6 Design: Scientific Focus

- The **scientific backdrop** for CMIP6 is the **WCRP Grand Science Challenges**:
 1. Clouds, Circulation and Climate Sensitivity
 2. Changes in Cryosphere
 3. Climate Extremes
 4. Regional Sea-level Rise
 5. Water Availability
 6. Near-Term Climate Prediction
 7. Biogeochemical Cycles and Climate Change
- The specific experimental design is focused on **three broad scientific questions**:
 1. How does the Earth System respond to forcing?
 2. What are the origins and consequences of systematic model biases?
 3. How can we assess future climate changes given climate variability, predictability and uncertainties in scenarios?

23 CMIP6-Endorsed MIPs



CMIP6: Participating Model Groups

	Institution	Country		Institution	Country		Institution	Country
1	AWI	Germany	12	DOE	USA	23	MRI	Japan
2	BCC	China	13	EC-Earth-Cons	Europe	24	NASA-GISS	USA
3	BNU	China	14	FGOALS	China	25	NCAR	USA
4	CAMS	China	15	FIO-RONM	China	26	NCC	Norway
5	CasESM	China	16	INM	Russia	27	NERC	UK
6	CCCma	Canada	17	INPE	Brazil	28	NIMS-KMA	Republic of Korea
7	CCCR-IITM	India	18	IPSL	France	29	NOAA-GFDL	USA
8	CMCC	Italy	19	MESSY-Cons	Germany	30	NUIST	China
9	CNRM	France	20	MIROC	Japan	31	TaiESM	Taiwan, China
10	CSIR-CSIRO	South Africa	21	MOHC	UK	32	THU	China
11	CSIRO-BOM	Australia	22	MPI-M	Germany	33	Seoul Nat.Uni	Republic of Korea

New in CMIP:

- 2 new model groups from Germany (AWI, MESSY-Consortium)
- 4 new model groups from China (CAMS, CasESM, NUIST, THU)
- 1 new model group from Brazil (INPE)
- 1 new model group from India (CCCR-IITM)
- 1 new model group from Taiwan, China (TaiESM)
- 1 new model group from USA (DOE)
- 2 new model group from Republic of Korea (NIMS-KMA, SAM0-UNICON)
- 1 new model group from South Africa / Australia (CSIR-CSIRO)

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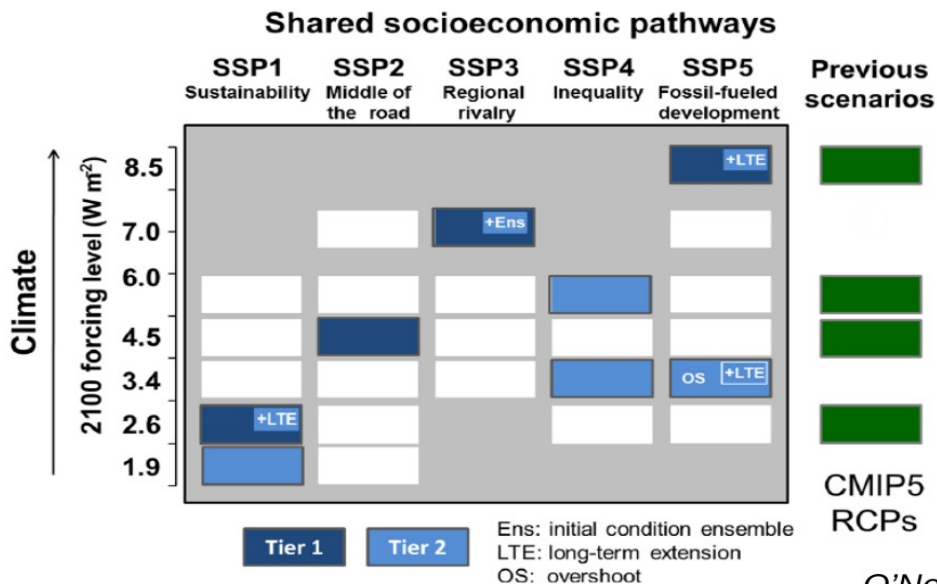
⇒ **13 new model groups so far**

* Other models can join providing DECK and historical simulations are submitted

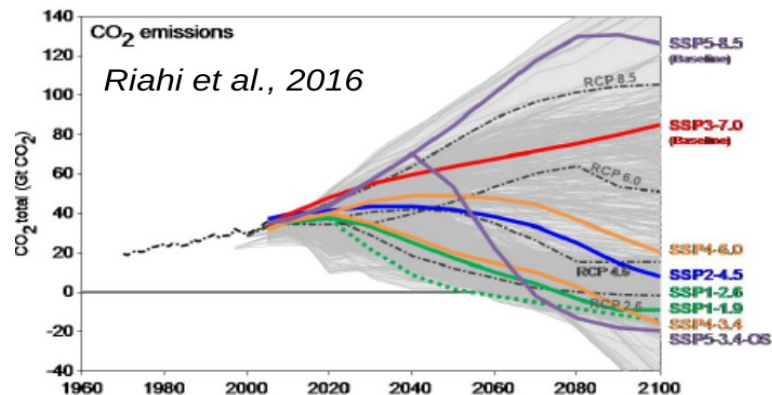
More models (>70)
 New models
 More complex models
 Higher resolution models

Key Messages: Model Projections / Predictions (2)

SSPs: set of baselines, with future developments in absence of new climate policies beyond those in place today



Future in CMIP6: 2015-2100 plus Extensions to 2300

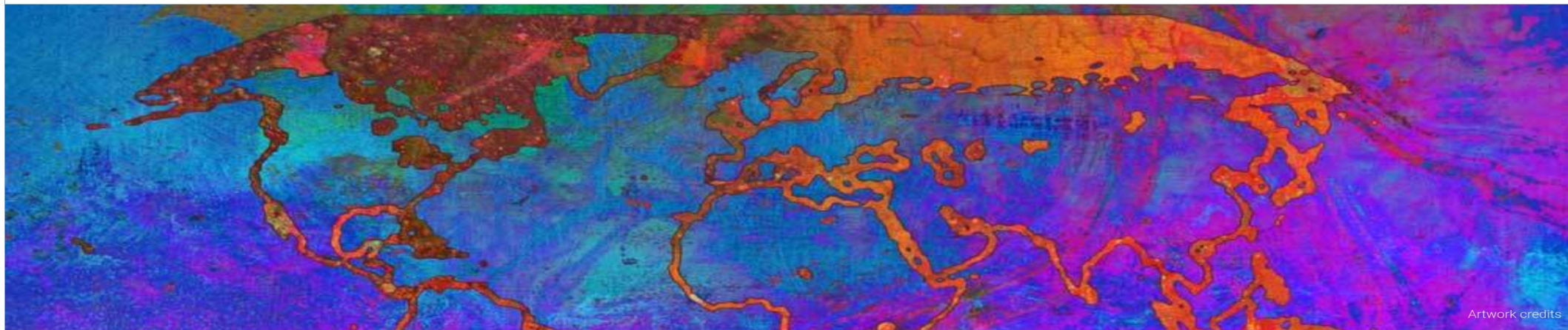


O'Neill et al., ScenarioMIP for CMIP6, GMD, 2016

ScenarioMIP: New scenarios span a similar range as the RCPs, but fill critical gaps, including

- Role of specific forcings such as land use and short-lived species (air quality)
- The effect of a peak and decline in forcing,
- The consequences of scenarios that limit warming to below 2 °C,

DCPP: Improvements in models, reanalysis, methods of initialization and ensemble generation, and data analysis will provide extended comprehensive decadal predictions



Artwork credits

Climate Change 2021: The Physical Science Basis

The Working Group I contribution to the Sixth Assessment Report addresses the most up-to-date physical understanding of the climate system and climate change, bringing together the latest advances in climate science.

Summary for Policymakers

The Summary for Policymakers provides a high-level summary of the current state of the climate, how it is changing, the role of human influence, and possible climate futures.

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Technical Summary

The Technical Summary provides a synthesis of the key findings of the Report and serves as a bridge between the Summary for Policymakers and the chapters of the full report.

