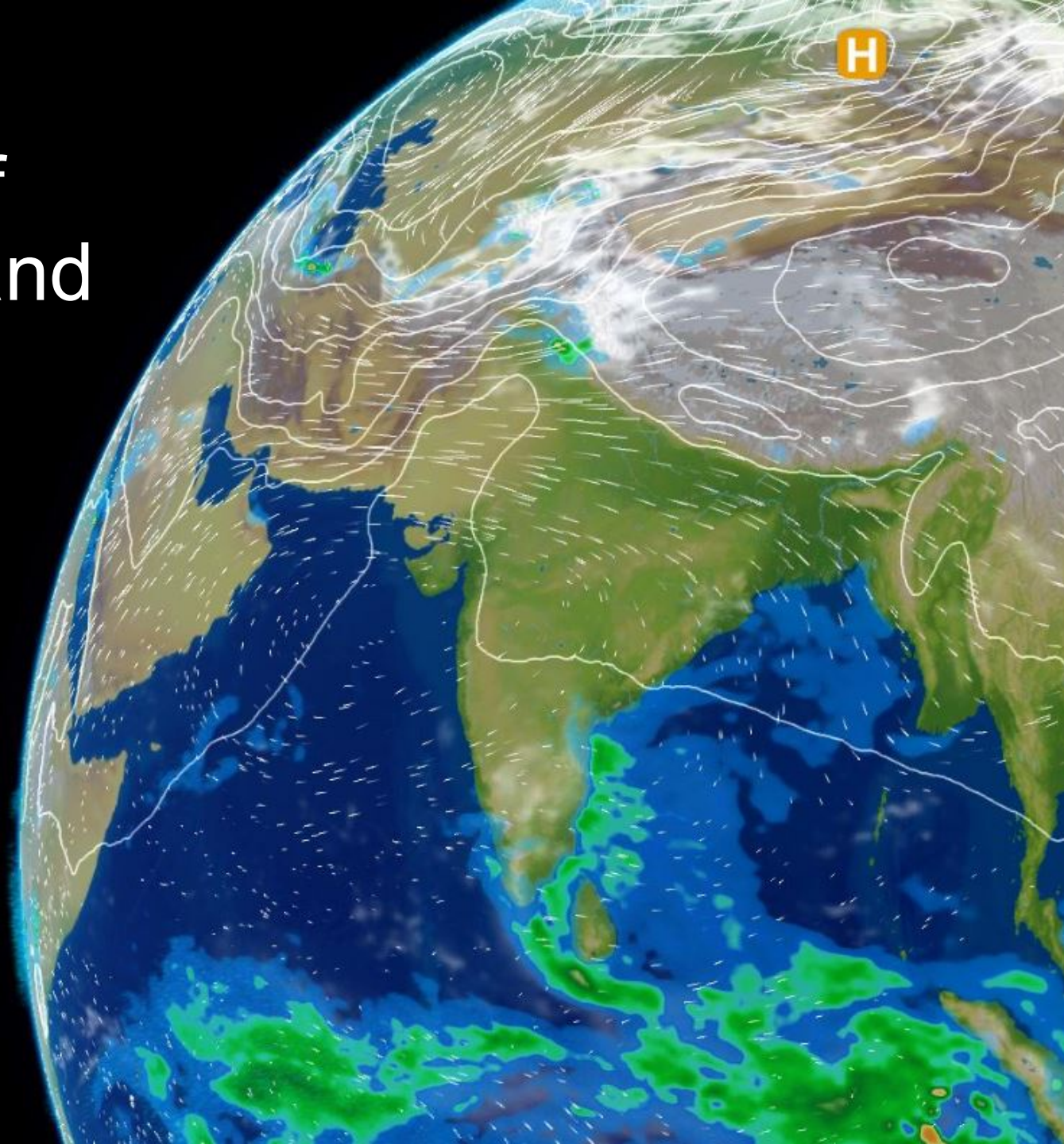
Fundamental concepts of climate change science and prediction

Dr Joseph Daron

CORDEX and ARRCC training on regional climate projections

Tuesday 13th October 2020

Thanks to the Met Office College and scientific collaborators; Rosanna Amato, Katy Richardson & Dan Copsey



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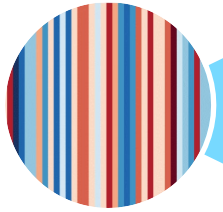
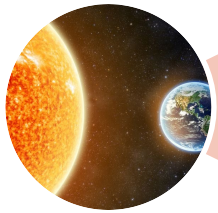
Objectives

Understand the basic principles of the climate system



Identify key internal and external drivers of climate variability



Explain how climate models work and generate future projections

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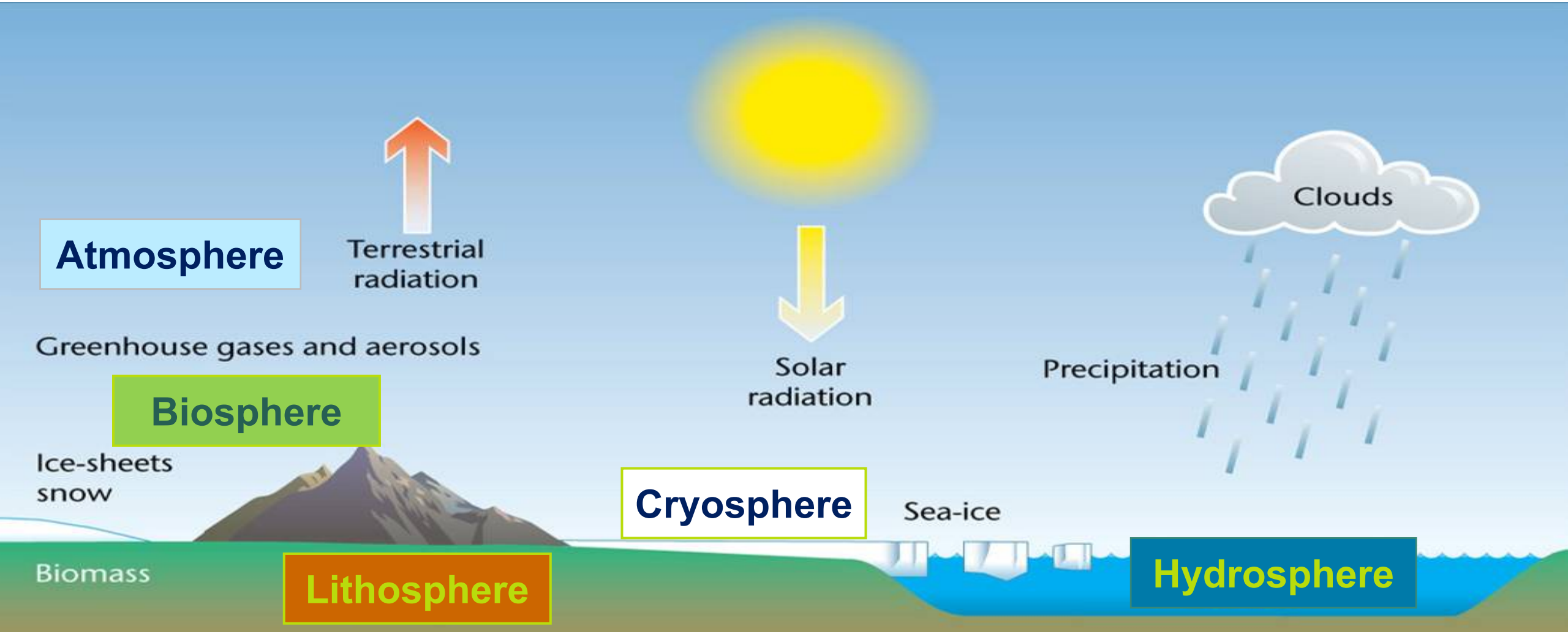
The Climate System

Simplified Climate System



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Global energy balance

Earth’s energy balance describes how the incoming energy from the sun is used and returned to space.

