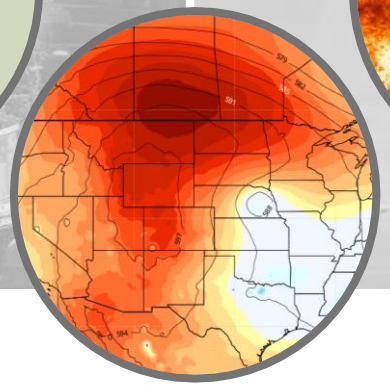
Possible futures in an uncertain world

What might the future look like?

https://shrinkthatfootprint.com/greenest-cities-in-the-world-top-5/

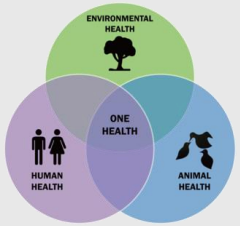

What might the future look like?

What would these different futures mean for health and wellbeing?



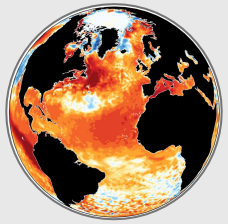
Today in context

Week 1



Future human and ecosystem health

Week 2

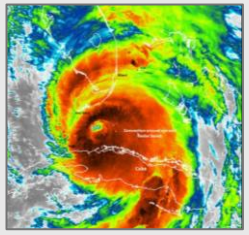


Scenarios of an uncertain future

Week 3

Measuring drivers of health risks

Week 4

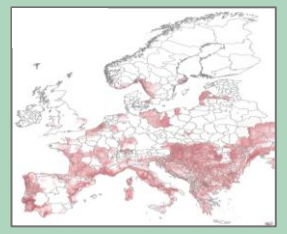


Prediction and forecasting

Week 5

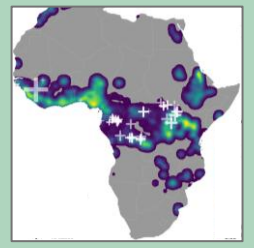
From models to solutions?

Week 7



Long-term futures for health

Week 8

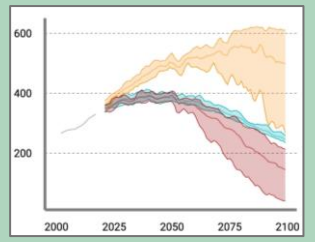


How well can we predict the future?

Week 9

Solutions for healthier cities

Week 10

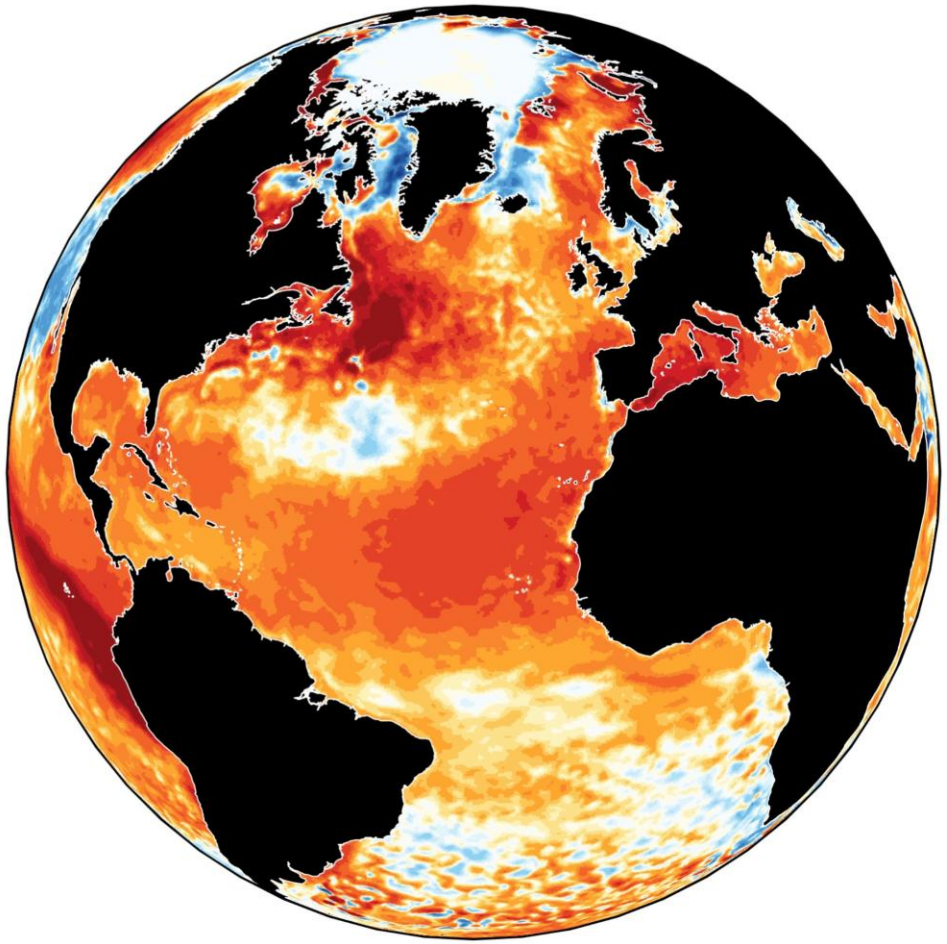


Communicating uncertainty

Week 11

Linking models to policy

Learning objectives



- Discuss how **scenarios of global and regional futures** can help to understand complex health and biodiversity risks in an uncertain world
- Explain **how future climatic and socioeconomic scenarios are generated** and quantified
- **Distinguish between predictions and scenarios** of future environmental, social and health factors
- Analyse and visualize **spatial data on extreme temperature**s in the present-day and near-future

The structure of today

Lecture:
Possible futures in an uncertain world

09:00-11:00

Practical:
Exploring and analyzing extreme heat exposure

14:00-17:00

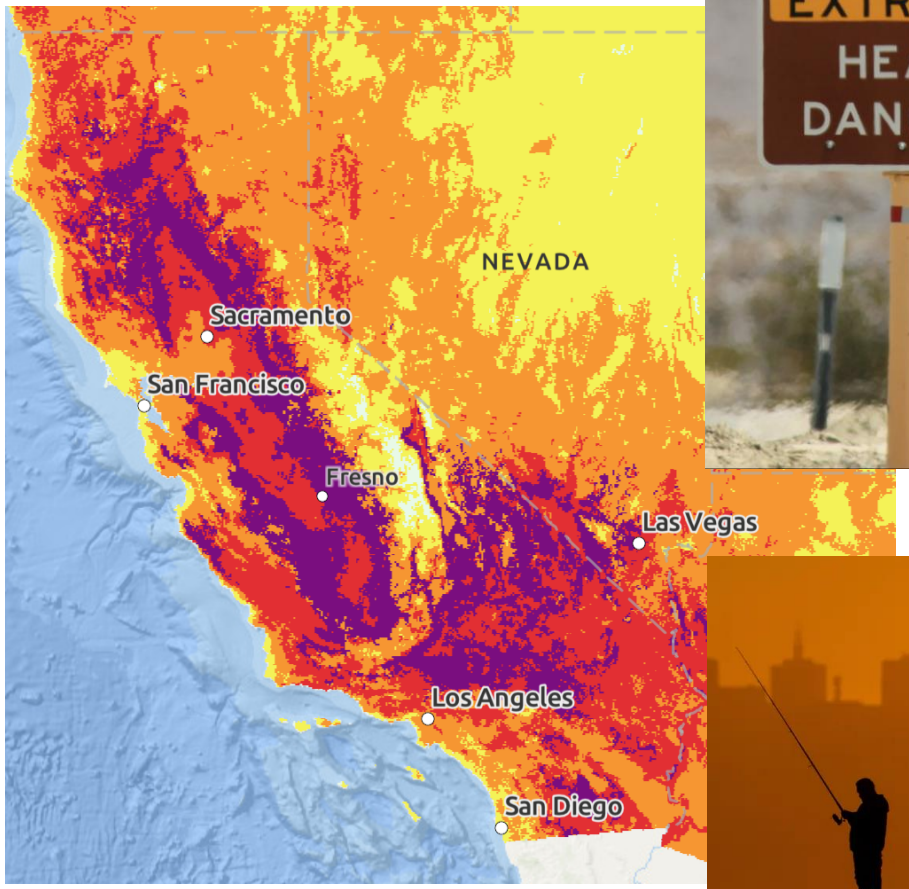
This afternoon's practical

R workshop: Exposure to extreme temperatures in the southwest USA (California and Nevada)

Spatial data handling, visualization and descriptive analysis, using present-day and future climate data

Workbook and data available at https://github.com/MSc-ECCH-UCL/BIOS0052-Human-And-Ecosystem-Health

14:00-17:00, Marshgate Room 636



What do you think the world will look like in 2070?

What do you think the world will look like in 2070?

How confident are you in your prediction?

Why?

The future is uncertain and contingent

Present day

Global communities cohere around a sustainable future

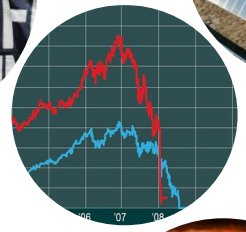
2100

Global cooperation dwindles and fragments, leading to conflict and runaway climate change

2100

The future is uncertain and contingent

Present day



2100

Global communities cohere around a sustainable future

2100

Global cooperation dwindles and fragments, leading to conflict and runaway climate change

How can we plan for the future under uncertainty?

Individual

Where should I buy a house?

Business/organization

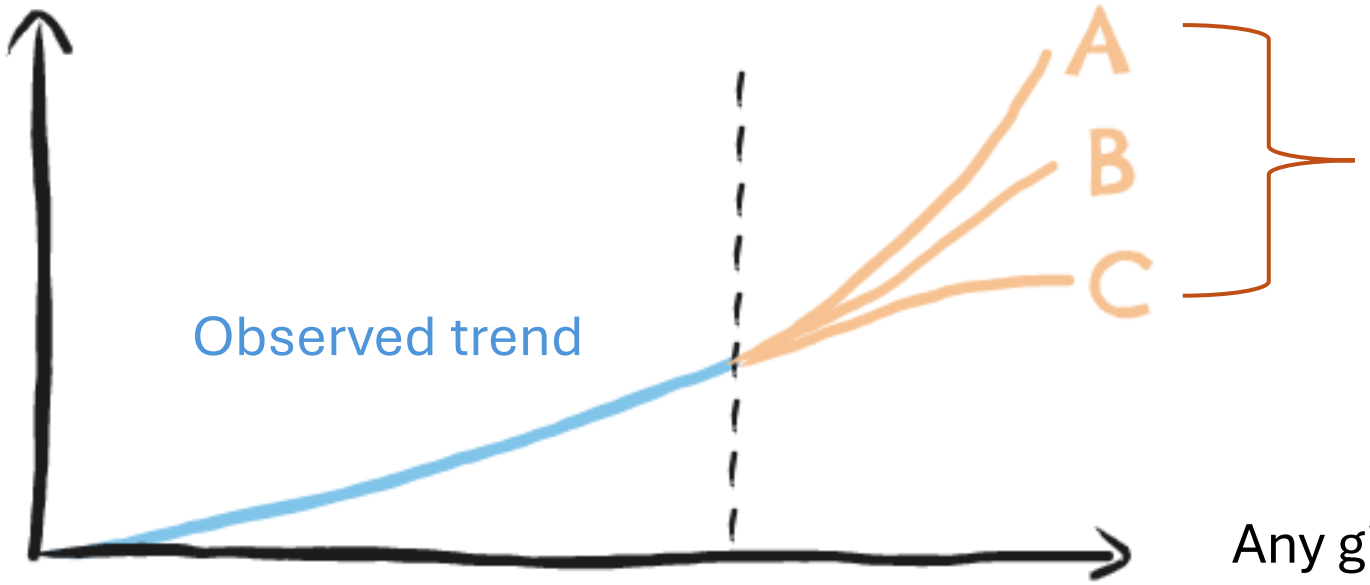
How can we futureproof profits against unexpected events?

Policy

What difference would deep emissions cuts make for health and economic prosperity? What adaptation measures would be most effective?

The essence of scenario analysis

Scenarios *(A, B and C)* –
plausible futures, differing in key assumptions about what will change

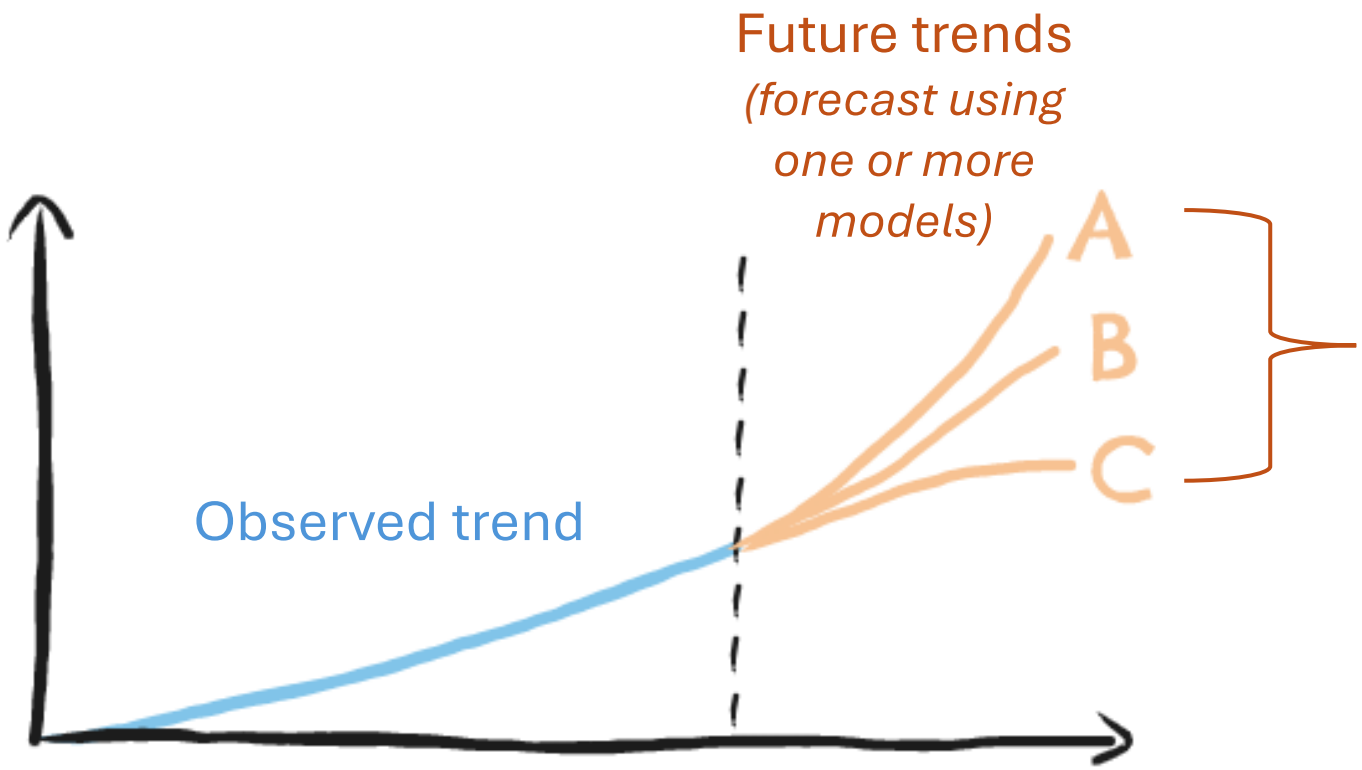


Forecast outcomes we are concerned about (e.g. profits, species population, global mean temperature) across this set of scenarios