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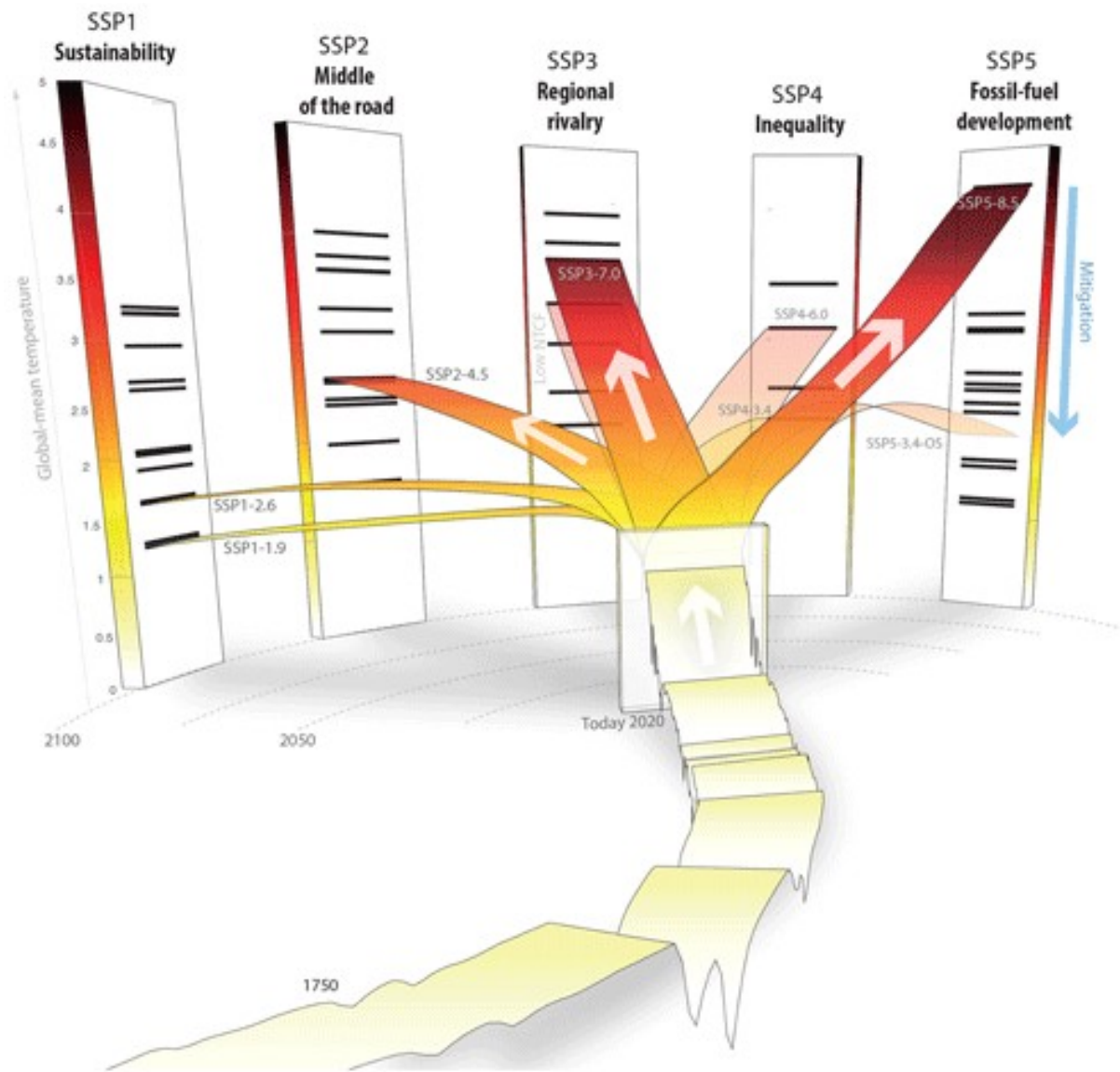
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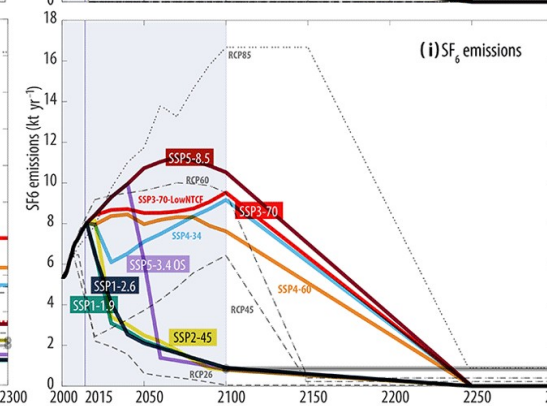
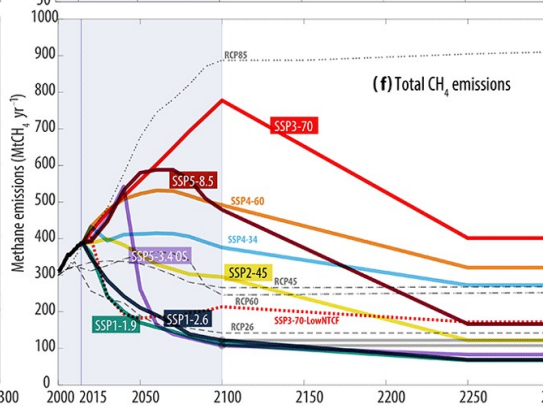
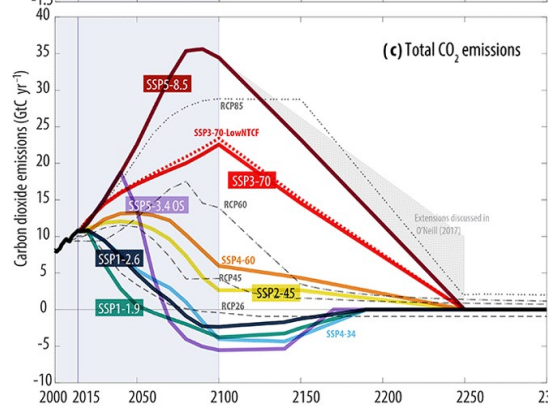
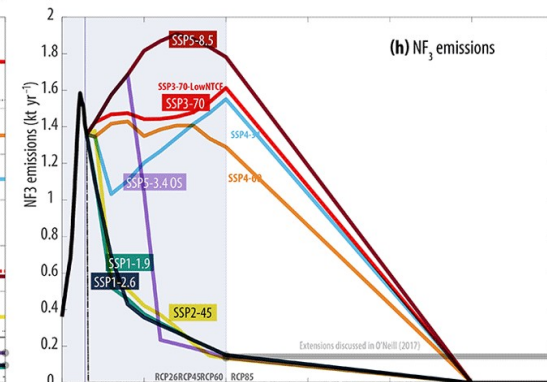
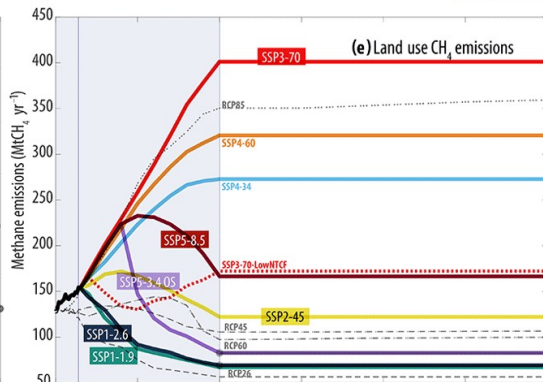
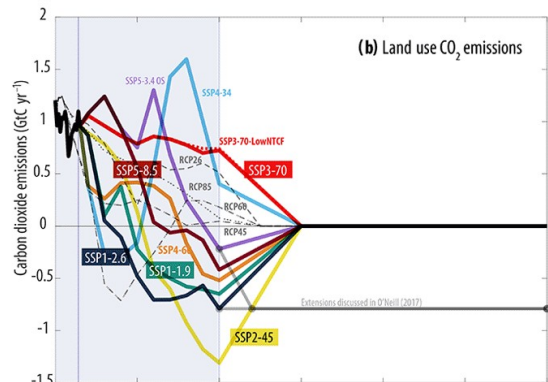
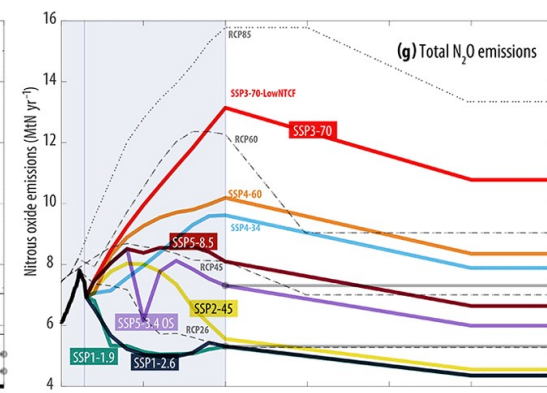
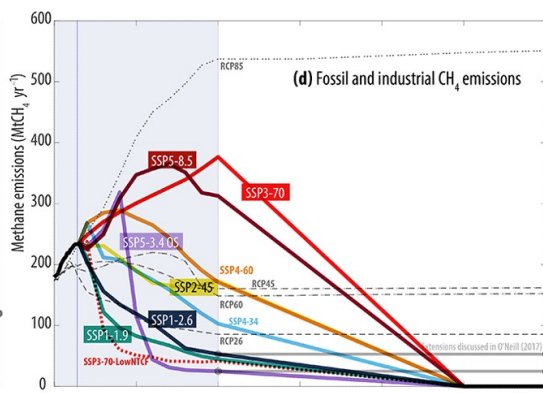
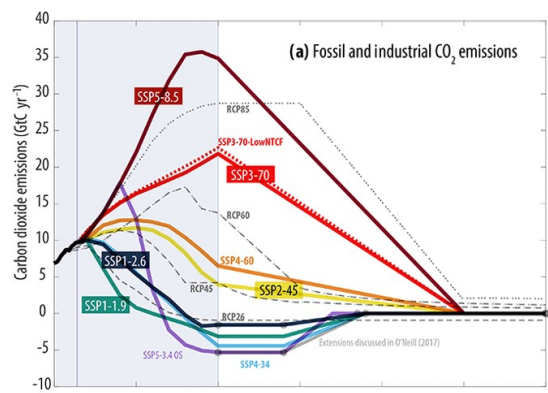
[FIGURES](#)

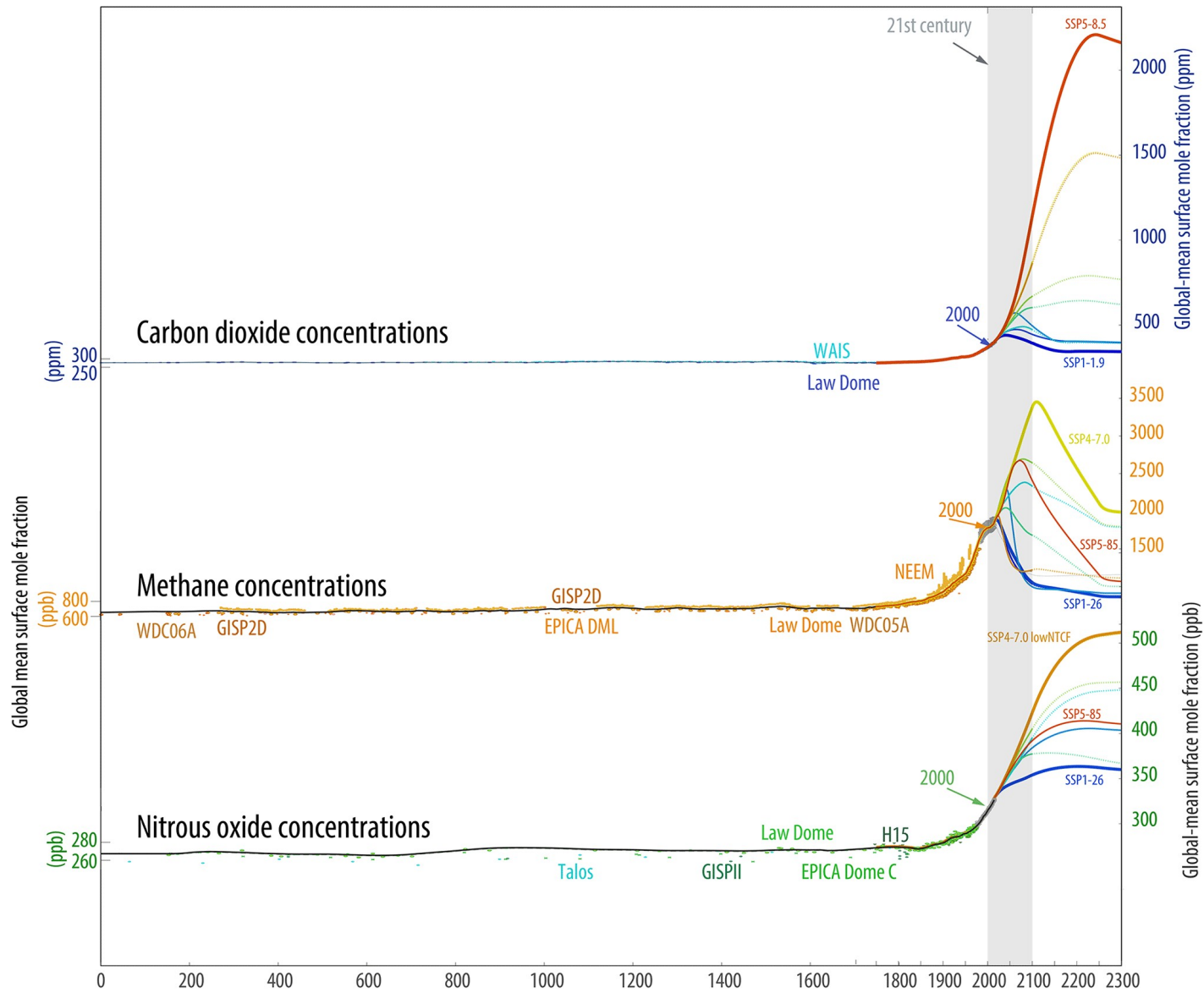
Full Report

The 13 chapters of the Working Group I report provide a comprehensive assessment of the current evidence on the physical science of climate change.