If incoming and outgoing energy are in balance, the earth's temperature remains constant.

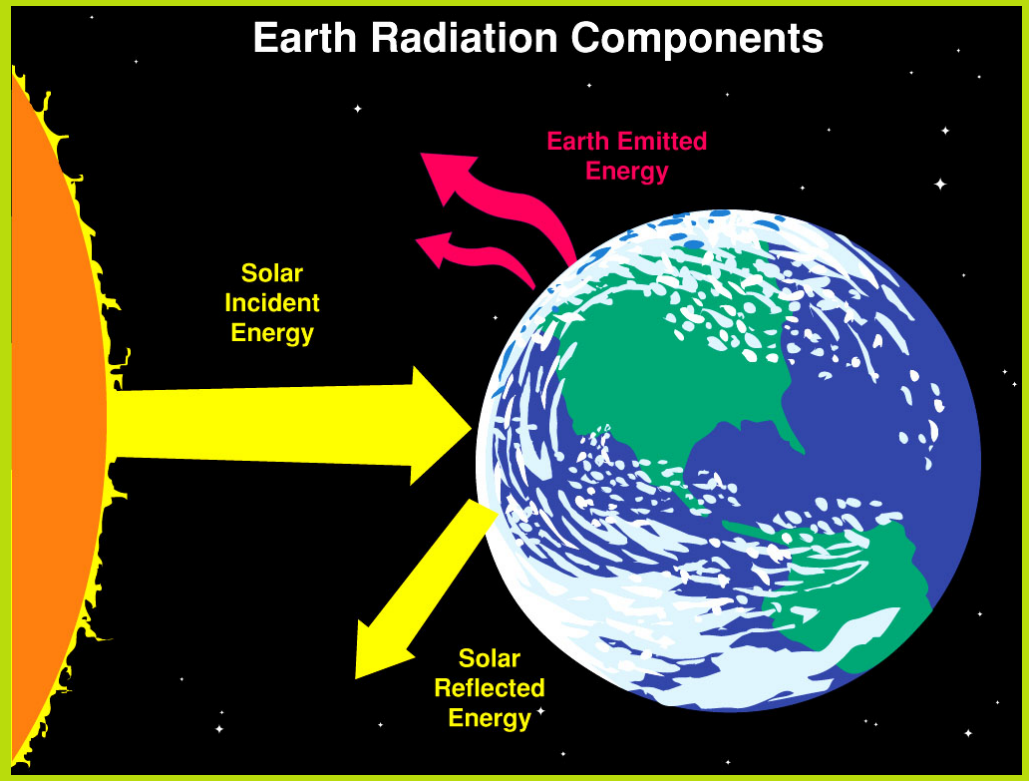
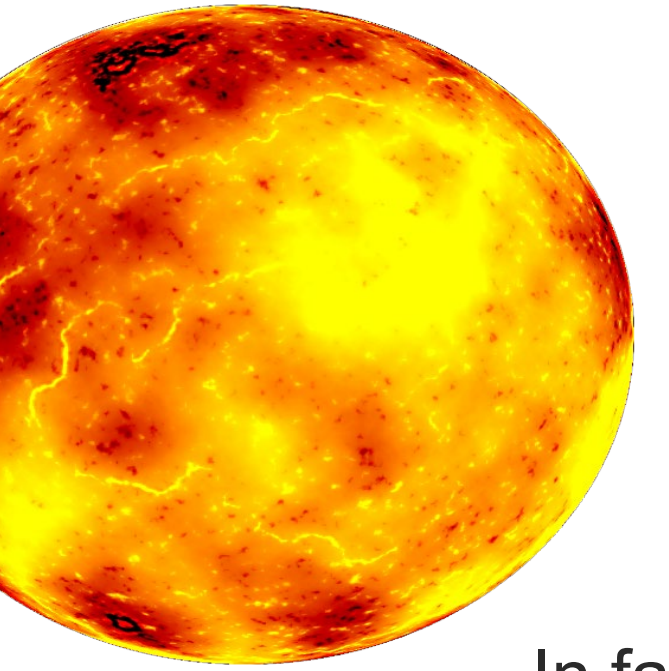


Image from visibleearth.nasa.gov

Planetary Energy Balance



Combining the distance from the Sun and reflectivity of the Earth, we predict a temperature of;

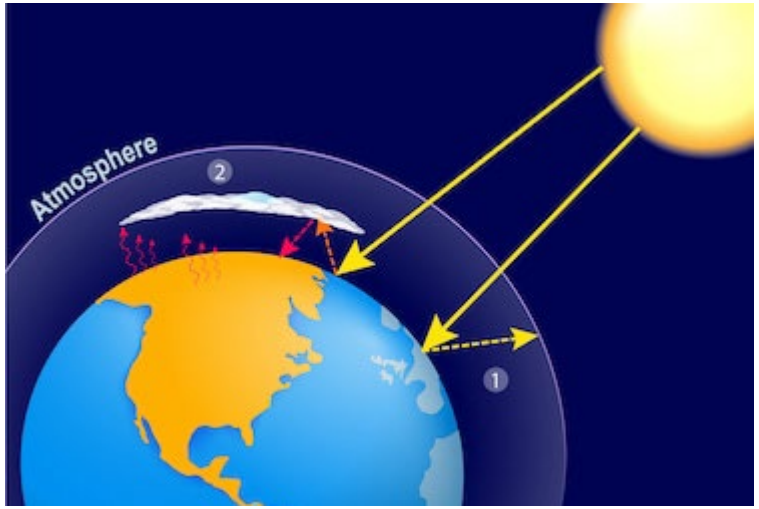
255 K (~ -18˚ C)

Greenhouse Effect

In fact, the mean surface temperature of the Earth is;

288 K (~ +15˚ C)

Why is there this difference?



Drivers of Climate Variability

What drives our climate?