Any given scenario is unlikely, but hope to **capture the range of future possibilities** across a set of scenarios

https://www.causal.app/blog/scenario-analysis-explained

The essence of scenario analysis



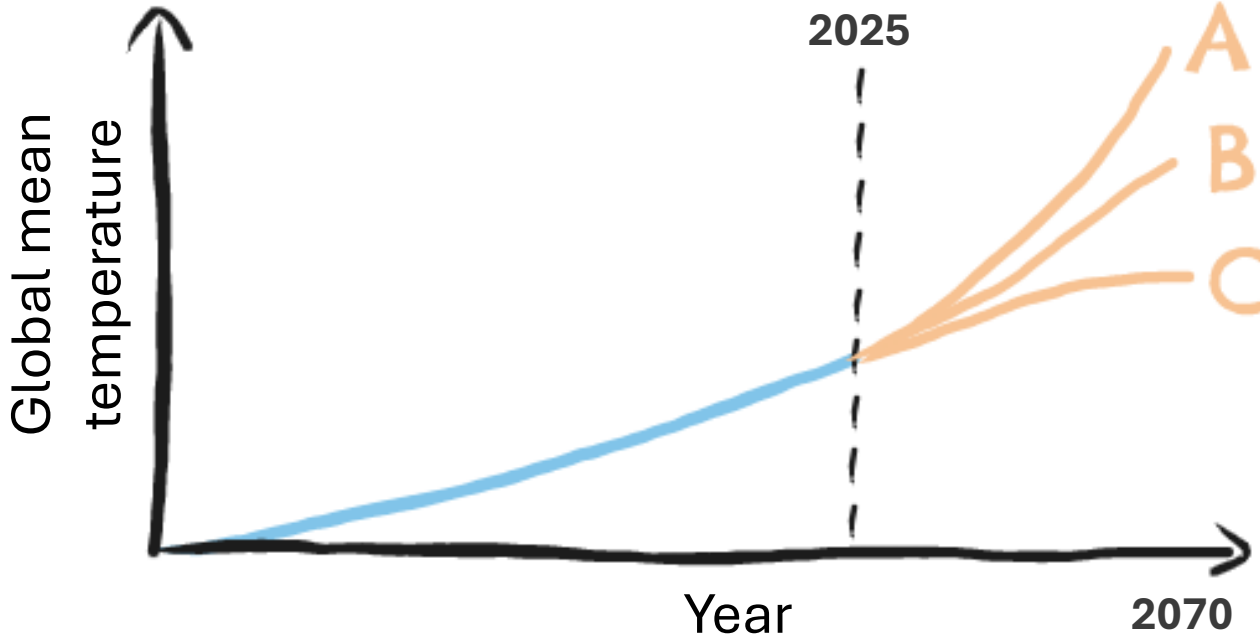
Not predictions!

Projections of what the future could look like **under the specific assumptions** of the scenario

"If X, then Y"

https://www.causal.app/blog/scenario-analysis-explained

Scenarios in climate change impact research



A: Global cooperation on climate policy abandoned

B: Slow global transition towards renewables with minimal additional legislation

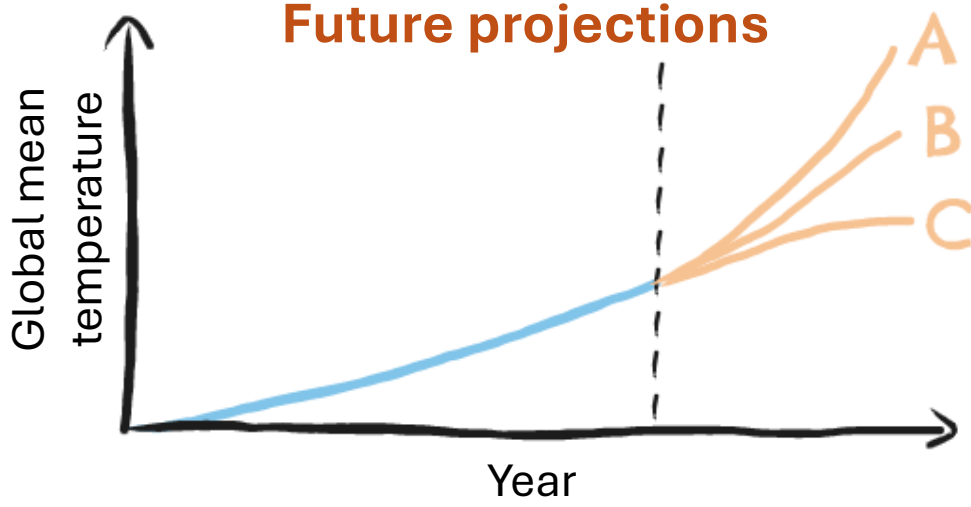
C: Rapid green transition to a low-carbon economy

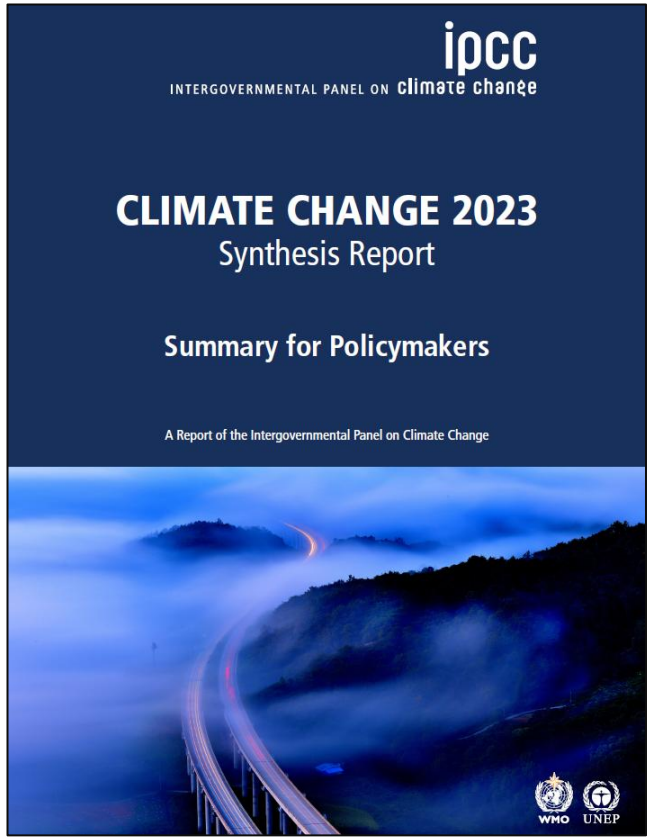
Possible futures

Scenario parameters (assumptions) – *(social, population, technical, economic, environmental, political trends)*

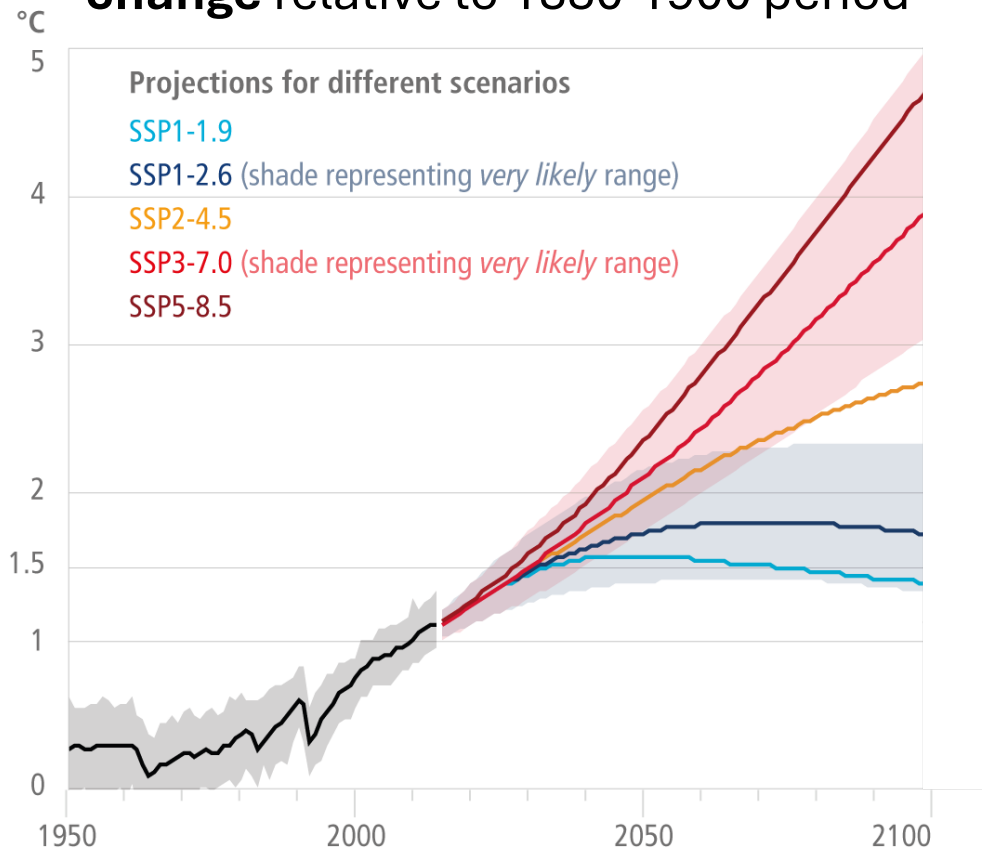
Computational models *(simulate ocean atmosphere, vegetation/biosphere, society)*

Future projections

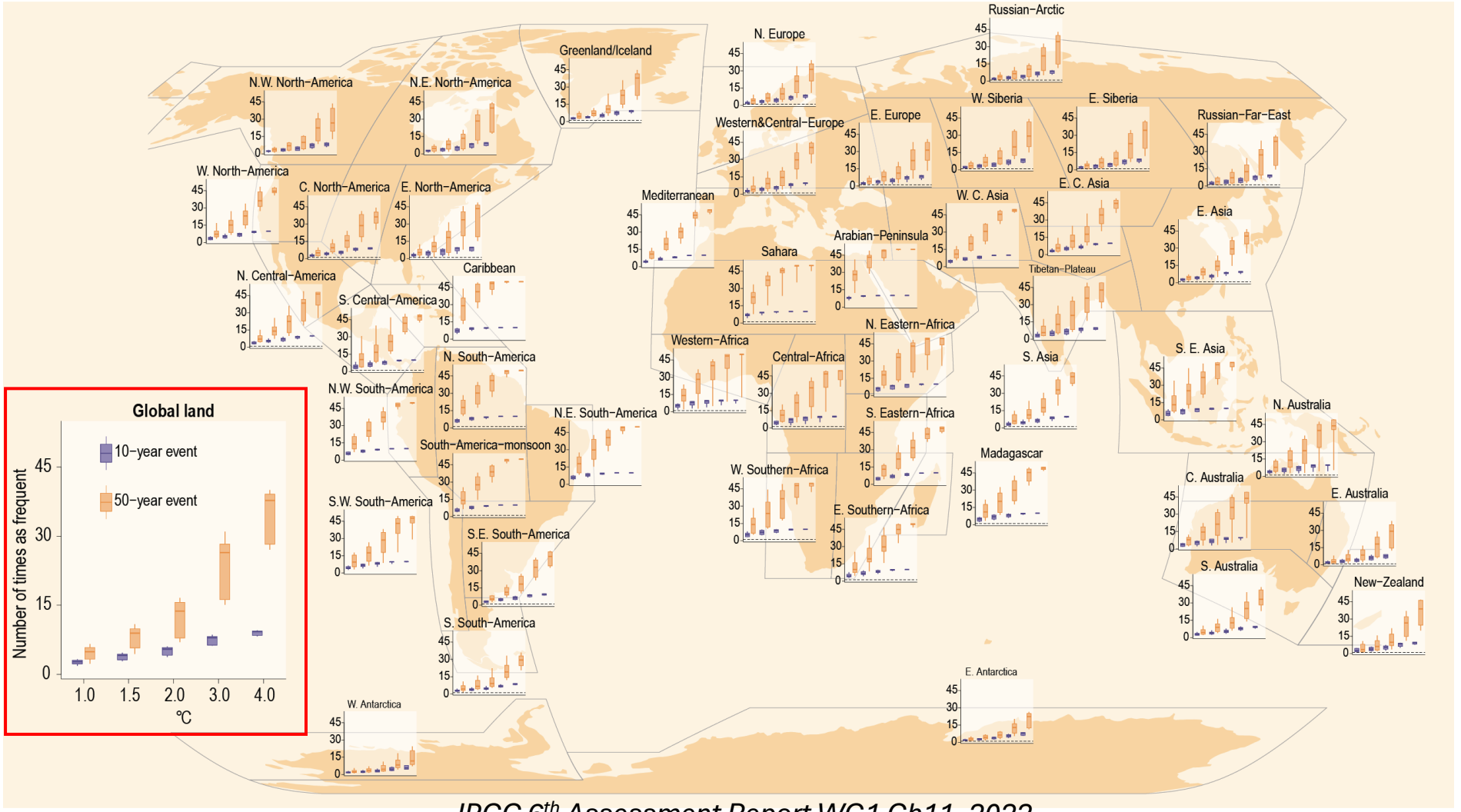




Global **mean surface temperature change** relative to 1850-1900 period



Changes in the frequency of **extreme heat events** per degree of warming

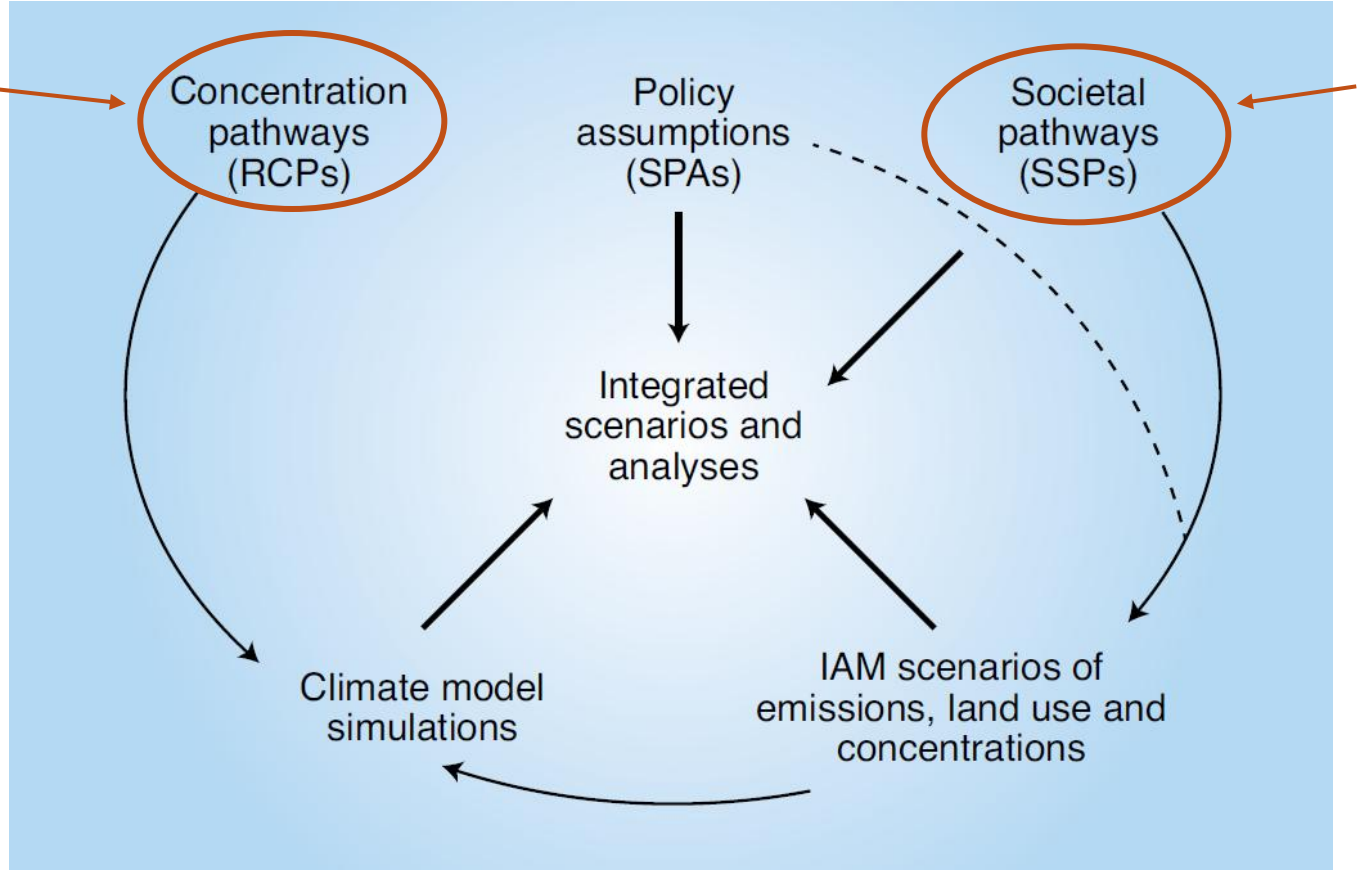


IPCC 6th Assessment Report WG1 Ch11, 2022

The current generation of climate scenarios: the RCP-SSPs

Representative Concentration Pathways (**RCPs**) – *atmospheric concentrations of greenhouse gases*