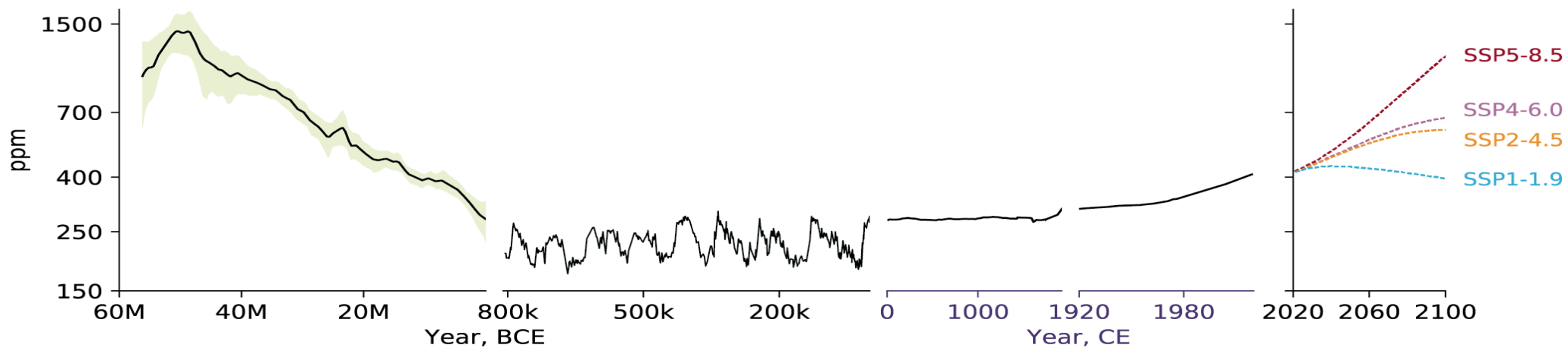
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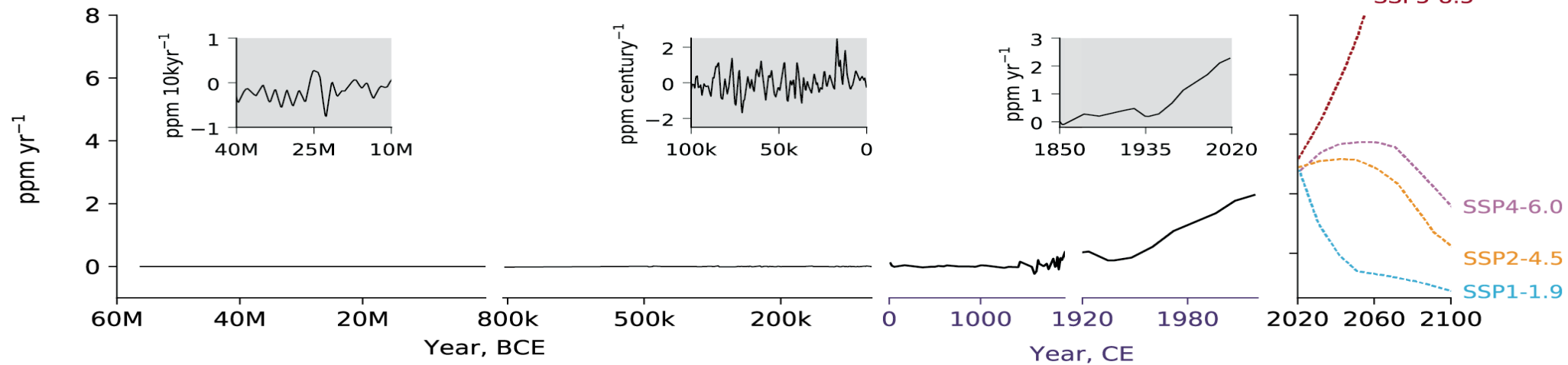


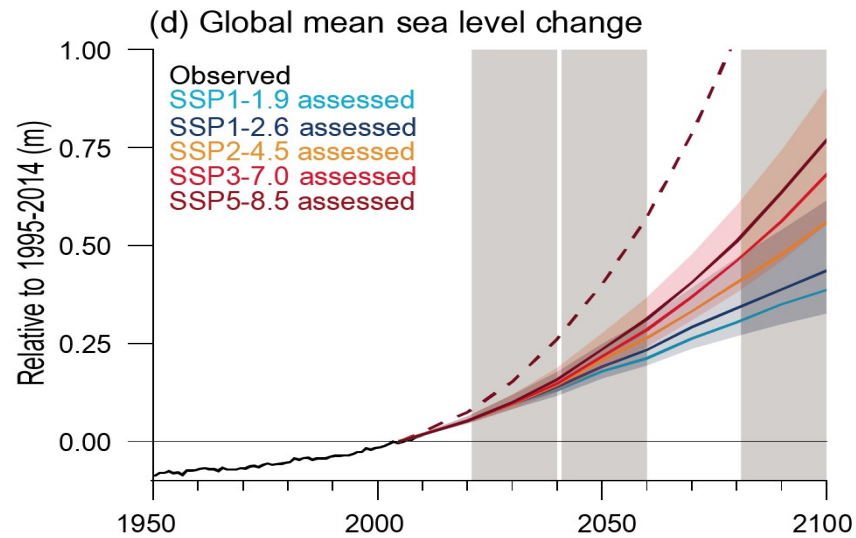
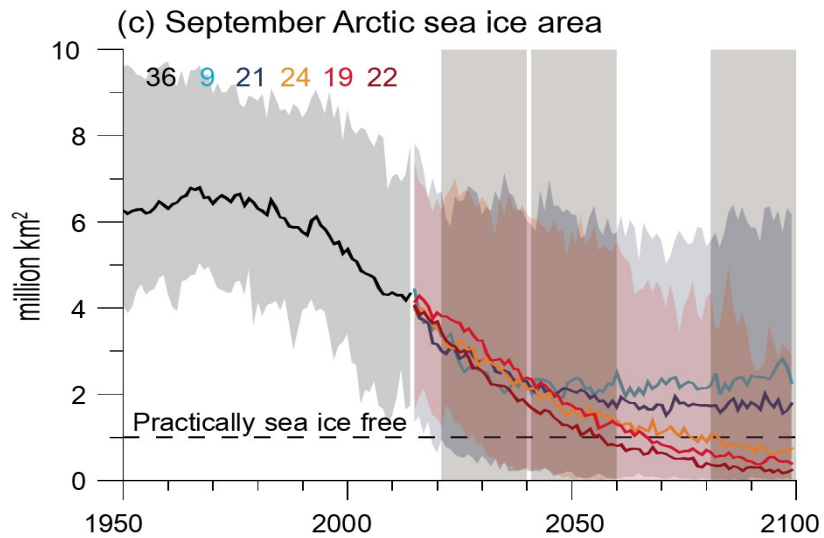
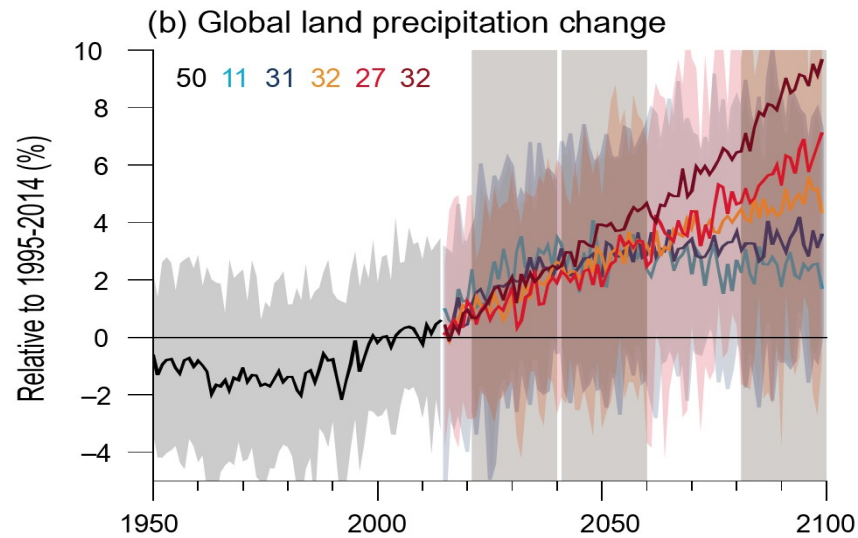
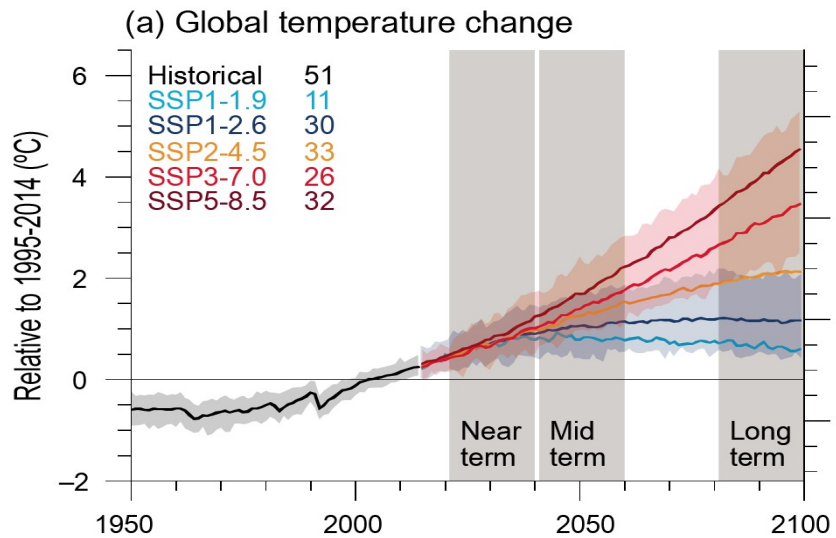