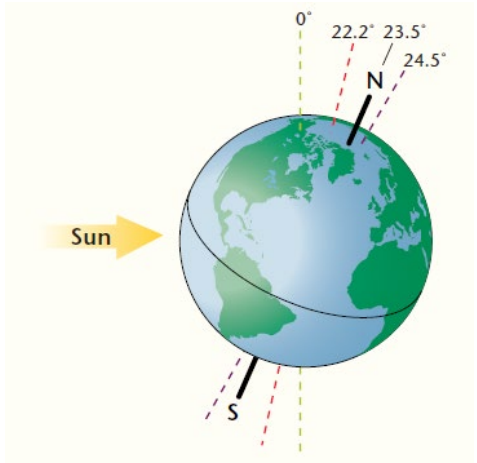
A **climate driver** is an

internal, external or man-made force

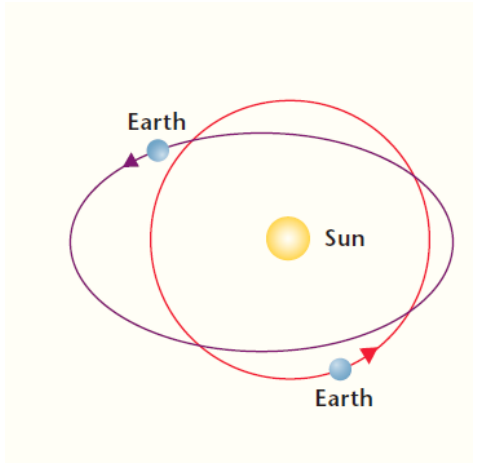
that unequivocally **influences processes** and can therefore be identified and measured to a degree of accuracy.

External “forcings” on the climate

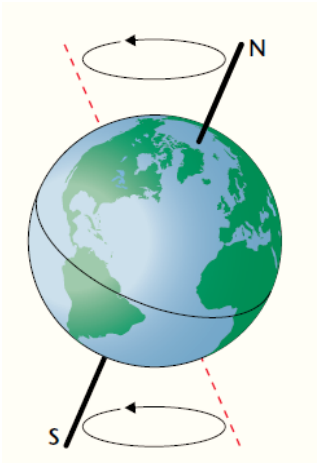
Croll-Milankovitch cycles



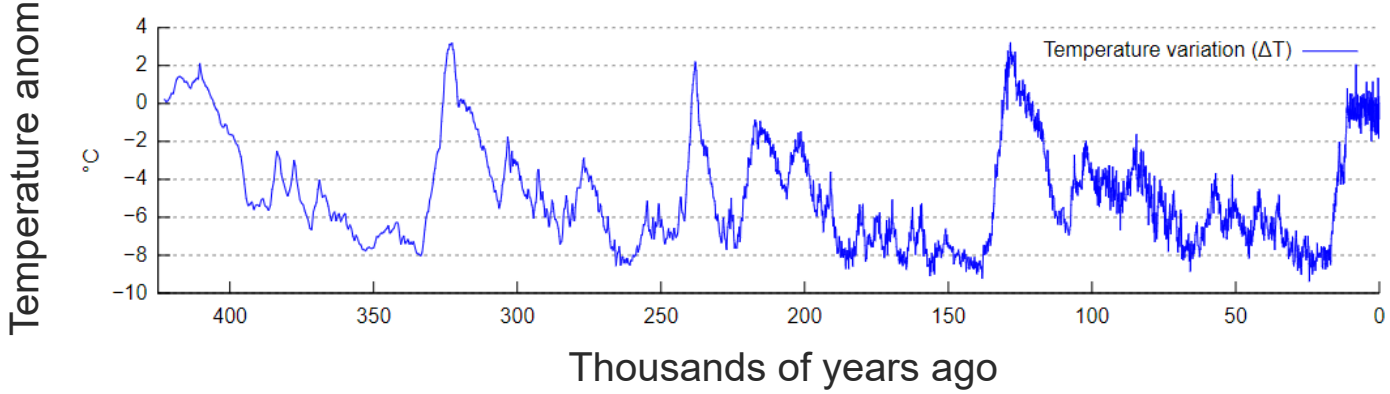
Obliquity
41,000 years



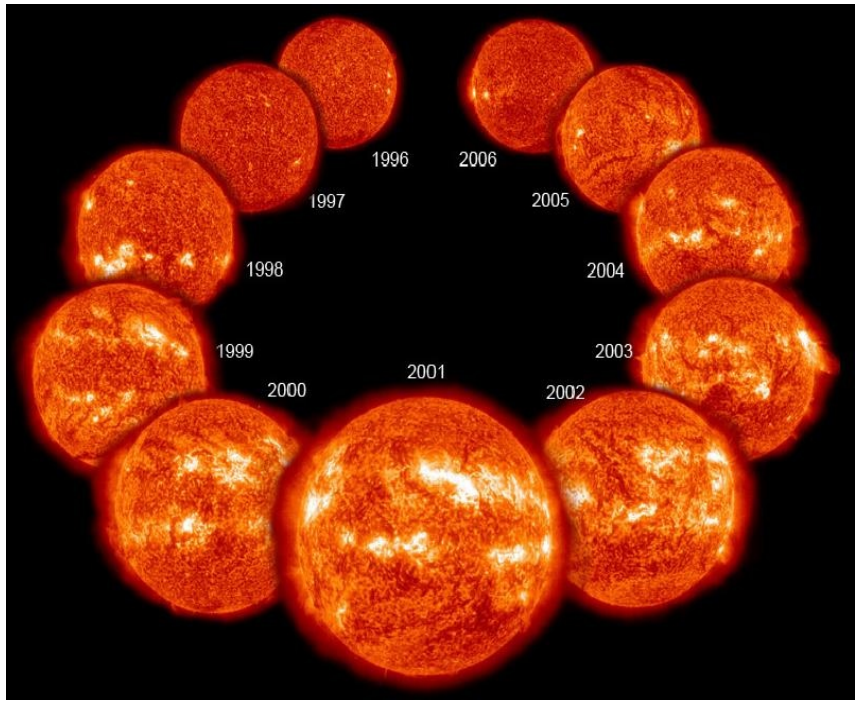
Eccentricity
100,000 years



Precession
26,000 years



Variations in Solar Irradiance

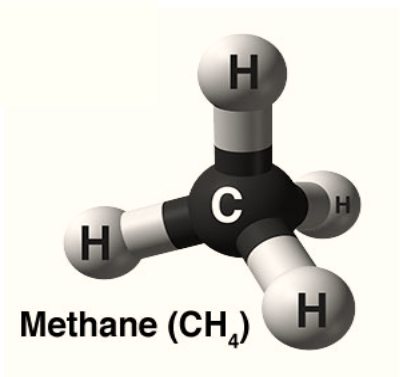


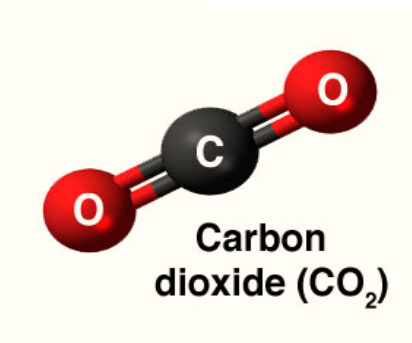
11 year cycle

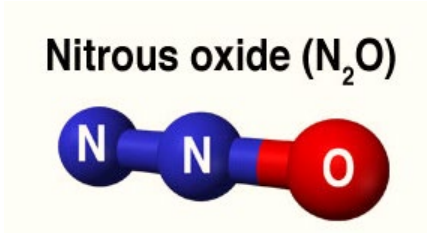
Graph: commons.wikimedia.org/wiki/File:Vostok_Petit_data.svg

Internal “forcings” on the climate

Greenhouse gases







Aerosols

Aerosols (e.g. dust, pollen, sea salt), either natural or man-made, can reflect or scatter the sun’s energy, reducing the amount of energy reaching the Earth’s surface