Describe magnitude of climate change

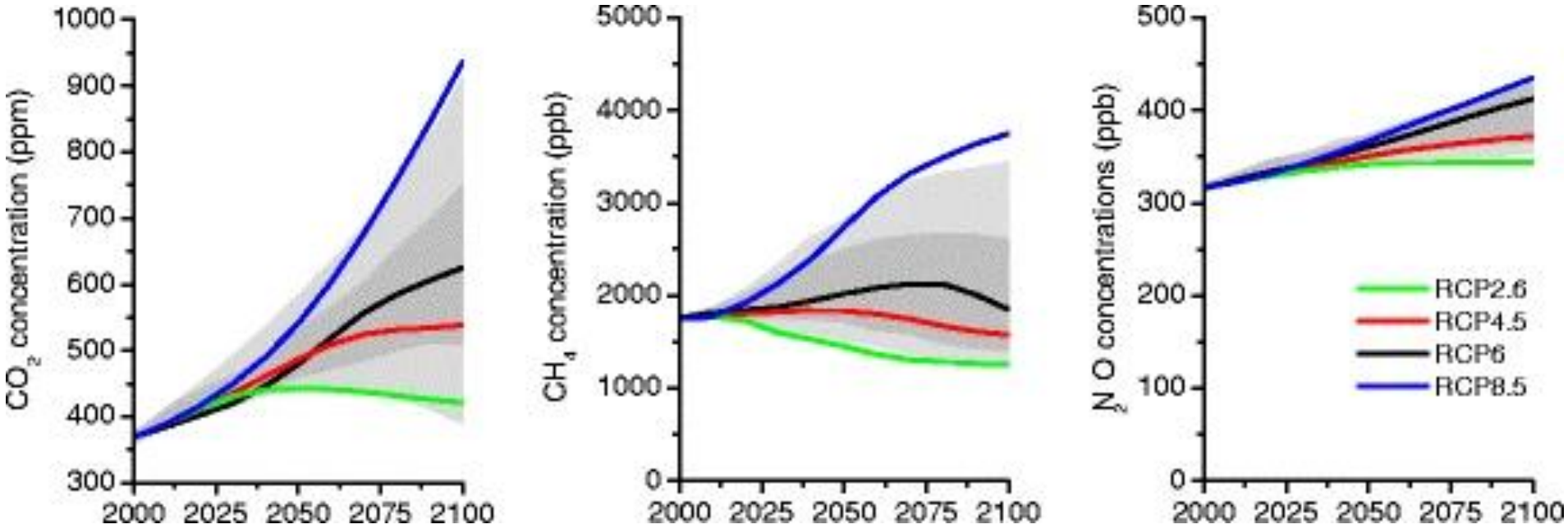


Shared Socioeconomic Pathways **(SSPs)** – *plausible futures of social, economic, technological and political development*

Describe future socioeconomic transitions

O'Neill et al. 2020, *Nature Climate Change*

Representative Concentration Pathways



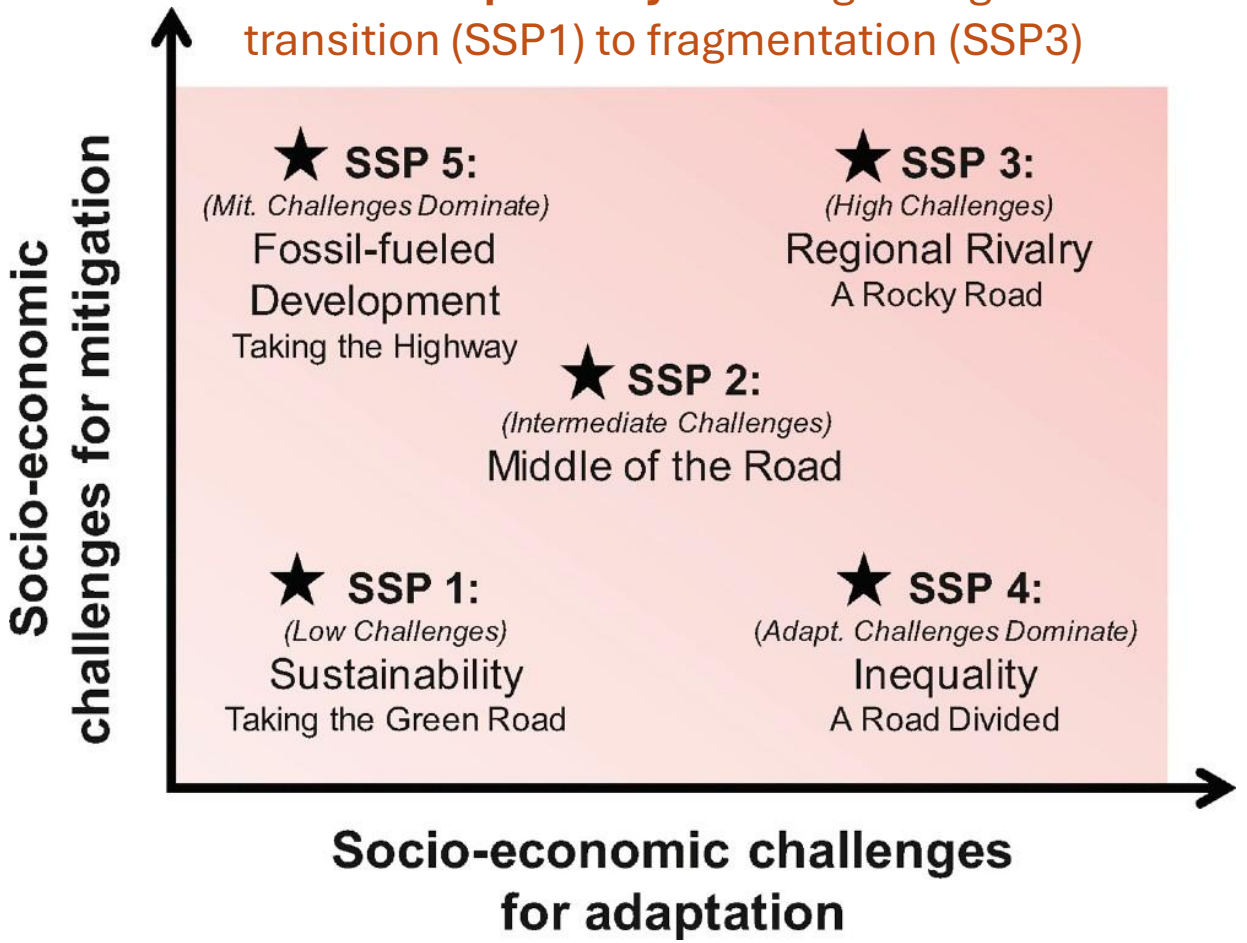
Different trends in **atmospheric GHG concentration** across the RCPs – from lowest (RCP2.6) to highest (RCP8.5)

Scenario name refers to radiative forcing (W/m^2) in 2100

Van Vuuren et al. 2011, *Climatic Change*

Shared Socioeconomic Pathways (SSPs)

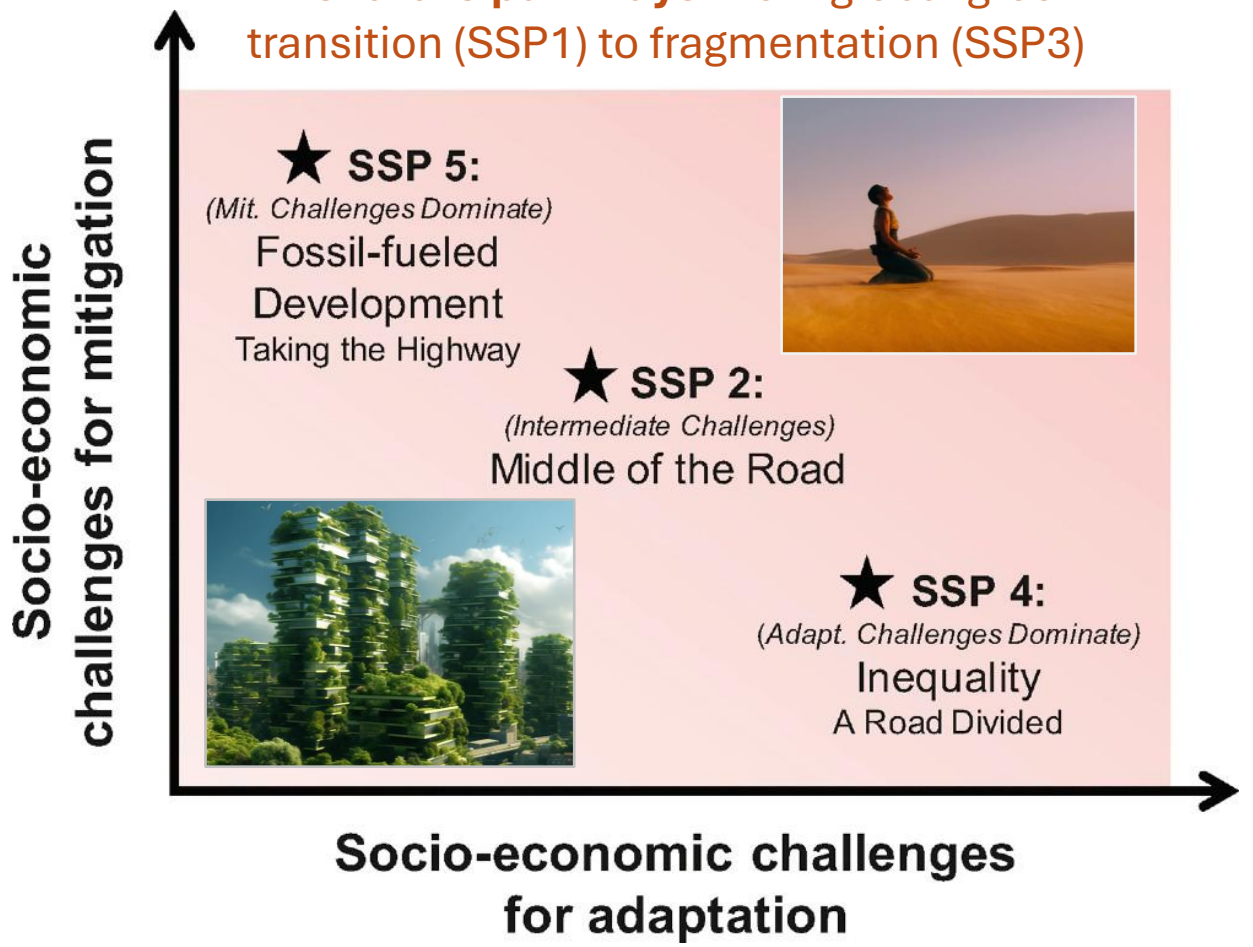
Five future pathways: from global green transition (SSP1) to fragmentation (SSP3)



O'Neill et al. 2015, *Global Environmental Change*

Shared Socioeconomic Pathways (SSPs)

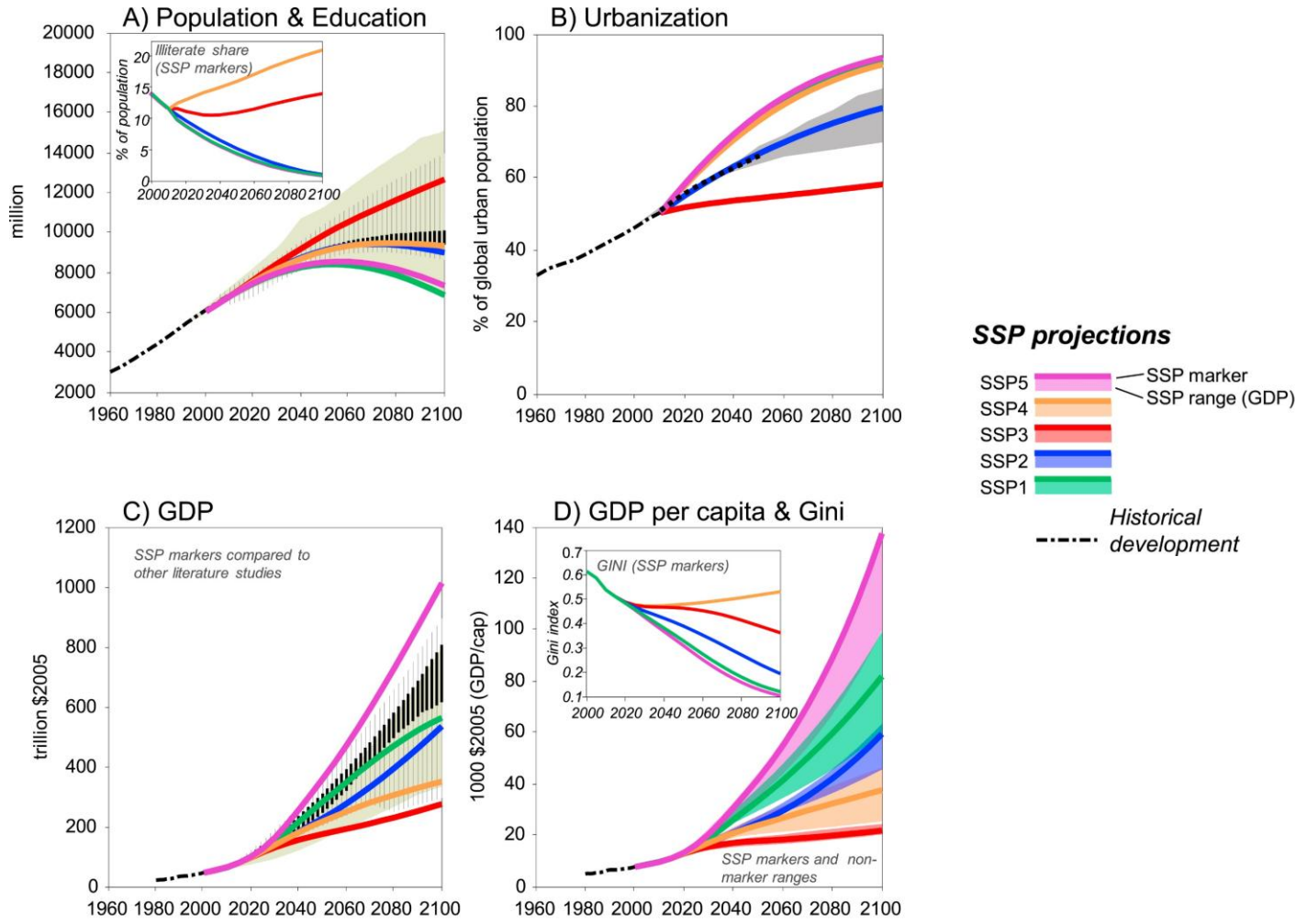
Five future pathways: from global green transition (SSP1) to fragmentation (SSP3)