(a) Atmospheric CO₂ concentrations

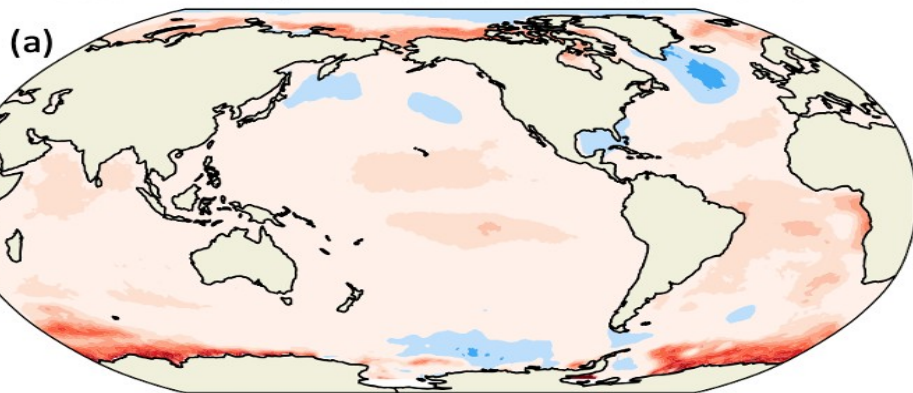


(b) Atmospheric CO₂ growth rate

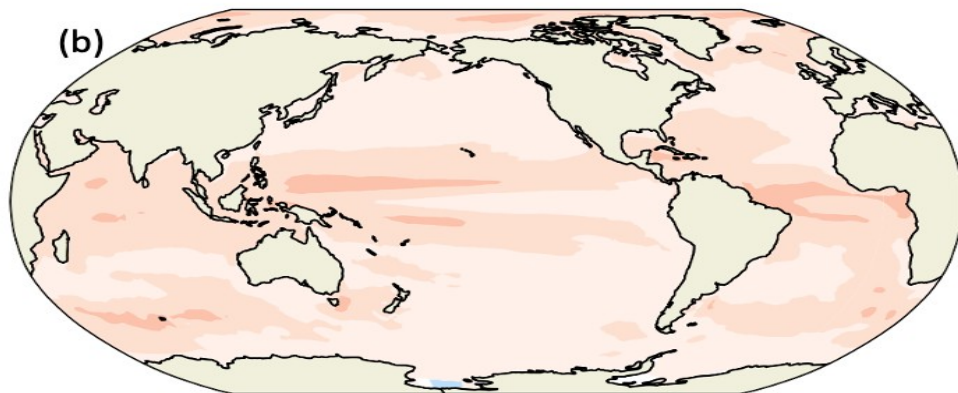




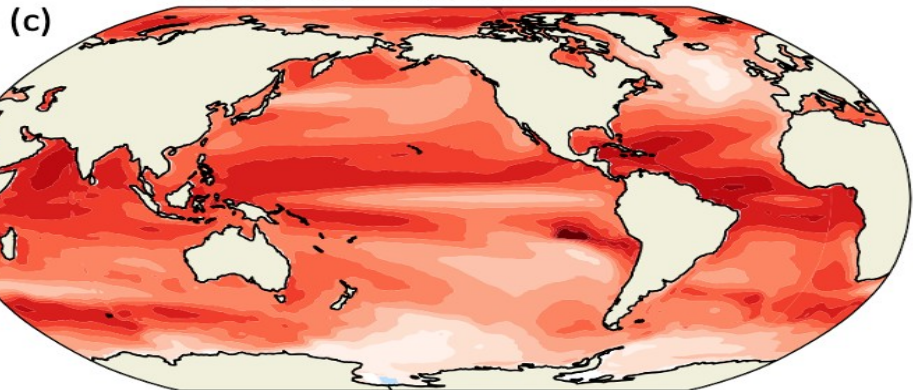
Observations (ERSSTv5 and Satellite): 1985-2014



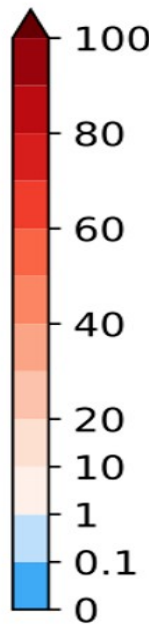
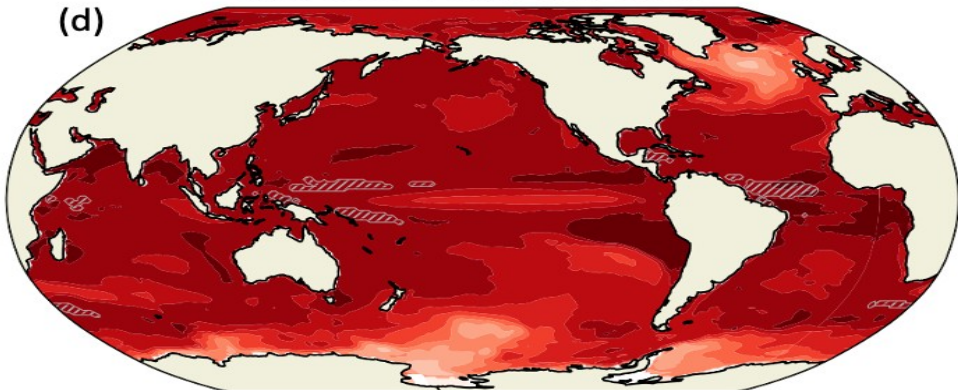
CMIP6: 1985-2014



CMIP6 SSP1-2.6: 2081-2100

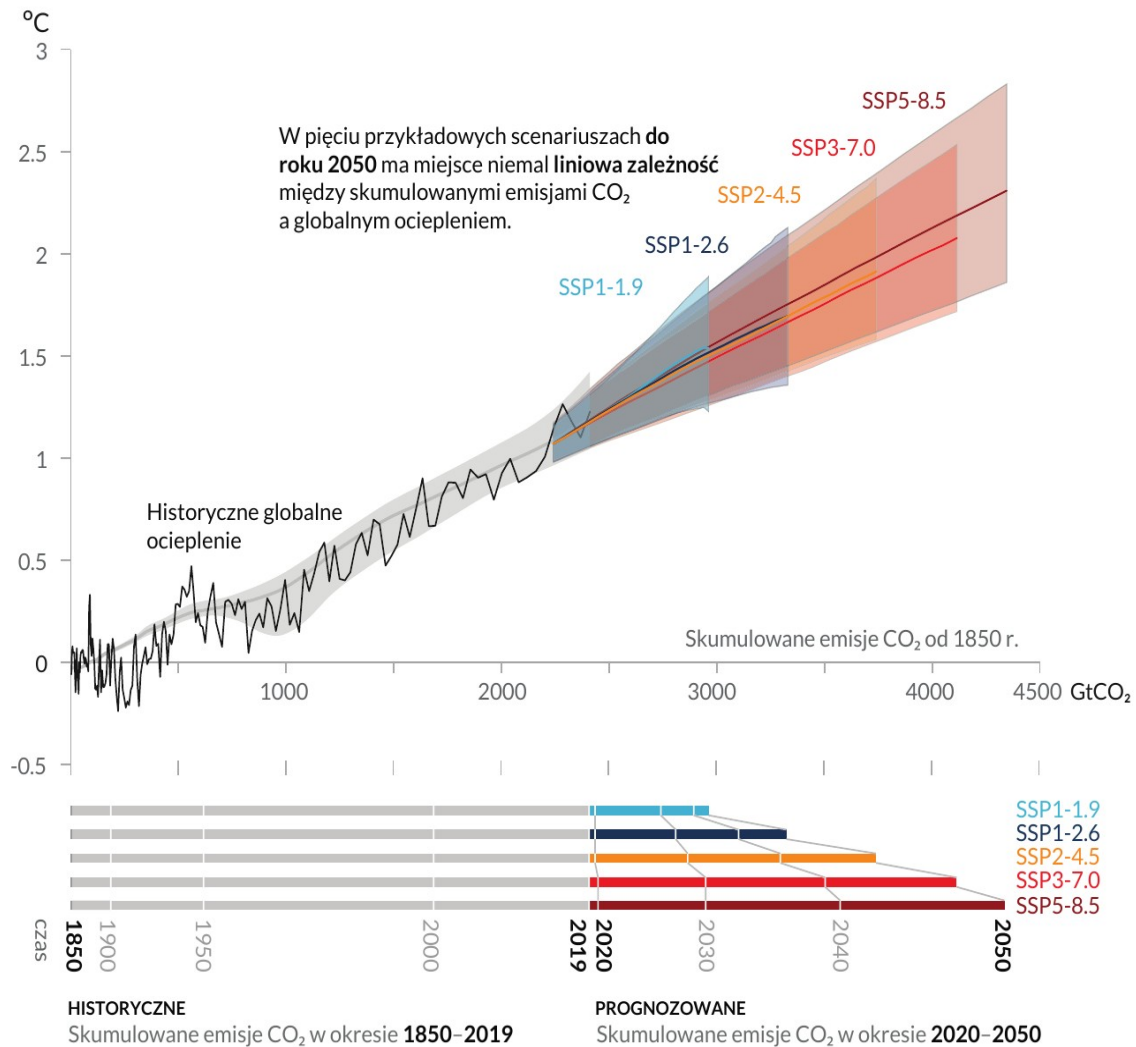


CMIP6 SSP5-8.5: 2081-2100



Każda tona emisji CO₂ powiększa globalne ocieplenie

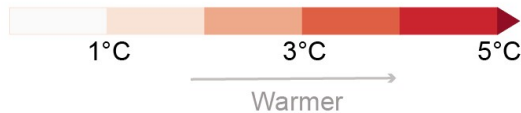
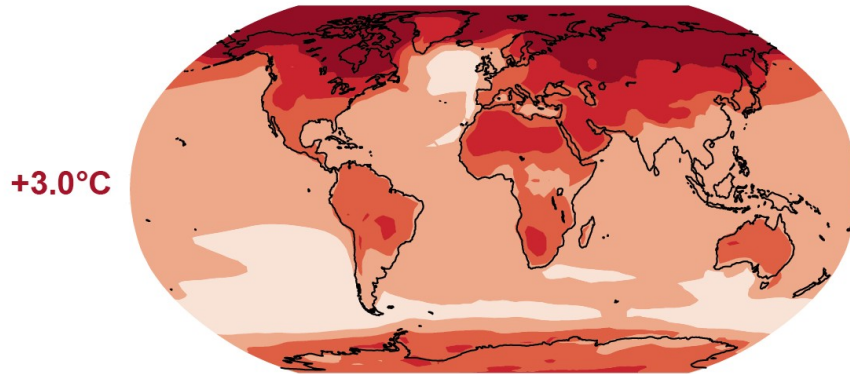
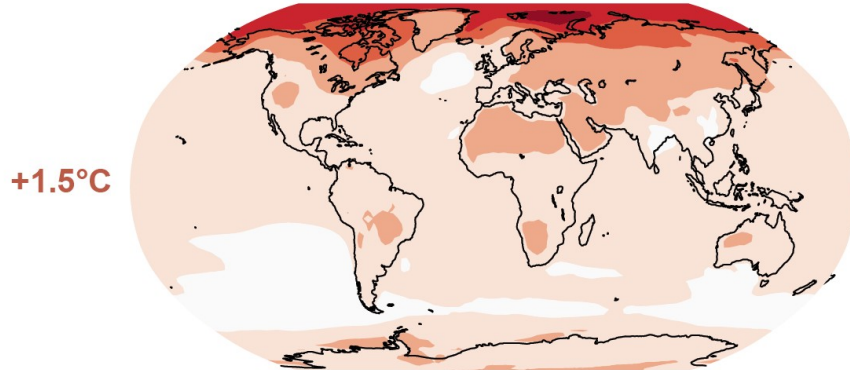
Wzrost globalnej temperatury powierzchni od okresu 1850–1900 r. (°C) w zależności od skumulowanych emisji CO₂ (GtCO₂)