Volcanic Eruptions

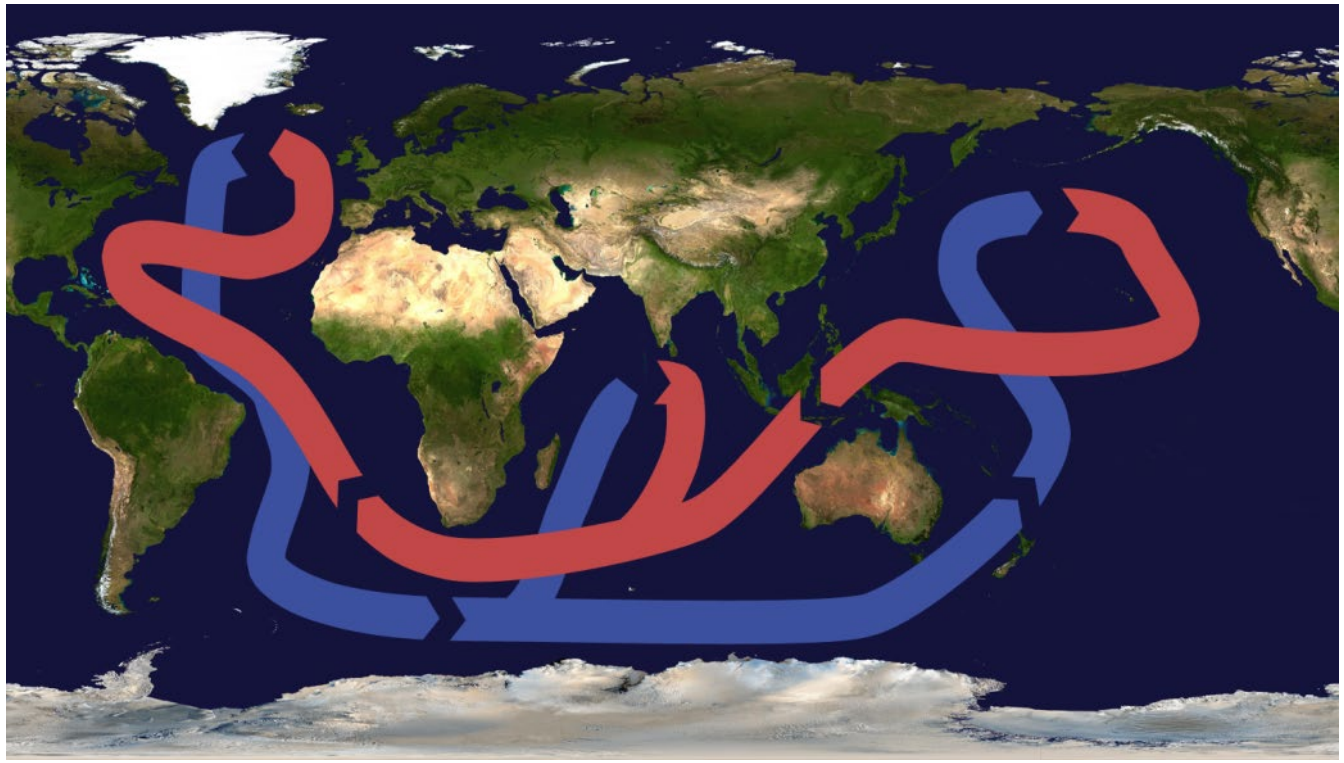
Volcanic eruptions result in sulphur dioxide entering the stratosphere.

Reacts with H_2O under sunlight to form sulphate aerosols which reflect and scatter incoming short-wave radiation.

Internal atmosphere-ocean interactions

Example modes of multi-year climate variability

- El Nino Southern Oscillation (ENSO)
- North Atlantic Oscillation (NAO)
- Indian Ocean Dipole (IOD)



Thermohaline Circulation

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Climate modelling

Why model climate?

1. **Understanding past** climate, verifying proxy data

2. **Climate prediction**
   - Forecasting long term **climate change** (global warming)
   - **Seasonal/Decadal Forecasting** – e.g. IOD, NAO and El Nino forecasting and effects on local climates

3. **Research**
   - Attribution of past climate extremes and events
   - Understanding climate variability
   - Exploring Earth system interactions and feedbacks
   - Investigating model biases
   - …

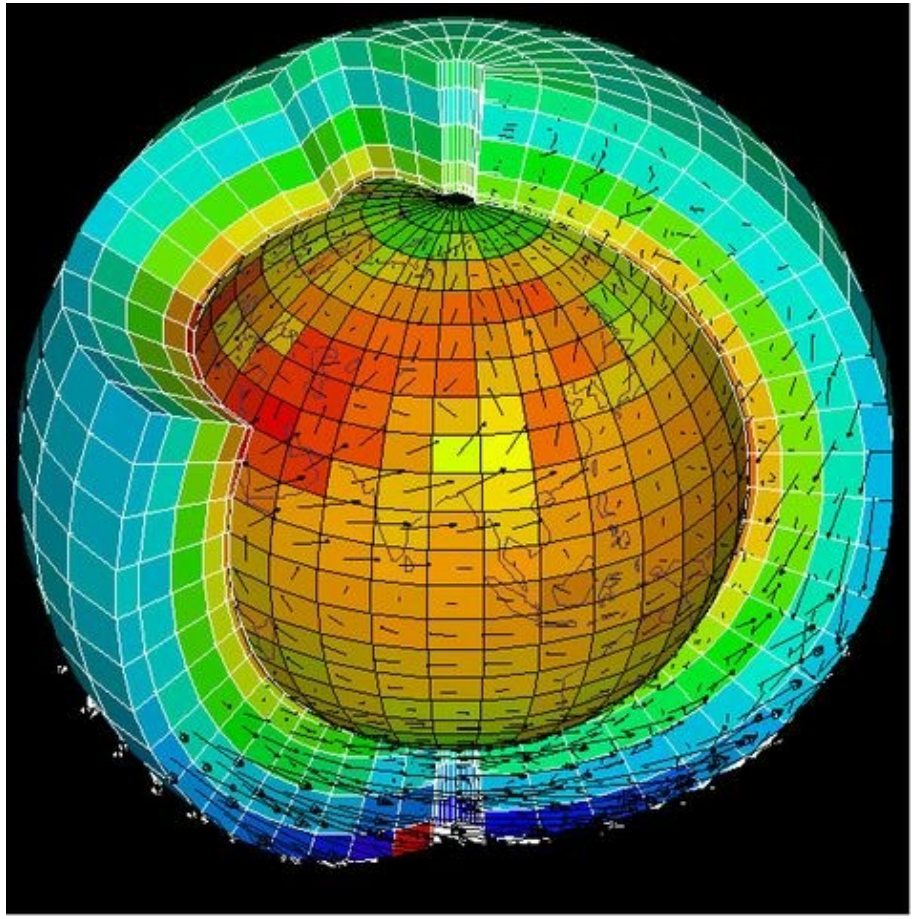
What is a climate model?