O'Neill et al. 2015, *Global Environmental Change*

Shared Socioeconomic Pathways (SSPs)

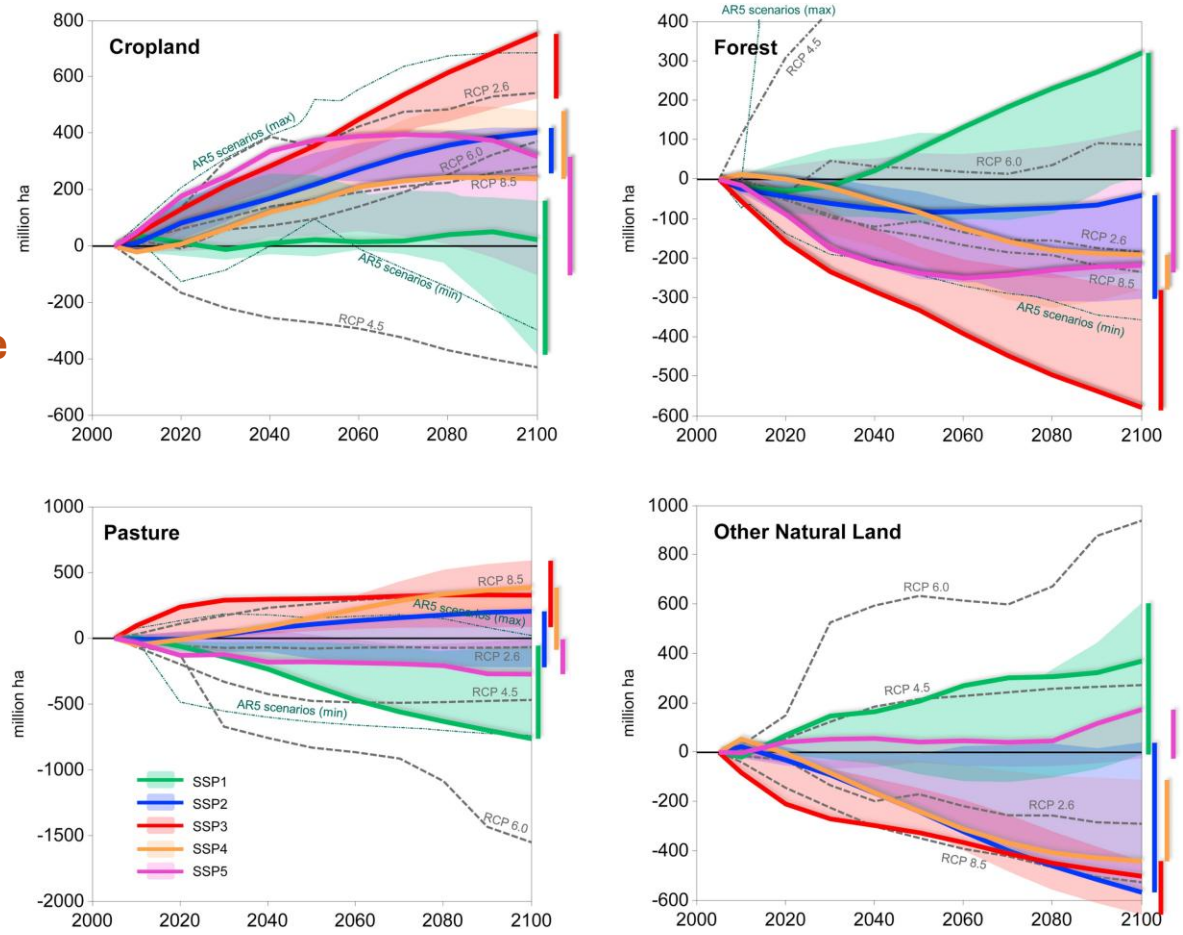
Different SSPs have very different implications for **population, economic growth, urbanization…**



Riahi et al. 2017, *Global Environmental Change*

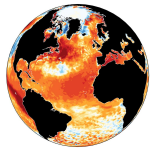
Shared Socioeconomic Pathways (SSPs)

… and also for **global land use change** (and consequent biodiversity impacts)

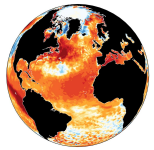


Riahi et al. 2017, *Global Environmental Change*

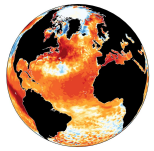
Who developed these scenarios and why are they useful?



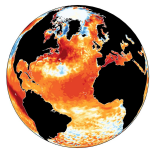
Developed by climate change researchers
(climate scientists, social scientists and impact researchers, mainly European and US institutions)



Capture uncertainty across a range of possible futures
(including different ways that society might change)



Provide a coherent set of modelling assumptions for the climate change research community
(enables comparison across different studies and research teams – using a standard set of reference scenarios!)



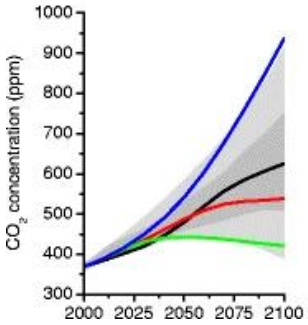
Enable consistent and comparable research into climate change impacts, adaptation and risks
(including for health researchers)

How are descriptive scenarios turned into quantitative predictions of the future?

Use of scenarios in climate change, ecology and health research

RCPs

(emissions pathways)

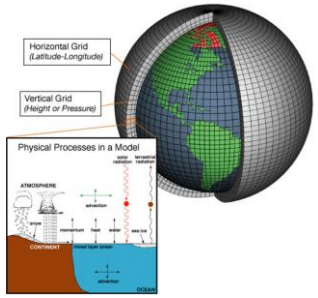


SSPs

(social, technological, land use and political pathways)

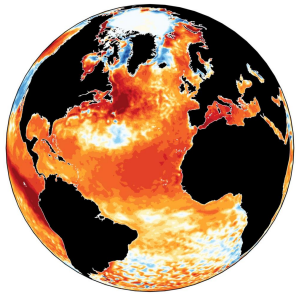
Earth system models

(simulate ocean atmosphere, vegetation/biosphere)



Future climate projections

(future temperature, rainfall, humidity, extremes…)



hazards

Biodiversity/ health impact studies

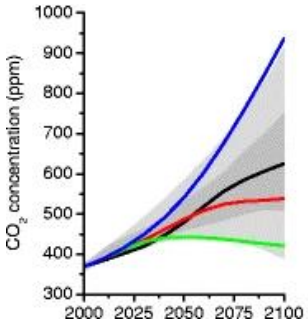
(species ranges, vectors, disease transmission, heat exposures…)

exposure, vulnerability, land use

Use of scenarios in climate change, ecology and health research

RCPs

(emissions pathways)



SSPs

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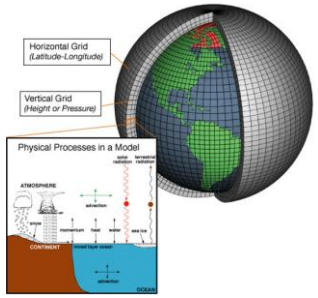
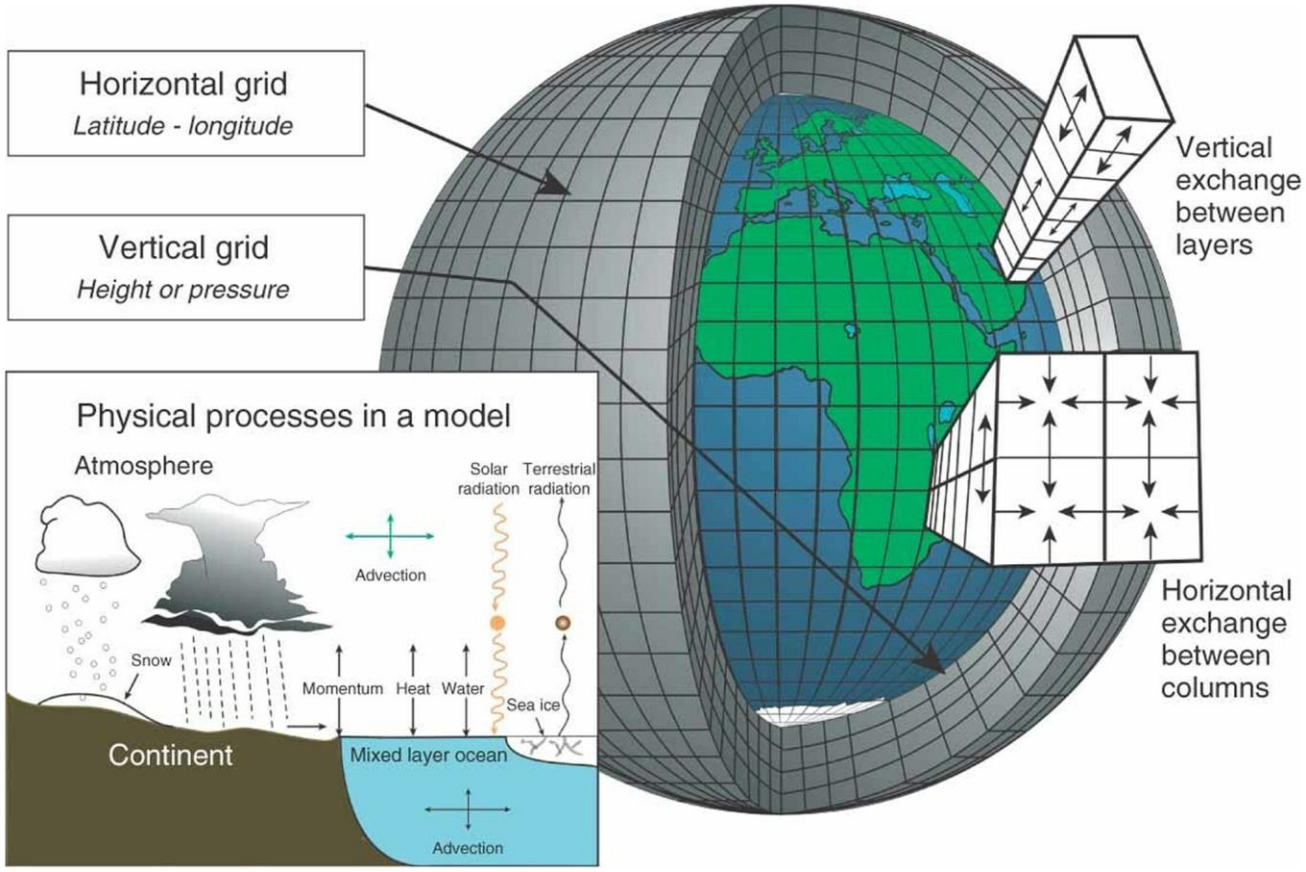


Modelling and forecasting the climate using physical principles



General circulation models (GCMs) – simulate coupled ocean and atmosphere

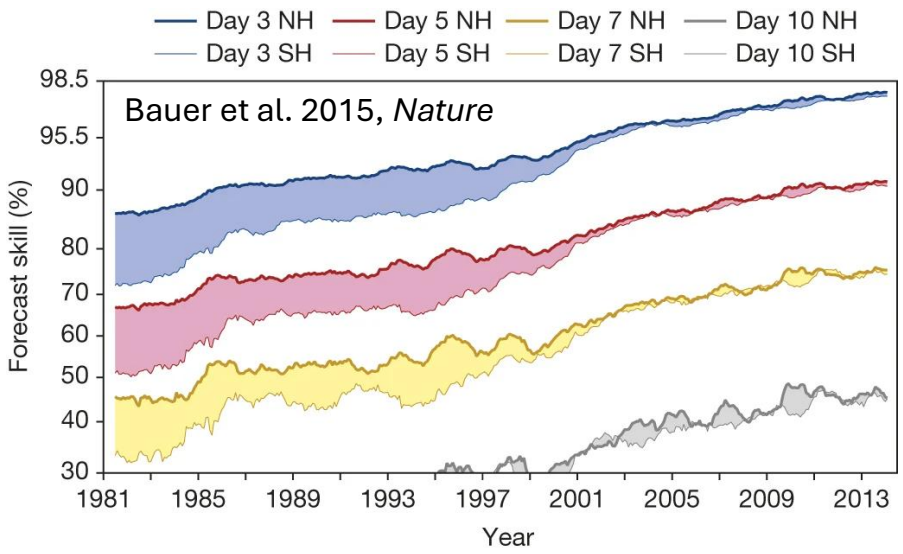
System of **equations** describing physical processes, run in **grid cells** across Earth

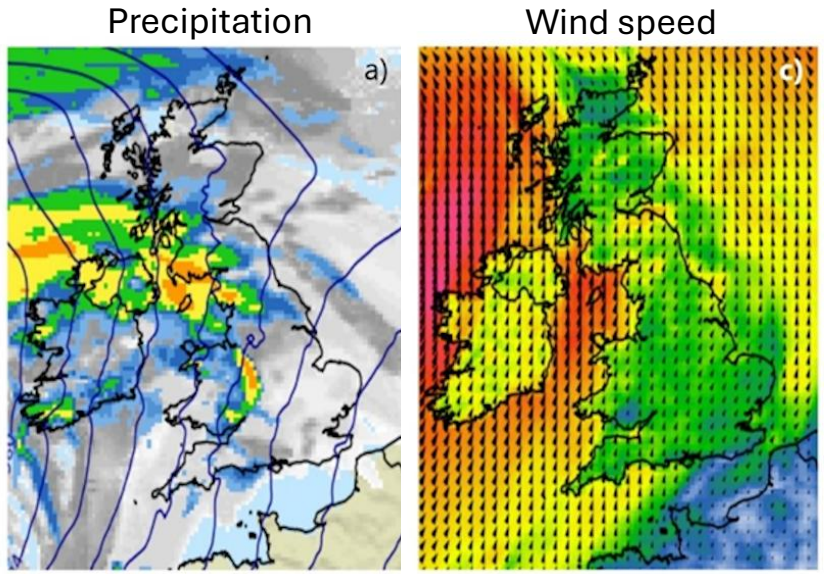
Models including vegetation/biosphere dynamics termed **Earth system models.**

Many different GCMs developed by different research teams – vary in complexity and processes included
(e.g. Met Office HadGEM3)

Balaji et al. 2022, *PNAS*

Modelling present-day climates: weather forecasting





https://www.metoffice.gov.uk/blog/2024/on-the-path-to-delivering-next-generation-uk-weather-forecasts

General circulation models – at the heart of present-day weather forecasting (*numerical weather prediction*; NWP)

Improvements in representation of physical processes and ensemble methods have **hugely improved forecast accuracy**!