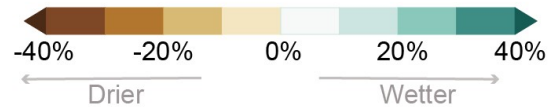
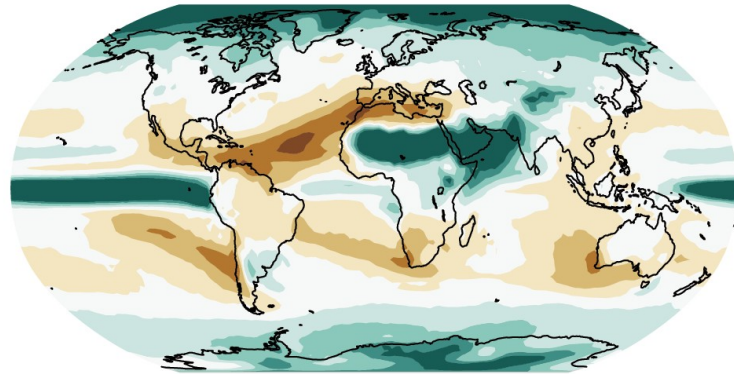
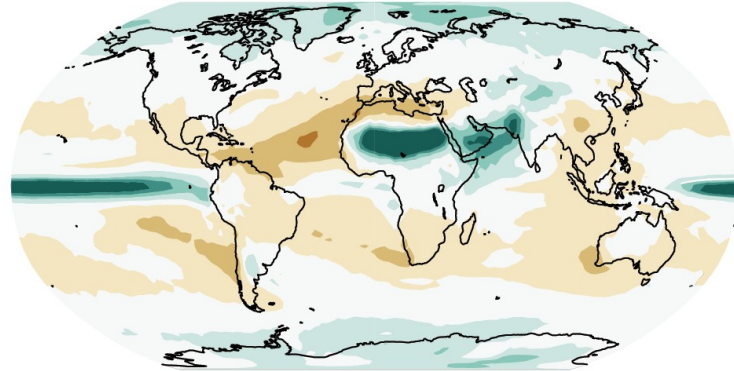
FAQ 4.3: Climate change and regional patterns

Climate change is not uniform and proportional to the level of global warming.

Warming will be **stronger** in the Arctic, on land and in the Northern Hemisphere

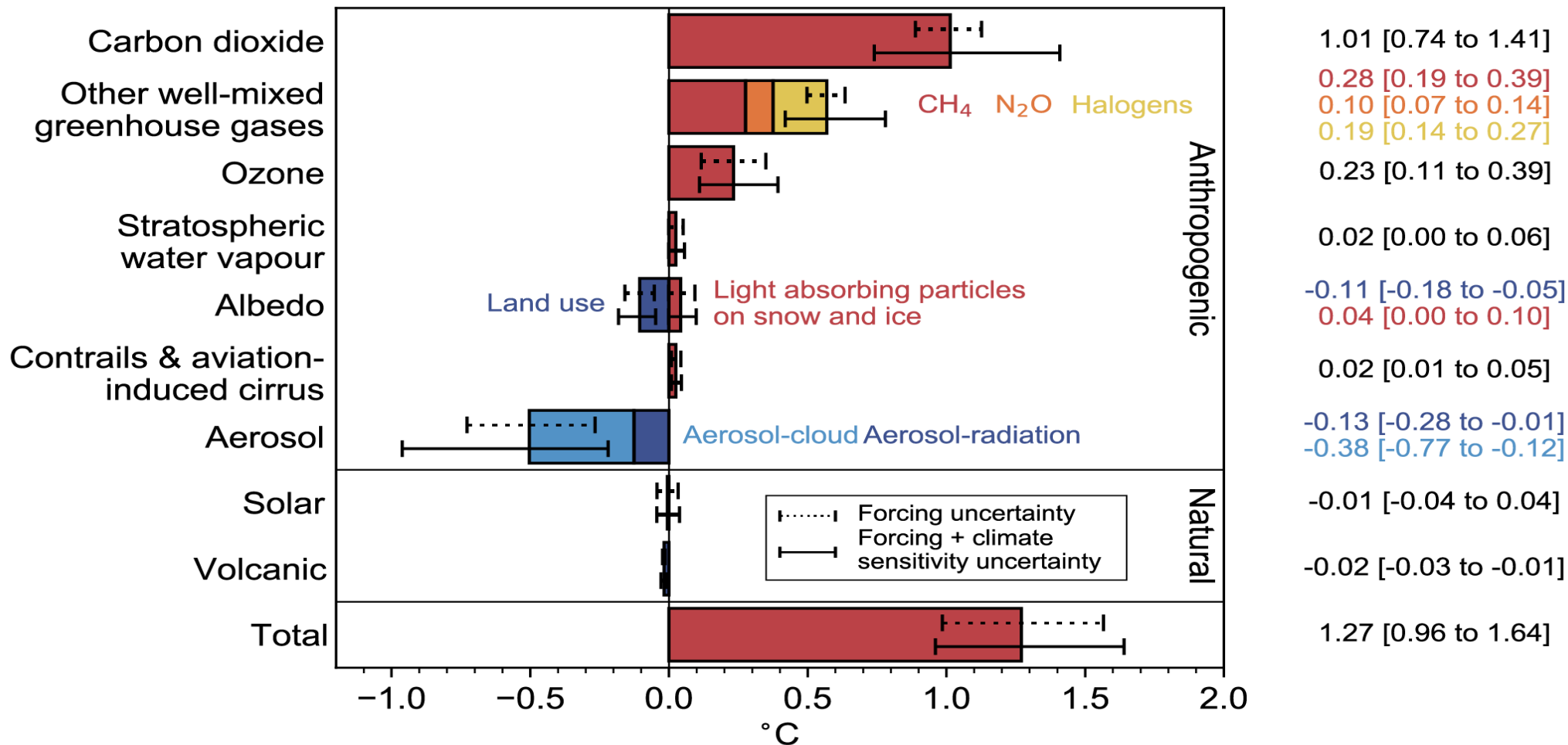


Precipitation will **increase** in high latitudes, the tropics and monsoon regions and **decrease** in the subtropics