"A **numerical representation** of the **climate system** that is **based on the physical, chemical, and biological properties**" (IPCC AR5 2013)

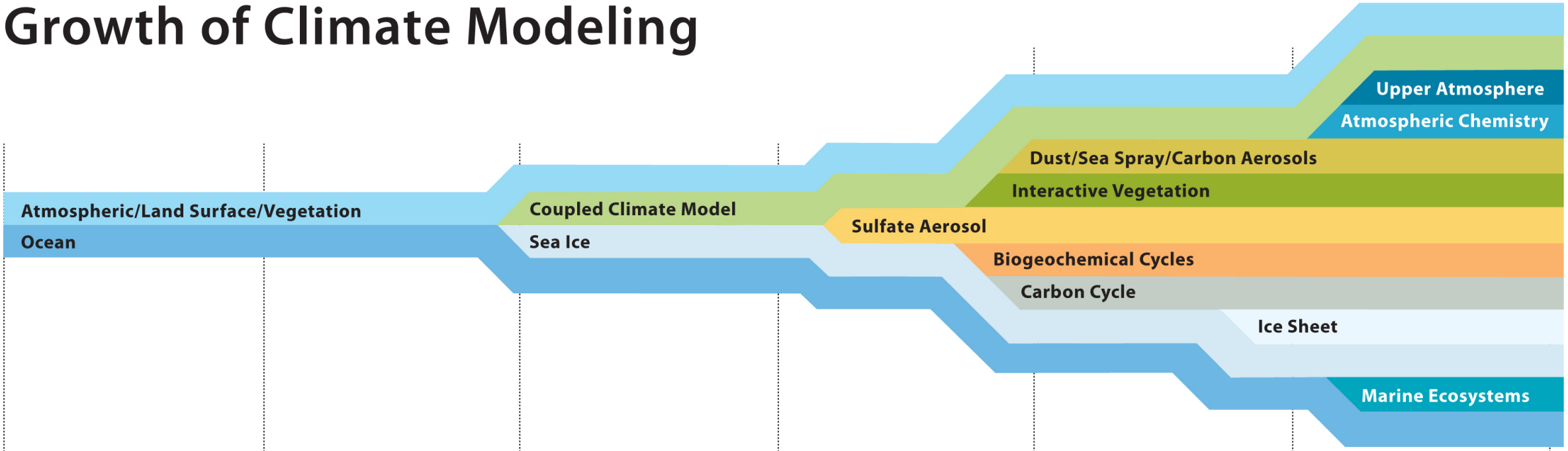
https://www.youtube.com/watch?v=Pn3ZKB1XLiQ&feature=emb_title

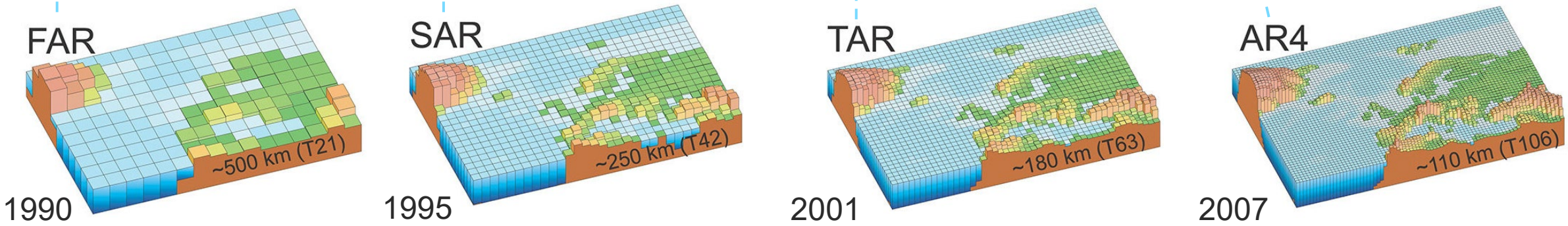
GCMs

- Global Climate or General Circulation Models
- Have resolutions typically 100-300km
- Many different GCMs are run by modelling centres all over the world
- These are compared during the different stages of the Coupled Model Intercomparison Project (CMIP) to support national and international climate change assessments