Next gen studies – incorporating machine learning/AI to boost forecast accuracy.

Modelling present-day climates: reanalysis

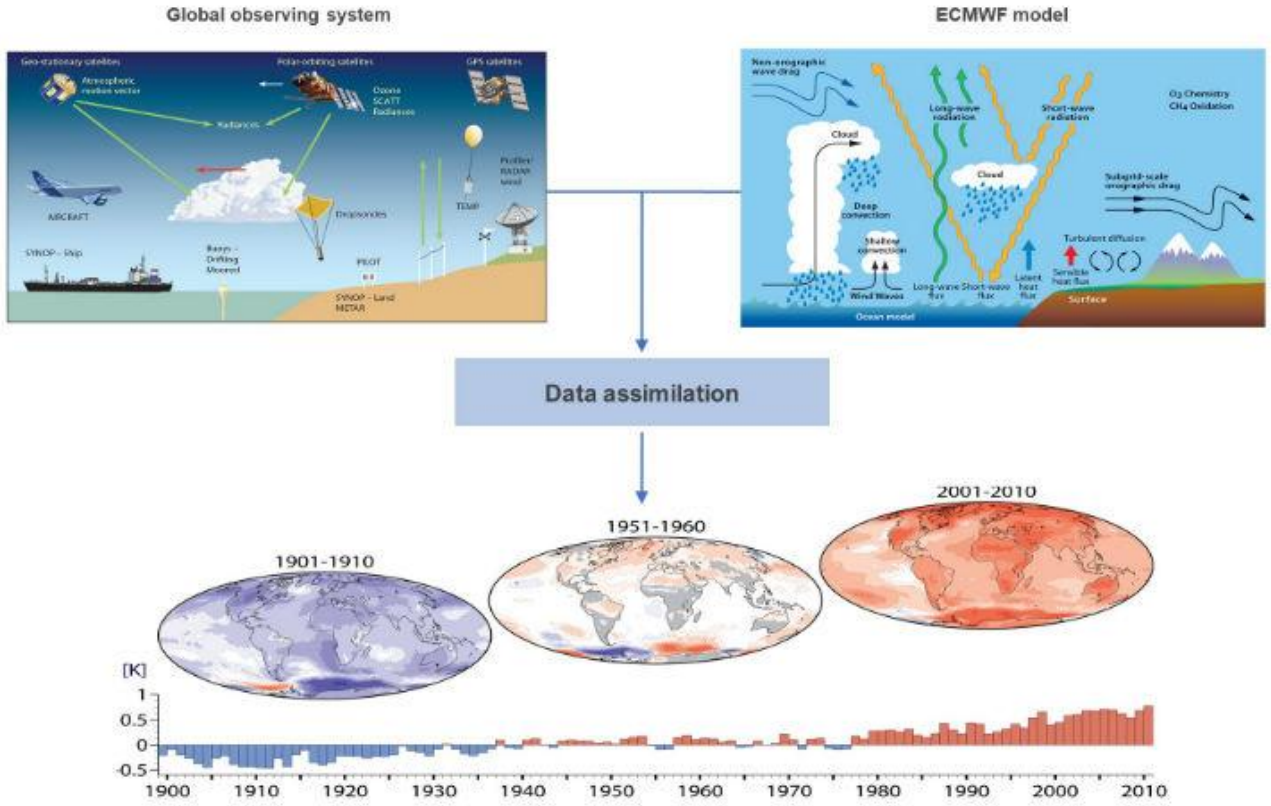


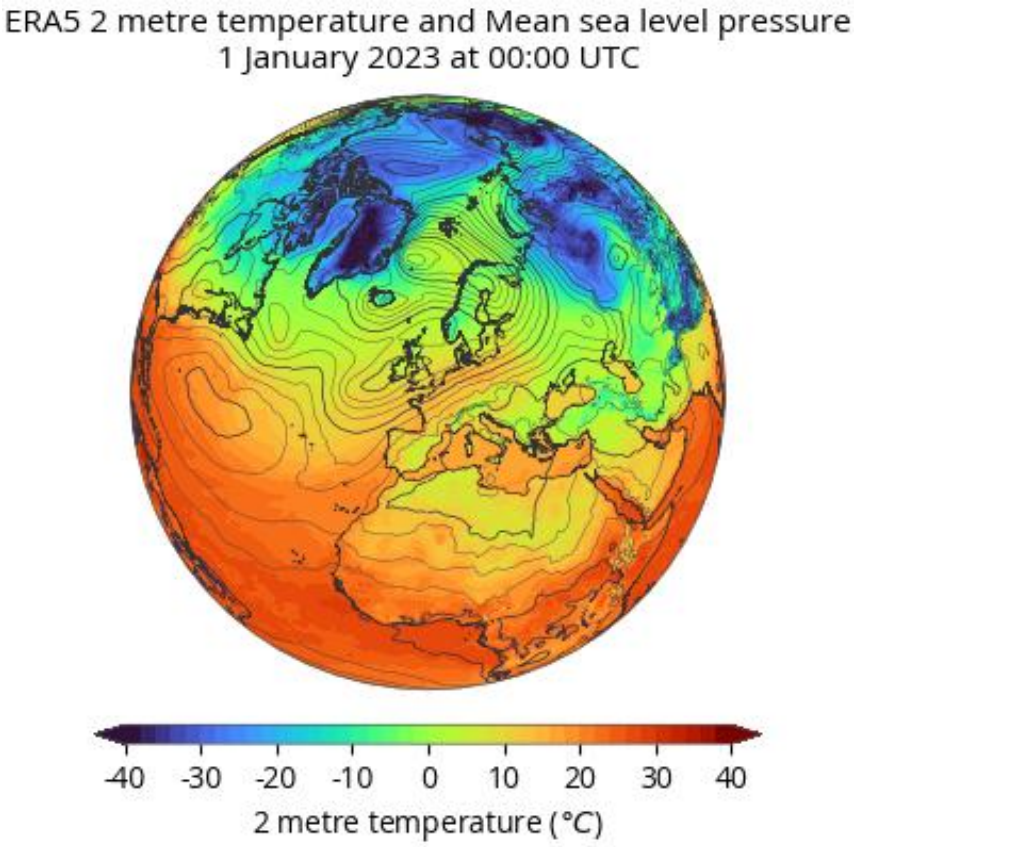
Image: ECMWF

Climate reanalysis: **“replaying the tape” of the global climate** since ~1950.

Huge modelling effort - **combine GCM simulations with observations** from weather stations around the world.

https://www.ecmwf.int/en/research/climate-reanalysis

Modelling present-day climates: reanalysis



https://cds.climate.copernicus.eu/datasets/reanalysis-era5-pressure-levels

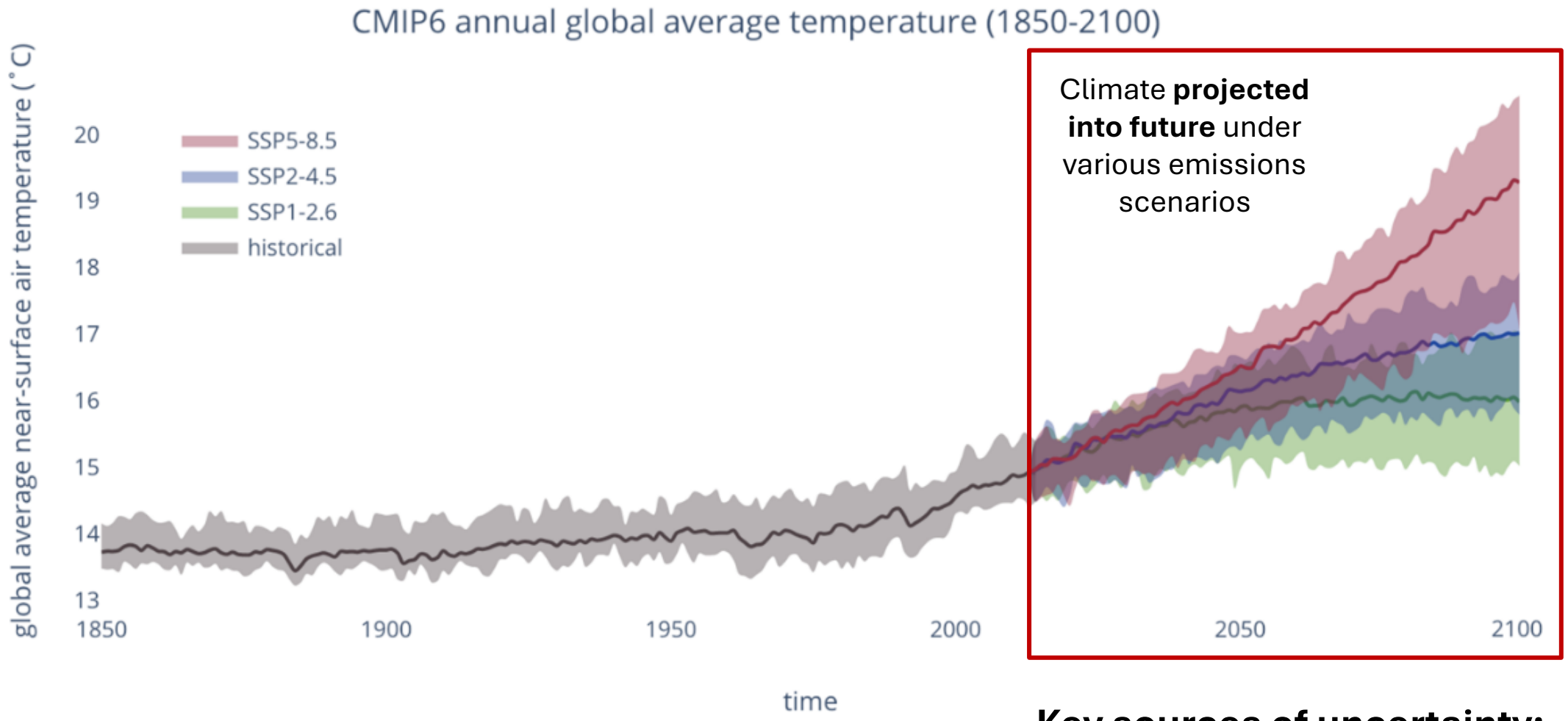
Climate reanalysis: **"replaying the tape" of the global climate** since ~1950.

Huge modelling effort - **combine GCM simulations with observations** from weather stations around the world.

ERA5 reanalysis – most detailed and accurate data on historical weather/climate

Essential tool for **research into climate influence on ecosystems and health –** more this afternoon and next week!

Modelling future climates: scenario projection



Key sources of uncertainty:

(1) Structural (model) uncertainty

(2) Scenario uncertainty

https://climate.copernicus.eu/latest-projections-future-climate-now-available

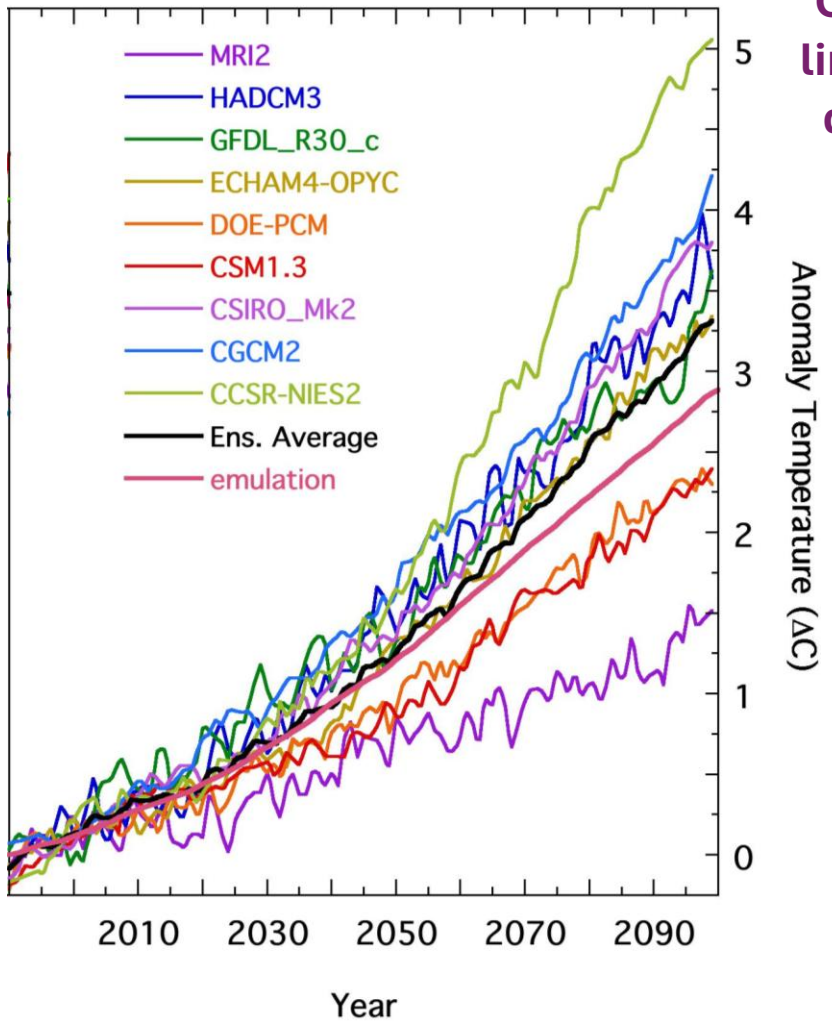
Structural uncertainty in climate models

How well does a particular model perform at predicting the weather or climate?

Different GCMs differ in representation of physical and Earth system processes, etc.

Structural uncertainty **– arises from differences in model structure and parameterization.**

Models **evaluated and calibrated** against continuous stream of present-day weather data.