Simulated temperature contributions in 2019 relative to 1750

°C



Attributed temperature change relative to 1750

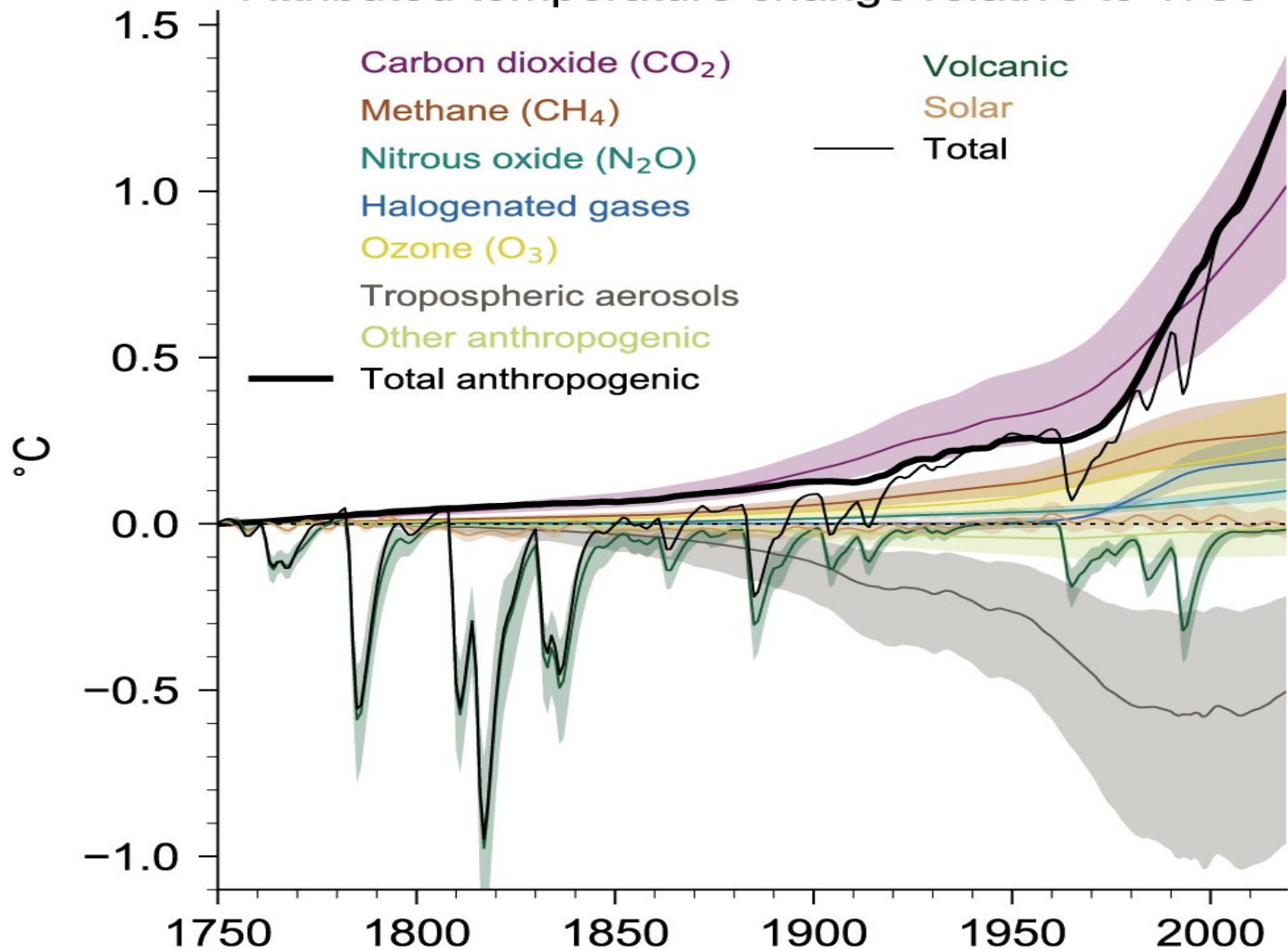
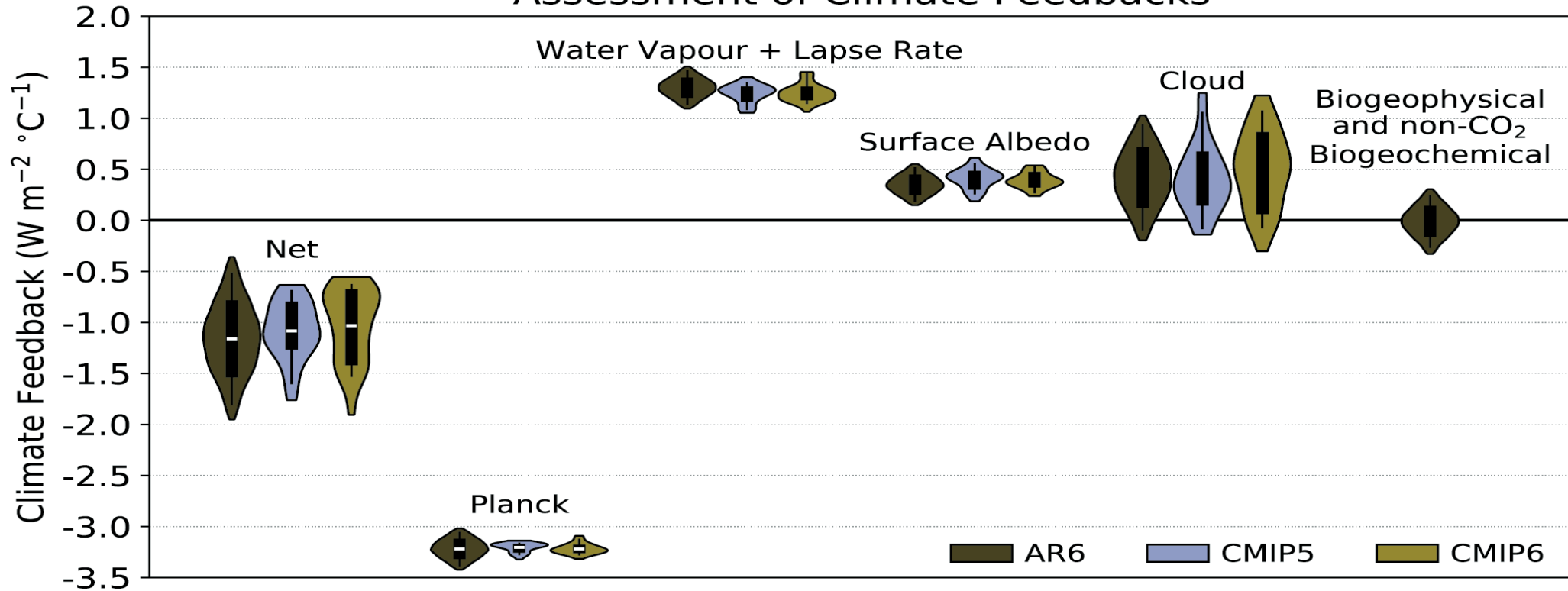


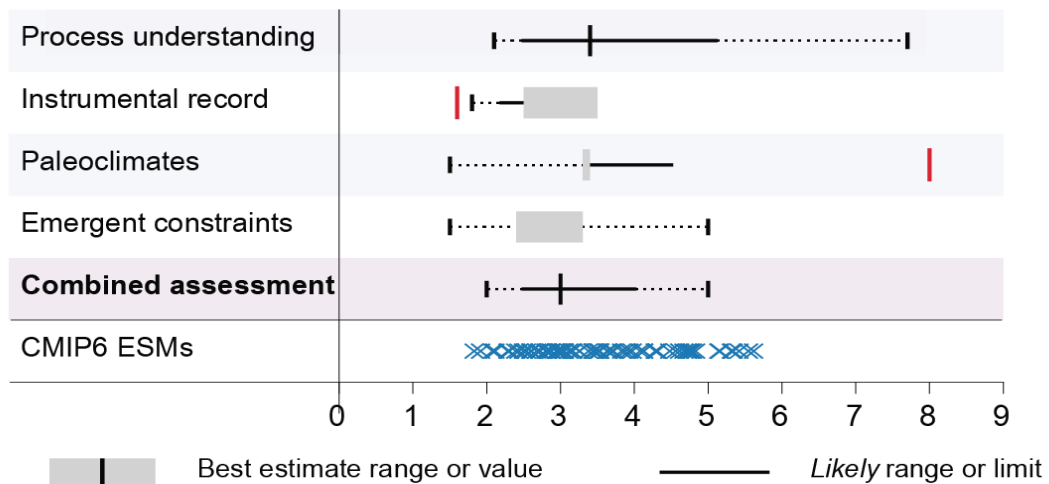
Table 7.10 | Synthesis assessment of climate feedbacks (central estimate shown in bold). The mean values and their 90% ranges in CMIP5/6 models, derived using multiple radiative kernels (Zelinka et al., 2020) are also presented for comparison.

Feedback Parameter $\alpha \times (W m^{-2} \text{ } ^\circ C^{-1})$	CMIP5 GCMs	CMIP6 ESMs	AR6 Assessed Ranges			
	Mean and 5–95% Interval	Mean and 5–95% Interval	Central Estimate	<i>Very likely</i> Interval	<i>Likely</i> Interval	Level of Confidence
Planck	-3.20 [-3.3 to -3.1]	-3.22 [-3.3 to -3.1]	-3.22	-3.4 to -3.0	-3.3 to -3.1	<i>high</i>
WV+LR	1.24 [1.08 to 1.35]	1.25 [1.14 to 1.45]	1.30	1.1 to 1.5	1.2 to 1.4	<i>high</i>
Surface albedo	0.41 [0.25 to 0.56]	0.39 [0.26 to 0.53]	0.35	0.10 to 0.60	0.25 to 0.45	<i>medium</i>
Clouds	0.41 [-0.09 to 1.1]	0.49 [-0.08 to 1.1]	0.42	-0.10 to 0.94	0.12 to 0.72	<i>high</i>
Biogeophysical and non-CO ₂ biogeochemical	Not evaluated	Not evaluated	-0.01	-0.27 to 0.25	-0.16 to 0.14	<i>low</i>
Residual of kernel estimates	0.06 [-0.17 to 0.29]	0.05 [-0.18 to 0.28]				
Net (i.e., relevant for ECS)	-1.08 [-1.61 to -0.68]	-1.03 [-1.54 to -0.62]	-1.16	-1.81 to -0.51	-1.54 to -0.78	<i>medium</i>
Long-term ice-sheet feedbacks (millennial scale)				>0.0		<i>high</i>

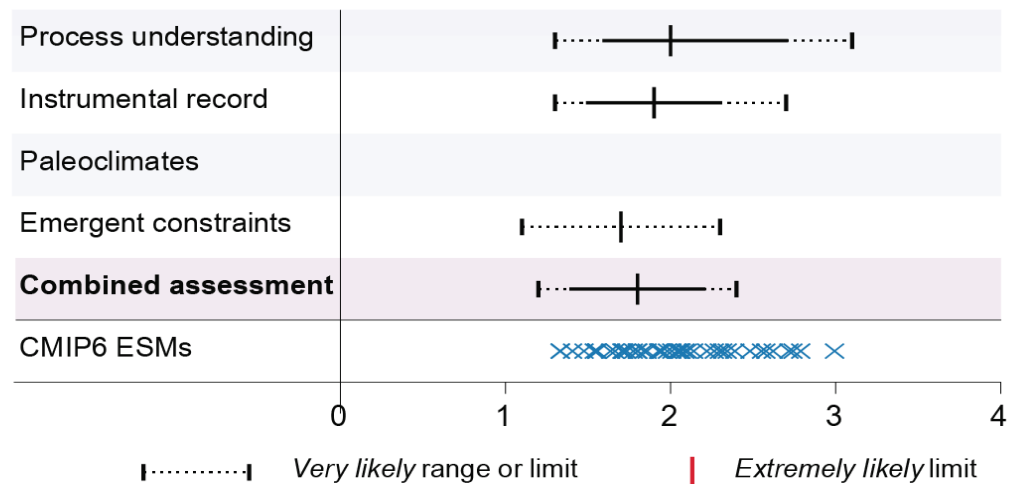
Assessment of Climate Feedbacks



(a) Equilibrium climate sensitivity estimates (°C)



(b) Transient climate response estimates (°C)



IPCC WGI Interactive Atlas

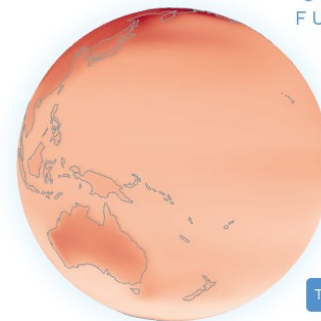
A novel tool for flexible spatial and temporal analyses of much of the observed and projected climate change information underpinning the Working Group I contribution to the Sixth Assessment Report, including regional synthesis for Climatic Impact-Drivers (CIDs).