Growth of Climate Modeling

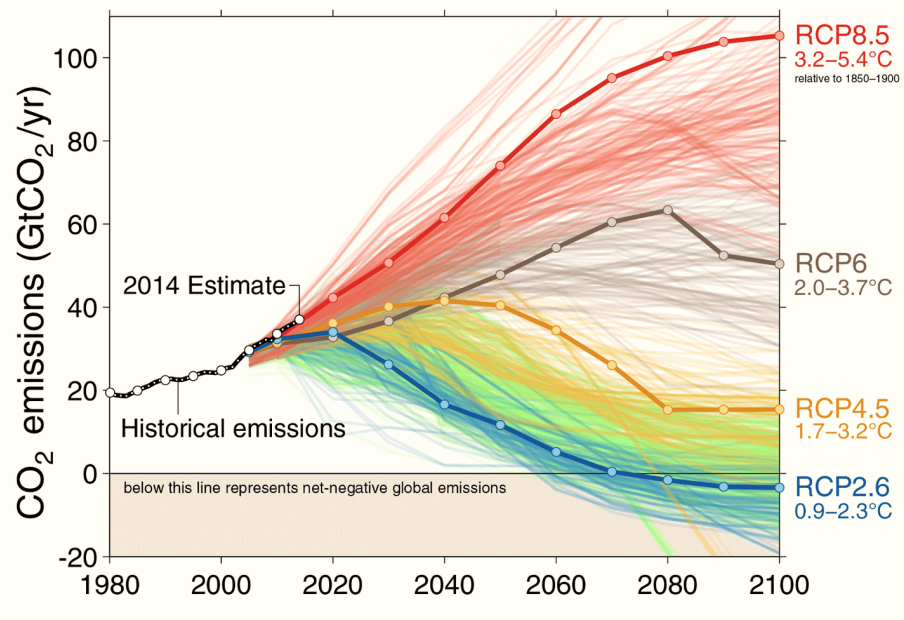




Top image: https://news.ucar.edu/sites/default/files/news/2011/predictFlow2.jpg

Future socio-economic pathways

IPCC AR5



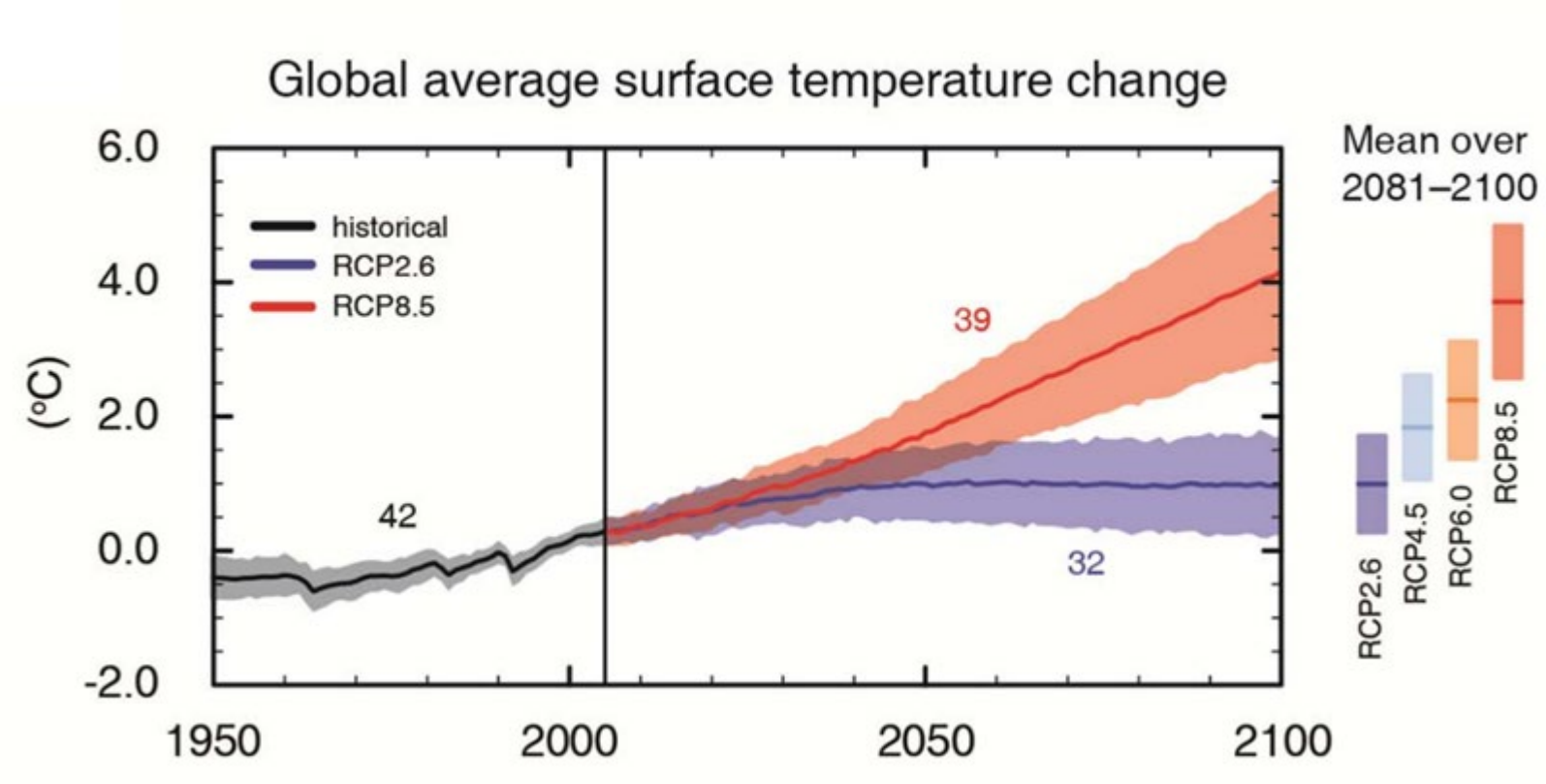
IPCC AR6

RCPs (Representative Concentration Pathways) provide the end of century net **climate forcing**.

SSPs (Shared Socioeconomic Pathways) explore **socio-economic** changes (e.g. population, energy demand, etc)

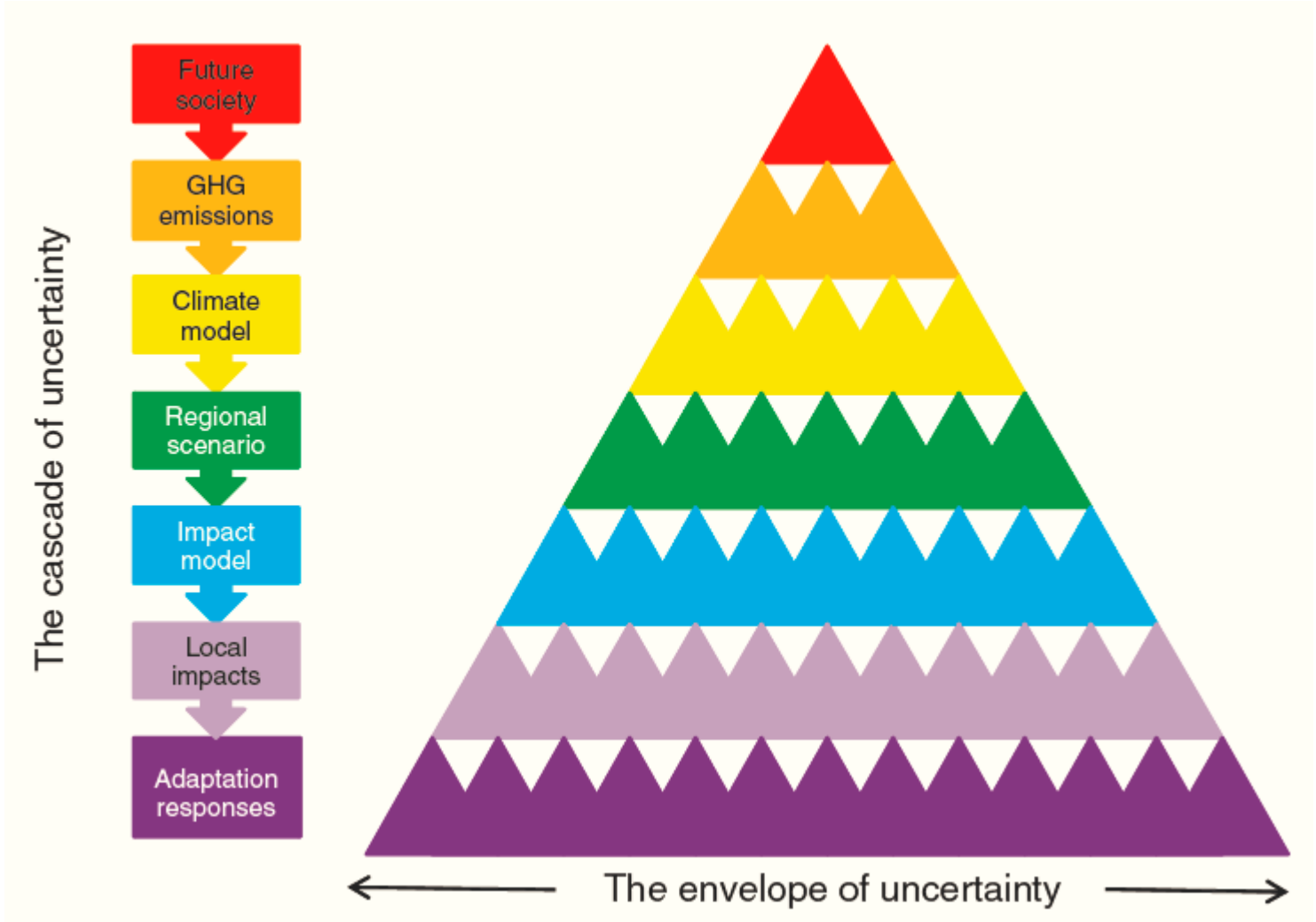
each SSP is consistent with a range of RCPs

Future climate projections



IPCC AR5 - Figure SPM.6a:
CMIP5 multi-model simulated time series from 1950 to 2100 for change in global annual mean surface temperature relative to 1986–2005. Projections are shown for the multi-model mean (solid lines) and the 5% to 95% range across the distribution of individual models (shading).

The “cascade of uncertainty”



Different sources of uncertainty will dominate on certain timeframes, regions of the world, or topics of interest.

All need to be considered.