Coloured lines show different models

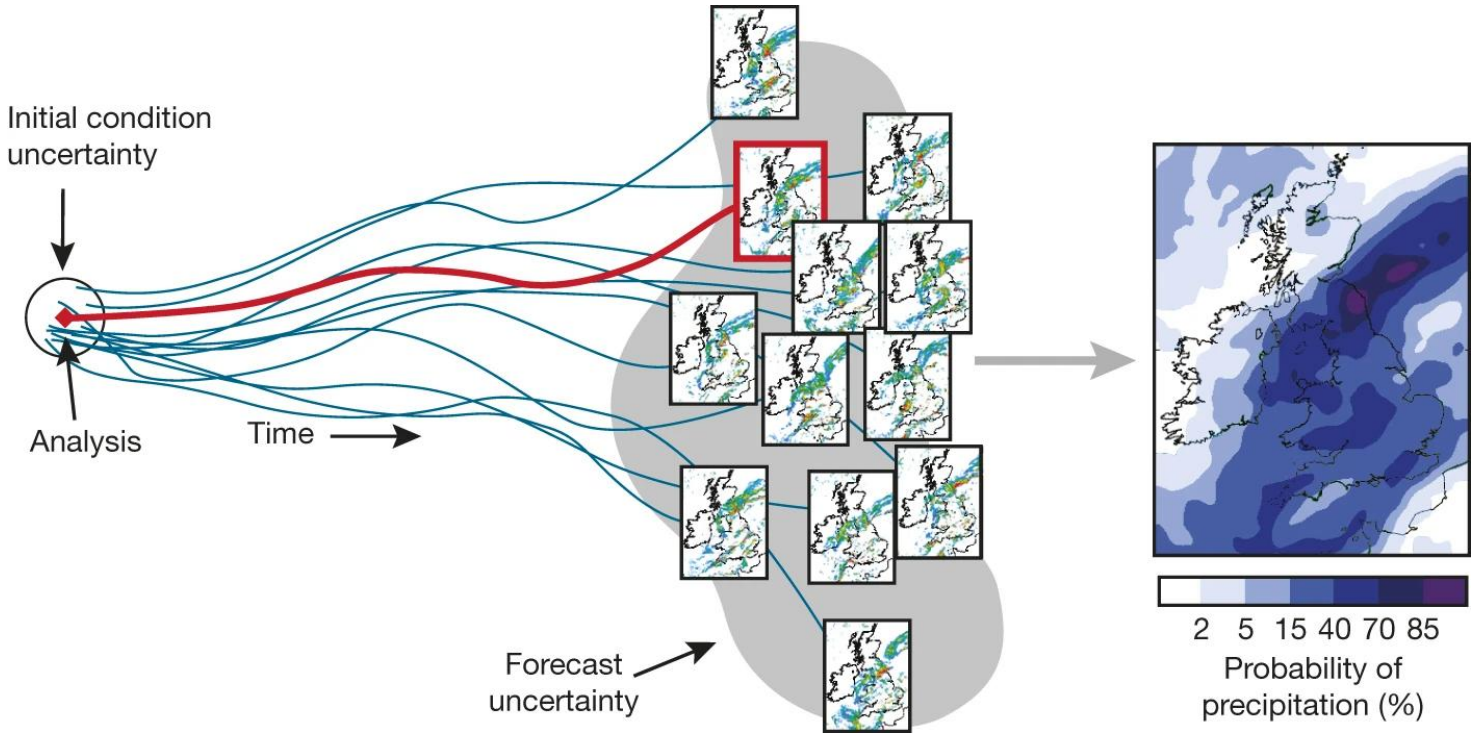
Frank et al. 2019, *Frontiers Earth Sci*

Addressing structural uncertainty through ensemble forecasting

Different models can be good at different tasks!
(e.g. predicting mean temperature vs frequency of extremes)

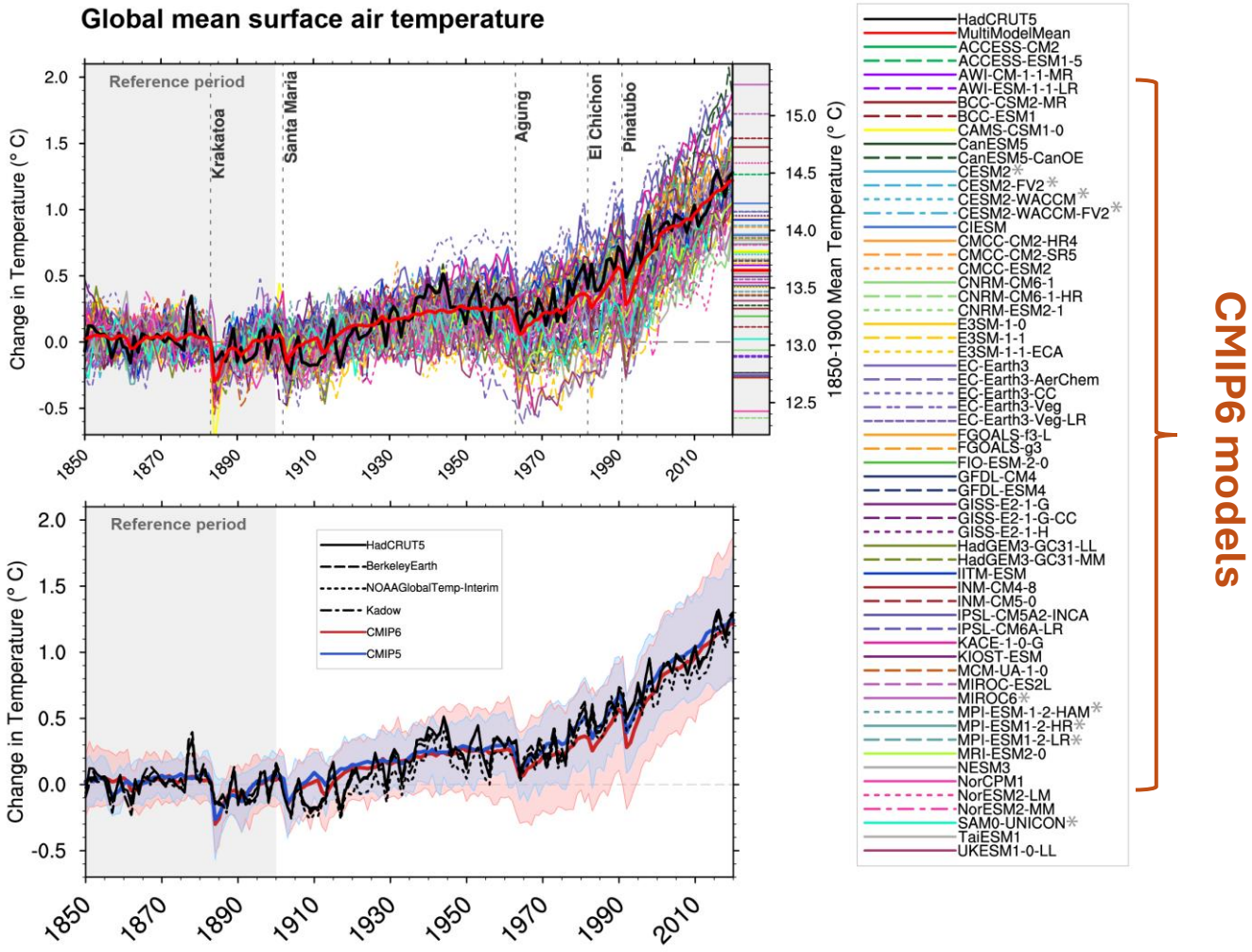
Principle of **ensemble forecasting** – many minds (models) are better than one

Key innovation that has driven up forecast accuracy
(compare ensemble mean and outliers to understand range of possible futures)



Bauer et al. 2015, *Nature*

Addressing structural uncertainty through ensemble forecasting



CMIP (Coupled Model Intercomparison Project)

(est. 1995 by World Climate Research Program)

Coordinates model comparison across climate modelling community

(each team runs a standard set of scenarios and experiments)

Currently 6th gen: **CMIP6**

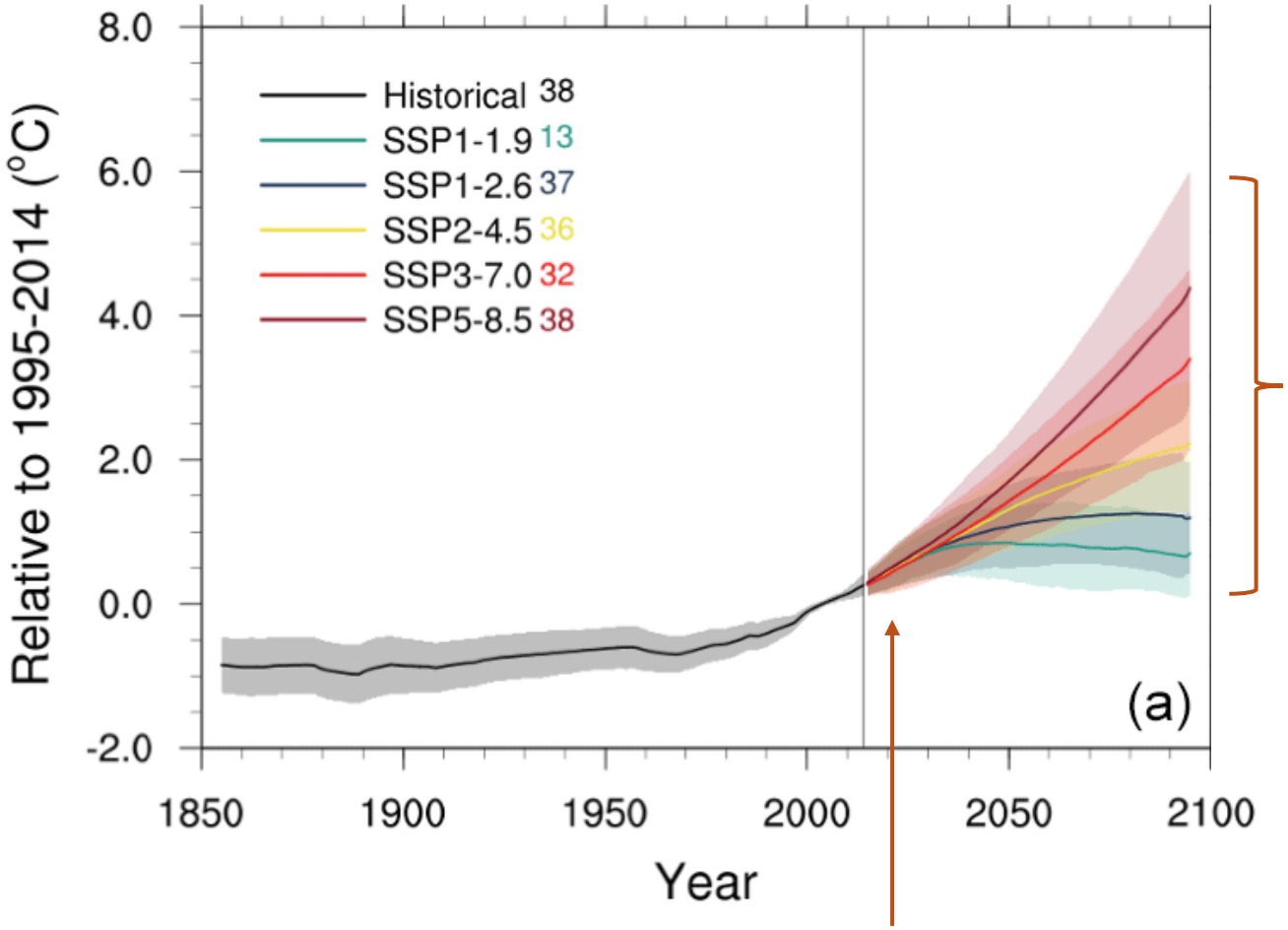
Outputs **underpin IPCC synthesis reports**, and wider climate change and impacts research

IPCC Sixth Assessment Report, 2021, *Chapter 1: Physical Science Basis*

Scenario uncertainty across different future emissions pathways

Coloured bands = structural uncertainty within scenarios

Different colours = different scenarios



Scenarios diverge further into the future – as futures become more different

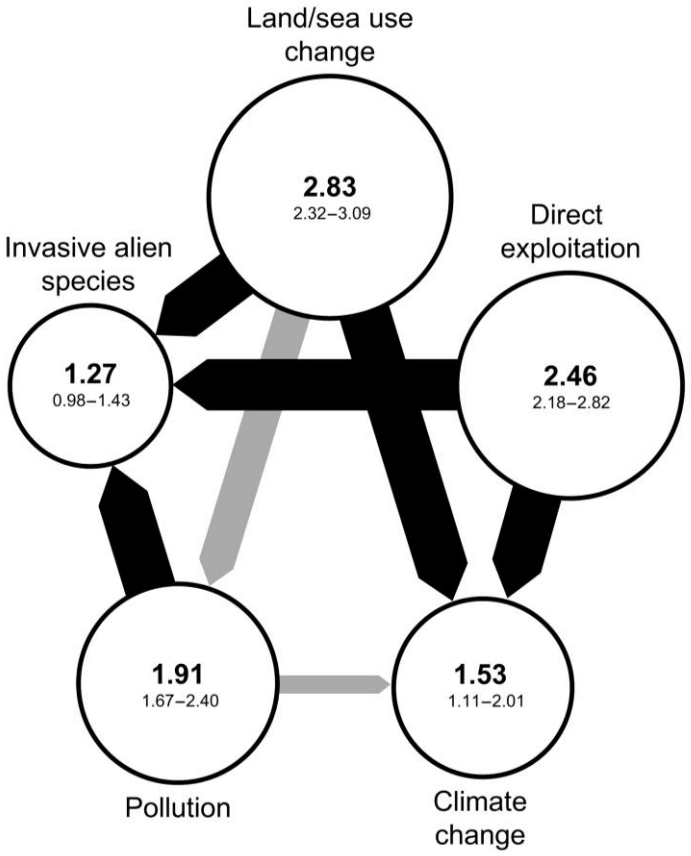
Near-term future predictions dominated by structural uncertainty + initial conditions

Tebaldi et al. 2021, *Earth System Dynamics*

How well can we predict future land use change?

How well can we predict future land use change?

Dominance hierarchy of current drivers of biodiversity loss



Jauregriberry et al 2022 *Sci Adv.*

Land use change is the **principal current driver** of biodiversity change

Projections of future landscapes are critical for biodiversity impact studies.

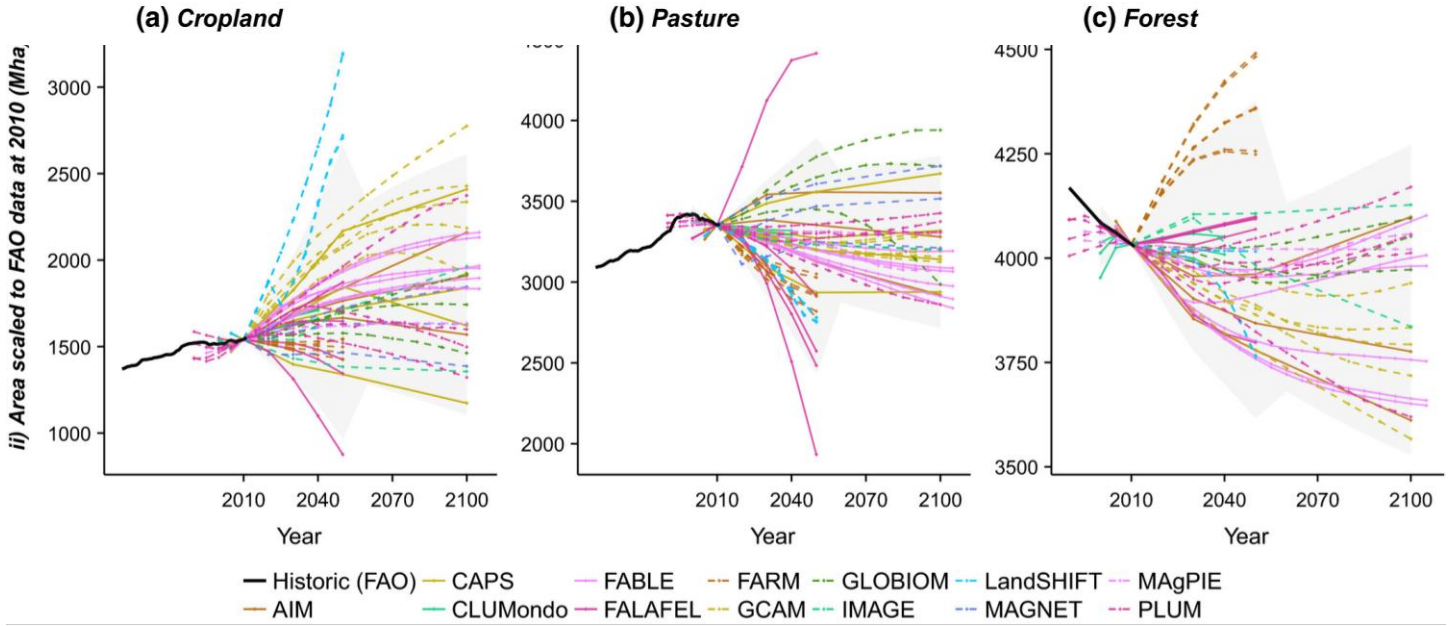
Much more complex than predicting the climate! Not just physical principles – social-political-ecological-economic drivers

How well can we predict future land use change?