[Errata and problem reporting](#)

[License, data and citation](#)

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OUR POSSIBLE
CLIMATE
FUTURES



+1.5°C

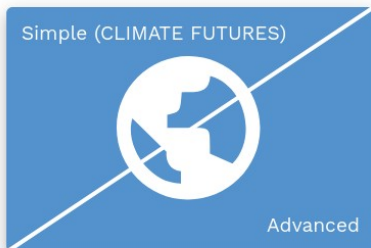
+2°C

+3°C

+4°C

Temperature

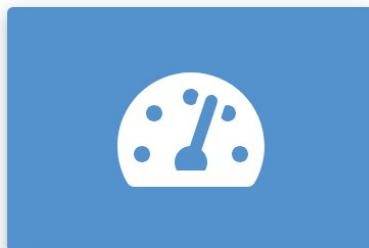
Precipitation



Simple (CLIMATE FUTURES)

Advanced

REGIONAL INFORMATION



REGIONAL SYNTHESIS



DOCUMENTATION

Copernicus Interactive Climate Atlas

Mean temperature (°C) - CMIP6 - Change - rel. to 1850-1900 - Warming 2°C - Annual

Mean temperature ▼ CMIP6 ▼

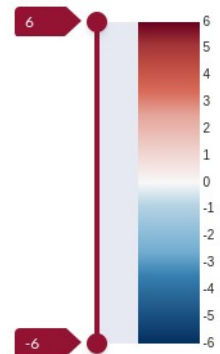
AR6 Regions ▼ 

Climatology and Changes Global warming levels



Quantity
Change ▼

Season
Annual ▼

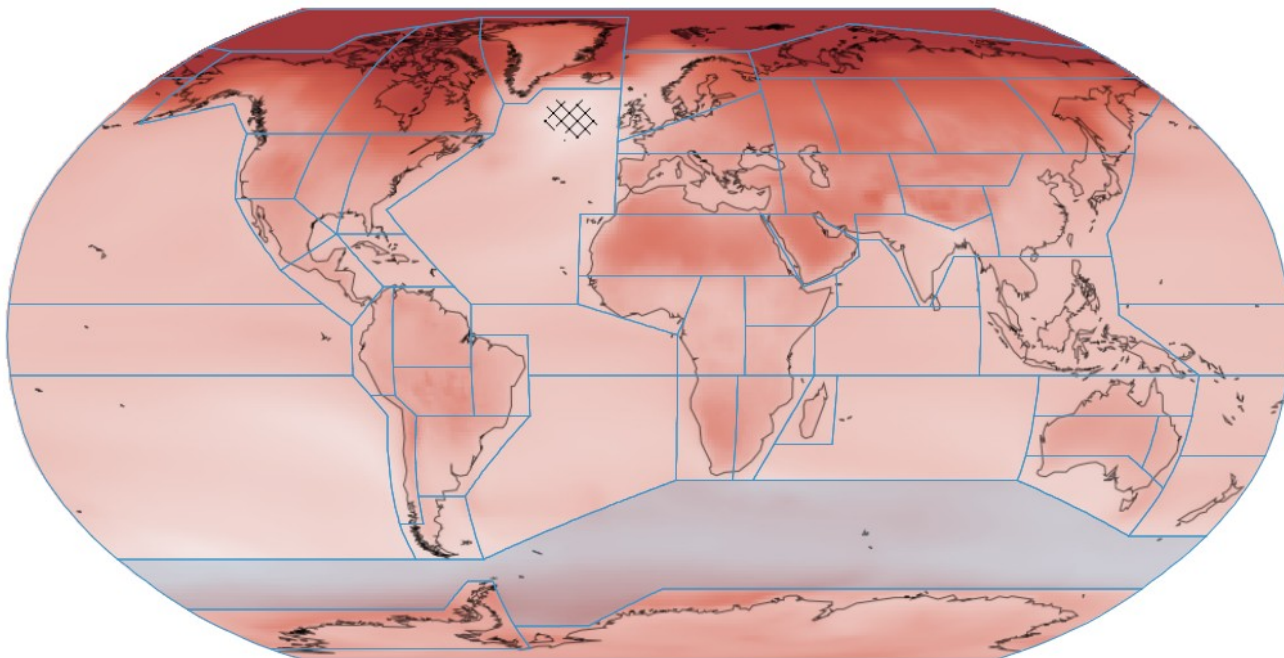


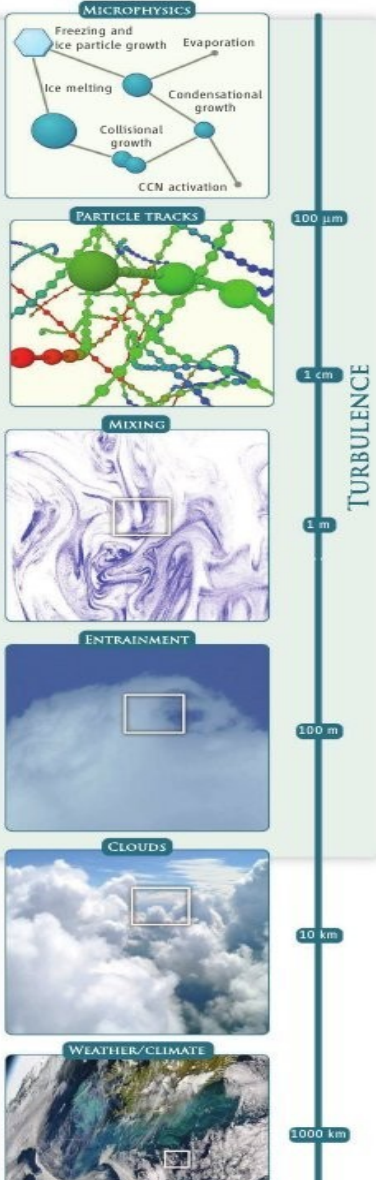
Units: °C

Robustness:

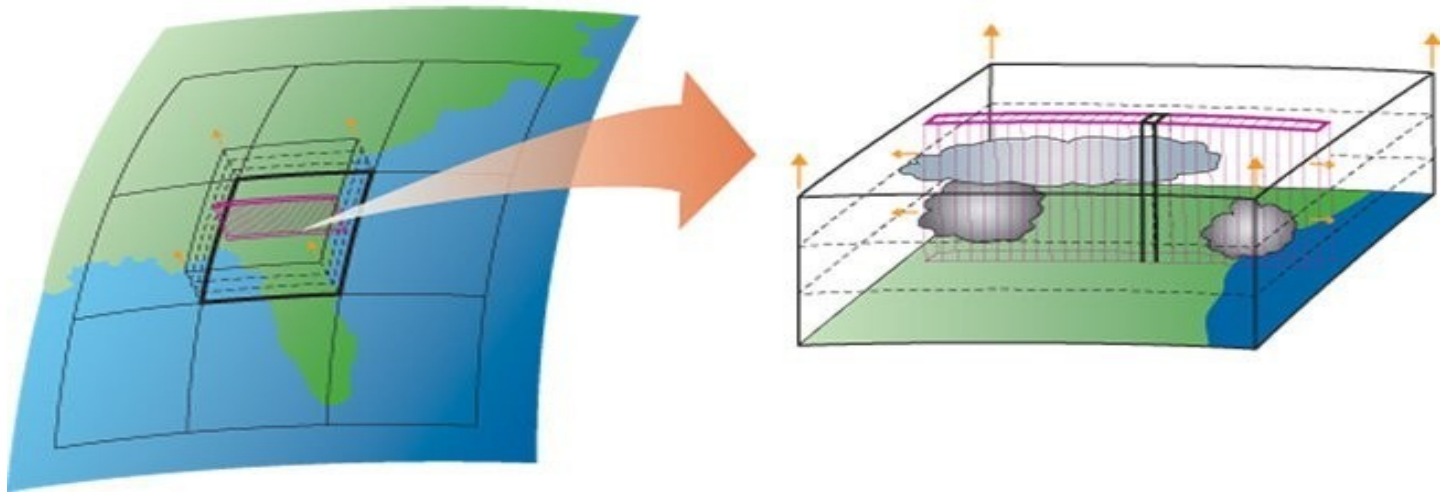
- Robust signal (original color)
- No change or no robust signal
- Conflicting signals

Palette ≡ Autofit ↻ Reset





Jak sobie radzimy z problemami?
 „Multiscale modeling” - modelowanie wieloskalowe,
 superparametryzacje, GIGA-LES, ILES,
 explicit cloud-resolving....



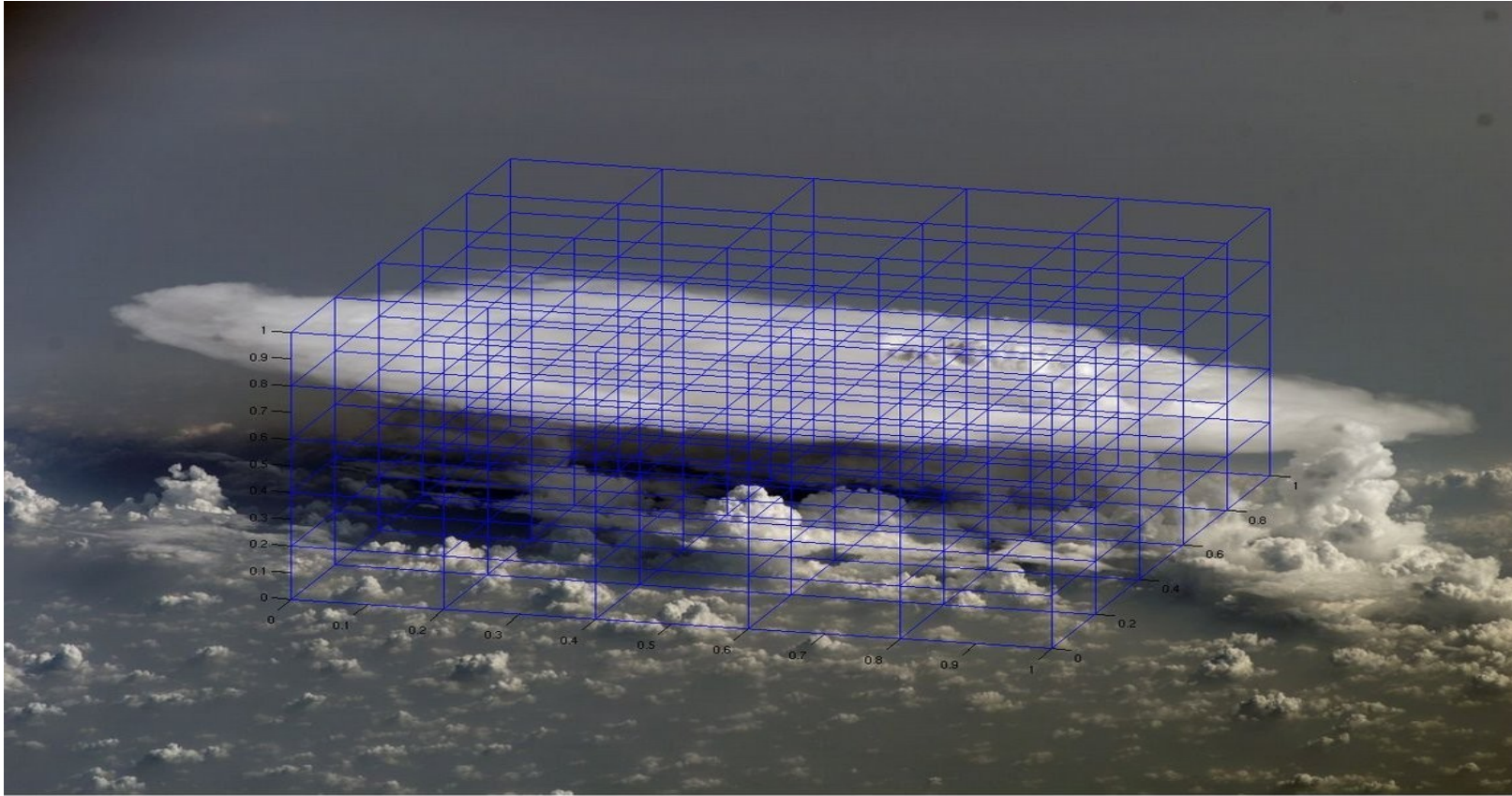
Bodenschatz, E., S.P. Malinowski, R.A. Shaw, F. Stratmann, 2010: Can We Understand Clouds without Turbulence? *Science*, **327**, 970 – 971.