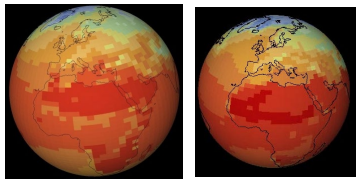
Wilby and Dessai, 2010
Robust Adaptation to Climate Change

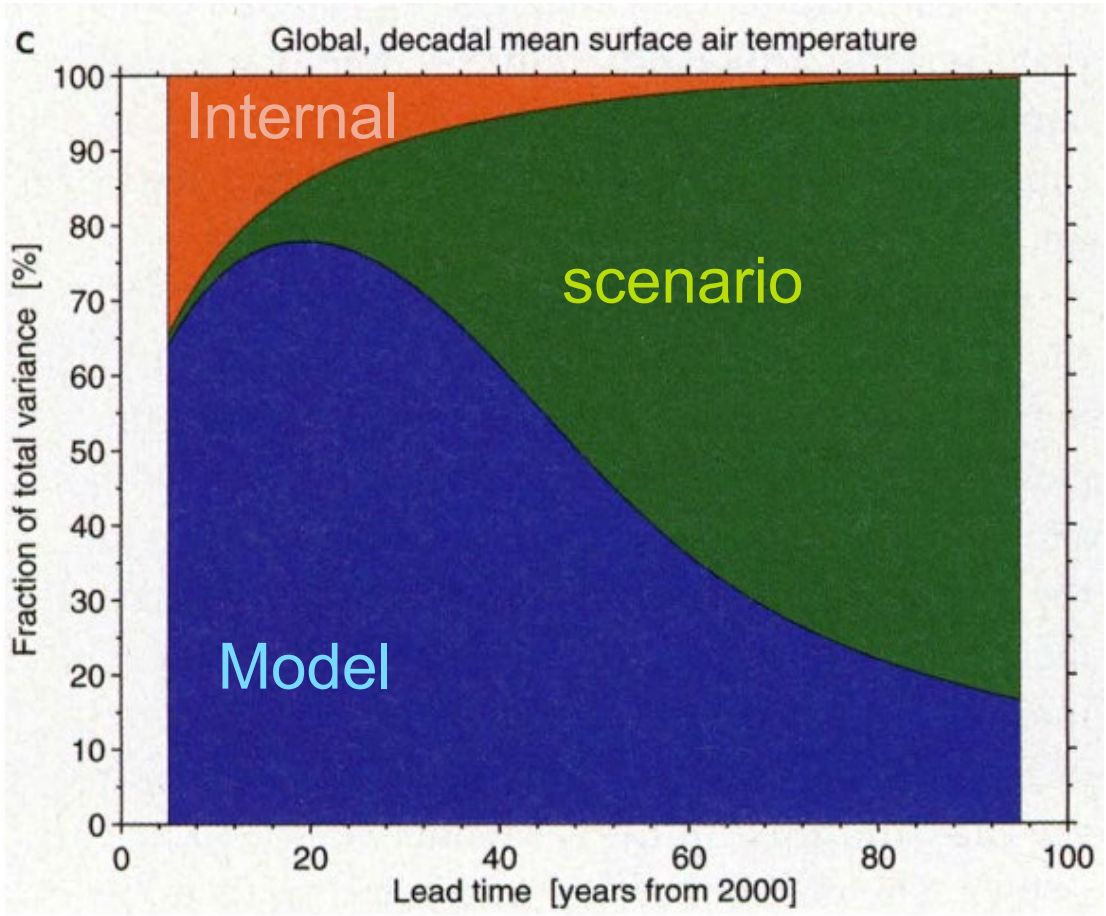
Met Office Sources and relative importance of uncertainties

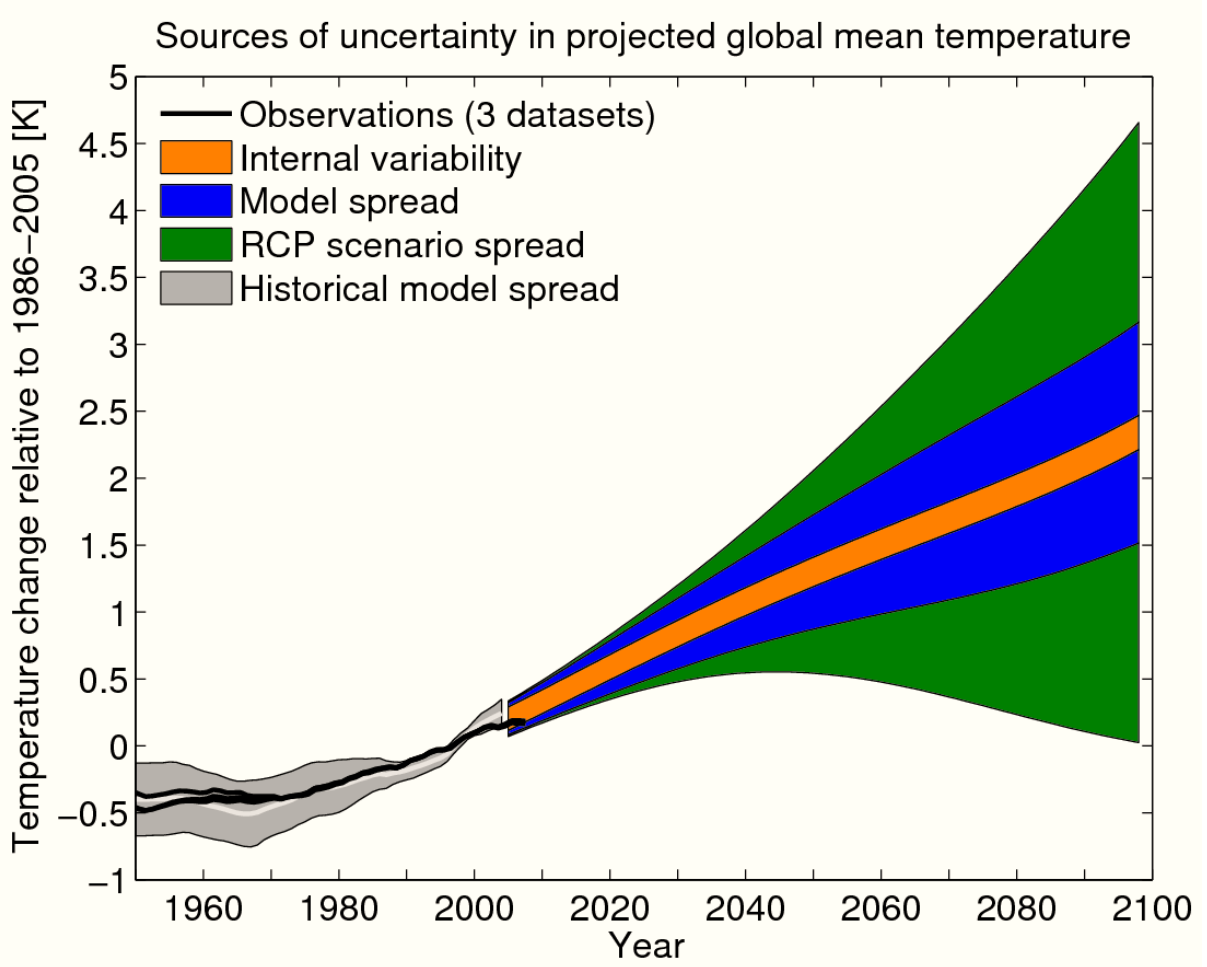
Internal climate variability

Greenhouse gas scenarios

Model spread







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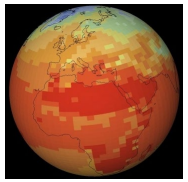