Land use changes projected using **economic models** *("Integrated Assessment Models")*

Simulate **land change to meet resource demand** from future human populations *(make strongly simplifying assumptions about the process of land conversion, largely ignore institutional power dynamics, etc)*

Massive uncertainty in future land change projections – **structural uncertainty exceeds scenario uncertainty**



Alexander et al, 2017, *Global Change Biology*

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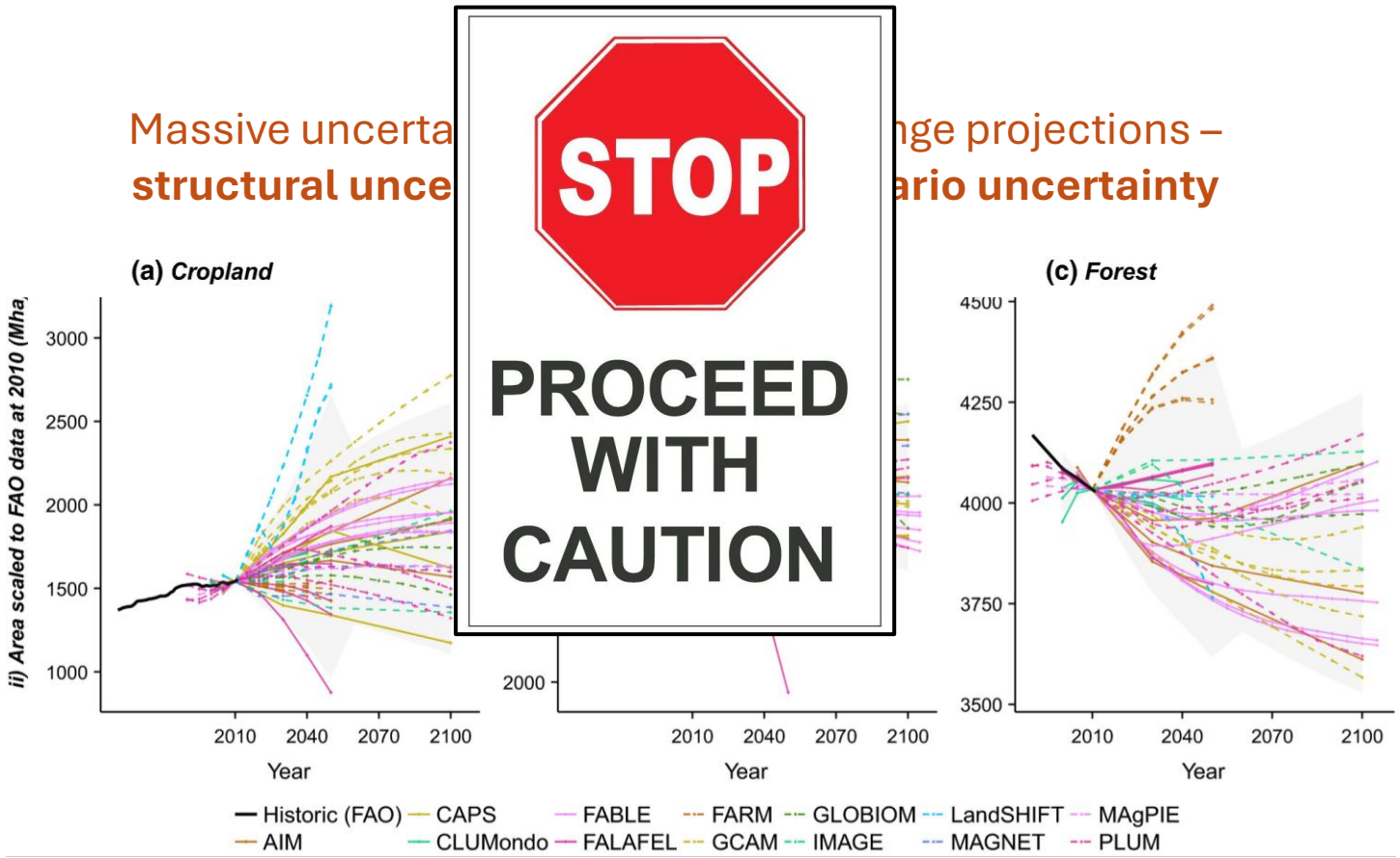
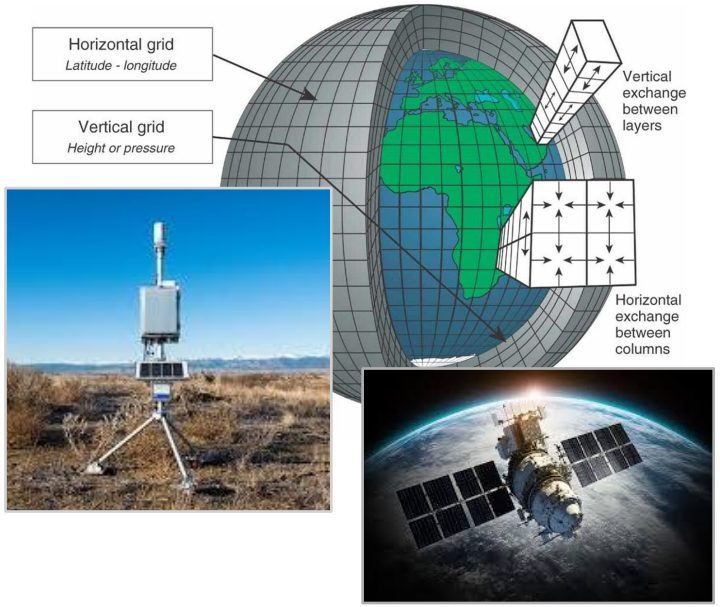


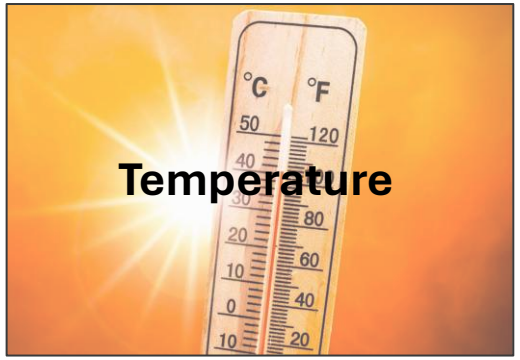
Alexander et al, 2017, *Global Change Biology*

How can scenarios help to understand future climate changes and their associated risks to health and biodiversity?

“Essential climate variables” for climate impact studies

Climate models
and/or observations

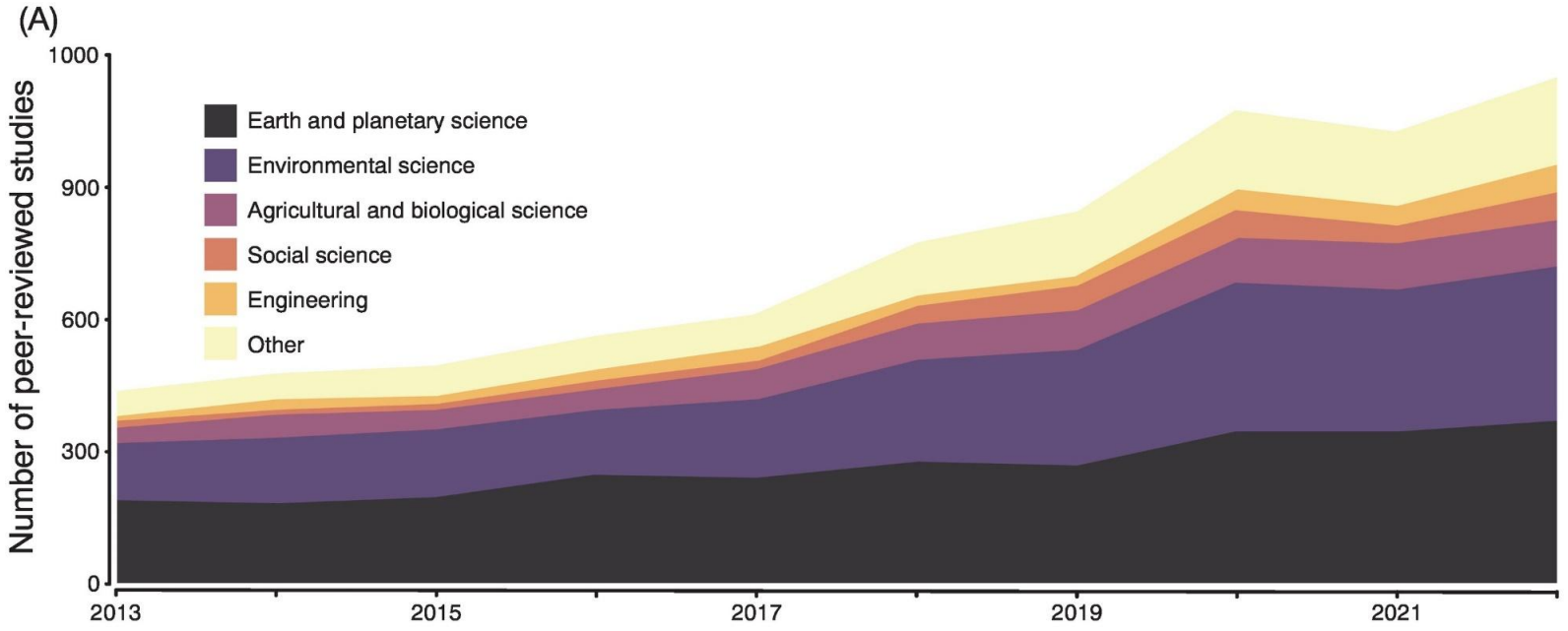


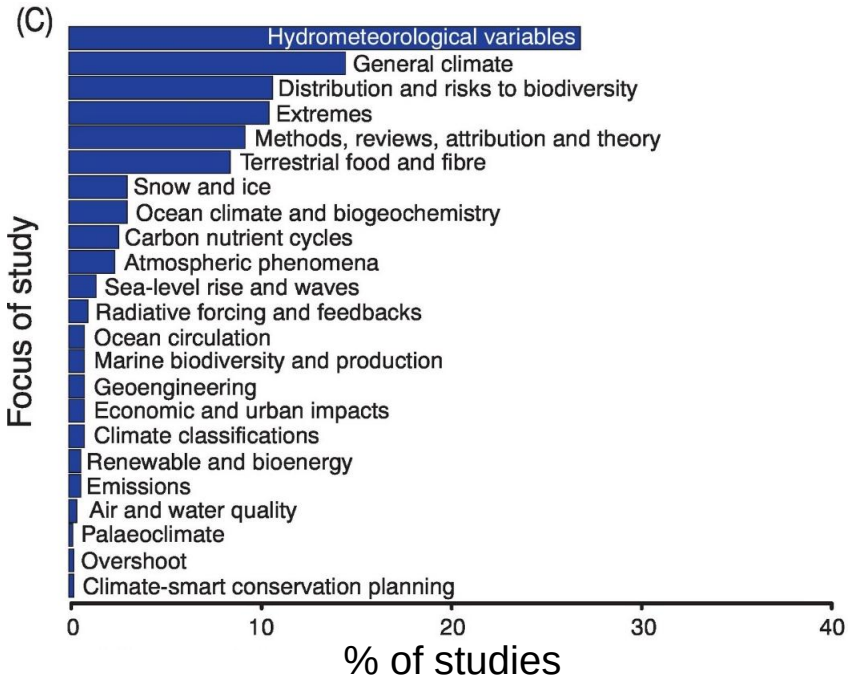


(hourly, daily, monthly, multiyear average)

(intensity, duration, frequency)

Climate model projections are widely used in impact studies





Review

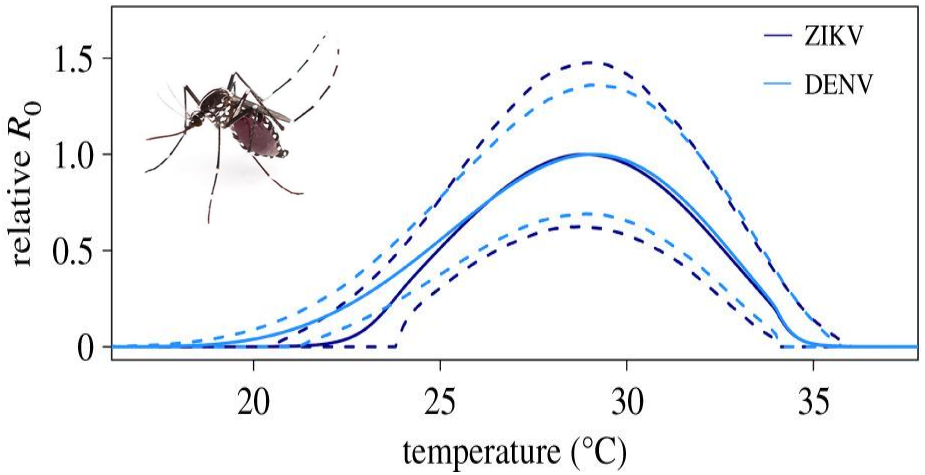
Demystifying global climate models for use in the life sciences

David S. Schoeman, [1,2,*] Alex Sen Gupta, [3,4,8] Cheryl S. Harrison, [5] Jason D. Everett, [6,7,8]

Climate hazards and extremes
Infectious disease risk
Food systems risk
Biodiversity change and risks

Impact studies of global or regional climate change on health

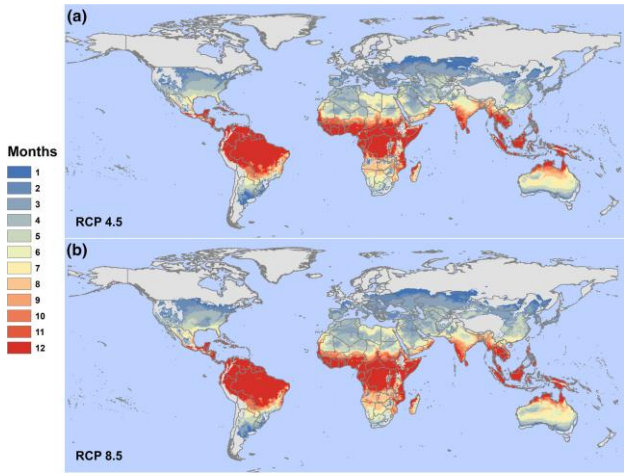
Statistical or mathematical model
linking health or biodiversity outcome(s) to climate