Randall D.A, Khairoutdinov M, Arakawa A, Grabowski W.W., 2003: Breaking the cloud parameterization deadlock . *Bull. Amer. Meteorol. Soc.*, **84**, 1547-1564.

I wiele wiele innych.....

Jakie problemy napotyka modelowanie prognozy pogody i klimatu?

Najważniejszy to wielkoskalowość przepływów w atmosferze i oceanie i konieczność parametryzacji procesów podskalowych (o rozmiarach mniejszych niż oczko siatki i zachodzących szybciej niż krok czasowy obliczeń)



About the Project

nextGEMS is a collaborative European project. Funded by the EU's Horizon 2020 programme, it will tap expertise from fourteen European Nations to develop two next generation (storm-resolving) Earth-system Models. Through breakthroughs in simulation realism, these models will allow us to understand and reliably quantify how the climate will change on a global and regional scale, and how the weather, including its extreme events, will look like in the future.



nextGEMS is a Horizon 2020 project funded by the European Commission. It is coordinated by Bjorn Stevens at the Max Planck Institute for Meteorology and Irina Sandu at the ECMWF. The nextGEMS consortium is made up of 26 institutes:

Max Planck Institute for Meteorology (MPI-M), Germany

European Centre for Medium-Range Weather Forecasts (ECMWF)

Alfred-Wegener-Institut (AWI), Germany

University of Bergen (UIB), Norway

University of Copenhagen (UCPH), Denmark

French National Centre for Scientific Research (CNRS), France

Stockholm University (SU), Sweden

University of Warsaw (UW), Poland

University of Oxford (UOXF), UK

Helmholtz Centre for Ocean Research Kiel (GEOMAR), Germany

Barcelona Supercomputing Center (BSC), Spain

University of Reading (UREAD), UK

Wageningen University (WU), The Netherlands

Eidgenössische Technische Hochschule Zürich (ETHZ), Switzerland

Universität Bern (UBERN), Switzerland

Instituto Português do Mar e da Atmosfera IP (IPMA), Portugal

University of Helsinki (UH), Finland

University of Trento (UNITN), Italy

Deutsches Klimarechenzentrum GmbH (DKRZ), Germany

Universidad Complutense de Madrid (UCM), Spain

French National Institute for Sustainable Development (IRD), France

Iberdrola Renovables Energía S.A.U. (IBE), Spain

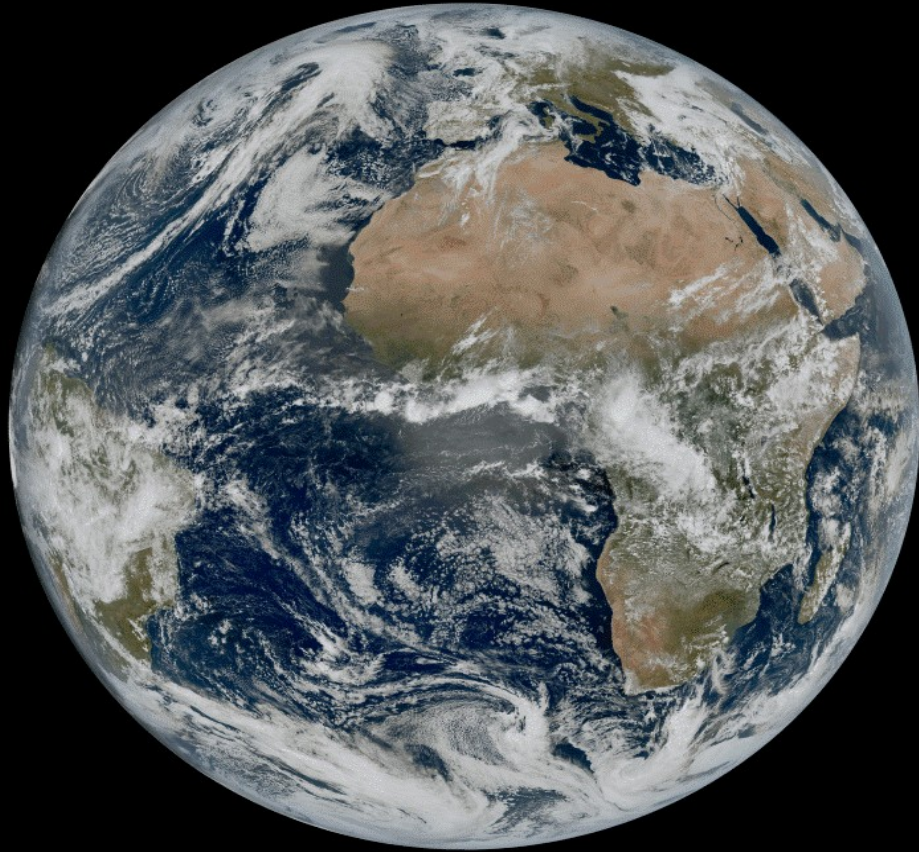
Institut Sénégalais de Recherches Agricoles (ISRA), Senegal

Latest Thinking GmbH (LT), Germany

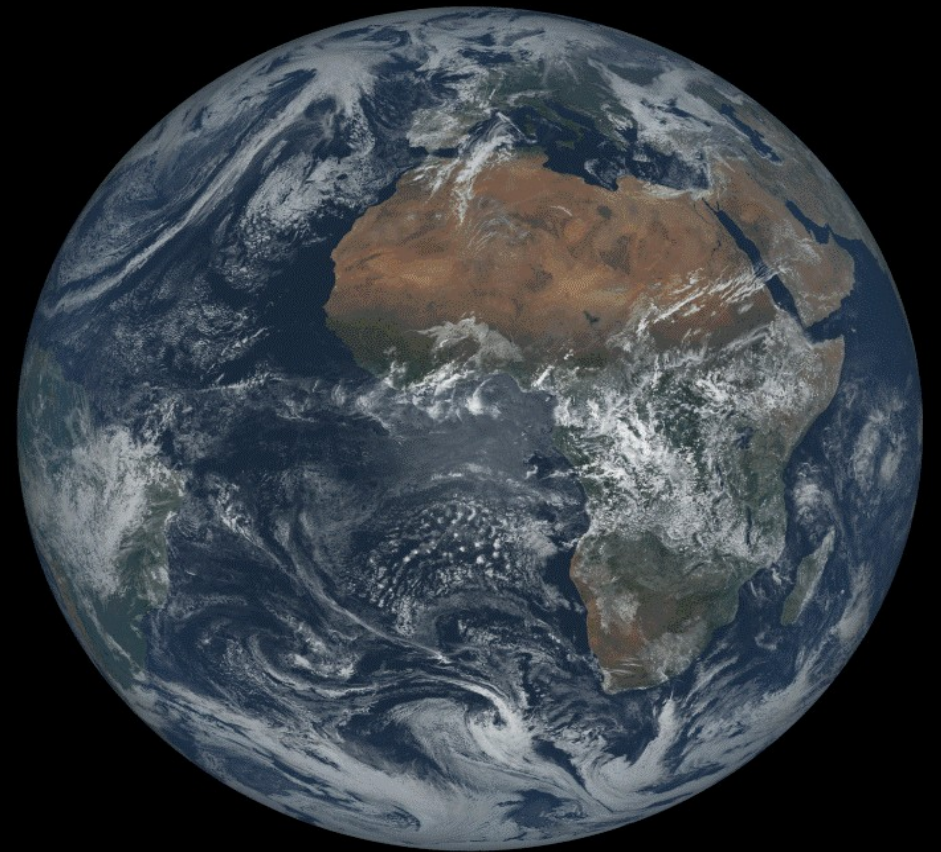
Karlsruhe Institute of Technology (KIT), Germany

University of Hamburg (UHH), Germany

MTG-I1 FCI



ECMWF IFS 2.8-km forecast



Pierwszy oficjalny obraz w świetle widzialnym z satelity MTG-FCI z EUMETSAT (po lewej) i 12-godzinna symulacja przy użyciu Zintegrowanego Systemu Prognozowania (IFS) ECMWF w rozdzielczości 2,8 km (po prawej), ważna na dzień 18 marca 2023 r. o godzinie 12:00 UTC. Źródło: EUMETSAT/ECMWF

Technika prognozowania klimatu : multimodel ensemble – pozwala a priori na ocenę prawdopodobieństwa sprawdzenia prognozy – podejście bayesowskie.

Dlaczego możemy (w ograniczonym stopniu) ufać prognozom klimatu:

- 1) modele bazują na podstawowych powszechnych prawach fizyki: zasadach zachowania energii, pędu, momentu pędu, masy....
- 2) w „wirtualnej rzeczywistości” modeli wielkości fizyczne i ich statystyki zachowują się w sposób rozsądny, a kolejne ulepszenia prowadzą do poprawy zachowań modeli zgodnie z naszym doświadczeniem i oczekiwaniami;
- 3) modele odtwarzają trendy i obserwowany rozkład przestrzenny wielu zmiennych;
- 4) testy modeli na przeszłych stanach atmosfery (w tym tych sytuacjach paleo, dla których mamy odpowiednie dane) stanowią dodatkowe, niezależne źródło weryfikacji;
- 5) różnorodne modele dają zgodne (w spodziewanych granicach) wyniki symulacji na tych samych danych;
- 6) prognozy nowej generacji modeli są zgodne ze starszymi;
- 7) potrafimy zinterpretować wyniki symulacji w sensie zrozumienia procesów fizycznych i sprzężeń.

R Knutti, 2008: Should we believe model predictions of future climate change? *Phil. Trans. R. Soc. A* 366, 4647–4664 doi:10.1098/rsta.2008.0169

Odnośniki do kilku wybranych modeli klimatu:

<http://www.cesm.ucar.edu/models/ccsm4.0/>

<https://www.mpimet.mpg.de/en/science/models/icon-esm/>

https://geos5.org/wiki/index.php?title=GEOS_GCM_Documentation_and_Access

<http://web.mit.edu/globalchange/www/climate.html>

<https://cds.climate.copernicus.eu/cdsapp#!/toolbox>