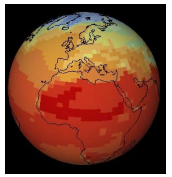

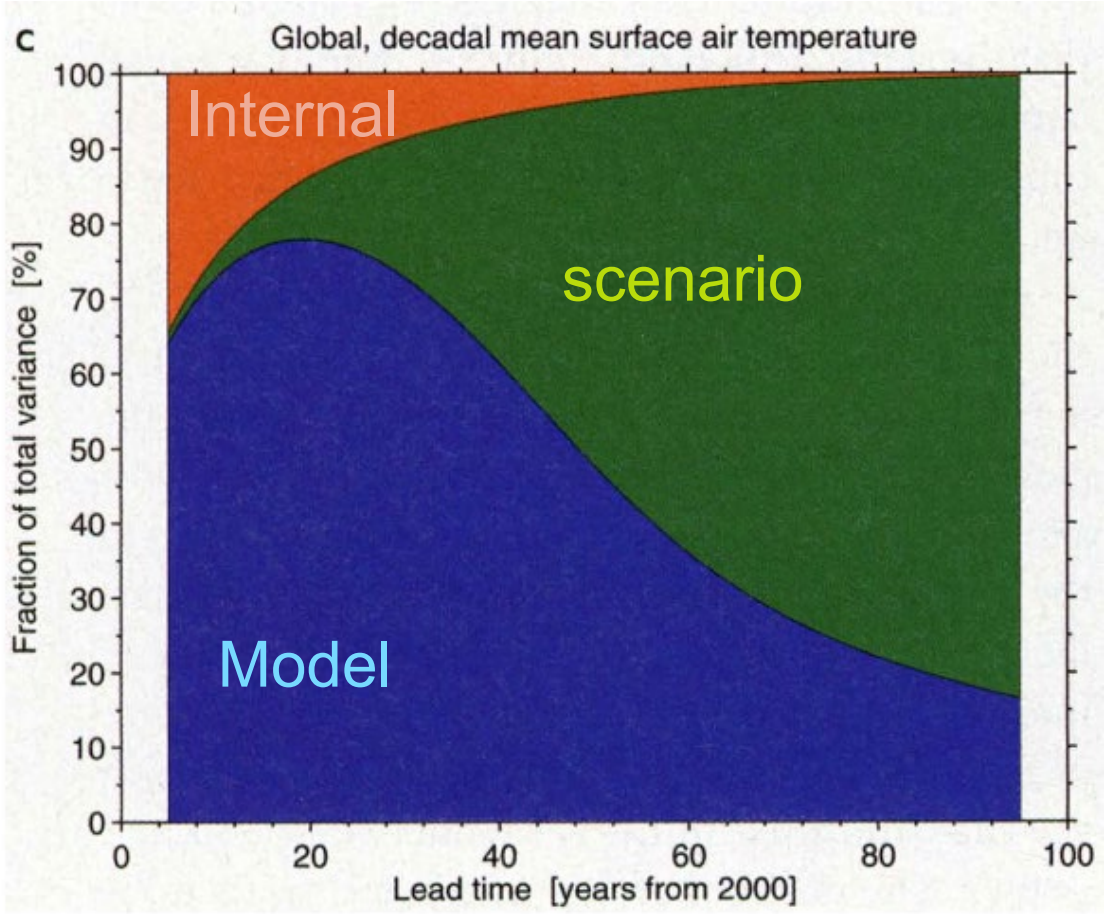

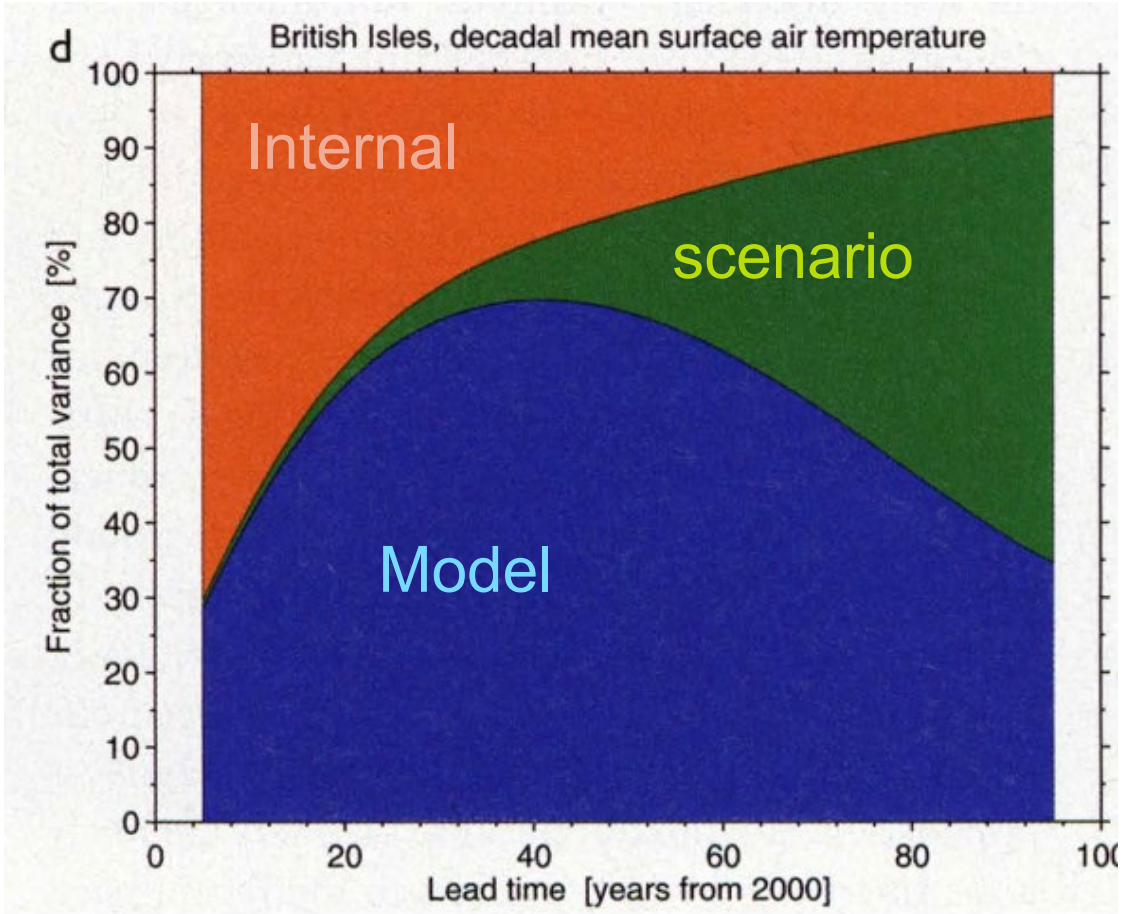

Hawkins and Sutton, 2009