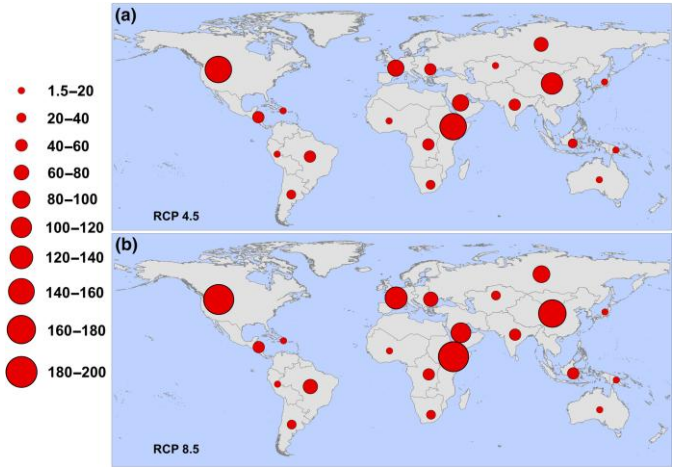
Tesla et al. 2018, *Proceedings B*

Predict from model onto future climate data

Projections – <u>not</u> forecasts!
(possible futures under scenario and model assumptions)



Months suitable for Zika in 2050
(RCP4.5 and 8.5)



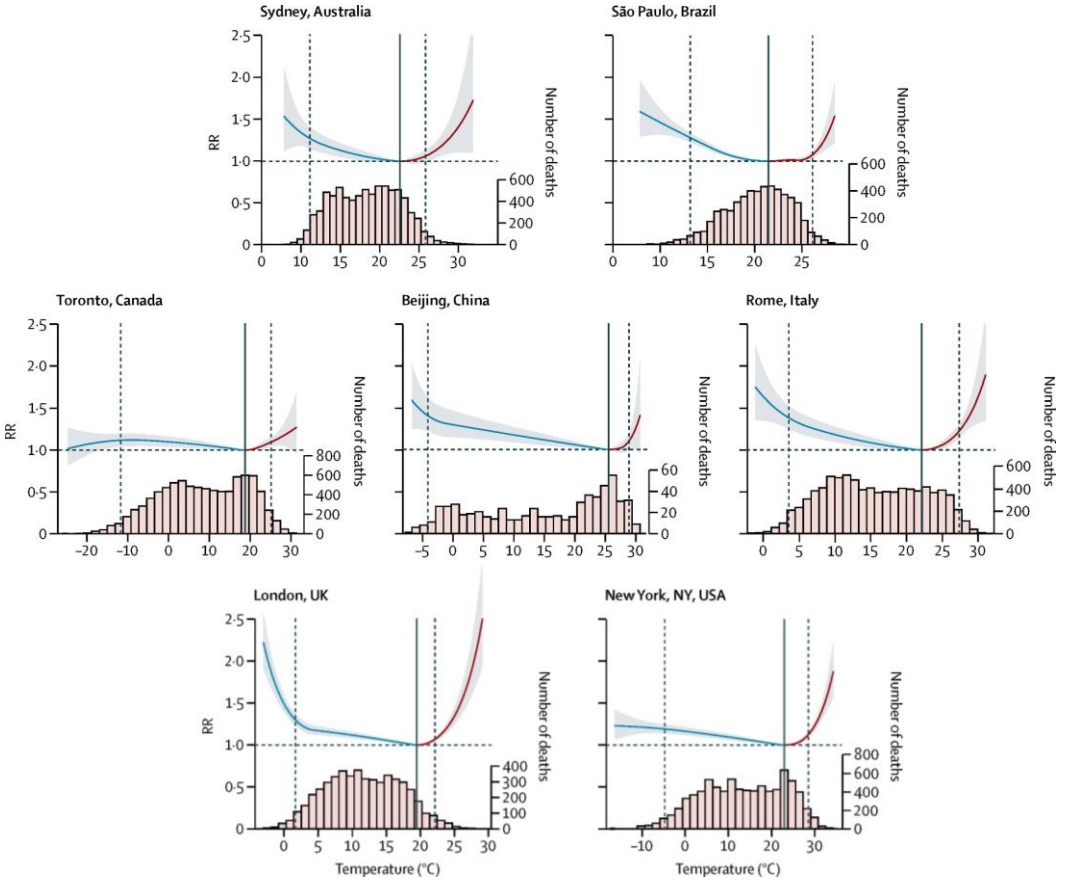
Change in population at risk by 2050
(RCP4.5 and 8.5)

Ryan et al. 2020, *Global Change Biology*

Impact studies of global or regional climate change on health

Heat and cold exposure –
heat stress/hypothermia, exacerbates cardiovascular/ respiratory disease, mental health, etc.

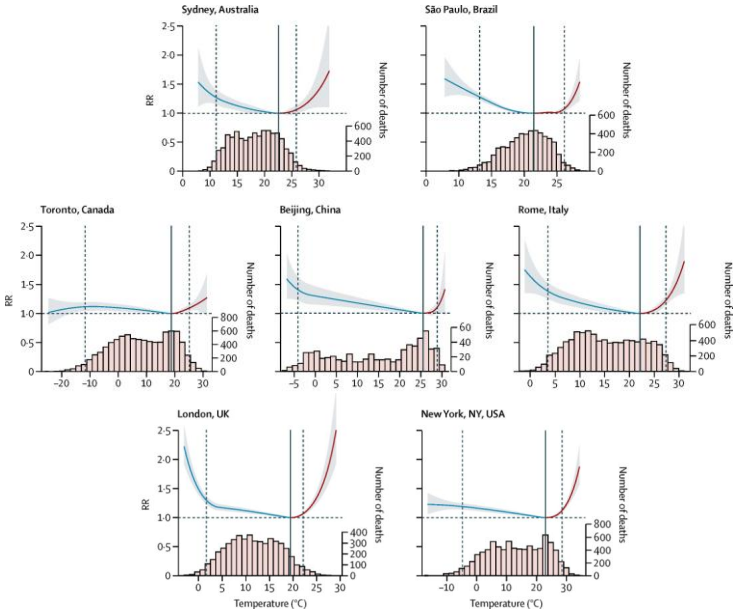
Relative **mortality risk (all-cause) by temperature,** across a set of cities

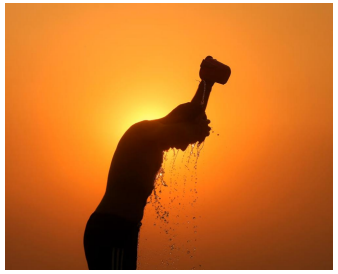


Gasparrini et al. 2015, *Lancet*

Impact studies of global or regional climate change on health

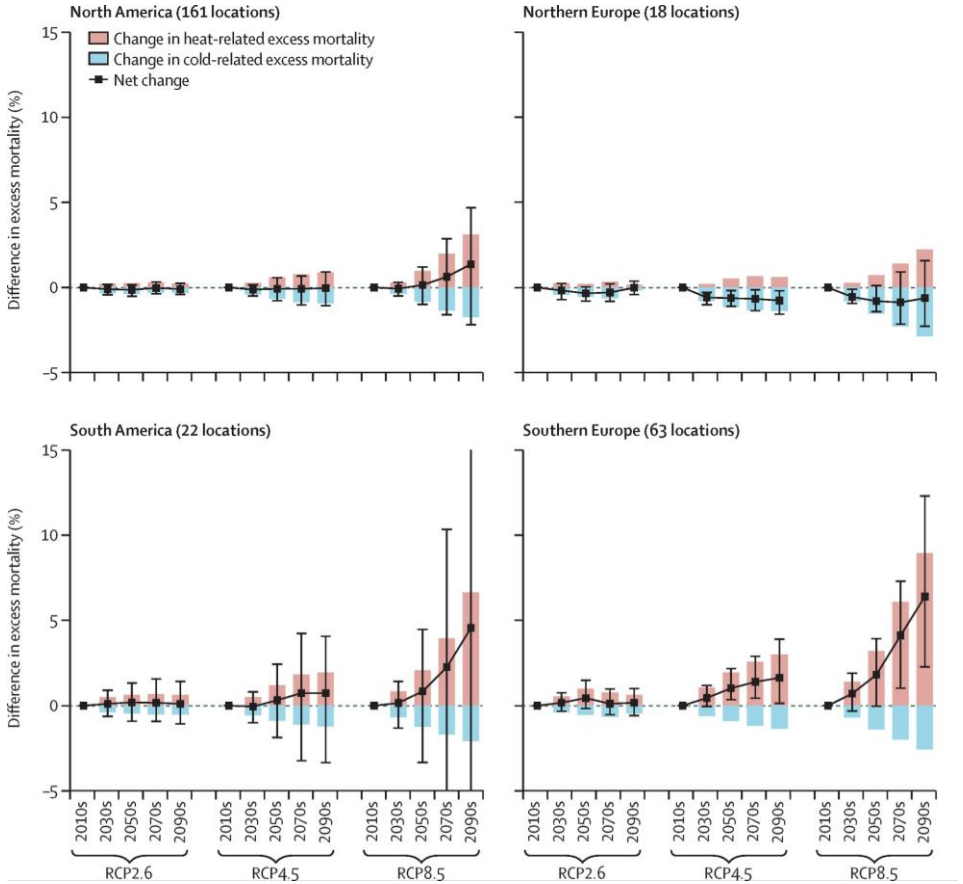
Statistical model of temperature-mortality relationship





Predict from model onto future climate data

Heat-related mortality projected to increase in most – <u>but not all</u> – regions, with worst outcomes in an RCP8.5 future



Gasparrini et al. 2017, *Lancet Planetary Health*

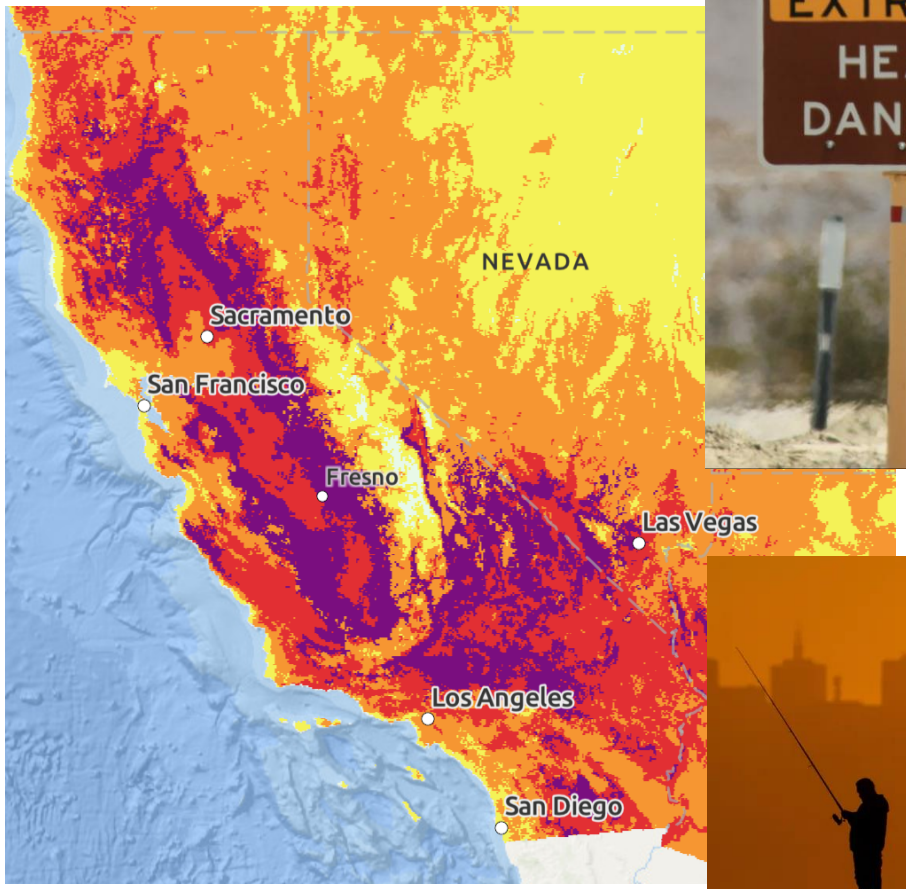
Impact studies of global or regional climate change on health

This afternoon's R workshop!

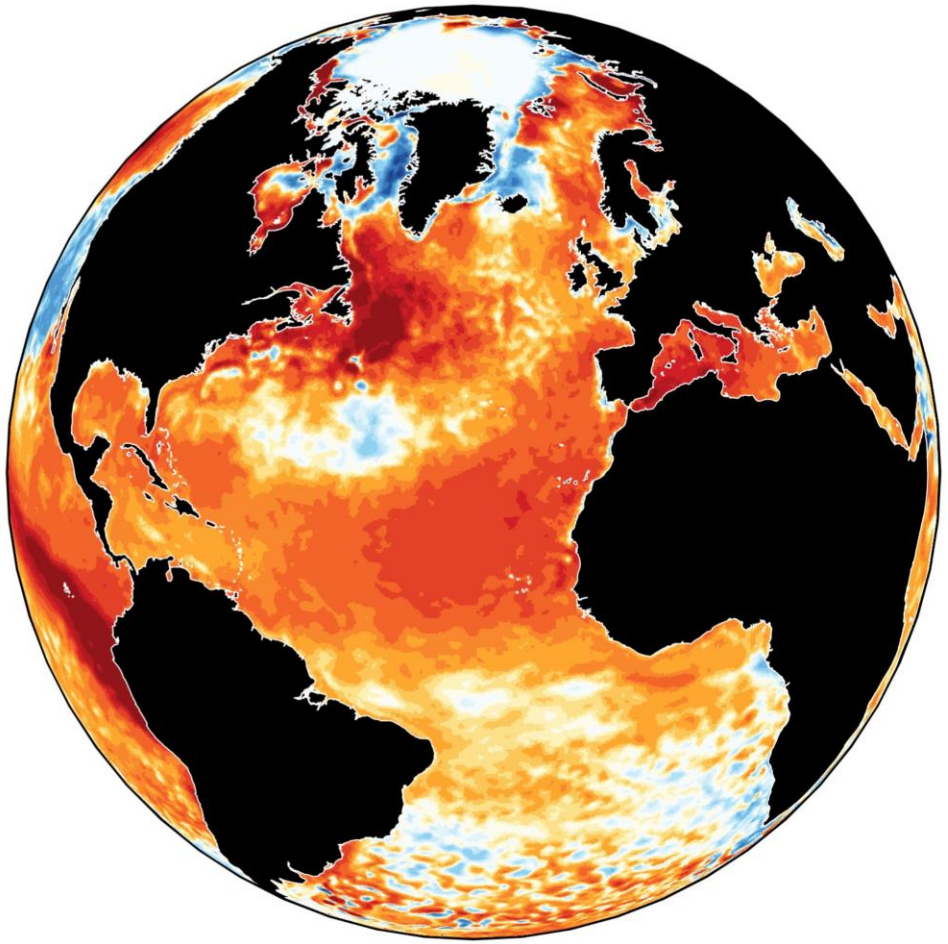
Exposure to extreme temperatures in the southwest USA

Workbook and data available on the module GitHub: https://github.com/MSc-ECCH-UCL/BIOS0052-Human-And-Ecosystem-Health

14:00-17:00, Marshgate Room 636



In summary…



- The future is inherently uncertain – **scenario analysis can help to assess future risks** in various plausible futures.
- Climate and Earth system models can **predict the state of the climate** under differing scenario assumptions.
- Uncertainty is not a sign of bad science, but inherent to understanding the world – **collaborative science** and **multi-model ensemble forecasts** are critical tools.
- **Predicting socio-ecological drivers (e.g. land use change) is much harder** than the climate – not grounded in same fundamental physical principles.
- Scenario predictions are **projections, not forecasts** – not “this outcome will happen”, but rather, “this outcome could happen under our assumptions”.

Questions?

See you at 14:00 in Marshgate 636!